Chapter 2 Units and Measurements

PHYSICAL QUANTITY

*All the quantities in terms of which laws of physics are described and which can be measured directly or indirectly are called **physical quantities**.* For example mass, length, time, speed, force etc.

Types of Physical Quantity

1. **Fundamental quantities :** The physical quantities which do not depend upon other physical quantities are called **fundamental** or **base physical quantities.** e.g. mass, length, time temperature electric current, luminous intensity and amount of substance.
2. **Derived quantities :**The physical quantities which depend on fundamental quantities are called **derived quantities** e.g. speed, acceleration, force, etc.

UNIT

The process of measurement is a *comparison process*.

Unit is the standard quantity used for comparision.

The chosen standard for measurement of a physical quantity, which has the same nature as that of the quantity is called the unit of that quantity.

Choice of a unit (Characteristics of a unit):

(1) It should be **suitable in size** (suitable to use)

(2) It should be **accurately defined** (so that everybody understands the unit in same way)

(3) It should be **easily reproducible**.

(4) It should **not change with time**.

(5) It should **not change with change in physical conditions** i.e., temperature, pressure, moisture etc.

(6) It should be **universally acceptable.**

Every measured quantity (its magnitude) comprises of a number and a unit. **Ex:** In the measurement of time, say

15 s

Number (n) Unit (u)

If Q is the **magnitude** of the quantity (which does not depend on the selection of unit) then

$$Q = n\,u = n_1\,u_1 = n_2\,u_2 \Rightarrow n \propto \frac{1}{u}$$

Where u_1 and u_2 are the units and n_1 and n_2 are the numerical values in two different system of units.

Fundamental (or Base) and Derived Units

Fundamental units are those, which are independent of unit of other physical quantity and cannot be further resolved into any other units or the units of fundamental physical quantities are called **fundamental or base units.** e.g., kilogram, metre, second etc,

All units other than fundamental are derived units (**which are dependent on fundamental units**) e.g., unit of speed (ms^{-1}) which depends on unit of length (metre) and unit of time (second), unit of momentum ($Kgms^{-1}$) depends on unit of mass, length and time etc.

SYSTEM OF UNITS

A system of units is a complete set of fundamental and derived units for all physical quantities.

Different types of system of units

F.P.S. (Foot - Pound - Second) system. (British engineering system of units.): In this system the unit of length is foot, mass is pound and time is second.

C.G.S. (Centimetre - Gram - Second) system. (Gaussian system of units): In this system the unit of length is centimetre, mass is gram and time is second.

M.K.S (Metre - Kilogram - Second) system. This system is related to mechanics only. In this system the unit of length is metre, mass is kilogram and time is second.

S.I. (International system) units: (Introduced in 1971) Different countries use different set of units. To avoid complexity, by international agreement, seven physical quantities have been chosen as fundamental or base physical quantities and two as supplementary. These quantities are

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

S.No	Supplementary physical quantity	Supplementary unit	Symbol
1	Plane angle	radian	rad
2	Solid angle	steradian	sr

Merits of S.I. Units :

(1) SI is a **coherent system** of units: This means that all derived units are obtained by multiplication and division without introducing any numerical factor.

(2) SI is a **rational system** of units: This is because it assigns only one unit to a particular physical quantity.

(3) SI is an **absolute system** of units: There is no gravitational unit in this system.

(4) SI system is **applicable to all branches** of science.

Conventions of writing of Units and their Symbols

- Unit is **never written with capital initial letter.**
- For a **unit named after scientist the symbol is a capital letter** otherwise not.
- The unit or symbol is **never written in plural form.**
- **Punctuations marks are not written** after the symbol.

Definitions of Fundamental Units

(i) **Metre :** One metre is equal to 1650763.73 wavelength in vacuum of the radiation corresponding to transition between the levels $2p_{10}$ and $5d_5$ of the krypton – 86 atom
Or
The distance travelled by light in vacuum in

$$\frac{1}{299,792,458}$$ second is called 1 metre.

(ii) **Kilogram :** The mass of cylinder (of height and diameter 39 cm) made of Platinum-iridium alloy kept at International Bureau of weights and measures in paris is defined as 1kg.

(iii) **Second :** It is the duration of 9,192,631,770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of Caesium (133) atom.

(iv) **Ampere :** It is the current which when flows through two infinitely long straight conductors of negligible cross-section placed at a distance of one metre in air or vacuum produces a force of 2×10^{-7} N/m between them.

(v) **Candela :** It is the luminous intensity in a perpendicular direction, of a surface of 1/600,000 square metre of a black body at the temperature of freezing platinum under a pressure of 1.013×10^5 N/m^2.

(vi) **Kelvin :** It is the 1/273.16 part of thermodynamic temperature of triple point of water.

(vii) **Mole :** It is the amount of substance which contains as many elementary entities as there are in 0.012 kg of Carbon-12.

S.I. Prefixes :

The magnitudes of physical quantities vary over a wide range. For example, the atomic radius, is equal to 10^{-10}m, radius of earth is 6.4×10^6 m and the mass of electron is 9.1×10^{-31} kg. The internationally recommended standard prefixes for certain powers of 10 are given in the table:

Prefix	Power of 10	Symbol
exa	18	E
peta	15	P
tera	12	T
giga	9	G
mega	6	M
kilo	3	k
hecto	2	h
deca	1	da
deci	–1	d
centi	–2	c
milli	–3	m
micro	–6	μ
nano	–9	n
pico	–12	p
femto	–15	f
atto	–18	a

Some Important Practical Units :

(1) For large distance (macro-cosm)

(a) Astronomical unit: It is the average distance of the centre of the sun from the centre of the earth.
1 A.U. = 1.496×10^{11}m

(b) Light year: It is the distance travelled by the light in vacuum in one year. 1 *ly* = 9.46×10^{15}m

(c) Parsec: One parsec is the distance at which an arc 1A.U. long subtends an angle of one second.
1 parsec = 3.1×10^{16}m

(2) For small distance (micro-cosm)
1 micron = 10^{-6}m   1nanometre = 10^{-9}m
1angstorm = 10^{-10}m   1fermi = 10^{-15}m

(3) For small area   1 barn = 10^{-28}m^2

(4) For heavy mass   1 ton = 1000kg
1quintal = 100kg   1slug = 14.57kg
1 C.S.L (chandrasekhar limit) = 1.4 times the mass of the sun

(5) For small mass   1 amu = 1.67×10^{-27}kg
1 pound = 453.6g = 0.4536 kg

(6) For small time   1 shake = 10^{-8}s

(7) For large time
Lunar month: It is the time taken by the earth to complete one rotation about its axis with respect to sun.
1L.M. = 27.3 days.
Solar day: It is the time taken by the earth to complete one rotation about its axis with respect to sun.
Sedrial day: It is the time taken by earth to complete one rotation on its axis with respect to distant star.

(8) For measuring pressure
1 bar = 1atm pressure = 10^5N/m^2 = 760mmHg
1torr = 1 mmHg
1 poiseuille = 10 Poise.

DIMENSIONS

*The powers to which the fundamental units of mass, length and time must be raised to represent the physical quantity are called the **dimensions** of that physical quantity.*

For example : Force = mass × acceleration

$$= \text{mass} \times \frac{v-u}{t} = [M]\frac{[LT^{-1}]}{[T]} = [MLT^{-2}]$$

Hence the dimensions of force are 1 in mass 1 in length and (– 2) in time.

Dimensional Formula :

Unit of a physical quantity expressed in terms of M, L and T is called dimensional formula. It shows how and which of the fundamental quantities represent the dimensions.

For example, the dimensional formula of work is $[ML^2T^{-2}]$

Dimensional Equation :

When we equate the dimensional formula with the physical quantity, we get the dimensional equation.

For example Work = $[ML^2T^{-2}]$

Classification of Physical Quantities (On the basis of dimensions) :

- Physical Quantity
  - Dimensional physical quantity
    - Dimensional constant — For e.g. c (velocity of light in vaccum) R(universal gas constant), σ(stefan's constant), h (Planck's constant), k (Boltzmann constant), G (universal gravitational constant) etc.
    - Dimensional variable — For e.g. distance, displacement, force, mass, time etc.
  - Dimensionless physical quantity
    - Dimensionless constant — For e.g. 0, 1, 2, ..., e, π, sin θ, cos θ, tan θ, etc.
    - Dimensionless variable — For e.g. plane angle, solid angle, strain, refractive index, dielectric constant, relative density, specific gravity, poisson's ratio etc.

Dimensional Formula of Some Important Physical Quantities :

S.No.	*Physical quantity*	*Relation with other quantities*	*Dimensional formula*
1.	Velocity (v)	$\frac{\text{Length}}{\text{Time}}$	$[M^0LT^{-1}]$
2.	Acceleration (a)	$\frac{\text{Velocity}}{\text{Time}}$	$[M^0LT^{-2}]$
3.	Momentum (p)	Mass × velocity	$[MLT^{-1}]$
4.	Force (F)	Mass × acceleration	$[MLT^{-2}]$
5.	Work	Force × displacement	$[ML^2T^{-2}]$
6.	Power (P)	$\frac{\text{Work}}{\text{Time}}$	$[ML^2T^{-3}]$
7.	Universal gravitational constant	$G = \frac{Fr^2}{m_1m_2}$	$[M^{-1}L^3T^{-2}]$
8.	Torque	$\vec{\tau} = \vec{r} \times \vec{F}$	$[ML^2T^{-2}]$
9.	Surface tension	$S = \frac{F}{\ell}$	$[MT^{-2}]$
10.	Gravitational potential	$V_G = \frac{W}{m}$	$[M^0L^2T^{-2}]$
11.	Coefficient of viscosity	$\eta = \frac{F}{A\frac{dv}{dx}}$	$[ML^{-1}T^{-1}]$
12.	Impulse	Force×time(F×t)	$[MLT^{-1}]$

13.	Strain	$\frac{\text{Change in length}}{\text{Original length}}\left(\frac{\Delta L}{L}\right)$	$[M^0L^0T^0]$
14.	Pressure gradient	$\frac{\text{Pressure}}{\text{Distance}}\left(\frac{P}{\ell}\right)$	$[ML^{-2}T^{-2}]$
15.	Plane angle	$\frac{\text{Arc}}{\text{Radius of circle}}\left(\frac{s}{r}\right)$	$[M^0L^0T^0]$
16.	Angular velocity	$\frac{\text{Angle}}{\text{Time}}\left(\frac{\theta}{t}\right)$	$[M^0L^0T^{-1}]$
17.	Radius of gyration	$\sqrt{\frac{\text{Moment of inertia of body}}{\text{Total mass of the body}}}\left(\sqrt{\frac{I}{\sum m_i}}\right)$	$[M^0L^1T^0]$
18.	Moment of force, moment of couple	Force × distance (F × s)	$[ML^2T^{-2}]$
19.	Angular frequency	$2\pi\times$frequency $(2\pi\nu)$	$[M^0L^0T^{-1}]$
20.	Pressure	$\frac{\text{Force}}{\text{Area}}$	$[ML^{-1}T^{-2}]$
21.	Efficiency	$\frac{\text{Output work or energy}}{\text{Input work or energy}}\left(\frac{W}{Q}\right)$	$[M^0L^0T^0]$
22.	Angular impulse	forque×time $(\tau \times t)$	$[ML^2T^{-1}]$
23.	Planck's constant	$\frac{\text{Energy}}{\text{Frequency}}\left(\frac{E}{\nu}\right)$	$[ML^2T^{-1}]$
24.	Heat capacity, Entropy	$\frac{\text{Heat energy}}{\text{Temperature}}\left(\frac{Q}{T}\right)$	$[ML^2T^{-2}K^{-1}]$
25.	Specific heat capacity	$\frac{\text{Heat energy}}{\text{Mass}\times\text{temperature}}\left(\frac{Q}{m\times\Delta T}\right)$	$[M^0L^2T^{-2}K^{-1}]$
26.	Thermal conductivity, K	$\frac{\text{Heat energy}\times\text{thickness}}{\text{Area}\times\text{temperature}\times\text{time}}\left(\frac{Q}{t}=-KA\frac{\Delta T}{\Delta x}\right)$	$[MLT^{-3}K^{-1}]$
27.	Thermal Resistance, R	$\frac{\text{Length}}{\text{Thermal conductivity}\times\text{area}}$	$[M^{-1}L^{-2}T^3K]$
28.	Bulk modulus (B) or (compressibility)$^{-1}$	$\frac{\text{Volume}\times\text{(change in pressure)}}{\text{Change in volume}}\left(-V\frac{\Delta P}{\Delta V}\right)$	$[ML^{-1}T^{-2}]$
29.	Stefan's constant (σ)	$\frac{\text{(Energy/area)}}{\text{Time}\times(\text{temperature})^4}\left(\begin{array}{l}Q=\sigma AtT^4\\E=Q/A.t=\sigma T^4\end{array}\right)$	$[ML^0T^{-3}K^{-4}]$
30.	Universal gas constant R	$\frac{\text{Pressure}\times\text{volume}}{\text{Mole}\times\text{temperature}}\left(\frac{PV}{nT}\right)$	$[ML^2T^{-2}K^{-1}mol^{-1}]$
31.	Voltage, electric potential (V) or electromotive force (e)	$\frac{\text{Work}}{\text{Charge}}\left(\frac{W}{q}\right)$	$[ML^2T^{-3}A^{-1}]$

32.	Capacitance (C)	$\frac{\text{Charge}}{\text{Potential difference}}\left(\frac{q}{V}\right)$	$[M^{-1}L^{-2}T^{4}A^{2}]$
33.	Electric field $(\vec{E})$	$\frac{\text{Electric force}}{\text{Charge}}\left(\frac{F}{q}\right)$	$[MLT^{-3}A^{-1}]$
34.	Magnetic field$(\vec{B})$, magnetic induction, magnetic flux density	$\frac{\text{Force}}{\text{Current}\times\text{length}}[F = I\ell B\sin\theta]$	$[ML^{0}T^{-2}A^{-1}]$
35.	Magnetic flux (ϕ_m)	$\phi = BA\cos\theta$	$[ML^{2}T^{-2}A^{-1}]$
36.	Inductance coefficient of self inductance (L) or coefficient of mutual inductance (M)	$\frac{\text{Magnetic flux}}{\text{Current}}\left(\frac{\phi_m}{I}\right)$	$[ML^{2}T^{-2}A^{-2}]$
37.	Magnetic field strength or magnetic moment density (I)	$\frac{\text{Magnetic moment}}{\text{Volume}}\left(\frac{M}{V}\right)$	$[M^{0}L^{-1}T^{0}A]$
38.	Permittivity constant in free space ε_o	$\frac{(\text{Charge})^2}{4\pi\times\text{electrostatic force}(\text{distance})^2}\left(\frac{q^2}{4\pi\times F\times r^2}\right)$	$\left[M^{-1}L^{-3}T^{4}A^{2}\right]$
39.	Faraday constant (F), charge	Avagadro constant × elementry charge	$[M^{0}L^{0}TA\,mol^{-1}]$
40.	Mass defect, (Δm)	(Sum of masses of nucleons – mass of nucleus)$(M_P+M_N-M_{nucleus})$	$[ML^{0}T^{0}]$
41.	Resonant frequency (f_r)	$\frac{1}{T_r}$	$[M^{0}L^{0}T^{-1}]$
42.	Power of lens	$(\text{Focal length})^{-1}\left(\frac{1}{f}\right)$	$\left[M^{0}L^{-1}T^{0}\right]$
43.	Refractive index	$\frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$	$[M^{0}L^{0}T^{0}]$
44.	Wave number	$\frac{2\pi}{\text{Wavelength}}$	$\left[M^{0}L^{-1}T^{0}\right]$
45.	Binding energy of nucleus	Mass defect × (speed of light in vacuum)^2	$\left[ML^{2}T^{-2}\right]$
46.	Conductance (c)	$\frac{1}{\text{Resistance}}$	$\left[M^{-1}L^{-2}A^{2}T^{3}\right]$
47.	Fluid flow rate	$\left(\frac{\pi}{8}\right)\frac{(\text{Pressure})\times(\text{radius})^4}{(\text{Viscosity coefficient})\times(\text{length})}$	$\left[M^{0}L^{3}T^{-1}\right]$
48.	Inductive reactance	(Angular frequency × inductance)	$\left[ML^{2}T^{-3}A^{-2}\right]$
49.	Capacitive reactance	(Angular frequency × capacitance)$^{-1}$	$\left[ML^{2}T^{-3}A^{-2}\right]$
50.	Magnetic dipole moment	$\frac{\text{Torque}}{\text{Magnetic field}}$ or Current × area	$\left[M^{0}L^{2}T^{0}A\right]$

Short cuts / Time saving techniques

1. To find dimensions of a typical physical quantity which is involved in a number of formulae, try to use that formula which is easiest for you. For example if you want to find the dimensional formula of magnetic induction then you can use the following formulae

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2},\ B = \mu_0 nI,\ F = qvB,\ \tau = MB\sin\theta$$

Out of these the easiest is probably the third one.

2. If you have to find the dimensional formula of a combination of physical quantities, then instead of finding the dimensional formula of each, try to correlate the combination of physical quantities with a standard formula. For example, if you have to find the dimension of CV^2, then try to use formula $E = \frac{1}{2}CV^2$ where E is energy of a capacitor.

3. $\frac{1}{\sqrt{\mu_0\varepsilon_0}} = c$ = velocity of light in vacuum

- Dimensions of the following are same

$$\text{Work} = PV = nRT = qV = CV^2 = \frac{q^2}{c} = \frac{V^2}{R}\times t = LI^2$$

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

- Dimensions of the following are same
  Force = Impulse / time
  = q v B = q E
  = Thrust
  = weight = energy gradient $[MLT^{-2}]$

- The dimension of $RC = \frac{L}{R}$ is same as that of time
- Dimensions of the following are same

$$\text{velocity} = \sqrt{\frac{T}{\mu}} = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = f\times\lambda \qquad [M^\circ LT^{-1}]$$

- Dimensions of the following are same

$$\text{Frequency} = \frac{R}{L} = \sqrt{\frac{k}{m}} = \sqrt{\frac{MB}{I}} = \frac{1}{\sqrt{LC}} \quad [M^\circ L^\circ T^{-1}]$$

- Dimensions of the following are same
  (E) Modulus of elasticity = Y (Young's modulus)
  = B (Bulk modulus)
  = η (Modulus of rigidity)
  = Stress

$$= \text{Pressure} = \frac{1}{\text{Compressibility}}$$

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

- Dimensions of the following are same
  Acceleration, retardation, centripetal acceleration, centrifugal acceleration, gravitational intensity/strength. $[M^\circ LT^{-2}]$
- Dimensions of the following are same
  Water equivalent, thermal capacity, entropy, Boltzmann's constant. $[ML^2T^{-2}K^{-1}]$

Keep in Memory

The dimensional formula of
- all trigonometric ratio is $[M^0L^0T^0]$
- x in e^x is $[M^0L^0T^0]$
- e^x is $[M^0L^0T^0]$
- x in log x is $[M^0L^0T^0]$
- log x is $[M^0L^0T^0]$

Example 1.
Find out the unit and dimensions of permittivity of free space.

Solution :
According to Coulomb's law

$$\varepsilon_0 = \frac{[q^2]}{4\pi[F][r^2]} = \frac{[A^2T^2]}{[MLT^{-2}][L^2]} = [M^{-1}L^{-3}T^4A^2]$$

$$\text{Its unit} = \frac{\text{coulomb}^2}{\text{newton}\times\text{metre}^2} = \frac{(\text{coulomb})^2}{\text{joule}\times\text{metre}} = \frac{\text{coulomb}}{\text{volt}\times\text{metre}}$$

$CV^{-1}m^{-1}$

Example 2.
Find out the unit and dimensions of coefficient of self or mutual inductance of.

Solution :

$e = L\left(\frac{dI}{dt}\right)$ or $M\left(\frac{dI}{dt}\right)$, where e is induced electromotive force (e.m.f.)

$$\therefore L = e\left(\frac{dt}{dI}\right) = \frac{W}{q}\left(\frac{t}{I}\right)$$

$$\text{or} \quad [L] = \frac{[ML^2T^{-2}][T]}{[AT][A]} = [ML^2T^{-2}A^{-2}]$$

Its unit is volt × sec/amp or ohm × sec or henry.

Example 3.
Find out the unit and dimensions of magnetic field intensity .

Solution :

$$\text{As } B = \mu H, \text{ hence } H = \frac{B}{\mu} = \frac{1}{4\pi}\frac{Id\ell\sin\theta}{r^2};$$

$$\therefore H = \frac{[A][L]}{[L^2]} = [M^\circ L^{-1}T^\circ A]$$

Its unit is ampere /metre in SI system. In c.g.s. system, the unit is oersted.

Example 4.
Find out the unit and dimensions of magnetic permeability of free space or medium.

Solution :
According to Biot-Savart's law

$$B = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2} \text{ and } F = BI\,\ell\sin\theta$$

$$\text{or} \quad \frac{F}{I\ell\sin\theta} = B = \frac{\mu_0 Id\ell\sin\theta}{4\pi r^2};$$

$\therefore \mu$ or $\mu_0 = \dfrac{Fr^2}{I^2 \ell^2}$ (dimensionally)

Hence $[\mu]$ or $[\mu_0] = \dfrac{[MLT^{-2}][L^2]}{[A^2][L^2]} = [MLT^{-2}A^{-2}]$

Its units are

$$\frac{N - m^2}{amp^2 - m^2} = \frac{newton}{amp^2} = \frac{joule/metre}{amp^2} = \frac{volt \times coulomb}{amp \times amp \times metre}$$

$$= \frac{ohm \times sec}{metre} = \frac{henry}{metre} = \frac{tesla \times metre}{amp.}$$

Example 5.

The dimensions of physical quantity X in the equation Force = $\dfrac{X}{Density}$ *is given by*

(a) $[ML^4T^{-2}]$ (b) $[M^2L^{-2}T^{-1}]$
(c) $[M^2L^{-2}T^{-2}]$ (d) $[ML^{-2}T^{-1}]$

Solution :

(c) $\because$ Force $= \dfrac{X}{denisty}$

$\therefore$ X = Force × density

Hence X has dimensions

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

Example 6.

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

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

Solution :

(d) $L = F^x A^y T^z$

$M^0L^1T^0 = [MLT^{-2}]^x [LT^{-2}]^y T^z$

$= M^x L^{x+y} T^{-2x-2y+z}$

$x = 0, x + y = 1, -2x - 2y + z = 0$

$x = 0, y = 1, z = 2$

Hence, $L = AT^2$

DIMENSIONAL ANALYSIS AND ITS APPLICATIONS

Principle of Homogeneity :

Only those physical quantities can be added /subtracted/equated /compared which have the same dimensions.

Uses of Dimensions :

(1) Conversion of one system of unit into another

Example : Convert a pressure of 10^6 dyne/cm^2 in S.I units.

Sol. We know that $1N = 10^5$ dyne $\Rightarrow$ 1 dyne $= 10^{-5}$ N

Also 1m = 100 cm $\Rightarrow$ 1cm $= 10^{-2}$ m

Now, the pressure 10^6 dyne/cm^2 in SI unit is

$$10^6 \frac{dyne}{cm \times cm} = 10^6 \times \frac{10^{-5} N}{10^{-2} m \times 10^{-2} m} = 10^5 N/m^2$$

(2) Checking the accuracy of various formulae

Example : Check the correctness of the following equation dimensionally

$F = \eta A \dfrac{dv}{dx} \sin\theta$ *where F = force, η = coefficient of viscosity, A = area, $\dfrac{dv}{dx}$ = velocity gradient w.r.t distance, θ = angle of contact*

Sol. L.H.S = force = $[MLT^{-2}]$

$$R.H.S = \eta A \frac{dv}{dx}(\sin\theta) = M^1L^{-1}T^{-1}L^2 \times \frac{LT^{-1}}{L} = \left[MLT^{-2}\right]$$

The equation is dimensionally correct.

⚠ **CAUTION :** Please note that the above equation is not correct numerically. The conclusion is that an equation, if correct dimensionally, may or may not be numerically correct. Also remember that if an equation is dimensionally incorrect, we can conclude with surety that the equation is incorrect.

(3) Derivation of formula

Example : The air bubble formed by explosion inside water performed oscillation with time period T which is directly proportional to P^a d^b E^c where P is pressure, d is density and E is the energy due to explosion. Find the values of a, b and c.

Sol. Let us assume that the required expression for time period is $T = K P^a d^b E^c$

where K is a dimensionless constant.

Writing dimensions on both sides,

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

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

Equating the powers,

$a + b + c = 0$ ....(1)

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

$-2a - 2c = 1$ ....(3)

Solving these equations, we get,

$$a = -\frac{5}{6}, b = \frac{1}{2}, c = \frac{1}{3}.$$

Limitations of Dimensional Analysis :

(1) No information about the dimensionless constant is obtained during dimensional analysis
(2) Formula cannot be found if a physical quantity is dependent on more than three physical quantities.
(3) Formula containing trigonometrical /exponential function cannot be found.
(4) If an equation is dimensionally correct it may or may not be absolutely correct.

Example 7.

Find the dimensions of a and b in the Van der waal's equation $\left(P + \dfrac{a}{V^2}\right)(V - b) = RT$

where P is pressure and V is volume of gas.

Solution :

Dimensionally $P = \frac{a}{V^2}$ [By principle of homogeneity]

$\Rightarrow ML^{-1}T^{-2} = \frac{a}{V^2} \Rightarrow a = [ML^5 T^{-2}]$

Also dimensionally V=b [By principle of homogeneity]

$\therefore$ b = [L^3]

Example 8.

The formula $v^2 = \frac{3mg\ell\,(1-\cos\theta)}{M\,(1+\sin^2\theta)}$ *is obtained as the solution of a problem. Use dimensions to find whether this is a reasonable solution (v is a velocity, m and M are masses,* ℓ *is a length and g is gravitational acceleration).*

Solution :

Dimensions of L.H.S. = $[LT^{-1}]^2 = [L^2T^{-2}]$

Dimensions of R.H.S. = $\frac{[M]\,[LT^{-2}]\,[L]}{[M]} = [L^2T^{-2}]$

Hence formula is reasonable.

Example 9.

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 the dimensions of D.*

Solution :

By homogeneity theory of dimension

Dimension of (N)

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

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

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

Example 10.

Let us consider an equation $\frac{1}{2}mv^2 = mgh$ *where m is the mass of the body, v its velocity, g is the acceleration due to gravity and h is the height. Check whether this equation is dimensionally correct.*

Solution :

The dimensions of LHS are

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

The dimensions of RHS are

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

The dimensions of LHS and RHS are the same and hence the equation is dimensionally correct.

Example 11.

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

Solution :

1 cal = 4.2 kg $m^2\,s^{-2}$.

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

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

Comparing with $[M^aL^bT^c]$, we find that

a = 1, b = 2, c = – 2

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

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

$$= 4.2\,\alpha^{-1}\,\beta^{-2}\,\gamma^2$$

SIGNIFICANT FIGURES

The number of digits, which are known reliably in our measurement, and one digit that is uncertain are termed as significant figures.

Rules to determine the numbers of significant figures:

1. All non-zero digits are significant. 235.75 has five significant figures.
2. All zeroes between two non-zero digits are significant. 2016.008 has seven significant figures.
3. All zeroes occurring between the decimal point and the non-zero digits are not significant. provided there is only a zero to left of the decimal point. 0.00652 has three significant figures.
4. All zeroes written to the right of a non-zero digit in a number written without a decimal point are not significant. This rule does not work if zero is a result of measurement. 54000 has two significant figures whereas 54000m has five significant figures.
5. All zeroes occurring to the right of a non-zero digit in a number written with a decimal point are significant. 32.2000 has six significant figures.
6. When a number is written in the exponential form, the exponential term does not contribute towards the significant figures. 2.465×10^5 has four significant figures.

Keep in Memory

1. The significant figures depend upon the least count of the instrument.
2. The number of significant figure does not depend on the units chosen.

ROUNDING OFF

1. If digit to be dropped is less than 5 then preceding digit should be left unchanged.
2. If digit to be dropped is more than 5 then one should raise preceding digit by one.
3. If the digit to be dropped is 5 followed by a digit other than zero then the preceding digit is increased by one.
4. If the digit to be dropped is 5 then the preceding digit is not changed if it is even.
5. If digit to be dropped is 5 then the preceding digit is increased by one if it is odd.

Arithmetical Operations with Significant Figures and Rounding off :

(1) **For addition or subtraction**, write the numbers one below the other with all the decimal points in one line. Now locate the first column from the left that has a doubtful digit. All digits right to this column are dropped from all the numbers and rounding is done to this column. Addition subtraction is then done.

Example : Find the sum of 23.623 and 8.7 to correct significant figures.

Sol. **Step-1 :-** 23.623 + 8.7 **Step-2 :-** 23.6 + 8.7=32.3

(2) **In multiplication and division** of two or more quantities, the number of significant digits in the answer is equal to the number of significant digits in the quantity, which has minimum number of significant digits.

The insignificant digits are dropped from the result if they appear after the decimal point. They are replaced by zeroes if they appear to the left of the decimal point. The least significant digit is rounded off.

Example : 107.88 (5. S. F.)

$\times$ 0.610 (3 S. F.)

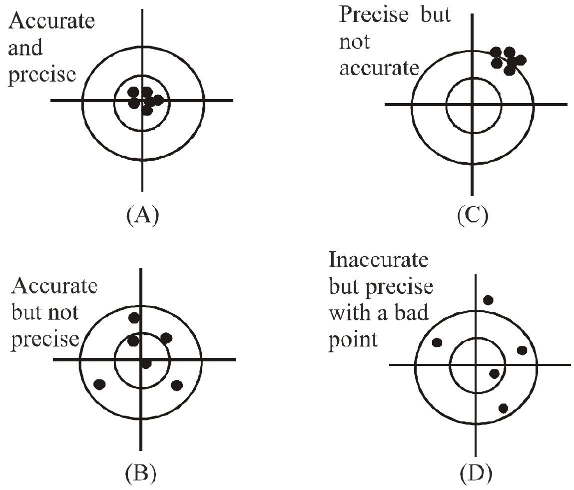
$= 65.8068 \cong 65.8$

ACCURACY, PRECISION OF INSTRUMENTS AND ERRORS IN MEASUREMENTS :

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.* This only applies to experiments where this is the goal like measuring the speed of light.

*A **precise** measurement is one that we can make to a large number of decimal places.*

The following diagrams illustrate the meaning of terms accuracy and precision :



In the above figure : The centre of the target represents the accepted value. The closer to the centre, the more accurate the experiment. The extent of the scatter of the data is a measure of the precision.

A- Precise and accurate, B- Accurate but imprecise, C- Precise but not accurate, D- Not accurate nor precise

When successive measurements of the same quantity are repeated there are different 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!)

Error in measurements *is the difference of actual or true value and measured value.*

Error = True value – Measured value

Keep in Memory

1. Accuracy depends on the least count of the instrument used for measurement.
2. In the addition and subtraction operation, the result contains the minimum number of decimal places of the figures being used
3. In the multiplication and division operation, the result contains the minimum number of significant figures.
4. Least count (L.C.) of vernier callipers = one MSD – one VSD

   where MSD = mains scale division

   VSD = vernier scale division
5. Least count of screw gauge (or spherometer)

   $= \dfrac{\text{pitch}}{\text{no of divisions on circular scale}}$

   where pitch is the ratio of number of divisions moved on linear scale and number of rotations given to circular scale.
6. Pure number or unmeasured value do not have significant numbers
7. Change in the position of decimal does not change the number of significant figures.

   Similarly the change in the units of measured value does not change the significant figures.

Example 12.

Each side of a cube is measured to be 7.203 m. What are the total surface area and the volume of the cube to appropriate significant figures?

Solution :

The number of significant figures in the measured length 7.203 m is 4. The calculated area and the volume should therefore be rounded off to 4 significant figures.

Surface area of the cube $= 6(7.203)^2\ m^2$
$= 311.299254\ m^2 = 311.3\ m^2$

Volume of the cube $= (7.203)^3\ m^3 = 373.714754\ m^3$
$= 373.7\ m^3$

Example 13.

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

Solution :

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.

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

Example 14.

The mass of a box measured by a grocer's balance is 2.300 kg. Two gold pieces of masses 20.15 g and 20.17 g are added to the box. What is (a) the total mass of the box, (b) the difference in the masses of the pieces to correct significant figures ?

Solution :

(a) Total mass = 2.3403 kg = 2.3 kg (upto 2 S. F.)

(b) Difference = 20.17 g – 20.15 g (upto 4 S. F.)

COMMON ERRORS IN MEASUREMENTS

It is not possible to measure the 100% correct value of any physical quantity, even after measuring it so many times. There always exists some uncertainty, which is usually referred to as experimental error.

Experimental errors :

(i) **Random error :** *It is the error that has an equal chance of being positive or negative.*

It occurs irregularly and at random in magnitude and direction. It can be caused

(a) by the lack of perfection of observer

(b) if the measuring instrument is not perfectly sensitive.

(ii) **Systematic error :** *It tends to occur in one direction either positive or negative.* It occurs due to

(a) measuring instrument having a zero error.

(b) an instrument being incorrectly calibrated (such as slow- running-stop clock)

(c) the observer persistently carrying out a mistimed action (e.g., in starting and stopping a clock)

For measuring a particular physical quantity, we take a number of readings. Let the readings be $X_1, X_2 ...., X_n$. Then the mean value is found as follows

$$X_{mean}(or\ true\ value) = \bar{X} = \frac{X_1 + X_2 + ... + X_n}{n}$$

Methods of Expressing Error:

Absolute error: *It is the difference between the mean value and the measured value of the physical quantity.*

$$|\Delta X_1| = |X_{mean} - X_1|$$
....
....
$$|\Delta X_n| = |X_{mean} - X_n|$$

Mean absolute error:

$$\Delta X_{mean} \text{ or } \Delta\bar{X} = \frac{|\Delta X_1| + |\Delta X_2| + ... + |\Delta X_n|}{n}$$

Relative error: *It is the ratio of the mean absolute error and the value of the quantity being measured.*

$$Relative\ error\ (\delta a) = \frac{\Delta X_{mean}}{X_{mean}}$$

Percentage error: *It is the relative error expressed in percent*

$$Percentage\ error = \frac{\overline{\Delta X}}{\bar{X}} \times 100\%$$

To find the maximum error in compound quantities we proceed as :

(i) **Sum and difference :** We have to find the sum or difference of two values given as (a ± Δa) and (b ± Δb), we do it as follows

$X \pm \Delta X = (a \pm \Delta a) + (b \pm \Delta b) = (a + b) \pm (\Delta a + \Delta b)$

$\Rightarrow X = a + b$ and $\Delta X = \Delta a + \Delta b$ in case of sum

And $X = (a - b)$ and $\Delta X = \Delta a + \Delta b$ in case of difference.

(ii) **Product and quotient :** We add the fractional or percentage errors in case of finding product or quotient.

If P = ab then $\frac{\Delta P}{P} = \pm\left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right)$

If $Q = \frac{a}{b}$ then $\frac{\Delta Q}{Q} = \pm\left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right)$

(iii) **Power of a quantity :** If $x = a^n$ then $\frac{\Delta X}{X} = n\left(\frac{\Delta a}{a}\right)$

Example :

For $Q = \frac{x^2}{y}$, If $\frac{\Delta x}{x} \times 100 = 3\%$ and $\frac{\Delta y}{y} \times 100 = 4\%$

then $\frac{\Delta Q}{Q} \times 100 = (2 \times 3 + 4)\% = 10\%$

Similarly :

If $A = \frac{m^p n^q}{c^r}$ then $\frac{\Delta A}{A} = \pm\left[p\frac{\Delta m}{m} + q\frac{\Delta n}{n} + r\frac{\Delta c}{c}\right]$

Keep in Memory

1. More the accuracy, smaller is the error.
2. Absolute error $|\Delta X|$ is always positive.
3. $|\Delta X|$ has the same dimensions as that of X.
4. If the least count of measuring instrument is not given and the measured value is given the least error in the measurement can be found by taking the last digit to be 1 and rest digit to be zero. For e.g. if the measured value of mass m = 2.03 kg then $\Delta m = \pm 0.01$ kg.
5. If a number of physical quantities are involved in an expression then the one with higher power contributes more in errors and therefore should be measured more accurately.
6. Relative error is a dimensionless quantity.

7. We are always interested in calculating the maximum possible error.

Example 15.

In an experiment, the refractive index of water was observed as 1.29, 1.33, 1.34, 1.35, 1.32, 1.36, 1.30 and 1.33. Calculate the mean value, mean absolute error and percentage error in the measurement.

Solution :

Mean value of refractive index,

$$\bar{\mu} = \frac{1.29+1.33+1.34+1.35+1.32+1.36+1.30+1.33}{8}$$

$$= 1.33$$

Absolute error in measurement,

$\Delta\mu_1 = 1.33 - 1.29 = +0.04$, $\Delta\mu_2 = 1.33 - 1.33 = 0.00$,

$\Delta\mu_3 = 1.33 - 1.34 = -0.01$, $\Delta\mu_4 = 1.33 - 1.35 = -0.02$,

$\Delta\mu_5 = 1.33 - 1.32 = +0.01$, $\Delta\mu_6 = 1.33 - 1.36 = -0.03$,

$\Delta\mu_7 = 1.33 - 1.30 = +0.03$, $\Delta\mu_8 = 1.33 - 1.33 = 0.00$

So, mean absolute error,

$$(\overline{\Delta\mu}) = \frac{|0.04|+|0.01|+|0.02|+|0.01|+|0.03|+|0.03|+|0|}{8}$$

$$= 0.0175 \approx 0.02$$

$$\text{Relative error} = \pm\frac{\overline{\Delta\mu}}{\bar{\mu}} = +\frac{0.02}{1.33} = \pm 0.015 = \pm 0.02$$

$$\text{Percentage error} = \pm\frac{0.02}{1.33} \times 100\% = \pm 1.5\%$$

Example 16.

The length and breadth of a rectangle are (5.7 ± 0.1) cm and (3.4 ± 0.2) cm. Calculate area of the rectangle with error limits.

Solution :

Here, $\ell = (5.7 \pm 0.1)$ cm, $b = (3.4 \pm 0.2)$ cm

Area $A = \ell \times b$

$= 5.7 \times 3.4 = 19.38$ cm²

$= 19.0$ cm² (Rounding off to two significant figures)

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

$$= \pm\left(\frac{0.34 + 1.14}{5.7 \times 3.4}\right)$$

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

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

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

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

Example 17.

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?

Solution :

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

velocity, $v = \frac{s}{t} = \frac{13.8}{4.0} = 3.45\ \text{ms}^{-1} = 3.5\ \text{ms}^{-1}$

(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

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

Example 18.

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 (ii) in parallel, with percentage error ?

(a) $16\Omega \pm 23\%, 3\Omega \pm 6.25\%$ (b) $3\Omega \pm 2.3\%, 3\Omega \pm 6.25\%$

(c) $3\Omega \pm 23\%, 16\Omega \pm 6.25\%$ (d) $16\Omega \pm 6.25\%, 3\Omega \pm 23\%$

Solution :

(d) $R_S = R_1 + R_2 = 16\ \Omega$; $R_P = \frac{R_1 R_2}{R_1 + R_2} = \frac{R_1 R_2}{R_S} = 3\ \Omega$

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

$$\Rightarrow \frac{\Delta R_S}{R_S} \times 100 = \frac{1}{16} \times 100\% = 6.25\%$$

$$\Rightarrow R_S = 16\Omega \pm 6.25\%$$

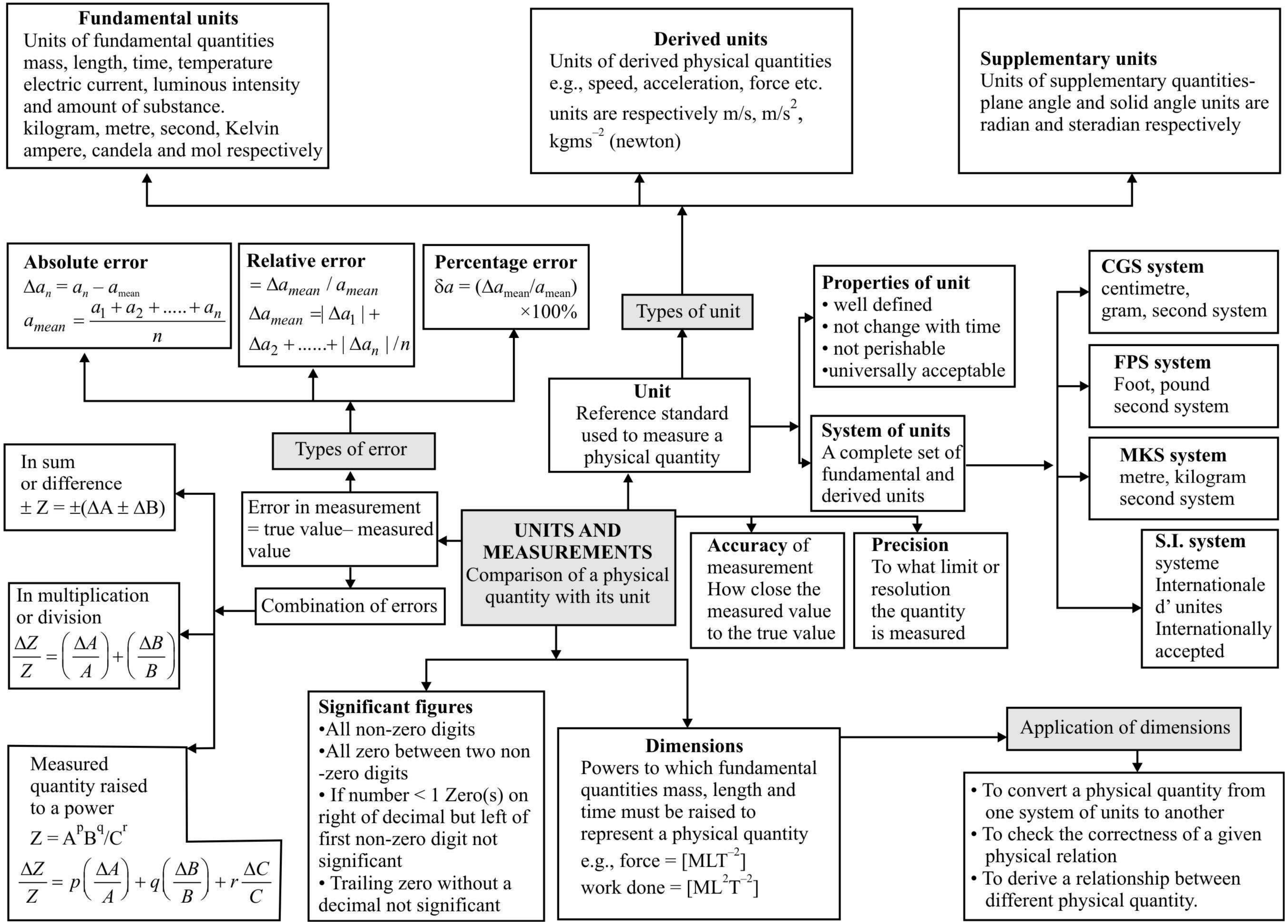
Similarly, $R_P = \frac{R_1 R_2}{R_S}$

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

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

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

CONCEPT MAP


Fundamental units
Units of fundamental quantities mass, length, time, temperature electric current, luminous intensity and amount of substance.
kilogram, metre, second, Kelvin ampere, candela and mol respectively
Derived units
Units of derived physical quantities e.g., speed, acceleration, force etc.
units are respectively m/s, m/s^2, $kgms^{-2}$ (newton)
Supplementary units
Units of supplementary quantities- plane angle and solid angle units are radian and steradian respectively
Absolute error
$\Delta a_n = a_n - a_{mean}$
$a_{mean} = \frac{a_1 + a_2 + ... + a_n}{n}$
Relative error
$= \Delta a_{mean} / a_{mean}$
$\Delta a_{mean} = |\Delta a_1| + \Delta a_2 + ... + |\Delta a_n| / n$
Percentage error
$\delta a = (\Delta a_{mean}/a_{mean}) \times 100\%$
Types of unit
Properties of unit
• well defined
• not change with time
• not perishable
•universally acceptable
CGS system
centimetre, gram, second system
FPS system
Foot, pound second system
MKS system
metre, kilogram second system
S.I. system
systeme Internationale d' unites Internationally accepted
Unit
Reference standard used to measure a physical quantity
System of units
A complete set of fundamental and derived units
Types of error
In sum or difference
$\pm Z = \pm(\Delta A \pm \Delta B)$
Error in measurement = true value– measured value
UNITS AND MEASUREMENTS
Comparison of a physical quantity with its unit
Accuracy of measurement
How close the measured value to the true value
Precision
To what limit or resolution the quantity is measured
Combination of errors
In multiplication or division
$\frac{\Delta Z}{Z} = \left(\frac{\Delta A}{A}\right) + \left(\frac{\Delta B}{B}\right)$
Measured quantity raised to a power
$Z = A^p B^q / C^r$
$\frac{\Delta Z}{Z} = p\left(\frac{\Delta A}{A}\right) + q\left(\frac{\Delta B}{B}\right) + r\frac{\Delta C}{C}$
Significant figures
•All non-zero digits
•All zero between two non -zero digits
• If number < 1 Zero(s) on right of decimal but left of first non-zero digit not significant
• Trailing zero without a decimal not significant
Dimensions
Powers to which fundamental quantities mass, length and time must be raised to represent a physical quantity
e.g., force = $[MLT^{-2}]$
work done = $[ML^2T^{-2}]$
Application of dimensions
• To convert a physical quantity from one system of units to another
• To check the correctness of a given physical relation
• To derive a relationship between different physical quantity.

EXERCISE - 1
Conceptual Questions

1. Temperature can be expressed as derived quantity in terms of
   (a) length and mass
   (b) mass and time
   (c) length, mass and time
   (d) None of these
2. What is the unit of "a" in Vander Waal's gas equation?
   (a) Atm litre^{-2} mol^2 (b) Atm litre^2 per mol
   (c) Atm litre^{-1} mol^2 (d) Atm litre^2 mol^{-2}
3. Random error can be eliminated by
   (a) careful observation
   (b) eliminating the cause
   (c) measuring the quantity with more than one instrument
   (d) taking large number of observations and then their mean.
4. If e is the charge, V the potential difference, T the temperature, then the units of $\frac{eV}{T}$ are the same as that of
   (a) Planck's constant (b) Stefan's constant
   (c) Boltzmann constant (d) gravitational constant
5. If $f = x^2$, then the relative error in f is
   (a) $\frac{2\Delta x}{x}$ (b) $\frac{(\Delta x)^2}{x}$
   (c) $\frac{\Delta x}{x}$ (d) $(\Delta x)^2$
6. Two quantities A and B have different dimensions which mathematical operation given below is physically meaningful?
   (a) A/B (b) A + B
   (c) A – B (d) A = B
7. Which of the following systems of units is not based on units of mass, length and time alone
   (a) SI (b) MKS
   (b) CGS (d) FPS
8. Unit of latent heat is
   (a) J Kg^{-1} (b) J mol^{-1}
   (c) N Kg^{-1} (d) N mol^{-1}
9. Dyne-sec is the unit of
   (a) momentum (b) force
   (c) work (d) angular momentum
10. Illuminance of a surface is measured in
    (a) Lumen (b) candela
    (c) lux (d) lux m^{-2}
11. SI unit of electric polarisation is
    (a) Cm^{-2} (b) coulomb
    (c) ampere (d) volt
12. The SI unit of coefficient of mutual inductance of a coil is
    (a) henry (b) volt
    (c) farad (c) weber
13. Light year is
    (a) light emitted by the sun in one year.
    (b) time taken by light to travel from sun to earth.
    (c) the distance travelled by light in free space in one year.
    (d) time taken by earth to go once around the sun.
14. The SI unit of pressure is
    (a) atmosphere (b) bar
    (c) pascal (d) mm of Hg
15. Electron volt is a unit of
    (a) potential difference (b) charge
    (c) energy (d) capacity
16. Dimensions of impulse are
    (a) $[MLT^{-1}]$ (b) $[MLT^2]$
    (c) $[MT^{-2}]$ (d) $[ML^{-1}T^{-3}]$
17. The S.I. unit of pole strength is
    (a) Am^2 (b) Am
    (c) A m^{-1} (d) Am^{-2}
18. Which is dimensionless?
    (a) Force/acceleration (b) Velocity/acceleration
    (c) Volume/area (d) Energy/work
19. Potential is measured in
    (a) joule/coulomb (b) watt/coulomb
    (c) newton-second (d) None of these
20. Maxwell is the unit of
    (a) magnetic susceptibility
    (b) intensity of Magnetisation
    (c) magnetic Flux
    (d) magnetic Permeability
21. The mass of the liquid flowing per second per unit area of cross-section of the tube is proportional to (pressure difference across the ends)^n and (average velocity of the liquid)^m. Which of the following relations between m and n is correct?
    (a) m = n (b) m = – n
    (c) m^2 = n (d) m = – n^2
22. Which of the following is a derived physical quantity?
    (a) Mass (b) Velocity
    (c) Length (d) Time
23. N kg^{-1} is the unit of
    (a) velocity (b) force
    (c) acceleration (d) None of these
24. Which physical quantities have same dimensions?
    (a) Moment of couple and work
    (b) Force and power
    (c) Latent heat and specific heat
    (d) Work and power
25. The expression [ML^{-1} T^{-2}] does not represent
    (a) pressure (b) power
    (c) stress (d) Young's modulus

EXERCISE - 2
Applied Questions

1. What are the units of magnetic permeability?
(a) Wb A^{-1} m^{-1} (b) Wb^{-1} Am
(c) Wb A m^{-1} (d) Wb A^{-1} m

2. The dimensions of pressure gradient are
(a) $[ML^{-2} T^{-2}]$ (b) $[ML^{-2} T^{-1}]$
(c) $[ML^{-1} T^{-1}]$ (d) $[ML^{-1} T^{-2}]$

3. The dimensions of Rydberg's constant are
(a) $[M^0 L^{-1} T]$ (b) $[MLT^{-1}]$
(c) $[M^0 L^{-1} T^0]$ (d) $[ML^0 T^2]$

4. The dimensions of universal gas constant are
(a) $[L^2 M^1 T^{-2} K^{-1}]$ (b) $[L^1 M^2 T^{-2} K^{-1}]$
(c) $[L^1 M^1 T^{-2} K^{-1}]$ (d) $[L^2 M^2 T^{-2} K^{-1}]$

5. The dimensions of magnetic moment are
(a) $[L^2 A^1]$ (b) $[L^2 A^{-1}]$
(c) $[L^2 / A^3]$ (d) $[LA^2]$

6. The dimensions of Wien's constant are
(a) $[ML^0 T K]$ (b) $[M^0 LT^0 K]$
(c) $[M^0 L^0 T K]$ (d) [MLTK]

7. The unit and dimensions of impedance in terms of charge Q are
(a) mho, $[ML^2 T^{-2} Q^{-2}]$ (b) ohm, $[ML^2 T^{-1} Q^{-2}]$
(c) ohm, $[ML^2 T^{-2} Q^{-1}]$ (d) ohm, $[MLT^{-1} Q^{-1}]$

8. If L denotes the inductance of an inductor through which a current i is flowing, the dimensions of L i^2 are
(a) $[ML^2 T^{-2}]$
(b) $[MLT^{-2}]$
(c) $[M^2 L^2 T^{-2}]$
(d) Not expressible in M, L, T

9. The dimensional formula of wave number is
(a) $[M^0 L^0 T^{-1}]$ (b) $[M^0 L^{-1} T^0]$
(c) $[M^{-1} L^{-1} T^0]$ (d) $[M^0 L^0 T^0]$

10. The period of a body under S.H.M. is represented by: $T = P^a D^b S^c$ where P is pressure, D is density and S is surface tension, then values 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 1/3

11. The time of oscillation T of a small drop of liquid depends on radius r, density ρ and surface tension S. The relation between them is given by
(a) $T \propto \sqrt{\frac{S}{\rho r^3}}$ (b) $T \propto \sqrt{\frac{\rho r^3}{S}}$
(c) $T \propto \sqrt{\frac{S^2 r^3}{\rho}}$ (d) $T \propto \sqrt{\frac{\rho r^3}{S}}$

12. The potential energy of a particle varies with distance x from a fixed origin as $V = \frac{A\sqrt{x}}{x+B}$ where A and B are constants. The dimensions of AB are
(a) $[M^1 L^{5/2} T^{-2}]$ (b) $[M^1 L^2 T^{-2}]$
(c) $[M^{3/2} L^{5/2} T^{-2}]$ (d) $[M^1 L^{7/2} T^{-2}]$

13. Distance travelled by a particle at any instant 't' can be represented as $S = A(t + B) + Ct^2$. The dimensions of B are
(a) $[M^0 L^1 T^{-1}]$ (b) $[M^0 L^0 T^1]$
(c) $[M^0 L^{-1} T^{-2}]$ (d) $[M^0 L^2 T^{-2}]$

14. The deBroglie wavelength associated with a particle of mass m and energy E is $h/\sqrt{2mE}$. The dimensional formula of Planck's constant h is
(a) $[M^2 L^2 T^{-2}]$ (b) $[ML^2 T^{-1}]$
(c) $[MLT^{-2}]$ (d) $[ML^2 T^{-2}]$

15. The velocity of a body which falls under gravity varies as $g^a h^b$, where g is acc. due to gravity and h is the height. The values of a and b are
(a) a = 1, b = 1/2 (b) a = b = 1
(c) a = 1/2, b = 1 (d) a = 1/2; b = 1/2

16. The velocity v of a particle at time t is given by $v = at + \frac{b}{t+c}$
The dimensions of a, b c are respectively
(a) $[LT^{-2}]$, [L], [T] (b) $[L^2]$, [T] and $[LT^2]$
(c) $[LT^2]$, [LT] and [L] (d) [L], [LT] and $[T^2]$

17. The dimensions of Hubble's constant are
(a) $[T^{-1}]$ (b) $[M^0 L^0 T^{-2}]$
(c) $[MLT^4]$ (d) $[MT^{-1}]$

18. Error in the measurement of radius of a sphere is 1%. Then error in the measurement of volume is
(a) 1% (b) 5%
(c) 3% (d) 8%

19. Subtract 0.2 J from 7.26 J and express the result with correct number of significant figures.
(a) 7.1 J (b) 7.06 J
(c) 7.0 J (d) 7 J

20. Multiply 107.88 by 0.610 and express the result with correct number of significant figures.
(a) 65.8068 (b) 65.807
(c) 65.81 (d) 65.8

21. When 97.52 is divided by 2.54, the correct result is
(a) 38.3937 (b) 38.394
(c) 38.39 (d) 38.4

22. Relative density of a metal may be found with the help of spring balance. In air the spring balance reads (5.00 ± 0.05) N and in water it reads (4.00 ± 0.05) N. Relative density would be
(a) (5.00 ± 0.05)N (b) $(5.00 \pm 11\%)$
(c) (5.00 ± 0.10) (d) $(5.00 \pm 6\%)$

23. Area of a square is (100 ± 2) m^2. Its side is
(a) (10 ± 1)m (b) (10 ± 0.1)m
(c) $(10 \pm \sqrt{2})$m (d) $10 \pm \sqrt{2}\%$

24. Let Q denote the charge on the plate of a capacitor of capacitance C. The dimensional formula for $\frac{Q^2}{C}$ is
(a) $[L^2M^2T]$ (b) $[LMT^2]$
(c) $[L^2MT^{-2}]$ (d) $[L^2M^2T^2]$

25. If L and R denote inductance and resistance then dimension of L/R is
(a) $[M^0L^0T^0]$ (b) $[M^0L^0T]$
(c) $[M^2L^0T^2]$ (d) $[MLT^2]$

26. The dimensional formula of current density is
(a) $[M^0L^{-2}T^{-1}Q]$ (b) $[M^0L^2T^1Q^{-1}]$
(c) $[MLT^{-1}Q]$ (d) $[ML^{-2}T^{-1}Q^2]$

27. The least count of a stop watch is 0.2 second. The time of 20 oscillations of a pendulum is measured to be 25 second. The percentage error in the measurement of time will be
(a) 8% (b) 1.8%
(c) 0.8% (d) 0.1%

28. The dimensional formula for relative density is
(a) $[M L^{-3}]$ (b) $[M^0 L^{-3}]$
(c) $[M^0 L^0 T^{-1}]$ (d) $[M^0 L^0 T^0]$

29. The solid angle sustended by the total surface area of a sphere, at the centre is
(a) 4π (b) 2π
(c) π (d) 3π

30. If C and L denote the capacitance and inductance, the dimensions of LC are
(a) $[M^0 L^0 T^{-1}]$ (b) $[M^0 L^{-1} T^0]$
(c) $[M^{-1} L^{-1} T^0]$ (d) $[M^0 L^0 T^2]$

31. The dimensions of solar constant is
(a) $[M^0 L^0 T^0]$ (b) $[MLT^{-2}]$
(c) $[ML^2 T^{-2}]$ (d) MT^{-3}

32. The dimensions of $\frac{1}{\epsilon_o}\frac{e^2}{hc}$ are
(a) $M^{-1} L^{-3} T^4 A^2$ (b) $ML^3 T^{-4} A^{-2}$
(c) $M^0 L^0 T^0 A^0$ (d) $M^{-1} L^{-3} T^2 A$

33. The dimensional formula for entropy is
(a) $[MLT^{-2} K^1]$ (b) $[ML^2 T^{-2}]$
(c) $[ML^2 T^{-2} K^{-1}]$ (d) $[ML^2 T^{-2} K]$

34. Dimensions of specific heat are
(a) $[ML^2 T^{-2} K]$ (b) $[ML^2 T^{-2} K^{-1}]$
(c) $[ML^2 T^2 K^{-1}]$ (d) $[L^2 T^{-2} K^{-1}]$

35. L, C, R represent physical quantities inductance, capacitance and resistance respectively. The combinations which have the dimensions of frequency are
(a) 1/RC (b) R/L
(c) $1/\sqrt{LC}$ (d) C/L

36. The physical quantity which has the dimensional formula $[M^1T^{-3}]$ is
(a) surface tension (b) solar constant
(c) density (d) compressibility

37. Which of the following is the most accurate?
(a) 200.0 m (b) 20×10^1 m
(c) 2×10^2 m (d) data is inadequate

38. The velocity of water waves (v) may depend on their wavelength λ, the density of water ρ and the acceleration due to gravity, g. The method of dimensions gives the relation between these quantities is
(a) v (b) $v^2 \propto g\lambda$
(c) $v^2 \propto g\lambda^2$ (d) $v^2 \propto g^{-1}\lambda^2$

39. The time dependence of a physical quantity p is given by $p = p_0 \exp.(-\alpha t^2)$, where α is a constant and t is the time. The constant α
(a) is dimensionless (b) has dimensions T^{-2}
(c) has dimensions T^2 (d) has dimensions of p.

40. In the eqn. $\left(P + \frac{a}{V^2}\right)(V - b) = \text{constant}$, the unit of a is
(a) dyne × cm^5 (b) dyne × cm^4
(c) dyne/cm^3 (d) dyne × cm^2

41. Dimensions of 'ohm' are same as (where h is Planck's constant and e is charge)
(a) $\frac{h}{e}$ (b) $\frac{h^2}{e}$ (c) $\frac{h}{e^2}$ (d) $\frac{h^2}{e^2}$

42. The Richardson equation is given by $I = AT^2e^{-B/kT}$. The dimensional formula for AB^2 is same as that for
(a) $I\,T^2$ (b) kT
(c) $I\,k^2$ (d) $I\,k^2/T$

43. The unit of current in C.G.S. system is
(a) 10 A (b) 1/10 A
(c) 1/100 A (d) 1/1000 A

44. Which of the following do not have the same dimensional formula as the velocity?
Given that μ_0 = permeability of free space, ε_0 = permittivity of free space, ν = frequency, λ = wavelength, P = pressure, ρ = density, ω = angular frequency, k = wave number,
(a) $1/\sqrt{\mu_0 \varepsilon_0}$ (b) $\nu\lambda$
(c) $\sqrt{P/\rho}$ (d) ωk

45. A cube has numerically equal volume and surface area. The volume of such a cube is
(a) 1000 unit (b) 200 unit
(c) 216 unit (d) 300 unit

46. A spherical body of mass m and radius r is allowed to fall in a medium of viscosity η. The time in which the velocity of the body increases from zero to 0.63 times the terminal velocity (v) is called time constant τ. Dimensionally τ can be represented by
(a) $\frac{mr^2}{6\pi\eta}$ (b) $\sqrt{\left(\frac{6\pi m r \eta}{g^2}\right)}$
(c) $\frac{m}{6\pi\eta r v}$ (d) None of these

47. A quantity is represented by $X = M^a L^b T^c$. The % error in measurement of M, L and T are α%, β% and γ% respectively. The % error in X would be
(a) $(\alpha a + \beta b + \gamma c)\%$ (b) $(\alpha a - \beta b + \gamma c)\%$
(c) $(\alpha a - \beta b - \gamma c) \times 100\%$ (d) None of these

48. In a Vernier calliper, N divisions of vernier scale coincide with (N–1) divisions of main scale (in which one division represents 1 mm). the least count of the instrument in cm. should be
(a) N (b) N – 1
(c) $\frac{1}{10N}$ (d) $\frac{1}{N-1}$

49. What is the fractional error in g calculated from $T = 2\pi\sqrt{\ell/g}$? Given fraction errors in T and l are $\pm$ x and $\pm$ y respectively.
(a) $x + y$ (b) $x - y$
(c) $2x + y$ (d) $2x - y$

50. Conversion of 1 MW power in a New system of units having basic units of mass, length and time as 10 kg, 1 dm and 1 minute respectively is
(a) 2.16×10^{10} unit (b) 2×10^4 unit
(c) 2.16×10^{12} unit (d) 1.26×10^{12} unit

51. A resistor of 10 k Ω having tolerance 10% is connected in series with another resistor of 20 k Ω having tolerance 20%. The tolerance of the combination will be
(a) 10% (b) 13%
(c) 30% (d) 20%

52. Using mass (M), length(L), time (T) and electric current (A) as fundamental quantities the dimensions of permittivity will be
(a) $[MLT^{-1}A^{-1}]$ (b) $[MLT^{-2}A^{-2}]$
(c) $[M^{-1}L^{-3}T^{+4}A^2]$ (d) $[M^2L^{-2}T^{-2}A^2]$

53. The percentage errors in the measurement of mass and speed are 2% and 3% respectively. The error, in kinetic energy obtained by measuring mass and speed, will be
(a) 12 % (b) 10 %
(c) 8 % (d) 2 %

54. The density of a cube is measured by measuring its mass and length of its sides. If the maximum error in the measurement of mass and length are 4% and 3% respectively, the maximum error in the measurement of density will be
(a) 7% (b) 9%
(c) 12% (d) 13%

55. The speed of sound in a gas is given by $v = \sqrt{\frac{\gamma RT}{M}}$
R = universal gas constant,
T = temperature
M = molar mass of gas
The dimensional formula of γ is
(a) $[M^0L^0T^0]$ (b) $[M^0LT^{-1}]$
(c) $[MLT^{-2}]$ (d) $[M^0L^0T^{-1}]$

56. Specific gravity has .... dimensions in mass, ... dimensions in length and .... dimensions in time.
(a) 0, 0, 0 (b) 0, 1, 0
(c) 1, 0, 0 (d) 1, 1, 3

57. If I is the moment of inertia and ω the angular velocity, what is the dimensional formula of rotational kinetic energy $\frac{1}{2}I\omega^2$?
(a) $[ML^2T^{-1}]$ (b) $[M^2L^{-1}T^{-2}]$
(c) $[ML^2T^{-2}]$ (d) $[M^2L^{-1}T^{-2}]$

58. Given that $r = m^2 \sin \pi t$, where t represents time. If the unit of m is N, then the unit of r is
(a) N (b) N^2
(c) Ns (d) N^2s

59. The dimensional formula of farad is
(a) $[M^{-1}L^{-2}TQ]$ (b) $[M^{-1}L^{-2}T^2Q^2]$
(c) $[M^{-1}L^{-2}TQ^2]$ (d) $[M^{-1}L^{-2}T^2Q]$

60. If time T, acceleration A and force F are regarded as base units, then the dimensional formula of work is
(a) [FA] (b) [FAT]
(c) $[FAT^2]$ (d) $[FA^2T]$

61. Turpentine oil is flowing through a capillary tube of length ℓ and radius r. The pressure difference between the two ends of the tube is p. The viscosity of oil is given by : $\eta = \frac{p(r^2 - x^2)}{4v\ell}$. Here v is velocity of oil at a distance x from the axis of the tube. From this relation, the dimensional formula of η is

(a) $[ML^{-1}T^{-1}]$ (b) $[MLT^{-1}]$
(c) $[ML^2T^{-2}]$ (d) $[M^0L^0T^0]$

62. The dimensional formula of velocity gradient is

(a) $[M^0L^0T^{-1}]$ (b) $[MLT^1]$
(c) $[ML^0T^{-1}]$ (d) $[M^0LT^{-2}]$

63. The thrust developed by a rocket-motor is given by $F = mv + A(P_1 - P_2)$ where m is the mass of the gas ejected per unit time, v is velocity of the gas, A is area of cross-section of the nozzle, P_1 and P_2 are the pressures of the exhaust gas and surrounding atmosphere. The formula is dimensionally

(a) correct
(b) wrong
(c) sometimes wrong, sometimes correct
(d) Data is not adequate

64. If E, m, J and G represent energy, mass, angular momentum and gravitational constant respectively, then the dimensional formula of EJ^2/m^5G^2 is

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

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

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

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

(a) 0.5 mm (b) 1 mm
(c) 2 mm (d) $\frac{1}{4}$ mm

67. The pitch of the screw gauge is 0.5 mm. Its circular scale contains 50 divisions. The least count of the screw gauge is

(a) 0.001 mm (b) 0.01 mm
(c) 0.02 mm (d) 0.025 mm

68. If x = a – b, then the maximum percentage error in the measurement of x will be

(a) $\left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right) \times 100\%$ (b) $\left(\frac{\Delta a}{a} - \frac{\Delta b}{b}\right) \times 100\%$
(c) $\left(\frac{\Delta a}{a-b} + \frac{\Delta b}{a-b}\right) \times 100\%$ (d) $\left(\frac{\Delta a}{a-b} - \frac{\Delta b}{a-b}\right) \times 100\%$

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

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

70. The pressure on a square plate is measured by measuring the force on the plate and length of the sides of the plate by using the formula $P = \frac{F}{\ell^2}$. If the maximum errors in the measurement of force and length are 4% and 2% respectively, then the maximum error in the measurement of pressure is

(a) 1% (b) 2%
(c) 8% (d) 10%

71. In a simple pendulum experiment for the determination of acceleration due to gravity, time period is measured with an accuracy of 0.2% while length was measured with an accuracy of 0.5%. The percentage accuracy in the value of g so obtained is

(a) 0.25% (b) 0.7%
(c) 0.9% (d) 1.0%

72. The dimensions of a rectangular block measured with callipers having least count of 0.01 cm are 5 mm × 10 mm × 5 mm. The maximum percentage error in the measurement of the volume of the block is

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

73. Consider the following pairs of quantities

1. Young's modulus; pressure
2. Torque; energy
3. Linear momentum; work
4. Solar day; light year.

In which cases are the dimensions, within a pair, same?

(a) 1 and 3 (b) 1 and 4
(c) 1 and 2 (d) 2 and 4

74. Which one of the following has the same dimension as that of time, if R is resistance, L inductance and C is capacitance?

(a) RC (b) $\sqrt{LC}$
(c) L/R (d) All of the above

75. The equation of a wave is given by

$y = a \sin \omega\left(\frac{x}{v} - k\right)$, where ω is angular velocity and v is linear velocity. The dimensions of K will be

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

76. In the equation $X = 3YZ^2$, X and Z are dimensions of capacitance and magnetic induction respectively. In MKSQ system, the dimensional formula for Y is

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

77. A force is given by $F = at + bt^2$, where t is time, the dimensions of a and b are

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

78. The frequency of vibration of a string is given by $f = \frac{n}{2L}\sqrt{\frac{T}{m}}$, where T is tension in the string, L is the length, n is number of harmonics. The dimensional formula for m is

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

79. The dimensions of voltage in terms of mass (M), length (L) and time (T) and ampere (A) are

(a) $[ML^2T^{-2}A^{-2}]$ (b) $[ML^2T^3A^{-1}]$
(c) $[ML^2T^{-3}A^1]$ (d) $[ML^2T^{-3}A^{-1}]$

80. Suppose the kinetic energy of a body oscillating with amplitude A and at a distance x is given by

$$K = \frac{Bx}{x^2 + A^2}$$

The dimensions of B are the same as that of

(a) work/time (b) work × distance
(c) work/distance (d) work × time

81. The dimensions of magnetic field in M, L, T and C (coulomb) are given as

(a) $[MLT^{-1} C^{-1}]$ (b) $[MT^2 C^{-2}]$
(c) $[MT^{-1} C^{-1}]$ (d) $[MT^{-2} C^{-1}]$

82. Two full turns of the circular scale of a screw gauge cover a distance of 1mm on its main scale. The total number of divisions on the circular scale is 50. Further, it is found that the screw gauge has a zero error of – 0.03 mm. While measuring the diameter of a thin wire, a student notes the main scale reading of 3 mm and the number of circulr scale divisions in line with the main scale as 35. The diameter of the wire is

(a) 3.32 mm (b) 3.73 mm
(c) 3.67 mm (d) 3.38 mm

83. 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
(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

84. The density of a material in CGS system of units is $4 g/cm^3$. In a system of units in which unit of length is 10 cm and unit of mass is 100 g, the value of density of material will be

(a) 0.4 (b) 40
(c) 400 (d) 0.04

85. 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

$$P = \frac{a^3b^2}{cd}$$

% error in P is

(a) 10% (b) 7%
(c) 4% (d) 14%

86. What is the fractional error in g calculated from $T = 2\pi\sqrt{\ell/g}$? Given fractional errors in T and l are ± x and ± y respectively.

(a) x + y (b) x – y
(c) 2x + y (d) 2x – y

87. The resistance R of a wire is given by the relation $R = \frac{\rho\ell}{\pi r^2}$. Percentage error in the measurement of ρ, ℓ and r is 1%, 2% and 3% respectively. Then the percentage error in the measurement of R is :

(a) 6 (b) 9
(c) 8 (d) 10

88. What are the dimensions of permeability ?

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

89. The physical quantity having the dimensions $[M^{-1}L^{-3}T^3A^2]$ is

(a) resistance (b) resistivity
(c) electrical conductivity (d) electromotive force

90. The time of reverberation of a room A is one second. What will be the time (in seconds) of reverberation of a room, having all the dimensions double of those of room A?

(a) 2 (b) 4
(c) $\frac{1}{2}$ (d) 1

91. Which of the following is the unit of molar gas constant?

(a) $JK^{-1} mol^{-1}$ (b) Joule
(c) JK^{-1} (d) $J mol^{-1}$

92. Density of liquid is $16.8 g cm^{-3}$. Its value in the International System of Units is

(a) $16.8 kgm^{-3}$ (b) $168 kgm^{-3}$
(c) $1680 kgm^{-3}$ (d) $16800 kgm^{-3}$

93. The dimensional formula of couple is

(a) $[ML^2T^{-2}]$ (b) $[MLT^2]$
(c) $[ML^{-1}T^{-3}]$ (d) $[ML^{-2}T^{-2}]$

94. The refractive index of water measured by the relation $\mu = \frac{\text{real depth}}{\text{apparent depth}}$ is found to have values of 1.34, 1.38, 1.32 and 1.36; the mean value of refractive index with percentage error is

(a) $1.35 \pm 1.48\,\%$ (b) $1.35 \pm 0\,\%$
(c) $1.36 \pm 6\,\%$ (d) $1.36 \pm 0\,\%$

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

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

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

(a) 0.52 cm (b) 0.59 cm
(c) 0.56 cm (d) 0.53 cm

96. 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 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of 1s resolution. The accuracy in the determination of g is

(a) 1% (b) 5%
(c) 2% (d) 3%

DIRECTIONS for Qs. (97 to 100) : Each question contains STATEMENT-1 and STATEMENT-2. Choose the correct answer (ONLY ONE option is correct) from the following

(a) Statement -1 is false, Statement-2 is true
(b) Statement -1 is true, Statement-2 is true; Statement -2 is a correct explanation for Statement-1
(c) Statement -1 is true, Statement-2 is true; Statement -2 is not a correct explanation for Statement-1
(d) Statement -1 is true, Statement-2 is false

97. **Statement 1 :** The number of significant figures depends on the least count of measuring instrument.

Statement 2 : Significant figures define the accuracy of measuring instrument.

98. **Statement 1 :** Absolute error may be negative or positive.

Statement 2 : Absolute error is the difference between the real value and the measured value of a physical quantity.

99. **Statement 1 :** In the measurement of physical quantities direct and indirect methods are used.

Statement 2 : The accuracy and precision of measuring instruments along with errors in measurements should be taken into account, while expressing the result.

100. **Statement 1 :** Energy cannot be divided by volume.

Statement 2 : Because dimensions for energy and volume are different.

EXERCISE - 3
Exemplar & Past Years NEET/AIPMT Questions

Exemplar Questions

1. The number of significant figures in 0.06900 is

(a) 5 (b) 4
(c) 2 (d) 3

2. 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

3. The mass and volume of a body are 4.237 g and 2.5 cm^3, respectively. The density of the material of the body in correct significant figures is

(a) $1.6048\ g\ cm^{-3}$ (b) $1.69\ g\ cm^{-3}$
(c) $1.7\ g\ cm^{-3}$ (d) $1.695\ g\ cm^{-3}$

4. 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

5. The length and breadth of a rectangular sheet are 16.2 ± 0.1 cm and 10.1 ± 0.1 cm, 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) $163.62 \pm 3\ cm^2$

6. Which of the following pairs of physical quantities does not have same dimensional forrmula?

(a) Work and torque
(b) Angular momentum and Planck's constant
(c) Tension and surface tension
(d) Impulse and linear momentum

7. Measure of two quantities along with the precision of respective measuring instrument is

$A = 2.5\ ms^{-1} \pm 0.5\ ms^{-1}$,

$B = 0.10\ s \pm 0.01\ s$. The value of AB will be

(a) $(0.25 \pm 0.08)\,m$ (b) $(0.25 \pm 0.5)\,m$
(c) $(0.25 \pm 0.05)\,m$ (d) $(0.25 \pm 0.135)\,m$

8. You measure two quantities as $A = 1.0\ m \pm 0.2\ m$, $B = 2.0\ m \pm 0.2\ m$. We should report correct value for $\sqrt{AB}$ as

(a) $1.4\ m \pm 0.4\ m$ (b) $1.41\ m \pm 0.15\ m$
(c) $1.4\ m \pm 0.3\ m$ (d) $1.4\ m \pm 0.2\ m$

9. Which of the following measurement is most precise?

(a) 5.00 mm (b) 5.00 cm
(c) 5.00 m (d) 5.00 km

10. The mean length of an object is 5 cm. Which is the following measurement is most accurate?
(a) 4.9 cm (b) 4.805 cm
(c) 5.25 cm (d) 5.4 cm

11. Young's modulus of steel is 1.9×10^{11} N/m^2. When expressed in CGS units of dyne/cm^2, it will be equal to ($1\text{N} = 10^5$ dyne, $1\text{ m}^2 = 10^4 \text{ cm}^2$)
(a) 1.9×10^{10} (b) 1.9×10^{11}
(c) 1.9×10^{12} (d) 1.9×10^{13}

12. If momentum (p), area (A) and time (T) are taken to be fundamental quantities, then energy has the dimensional formula
(a) $[pA^{-1}T^1]$ (b) $[p^2AT]$
(c) $[pA^{-1/2}T]$ (d) $[pA^{1/2}T]$

NEET/AIPMT (2013-2017) Questions

13. 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 $P = \dfrac{a^3b^2}{cd}$ % error in P is:
(a) 10% (b) 7% ***[2013]***
(c) 4% (d) 14%

14. The pair of quantities having same dimensions is
(a) Young's modulus and energy ***[NEET Kar. 2013]***
(b) impulse and surface tension
(c) angular momentum and work
(d) work and torque

15. If force (F), velocity (V) and time (T) are taken as fundamental units, then the dimensions of mass are : ***[2014]***
(a) $[F\,V\,T^{-1}]$ (b) $[F\,V\,T^{-2}]$
(c) $[F\,V^{-1}\,T^{-1}]$ (d) $[F\,V^{-1}\,T]$

16. If energy (E), velocity (V) and time (T) are chosen as the fundamental quantities, the dimensional formula of surface tension will be : ***[2015]***
(a) $[EV^{-1}T^{-2}]$ (b) $[EV^{-2}T^{-2}]$
(c) $[E^{-2}V^{-1}T^{-3}]$ (d) $[EV^{-2}T^{-1}]$

17. If dimensions of critical velocity υ_c of a liquid flowing through a tube are expressed as $[\eta^x \rho^y r^x]$, 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 : ***[2015 RS]***
(a) –1, –1, 1 (b) –1, –1, –1
(c) 1, 1, 1 (d) 1, –1, –1

18. A physical quantity of the dimensions of length that can be formed out of c, G and $\dfrac{e^2}{4\pi\varepsilon_0}$ is [c is velocity of light, G is universal constant of gravitation and e is charge] ***[2017]***
(a) $c^2\left[G\dfrac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$ (b) $\dfrac{1}{c^2}\left[\dfrac{e^2}{G4\pi\varepsilon_0}\right]^{1/2}$
(c) $\dfrac{1}{c}G\dfrac{e^2}{4\pi\varepsilon_0}$ (d) $\dfrac{1}{c^2}\left[G\dfrac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$

Hints & Solutions

EXERCISE - 1

1. (d) Temperature is one of the basic physical quantities.
2. (b) The vander Waal's gas equation is

$$(P+\frac{a}{V^2})(V-b)=RT \text{ for one mole.}$$

$$\&\ \left(P+\frac{\mu a}{V^2}\right)(V-\mu b)=\mu RT \text{ for } \mu \text{ mole}$$

Dimensionally in first bracket on L.H.S

$$[P]=\left[\frac{\mu a}{V^2}\right]\Rightarrow[a]=\frac{[P]V^2}{\mu}$$

$$\text{Dimension of } [a]=\left[\frac{\text{atm. litre}^2}{\text{mole}}\right]$$

3. (d)
4. (c) $\frac{eV}{T}=\frac{W}{T}=\frac{PV}{T}=R$

and $\frac{R}{N}=$ Boltzmann constant.

5. (a) 6. (a)
7. (a) SI is based on seven fundamental units.
8. (a) $L=\frac{Q}{m}=\frac{J}{kg}=J\,kg^{-1}$
9. (a) As force = change in momentum/time.
$\therefore$ force × time = change in momentum
10. (c) Illuminance is intensity of illumination measured in lux.
11. (a) $P=\frac{Q_i}{A}=\frac{C}{m^2}=Cm^{-2}$
12. (a)
13. (c) 1 light year = speed of light in vacuum × no. of seconds in one year = $(3\times10^8)\times(365\times24\times60\times60)=9.467\times10^{15}$ m.
14. (c) 1 pascal = $1\ N/m^2$.
15. (c) Electron volt is a unit of energy & $1eV=1.6\times10^{-19}$ joule
16. (a) Impulse = force × time $=MLT^{-2}\times T=[M^1LT^{-1}]$.
17. (b) Pole strength, $m=\frac{M}{2\ell}=\frac{A\,m^2}{m}=A\,m.$
18. (d) Both energy and work have same unit.
$\therefore$ energy/work is a pure number.
19. (a) Potential is work done per unit charge.
20. (c) Maxwell is the unit of magnetic flux in C.G.S system.
1 Wb(S.I unit) = 10^8 maxwell
21. (b) Let $M=p^nv^m$

$$ML^{-2}T^{-1}=(ML^{-1}T^{-2})^n(LT^{-1})^m$$
$$=M^nL^{-n+m}T^{-2n-m}$$
$$\therefore\ n=1;\ -n+m=-2$$
$$\therefore\ m=-2+n=-2+1=-1 \qquad \therefore\ m=-n$$

22. (b)
23. (c) $N\,kg^{-1}$ = force/mass = acceleration
24. (a) Moment of couple = force × distance $=[M^1L^2T^{-2}]$

work = force × distance $=[M^1L^2T^{-2}]$.

25. (b) Power $=\frac{\text{energy}}{\text{time}}=\frac{ML^2T^{-2}}{T}=[ML^2T^{-3}]$.

EXERCISE - 2

1. (a) From Biot Savart's law

$$B=\frac{\mu_0}{4\pi}\frac{i\,dl\,\sin\theta}{r^2}$$

$$\mu_0=\frac{4\pi\,Br^2}{i\,dl\,\sin\theta}=\frac{Wb\,m^{-2}m^2}{A\,m}=Wb\,A^{-1}\,m^{-1}$$

2. (a) Pressure gradient $=\frac{\text{Pressure difference}}{\text{distance}}$.

$$[\text{Pressure gradient}]=\frac{ML^{-1}T^{-2}}{L}=\left[ML^{-2}T^{-2}\right]$$

3. (c) From $\frac{1}{\lambda}=R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$,

dimensions of $R=\frac{1}{L}=L^{-1}=[M^0L^{-1}T^0]$

4. (a) $R=\frac{PV}{\mu T}=\frac{W}{\mu T}=\frac{ML^2T^{-2}}{mol\,K}$

where μ is number of mole of the gas
$=[M^1L^2T^{-2}K^{-1}mol^{-1}]$

5. (a) M = current × area = $AL^2=[L^2A^1]$
6. (b) $b=\lambda_m T=LK=[M^0L^1T^0K^1]$
7. (b) Impedance $=\frac{V}{I}=\frac{W}{QI}=\frac{ML^2T^{-2}}{Q\,QT^{-1}}$

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

8. (a) Energy stored in an inductor $=\frac{1}{2}Li^2=[ML^2T^{-2}]$

9. (b) Wave number $\bar{v}=\frac{1}{\lambda}=\frac{1}{L}=[M^0L^{-1}T^0]$.

10. (a) $T=P^aD^bS^c$

$M^0L^0T^1=(ML^{-1}T^{-2})^a(ML^{-3})^b(MT^{-2})^c$

$=M^{a+b+c}L^{-a-3b}T^{-2a-2c}$

Applying principle of homogeneity

$a+b+c=0;\ -a-3b=0;\ -2a-2c=1$

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

11. (b) $\sqrt{\frac{\rho r^3}{S}}=\sqrt{\frac{ML^{-3}L^3}{MT^{-2}}}=T$

12. (d) $B=x=[L];\ A\sqrt{x}=Vx;\ A=V\sqrt{x}$

$=ML^2T^{-2}L^{1/2}=ML^{5/2}T^{-2}$

$AB=(ML^{5/2}T^{-2})(L)=[M^1L^{7/2}T^{-2}]$

13. (b) In $S=A(t+B)+Ct^2$; B is added to time t. Therefore, dimensions of B are those of time.

14. (b) $h=\lambda\sqrt{2mE}=L\sqrt{M(ML^2T^{-2})}=[ML^2T^{-1}]$

15. (d) $v=g^ah^b;\ [M^0LT^{-1}]=(LT^{-2})^aL^b=L^{a+b}T^{-2a}$

$\therefore\ a+b=1;\ -2a=-1\quad a=1/2$

$\therefore\ b=1/2$

16. (a) As c is added to t, $\therefore\ c=[T]$

$a=\frac{v}{t}=\frac{LT^{-1}}{T}=[LT^{-2}]$,

$b=v(t+c)=LT^{-1}\times T=[L]$

17. (a) Hubble's constant, $H=\frac{\text{velocity}}{\text{distance}}=\frac{[LT^{-1}]}{[L]}$

$=[T^{-1}]=70\times10^{-3}\ N/m$.

18. (c) $V=\frac{4}{3}\pi r^3$;

$\frac{\Delta V}{V}\times100=3\left(\frac{\Delta r}{r}\right)\times100=3\times1\%=3\%$

19. (a) Subtraction is correct upto one place of decimal, corresponding to the least number of decimal places. $7.26-0.2=7.06=7.1$ J.

20. (d) Number of significant figures in multiplication is three, corresponding to the minimum number $107.88\times0.610=65.8068=65.8$

21. (d) $\frac{97.52}{2.54}=38.393=38.4$ (with least number of significant figures, 3).

22. (d) Relative density $=\frac{\text{Weight of body in air}}{\text{Loss of weight in water}}$

$=\frac{5.00}{5.00-4.00}=\frac{5.00}{1.00}$

$\frac{\Delta\rho}{\rho}\times100=\left(\frac{0.05}{5.00}+\frac{0.05}{1.00}\right)\times100$

$=(0.01+0.05)\times100$

$=0.06\times100=6\%$

$\therefore$ Relative density $=5.00\pm6\%$

23. (a) Area = $(\text{Length})^2$

or length $=(\text{Area})^{1/2}$

$=(100\pm2)^{1/2}$

$=(100)^{1/2}\pm\frac{1}{2}\times2$

$=(10\pm1)$m

24. (c) We know that $\frac{Q^2}{2C}$ is energy of capacitor so it represent the dimension of energy $=[ML^2T^{-2}]$.

25. (b) $L/R=\frac{\text{Volt}\times\text{sec/amp.}}{\text{Volt/amp.}}=\text{sec.}=[M^0L^0T]$

26. (a) Current density $=\frac{\text{Current}}{\text{area}}=\frac{Q}{\text{area}\times t}$

27. (c) $\frac{0.2}{25}\times100=0.8$

28. (d) 29. (a)

30. (d) From $\nu=\frac{1}{2\pi\sqrt{LC}}$

$LC=\frac{1}{(2\pi\nu)^2}=\frac{1}{(T^{-1})^2}=T^2=[M^0L^0T^2]$

31. (d) Solar constant = energy/sec/area

$=\frac{ML^2T^{-2}}{TL^2}=[MT^{-3}]$

32. (c) From $F=\frac{1}{4\pi\varepsilon_o}\frac{e^2}{r^2}$

$\therefore\ \frac{e^2}{\varepsilon_o}=4\pi Fr^2$ (dimensionally)

$\frac{e^2}{\varepsilon_o hc}=\frac{4\pi Fr^2}{hc}=\frac{(MLT^{-2})L^2}{ML^2T^{-1}[LT^{-1}]}=[M^0L^0T^0A^0]$,

$\frac{e^2}{\varepsilon_o hc}$ is called fine structure constant & has value $\frac{1}{137}$.

33. (c) Entropy $= \frac{Q}{T} = \frac{ML^2T^{-2}}{K} = [ML^2T^{-2}K^{-1}]$

34. (d) $s = \frac{Q}{m\theta} = \frac{ML^2T^{-2}}{MK} = [L^2T^{-2}K^{-1}]$

35. (c) $\frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(ML^2T^{-2}A^{-2}) \times (M^{-1}L^{-2}T^4A^2)}}$

$= \frac{1}{\sqrt{T^2}} = T^{-1}$

36. (b) Solar constant = energy/area/time

$= \frac{ML^2T^{-2}}{L^2T} = [M^1T^{-3}]$.

37. (a)

38. (b) $v = k\lambda^a\rho^b g^c$

$[M^0LT^{-1}] = L^a(ML^{-3})^b(LT^{-2})^c$

$= M^b L^{a-3b+c} T^{-2c}$

$\therefore$ $b = 0$; $a - 3b + c = 1$

$-2c = -1 \Rightarrow c = 1/2 \quad \therefore a = \frac{1}{2}$

$v \propto \lambda^{1/2}\rho^0 g^{1/2}$ or $v^2 \propto \lambda g$

39. (b) In $p = p_0$ exp. $(-\alpha t^2)$ is dimensionless

$\therefore \alpha = \frac{1}{t^2} = \frac{1}{T^2} = [T^{-2}]$

40. (b) As $\frac{a}{V^2} = P$

$\therefore a = PV^2 = \frac{dyne}{cm^2}(cm^3)^2 = dyne \times cm^4$

41. (c) $\frac{h}{e^2} = \frac{ML^2T^{-1}}{(AT)^2} = ML^2T^{-3}A^{-2}$ = Resistance (ohm)

42. (c) $I = AT^2 e^{-B/kT}$
Dimensions of $A = I/T^2$; Dimensions of $B = kT$
($\because$ power of exponential is dimensionless)

$AB^2 = \frac{\mathbf{I}}{T^2}(kT)^2 = \mathbf{I}k^2$

43. (a) The C.G.S unit of current is called biot (Bi) i.e.,

$1A = \frac{1C}{1\,sec} = \frac{(1/10)\text{e.m.u of charge}}{sec} = \frac{1}{10}Bi$

or 1Bi = 10A

44. (d) $\omega k = \frac{1}{T} \times \frac{1}{L} = [L^{-1}T^{-1}]$

The dimensions of the quantities in a, b, c are of velocity $[LT^{-1}]$

45. (c) Volume (L^3) = surface area $(6L^2)$
$\therefore$ $L = 6$, volume $= 6^3 = 216$

46. (d) None of the expressions has the dimensions of time.

47. (a) $X = M^a L^b T^c$;

$\frac{\Delta X}{X} \times 100 = \left(\frac{a\,\Delta M}{M} + \frac{b\,\Delta L}{L} + \frac{c\,\Delta T}{T}\right) \times 100$

$= (a\alpha + b\beta + c\gamma)\%$

48. (c) N VD = (N – 1) MD

$1\ VD = \left(\frac{N-1}{N}\right)MD$

L.C. = Least count = 1MD – 1VD

$L.C. = \left(1 - \frac{N-1}{N}\right)MD$

$= \frac{1}{N}M.D. = \frac{0.1}{N}cm = \frac{1}{10N}cm$

$= \frac{\text{value of 1 part on main scale}}{\text{number of parts on vernier scale}}$

where V.D. = vernier division, M.D. Main scale division.

49. (c) From $T = 2\pi\sqrt{\frac{\ell}{g}}$; $g = 4\pi^2\frac{\ell}{T^2}$

$\frac{\Delta g}{g} = \frac{\Delta\ell}{\ell} + \frac{2\Delta T}{T} = (y + 2x)$

50. (c) We have, $n_1u_1 = n_2u_2$

$n_2 = n_1\left(\frac{u_1}{u_2}\right)$

$= 10^6 \times \left(\frac{M_1}{M_2}\right)\left(\frac{L_1}{L_2}\right)^2\left(\frac{T_1}{T_2}\right)^{-3}$

$= 10^6 \times \left(\frac{1\,kg}{10\,kg}\right)\left(\frac{1\,m}{1\times10^{-1}m}\right)^2\left(\frac{1\,s}{60\,s}\right)^{-3}$

$= 10^6 \times \left(\frac{1}{10}\right)(10)^2(60)^3$

$= 10^7 \times (60)^3 = 2.16 \times 10^{12}$ units.

51. (c) Effective resistance

$R_S = (10k\Omega \pm 10\%) + (20k\Omega \pm 20\%)$

$\therefore$ Tolerance of the combination = $(30k\Omega \pm 30\%)$

52. (c) Force, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2} \Rightarrow \varepsilon_0 = \frac{q_1 \cdot q_2}{4\pi Fr^2}$

So dimension of ε_0

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

53. (c) Percentage error in mass $\left(\frac{\Delta m}{m}\times 100\right) = 2\%$ and percentage error in speed $\left(\frac{\Delta v}{v}\times 100\right) = 3\%$.

$$E = \frac{1}{2}mv^2$$

$$\therefore \frac{\Delta E}{E}\times 100 = \frac{\Delta m}{m}\times 100 + 2\frac{\Delta V}{V}\times 100$$

$$= 2\% + 2 \times 3\% = 8\%.$$

54. (d) Density $= \frac{\text{Mass}}{\text{Volume}}$

$$\rho = \frac{M}{L^3}, \quad \frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + 3\frac{\Delta L}{L}$$

% error in density = % error in Mass + 3 (% error in length)

$= 4 + 3(3) = 13\%$

55. (a) Ratio of specific heat, $\gamma = \frac{C_p}{C_v}$
56. (a) Specific gravity is the ratio of density of substance and density of water at 4°C. The ratio of like quantities is dimensionless.
57. (c) Dimensionally K.E = Work
58. (b) Trigonometric ratio are a number and hence demensionless
59. (b) $[C] = \left[\frac{Q}{V}\right] = \left[\frac{Q^2}{W}\right] = [M^{-1}L^{-2}T^2Q^2]$
60. (c) $[A] = [LT^{-2}]$ or $[L] = [AT^2]$

    $[\text{Work}] = [\text{Force} \times \text{Distance}] = [FL] = [FAT^2]$
61. (a) η is the coefficient of viscosity.
62. (a) Velocity gradient is velocity per unit distance.
63. (a) Use principle of homogeneity.
64. (a) $\frac{[ML^2T^{-2}][ML^2T^{-1}]^2}{[M^5][M^{-1}L^3T^{-2}]^2} = [M^0L^0T^0] = \text{angle.}$
65. (c) $10\,VD = 9MD$, $1VD = \frac{9}{10}MD$

    Vernier constant = 1 MD – 1 VD

    $= \left(1-\frac{9}{10}\right)MD = \frac{1}{10}MD = \frac{1}{10}\times\frac{1}{2} = 0.05\text{ mm}$
66. (c) $\frac{0.1}{10} = \left(1-\frac{19}{20}\right)MSD \Rightarrow \frac{1}{100} = \frac{1}{20}\times 1MSD$

    $\Rightarrow 1\text{ MSD} = \frac{1}{5}\times 10 = 2$
67. (b) Least count $= \frac{0.5}{50} = 0.01\text{mm}$
68. (c) Maximum absolute error is $\Delta a + \Delta b$. Therefore the percentage error $= \frac{\text{absolute error}}{\text{actual value}}\times 100$
69. (d) $\frac{\Delta Q}{Q}\times 100 = \frac{2\Delta I}{I}\times 100 + \frac{\Delta R}{R}\times 100 + \frac{\Delta t}{t}\times 100$

    $= 2\times 2\% + 1\% + 1\% = 6\%.$
70. (c) $\frac{\Delta P}{P}\times 100 = \frac{\Delta F}{F}\times 100 + 2\frac{\Delta\ell}{\ell}\times 100 = 4\% + 2\times 2\%$

    $= 8\%$
71. (c) $T = 2\pi\sqrt{\frac{\ell}{g}}$, $g \propto \frac{\ell}{T^2}$

    $\therefore \frac{\Delta g}{g}\times 100 = 0.5\% + 2\times 0.2\% = 0.9\%$
72. (a) % error $= \frac{0.01}{0.5}\times 100 + \frac{0.01}{1.0}\times 100 + \frac{0.01}{0.5}\times 100$

    $= 2 + 1 + 2 = 4 + 1 = 5$
73. (c)
74. (b) $[\sqrt{LC}] = \sqrt{ML^2T^{-2}A^{-2}.M^{-1}L^{-2}T^4A^2} = T$
75. (c) The quantity $\left(\frac{\omega x}{v} - \omega k\right)$ has dimension of angle and hence ωk is dimensionless being angle.
76. (d) $[Y] = \frac{[X]}{[Z^2]} = \frac{M^{-1}L^{-2}T^4A^2}{M^2T^{-4}A^{-2}} = M^{-3}L^{-2}Q^4T^4$

    $\left(\because A = \frac{Q}{T}\right)$
77. (c) $[at] = [F]$ amd $[bt^2] = [F]$

    $\Rightarrow [a] = MLT^{-3}$ and $[b] = MLT^{-4}$
78. (c) Clearly, $m = \frac{n^2T}{4f^2L^2}$; $[m] = \frac{MLT^{-2}}{T^{-2}.L^2}$
79. (d) $[V] = \left[\frac{W}{Q}\right] = \frac{ML^2T^{-2}}{AT} = ML^2A^{-1}T^{-3}$
80. (b) From $K = \frac{Bx}{x^2 + A^2} = \frac{Bx}{x^2} = \frac{B}{x}$

    $\therefore B = K \times x = \text{K.E.} \times \text{distance} = \text{work} \times \text{distance}$

81. (c) We know that F = q v B

$$\therefore \quad B = \frac{F}{qv} = \frac{MLT^{-2}}{C \times LT^{-1}} = MT^{-1}C^{-1}$$

82. (d) Least count of screw gauge = $\frac{0.5}{50}$ mm = 0.01mm

$\therefore$ Reading = [Main scale reading + circular scale reading × L.C] – (zero error)

$= [3 + 35 \times 0.01] - (-0.03) = 3.38$ mm

83. (d) Pressure = $\frac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$

$\Rightarrow$ a = 1, b = – 1, c = – 2.

84. (b) In CGS system, $d = 4\frac{g}{cm^3}$

The unit of mass is 100g and unit of length is 10 cm, so

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

$$= \frac{4}{100} \times (10)^3 \cdot \frac{100g}{(10cm)^3} = 40 \text{ unit}$$

85. (d) $P = \frac{a^3b^2}{cd}, \frac{\Delta P}{P} \times 100\% = 3\frac{\Delta a}{a} \times 100\% + 2\frac{\Delta b}{b} \times 100\% + \frac{\Delta c}{c} \times 100\% + \frac{\Delta d}{d} \times 100\%.$

$= 3 \times 1\% + 2 \times 2\% + 3\% + 4\% = 14\%$

86. (c) From $T = 2\pi\sqrt{\frac{\ell}{g}};\ g = 4\pi^2\frac{\ell}{T^2}$

$$\frac{\Delta g}{g} = \frac{\Delta\ell}{\ell} + \frac{2\Delta T}{T} = (y + 2x)$$

87. (b) Given = $R = \frac{\rho\ell}{\pi r^2}$, then $\frac{\Delta R}{R} \times 100$

$$= \frac{\Delta\rho}{\rho} \times 100 + \frac{\Delta\ell}{\ell} \times 100 + 2\frac{\Delta r}{r} \times 100$$

$= 1\% + 2\% + 2 \times 3\% = 9\%$

88. (b) The magnetic field at a point near a long straight conductor is given by

$$B = \frac{\mu_0}{4\pi}.\frac{2I}{r} \Rightarrow \mu_0 = \frac{4\pi rB}{2I}$$

$$\therefore \quad [\mu_0] = \frac{[r][B]}{[I]} = \frac{L.MT^{-2}A^{-1}}{I} \qquad \left(\because B = \frac{F}{qv}\right)$$

$= MLT^{-2}A^{-2}$

89. (c) Resistivity, $\rho = \frac{m}{ne^{2\tau}}$

$\rho = [ML^3T^{-3}A^{-2}]$

So, electrical conductivity

$\sigma = \frac{1}{\rho}$

$\sigma = [M^{-1}L^{-3}T^3A^2]$

90. (a) Reverberation time,

$$t = \left(\frac{d}{V}\right)_{forward} + \left(\frac{d}{V}\right)_{backward}$$

when dimensions double then, d′ = 2d

$$\therefore \quad t' = \frac{d'}{V} + \frac{d'}{V} = \frac{2d}{V} + \frac{2d}{V} = 2\left(\frac{d}{V} + \frac{d}{V}\right)$$

$$\Rightarrow \quad t' = 2t \quad \left(\because \frac{d}{V} + \frac{d}{V} = t\right)$$

91. (a) $R = \frac{PV}{nT} = \frac{J}{mol\ K} = J\ K^{-1}\ mol^{-1}$.

92. (d) 16.8 gcm^{-3} = 16800 Kgm^{-3}.

93. (a) Dimensionally couple = Torque = Work

94. (a) The mean value of refractive index,

$$\mu = \frac{1.34 + 1.38 + 1.32 + 1.36}{4} = 1.35$$

and

$$\Delta\mu = \frac{|(1.35 - 1.34)| + |(1.35 - 1.38)| + |(1.35 - 1.32)| + |(1.35 - 1.36)|}{4}$$

= 0.02

Thus $\frac{\Delta\mu}{\mu} \times 100 = \frac{0.02}{1.35} \times 100 = 1.48$

95. (b) Least count = $\frac{0.1}{10}$ = 0.01 cm

d_1 = 0.5 + 8 × 0.01 + 0.03 = 0.61 cm
d_2 = 0.5 + 4 × 0.01 + 0.03 = 0.57 cm
d_3 = 0.5 + 6 × 0.01 + 0.03 = 0.59 cm

Mean diameter = $\frac{0.61 + 0.57 + 0.59}{3}$

= 0.59 cm

96. (d) As, $g = 4\pi^2\frac{l}{T^2}$

$$\text{So, } \frac{\Delta g}{g} \times 100 = \frac{\Delta l}{l} \times 100 + 2\frac{\Delta T}{T} \times 100$$

$$= \frac{0.1}{20} \times 100 + 2 \times \frac{1}{90} \times 100 = 2.72 \simeq 3\%$$

97. (c) 98. (b)
99. (b) 100. (a)

EXERCISE - 3

Exemplar Questions

1. (b) In 0.06900, the two zeroes before six are not siginificant and two zeroes on right side of 9 are significant figures. Hence, number of significant figures are four (6900).
2. (b) In addition the result will be in least number of places after decimal and minimum number of significant figure. The sum of the given numbers can be calculated as 663.821. The number with least decimal places is 227.2 is correct to only one decimal place but in addition of numbers, the final result should be rounded off to one decimal place i.e., 664.
3. (c) As we know that in multiplication or division, the final result should retain as many significant figures as are there in the original number with the least significant figures.
   The significant figure in given numbers 4.237 g and 2.5 cm^3 are four and two respectivey so, density should be reported to two significant figures.
   $$\text{Density} = \frac{4.237\ \text{g}}{2.5\ \text{cm}^3} = 1.6948 = 1.7\ \text{g.cm}^{-3}$$
   $\therefore$ As rounding off the number upto 2 significant figures, we get density = 1.7.
4. (d) Rounding off 2.745 upto 3 significant figures here IVth digit is 5 and its preceding is even, so no change in 4. Thus answer would be 2.74. Rounding off 2.735 upto 3 significant figures, here IV digit is 5 and its preceding digit is 3 (odd). So 3 is increased by 1 answer become would be 2.74.
5. (a) If Δx is error in a physical quantity, then relative error is calculated as $\frac{\Delta x}{x}$.
   Given that,
   Length $l = (16.2 \pm 0.1)$ cm
   Breadth $b = (10.1 \pm 0.1)$ cm
   $\because\ \Delta l = 0.1$ cm, $\Delta b = 0.1$ cm
   Area $(A) = l \times b = 16.2 \times 10.1 = 163.62\ cm^2$
   In significant figure rounding off to three significant digits, area $A = 164\ cm^2$
   $$\frac{\Delta A}{A} = \frac{\Delta l}{l} + \frac{\Delta b}{b} = \frac{0.1}{16.2} + \frac{0.1}{10.1}$$
   $$= \frac{1.01 + 1.62}{16.2 \times 10.1} = \frac{2.63}{163.62}$$
   $$\text{So, } \Delta A = A \times \frac{2.63}{163.62} = 164 \times \frac{2.63}{163.62}$$
   $$= 2.636\ cm^2$$
   Now rounding off up to one significant figure $\Delta A = 3\ cm^2$.
   So, Area $A = A \pm \Delta A = (164 \pm 3)\ cm^2$.
6. (c) **a.** Work = force × distance
   $= [MLT^{-2}][L] = [ML^2T^{-2}]$
   Torque = F × d = $[ML^2T^{-2}]$
   LHS and RHS has same dimensions.

   b. Angular momentum (L)
   $= mvr = [M][LT^{-1}][L]$
   $= [ML^2T^{-1}]$
   $$\text{Planck's constant } h = \frac{E}{\nu}$$
   $$= \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}] \quad \left(\because E = h\nu \text{ and } \nu = \frac{1}{T}\right)$$
   So, dimensions of h and L are equal.

   c. Tension = force = $[MLT^{-2}]$
   $$\text{Surface tension} = \frac{\text{force}}{\text{length}} = \frac{[MLT^{-2}]}{[L]}$$
   $$= [ML^0T^{-2}]$$

   d. Impulse = force × time = $[MLT^{-2}][T]$
   $= [MLT^{-1}]$
   Momentum = mass × velocity
   $= [M][LT^{-1}] = [MLT^{-1}]$
   LHS and RHS has same dimensions.
   Hence only (c) options of Physical quantities does not have same dimensions.
7. (a) By applying the Rule of significant figure in multiplication and addition.
   As given that,
   $A = 2.5\ ms^{-1} \pm 0.5\ ms^{-1}$, $B = 0.10\ s \pm 0.01\ s$
   $x = AB = (2.5)(0.10) = 0.25$ m (consider only significant figure value)
   $$\frac{\Delta x}{x} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$
   $$\frac{\Delta x}{x} = \frac{0.5}{2.5} + \frac{0.01}{0.10} = \frac{0.05 + 0.025}{0.25} = \frac{0.075}{0.25}$$
   $\Delta x = 0.075 = 0.08$ m
   (rounding off to two significant figures.)
   $AB = (0.25 \pm 0.08)$ m
8. (d) As given that,
   $A = 1.0\ m \pm 0.2\ m$, $B = 2.0\ m \pm 0.2\ m$
   So, $X = \sqrt{AB} = \sqrt{(1.0)(2.0)} = 1.414$ m
   Rounding off upto two significant digit
   $X = 1.4\ m = (r)$ (Let)
   $$\frac{\Delta x}{x} = \frac{1}{2}\left[\frac{\Delta A}{A} + \frac{\Delta B}{B}\right] = \frac{1}{2}\left[\frac{0.2}{1.0} + \frac{0.2}{2.0}\right]$$
   $$= \frac{0.6}{2 \times 2.0}$$
   $$\Rightarrow \Delta x = \frac{0.6x}{2 \times 2.0} = \frac{0.6 \times 1.4}{2 \times 2.0} = 0.212$$
   Rounding off upto one significant digit
   $\Delta x = 0.2\ m = \Delta r$ (Let)
   So, correct value of
   $$\sqrt{AB} = r + \Delta r = (1.4 \pm 0.2)\ \text{m}$$

9. (a) For the most precise measurement, the unit must be least and number of digits including zeroes after decimal must be zero.
Now, take first option,
As here 5.00 mm has the smallest unit and the error in 5.00 mm is least (commonly taken as 0.01 mm if not specified), hence, 5.00 mm is most precise.

10. (a) Now, checking the errors with each options one by one,
$|\Delta l_1| = |5 - 4.9| = 0.1$ cm
$|\Delta l_2| = |5 - 4.805| = 0.195$ cm
$|\Delta l_3| = |5.25 - 5| = 0.25$ cm
$|\Delta l_4| = |5.4 - 5| = 0.4$ cm
Error Δl_1 is least or minimum.
So, 4.9 cm is most precise.

11. (c) It is given that Young's modulus (Y) is,
$Y = 1.9 \times 10^{11}$ N/m^2
1N = 10^5 dyne
So, $Y = 1.9 \times 10^{11} \times 10^5$ dyne/m^2
Convert meter to centimeter
$\because$ 1 m = 100 cm
$Y = 1.9 \times 10^{11} \times 10^5$ dyne/$(100)^2$ cm^2
$= 1.9 \times 10^{16-4}$ dyne/cm^2
$Y = 1.9 \times 10^{12}$ dyne/cm^2

12. (d) Given that fundamental quantities are momentum (p), area (A) and time (T).
Let us consider the dimensional formula for

$$E \propto [p^a A^b T^c]$$

$$E = kp^a A^b T^c]$$

where k is dimensionless constant of proportionality.
Dimensions of energy $[E] = [ML^2T^{-2}]$ and Dimension of momentum $p = mv = [MLT^{-1}]$
Dimension of Area $[A] = [L^2]$
Dimension of Time $[T] = [T]$
Dimension of energy $[E] = [K]\,[p]^a[A]^b[T]^c$
Putting all the dimensions, value
$ML^2T^{-2} = [MLT^{-1}]^a\,[L^2]^b\,[T]^c$
$= M^aL^{2b+a}T^{-a+c}$
By principle of homogeneity of dimensions,

$$a = 1,\ 2b + a = 2 \Rightarrow 2b + 1 = 2 \Rightarrow b = \frac{1}{2}$$

$-a + c = -2$
$c = -2 + a = -2 + 1 = -1$
So, Dimensional formula (of energy)
$E = [pA^{1/2}T^{-1}]$

$$E = [pA^{1/2}T^{-1}]$$

NEET/AIPMT (2013-2017) Questions

13. (d) $P = \dfrac{a^3b^2}{cd}$, $\dfrac{\Delta P}{P} \times 100\% = 3\dfrac{\Delta a}{a} \times 100\% + 2\dfrac{\Delta b}{b} \times$

$100\% + \dfrac{\Delta c}{c} \times 100\% + \dfrac{\Delta d}{d} \times 100\%.$

$= 3 \times 1\% + 2 \times 2\% + 3\% + 4\% = 14\%$

14. (d) Work = Force × displacement
Torque = Force × force arm
= mass × acceleration × length
$= [M] \times [LT^{-2}] \times [L] = [ML^2T^{-2}]$

15. (d) Force = mass × acceleration
$\Rightarrow$ [Mass]

$$= \left[\frac{\text{force}}{\text{acceleration}}\right]$$

$$= \left[\frac{\text{force}}{\text{velocity / time}}\right] = [F\,V^{-1}\,T]$$

16. (b) Let surface tension
$s = E^a V^b T^c$

$$\frac{MLT^{-2}}{L} = (ML^2T^{-2})^a \left(\frac{L}{T}\right)^b (T)^C$$

Equating the dimension of LHS and RHS
$ML^0T^{-2} = M^aL^{2a+b}\,T^{-2a-b+c}$
$\Rightarrow\ a = 1,\ 2a + b = 0,\quad -2a - b + c = -2$
$\Rightarrow\ a = 1,\ b = -2,\ c = -2$
Hence, the dimensions of surface tension are $[E\,V^{-2}\,T^{-2}]$

17. (d) Applying dimensional method :
$v_c = \eta^x \rho^y r^z$
$[M^0LT^{-1}] = [ML^{-1}T^{-1}]^x\,[ML^{-3}T^0]^y\,[M^0LT^0]^z$
Equating powers both sides
$x + y = 0;\ -x = -1 \therefore x = 1$
$1 + y = 0 \therefore y = -1$
$-x - 3y + z = 1$
$-1 - 3(-1) + z = 1$
$-1 + 3 + z = 1$
$\therefore z = -1$

18. (d) Let dimensions of length is related as,

$$L = [c]^x[G]^y\left[\frac{e^2}{4\pi\varepsilon_0}\right]^z$$

$$\frac{e^2}{4\pi\varepsilon_0} = ML^3T^{-2}$$

$L = [LT^{-1}]^x\,[M^{-1}L^3T^{-2}]^y[ML^3T^{-2}]^z$
$[L] = [L^{x+3y+3z}\,M^{-y+z}\,T^{-x-2y-2z}]$
Comparing both sides
$-y + z = 0 \Rightarrow y = z$ ...(i)
$x + 3y + 3z = 1$ ...(ii)
$-x - 4z = 0\quad (\because y = z)$ ...(iii)
From (i), (ii) & (iii)

$$z = y = \frac{1}{2},\ x = -2$$

$$\text{Hence, } L = c^{-2}\left[G \cdot \frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$$