PHYSICS

CLASS-XI NEET

MODULE-01

Units and measurements

Motion in a straight line | Motion in a plane | Laws of motion

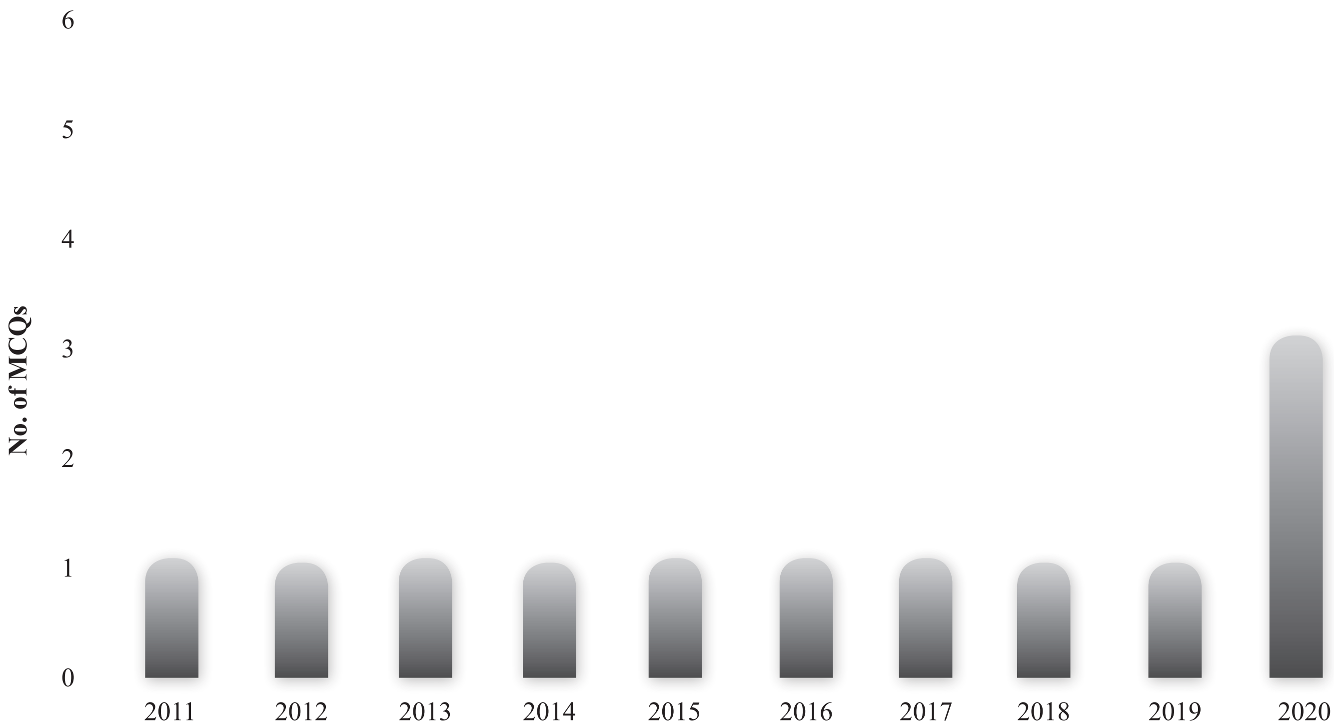
Physics Wallah

CHAPTER 1

Units and Measurements

Scan for Video Solution

Past Year NEET Trend



Investigation Report

TARGET EXAM	PREDICTED NO. OF MCQs	CRITICAL CONCEPTS
NEET	1-2	• SI units, Dimensional Analysis, Errors

Perfect Practice Plan

TOPIC-WISE MCQs	LEARNING-PLUS	MULTI-CONCEPT QUESTIONS	NEET PAST 10 YEAR QUESTIONS	TOTAL MCQs
75	29	16	17	137

Physical Quantities

All quantities that can be measured are called physical quantities. *e.g.* length, mass, force, work done, etc. In physics we study about physical quantities and their inter relationship.

There are two types of physical quantities

(i) Fundamental quantities

(ii) Derived quantities

Fundamental Quantity: Physical quantities which cannot be expressed in terms of any other physical quantites are called fundamental physical quantities.

E.g. length, mass, time, temperature etc.

Derived Quantity: Physical Quantities which are derived from fundamental quantities are called derived quantities.

E.g. Area, density, force etc.

Measurement

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

Different countries followed different standards.

Units of Measurement:

☺ A fixed measurement chosen as a standard of measurement to measure a physical quantity is called a **Unit.**

☺ To measure a physical quantity means to determine the number of times its standard unit is contained in that physical quantity.

☺ A standard Unit is necessary for the sake of

(i) Accuracy,

(ii) Convenience,

(iii) Uniformity and

(iv) Equal justice to all.

☺ The standard unit chosen should have the following characteristics.

(i) Consistency (or) invariability

(ii) Availability (or) reproducibility

(iii) Imperishability (Permanency)

(iv) Convenience and acceptability.

☺ The numerical value obtained on measuring a physical quantity is inversely proportional to the magnitude of the unit chosen.

$$\boxed{n \propto \frac{1}{U}} \Rightarrow \boxed{n_1 U_1 = n_2 U_2}$$

Where n_1 and n_2 are the numerical values U_1 and U_2 are the units of same physical quantity in different systems.

Fundamental unit: The unit used to measure the fundamental quantity is called fundamental unit.

e.g., Metre for length, kilogram for mass etc.

Derived unit: The unit used to measure the derived quantity is called derived unit.

e.g., m^2 for area, gm cm^{-3} for density etc...

Systems of Units:

☺ There are four systems of units

F.P.S C.G.S

M.K.S SI

☺ **FPS or British Engineering system:** In this system length, mass and time are taken as fundamental quantities and their base units are foot (*ft*), pound (*lb*) and second (*s*) respectively.

☺ **CGS or Gaussian system:** In this system the fundamental quantities are length, mass and time and their respective units are centimetre (*cm*), gram (*g*) and second (*s*).

☺ **MKS system:** In this system also the fundamental quantities are length, mass and time but their fundamental units are metre (*m*), kilogram (*kg*) and second (*s*) respectively.

☺ Units of some fundamental physical quantities in different systems

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

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

☺ Based on SI there are three categories of physical quantities.

7 fundamental quantities

2 supplementary quantities

and derived quantities

Set of Fundamental Quantities

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

Fundamental Quantities and Their S.I. Units

☺ There are seven fundamental quantities and two supplementary quantities in S.I. system. The names and units with symbols are given below:

SI base quantities and their units

S. No.	Physical quantity	Unit	Symbol
1	Length	Metre	m
2	Mass	Kilogram	kg
3	Time	Second	s
4	Temperature	Kelvin	kg
5	Electric current	Ampere	A
6	Luminous Intensity	Candela	cd
7	Amount of substance	Mole	mol

Supplementary quantities			
1.	Plane angle	Radian	Rad
2.	Solid angle	Steradian	sr

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

— KEY NOTE —

Rules for Writing Units:

- Symbols for a unit named after a scientist should have a capital letter. eg: *N* for newton, *W* for watt, A for ampere.
- Full names of the units,even when they are named after a scientist should not be written with a capital letter. Eg: newton, watt, ampere, metre.
- Units do not take plural form.

  Eg: 10 kg but not 10 kgs, 20 W but not 20 Ws, 2A but not 2 As
- No full stop or punctuation mark should be used within or at the end of symbols for units.

  Eg: 10 W but not 10 W.

Some special units for length:

angstrom (Å) = 10^{-10} *m* = 10^{-8} cm

nanometre (nm) = 10^{-9} *m* = 10 Å

Fermi = 10^{-15} *m*

Micron = 10^{-6} *m*

X-ray unit = 10^{-13} *m*

1 A.U. = Distance between sun & earth

= 1.496×10^{11} *m*

Light year = 9.46×10^{15} *m*

Par sec = 3.26 light years = 30.84×10^{15} *m*

Bohr radius = 0.5×10^{-10} *m*

Mile = 1.6 km

Some special units for Mass:

Quintal = 100 kg

Metric ton = 1000 kg

Atomic mass unit (a.m.u) = 1.67×10^{-27} kg

Chandra Sekhar Limit =1.4 times mass of the sun

Some special units for Time:

One day = 86400 second

Shake = 10^{-8} second

☺ One light year is distance travelled by light in one year in vacuum or air. This unit is used in astronomy.

☺ Astronomical unit is the mean distance of the earth from the sun. This unit is used in astronomy.

Abbreviations for multiples and sub multiples:

MACRO Prefixes

Multiplier	Symbol	Name
10^1	da	Deca
10^2	h	Hecto
10^3	K	Kilo
10^6	M	Mega
10^9	G	Giga
10^{12}	T	Tera
10^{15}	P	Peta
10^{18}	E	Exa
10^{21}	Z	Zetta
10^{24}	Y	Yotta

MICRO Prefixes

Multiplier	Symbol	Name
10^{-1}	d	deci
10^{-2}	c	centi
10^{-3}	m	milli
10^{-6}	μ	micro
10^{-9}	n	nano
10^{-12}	p	pico
10^{-15}	f	femto
10^{-18}	a	atto
10^{-21}	z	zpto
10^{-24}	y	yocto

Some important conversions:

☺ $1Kmph = \frac{5}{18} ms^{-1}$

1 newton = 10^5 dyne

1 joule = 10^7erg

1 calorie = 4.18 J

1eV = 1.6×10^{-19} J

1 gcm^{-3} = 1000 Kgm^{-3}

1 lit = 1000 cm^3 = 10^{-3} m^3

1KWH = 36×10^5 J

1 HP = 746 W

1 degree = 0.017 rad

1 cal g^{-1} = 4180 JKg^{-1}

1Kgwt = 9.8 N

1 telsa = 10^4 gauss

1 Am^{-1} = $4\pi \times 10^{-3}$ oersted

1 weber = 10^8 maxwell

Train Your Brain

Q. Convert 1 newton (SI unit of force) into dyne (CGS unit of force)

Ans. The dimensional equation of force is

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

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

$$n_2u_2 = n_1u_1 \Rightarrow n_2 = n_1\left[\frac{M_1}{M_2}\right]^1\left[\frac{L_1}{L_2}\right]^1\left[\frac{T_1}{T_2}\right]^{-2} = 1$$

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

$\Rightarrow 10^5$ Dyne = 1 N

Some physical constants and their values:

☺ 1 amu = 1.67×10^{-27} Kg = 931 MeV

1 atm = 76 cm Hg = 1.013×10^5 Pa

Avagadro number (N) = 6.023×10^{23}

Permittivity of free space = 8.854×10^{-12} Fm^{-1}

Permeability of free space (μ_0) = $4\pi \times 10^{-7}$ Hm^{-1}

Joule's constant (J) = 4.186 J Cal^{-1}

Planck's constant (h) = 6.62×10^{-34} Js

Rydberg constant (R) = 1.0974×10^7 m^{-1}

Boltzmann's constant (K) = 1.38×10^{-23} JK^{-1}

Stefan's constant (σ) = 5.67×10^{-8} Wm^{-2} K^{-4}

Universal gas constant (R) = 8.314 J mol^{-1} K^{-1}

= 1.98 cal mol^{-1} K^{-1}

Wien's constant (b) = 2.93×10^{-3} mK

Measurement of Length

☺ We are familiar with some direct methods for the measurement of length. For example, a metre scale is used for lengths from 10^{-3} m to

Dimensions and Dimensional Formula

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

Force = mass × acceleration

$$\text{mass} \times \frac{\text{length/time}}{\text{time}}$$

= mass × length × (time)$^{-2}$

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

[Force] = MLT^{-2}

Similarly energy has dimensional formula given by

[Energy] = ML^2T^{-2}

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

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

Physical quantity can be further of four types :

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

Dimensional Equation

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

Dimension

☺ Dimensions of a physical quantity are the powers to which the fundamental units are to be raised to obtain one unit of that quantity

Dimensional Formula

☺ An expression showing the powers to which the fundamental units are to be raised to obtain one unit of the derived quantity is called Dimensional formula of that quantity.

In general the dimensional formula of a quantity can be written as $[M^xL^yT^z]$. Here x,y,z are dimensions.

Dimensional Constants

☺ The physical quantities which have dimensions and have a fixed value are called dimensional constants.

Eg:Gravitational Constant (G), Planck's Constant (h), Universal gas constant (R), Velocity of light in vacuum (c) etc.,

Dimensionless Quantities

☺ Dimensionless quantities are those which do not have dimensions but have a fixed value.

(a) Dimensionless quantities without units.

Eg: Pure numbers,angle etc.,

(b) Dimensionless quantities with units.

Eg: Angular displacement-radian, Joule's constant-joule/calorie,etc.,

Principle of Homogeneity

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

Dimensional Variables

☺ Dimensional variables are those physical quantities which have dimensions and do not have fixed value.

Eg: velocity, acceleration, force, work, power... etc.

Dimensionless Variables

☺ Dimensionless variables are those physical quantities which do not have dimensions and do not have fixed value.,

Eg: Specific gravity, refractive index, Coefficient of friction, Poisson's Ratio etc.,

Train Your Brain

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

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

Thus, $[a]$ = length = L

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

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

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

Uses of Dimensional Analysis

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

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

— KEY NOTE —

- Powers are dimensionless
- Sin q, eq, cos q, log q gives dimensionless value and in above expression q is dimensionless
- We can add or subtract quantity having same dimensions.

Train Your Brain

Q. The position of a particle at time t, is given by the equation, $x(t) = \frac{v_0}{\alpha}(1 - e^{-\alpha t})$, where v_0 is a constant and $\alpha > 0$. The dimensions of v_0 & α are respectively.

a. $M^0L^1T^0$ & T^{-1}　　b. $M^0L^1T^{-1}$ & T

c. $M^0L^1T^{-1}$ & T^{-1}　　d. $M^1L^1T^{-1}$ & LT^{-2}

Ans. (c) $[V_0] = [x][\alpha] = M^0L^1T^{-1}$ & $[\alpha][t] = M^0L^0T^0$

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

Q. Check the accuracy of the relation $T = 2\pi\sqrt{\frac{L}{g}}$ for a simple pendulum using dimensional analysis.

Ans. The dimensions of LHS = the dimension of $T = [M^0L^0T^1]$

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

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

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

(ii) To establish a relation between different physical quantities

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

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

It is based on the fact that,

Numerical value × unit = constant

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

$n_1u_1 = n_2u_2$

Train Your Brain

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

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

Combining all the three factors, we get

$t \propto m^a\ell^bg^c$　or　$t \propto Km^a\ell^bg^c$

Where K is a dimensionless constant of proportionality. Writing down the dimensions on either side of equation, we get

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

Comparing dimensions we can get $t = K\sqrt{\frac{\ell}{g}}$

Q. A calorie is a unit of heat or energy and it equals about 4.2 J, where 1 J = 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 metre, the unit of time is γ second. Show that a calorie has a magnitude 4.2 $\alpha^{-1}\beta^{-2}\gamma^2$ in terms of the new units.

Ans. 1 cal = 4.2 kg m^2s^{-2}

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

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

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

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

The Following is the list of some Physical Quantities with their Formula and Dimensional Formula				
S. No.	**Physical Quantity**	**Explanation or Formulae**	**Dimensional Formulae**	**S.I.Unit**
1.	Distance, Displacement, Wave Length, Radius of gyration, Circumference, Perimeter, Light year, Par-sec.		$[M^0 L^1 T^0]$	m
2.	Mass		$[M^1 L^0 T^0]$	kg
3.	Period of oscillation, Time, time constant	$T = \dfrac{\text{total time}}{\text{No.of oscillations}}$ T = Capacity × Resistance	$[M^0 L^0 T^1]$	s
4.	Frequency	Reciprocal of time period $n = \dfrac{1}{T}$	$[M^0 L^0 T^{-1}]$	Hertz (Hz)
5.	Area	A = length × breadth	$[M^0 L^2 T^0]$	m^2
6.	Volume	V = Length × breadth × height	$[M^0 L^3 T^0]$	m^3
7.	Density	$D = \dfrac{\text{Mass}}{\text{Volume}}$	$[M^1 L^{-3} T^0]$	kgm^{-3}
8.	Linear density	$\lambda = \dfrac{\text{Mass}}{\text{Length}}$	$[M^1 L^{-1} T^0]$	kgm^{-1}
9.	Speed, Velocity	$v = \dfrac{\text{displacement}}{\text{time}}$	$[M^0 L^1 T^{-1}]$	ms^{-1}
10.	Acceleration	$a = \dfrac{\text{Change in Velocity}}{\text{time}}$	$[M^0 L^1 T^{-2}]$	ms^{-2}
11.	Linear Momentum	P = mass × velocity	$[M^1 L^1 T^{-1}]$	$kgms^{-1}$
12.	Impulse	J = Force × time	$[M^1 L^1 T^{-2}]$	Ns
13.	Force	F = Mass × acceleration	$[M^1 L^1 T^{-2}]$	N
14.	Work,Energy,PE, KE, Strain Energy	W = Force × displacement P.E = mgh; KE = $\dfrac{1}{2}MV^2$ $SE = \dfrac{1}{2}$ × Stress × Strain × Volume	$[M^1 L^2 T^{-2}]$	J(or) N.m
15.	Power	$P = \dfrac{\text{Work}}{\text{time}}$	$[M^1 L^2 T^{-3}]$	JS^{-1} (or) watt
16.	Pressure , Stress, Modulus of Elasticity (Y, n, k)	pressure = $\dfrac{\text{Force}}{\text{Area}}$ $Y = \dfrac{\text{Stress}}{\text{Strain}}$	$[M^1 L^{-1} T^{-2}]$	Nm^{-2} (or) Pascal
17.	Strain	$\dfrac{\text{Change in dimension}}{\text{Original dimensions}}$	$[M^0 L^0 T^0]$	No units
18.	Strain energy density	$E = \dfrac{\text{Work}}{\text{Volume}}$	$[M^1 L^{-1} T^{-2}]$	Jm^{-3}
19.	Angular displacement	$\theta = \dfrac{\text{length of arc}}{\text{radius}}$	$[M^0 L^0 T^0]$	rad

The Following is the list of some Physical Quantities with their Formula and Dimensional Formula				
S. No.	**Physical Quantity**	**Explanation or Formulae**	**Dimensional Formulae**	**S.I.Unit**
20.	Angular Velocity	$\omega = \frac{\text{angular displacement}}{\text{time}}$	$[M^0 L^0 T^{-1}]$	rads^{-1}
21.	Angular acceleration	$\alpha = \frac{\text{Change in angular velocity}}{\text{time}}$	$[M^0 L^0 T^{-2}]$	rads^{-2}
22.	Angular momentum	L = Linear momentum × arm	$[M^1 L^2 T^{-1}]$	Js
23.	Planck's constant	$h = \frac{\text{energy}}{\text{frequency}}$	$[M^1 L^2 T^{-1}]$	Js
24.	Angular impulse	Torque × time	$[M^1 L^2 T^{-1}]$	Js
25.	Torque	$\tau = \text{force} \times \perp dis\tan ce$	$[M^1 L^2 T^{-2}]$	Nm
26.	Acceleration due to gravity(g)= gravitational field strength	$g = \frac{\text{weight}}{\text{mass}}$	$[M^0 L T^{-2}]$	ms^{-2} or Nkg^{-1}
27.	Universal gravitational Constant	$G = \frac{F.d^2}{M_1.M_2}$	$[M^{-1} L^3 T^{-2}]$	$\text{Nm}^2\ \text{kg}^{-2}$
28.	Moment of inertia	$I = MK^2$	$[M^1 L^2 T^0]$	kgm^2
29.	Velocity gradient	$\frac{dv}{dx}$	$[M^0 L^0 T^{-1}]$	S^{-1}
30.	Surface Tension, Surface energy, Spring Constant Force Constant	$S = \frac{\text{surface energy}}{\text{change in area}} = \frac{\text{force}}{\text{length}}$ $K = \frac{\text{force}}{\text{elongation}}$	$[M^1 L^0 T^{-2}]$	Nm^{-1} or Jm^{-2}
31.	Coefficient of Viscosity	$\eta = \frac{\text{tangential stress}}{\text{Velocity gradient}}$	$[M^1 L^{-1} T^{-1}]$	Pa s (or) Ns m^{-2}
32.	Gravitational Potential	Gravitational field × distance	$[M^0 L^2 T^{-2}]$	J.Kg^{-1}
33.	Heat energy	$ms\theta$	$[M^1 L^2 T^{-2}]$	Joule
34.	Temperature	θ	$[M^0 L^0 T^0.\ \theta^1]$	Kelvin (K)
35.	Thermal Capacity	$\frac{dQ}{d\theta} = \text{Mass} \times Sp.ht$	$[M^1 L^2 T^{-2}.\ \theta^{-1}]$	JK^{-1}
36.	Specific heat Capacity	$S(\text{or})C = \frac{\text{heat energy}}{\text{mass} \times \text{temp.}}$	$[M^0 L^2 T^{-2}.\ \theta^{-1}]$	$\text{JKg}^{-1}\ \text{K}^{-1}$
37.	Latent heat (or) Calorific value	$L = \frac{\text{heat energy}}{\text{mass}}$	$[M^0 L^2 T^{-2}]$	JKg^{-1}
38.	Water Equivalent	$W = MC$	$[M^1 L^0 T^0]$	kg
39.	Coefficient of Thermal expansion	α or β or γ ask	$[\theta^{-1}]$	k^{-1}
40.	Universal gas constant	$R = \frac{PV}{nT}$	$[M^1 L^2 T^{-2}\ \theta^{-1}\ \text{mol}^{-1}]$	$\text{Jmol}^{-1}\ \text{K}^{-1}$
41.	Gas constant (for 1 gram)	$r = \frac{R}{Mol.wt}$	$[M^0 L^2 T^{-2}\ \theta^{-1}\ \text{mol}^{-1}]$	$\text{Jkg}^{-1}\ \text{K}^{-1}$

The Following is the list of some Physical Quantities with their Formula and Dimensional Formula				
S. No.	**Physical Quantity**	**Explanation or Formulae**	**Dimensional Formulae**	**S.I.Unit**
42.	Boltzman constant (for 1 Molecule)	$k = \frac{R}{\text{AvagadroNo.}}$	$[M^1 L^2 T^{-2} \theta^{-1}]$	JK^{-1} molecule^{-1}
43.	Mechanical equivalent of heat	$J = \frac{W}{H}$	$[M^0 L^0 T^0]$	no S.I. units
44.	Coeff of Thermal Conductivity	$K = \frac{Q.d}{A\ \Delta\theta.t}$	$[M^1 L^1 T^{-3} \theta^{-1}]$	$Js^{-1}\ m^{-1}\ K^{-1}$ (or) $Wm^{-1}\ K^{-1}$
45.	Entropy	$\frac{dQ}{T} = \frac{\text{heat energy}}{\text{temperature}}$	$[M^1 L^2 T^{-2} \theta^{-1}]$	JK^{-1}
46.	Stefan's Constant	$\sigma = \frac{\Delta E}{\Delta A.\Delta T.\theta^4}$	$[M^1 L^0 T^{-3} \theta^{-4}]$	$Js^{-1}\ m^{-2}\ K^{-4}$ (or) $Wm^{-2}\ K^{-4}$
47.	Thermal resistance	$R = \frac{d\theta}{\left(\frac{dQ}{dt}\right)} = \frac{\text{temp} \times \text{time}}{\text{Heat}}$ or $R = \frac{d}{K.A}$	$[M^{-1} L^{-2} T^3 \theta^1]$	KsJ^{-1}
48.	Temperature gradient	$\frac{\text{Change in temp}}{\text{length}} = \frac{d\theta}{dl}$	$[\theta L^{-1}]$	Km^{-1}
49.	Pressure gradient	$\frac{\text{Change in pressure}}{\text{length}} = \frac{dp}{dl}$	$[M^1 L^{-2} T^{-2}]$	Pascal m^{-1}
50.	Solar constant	$\frac{\text{Energy}}{\text{area} \times \text{time}} = \frac{\Delta E}{A.T}$	$[M^1 L^0 T^{-3}]$	$Js^{-1}M^{-2}$ (or) Wm^{-2}
51.	Enthalpy	Heat. (ΔQ)	$[M^1 L^2 T^{-2}]$	Joule
52.	Pole strength	M = I.L (or) $\frac{\text{Magnetic Momement}}{\text{Mag.Length}}$	$[M^0 L T^0 A]$	Am
53.	Magnetic Moment	$M = 2l \times m$ = pole strength × length of magnet	$[M^0 L^2 T^0 A]$	Am^2
54.	Magnetic intensity (or) Magnetising field	$H = \frac{m}{4\pi d^2}$	$[M^0 L^{-1} T^0 A]$	Am^{-1}
55.	Intensity of Magnetisation	$I = \frac{\overline{M}}{V} = \frac{\text{Magnetic Moment}}{\text{Volume}}$	$[M^0 L^{-1} T^0 A]$	Am^{-1}
56.	Magnetic flux	$\phi = \overline{B} \times \overline{A}$ = (Magnetic induction × area)	$[M^1 L^2 T^{-2} A^{-1}]$	Wb
57.	Magnetic induction field strength	$\overline{B} = \frac{\phi}{A} = \frac{\text{Magnetic flux}}{\text{area}} = \frac{F}{il}$	$[M^1 L^0 T^{-2} A^{-1}]$	Tesla (or) Wbm^{-2} (or) $Na^{-1}\ m^{-1}$
58.	Magnetic permeability of free space	$\mu_0 = \frac{4\pi.Fd^2}{m_1.m_2}$	$[M^1 L^1 T^{-2} A^{-2}]$	Hm^{-1}

The Following is the list of some Physical Quantities with their Formula and Dimensional Formula				
S. No.	**Physical Quantity**	**Explanation or Formulae**	**Dimensional Formulae**	**S.I.Unit**
59.	Magnetic susceptibility	$\chi = \frac{I}{H}$	$[M^0 L^0 T^0]$	No units
60.	Electric current	I	$[M^0 L^0 T^0 A]$	A
61.	Charge	Q = Current × time	$[M^0 L^0 T .A]$	C
62.	Electric dipole moment	P = Charge × distance	$[M^0 L^0 T .A]$	Cm
63.	Electric field strength (or) Electric field Intensity	$E = \frac{\text{force}}{\text{Charge}}$	$[M^1 L T^{-3} A^{-1}]$	NC^{-1}
64.	Electrical flux (ϕ_E)	Electrical Intensity × area	$[M^1 L^3 T^{-3} A^{-1}]$	Nm^2C^{-1}
65.	Electric potential (or) Potential difference	$V = \frac{\text{Work}}{\text{Charge}}$	$[M^1 L^2 T^{-3} A^{-1}]$	V
66.	Electrical resistance	$R = \frac{\text{Pot.diff}}{\text{Current}}$	$[M^1 L^2 T^{-3} A^{-2}]$	Ω
67.	Electrical conductance	$C = \frac{1}{R} = \frac{1}{\text{Resistance}}$	$[M^{-1} L^{-2} T^3 A^2]$	mho (or) siemen (S)
68.	Specific resistances (or) Resistivity ρ (or)	$\rho = \frac{R.A}{l}$	$[M^1 L^3 T^{-3} A^{-2}]$	Ohm m
69.	Electrical conductivity Current density (Current per unit area of cross section)	$s = \frac{1}{\text{Resistivity}}$ J = Electrical Intensity × Conductivity or $\left(\frac{\text{Current}}{\text{area}}\right)$	$[M^{-1} L^{-3} T^3 A^2]$ $[M^0 L^{-2} T^0 A]$	Ohm^{-1} m^{-1} (or) siemen m^{-1} 70 Am^{-2}
71.	Capacitance	$C = \frac{Q}{V} = \frac{\text{Charge}}{\text{Potential}}$	$[M^{-1} L^{-2} T^4 A^2]$	F
72.	Self (or) Mutual Inductance	$L = \frac{dE}{\left(\frac{dI}{dt}\right)} = \frac{\text{Voltage} \times \text{time}}{\text{Current}}$	$[M^1 L^2 T^{-2} A^{-2}]$	H (or) Wb/amp
73.	Electrical permittivity of free space	$\varepsilon_0 = \frac{q_1 . q_2}{4\pi F d^2}$	$[M^{-1} L^{-3} T^4 A^2]$	farad/m
74.	Surface charge density	$\frac{\text{Charge}}{\text{area}}$	$[M^0 L^{-2} T^1 A^1]$	Cm^{-2}
75.	Luminous flux	$\frac{\text{Light energy}}{\text{time}}$	$[M^1 L^2 T^{-3}]$	Lumen
76.	Intensity of illumination (or) Iluminance	$I = \frac{\Delta E}{\Delta t . \Delta A} = \left(\frac{\text{Luminious flux}}{\text{area}}\right)$	$[M^1 L^0 T^{-3}]$	Lumen m^{-2} (or) Lux.
77.	Focal Power	$P = \frac{1}{\text{focal length}}$	$[M^0 L^{-1} T^0]$	Dioptre
78.	Wave number (Propagation constant)	$\bar{v} = \frac{1}{\lambda}$	$[M^0 L^{-1} T^0]$	m^{-1}

Physical Quantities Having Same Dimensional Formulas:

- ☺ Distance, Displacement, radius, light year wavelength, radius of gyration $[L]$
- ☺ Speed, Velocity, Velocity of light $[LT^{-1}]$
- ☺ Acceleration ,acceleration due to gravity, intensity of gravitational field, centripetal acceleration $[LT^{-2}]$
- ☺ Impulse, Change in momentum $[MLT^{-1}]$
- ☺ Force, Weight, Tension, Thrust $[MLT^{-2}]$
- ☺ Work, Energy, Moment of force or Torque, Moment of couple $[ML^2T^{-2}]$
- ☺ Force constant, Surface Tension, Spring constant, Energy per unit area $[MT^{-2}]$
- ☺ Angular momentum, Angular impulse, Planck's constant $[ML^2T^{-1}]$
- ☺ Angular velocity, Frequency, Velocity gradient, Decay constant, rate of disintegration $[T^{-1}]$
- ☺ Stress, Pressure, Modulus of Elasticity, Energy density $[ML^{-1}T^{-2}]$
- ☺ Latent heat, Gravitational potential $[L^2T^{-2}]$
- ☺ Specific heat, Specific gas constant $[L^2T^{-1}\theta^{-1}]$
- ☺ Thermal capacity, Entropy, Boltzmann constant, Molar thermal capacity, $[ML^2T^{-2}\theta^{-1}]$
- ☺ Wave number, Power of a lens, Rydberg constant $[L^{-1}]$
- ☺ Time, RC, $\frac{L}{R}, \sqrt{LC}\,(T)$
- ☺ Power, Rate of dissipation of energy, $[ML^2T^{-3}]$
- ☺ Intensity of sound, Intensity of radiation $[MT^{-3}]$
- ☺ Expansion coefficient, Temperature coefficient of resistance $[K^{-1}]$
- ☺ Electric potential, potential difference, electromotive force $[ML^2T^{-3}I^{-1}]$
- ☺ Intensity of magnetic field, Intensity of magnetization $[IL^{-1}]$
- ☺ Frequency, angular frequency, angular velocity, Disintegration constant and velocity gradient have same dimensional formula $[M^0L^0T^{-1}]$
- ☺ Relative velocity and velocity have same dimensional formula $[M^0LT^{-1}]$
- ☺ Work, energy, heat, torque have same dimensional formula $[ML^2T^{-2}]$
- ☺ Pressure, stress, coefficient of elasticity, energy density have same dimensional formula $[ML^{-1}T^{-2}]$
- ☺ Momentum and impulse have same dimensional formula $[MLT^{-1}]$
- ☺ Angular momentum and Plank's constant have same dimensional formula $[MLT^{-3}A^{-1}]$
- ☺ Electric field and potential gradient have same dimensional formula $[MLT^{-3}A^{-1}]$
- ☺ Surface tension, surface energy, force gradient and spring constant have same dimensional formula $[ML^0T^{-2}]$
- ☺ Acceleration and gravitational field intensity have same dimentions $[M^0LT^{-2}]$
- ☺ Force, weight and Energy gradient have same dimentions $[MLT^{-2}]$
- ☺ Rydberg's constant and propagation constant have the same dimentional formula $[M^0T^{-1}T^0]$
- ☺ Light year, wave length and radius of gyration have same dimentional formula $[M^0LT^0]$
- ☺ Strain, Poisson's ratio, refractive index, dielectric constant, coefficient of friction, relative permeability, Magnetic susceptibility, Electric susceptibility, angle, solid angle, Trigonometric ratios, exponential constant are all dimensionless.
- ☺ If L,C and R stands for inductance, capacitance and resistance respectively then $\frac{L}{R}, \sqrt{LC}$, RC and time have same dimentional formula $[M^0L^0T]$
- ☺ Coefficient of linear expansion, coefficient of superficial expansion and coefficient of cubic expansion have same dimesion $[M^0L^0T^0K^{-1}]$
- ☺ Solar constant and poynting vector have the same dimenstions $[ML^0T^{-3}]$

Train Your Brain

Q. If P is the pressure of a gas and ρ is its density, then find the dimension of velocity

a. $P^{1/2}\rho^{-1/2}$ b. $P^{1/2}\rho^{1/2}$
c. $P^{-1/2}\rho^{1/2}$ d. $P^{-1/2}\rho^{-1/2}$

Ans. (a) Method - I

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

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

Dividing eq. (1) by (2)

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

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

Method - II

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

$v = kP^a \rho^b$

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

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

Limitations Of Dimensional Analysis Method:

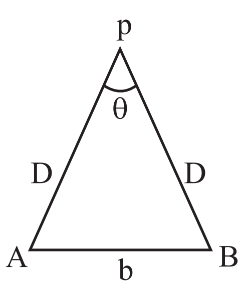
- ☺ Dimensionless quantities cannot be determined by this method. Constant of proportionality cannot be determined by this method. They can be found either by experiment (or) by theory.
- ☺ This method is not applicable to trigonometric, logarthmic and exponential functions.
- ☺ In the case of physical quantities which are dependent upon more than three physical quantities, this method will be difficult.
- ☺ In some cases, the constant of proportionality also possesses dimensions. In such cases we cannot use this system.
- ☺ If one side of equation contains addition or subtraction of physical quantities, we cannot use this method.

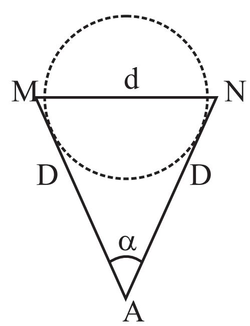
Measurement of Large Distances

- ☺ Larger distances such as the distance of a planet or a star from the earth cannot be measured directly with a metre scale. An important method in such cases is the parallax method.

  When an object located against a specific point on a wall is viewed with only one eye, say first with left eye and next with right eye, then the position of the object seems to change with respect to the point on the wall. This is called Parallax. The distance between the two points of observation is called the Basis.

  The distance D of a far away planet 'P' is measured by observing it from two different places on earth say A and B separated by distance $AB = b$ as shown in the figure.





  The angle θ between the two directions along which the planet is viewed at the two points is measured, which is called parallax angle or parallactic angle. Since θ is small, AB can be considered as an arc of length of a circle with center at P and the distance D as radius

$$\therefore b = D\theta \Rightarrow D = \frac{b}{\theta}$$

Once the distance 'D' of a planet is determined, the diameter 'd' and angular size of planet can be estimated by same method. Two diametrically opposite points M & N of planet are viewed through telescope from a point A on earth. The angle α between the two directions viewed is measured. Then by considering MN as arc of length of a circle with centre at A and the distance D as radius, we can write

$$d = D\alpha \left(\text{or}\right) \alpha = \frac{d}{D}$$

Estimation of Size of Molecule

- ☺ Very small sizes like size of molecule can be measured by special microscope called Tunnelling microscope. The size of molecules can be estimated by a simple method explained as below.

  To determine molecular size of oleic acid, diluted solution of oleic acid in alcohol of concentration 'C' is prepared. Lycopodium powder is spread on the surface of water taken in a trough. 'n' drops of prepared solution each of volume V are put in the water. The drops spread into a thin, large and roughly circular film of molecular thickness on water surface. The diameter of thin film is measured which gives the areas 'A' of the film. The thickness 't' of the film is nothing but molecular size as it is mono-molecular layer.

$\therefore$ Size of molecule = thickness of film

$$= \frac{\text{volume of the film}}{\text{area of the film}}$$

$$i.e., t = \frac{nVC}{A}$$

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

Unit	Definition and Conversion
1 fermi	$1f = 10^{-15}$ m
1 angstrom	$1Å = 10^{-10}$ m
1 astronomical unit	$1\ AU$ = (average distance of the sum from the earth) $= 1.496 \times 10^{11}$ m
1 light year	$1\ 1y = 9.46 \times 10^{15}$ m (Distance that light travels with velocity of 3×10^8m/ s) in 1 year
1 par sec	3.08×10^6 m Parsec is the distance at which average radius of earth's orbit subtends an angle of 1 arc second

Measurement of Mass

- ☺ Mass is a basic property of matter. It does not depend on the temperature, pressure or location of the object in space. The SI unit of mass is kilogram (kg).
- ☺ While dealing with atoms and molecules,the kilogram is an inconvenient unit. In this case, there is an important standard unit of mass, called the unified atomic mass unit (u), which has been established for expression the mass of atoms as “unified atomic mass unit is (1/12) of the mass of an atom of carbon-12 isotope”

  $\left({}^{12}_{6}C\right)$ Including the mass of electrons

  $1u = 1.6 \times 10^{-27}$ kg

— *KEY NOTE* —

Mass of commonly available objects can be determined by common balance. Large masses are determined by gravitational methods, while small masses are measured by mass spectroscopes, which work on the principle of motion of charged particles in electric and magnetic fields

Measurement Of Time

Measurement of Time

- ☺ To measure any time interval we need a clock. We now use an atomic standard of time, which is based on the periodic vibrations produced in a caesium atom. This is the basis of the caesium clock, sometimes called atomic clock. The caesium atomic clocks are very accurate. In Principle they provide portable standard. The national standard of time interval ‘second’ as well as the frequency is maintained through four caesium atomic clocks. A caesium atomic clock is used at the national physical Laboratory NPL),New Delhi to maintain the Indian standard of time.

Accuracy and precision:

- ☺ The numerical values obtained on measuring physical quantities depend upon the measuring instruments, methods of measurement.
- ☺ A unit of measurement of a physical quantity is the standard reference of the same physical quantity which is used for comparison of the given physical quantity.
- ☺ Accuracy refers to how closely a measured value agrees with the true values.
- ☺ Precision refers to what limit or resolution the given physical quantity can be measured
- ☺ Accuracy refers to the closeness of observed values to its true value of the quantity while precision refes to closeness between the different observed values of the same quantity .High precision does not mean high accuracy. The difference between accuracy and precision can be understand by the following example: Suppose three students are asked to find the length of a rod whose length is known to be 2.250cm .The observations are given in the table.

Student	Measurement-1	Measurement-2	Measurement-3	Average length
A	2.25cm	2.27cm	2.26cm	2.26cm
B	2.252cm	2.250cm	2.251cm	2.251cm
C	2.250cm	2.250cm	2.251cm	2.250cm

It is clear from the above table , that the observation taken by a student A are neither precise nor accurate. The observations of student B are more precise . The observations of student C are precise as will as accurate

Types of Errors

- ☺ Uncertainity in measurement of a physical quantity is called the error in measurement.
- ☺ The difference between the measured value and true value as per standard method without mistakes is called the error.
- ☺ Error = True value - Measured value Correction = – error
- ☺ True value means, standard value free of mistakes.
- ☺ Errors are broadly classified into 3 types:
  - (i) Systematic errors
  - (ii) Random errors
  - (iii) Gross errors

Systematic Errors

- ☺ The errors due to a definite cause and which follow a particular rule are called systematic errors. They always occur in one direction. Following are some systematic errors

Constant error

- ☺ Systematic errors with a constant magnitude are called constant errors.
- ☺ The constant arised due to imperfect design, zero error in the instrument or any other such defects. These are also called instrumental errors.

Zero error:

- ☺ The error due to improper designing and construction.

  Ex: If a screw gauge has a zero error of -4 head scale divisions, then every reading will be 0.004cm less than the true value.

Environmental Error:

☺ The error arised due to external conditions like changes in environment, changes in temperature, pressure, humidity etc.

Ex: Due to rise in temperature, a scale gets expanded and this results in error in measuring length.

Imperfection in Experimental technique or Procedure:

☺ The error due to experimental arrangement, procedure followed and experimental technique is called Imperfection error.

Ex: In calorimetric experiments, the loss of heat due to radiation, the effect on weighing due to buoyancy of air cannot be avoided.

Personal errors or observational errors:

☺ These errors are entirely due to personal pecularities like individual bias, lack of proper settings of the apparatus, carelessness in taking observations.

$$\text{Probable error} \propto \frac{1}{\text{no. of readings}}$$

Ex: Parallax error

Random Errors

☺ They are due to uncontrolled disturbances which influence the physical quantity and the instrument. These errors are estimated by statistical methods

$$\text{Random error} \propto \frac{1}{\text{no. of observations}}$$

Ex-:The errors due to line voltage changes and backlash error.

Backlash errors are due to screw and nut.

Gross Errors

☺ The cause for gross errors are improper recording, neglecting the sources of the error, reading the instrument incorrectly, sheer carelessness

Ex: In a tangent galvanometer experiment, the coil is to be placed exactly in the magnetic meridian and care should be taken to see that no other magnetic material are present in the vicinity.

☺ No correction can be applied to these gross errors.

☺ When the errors are minimized, the accuracy increases.

The systematic errors can be estimated and observations can be corrected.

☺ Random errors are compensating type. A physical quantity is measured number of times and these values lie on either side of mean value-with random errors. These errors are estimated by statistical methods and accuracy is achieved.

— *KEY NOTE* —

- Personal errors like parallax error can be avoided by taking proper care.
- The instrumental errors are avoided by calibrating the instrument with a standard value and by applying proper corrections.

True value and Errors

True Value

☺ In the measurement of a physical quantity the arithmetic mean of all readings which is found to be very close to the most accurate reading is to be taken as True value of the quantities. If a_1, a_2, a_3 .... a_n are readings then true value

$$a_{\text{mean}} = \frac{1}{n}\sum_{i=1}^{n} a_i$$

Absolute Errors

☺ The magnitude of the difference between the true value of the measured physical quantity and the value of individual measurement is called absolute error.

|True value - measured values|

$$\Delta a_i = |a_{\text{mean}} - a_i|$$

The absolute error is always positive.

Mean Absolute Error

☺ The arithmetic mean of all the absolute errors is considered as the mean absolute error or final absolute error of the value of the physical concenred.

$$\Delta a_{\text{mean}} = \frac{|\Delta a_1| + |\Delta a_2| + --- |\Delta a_n|}{n} = \frac{1}{n}\sum_{i=1}^{\infty} |\Delta a_i|$$

The mean absolute error is always positive.

Relative Error

☺ The relative error of a measured physical quantity is the ratio of the mean absolute error to the mean value of the quantity measured.

$$\text{Relative error} = \frac{\Delta a_{\text{mean}}}{a_{\text{mean}}}$$

It is a pure number having no units.

Percentage error

$$\delta a = \left[\frac{\Delta a_{\text{mean}}}{a_{\text{mean}}} \times 100\right]\%$$

— *KEY NOTE* —

Relative error and percentage error give a measure of accuracy i.e., percentage error increases accuracy decreases

Combination of Errors

☺ **Error due to addition**

If $Z = A + B$

$\Delta Z = \Delta A + \Delta B$ (Max. Possible error)

$Z \pm \Delta Z = (A \pm \Delta A) + (B \pm \Delta B)$

Relative error $= \dfrac{\Delta A + \Delta B}{A + B}$

Percentage error $= \dfrac{\Delta A + \Delta B}{A + B} \times 100$

☺ **Error due to subtraction**

If $Z = A - B$

$\Delta Z = \Delta A + \Delta B$ (Max. Possible error)

$Z \pm \Delta Z = (A \pm \Delta A) - (B \pm \Delta B)$

Relative error $= \dfrac{\Delta A + \Delta B}{A - B}$

Percentage error $= \dfrac{\Delta A + \Delta B}{A - B} \times 100$

☺ Whether it is addition or subtraction, absolute error is same.

More admissible error $\Delta U = \pm\sqrt{(\Delta x)^2 + (\Delta y)^2}$

☺ In subtraction the percentage error increases.

☺ **Error due to Multiplication:**

If $Z = AB$ then $\dfrac{\Delta Z}{Z} = \dfrac{\Delta A}{A} + \dfrac{\Delta B}{B}$

$\dfrac{\Delta Z}{Z}$ is called fractional error or relative error.

Percentage error $= \dfrac{\Delta Z}{Z} \times 100$

$$= \left(\frac{\Delta A}{A} \times 100\right) + \left(\frac{\Delta B}{B} \times 100\right)$$

☺ Here Percentage error is the sum of individual percentage errors.

☺ **Error due to Division:**

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

Maximum possible relative error

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

Max. Percentage error in division $\dfrac{\Delta Z}{Z} = \dfrac{\Delta A}{A} + \dfrac{\Delta B}{B}$

☺ **Error due to Power:**

If $Z = A^n$

$$\frac{\Delta Z}{Z} = n\frac{\Delta A}{A}$$

☺ In more general form

If $Z = \dfrac{A^p B^q}{C^r}$ then maximum fractional error in Z is

$$\frac{\Delta Z}{Z} = p\frac{\Delta A}{A} + q\frac{\Delta B}{B} + r\frac{\Delta C}{C}$$

As we check for maximum error $a + ve$ sign is to be taken for the term $r\dfrac{\Delta C}{C}$

Maximum Percentage error in

$$Z = \frac{\Delta Z}{Z} \times 100 = p\frac{\Delta A}{A} \times 100 + q\frac{\Delta B}{B} \times 100 + r\frac{\Delta C}{C} \times 100$$

Train Your Brain

Q. In an experiment, two capacities measured are (1.3 ± 0.1) μF and (2.4 ± 0.2) μF. Calculate the total capacity if the two capacitors are connected in parallel with percentage error

Ans. Here, $C_1 = (1.3 \pm 0.1)$ μF and $C_2 = (2.4 \pm 0.2)$ μF.

In parallel, $C_p = C_1 + C_2 = 1.3 + 2.4 = 3.7$ μF

$\Delta C_p = \pm(\Delta C_1 + \Delta C_2) = \pm(0.1 + 0.2) = \pm 0.3$ % error

$= \pm\dfrac{0.3}{3.7} \times 100 = \pm 8.1\%$

Hence, $C_p = (3.7 \pm 0.3)$ μF = 3.7 μF ± 8.1%

Significant Figures:

☺ A significant figure is defined as the figure, which is considered reasonably, trust worthy in number.

Eg: π = 3.141592654

(upto 10 digits)

= 3.14 (with 3 figures)

= 3.1416 (upto 5 digits)

— KEY NOTE —

The significant figures indicate the extent to which the readings are reliable.

Rules for determining the number of significant figures:

☺ All the non-zero digits in a given number are significant without any regard to the location of the decimal point if any.

Ex: 194,52 has five significant digits.

1945.2 or 194.52 all have the same number of significant digits,that is 5.

☺ All zeros accruing between two non zero digits are significant without any regard to the location of decimal point if any.

Ex: 107008 has six significant digits.

107.008 or 1.07008 has also got six significant digits.

☺ If the number is less than one, all the zeros to the right of the decimal point but to the first non-zero digit are not significant.

Ex: 0.000408

In this example all zeros before 3 are non-significant.

(i) All zeros to the right of a decimal point are significant if they are not followed by a non-zero digit.

Ex: 40.00 has 4 significant digits

(ii) All zeros to the right of the last non-zero digit after the decimal point are significant.

Ex: 0.05700 has 4 significant digits

☺ All zeros to the right of the last non-zero digit in a number having no decimal point are not significant.

Ex: 4030 has 3 significant digits

Rounding off numbers

☺ The process of omitting the non significant digits and retaining only the desired number of significant digits, incorporating the required modifications to the last significant digit is called rounding off the number.

Rules for rounding off numbers:

☺ The preceding digit is raised by 1 if the immediate insignificant digit to the dropped is more than 5.

Ex: 4727 is rounded off to three significant figures as 4730.

☺ The preceding digit is to be left unchanged if the immediate insignificant digit to be dropped is less than 5.

Ex: 4722 is rounded off to three significant figures as 4720

☺ If the immediate insignificant digit to be dropped is 5 then there will be two different cases

(a) If the preceding digit is even, it is to be unchanged and 5 is dropped.

Ex: 4.7252 is to be rounded off to two decimal places. The digit to be dropped here is 5 (along with 3) and the preceding digit 2 is even and hence to be retained as two only

4.7252 = 4.72

(b) If the preceding digit is odd, it is to be raised by 1

Ex: 4.7153 is to be rounded off to two decimal places. As the preceding digit 1 is odd, it is to be raised by 1 as 2.

4.7153 = 4.72

Rules for Arithmetic Operations with significant Figures:

☺ In multiplication or division, the final result should retain only that many significant figures as are there in the original number with the least number of significant figures.

Ex: But the result should be limited to the least number of significant digits-that is two digits only. So final answer is 9.9.

☺ In addition or subtraction the final result should retain only that many decimal places as are there in the number with the least decimal places.

Ex: 2.2 + 4.08 + 3.12 + 6.38 = 15.78. Finally we should have only one decimal place and hence 15.78 is to be rounded off as 15.8.

Train Your Brain

Q. Two bodies of masses (15.6 ± 0.2) gram and (23.9 ± 0.3) gram are put in a bag of negligible mass. What is the total mass of bag?

Ans. Sum of the masses = 15.6 + 23.9

= 39.5 g

Max. Error in sum of masses = ± (0.2 + 0.3)

= ± 0.5 g

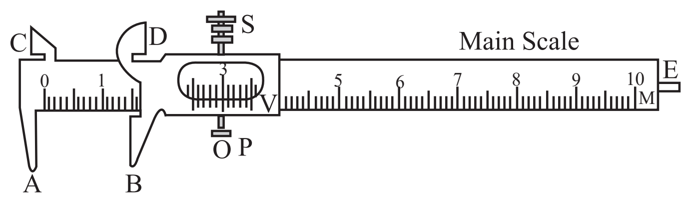
∴ Total mass = (39.5 ± 0.5) gram

Vernier Callipers

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

Its main parts are as follows:

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



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

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

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

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

Determination of least count (Vernier Constant)

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

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

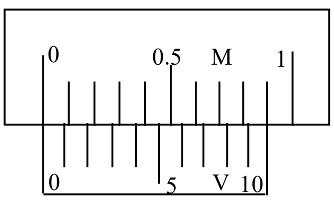
$$\text{or} \quad \text{V.C.} = 1\ \text{M.S.D.} - 1\ \text{V.S.D.} = \left(1-\frac{n-1}{n}\right)\text{M.S.D} = \frac{1}{n}\text{M.S.D}$$

Determination of zero error and zero correction

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

One of the following situations will arise.

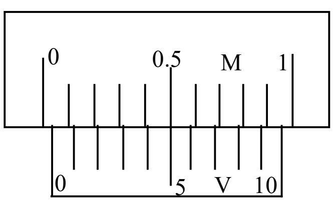
(i) Zero of Vernier scale coincides with zero of main scale (see figure)



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

Actual length = observed (measured) length.

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



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

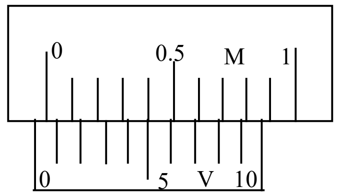
Hence, N = 0, n = 5, L.C. = 0.01 cm.

Zero error N = n × (L.C.) = 0 + 5 × 0.01 = + 0.05 cm

Zero correction = – 0.05 cm.

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

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



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

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

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

Zero error = N + n × (L.C.) = – 0.1 + 5 × 0.01 = –0.05 cm.

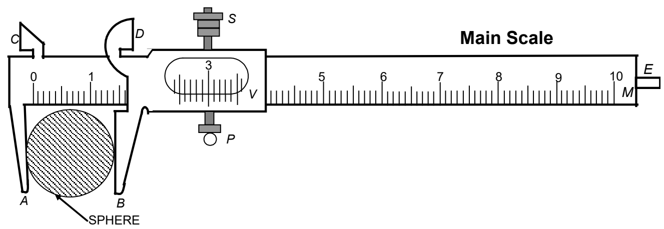
Zero correction = +0.05 cm.

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

Experiment

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

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



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

If nth division of vernier scale coincides with any division of main scale, then vernier scale reading (V.S.R.)

= n × (L.C.) (L.C. is least count of vernier callipers)

= n × (V.C.) (V.C. is vernier constant of vernier callipers)

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

Precautions (to be taken)

1. Motion of vernier scale on main scale should be made smooth (by oiling if necessary).
2. Vernier constant and zero error should be carefully found and properly recored.
3. The body should be gripped between the jaws firmly but gently (without undue pressure on it from the jaws).

4. Observations should be taken at right angles at one place and taken at least at three different places.

Sources of Error

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

Train Your Brain

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

Ans. Length measured with vernier callipers

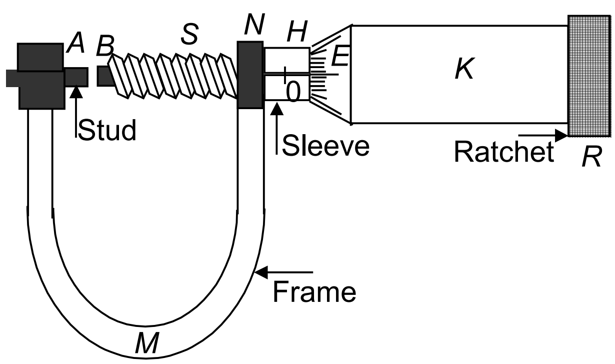
= reading before the zero of vernier scale + number of vernier divisions coinciding

with any main scale division × least count

= 10 mm + 0 × 0.1 mm = 10 mm = 1.00 cm

Screw Gauge

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



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

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

Determination of least count of screw gauge

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

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

Then, pitch of the screw

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

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

Then, least count

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

The least count is generally 0.001 cm.

Determination of zero error and zero correction

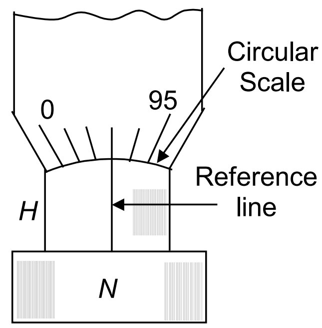
For this purpose, the screw is rotated forward till plane face B of the screw just touches the fixed plane face A of the stud and edge of cap comes on zero mark of linear scale. Screw gauge is held keeping the linear scale vertical with its zero downwards.

One of the following three situations will arise.

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

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

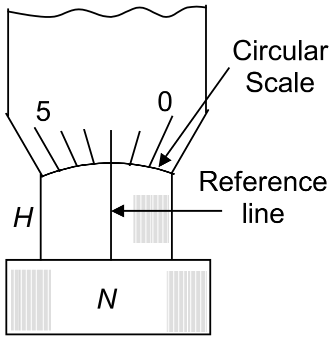
Actual thickness = Observed (measured) thickness.



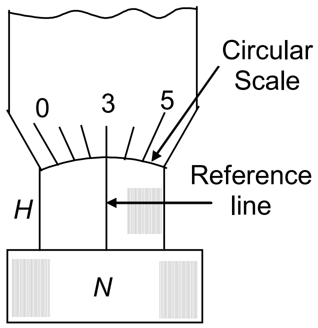
(ii) **Zero mark of circular scale remains on right of reference line and does not cross** it (see figure).

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

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



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



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

Experiment

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

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

Theory:

(1) Determine of least count of screw gauge

(2) If with the wire between plane faces A and B, the edge of the cap lies ahead of Nth division of linear scale.

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

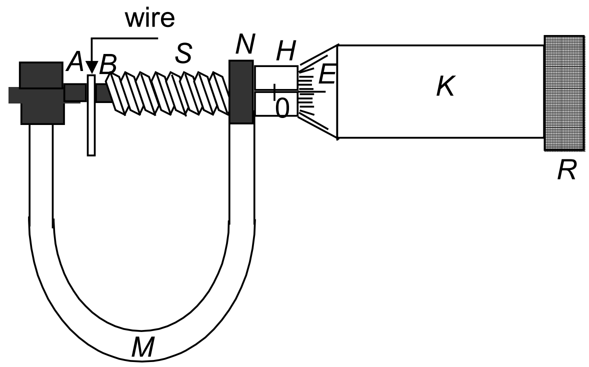
If nth division of circular scale lies over reference line.

Then, circular scale reading (C.S.R.) = n × (L.C.)

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

Total reading (T.R.) = L.S.R. + C.S.R. = N + n × (L.C.)

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



Calculation

Mean diameter of the wire,

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

= … cm

Mean length of the wire,

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

Volume of the wire

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

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

Precaution (to be taken)

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

Sources of Error

(i) The screw may have friction.

(ii) The screw gauge may have back-lash error.

(iii) Circular scale divisions may not be of equal size.

(vi) The wire may not be uniform.

Train Your Brain

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

a. 0.020 cm b. 0.002 cm
c. 0.010 cm d. 0.001 cm

Ans. (b) In vernier calliper main scale 10 cm.

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

= 0.05 cm.

25 V = 24S.

V = S

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

$\because$ 1S = 0.05 cm

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

Least count = 0.002 cm

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

a. 0.005 cm b. 0.05 cm
c. 0.02 cm d. 0.01 cm

Ans. (c) 1 main scale div = 0.1 cm

10V = 8S

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

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

But 1S = 0.1 cm

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

Least count = 0.02 cm

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

a. Calculate the pitch of the screw gauge
b. Calculate the least count of the screw gauge

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

Pitch of screw = Linear distance traveled in one Revolution

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

Least count

$$= \frac{\text{Pitch}}{\text{no. of divisions in circular scale}}$$

$$= \frac{0.05}{50} = 0.001 \text{ cm}$$

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

Ans. Thickness of sheet = 2.84 mm.

Pitch of screw = 0.5 mm.

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

Thickness = (5 × 0.5 + 34 × 0.01) mm

= (2.5 + 0.34) = 2.84 mm

ILLUSTRATIONS

1. A new system of units is proposed in which, unit of mass is α kg, unit of length is β m and unit of time is γ s. What will be value of 5 J in this new system?

a. $5\alpha\beta^2\gamma^{-2}$ b. $5\alpha^{-1}\beta^{-2}\gamma^2$
c. $5\alpha^{-2}\beta^{-1}\gamma^{-2}$ d. $5\alpha^{-1}\beta^2\gamma^2$

Ans. (b) Joule is a unit of energy.

$n_1 = 5$ $n_2 = ?$
$M_1 = 1$ kg $M_2 = \alpha$ kg
$L_1 = 1$ m $L_2 = \beta$ m
$T_1 = 1$ s $T_2 = \gamma$ s

Dimensional formula of energy is $[ML^2T^{-2}]$. Comparing with $[M^aL^bT^c]$, we get

$a = 1, b = 2, c = -2$

$$\text{As, } n_2 = n_1\left(\frac{M_1}{M_2}\right)^a\left(\frac{L_1}{L_2}\right)^b\left(\frac{T_1}{T_2}\right)^c$$

$$= 5\left(\frac{1\text{kg}}{\alpha\,\text{kg}}\right)^1\left(\frac{1\text{m}}{\beta\,\text{m}}\right)^2\left(\frac{1\text{s}}{\gamma\,\text{s}}\right)^{-2} = \frac{5\gamma^2}{\alpha\beta^2} = 5\alpha^{-1}\beta^{-2}\gamma^2$$

2. Given that $y = A\sin\left[\left(\frac{2\pi}{\lambda}(ct - x)\right)\right]$ where y and x are measured in meter. Which of the following statements are true?

a. The unit of λ is same as that of x and A
b. The unit of λ is same as of x but not of A
c. The unit of c is same as that of $\frac{2\pi}{\lambda}$
d. The unit of (ct – x) is same as that of $\frac{2\pi}{\lambda}$

Ans. (a) $f = A\sin\left[\left(\frac{2}{\ }\right)\right][ct - x]$. Since Angle has $[M^oL^oT^o]$ dimensions. ∴ $\left[\frac{2}{\ }(ct - x)\right]$ needs to be dimensionless

$$\therefore \frac{c}{\lambda}t = \left[M^oL^oT^o\right], \lambda = ct = \left[M^oL^1T^o\right]$$

$x = \lambda = \left[M^0L^1T^0\right]$, A = $[M^0 L^1 T^0]$

3. If the unit of force and length are doubled, the unit of energy will be:

a. 1/4 times the original b. 1/2 times the original
c. 2 times the original d. 4 times the original

Ans. (d) Work = Energy = F'. L' = 2 F × 2 L, 4 times the original

4. The speed of light c, gravitational constant G and Planck's constant h are taken as fundamental units in a system. The dimensions of time in this new system should be:

a. $[G^{1/2}h^{1/2}c^{-5/2}]$ b. $[G^{-1/2}h^{1/2}c^{-1/2}]$
c. $[G^{-1/2}h^{1/2}c^{-3/2}]$ d. $[G^{-1/2}h^{1/2}c^{1/2}]$

Ans. (a) c = $[M^0 L^1 T^{-1}]$, G = $[M^{-1} L^3 T^{-2}]$, h = $[M^1 L^2 T^{-1}]$

$T = c^a G^b h^c$

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

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

a + 3b + 2c = 0, a + 2b + c = –1

Solving the three equations

a = –5/2, b = ½, c = 1/2

$T = [c^{-5/2} G^{1/2} h^{1/2}]$

5. By what percentage should the pressure of a given mass of gas be increased so as the decrease in its volume is 10% at a constant temperature?

a. 5% b. 7.2%
c. 12.5% d. 11.1%

Ans. (d) PV = constant

$$P'\left(V - \frac{10V}{100}\right) = PV$$

$$P'\left(\frac{100V - 10V}{100}\right) = PV$$

$$P'\left(\frac{90V}{100}\right) = PV \to P' = \frac{10}{9}P = 1.11P = 111\%$$

6. Percentage error in the measurement of mass and speed are 2% and 3% respectively. The error in the estimation of kinetic energy obtained by measuring mass and speed will be:

a.12% b. 10%
c. 2% d. 8%

Ans. (d) $K = \frac{1}{2}mV^2$

$$\frac{\Delta K}{K} = \frac{\Delta m}{m} + \frac{2\Delta V}{V}$$

$$\frac{K}{K} = 2 + 3\times 2$$

$$\frac{\Delta K}{K} = 8\%$$

7. If E, m, l and G denote energy, mass, angular momentum and gravitational constant respectively, the quantity $\left(\frac{El^2}{m^5G^2}\right)$ has the dimensions of:

a. Mass b. Length
c. Time d. Angle

Ans. (d) $\left(\frac{El^2}{m^5G^2}\right) = \frac{[M^1L^2T^{-2}][ML^2T^{-1}]^2}{[M^5][M^{-2}L^6T^{-4}]}$

$$= \frac{\left[M^3L^6T^{-4}\right]}{\left[M^3L^6T^{-4}\right]} = \left[M^0L^0T^0\right]$$

Mass = $[M^1]$ Length = $[L^1]$

Time = $[T^1]$

8. If $Z = \frac{A^4 B^{1/3}}{CD^{3/2}}$ and ΔA, ΔB, ΔC and ΔD are their absolute errors in A, B, C and D respectively. The relative error in Z is:

a. $\frac{\Delta Z}{Z} = 4 \times \frac{\Delta A}{A} + \frac{1}{3}\frac{\Delta B}{B} + \frac{\Delta C}{C} + \frac{3}{2}\frac{\Delta D}{D}$

b. $\frac{\Delta Z}{Z} = 4\frac{\Delta A}{A} + \frac{1}{3}\frac{\Delta B}{B} - \frac{\Delta C}{C} - \frac{3}{2}\frac{\Delta D}{D}$

c. $\frac{\Delta Z}{Z} = 4\frac{\Delta A}{A} + \frac{1}{3}\frac{\Delta B}{B} + \frac{\Delta C}{C} - \frac{3}{2}\frac{\Delta D}{D}$

d. $\frac{\Delta Z}{Z} = 4\frac{\Delta A}{A} + \frac{1}{3}\frac{\Delta B}{B} - \frac{\Delta C}{C} + \frac{3}{2}\frac{\Delta D}{D}$

Ans. (a) $Z = \frac{A^4 B^{1/3}}{CD^{3/2}}$

$$\frac{\Delta Z}{Z} = 4 \times \frac{\Delta A}{A} + \frac{1}{3}\frac{\Delta B}{B} + \frac{\Delta C}{C} + \frac{3}{2}\frac{\Delta D}{D}$$

9. 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: $P = \frac{a^3 b^2}{cd}$ % error in P is:

a. 4% b. 14%

c. 10% d. 7%

Ans. (b) $P = \frac{a^3 b^2}{cd} \Rightarrow \frac{\Delta P}{P} = \pm\left(3\frac{\Delta a}{a} + 2\frac{\Delta b}{b} + \frac{\Delta c}{c} + \frac{\Delta d}{d}\right)$

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

10. The respective number of significant figure for the number 23.023, 0.0003 and 2.1×10^{-3} are:

a. 5, 1, 2 b. 5, 1, 5

c. 5, 5, 2 d. 4, 4, 2

Ans. (a) 23.023 → 5, 0.0003 = 1, $2.1 \times 10^{-3} = 2$

11. The dimensions of coefficient of viscosity and self inductance are:

a. $[M L^{-1} T^{-1}]$, $[M L^2 T^{-2} I^{-2}]$

b. $[M^2 L^{-1} T^{-1}]$, $[M L^2 T^{-1} I^{-2}]$

c. $[M L^{-1} T^{-1}]$, $[M L^3 T^{-1} I^{-2}]$

d. $[M^1 L^1 T^{-2}]$, $[M^1 L^3 T^2 I^{-3}]$

Ans. (a) $\eta = \frac{F}{A(\Delta V / \Delta 7)} = \frac{\text{dimensions of force}}{\text{D. of area} \times \text{D. of velocity gradient}}$

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

$$L = \frac{\text{dimensions of e}}{\text{D. of I / dimension of t}} = \frac{[ML^2T^{-3}I^{-1}]}{[I/T]}$$

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

11. $S_t = U + \frac{1}{2}a(2t-1)$ is:

a. Only numerically correct

b. Only dimensionally correct

c. Both numerically and dimensionally correct

d. Neither numerically nor dimensionally correct

Ans. (d) S_t = distance traveled, U = velocity so, it is not dimensionally correct.

12. What are dimensions of E/B?

a. $[LT^{-1}]$ b. $[LT^{-2}]$

c. $[MLT^{-1}]$ d. $[ML^2T^{-1}]$

Ans. (a) $\frac{E}{B} = \frac{MLT^{-3}A^{-1}}{MT^{-2}A^{-1}}$

$$\frac{E}{B} = LT^{-1}$$

2nd solutions

Ratio E/B is the speed of cm wave.

∴ Dimension of E/B is the dimension of speed.

13. A physical quantity is given by $X = [M^a L^b T^c]$. The percentage error in measurements of M, L and T are α, β, γ. Then, the maximum % error in the quantity X is:

a. $a\alpha + b\beta + c\gamma$ b. $a\alpha + b\beta - c\gamma$

c. $\frac{a}{\alpha} + \frac{b}{\beta} + \frac{c}{\gamma}$ d. None of these

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

$$\frac{dX}{X} = a\frac{dM}{M} + b\frac{dL}{L} + c\frac{dT}{T}$$

$$\frac{dX}{X} = a\alpha + b\beta + c\gamma$$

14. In dimension of critical velocity, of liquid flowing through a tube are expressed as $v_c \propto [\eta^x \rho^y r^z]$ where η, ρ and r are the coefficient of viscosity of liquid, density of liquid and radius of the tube respectively, then the values of x, y and z are given by:

a. 1, 1, 1 b. 1, –1, –1

c. –1, –1, 1 d. –1, –1, –1

Ans. (b) $v_c \propto [\eta^x \rho^y r^z]$

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

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

Taking comparison on both size

$x + y = 0, -x - 3y + z = 1, -x = -1$

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

15. The absolute error in density of a sphere of radius 10.01 m and mass 4.692 kg is:

a. 3.59 kg m^{-3} b. 4.692 kg m^{-3}

c. 0 d. 1.12 kg m^{-3}

Ans. (a) $\rho = \dfrac{m}{\frac{4}{3}\pi r^2} = \dfrac{4.692 \times 3}{4 \times 3.14 \times (10.01)^3 \times 10^{-6}}$

$\rho = 1.12 \times 10^3$ kg /m^3

abs. errors:

$\Delta m = 1$gm $= 0.001$ kg

$\Delta R = 0.01$ m

$$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 3\frac{\Delta r}{r}$$

$$\Delta\rho = \left(\frac{0.001}{4.692} + \frac{3 \times 0.01}{10.01}\right) \times 1.12 \times 10^3$$

$= 3.59$ kg /m^3

16. The dimension of Planck's constant equals to that of:

a. Energy

b. Momentum

c. Angular momentum

d. Power

Ans. (c) Dimensions of Planck's constant, $h = \dfrac{\text{Energy}}{\text{Frequency}}$

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

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

Dimensions of angular momentum L

= Moment of inertia I × Angular velocity

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

17. In the following dimensionally constant equations, we have $F = \dfrac{X}{\text{Linear density}} + Y$ where F = force. The dimensional formula of X are Y are:

a. $[M\,L\,T^{-2}]$, $[M^2\,L^0\,T^{-2}]$

b. $[M^2\,L^0\,T^{-2}]$, $[M\,L\,T^{-2}]$

c. $[M\,L^2\,T^{-4}]$, $[M^2\,L^{-2}\,T^{-2}]$

d. None of these

Ans. (b) $[F] = \left[\dfrac{X}{L.D}\right] + [Y]$

$\therefore [Y] = [F] = [MLT^{-2}]$

$$\left[MLT^{-2}\right] = \left[\frac{X}{ML^{-1}}\right] \Rightarrow X = \left[M^2L^0T^{-2}\right]$$

18. Dimensions of resistance in an electrical circuit, in terms of dimension of mass M, length L, time T and current I, would be:

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

b. $[ML^2T^{-1}I^{-1}]$

c. $[ML^2T^{-3}I^{-2}]$

d. $[ML^2T^{-3}I^{-1}]$

Ans. (c) According to Ohm's law,

$V = RI$ or $R = \dfrac{V}{I}$

Dimensions of $V = \dfrac{W}{q} = \dfrac{\left[ML^2T^{-2}\right]}{[IT]}$

$$\therefore [R] = \frac{\left[ML^2T^{-2} / IT\right]}{[I]} = \left[ML^2T^{-3}I^{-2}\right]$$

19. If $A = (1.0\text{ m} \pm 0.2)$ gm and $B = (2.0 \pm 0.2)$ m, then $\sqrt{AB}$ is:

a. 1.4 m ± 0.4 m

b. 1.41 m ± 0.15 m

c. 1.4 m ± 0.3 m

d. 1.4 m ± 0.2 m

Ans. (d) $x = \sqrt{AB} = \sqrt{1.0 \times 2.0} = 1.414$ m

Rounding off x = 1.4 m

$$\frac{\Delta x}{x} = \frac{1}{2}\left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right) = \frac{1}{2}\left(\frac{0.2}{1.0} + \frac{0.2}{2.0}\right) = 0.2 \text{ m (in rounded figure)}$$

$\therefore \sqrt{AB} = (1.4 \pm 0.2)$ m

ABOUT PHYSICS WALLAH

Alakh Pandey is one of the most renowned faculty in NEET & JEE domain's Physics. On his YouTube channel, Physics Wallah, he teaches the Science courses of 11th and 12th standard to the students aiming to appear for the engineering and medical entrance exams.

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