UNITS AND MEASUREMENTS

Notes :

(i) Physical quantities: Quantities which can be measured directly or indirectly and in terms of which laws of physics can be expressed are called physical quantities.

(ii) The physical quantity which is to be measured is compared with a standard quantity and it is expressed in the form $Q = nu$

where 'n' is the measure or magnitude and 'u' is the unit in which it is measured.

Note : numerical value 'n' is inversely proportional to the size of the unit 'u' $n \propto \frac{1}{u}$

For eg : $6000 g = 6 kg$

(iii) Fundamental Quantities / base quantities: The physical quantities which are independent of other physical Quantities

For eg: length, mass, time etc.

(iv) Any physical quantity that can be derived from fundamental physical quantities ~~are~~ is called derived quantity

For eg : $\text{Speed} = \frac{\text{distance}}{\text{time}}$

System of Fundamental Units

1. CGS system / Gaussian system : In this system, fundamental units of length, mass and time are centimetre, gram and second respectively.

(ii) MKS System : In this system, the units of length, mass and time are metre, kilogram and second.

(iii) FPS system (British Engineering system) _ In this system, length is expressed in foot, Mass in pound and time in Second.

V There are seven base quantities and base units associated with them. They are given below.

S.No	Base Quantity	Base Unit	Symbol
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Thermodynamic Temperature	Kelvin	K
5.	Electric current	Ampere	A
6.	Amount of Substance	mole	mol
7.	luminous Intensity	Candela	Cd

(Refer T.B. to see how each base unit is defined)

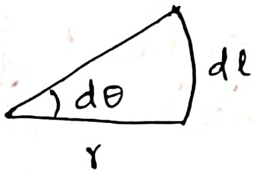
SI unit : It is the internationally accepted system of units and measurements. (Abbreviated for System Internationale d' Units). In SI, there are 7 base units and two Supplementary Units.

The two supplementary units are plane angle and Solid angle which are defined as follows.

plane angle : It is defined as the ratio of the length of arc to the radius of the circle of which it is a part of

$$d\theta = \frac{dl}{r}$$

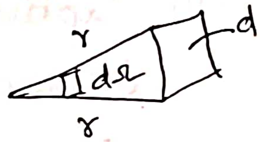
SI unit of plane angle is radian (rad)



Relation b/w degree and radian.

$$1^\circ = \frac{\pi}{180} \text{ rad}$$

Solid angle : It is defined as the ratio of the area intercepted on the surface by the apex to the square of the radius



$$d\Omega = \frac{dA}{r}$$

SI unit of solid angle is steradian (sr)

Advantages of SI units

1. These are more logical and coherent.
2. Easily reproducible
3. Invariant in time as they are based on some universal constants
4. The derived units are practical
5. Applicable to all branches of physics.

Unit : Prefixes

Various multiples and sub-multiples of a unit can be obtained by the use of prefixes in the table below

Sub multiple	prefix	Symbol
10^{-1}	Deci	d
10^{-2}	Centi	c
10^{-3}	milli	m
10^{-6}	Micro	μ
10^{-9}	Nano	n
10^{-12}	Pico	p
10^{-15}	fermi/femto	f

Other Common Submultiples:

10^{3}	Kilo	k
10^{6}	Mega	M
10^{9}	Giga	G
10^{12}	Tera	T

Significant figures : The reliable digits plus the first uncertain digit are known as significant figures.

Rules for Significant figures

(i) All non zero digits are significant. Eg : 1234 — 4 s.f.

(ii) Captive zeroes are significant
(Zeroes that appear b/w two non zero digits → captive zeroes)

Eg : 82004 — 5 s.f.

(iii) Zeroes to the left of a non-zero digit with or without decimal point are not significant

Eg : 0326 → 3 s.f.

0.0078 → 2 s.f. (Zeroes are to the left of a non zero digit - not significant)

(iv) Trailing zeroes are not significant if it appears without a decimal point but they are significant if they appear (to the right) after a decimal point.

Eg 1. 91300 → 3 s.f.

2. 88.00 → 4 s.f.

3. 0.007800 → 4 s.f.

In short

0.0070650

- 0.00 → Insignificant
- 0 (between 7 and 6) → significant
- 0 (last) → significant.

(V) All the zeroes that are on the right of last non zero digit are significant if they come from a measurement

Eg : 1090 m → 4 s.f.

Rounding off to correct no. of significant figures :

whenever there is a combination of measurements to be applied in an equation, the final result / answer can be rounded off to measurement with least no. of significant figures

Eg 1. length = 1.24 cm   breadth = 0.8 cm

find Area :

$A = l \times b = 1.24 \times 0.8 = 0.992\ cm^2$

which has 3 S.f, it can be rounded off to 1 S.f. as $b = 0.8$ cm → has one S.f.

$\therefore A = 1\ cm^2$

Eg : 2 Area of a square is $5.29\ cm^2$. Area of seven such squares taking into account the significant figures will be

$7 \times 5.29 = 37.03$ → 4 S.f.

round off to 3 S.f

Answer is $37.0\ cm^2$

Application of dimensional analysis (continued)

III Conversion of a physical quantity from one system of units to another.

A physical quantity is expressed as a product of a number and its unit. Let there be a physical quantity of dimensions a, b, and c in terms of M, L and T resp. whose dimensional formula is $M^a L^b T^c$. If its numerical value is n_1 in one system and if its numerical value be n_2 in another system of units then

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

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

Eg: How much dyne is 1 Newton?

Given 1 Newton ; $n_1 = 1$ in SI unit

Dimensional formula for force $[MLT^{-2}]$

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

Dyne is the CGS unit ; ∴ $M_2 L_2 T_2$ represent cm, g and s

substituting ; $$n_2 = 1 \left[\frac{kg}{g}\right]^1 \left[\frac{m}{cm}\right]^1 \left[\frac{s}{s}\right]^{-2}$$

$$= 1 \left[\frac{1000g}{g}\right] \left[\frac{100cm}{cm}\right]^1 \left[\frac{s}{s}\right]^{-2}$$

$$1N = 1000 \times 100 = 10^5 \text{ dyne.}$$

Eg: 2 If the acceleration due to gravity be represented by unity and one second be unit of time, what must be unit of length for this new system of unit?

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

for SI system $n_1 = 9.8\ m/s^2$

$L_1 = 1m$

$T_1 = 1s$

for new system, $n_2 = 1$ (given)

$$1 = 9.8 \left[\frac{m}{L_2}\right]^1 \left[\frac{s}{s}\right]^{-2}$$

$\therefore L_2 = 9.8\ m$

Eg: 3. Find the value of 10 Joule on a system having 100g, 10 cm and 30 s as fundamental units

Sol: $[W] = [ML^2T^{-2}]$

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

Given system SI	New system
$n_1 = 10$	$n_2 = ?$
$M_1 = 1kg$	$M_2 = 100g$
$L_1 = 1m$	$L_2 = 10\ cm$
$T_1 = 1\ s$	$T_2 = 30s$

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

$$= 10 \left[\frac{1kg}{100g}\right]^1 \left[\frac{1m}{10\ cm}\right]^2 \left[\frac{1s}{30s}\right]^{-2}$$

$$= 10 \left[\frac{1000g}{100g}\right]^1 \left[\frac{100\ cm}{10\ cm}\right]^2 \left[\frac{1s}{30s}\right]^{-2}$$

$= 10 \times 10 \times 10^2 \times 30^2 \quad = 9 \times 10^6$

$10\,J = 9 \times 10^6$ New unit.

NCERT

4. 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 unit of mass equals α kg, the unit of length β m and unit of time γ s, show that a Calorie has a magnitude $4.2\, \alpha^{-1} \beta^{-2} \gamma^2$ in terms of new units.

Sol: Given $1\ Cal = 4.2\ J = 4.2\ kg\, m^2 s^{-2}$

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

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

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

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

$= 4.2\, \alpha^{-1} \beta^{-2} \gamma^2$ in new system.