UNIT – 1

UNITS AND DIMENSIONS

PHYSICAL QUANTITIES -:

- All the quantities in terms of which laws of physics are described & whose measurement is necessary are physical quantities.

OR

- A quantity that can be measured is called as physical quantity.
- It is also known as measurable quantity.
- Examples – length, mass, velocity, area, volume, density, temperature etc.

NON- PHYSICAL QUANTITIES

- A quantity that cannot be measured is called as non-physical quantity.
- It is also known as non-measurable quantity.
- Examples -: building, bus, road, t.v., radio etc.

DEFINITION OF SOME PHYSICAL QUANTITIES -:

1. MASS – Mass of a body is defined as the quantity of matter in the body, which can never be zero.

2. LENGTH – Length of an object may be defined as the distance of separation between any two points at the extreme end of the object.

3. TIME – It is very difficult to define time precisely. According to Einstein, "Time is what a clock reads".

4. DISTANCE – Distance of an object is defined as the total or complete path or actual path travelled by an object.

5. DISPLACEMENT – Displacement of a body is defined as the shortest distance between the final position & the initial position of the motion of the body.

6. SPEED – Speed of a body is defined as the distance covered by the body in one second.

7. VELOCITY – Velocity of a body is defined as the time rate of change of displacement.

8. ACCELERATION - Acceleration of a body is defined as the rate of change of velocity.

9. FORCE – (Qualitatively) Force is defined as that pull or push which produces or tends to produce, destroys or tends to destroy motion in a body, increases or decreases the speed of the body or changes its direction of motion.

10. MOMENTUM – (Qualitatively) Momentum of a body is defined as the amount of motion contained in a body.

11. WORK – (Qualitatively) Work is said to be done if a force acting on a body, displaces a body through a certain distance & the force has some component along the displacement.

12. POWER – The rate at which work is done is called power.

13. ENERGY – It is ability of the body to do some work.

CLASSIFICATION OF PHYSICAL QUANTITIES

PHYSICAL QUANTITIES

FUNDAMENTALQUANTITIES **DERIVED QUANTITIES**

FUNDAMENTAL QUANTITIES -:

- A physical quantity which does not depend on any other physical quantity for its measurement is known as fundamental (Basic) quantity.

OR

- Those quantities which can neither be derived from one another nor they can be resolved (broken) into anything more basic are called fundamental quantities.
- There are 7 fundamental quantities.
- Examples- mass, length, time, temperature, current, luminous intensity, amount of substance.

DERIVED QUANTITIES -:

- The physical quantities which are expressed in terms of more than one fundamental quantities are called as derived quantities.

OR

- The physical quantity that depends upon other physical quantities for its measurement is known as derived quantity.
- Except 7 fundamental quantities, all other quantities are derived quantities.
- Examples -: area, volume, force, momentum etc.

SUPPLEMENTARY QUANTITIES -:

- Plane angle (θ)
- Solid angle (Ω)

UNITS -:

- The chosen standard of measurement of a quantity which has essentially the same nature as that of the quantity is called the unit of the quantity.

OR

- Internationally accepted reference standard to measure a physical quantity.

CHARACTERISTICS OF A UNIT -:

- It should be invariable.
- It should be of convenient size.
- It should be easily available.
- It should be non- perishable.

SYSTEMS OF UNITS -:

There are 3 major systems of units.

1. F.P.S. SYSTEM -:

- In this system the basic units of length, force (instead of mass) & time chosen as the fundamental quantities are foot, pound & second respectively.
- It is also known as British system.

2. CGS SYSTEM -:

- In this system the basic units of length, mass & time chosen as the fundamental quantities are centimeter, gram & second respectively.
- It is also known as French or Gaussian system.

3. MKS SYSTEM -:

- In this system the basic units of length, mass & time chosen as the fundamental quantities are meter, kilogram & second respectively.
- It is also known as Metric system.

S.I. UNITS -: (THE INTERNATIONAL SYSTEM OF UNITS)

Each of above 3 systems of units is sufficient only to describe all physical quantities in mechanics. However for the description of physical quantities in field of electricity, thermodynamics & optics introduction of some additional basic units is necessary. Therefore the systems of units mentioned above are not complete & coherent.

- The 11^{th} **General Conference On Weights & Measures** which met in Paris in 1960, introduced a new system of units called S.I. System, which covers all fields of science & technology.
- The S.I. system consist of 3 classes of units.

1. Base units – The units of fundamental quantities are called Base units or fundamental units.

QUANTITY	**UNIT**	**SYMBOL**
Length(l)	meter	m
Mass(m)	kilogram	kg
Time(t)	second	s

Electric current(i)	ampere	A
Temperature(T)	kelvin	K
Luminosity	candela	Cd
Amount of substance	mole	mol

2. Supplementary units – The units of Supplementary quantities are called Supplementary units.

QUANTITY	**UNIT**	**SYMBOL**
Plane angle	Radian	rad
Solid angle	steradian	sr

3. Derived units – The units of derived quantities are called derived units.

Derived units can be obtained by simple multiplication & or division of base and supplementary units.

Examples -

QUANTITY	**UNIT**	**SYMBOL**
Area	$(\text{meter})^2$	m^2
momentum	(kilogram.meter)/second	kgm s^{-1}

PREFIXES FOR LARGER & SMALLER UNITS IN POWERS OF TEN

SUB MULTIPLES (SMALLER)			**MULTIPLES (LARGER)**		
PREFIX	**ABBREVIATION**	**VALUE**	**PREFIX**	**ABBREVIATION**	**VALUE**
deci-	d	10^{-1}	*Deca-*	D	10^{1}
centi-	c	10^{-2}	*Hecta-*	H	10^{2}
milli-	m	10^{-3}	*Kilo-*	k	10^{3}
micro-	μ	10^{-6}	*Mega-*	M	10^{6}
nano-	n	10^{-9}	*Giga-*	G	10^{9}
pico-	p	10^{-12}	*Tera-*	T	10^{12}
femto-	f	10^{-15}	*Peta-*	P	10^{15}
atto-	a	10^{-18}	*Exa-*	E	10^{18}

DIMENSIONS -:

- Dimensions of a physical quantity are the powers to which the fundamental units be raised in order to represent that quantity.

DIMENSIONAL FORMULA -:

- Dimensional formula of a physical quantity is the formula which tells us how and which of the fundamental units have been used for the measurement of that quantity.

QUANTITY	DIMENSION
Mass	$[M^1]$ or $[M^1L^0T^0]$
Length	$[L^1]$ or $[M^0L^1T^0]$
Time	$[T^1]$ or $[M^0L^0T^1]$
Temperature	$[K^1]$ or $[M^0L^0T^0K^1A^0]$
Current	$[A^1]$ or $[M^0L^0T^0K^0A^1]$

- The pure numbers (1, 2, 3…$\pi, e\ etc$) & all trigonometric functions have no dimensions.

DETERMINATION OF DIMENSIONS OF A PHYSICAL QUANTITY -:

Dimensions of a physical quantity can be determined as follows –

1. Write the formula for the quantity, with the quantity of L.H.S. of the equation.

2. Convert all the quantities on R.H.S. into the fundamental quantities mass, length & time.

3. Substitute M, L & T for mass, length & time respectively.

4. Collect terms of M, L & T in a square bracket without commas in between them & find their resultant powers which give the dimensions of the quantity in mass, length & time respectively.

Examples-

1. Volume = length × breadth × thickness

$$= [L] \times [L] \times [L]$$

$$= [L^3] \text{ or } [M^0L^3T^0]$$

So, the dimensions of volume are 0, 3 & 0 in mass, length & time respectively.

$$\textbf{2. Velocity} = \frac{\textbf{Displacement}}{\textbf{Time}}$$

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

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

So, the dimensions of velocity are 0, 1 & -1 in mass, length & time respectively.

DIMENSIONAL EQUATION -:

- An equation written in the following manner is called dimensional equation.

$$\text{Volume} = [M^0L^3T^0]$$

PRINCIPLE OF HOMOGENEITY -:

- It states that the dimensional formula of every term on the two sides of a correct relation must be same.
- Two quantities in addition or subtraction should have same dimension.
- Quantities on either side of an expression or equation should have the same dimension.
- Using this principle we can check the correctness of a physical equation.

Uses of dimensional analysis -:

1. To convert the values of a physical quantity from one system to another.
2. To check the correctness of a given relation.
3. To derive a relation between various physical quantities.

All these uses are based upon the "***Principle of Homogeneity***".

CHECKING THE DIMENSIONAL CORRECTNESS OF PHYSICAL RELATIONS -:

Let us check the correctness of the relation

$$S = ut + {}^1/_2\, at^2$$

L.H.S.

Dimensional formula of **S** or $[S] = [L^1]$

R.H.S.

Dimensional formula of ***ut*** or $[ut] = [u].[t]$

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

Dimensional formula of $\boldsymbol{{}^1/_2\, at^2}$ or $[{}^1/_2\, at^2] = [a].[t^2]$

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

So L.H.S. = R.H.S.

Since the dimensional formulae of all the terms involved in the above relation are $[L^1]$.

So the given relation is **dimensional correct**.