Units and Measurements

1. The numerical value (n) of a physical quantity is inversely proportional to the unit (u) in which it is expressed.

   $n \alpha \frac{1}{u}$ (Or) $n_1u_1 = n_2u_2$.

2. The quantities that are independent of other quantities are called fundamental quantities. The units of these fundamental quantities are called fundamental units.
3. The quantities that are derived from fundamental quantities are called derived quantities. The units of these derived quantities are called derived units.
4. The basic systems of units :

Fundamental Quantity	System of units		
	C.G.S.	**M.K.S.**	**F.P.S.**
Length	Centimeter	Metre	Foot
Mass	Gram	Kilogram	Pound
Time	Second	Second	Second

5. Fundamental quantities in SI system :

Physical quantity	Unit	Symbol
Length	Metre	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Intensity of light	Candela	cd
Quantity of substance	Mole	mol

Supplementary quantities

Plane angle	Radian	rad
Solid angle	Steradian	sr

13. **Metre**: A metre is equal to 1650763.73 times the wavelength of the light emitted in vacuum due to electronic transition from $2p^{10}$ state to $5d^{5}$ state in Krypton–86. But in 1983, 17th General Assembly of weights and measures, adopted a new definition for the metre in terms of velocity of light. According to this definition, metre is defined as the distance travelled by light in vacuum during a time interval of 1/299, 792, 458 of a second.
14. **Kilogram**: The mass of a cylinder of platinum–iridium alloy kept in the International Bureau of weights and measures preserved at Serves near Paris is called one kilogram.
15. **Second**: The duration of 9192631770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of caesium–133 atom is called one second.
16. **Ampere** : The current which when flowing in each of two parallel conductors of infinite length and negligible cross–section and placed one metre apart in vacuum, causes each conductor to experience a force of 2×10^{-7} Newton per metre of length is known as one ampere.
17. **Kelvin**: The fraction of 1/273.16 of the thermodynamic temperature of the triple point of water is called Kelvin.
18. **Candela**: The luminous intensity in the perpendicular direction of a surface of a black body of area 1/600000 m^2 at the temperature of solidifying platinum under a pressure of 101325 Nm^{-2} is known as one candela.
19. **Mole**: The amount of a substance of a system which contains as many elementary entities as there are atoms in 12×10^{-3} kg of carbon–12 is known as one mole.
20. **Radian:** The angle made by an arc of the circle equivalent to its radius at the centre is known as radian. 1 radian = $57^{o}17^{l}45^{ll}$.
21. **Steradian**: The angle subtended at the centre by one square metre area of the surface of a sphere of radius one metre is known as steradian.

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

23. The expression showing the powers to which the fundamental units are to be raised to obtain one unit of a derived quantity is called the dimensional formula of that quantity.

24. Dimensional Constants: The physical constants which have dimensions are called dimensional constants. Eg: Gravitational constant (G), Planck's constant (h), Universal gas constant (R) etc.

25. Dimensionless quantities: The physical quantities which do not have dimensions are called dimensionless quantities

a) Dimensionless quantities without units. Eg: numbers, □, sin□, tan□….etc.,

b) Dimensionless quantities with units. Eg : Angular displacement – radian, Joule's constant – joule/calorie, etc.,

26. Dimensional variables: The physical quantities which have dimensions and do not have fixed value are called dimensional variables. Eg: Velocities, acceleration, force, work, etc.

27. Dimensionless variables: The physical quantities which do not have dimensions and do not have fixed value dimensions are called dimensionless variables. Eg: Specific gravity, refractive index, coefficient of friction, etc.

28. Uses of dimensional formulae: These are used to a) verify the correctness of a physical equation, b) derive relationship between physical quantities and c) to convert the units of a physical quantity from one system to another system.

29. Principle of homogeneity: In any correct equation representing the relation between physical quantities, the dimensions of all the terms must be the same on both sides. Quantities having same dimensions can only be added or subtracted or equated.

30. Limitations of dimensional analysis

1. Dimensionless quantities and proportionality Constants cannot be determined by this method.
2. This method is not applicable to trigonometric, logarithmic and exponential functions.
3. In the case of physical quantities which depend upon more than three physical quantities, this method will be difficult.
4. If the constant of proportionality also possesses dimensions, this system cannot be used.

If one side of equation contains addition or subtraction of physical quantities, this method cannot be used

Dimensional formulae for some physical quantities

Physical quantity	Unit	Dimensional formula
Boltzmann's constant	JK^{-1}	$ML^2T^{-2}\theta^{-1}$
Bulk modulus	Nm^{-2}, Pa	$M^1L^{-1}T^{-2}$
Coefficient of linear or areal or volume expansion	$^oC^{-1}$ or K^{-1}	θ^{-1}
Surface tension	Nm^{-1} or Jm^{-2}	MT^{-2}
Thermal conductivity	$Wm^{-1}K^{-1}$	$MLT^{-3}\theta^{-1}$
Coefficient of viscosity ($F = \eta A \frac{dv}{dx}$)	poise	$ML^{-1}T^{-1}$
Compressibility	Pa^{-1}, m^2N^{-2}	$M^{-1}LT^2$
Electric capacitance	CV^{-1}, farad	$M^{-1}L^{-2}T^4I^2$
Electric conductance	Ohm^{-1} or mho or siemen	$M^{-1}L^{-2}T^3I^2$
Electric conductivity	siemen/metre or Sm^{-1}	$M^{-1}L^{-3}T^3I^2$
Electric charge or quantity of electric charge	coulomb	IT
Electric current	ampere	I
Electric dipole moment	Cm	LTI
Intensity of electric field	NC^{-1}, Vm^{-1}	$MLT^{-3}I^{-1}$
Electric resistance	ohm	$ML^2T^{-3}I^{-2}$
Emf (or) electric potential	volt	$ML^2T^{-3}I^{-1}$
Energy density	Jm^{-3}	$ML^{-1}T^{-2}$
coefficient of self induction	Henry (H)	$ML^2T^{-2}I^{-2}$

Intensity of gravitational field	Nkg^{-1}	$L^{1}T^{-2}$
Intensity of magnetization	Am^{-1}	$L^{-1}I$
Joule's constant or mechanical equivalent of heat	$Jcal^{-1}$	$M^{o}L^{o}T^{o}$
Latent heat	Jkg^{-1}	$M^{o}L^{2}T^{-2}$
Magnetic dipole moment	Am^{2}	$L^{2}I$
Magnetic flux	Weber (Wb)	$ML^{2}T^{-2}I^{-1}$
Magnetic induction	$NI^{-1}m^{-1}$ or T	$MT^{-2}I^{-1}$
Magnetic pole strength	Am	LI
Modulus of elasticity	Nm^{-2}, Pa	$ML^{-1}T^{-2}$
Moment of inertia	kgm^{2}	ML^{2}
Momentum	$kgms^{-1}$	MLT^{-1}
Permeability of free space	Hm^{-1} or NA^{-2}	$MLT^{-2}I^{-2}$
Permittivity of free space	Fm^{-1} or $C^{2}N^{-1}m^{-2}$	$M^{-1}L^{-3}T^{4}I^{2}$
Planck's constant	Js	$ML^{2}T^{-1}$
Poisson's ratio	—	$M^{o}L^{o}T^{o}$
Pressure coefficient or volume coefficient	$^{o}C^{-1}$ or θ^{-1}	θ^{-1}
Radioactivity	disintegrations per second	$M^{o}L^{o}T^{-1}$
Refractive index	—	$M^{o}L^{o}T^{o}$
Resistivity or specific resistance	Ω–m	$ML^{3}T^{-3}I^{-2}$
Specific conductance or conductivity	siemen/metre or Sm^{-1}	$M^{-1}L^{-3}T^{3}I^{2}$
Specific heat	$Jkg^{-1}\theta^{-1}$	$M^{o}L^{2}T^{-2}\theta^{-1}$
Stefan's constant	$Wm^{-2}\theta^{-4}$	$ML^{o}T^{-3}\theta^{-4}$
Universal gravitational constant	$Nm^{2}kg^{-2}$	$M^{-1}L^{3}T^{-2}$

Quantities having same dimensions

a) Work, energy, torque, moment of force, energy

b) Angular momentum, Planck's constant, rotational impulse

c) Stress, pressure, modulus of elasticity, energy density.

d) Force constant, surface tension, surface energy.

e) Angular velocity, frequency, velocity gradient

f) Gravitational potential, latent heat.

g) Thermal capacity, entropy, universal gas constant and Boltzmann are constant.