PHYSICS AND MEASUREMENT

UNITS AND DIMENSIONS

1. Unit

To measure a physical quantity we require a standard of measurement. This standard is called the unit of that physical quantity. The measure of any physical quantity = *nu*, where *n* = numerical value of the measure of the quantity, *u* = unit of the quantity.

2. System of units

The system of units was introduced by the General Conference on Weight and Measures in 1971 and was accepted internationally. It has seven basic units with two complementary units.

3. Base Units (Fundamental Units)

There are certain physical quantities which are very fundamental in nature. For well-developed system of measurements, seven base units are required.

By international agreement the seven bases units of the SI system are:

(i) The metre (m) - standard of length

(ii) The kilogram (kg) - standard of mass

(iii) The second (s) - standard of time

(iv) The ampere (A) - standard of electric current

(v) The kelvin (K) - standard of temperature

(vi) The candela (cd) - standard of luminous intensity

(vii) The mole (mol) - standard of amount of substance

4. Derived units

They can be expressed as fundamental quantities. Units of derived quantities are expressed in terms of fundamental units and are called derived units. For example, there are quantities of velocity, force, impulse etc.

5. Dimensions

All physical quantities represented by derived units can be expressed in terms of some combination of seven fundamental quantities. These seven fundamental quantities are called the seven dimensions of the physical world. They are represented by square brackets [k].

Dimensions of commonly used Physical Quantities

S. No.	Physical Quantity (Mechanics)	SI Units	Dimensional formula
1.	Velocity = displacement/time	m/s	M^0LT^{-1}
2.	Acceleration = velocity/time	m/s^2	M^0LT^{-2}
3.	Force = mass × acceleration	$kg\text{-}m/s^2$ = Newton or N	MLT^{-2}
4. 5. 6.	Work = force × displacement Energy Torque = force × perpendicular distance	$kg\text{-}m^2/s^2$ = N-m = Joule or J N-m	ML^2T^{-2}
7.	Power = work/time	J/s or watt	ML^2T^{-3}
8.	Momentum = mass × velocity	Kg-m/s	MLT^{-1}
9.	Impulse = force × time	Kg-m/s or N-s	MLT^{-1}
10. 11.	Angle = arc/radius	radian or rad no units	$M^0L^0T^0$

	Strain = $\frac{\Delta L}{L}$ or $\frac{\Delta V}{V}$		
12. 13. 14.	Stress = force/area Pressure = force/area Modulus of elasticity = stress/strain	N/m^2 N/m^2 N/m^2	$ML^{-1}T^{-2}$ $ML^{-1}T^{-2}$ $ML^{-1}T^{-2}$
15. 16.	Frequency = 1/ time period Angular velocity = angle/time	per sec or hertz (Hz) rad/s	$M^0L^0T^{-1}$ $M^0L^0T^{-1}$
17.	Moment of inertia = (mass) $(\text{distance})^2$	$kg\text{-}m^2$	ML^2T^0
18.	Surface tension = force/length	N/m	ML^0T^{-2}
19.	Gravitational constant $= \frac{\text{Force} \times (\text{distance})^2}{(\text{mass})^2}$	$N\text{-}m^2/kg^2$	$M^{-1}L^3T^{-2}$

S. No.	**Physical Quantity**	**SI Units**	**Dimensional formula**
1.	Thermodynamic temperature	kelvin (K)	$M^0L^0T^0K$

2.	Heat	joule	ML^2T^{-2}
3.	Specific heat	$Jkg^{-1}K^{-1}$	$M^0L^2T^{-2}K^{-1}$
4.	Latent heat	$J\ kg^{-1}$	$M^0L^2T^{-2}$
5.	Universal gas constant	$J\ mol^{-1}\ K^{-1}$	$ML^2T^{-2}K^{-1}mol^{-1}$
6.	Boltzmann's constant	JK^{-1}	$ML^2T^{-2}K^{-1}$
7.	Stefan's constant	$Js^{-1}m^{-2}\ K^{-4}$	$MT^{-3}K^{-4}$
8.	Planck's constant	Js	ML^2T^{-1}
9.	Solar constant	$J\ m^{-2}\ s^{-1}$	ML^0T^{-3}
10.	Thermal conductivity	$Js^{-1}m^{-1}\ K^{-1}$	$MLT^{-3}K^{-1}$
11.	Thermal resistance	$Kscal^{-1}$	$M^{-1}L^{-2}T^3K$
12.	Enthalpy	cal	ML^2T^{-2}
13.	Entropy	$cal\ K^{-1}$	$ML^2T^{-2}K^{-1}$

Quantities having same Dimensions

Dimension	**Quantity**
$[M^0L^0T^{-1}]$	Frequency, angular frequency, angular velocity, velocity gradient and decay constant
$[M^1L^2T^{-2}]$	Work, internal energy, potential energy, kinetic energy, torque, moment of force
$[M^1L^{-1}T^{-2}]$	Pressure, stress, Young's modulus, bulk modulus, modulus of rigidity, energy density
$[M^1L^1T^{-1}]$	Momentum, impulse
$[M^0L^1T^{-2}]$	Acceleration due to gravity, gravitational field intensity
$[M^1L^1T^{-2}]$	Thrust, force, weight, energy gradient
$[M^1L^2T^{-1}]$	Angular momentum and Planck's constant
$[M^1L^0T^{-2}]$	Surface tension, Surface energy (energy per unit area)
$[M^0L^0T^0]$	Strain, refractive index, relative density, angle, solid angle, distance gradient, relative permittivity (dielectric constant), relative permeability etc.
$[M^0L^2T^{-2}]$	Latent heat and gravitational potential
$[ML^2T^{-2}K^{-1}]$	Thermal capacity, gas constant, Boltzmann constant and entropy
$[M^0L^0T^1]$	$\sqrt{\frac{l}{g}}, \sqrt{\frac{m}{k}}, \sqrt{\frac{R}{g}}$, where l = length g = acceleration due to gravity, m = mass, k = spring constant, R = Radius of earth

$[M^0L^0T^1]$	$\frac{L}{R}, \sqrt{LC}, RC$ where *L* = inductance, *R* = resistance, *C* = capacitance
$[ML^2T^{-2}]$	$I^2Rt, \frac{V^2}{R}t, VIt, qV, LI^2, \frac{q^2}{C}, CV^2$ where *I* = current, *t* = time, *q* = charge, *L* = inductance, *C* = capacitance, *R* = resistance

APPLICATION OF DIMENSIONAL ANALYSIS

(i) In conversion of units from one system to other.

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

(iii) To establish the relation among various physical quantities.

(iv) To find dimensions of physical constants or co-efficients.

LEAST COUNT

The smallest measurement that can be taken with the help of a measuring instrument is called its least count.

Following two points are worth remembering regarding the least count.

(i) Least count represents the permissible error in the measurement.

(ii) It gives the limit of resolution of the instrument.