UNIT -1

UNITS AND DIMENSIONS

Unit

The unit of a physical quantity is an arbitrarily chosen standard which is widely accepted by the society and in terms of which other quantities of similar nature may be measured.

Standard

The actual physical embodiment of the unit of a physical quantity is known as a standard of that physical quantity.

• To express any measurement made we need the numerical value (n) and the unit (μ).

Measurement of physical quantity = Numerical value x Unit

For example: Length of a rod = 8 m

where 8 is numerical value and m (metre) is unit of length.

Fundamental Physical Quantity/Units

It is an elementary physical quantity, which does not require any other physical quantity to express it. It means it cannot be resolved further in terms of any other physical quantity. It is also known as basic physical quantity.

The units of fundamental physical quantities are called fundamental units.

For example, in M. K. S. system, Mass, Length and Time expressed in kilogram, metre and second respectively are fundamental units.

Derived Physical Quantity/Units

All those physical quantities, which can be derived from the combination of two or more fundamental quantities or can be expressed in terms of basic physical quantities, are called derived physical quantities.

The units of all other physical quantities, which car. be obtained from fundamental units, are called derived units. For example, units of velocity, density and force are m/s, kg/m3, kg m/s2 respectively and they are examples of derived units.

Systems of Units

Earlier three different units systems were used in different countries. These were CGS, FPS and MKS systems. Now-a-days internationally SI system of units is followed. In SI unit system, seven quantities are taken as the base quantities.

(i) CGS System. Centimetre, Gram and Second are used to express length, mass and time respectively.

(ii) FPS System. Foot, pound and second are used to express length, mass and time respectively.

(iii) MKS System. Length is expressed in metre, mass is expressed in kilogram and time is expressed in second. Metre, kilogram and second are used to express length, mass and time respectively.

(iv) SI Units. Length, mass, time, electric current, thermodynamic temperature, Amount of substance and luminous intensity are expressed in metre, kilogram, second, ampere, kelvin, mole and candela respectively.

1. **Definitions of Fundamental Units**

TABLE 2.1 SI Base Quantities and Units

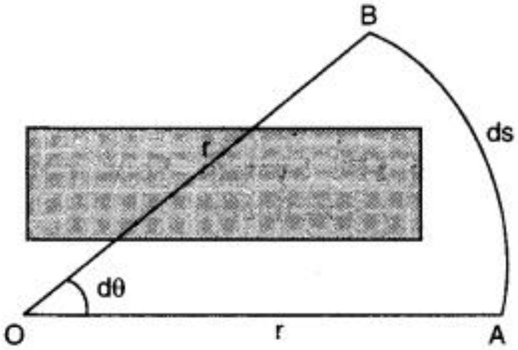
Base quantity	*SI Units*		
	Name	*Symbol*	*Definition*
Length	metre	m	The metre is the length of the path travelled by light in vacuum during a time interval of 1/299, 792, 458 of a second. (1983)
Mass	kilogram	kg	The kilogram is equal to the mass of the international prototype of the kilogram (a platinum-iridium alloy cylinder) kept at international Bureau of Weights and Measures, at Sevres, near Paris, France. (1889)
Time	second	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. (1967)
Electric current	ampere	A	The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length. (1948)
Thermodynamic Temperature	kelvin	K	The kelvin is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. (1967)
Amount of substance	mole	mol	The mole is the amount of substance of a system, which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12. (1971)
Luminous intensity	candela	cd	The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian. (1979)

Supplementary Units

Besides the above mentioned seven units,there are two supplementary base units. these are (i) radian (rad) for angle, and (ii) steradian (sr) for solid angle.

(*i*) **Radian (rad).** It is the unit of plane angle. One radian is an angle subtended at the centre of a circle by an arc of length equal to the radius of the circle.

$$d\theta = \left(\frac{ds}{r}\right) \text{ radian}$$

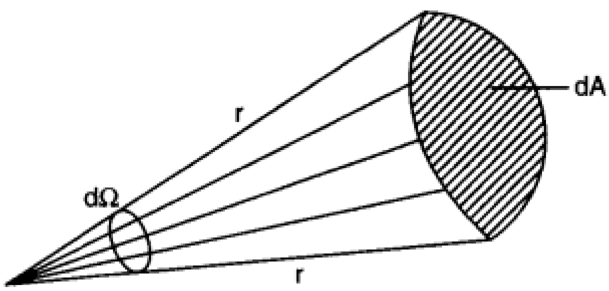


(*ii*) **Steradian (sr).** It is the unit of solid angle. One steradian is the solid angle subtended at the centre of a sphere by its surface whose area is equal to the square of the radius of the sphere. Solid angle in steradian,

$$d\Omega = \frac{\text{area cut out from the surface of sphere}}{(\text{radius})^2}$$

$$d\Omega = \left(\frac{dA}{r^2}\right) \text{ steradian}$$

Advantages of SI Unit System
SI Unit System has following advantages over the other Besides the above mentioned seven units, there are two supplementary base units. These are systems of units:



(i) It is internationally accepted,
(ii) It is a rational unit system,
(iii) It is a coherent unit system,
(iv) It is a metric system,
(v) It is closely related to CGS and MKS systems of units,
(vi) Uses decimal system, hence is more user friendly.

Other Important Units of Length
For measuring large distances e.g., distances of planets and stars etc., some bigger units of length such as 'astronomical unit', 'light year', parsec' etc. are used.
• The average separation between the Earth and the sun is called one astronomical unit.
1 AU = 1.496×10^{11} m.
• The distance travelled by light in vacuum in one year is called light year.
1 light year = 9.46×10^{15} m.

• The distance at which an arc of length of one astronomical unit subtends an angle of one second at a point is called parsec.
1 parsec = 3.08 x 10^{16} m
• Size of a tiny nucleus = 1 fermi = If = 10^{-15} m
• Size of a tiny atom = 1 angstrom = 1A = 10^{-10} m

Dimensions
The dimensions of a physical quantity are the powers to which the fundamental units of mass, length and time must be raised to represent the given physical quantity.

Dimensional Formula
The dimensional formula of a physical quantity is an expression telling us how and which of the fundamental quantities enter into the unit of that quantity.
It is customary to express the fundamental quantities by a capital letter, e.g., length (L), mass (AT), time (T), electric current (I), temperature (K) and luminous intensity (C). We write appropriate powers of these capital letters within square brackets to get the dimensional formula of any given physical quantity.

Applications of Dimensions
The concept of dimensions and dimensional formulae are put to the following uses:
(i) Checking the results obtained
(ii) Conversion from one system of units to another
(iii) Deriving relationships between physical quantities
(iv) Scaling and studying of models.
The underlying principle for these uses is the principle of homogeneity of dimensions. According to this principle, the ‘net’ dimensions of the various physical quantities on both sides of a permissible physical relation must be the same; also only dimensionally similar quantities can be added to or subtracted from each other.

TABLE 2.3 Range and order of lengths

Size of object or distance	*Length (m)*
Size of a proton	10^{-15}
Size of atomic nucleus	10^{-14}
Size of hydrogen atom	10^{-10}
Length of typical virus	10^{-8}
Wavelength of light	10^{-7}
Size of red blood corpuscle	10^{-5}
Thickness of a paper	10^{-4}
Height of the Mount Everest above sea level	10^{4}
Radius of the Earth	10^{7}
Distance of moon from the Earth	10^{8}
Distance of the Sun from the Earth	10^{11}
Distance of Pluto from the Sun	10^{13}
Size of our galaxy	10^{21}
Distance to Andromeda galaxy	10^{22}
Distance to the boundary of observable universe	10^{26}

TABLE 2.4 Range and order of masses

1.

Object	*Mass (kg)*
Electron	10^{-30}
Proton	10^{-27}
Uranium atom	10^{-25}
Red blood cell	10^{-13}
Dust particle	10^{-9}

TABLE 2.6 Dimensional Formulae of Some Physical Quantities

Physical Quantity	*Dimensional Formula*	*Physical Quantity*		*Dimensional Formula*
Area	L^2	Capacitance		$M^{-1} L^{-2} T^2 Q^2$
Volume	L^3	Electric current		I or $Q T^{-1}$
Density	$M L^{-3}$	Electric potential		$M L^2 T^{-2} Q^{-1}$
Velocity	$L T^{-1}$		or	$M L^2 T^{-3} I^{-1}$
Acceleration	$L T^{-2}$	Electric field		$M L^{-2} Q^{-1}$
Momentum	$M L T^{-1}$		or	$M L T^{-3} I^{-1}$
Force	$M L T^{-2}$	Inductance		$ML^2 Q^{-2}$
Energy, work	$M L^2 T^{-2}$		or	$M L^2 T^{-2} I^{-2}$
Power	$M L^2 T^{-3}$	Resistance		$M L^2 T^{-1} Q^{-2}$
Frequency	T^{-1}		or	$M L^2 T^{-3} I^{-2}$
Pressure	$M L^{-1} T^{-2}$	Magnetic flux		$M L^2 T^{-1} Q^{-1}$
Torque, couple	$M L^2 T^{-2}$		or	$M L^2 T^{-2} I^{-1}$
Moment of inertia	$M L^2$	Magnetic field vector H		$L^{-1} T^{-1} Q$
Temperature	K		or	$L^{-1} I$
Heat energy	$M L^2 T^{-2}$	Magnetic feild intensity, B		$M T^{-1} Q^{-1}$
Entropy	$M L^2 T^{-2} K^{-1}$		or	$M T^{-2} I^{-1}$
Specific heat capacity	$L^2 T^{-2} K^{-1}$	Permeability		$M L Q^{-2}$
Specific latent heat	$L^2 T^{-2}$		or	$M L T^{-2} I^{-2}$
Thermal conductivity	$M L T^{-3} K^{-1}$	Permittivity		$M^{-1} L^{-3} T^2 Q^2$
Electric charge	Q or IT		or	$M^{-1} L^{-3} T^4 I^2$

THERMOMETRY

It is a science of measuring temperature, temperature is one of the most measured physical quantity for process thermal monitoring and control.

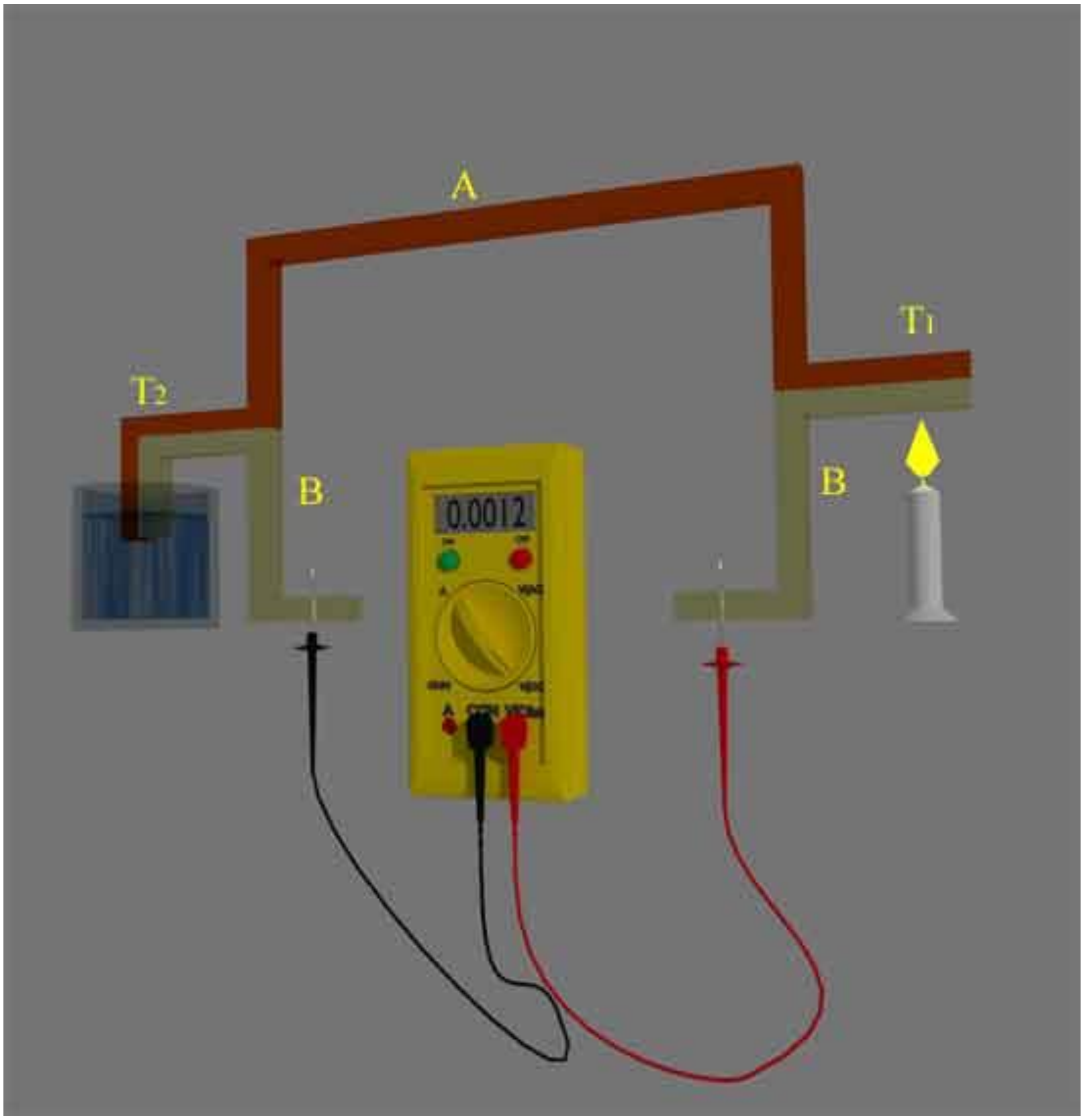
THERMOCOUPLE

It is a device or an instrument which measure temperature in thr form of an electric current.

THERMOELECTRIC EFFECT

The thermocouple is widely used temperature sensor in industry. Whenever two different types of metals are connected together, a thermoelectric potential (sometimes called thermoelectric EMF) is generated across the two free ends the metals according to the temperature of the joint. This is known as the thermoelectric effect.

In this fig.1, T_1 and T_2 are the temperatures which are presented in the junction points of metal A and B. T_1 is represented as hot junction and T_2 is represented as clod junction. So, the T_1 should be greater than the T_2. Now, $T_1 - T_2 = T$ This is nothing but the temperature difference of two temperatures. In thermocouple circuit, a thermoelectric potential is generated across the two free ends that is the function of junction temperature.



In thermocouple temperature sensor, the temperature of hot junction is measured in respect of cold junction . The thermoelectric potential is generated in thermocouple instrument is in range of μV. Hence, the voltmeter connected to measure the thermoelectric potential is extremely sensitive and the temperature can be read directly from this voltmeter, if it is calibrated properly in the scale of temperature.

Thermocouples are a very important class of device as they provide the most commonly used method of measuring temperatures in industry. The major reasons behind popularity of thermocouple temperature measurement are;

1. They are very strong and readings are uniform,
2. They can measure wide range of temperatures,
3. Their characteristics are almost linear with a accuracy of ± 0.05 %.

RESISTANCE THERMOMETREY

Resistance thermometers, also called resistance temperature detectors (RTDs), are sensors used to measure temperature. Many RTD elements consist of a length of fine wire wrapped around a ceramic or glass core but other constructions are also used. The RTD wire is a pure material, typically platinum, nickel, or copper. The material has an accurate resistance/temperature relationship which is used to provide an indication of temperature. As RTD elements are fragile, they are often housed in protective probes.

RTDs, which have higher accuracy and repeatability, are slowly replacing thermocouples in industrial applications below 600 °C.