UNITS

Units:

A unit can be defined as an internationally accepted standard for measuring quantities.

- Measurement has been included of a numeric quantity along with a specific unit.
- The units in the case of base quantities (such as length, mass etc.) are defined as Fundamental units.
- Derived units are the units that are the combination of fundamental units.
- Fundamental and Derived units constitute together as a System of Units.
- An internationally accepted system of units can be defined as Système Internationale d' Unites (This is how the International System of Units is represented in French) or SI. In 1971, it was produced and recommended by General Conference on Weights and Measures.
- The table shown below is the list of 7 base units mentioned by SI.

Fundamental Units

The fundamental units are the base units defined by International System of Units. These units are not derived from any other unit, therefore they are called fundamental 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. The seven base units are below in Table 2.1:

1. Meter (m) for Length
2. Second (s) for Time
3. Kilogram (kg) for Weight
4. Ampere (A) for Electric current
5. Kelvin (K) for temperature
6. Mole (mol) for Amount of substance
7. Candela (cd) for Luminous intensity

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)

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.

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.

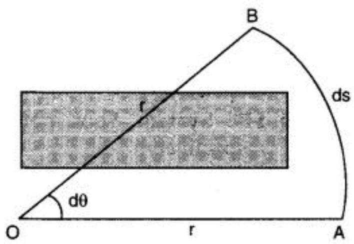
Quantity	Name	Symbol	Base Units
Area	square meter	A	m^2
Volume	cubic meter	V	m^3
Density	kilogram per cubic meter	ρ	kg/m^3
Speed	meters per second	v	m/s
Acceleration	meters per second squared	a	m/s^2
Pressure	pascal	Pa	$kg\ m^{-1}s^{-2}$
Force	newton	N	$kg\ m\ s^{-2}$
Energy	joule	J	$kg\ m^2\ s^{-2}$
Frequency	hertz	Hz	s^{-1}
Power	watt	W	$kg\ m^2\ s^{-3}$
Voltage	volt	V	$kg\ m^2\ s^{-3}A^{-1}$
Charge	coulomb	C	A s

Supplementary Units

Supplementary units are the dimensionless units that are used along with the base units to form derived units in the International system. Supplementary quantities are geometrical quantities of circle and sphere.
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,

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

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

Dimensional Units

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.

If Q is the unit of a derived quantity represented by Q = $M^aL^bT^c$, then $M^aL^bT^c$ is called dimensional formula and the exponents a, b and, c are called the dimensions.

1. **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.
2. **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.
3. **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

- If a given physical quantity has a dimensional formula $M^a L^b T^c$, then

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

Where M_1, L_1, T_1 and M_2, L_2, T_2 are the units of mass, length and time in two systems and n_1 and n_2, the numerical values of the physical quantity in these unit systems.

Scalars and Vectors

- **Scalars** are quantities that are fully described by a magnitude (or numerical value) alone.
  Scalar quantity is defined as the physical quantity with magnitude and no direction.

  Some physical quantities can be described just by their numerical value (with their respective units) without directions (they don't have any direction). The addition of these physical quantities follows the simple rules of the algebra. Here, only their magnitudes are added.

Examples of Scalar Quantities

There are plenty of scalar quantity examples, some of the common examples are:

- Mass
- Speed
- Distance
- Time
- Area
- Volume
- Density
- Temperature

- **Vectors** are quantities that are fully described by both a magnitude and a direction.
  A vector quantity is defined as the physical quantity that has both direction as well as magnitude.

  A vector with the value of magnitude equal to one and direction is called unit vector represented by a lowercase alphabet with a "hat" circumflex. That is "**û**".

Examples of Vector Quantities

Vector quantity examples are many, some of them are given below:

- Linear momentum
- Acceleration
- Displacement
- Momentum
- Angular velocity
- Force
- Electric field
- Polarization