

**Physical quantity**

All the quantities in terms of which basic laws of physics are expressed are known as physical quantities.

A physical quantity can be measured and expressed in its units.

Example: length, mass, time, work, power, energy etc.

**Classification of physical quantities**

On the basis of directional properties: **(a) Scalars**

**(b) Vectors**

On the basis of dependency properties: **(a) Fundamental quantities / Base quantities**

**(b) Derived quantities**

**Fundamental quantities:** The physical quantities which are independent of other quantities are known as fundamental quantities. In physics there are seven fundamental quantities.

- |                      |                        |                         |                               |
|----------------------|------------------------|-------------------------|-------------------------------|
| (1) Length           | (2) Mass               | (3) Time                | (4) Thermodynamic temperature |
| (5) Electric current | (6) Luminous intensity | (7) Amount of substance |                               |

**Derived quantities:** The physical quantities which depend on fundamental quantities are known as derived quantities. A derived quantity is expressed in terms of fundamental quantities.

Example: Force, momentum, work, speed, power etc.

**Supplementary quantities:** The quantities which are not a complete physical quantities but are helpful in derivation of some quantities are known as supplementary quantities.

Example: plane angle/angle, solid angle.

**Mode of study of physical quantities:** Physical quantities are studied in two respects.

**Qualitative study:** It is the study of basic properties of a physical quantity.

**Quantitative study:** It is the study of measurement of a physical quantity.

**Measurement:** The process of comparison of a physical quantity with a standard value of the quantity and the compared value both are known as measurement.

**Need of measurement:** For quantitative study of a physical quantity and experimental verification of laws of physics measurement is essential.

**Unit:** A standard value of a physical quantity in terms of which the quantity is compared is known as unit of the physical quantity.

Example: metre, kilogram, second, joule, ampere etc.

- A unit is defined by international committee of weights and measures.
- Its head quarter is in Sevres in France.

**Properties of unit**

- A unit should be well defined and available for comparing with other quantities.
- A unit must be invariable, means the value of a unit doesn't change by changing any parameters.
- The size of a unit is convenience in use.

**Rules for writing of units:**

- In full form a unit should be started with lower case letter.  
Ex: ampere, newton, joule, metre, kelvin etc.
- Symbol of a unit which is name after a scientist is upper case letter.  
Ex: N for newton, J for joule, A for ampere, K for kelvin etc.
- Symbol of a unit which not a name after a scientist is lower case letter.  
Ex: m for metre, ft for foot, s for second, mol for mole etc.
- Symbol of a unit should not be in plural form.  
Ex: 350 m not 350 ms, 20 kg not 20 kgs etc.

- In a compound unit there should be a gap between the unit of two different quantities.  
Ex: Speed  $v = 20 \text{ m s}^{-1}$ , momentum  $P = 12 \text{ kg m s}^{-1}$  etc.
- There should be no gap between a unit and prefix.

**System of units:** It is a set of fundamental units and derived units which is used in measurement.

Different system of units are:

- (1) **FPS system/ British system:** In this system unit of length is **foot (ft)**, unit of mass is **pound (lb)** and unit of time is **second (s)**.
- (2) **FPS engineering system:** In this system unit of length is **foot (ft)**, unit of weight is **poundal (pdl)** and unit of time is **second (s)**.
- (3) **CGS system/ Gaussian system:** In this system unit of length is **centimetre (cm)**, unit of mass is **gram (g)** and unit of time is **second (s)**.
- (4) **MKS system:** In this system unit of length is **metre (m)**, unit of mass is **kilogram (kg)** and unit of time is **second (s)**.
- (5) **SI system/ International system of units:** In this system units of seven fundamental quantities and two supplementary quantities are given.

Fundamental quantity	SI unit
Length	metre (m)
Mass	kilogram (kg)
Time	second (s)
Thermodynamic temperature	kelvin (K)
Electric current	ampere (A)
Luminous intensity	candela (cd)
Amount of substance	mole (mol)

Supplementary quantity	SI unit
Plane angle	radian (rad)
Solid angle	steradian (sr)

### Properties of SI systems:

- SI system is a rational system. SI unit of all form of a physical quantity are same, where practical unit of different form of a quantity are different.
- SI system is a coherent system. A derived SI unit is the product of base SI unit and supplementary SI unit.
- SI system is a metric system. Multiple and submultiple units are making by using prefixes in power of 10.

### Classification of units:

(1) **Fundamental units/ Base units:** The units of a fundamental quantities are known as fundamental units/ base units.

Example: metre, foot, mile, kilogram, ampere, kelvin etc.

- According to modern principle fundamental units are not independent of each other.

(2) **Derived unit:** A unit of a derived quantity is known as derived unit.

Example: joule, newton, volt, coulomb, tesla etc.

(3) **Supplementary unit:** A unit of a supplementary quantity is known as supplementary unit.

Example: radian (rad), steradian (sr)

(4) **Practical units:** The units which are used in practice for convenience are known as practical units.

Example: light year (ly), horse power (hp), mile, electron volt (eV), calorie (cal), kilo watt hour (kWh)

- A practical unit may be fundamental or may be derived.
- A practical unit may belong to a particular system or may not.

(5) **Improper units:** The units which are not of the same nature as that of the physical quantities for which they are used are called improper units.

Ex: **kilogram weight (kg-wt)** is a unit of force but it seems to a unit of mass, **parallactic second** is a unit of length but it seems to a unit of time.

**Definition of SI base units:**

**metre (m):** It is a SI unit of length. According to most precise definition one metre is equal to the length of the distance travelled by light in vacuum in  $\frac{1}{299792458}$  second. (1983)

→ One metre is also equal to 1650763.73 wavelengths of the light emitted by krypton kr- 86.

**kilogram (kg):** it is SI unit of mass. One kilogram is assumed as the mass of a cylindrical rod of platinum- iridium of length and diameter both 3.9 cm kept at international bureau of weights and measures. (1889)

**second (s):** It is SI unit of time. One second is the duration of 9,192,631,770 periods of the radiation corresponds to the transition between the two hyperfine levels of the ground state of the cesium -133 atoms. (1967)

**kelvin (K):** It is SI unit of thermodynamic temperature. One kelvin is the fraction (1/273.16) of the thermodynamic temperature of the triple point of water. (1967)

**ampere (A):** It is SI unit of electric current. One ampere is equal to that value of electric current which if maintained in two straight parallel conductive wires of infinite length of negligible circular cross-section and placed 1 metre apart in vacuum, would produce between the conductors a force equal to  $2 \times 10^{-7}$  newton per metre of length. (1948)

**candela (cd):** It is SI unit of luminous intensity. One candela is the luminous intensity in a given direction of a source that emits monochromatic radiation of frequency  $540 \times 10^{12}$  hertz and that has a radiant intensity in that direction of 1/683 watt per steradian. (1979)

Or

One candela is the luminous intensity of a black body through a surface area of  $1/100000 \text{ m}^2$  in perpendicular direction at normal pressure  $101325 \text{ N / m}^2$  and temperature freezing point of platinum.

**mole (mol):** It is SI unit of amount of substance. One mole is the amount of substance of a system, which contains as many elementary entities as there are atoms in 0.012 kg of carbon -12. (1971)

**Supplementary SI units:**

**radian (rad):** It is SI unit of plane angle. One radian is equal to a plane angle subtended by a circular arc at its centre which length is equal to radius.

**steradian (sr):** It is SI unit of solid angle. One steradian is equal to a solid angle subtended by a spherical surface at its centre which area is equal to square of its radius.

**Important Prefixes:**

Factor	Prefix	Symbol	Factor	Prefix	Symbol
$10^{24}$	Yetta	Y	$10^{-24}$	Yocto	y
$10^{21}$	Zetta	Z	$10^{-21}$	zepto	z
$10^{18}$	Exa	E	$10^{-18}$	Atto	a
$10^{15}$	Peta	P	$10^{-15}$	femto	f
$10^{12}$	Tera	T	$10^{-12}$	pico	p
$10^9$	Giga	G	$10^{-9}$	nano	n
$10^6$	Mega	M	$10^{-6}$	micro	$\mu$
$10^3$	Kilo	k	$10^{-3}$	milli	m
$10^2$	Hecto	h	$10^{-2}$	centi	c
<b>10</b>	Deca	da	$10^{-1}$	deci	d

**Some Important Practical Units and conversion Factors****Length:**

1 fermi (f) =  $10^{-15}$  m = 1 fm, it is used to measure radius of nucleus.

1 X-ray unit (XU) =  $10^{-13}$  m

1 angstrom (Å) =  $10^{-10}$  m, it is used to measure wavelength

1 bohr radius = 0.529 (Å)

1 micron =  $10^{-6}$  m = 1 micrometer ( $\mu\text{m}$ )

1 inch (1'') = 2.54 cm

1 foot (1') = 12 inches = 30.48 cm = 0.3048 m

1 yard = 3 feet = 91.44 cm

1 mile = 1760 yards = 1608 m  $\approx$  1.6 km

1 nautical mile = 1852 m = 6080 ft

1 astronomical unit (AU) =  $1.496 \times 10^{11}$  m

1 light year (ly) =  $9.46 \times 10^{15}$  m

1 parallaxic second (parsec) = 3.26 ly =  $3.08 \times 10^{16}$  m

- one astronomical unit (AU) is the average distance between the Earth and the Sun.
- one light year is the length of distance travelled by light in vacuum in one year.
- one parallaxic second (parsec) is the distance at which 1 AU subtends an angle of one second of arc.

**Mass**

1 atomic mass unit (amu or u) =  $1.66 \times 10^{-27}$  kg

1 carat = 200 mg

1 ounce = 28.35 g

1 slug = 14.59 kg.

1 pound (lb) = 0.4536 kg

1 quintal = 100 kg

1 tonne (or metric ton) = 10 quintal =  $10^3$  kg

1 chandrashekhar limit = 1 CSL = 1.4 times of the mass of the Sun =  $2.8 \times 10^{30}$  kg

**Time**

1 mean solar day = 24 hours = it is the time taken by the Earth to complete one rotation about its axis.

1 sidereal month = 27.3 days = it is the time taken by the Moon to return to a given position as seen from a fixed star

1 mean solar year = 365.24 average solar days = it is the time taken by the Earth to complete one revolution around the Sun.

1 shake =  $10^{-8}$  s, used in microscopic physics.

- 1 year = 365.24 days =  $3.156 \times 10^7$  s
- 1 day = 86400 s = 1440 min

**Area**

1 acre = 4840 square yards = 43,560 ft<sup>2</sup>

1 square mile = 640 acres

1 are = 100 m<sup>2</sup>

1 hectare = 100 ares =  $10^4$  m<sup>2</sup>

1 barn =  $10^{-28}$  m<sup>2</sup>

**volume**

1 litre (l) =  $10^3$  cm<sup>3</sup> =  $10^3$  cc =  $10^{-3}$  m<sup>3</sup>

1 U.S. fluid gallon = 231 inch<sup>3</sup> = 3.788 litres

1 British gallon = 1.201 US fluid gallons = 4.549 litres

- one litre is equal to the volume of a cube of side 10 cm.

**Density:**

$1 \text{ kg m}^{-3} = 10^{-3} \text{ g cm}^{-3} = 10^{-3} \text{ kg L}^{-1}$

**Speed:**

$1 \text{ km h}^{-1} = 5 / 18 \text{ m s}^{-1} = 0.2778 \text{ m s}^{-1} = 0.6215 \text{ mi h}^{-1}$

$1 \text{ m s}^{-1} = 18/5 \text{ km h}^{-1} = 3.6 \text{ km h}^{-1} = 2.24 \text{ mi h}^{-1}$

$1 \text{ mi h}^{-1} = 0.4470 \text{ m s}^{-1} = 1.609 \text{ km h}^{-1} = 1.467 \text{ ft s}^{-1}$

**Force**

SI unit = newton (N) =  $\text{kg m s}^{-2}$

CGS unit = dyne =  $\text{g cm s}^{-2}$

FPS unit = poundal =  $\text{lb ft s}^{-2}$

1 newton (N) =  $10^5$  dynes  $\Rightarrow$  1 dyne =  $10^{-5}$  N

1 poundal (pdl) =  $1 \text{ lb-ft s}^{-2} = 0.1383 \text{ N}$

1 kilogram-force (kg f) = 1 kilogram-weight (kg wt) = 9.8 N

1 gram-force = 1 gram-weight (g wt) = 981 dynes =  $9.8 \times 10^{-3}$  N

1 pound force = 32.16 poundals = 4.448 N

**Pressure**

SI unit = pascal (Pa) =  $\text{N m}^{-2}$

CGS unit = dyne  $\text{cm}^{-2}$

1 pascal (Pa) =  $1 \text{ N m}^{-2} = 10 \text{ dynes cm}^{-2}$  SI unit

1 bar = 76 cm of Hg =  $1.01325 \times 10^5$  Pa, it is normal atmospheric pressure

1 torr = 1mm of Hg = 133.3 Pa

1 bar = 760 torr

**Work and Energy**

SI unit = joule (J)

CGS unit = erg

FPS unit = poundal-foot

1 joule =  $10^7$  ergs

1 kg f - m = 9.8 J

1 pound force - ft = 32.16 poundals-ft

1 watt-hour (W h) =  $3.6 \times 10^3$  J

1 horsepower-hour = 746 watt-hours

1 calorie = 4.186 J =  $4.186 \times 10^7$  ergs

1 kilo watt-hour (Kw-h) =  $3.6 \times 10^6$  J

1 electron volt (eV) =  $1.6 \times 10^{-19}$  J

Practical unit of different form of energy are different

Heat energy - calorie (cal)

Electric energy - kilo watt-hour (kW-h)

Light energy - electron-volt (eV)

**Power**

SI unit = watt (W) =  $\text{N m s}^{-1} = \text{J s}^{-1}$

CGS unit = dyne  $\text{cm s}^{-1} = \text{erg s}^{-1}$

FPS unit = poundal  $\text{ft s}^{-1}$

1 watt (W) =  $10^7$  erg  $\text{s}^{-1}$

1 horsepower (hp) = 550 pound force-ft  $\text{s}^{-1} = 550 \times 32.16$  poundal  $\text{ft s}^{-1} = 746 \text{ W}$

**Plane Angle**

SI unit = radian (rad)

1 rad =  $180^\circ / \pi = 57.3^\circ$

1 degree =  $\frac{\pi}{180}$  rad =  $1.745 \times 10^{-2}$  rad = 60 minutes = 60'

1 minute =  $1^\circ/60 = 2.9 \times 10^{-4}$  rad

1 second =  $1'/60 = 4.85 \times 10^{-6}$  rad

1 revolution =  $360^\circ = 2 \pi$  rad = 6.283 rad

**Solid Angle**

At centre of sphere =  $4 \pi$  steradians = 12.57 sr

**Electric charge**

SI unit = coulomb (C)

CGS unit = stat coulomb = franklin

Electrostatic unit (esu) = stat coulomb = franklin

Electromagnetic unit = ab coulomb

1 stat coulomb =  $\frac{1}{3 \times 10^9}$  C

1 ab coulomb = 10 C

1 ampere hour (A h) = 3600 C

1 faraday = 96485 C  $\cong$  96500 C

**Electric Potential**

SI unit = volt (V)                      CGS unit = stat volt

$$1 \text{ volt} = 1 \text{ J C}^{-1}$$

$$1 \text{ stat - V} = 300 \text{ V}$$

$$1 \text{ V} = 10^8 \text{ ab - V}$$

**Electric Current**

SI unit = ampere (A)

CGS unit = ab ampere = biot (Bi), it is also electromagnetic

Electrostatic unit = stat ampere

$$1 \text{ ampere (A)} = 1 \text{ C s}^{-1}$$

$$1 \text{ ab ampere} = 1 \text{ biot} = 10 \text{ A}$$

$$1 \text{ stat ampere} = \frac{1}{3 \times 10^9} \text{ A}$$

**Resistance**

SI unit = ohm ( $\Omega$ ) =  $\text{V A}^{-1}$

CGS unit = ab ohm, it is also electromagnetic unit

Electrostatic unit = stat ohm

$$1 \text{ stat - } \Omega = 9 \times 10^{11} \Omega$$

$$1 \text{ ab - } \Omega = 10^{-9} \Omega$$

**Capacitance**

SI unit = farad (F)

CGS unit = stat farad, it is also electrostatic unit

Electromagnetic unit = ab farad

$$1 \text{ stat - F} = \frac{1}{9 \times 10^{11}} \text{ F}$$

$$1 \text{ ab - F} = 10^9 \text{ F}$$

**Inductance**

SI unit = henry (H)

CGS unit = electromagnetic unit = ab - H

Electrostatic unit = stat - H

$$1 \text{ ab - H} = 10^{-9} \text{ H}$$

$$1 \text{ stat - H} = \frac{1}{9 \times 10^{11}} \text{ H}$$

**Magnetic flux**

SI unit = weber (Wb) = tesla  $\text{m}^2$

CGS unit = maxwell (Mx) = gauss  $\text{cm}^2$

$$1 \text{ Wb} = 10^8 \text{ Mx (maxwell)}$$

**Magnetic Induction / magnetic field**

SI unit = tesla (T)                      CGS unit = gauss (G)

$$1 \text{ T (tesla)} = 10^4 \text{ G (gauss)}$$

**Magnetising field of magnetic intensity (H - vector)**

SI unit =  $\text{A s}^{-1}$                       CGS unit = oersted (Oe)

$$1 \text{ A m}^{-1} = 4 \pi \times 10^{-3} \text{ Oe (oersted)}$$

$$1 \text{ Oe} = 79.58 \text{ A m}^{-1}$$

**Radioactivity**

1 becquerel (Bq) = 1 disintegration per second (SI unit)

1 curie (Ci) =  $3.7 \times 10^{10}$  disintegration per second

1 rutherford (Rd) =  $10^6$  disintegration per second