UNITS AND MEASUREMENTS

CHAPTER CHECKLIST

- Physical Quantities
- Physical Unit
- Significant Figures and Rounding off
- Dimensional Formulae and Dimensional Equations

System of Units

In order to define units for all fundamental quantities or base quantities, we use the term fundamental units or base units and then to define units for all other quantities as products of powers of the base units that we call derived units. Hence, a complete set of these units, i.e. both the base units and derived units, is known as the system of units.

PHYSICAL QUANTITIES

All those quantities which can be measured directly or indirectly and in terms of which the laws of physics can be expressed are called physical quantities.

Physical quantities can be further divided into two types:

(i) Fundamental Quantities

Those physical quantities which are independent of other physical quantities and are not defined in terms of other physical quantities, are called fundamental quantities or base quantities.

e.g. Mass, length, time, temperature, luminous intensity, electric current and the amount of substance, etc.

(ii) Derived Quantities

Those quantities which can be derived from the fundamental quantities are called derived quantities. e.g. Velocity, acceleration and linear momentum, etc.

MEASUREMENT OF PHYSICAL QUANTITIES

Hence, to express the measurement of a physical quantity, we need to know two things

(i) The unit in which the quantity is measured.

(ii) The numerical value or the magnitude of the quantity(n), i.e. the number of times that unit (u) is contained in the given physical quantity.

or

$$\boxed{Q = nu}$$

Numerical Value Inversely Proportional to the Size of Unit

The numerical value (n) is inversely proportional to the size (u) of the unit.

$$n \propto \frac{1}{u} \Rightarrow nu = \text{constant}.$$

We may write as

$Q = n, u_1 = nu_2$

PHYSICAL UNIT

The standard amount of a physical quantity chosen to measure the physical quantity of the same kind is called a physical unit.

The essential requirements of physical unit are given as below:

(i) It should be of suitable size.

(ii) It should be easily accessible.

(iii) It should not vary with time.

(iv) It should be easily reproducible.

(v) It should not depend on physical conditions like pressure, volume, temperature, etc.

THE INTERNATIONAL SYSTEM OF UNITS

A system of units is the complete set of units, both fundamental and derived for all kinds of physical quantities.

The common systems of units used in mechanics are given below

(i) **FPS System** It is the British engineering system of units, which uses foot as the unit of length, pound as the unit of mass and second as the unit of time.

(ii) **CGS System** It is based on Gaussian system of units, which uses centimetre, gram and second for length, mass and time, respectively.

(iii) **MKS System** It uses metre, kilogram and second as the fundamental units of length, mass and time, respectively.

(iv) **International System of Units** (SI Units) The system of units, which is accepted internationally for measurement is the System Internationaled' Units (French for International System of Units) abbreviated as SI.

SI base quantities and units

Length (Metre) --- One metre is the length of the path travelled by light. in vacuum during a timeinterval of 1/299,792 458 of a second. (1983)

Mass (Kilogram)----One 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) ---One second is the duration of 9,192.631,770 periods of the radiation correspondingTimeSecondto the transition between the two hyperfine levels of the ground state of thecesium-133 atom: (1967)

Electric current (Ampere)---One ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 m apart in vacuum, would produce a force between these conductors equal to 2x 10 N/m of length. (1948)

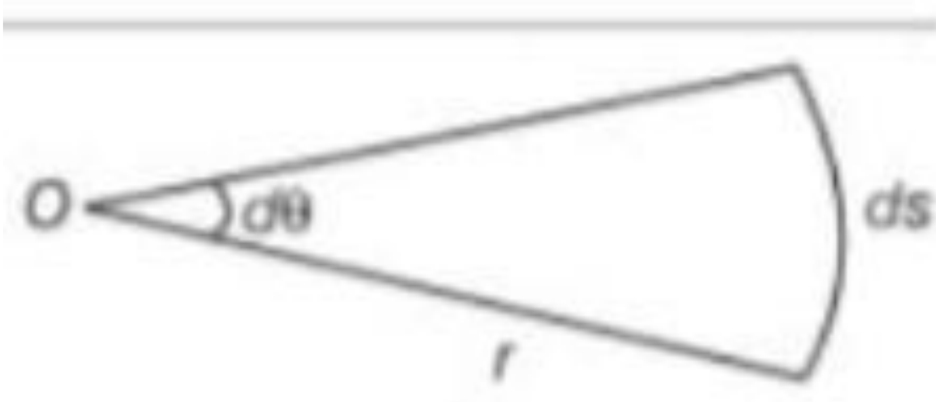
Thermodynamic temperature (Kelvin)----One kelvin is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. (1967)

Amount of substance(mole)--One mole is the amount of substance of a system which contains as manyelementary entities as there are atoms in 0.012 kg of carbon-12. (1971)

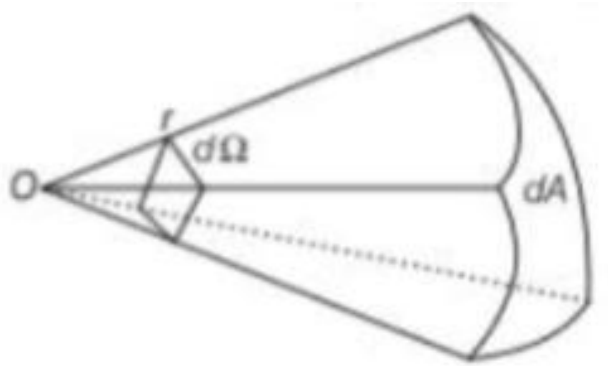
Luminous intensity (candela)--One candela is the luminous intensity in a given direction of a source that emits monochromatic radiation of frequency 540 x 10 Hz and that has a radiant intensity in that direction of 1/683 watt per steradian (1979)

Supplementaryquantity

Plane angle(Radian)--One radian is the angle subtended at the centre of a circle by an arc equal in length to the radius of the circle.



Solid angle(Steradian)--One steradian is the solid angle subtended at thecentre of a sphere, by that surface of the sphere.which is equal in area, to the square of radius of the sphere.



EXAMPLE |1| Conversion of Units

Calculate the angle of

(i) $1°$ (degree)

(ii) $1''$ (second of arc or arc sec) in radian. [NCERT]

Sol. (i) $1° = \dfrac{2\pi}{360}\text{ rad} = \dfrac{\pi}{180} = \dfrac{22}{7\times 180}$

$$= 1.746\times 10^{-2}\text{ rad}$$

(ii) $1\text{ arc sec} = 1'' = \dfrac{1'}{60} = \dfrac{1°}{60\times 60}$

$$= \frac{1}{60\times 60}\times\frac{\pi}{180}\text{ rad}$$

$$= 4.85\times 10^{-6}\text{ rad}$$

Rules for Writing SI Units

- Small letters are used for symbols of units.
- Symbols are not followed by a full stop.
- The initial letter of a symbol is capital only when the unit is named after a scientist.
- The full name of a unit always begins with a small letter even if it has been named after a scientist.
- Symbols do not take plural form.

ADVANTAGES OF SI OVER OTHER SYSTEMS OF UNITS

(i) **SI is a coherent system of units** All derived units can be obtained by simple multiplication or division of fundamental units without introducing any numerical factor.

(ii) **SI is a rational system of units** It uses only one unit for a given physical quantity. e.g, all forms of energy are measured in joule. On the other hand, in MKS system, the mechanical energy is measured in joule, heat energy in calorie and electrical energy in watt hour.

(iii) **SI is a metric system** The multiples and submultiples of SI units can be expressed as powers of 10.

$$\text{i.e. } a \times 10^{\pm b}.$$

(iv) **SI is an absolute system of units** It does not use gravitational units. The use of '*g*' is not required.

Some General Units (Outside from SI)

Name	Symbol	Value in SI Unit
Minute	min	60 s
Hour	h	60 min = 3600 s
Day	d	24 h = 86400 s
Year	y	365.25 d = 3.156×10^7 s
Degree	°	$1° = (\pi/180)$ rad
Litre	L	$1\ dm^3 = 10^{-3}\ m^3$

SOME IMPORTANT PRACTICAL UNITS

For Length/Distance

(i) **Astronomical Unit** It is the mean distance of the earth from the sun. 1 AU $= 1.496 \times 10^{11}$ m.

(ii) **Light year** It is the distance travelled by light in vacuum in one year. 1 ly $= 9.46 \times 10^{15}$ m

(iii) **Parallactic second** It is the distance at which an arc of length 1 astronomical unit subtends an angle of 1 second of arc. 1 parsec $= 3.084 \times 10^{16}$ m $= 3.26$ ly

(iv) **Micron or micrometer,** $1\ \mu m = 10^{-6}$ m

(v) **Nanometer,** $1\ nm = 10^{-9}$ m

(vi) **Angstrom unit,** $1\ \text{Å} = 10^{-10}$ m

(vii) **Fermi** This unit is used for measuring nuclear sizes $1\ Fm = 10^{-15}$ m

EXAMPLE |2| Length Conversion

How many parsec are there in one metre?

Sol. Given, 1 parsec $= 3.084 \times 10^{16}$ m

EXAMPLE |3| Relation between different unit of length

Deduce relations between astronomical unit, light year and parsec. Arrange them in decreasing order of their magnitudes.

7. The damping force on an oscillator is directly proportional to the velocity. The unit of the constant of proportionality is

(a) kg ms^{-1} (b) kg ms^{-2} (c) kg s^{-1} (d) kg s

9. Number of degrees present in one radian is

(a) 58° (b) 57.3° (c) 56.3° (d) 56°

28. The radius of atom is of the order of 2 Å and radius of a nucleus is of the order of fermi. How many magnitudes higher is the volume of atom as compared to the volume of nucleus?

29. The unit of length convenient on the atomic scale is known as an angstrom and is denoted by Å.

$1\ \text{Å} = 10^{-10}$ m. The size of the hydrogen atom is about 0.5 Å. What is the total atomic volume in m^3 of a mole of hydrogen atoms? [NCERT]

Sol. Radius of a hydrogen atom $(r) = 0.5\ \text{Å} = 0.5 \times 10^{-10}$ m

Volume of each hydrogen atom $(V) = \frac{4}{3}\pi r^3$

$$= \frac{4}{3} \times 3.14 \times (0.5 \times 10^{-10})^3$$

$$= 5.234 \times 10^{-31}\ \text{m}^3$$

Number of atoms in 1 mole of hydrogen

$$= \text{Avogadro's number } (N)$$

$$= 6.023 \times 10^{23}$$

$\therefore$ Atomic volume of 1 mole of hydrogen atoms (V')

$$= \text{Volume of a hydrogen atom} \times \text{Number of atoms}$$

$$V' = V \times N$$

$$= 5.236 \times 10^{-31} \times 6.023 \times 10^{23}\ \text{m}^3$$

$$= 3.152 \times 10^{-7}\ \text{m}$$

30. Why has second been defined in terms of periods of radiations from cesium-133?