# UNITS AND DIMENSIONS

**Physical Quantity:** A quantity that can be measurable is called Physical quantity.
Ex; mass, length, time, temperature, electric current, force, velocity, density……..
The physical quantities are two types:

1. Fundamental quantities
2. Derived quantities

**Fundamental quantities:** Fundamental quantities are those which do not depend on other quantities.
Ex: length, mass, time, temperature …

**Derived quantities**: Derived quantities are those which depend and derived from other quantities.
Ex: velocity, work, force …

**Unit:** The standard measurement of physical quantity is called it's unit.

**Characteristics of unit :**
Following are the important characteristics of standard unit:
(i) It should be easily understandable.
(ii).It should be changed with change in physical factors.
(iii) It should not change with place or time.
(iv) It should be easily reproduced.
(vi) It should be well defined.

**Fundamental unit**: The unit of fundamental physical quantity is called fundamental unit.
Ex: m, kg, s, K…….

**Derived unit:** The unit of derived physical quantity is called derived unit.
Ex: m/s, m/$s^2$, N, J…

**SYSTEM OF UNITS:**

| System | Length | Mass | Time |
|---|---|---|---|
| F.P.S. | Foot | Pound | Second |
| C.G.S. | Centimetre | Gram | Second |
| M.K.S. | Metre | Kilogram | second |

In all these three systems only three physical quantities mass, length and time are considered to be fundamental quantities.

**SI system:**
The international system that is used to measure physical quantities is called SYSTEM OF UNITS (SI System).
In SI systems there are 3 types of units

1. **Base Units**
2. **Supplementary Units**
3. **Derived Units**

**Base Units:** Seven physical quantities are identified as base physical quantities. The units of these quantities are called base units.

| S.No. | Base Quantities | Unit | Symbol |
|---|---|---|---|
| 1. | Length | metre | m |
| 2. | Mass | kilogram | Kg |
| 3. | Time | second | s |
| 4. | Thermodynamic temperature | Kelvin | K |
| 5. | Electric Current | ampere | A |

| | | | |
|---|---|---|---|
| 6. | Luminous Intensity | candela | Cd |
| 7. | Amount of substance | mole | mol |

**Supplementary Units:** Two physical quantities are identified as supplementary physical quantities. The units of these quantities are called supplementary units

| S.No | Supplementary Quantity | Unit | Symbol |
|---|---|---|---|
| 1. | Plane angle | Radian | rad |
| 2. | Solid angle | Steradian | sr |

**Derived units:** The physical quantities other than base and Supplementary are called derived physical quantities. The units of these quantities are called derived units.

| S.No. | Derived units | Formula | Unit |
|---|---|---|---|
| 1. | Area | l x b | $m^2$ |
| 2. | Volume | l x b x h | $m^3$ |
| 3. | Density | Mass/volume | $Kg/m^3$ |
| 4. | Speed, Velocity | Distance/time | m/s |
| 5. | Acceleration | Velocity/time | $m/s^2$ |
| 6. | Momentum | Mass x volume | $kgm^3$ |
| 7. | Force | Mass x acceleration | newton |
| 8. | Pressure | Force/area | pascal |

**Multiples and Submultiples in SI system:**
In SI system there are multiples and submultiples to express very large and very small values in short form.

| Multiples of SI units | | | | Submultiples of SI units | | |
|---|---|---|---|---|---|---|
| **S.No.** | **Multiplier** | **Prefix** | **Symbol** | **Multiplier** | **Prefix** | **Symbol** |
| 1. | $10^{-1}$ | deci | d | $10^{1}$ | deca | da |
| 2. | $10^{-2}$ | centi | c | $10^{2}$ | hector | h |
| 3. | $10^{-3}$ | milli | m | $10^{3}$ | kilo | K |
| 4. | $10^{-6}$ | micro | $\mu$ | $10^{6}$ | mega | M |
| 5. | $10^{-9}$ | nano | n | $10^{9}$ | giga | G |
| 6. | $10^{-12}$ | pico | p | $10^{12}$ | tera | T |
| 7. | $10^{-15}$ | femto | f | $10^{15}$ | peta | P |
| 8. | $10^{-18}$ | atto | a | $10^{18}$ | exa | E |
| 9. | $10^{-21}$ | zepto | z | $10^{21}$ | zetta | Z |
| 10. | $10^{-24}$ | yocto | y | $10^{24}$ | yotta | Y |

**Rules of writing SI Units:**

1.Full names of the units, even when they are named after a scientist should not be written with a capita letter.

| Correct | Wrong |
|---|---|
| newton | Newton |
| metre | Metre |
| second | Second |

2.The symbols of the units named after a scientist should be a capital letter and the symbols of other units should be small letter.

| Unit | Correct | Wrong |
|---|---|---|
| newton | N | n |
| metre | m | M |

3.Unit should be written either in full or in agreed symbols only.

| Unit | Correct | Wrong |
|---|---|---|
| ampere | A | amp |
| second | s | sec |

4.Units do not take plural form.

| Correct | Wrong |
|---|---|
| 10 kg | 10 kgs |
| 20 W | 20 Ws |
| 2 A | 2 As |

5.No full stop or punctuation mark should be used within or at the end of symbols for units.

| Correct | Wrong |
|---|---|
| 10 W | 10 W. |
| 20 kg | 20 kg; |
| 2 A | 2 A, |

6.A small gap should be left between the numerical and symbol of the unit.

| Correct | Wrong |
|---|---|
| 10 m | 10m |
| 20 kg | 20kg |

7.No gap should be left between the prefix and the symbol of the unit.

| Correct | Wrong |
|---|---|
| 10 mm | 10 m m |
| 20 µs | 20 µ s |

**Advantages of SI units:**

- **It is a coherent system of units.** Because all derived units can be obtained by simple multiplication or division of fundamental units.
- **It is a comprehensive system of units.** Because it covers all branches of science and engineering.
- **All the countries are followed SI system.**
- **S.I. is a rational system of units.** Because it assigns only one unit to a particular physical quantity
  Ex: Joule is the S.I. unit for all types of energies while MKS units of mechanical energy, heat energy and electrical energy are Joule, calorie and watt hour respectively.
- **It is an absolute system of units.** There are no gravitational units on the system. The use of factor 'g' is thus eliminated.
- **It is a metric system of units**. Because the multiples and submultiples are expressed as powers of 10.

# DIMENSIONS

**Dimensions:** Dimensions of a physical quantity are the powers to which the fundamental units are raised to obtain one unit of that quantity.

**Dimensional Formula:** The formula which represents the relation between fundamental quantities and derived quantity is called dimensional formula.

If Q is the unit of a derived quantity represented by Q = $M^a L^b T^c$

Here $M^a L^b T^c$ is called dimensional formula and the exponents a,b and c are called the dimensions.

**Derivation for dimensional formulae of different physical quantities:**

| S.No. | Physical Quantity | Formula | Dimensional Formula | SI Unit |
|---|---|---|---|---|
| 1. | Area | Length x breadth | $L^2$ | $m^2$ |
| 2. | Volume | Length x breadth x height | $L^3$ | $m^3$ |
| 3. | Density | mass / volume | $ML^{-3}T^0$ | $\frac{kg}{m^3}$ |
| 4. | a)Energy density<br>b)Pressure<br>c)Stress,<br>d)Modulus of elasticity | $Energy/volume$<br>$Force/Area$<br>$Stress/Strain$ | $ML^{-1}T^{-2}$ | $\frac{kg}{m^3}$ |
| 5. | a)Velocity<br>b)Speed | Displacement / time<br>Distance / time | $M^0L^1T^{-2}$ | m / s |
| 6. | Acceleration | Velocity / time | $LT^{-2}$ | m / $s^2$ |
| 7. | Force | Mass x acceleration | $MLT^{-2}$ | Kgm/$s^2$(or ) newton |
| 8. | a)Linear momentum<br>b) Impulse | Mass x Velocity<br>Force x Time | $ML^1T^{-1}$ | Kg m/s(or) N-s |
| 9. | a)Moment of force (or) Torque<br>b)Work<br>c)Energy | Force x displacement | $M^2L^2T^{-2}$ | Nm<br>joule<br>joule |
| 10. | Power | Work / time | $ML^2T^{-3}$ | watt |
| 11. | Angle or angular displacement | Arc / radius | $M^0L^0T^0$ | rad |

| | | | | |
|---|---|---|---|---|
| 12. | a)Angular velocity<br>b)Velocity gradient<br>c)Frequency | $\omega = \frac{\theta}{t}$<br>$\frac{dv}{dx}$<br>$\frac{1}{timeperiod}$ | $M^0L^0T^{-1}$ | rad / s<br>$s^{-1}$<br>Hz |
| 13. | Gravitational constant(G) | $\frac{force \times (distance^2)}{mass^2}$ | $M^{-1}L^3T^{-2}$ | $Nm^2\,kg^{-2}$ |
| 14. | Surface tension | $\frac{F}{l}$ | $ML^0T^{-2}$ | $N/$m |
| 15. | Coefficient of viscosity(η) | $\frac{F}{A\frac{dv}{dx}}$ = pressure x time | $ML^{-1}T^{-1}$ | Pa - s |
| 16. | a)Thermal Capacity<br>b)Boltzman's Constant | $\frac{Heat}{Temperature}$<br>PV/ NT | $ML^2T^{-2}K^{-1}$ | $J\,K^{-1}$ |
| 17. | a)Specific heat<br>b)Specific gas constant | $\frac{Q}{m\Delta\theta}$<br>$r = \frac{PV}{mT}$ | $L^2T^{-2}K^{-1}$ | $Jkg^{-1}K^{-1}$ |
| 18. | a)Universal gas constant<br>b)Molar specific heat | $R = \frac{PV}{nT}$<br>$C_p - C_v = R$ | $ML^2T^{-2}K^{-1}mol^{-1}$ | $Jmol^{-1}\,K^{-1}$ |
| 19. | Magnetic Pole Strength | m = I x L | IL | Am |
| 20. | Magnetic moment | M = 2l x m | $IL^2$ | $Am^2$ |
| 21. | Magnetic Induction | B = $\frac{F}{m}$ | $MT^{-2}I^{-1}$ | Tesla |
| 22. | Electric Current | I | I | Ampere |
| 23. | Electric Charge | Q = it | IT | Coulomb |
| 24. | Electric Potential | V = Power / Current | $ML^2T^{-3}I^{-1}$ | volt |
| 25. | Electric Resistance | R = $\frac{V}{I}$ | $ML^2T^{-3}I^{-2}$ | ohm |

**Principle of Homogeneity of Dimensions:**

It states that an equation is dimensionally correct if the dimensions of the various terms on both sides of the equation are same.

This principle is based on the fact that two quantities of the same dimension only can be added up, and the resulting quantity also possesses the same dimension.

i.e. In equation X + Y = Z is valid if the dimensions of X, Y and Z are same.

**Dimensionless quantities:**

Dimensionless quantities are those which do not have dimensions but have a fixed value.

a)Dimensionless quantities without units. Ex: Pure numbers, π e, sinθ, cosθ tanθ …. etc.,

b) Dimensionless quantities with units.
Ex : Angular displacement – radian, Joule's constant - joule/calorie

**Dimensional Constants:**

The physical quantities which have dimensions and have a fixed value are called dimensional constants.
Ex: Gravitational constant (G), Planck's constant (h), Universal gas constant (R), Velocity of light in vacuum (C) etc.

**APPLICATIONS OF DIMENSIONAL ANALYSIS:**

The applications of dimensional analysis are

1. To convert a physical quantity from one system of units to another.
2. To check the dimensional correctness of a given equation.
3. Establish a relationship between different physical quantities in an equation.

**Limitations of Dimensional Analysis:**

Limitations of Dimensional Analysis are

1. It cannot determine value of dimensionless constants and numbers
2. We cannot use this method to equations involving exponential, logarithmic and trigonometric functions
3. It cannot be applied to an equation involving more than three physical quantities.
4. It is a too not a solution i.e. It can check only if the equation is dimensionally correct or not. But cannot say the equation is absolutely correct.
5. Physical quantity is a sum of two terms dimensional analysis cannot be applied.