Measurement and Units, Doc. Version 1.0

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Measurement and Units

There are two types of units, they are

i) Fundamental unit
ii) Derived unit

The substance which has a numeric value and unit is called physical quantity. Fundamental units contains below physical quantity and units.

Physical Quantity	Units
Mass	Kg (Kilogram)
Length	M (Meter)
Time	S (Second)
Temperature	K (Kelvin)
Amount of Substance	Mole
Luminous Intensity	Cd (Candela)
Electric Current	A (Ampere)

All the derived units are derived from above fundamental units.

Dimension:

The dimension of a physical quantity is defined as the power to be raised on fundamental units Length (L), Mass (M) and Time (T) to give the unit of that physical quantity.

Example:

$$Volume\ (V) = length \times breadth \times height$$
$$= m \times m \times m = m^3$$
$$\therefore Volume = [\mathrm{M}^0\mathrm{L}^3\mathrm{T}^0]$$

The dimension of volume are 0,3 and 0 in mass, length and time respectively. Like this, dimensional formulae are derived.

Dimensional Formula

An expression which shows how and which fundamental units are involved into the unit of physical quantity are called the dimensional formula of physical quantity. Some are given below:

S.N.	Physical Quantity	S.I. Unit	Dimensional Formula	Dimension in M,L and T
1.	Force	$\mathrm{KgMS^{-1}}$	$[\mathrm{MLT^{-2}}]$	1,1 and -2
2.	Universal Gravitational Constant	$\mathrm{Nm^2Kg^{-2}}$	$[\mathrm{M^{-1}L^3T^{-2}}]$	-1,3 and -2
3.	Pressure/Stress	$\mathrm{KgM^{-1}S^{-2}}$	$[\mathrm{ML^{-1}T^{-2}}]$	1,-1 and -2
4.	Density	$\mathrm{KgM^3}$	$[\mathrm{ML^{-3}T^0}]$	1,-3 and 0
5.	Impulse			
6.	Work/Energy/torque	$\mathrm{KgM^2S^{-2}}$	$[\mathrm{ML^2T^{-2}}]$	1,2 and -2
7.	Power	$\mathrm{KgM^2S^{-3}}$	$[\mathrm{ML^2T^{-3}}]$	1,1 and -3
8.	Momentum	$\mathrm{KgM^3S^{-2}}$	$[\mathrm{ML^3S^{-3}}]$	1,3 and -3
9.	Specific Heat Capacity	j/KgK	$[\mathrm{L^2T^{-2}K^{-1}}]$	2,-2 and -1

Uses of dimensional equations: The uses of dimensional equations with their examples are as follows;

To check the correctness of physical relation: A dimensional equation can be used as the basic property to check the correctness of a physical relation.

For example, let us consider an equation, $E = mc^2$ ________(i)
Where, E is energy, M is mass and C is velocity of light
Now, *Dimensional Formula of E = [ML$^2T^{-2}$]*
Dimensional Formula of M = [M]

Dimensional Formula of C = $[LT^{-1}]$

Putting these values in equation (i) *we get,*

$$[ML^2T^{-2}] = [M]\,[LT^{-1}]^2$$

$$= [ML^2T^{-2}]$$

To derive physical relation between physical quantities:

For example, Let us consider an example of simple pendulum.

The time period (T) of simple pendulum may depend upon length of pendulum (l), mass of the bob (m) and acceleration due to gravity (g)

i.e. $T \propto l^x$

$T \propto m^y$

$T \propto g^z$

Combining all the relations above, we get

$T \propto l^x m^y g^z \quad [Where, x, y\ and\ z\ are\ integers.]$

$T = k\, l^x m^y g^z \quad [Where\ k\ is\ proportionality\ constant]$

Now the dimensional formula of

$T = [\mathrm{T}]$

$l = [\mathrm{L}]$

$m = [\mathrm{M}]$

$g = [\mathrm{LT}^{-2}]$

Putting these values in eq^n (i)

$[\mathrm{T}] = [\mathrm{L}]^x[\mathrm{M}]^y[\mathrm{LT}^{-2}]^z$

$[\mathrm{T}] = [\mathrm{L}^{x+z}][\mathrm{M}^y][\mathrm{T}^{-2z}]$

Equating the power of MLT on both sides and solving the equations we get, $x = \frac{1}{2}, y = 0\ and\ z = -\frac{1}{2}$

Now putting the values in equation (i)*, we get*

$$T = k\sqrt{\frac{l}{g}}$$

Experimentally it has found that the value of K is 2π.

So, we get, $T = 2\pi\sqrt{\frac{l}{g}}$

To convert a system of unit to another:

Let us consider n_1 and U_1 are numerical values and fundamental unit of length, mass and time in one system of a physical quantity. Similarly, n_2 and U_2 are numerical values and fundamental unit of length mass and time in another system of the same physical quantity.

Now, The physical quantity $(Q) = n_1U_1 = n_2U_2$

$$\text{i.e. } \mathrm{n_1[M_1]^a[L_1]^b[T_1]^c = n_2[M_2]^a[L_2]^b[T_2]^c}$$

Where, M_1, L_1 and T_1 are the units of mass, length and time in the first system of unit. M_2, L_2 and T_2 are the units of mass, length and time in another system of unit and a, b & c are dimension of mass, length and time. Then,

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

Example: Convert 1000gm/cm^3 into Kg/m^3.

Sol^n:

We know that, Given physical quantity is density.

We also know that the dimensional formula of density,

$$\rho = [\mathrm{ML^{-3}T^0}]\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(i)$$

We know, $n_2 = n_1 \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$ ________________ (ii)

Comparing equation $(i) and$ (ii)*, we get,* $a = 1, b = -3$ and $c = 0$

Given,

$n_1 = 1000$ *and* $n_2 = ?$

$M_1 = 1gm$ $M_2 = 1kg$

$L_1 = 1cm$ $L_2 = 1m$

$T_1 = 1sec$ $T_2 = 1sec$

Now, putting these values in equation (ii) *we get,*

$$n_2 = 1000 \left[\frac{1gm}{1kg}\right]^a \left[\frac{1cm}{1m}\right]^b \left[\frac{1sec}{1sec}\right]^c$$

$$= 1000 \times \frac{1}{1000} \times \left[\frac{1}{100}\right]^{-3} = 1000000$$

$$\therefore n_2 = 10^6$$

Limitation of Dimensional Formula

a. It doesn't tell us whether the quantity is vector or not.
b. Physical relations involving exponential, trigonometric and logarithmic functions cannot be derived.
c. It fails to derive the relation if the physical quantity depends upon more than 3 physical quantities.

Precision and Accuracy:

It is the two different concept precision of a measurement means how close the different measurement are if we measure the quantity with an instruments which has smaller value of least count, readings will be closer to each other. But they are not accurate, they are precise. So precision shows the closeness of reading. The precision is the degree of agreement among the series of measurement of same quantities. Good precision means the readings are mostly very good or close to their mean value and associated with small uncertainties.

Accurate measurement means how close the measured value is to the true values. Accuracy is the closeness of a measurement with a true value.