# Physics and Measurements:

All physical quantities are measured in their own "units" and compared to "standards".

Units
- base units ( meter, Kilogram, second)
  - length, mass, time
- derived units ( $meter^2$, $meter^3$, $g/cm^3$)
  - area, volume, density

## Standards of Length, Mass, and Time:

Standard International System of Units (SI). In SI units $\Rightarrow$

Standard of mass: One kilogram (kg)

Standard of Length: One meter (m)

Standard of Time: One second (s)

1 kg : Platinum-Iridium alloy put under stable conditions in Paris-France.

1 m : Distance traveled by light in vacuum during a time of $\frac{1}{299792458}$ seconds.

1 s : The time required for Cs 133 atom to undergo 9192631770 vibrations

$$\text{Density } \rho = \frac{m}{V} \quad \begin{matrix} m \rightarrow \text{mass} \\ V \rightarrow \text{Volume} \end{matrix}$$

For Al $\Rightarrow \rho = 2.7\ g/cm^3$

Pb $\Rightarrow \rho = 11.3\ g/cm^3$

There are 3 Systems of units

| System | Mass | Length | Time |
|---|---|---|---|
| MKS (SI) | kg | m | s |
| CGS | g | cm | s |
| BE | slug | ft | s |

Conversion of units:

Density $\rho$ is given in units of $g/cm^3$.

$1\ g = 1\ \text{gram} = 1 \times 10^{-3}\ kg$.

$1\ cm = 1 \times 10^{-2}\ m \Rightarrow 1\ cm^3 = 1 \times 10^{-6}\ m^3$

$\Rightarrow$

$$\frac{g}{cm^3} = \frac{1 \times 10^{-3}\ kg}{1 \times 10^{-6}\ m^3} = 1 \times 10^{3}\ kg/m^3.$$

$\Rightarrow$ For Al $\Rightarrow \rho = 2.7\ \frac{g}{cm^3} = 2.7 \times 10^3\ kg/m^3$.

$1\ km = 1 \times 10^3\ m$.

$1\ kg = 1 \times 10^3\ g$. $\qquad k = 10^3$

$1\ kV = 1 \times 10^3\ V$

$1\ MV = 1 \times 10^6\ V$

$1\ GV = 1 \times 10^6\ V$

and so on.

There are also subunits

$1\ cm = 1 \times 10^{-2}\ m$. | $1\ nm = 1 \times 10^{-9}\ m$.

$1\ mm = 1 \times 10^{-3}\ m$ | $1\ pm = 1 \times 10^{-2}\ m$.

$1\ \mu m = 1 \times 10^{-6}\ m$ | $\vdots$

## Mathematical Notation

$1000 = 10^3$

$1000000 = 10^6$

$0.0015 = 1.5 \times 10^{-3}$

$15000 = 1.5 \times 10^4$

## Dimensional Analysis:

In any equation, both sides must have the same units

Example: Motion under constant acceleration

$$x = v_0 t + \frac{1}{2} a t^2$$

$x$ = distance, $a$ = acceleration, $t$ = time

$x \Rightarrow L$ or $m$, $a \Rightarrow \frac{L}{T^2}$ or $\frac{m}{s^2}$, $t \Rightarrow T$ or $s$

Note: the constant $\frac{1}{2}$ has no units

Check the dimensions of the above equation

Left side: $L$ or $m$.

Right side: First term: $\frac{L}{T} \cdot T$ or $\frac{m}{s} \cdot s$

$\Rightarrow L$ or $m$.

Second term: $\frac{L}{T^2} \cdot T^2$ or $\frac{m}{s^2} s^2$

$\Rightarrow L$ or $m$.

Note: Each term on both side of the equation must have the same dimensions or units.

Suppose we have no clue on the equation except that $x \propto a^n t^k$ , $n, k$ are numbers to be determined

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Prove by dimensional analysis that

$n = 1$ , $k = 2$

Left side: Has dimensions of Length L

Right side: Must have the same dimensions

$$L^1 \equiv \left(\frac{L}{T^2}\right)^n T^m$$

$$\Rightarrow$$

$$L^1 \equiv L^n T^{m-2n}$$

Comparing both sides $\Rightarrow$

$n = 1$ , $m - 2n = 0 \Rightarrow m = 2n = 2$

$\Rightarrow$

$x \propto a^1 t^2$

or

$x \propto a t^2$ وهو المطلوب