1-5 Units, Standards, and the SI System:

The measurement of any quantity is made relative to a particular standard or **unit**, and this unit must be specified along with the numerical value of the quantity.

For example, when we measure the hight of a table, we may write 2 m.
→ Unit (meter)

We shall write the unit because meters is very different from inshes (in). or feet.

For any unit we use, such as **distance** or **time** or **Mass** we need to define a standard so any one need to make a measurement can refer to the standard and to communicate.

In the International System (SI system) by the French Academy of Sciences, the units for **length. Mass, Time** are:-

$\underbrace{\text{meter (m), Kilogram (Kg), second (s)}}$

before this was called the mKS

Sometimes people use the cgs (cm, gram, second)

but we shall mostly use the SI (mKS) and in (1-6) we will learn how to convert from mKs ⇄ cgs easily.

Scientists, in the interest of simplicity, want the smallest number of **base** quantities possible consistent with a full description of the physical world. This number turns out to be seven, and those are:-

Quantity	Unit	Abbreviation
Length	meter	m
Time	second	S
Mass	Kilogram	Kg
Electric current	ampere	A
Temprerture	Kelvin	K
Amount of subi	mole	mol
Luminous intensity	candela	cd

* when another quantities can be expressed in terms of the base quantities we call them **Derived** quantities

Example (1)

Show that force which has units of (newton) can be exprerred in terms of L, M, T.

Sol. $F = \overset{\text{mass}}{m}a$ - acceleration

$$1\,N = 1\,Kg \cdot 1\,\frac{m}{s^2} = M \cdot \frac{L}{T^2}$$

Therefor the Newton is a derived quantity, since we can express it in terms of a combination of the base units L, M, T.

1-6 converting Units :

Often we are given a quantity in one set of units, but we want it expressed in another set of units, for example, suppose we measure the length of a pen that is 3 (in) and we want to express this in cm →

$1 (in) = 2.54\ cm$

$1 = 2.54 \frac{cm}{(in)}$ ⇐ num = 1

length of pen = $3 (in) = 3 (in) \cdot 1$

$= 3 \cancel{(in)} \cdot (2.54) \frac{cm}{\cancel{(in)}}$ [Conversion factor] ←

$= 7.62\ cm$.

Example (1)

The speed of a car is 100 Km/h. Express the speed in terms of m/s.

$1\ Km = 1000\ m \rightarrow 1 = 1000 \frac{m}{Km}$ $\boxed{1}$

$1\ h = 3600\ s \rightarrow 1 = 3600 \frac{s}{h}$ $\boxed{2}$

Speed of a car is $= 100\ Km/h \cdot (1)$

$= 100\ \cancel{Km}/\cancel{h} \cdot \left(1000 \frac{m}{\cancel{Km}}\right) \cdot \left(\frac{1}{3600} \frac{\cancel{h}}{s}\right)$

$= \frac{1000}{36}\ m/s$

$\approx 27.8\ m/s$

* Note: 1 ft = 12 (in)

1 (in) = 2.54 cm

1 mi = 5280 ft

1 h = 3600 s

Metric (SI) prefixes :-

Prefix	Abbreviation	Value
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera*	T	10^{12}
giga*	G	10^{9}
mega*	M	10^{6}
kilo*	K	10^{3}
hecto	h	10^{2}
deka	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro*	μ	10^{-6}
nano*	n	10^{-9}
pico*	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

Example (2)

The speed limit is 55 mi/h or mph, Find:

(a) This speed in meters per second.

(b) This speed in Kilometers per hour.

Sol. (a) The speed $= 55\ mi/h \cdot (1) \cdot (1) \cdot (1)$

$= 55\ \cancel{mi}/h \cdot \left(5280 \frac{\cancel{ft}}{\cancel{mi}}\right) \cdot \left(12 \frac{\cancel{(in)}}{\cancel{ft}}\right) \cdot \left(0.0254 \frac{m}{\cancel{(in)}}\right)$

$= 88513\ m/\cancel{h} \cdot \left(\frac{1\ \cancel{h}}{3600\ s}\right)$

$\approx 25\ m/s$.

(b) $88513\ \cancel{m}/h \cdot \left(\frac{1\ Km}{1000\ \cancel{m}}\right) = 88.5\ Km/h$

* $1\ m = 100\ cm \longrightarrow 1\ m^3 = 10^6\ cm^3 \longrightarrow 1 = \frac{1\ m^3}{10^6\ cm^3}$

* $1\ kg = 1000\ gm \longrightarrow 1 = \frac{1000\ g}{kg}$

Density of water is 1000 kg/m^3, find the density in g/cm^3:

Density $= 1000 \frac{\cancel{kg}}{\cancel{m^3}} \times \frac{1000\ g}{1\ \cancel{kg}} \times \frac{\cancel{m^3}}{10^6\ cm^3} = 1\ g/cm^3$

1-8 Dimensions :-

When we speak of the dimensions of a quantity, we are refering to the type of base units or base quantities that make it up. Note that the formula for a quantity may be different in some cases. For example, the area of a triangle of base b and height h is $A = \frac{1}{2}bh$, whereas the area of a circle of radius r is $A = \pi r^2$. The formulas are different, but the dimensions are always : $[L^2]$.

And the question is : Where we can use Dimensions ?

$\boxed{1}$ Dimensional analysis : which can be used to check if relationships are incorrect. For example : $v = v_0 + \frac{1}{2}at^2$, let's do a dimensional check, Note that numerical factors like $\frac{1}{2}$ here do not affect the checking process.

$$v = v_0 + \frac{1}{2}at^2$$

$$\left[\frac{L}{T}\right] \overset{??}{=} \left[\frac{L}{T}\right] + \frac{1}{2}\left[\frac{L}{T^2}\right].[T^2]$$

$$\overset{??}{=} \left[\frac{L}{T}\right] + [L].$$

The dimensions are incorrect.

$\boxed{2}$ A quick check on an equation :

For example, consider a simple pendulum of length ℓ. Suppose that you can't remember whether the equation for the period T is =

$T = 2\pi\sqrt{\ell/g}$ or $T = 2\pi\sqrt{g/\ell}$

$$[T] = \sqrt{\frac{\cancel{[L]}}{[\cancel{L}/T^2]}} = [T]$$

It shows the the 1st former is correct.

*Note :- A dimensional check can Only tell you when a relationship is wrong, it can't tell you if it is completely right, such as a dimensionless numerical factor could be missing like : ($\frac{1}{2}$, 2π).

* Do the following questions :-

page (18) → 12/13/14/15

page (19) → 36/37/38

* Consider : $v_f = v_i + 2at$, check the dimensions.

$$\left[\frac{L}{T}\right] \overset{?}{=} \left[\frac{L}{T}\right] + \left[\frac{L}{T^{\cancel{2}}}\cancel{T}\right]$$

$$\left[\frac{L}{T}\right] = \left[\frac{L}{T}\right] + \left[\frac{L}{T}\right] \longrightarrow$$ Dimensionally correct but wrong from the physics point of view

* If an equation is dimensionally wrong it is physically wrong

* If an equation is dimensionally correct it's not necessary to be physically correct as mentioned above