Introduction to Physics

Physics is how we appreciate nature and understand its laws. We can see a bird is suddenly airborne from rest as she flaps her wings. With this understanding, an analogy can be drawn on the concepts of Lift, drag and aerodynamics. We can see that a stone thrown in water drowns whereas the bamboo stick floats. With this understanding, an analogy can be drawn on the concepts of Buoyancy. We can see an object thrown up in the sky comes back and falls down. With this understanding, an analogy can be drawn on the concepts of laws of Gravitation force. We can see that we can walk steadily on a rough road but slip on an icy terrain. With this understanding, an analogy can be drawn on the concepts of Friction. Thus nature and Physics go hand in hand.

Courtesy: rawpixel.com and https://www.isro.gov.in/

Units

A body named Conférence Générale des Poids et Mesures or CGPM also known as General Conference on Weight and Measures in English has been given the authority to decide the units by international agreement.

SI Units

In 1971 CGPM held its meeting and decided a system of units which is known as the International System of Units. It is abbreviated as SI from the French name Le Systéme International d'Unités. This system is widely used throughout the world.

SL No.	Quantity	Name of Unit	Symbol
1	Length	meter	**m**
2	Mass	Kilogram	**Kg**
3	Time	Second	**s**
4	Electric current	Ampere	**A**
5	Thermodynamic Temperature	Kelvin	**K**
6	Amount of Substance	Mole	**mol**
7	Luminous Intensity	Candela	**cd**
8	plane angle	Radian	**rad**
9	solid angle	Steradian	**sr**

The mass of an electron is **9.1×10^{-31} kg** and that of our galaxy is about **2.2×10^{41} kg.**

Prefixes				
Purpose	**Name**	**Symbol**	**Factor**	**Name**
larger quantities or whole units	quetta	Q	10^{30}	nonillion
	ronna	R	10^{27}	octillion
	yotta	Y	10^{24}	septillion
	zetta	Z	10^{21}	sextillion
	exa	E	10^{18}	quintillion
	peta	P	10^{15}	quadrillion
	tera Example: terahertz	T	10^{12}	trillion
	giga Example: gigawatt	G	10^{9}	billion

	mega	M	10^{6}	million
	kilo Example: kiloliter	k	10^{3}	thousand
	hecto Example: hectare	h	10^{2}	hundred
	deka Example: dekameter	da	10^{1}	ten
	meter		10^{0}	one
smaller quantities or sub units	deci Example: decimeter	d	10^{-1}	tenth
	centi Example: centigram	c	10^{-2}	hundredth
	milli Example: milliliter	m	10^{-3}	thousandth
	micro Example: microgram	µ	10^{-6}	millionth
	nano Example: nanometer	n	10^{-9}	billionth
	pico Example: picogram	p	10^{-12}	trillionth
	femto Example: femtosecond	f	10^{-15}	quadrillionth
	atto	a	10^{-18}	quintillionth
	zepto Example: zeptosecond	z	10^{-21}	sextillionth
	yocto Example: yoctosecond	y	10^{-24}	septillionth
	ronto	r	10^{-27}	octillionth
	quecto	q	10^{-30}	nonillionth

Courtesy: https://www.nist.gov/

Dimension:

Physical Quantities are derived based on base quantities. The base quantities are represented by one letter symbols. Generally, mass is denoted by **M**, length by **L**, time by **T** and electric current by **I**. The thermodynamic temperature, the amount of substance and the luminous intensity are denoted by the symbols of their units **K, mol** and **cd** respectively.

For eg.

$$\begin{aligned} force &= mass \times acceleration \\ &= mass \times \frac{velocity}{time} \\ &= mass \times \frac{length/time}{time} \\ &= mass \times length \times (time)^{-2}. \end{aligned}$$

Thus Force = MLT^{-2}

Problem: Calculate the dimensional formula of Energy E = ½ mv^2

<u>Homogeneity of Dimensions in an Equation</u>

The dimensions of all the terms in an equation must be identical

Let us consider the equation: x = u.t + ½ $a.t^2$

$$[x] = \mathrm{L}$$

$$[ut] = velocity \times time = \frac{length}{time} \times time = \mathrm{L}$$

$$\left[\frac{1}{2} at^2\right] = [at^2] = acceleration \times (time)^2$$

$$= \frac{velocity}{time} \times (time)^2 = \frac{length/time}{time} \times (time)^2 = \mathrm{L}$$

Example: Frequency $= \dfrac{1}{2\pi}\sqrt{\dfrac{K}{m}} = \dfrac{1}{2\pi}\sqrt{\dfrac{(\frac{F}{L})}{m}}$

$$= \frac{1}{2\pi}\sqrt{\frac{MLT^{-2}}{L.M}} = 1/T = Hz \text{ (Hertz)}$$

Find the dimensional formulae of the following quantities:

(a) *The universal constant of gravitation G,*
(b) *The surface tension S,*
(c) *The thermal conductivity k and*
(d) *The coefficient of viscosity* η.

Some equations involving these quantities are

$$F = \frac{Gm_1 m_2}{r^2}, \qquad S = \frac{\rho g r h}{2},$$

$$Q = k\frac{A(\theta_2 - \theta_1)t}{d} \quad \text{and} \quad F = -\eta A\frac{v_2 - v_1}{x_2 - x_1}$$

(a) $F = G\dfrac{m_1 m_2}{r^2}$

$$G = \frac{Fr^2}{m_1 m_2}$$

$$[G] = \frac{[\mathrm{F}]\mathrm{L}^2}{\mathrm{M}^2} = \frac{\mathrm{MLT}^{-2}.\mathrm{L}^2}{\mathrm{M}^2} = \mathrm{M}^{-1}\mathrm{L}^3\mathrm{T}^{-2}.$$

(b) $S = \dfrac{\rho g r h}{2}$

or, $[S] = [\rho]\,[g]\mathrm{L}^2 = \dfrac{\mathrm{M}}{\mathrm{L}^3}\cdot\dfrac{\mathrm{L}}{\mathrm{T}^2}\cdot\mathrm{L}^2 = \mathrm{MT}^{-2}.$

(c) $Q = k\dfrac{A(\theta_2 - \theta_1)t}{d}$

or, $k = \dfrac{Qd}{A(\theta_2 - \theta_1)t}.$

Here, Q is the heat energy having dimension $\mathrm{ML}^2\mathrm{T}^{-2}$, $\theta_2 - \theta_1$ is temperature, A is area, d is thickness and t is time. Thus,

$$[k] = \frac{\mathrm{ML}^2\mathrm{T}^{-2}\mathrm{L}}{\mathrm{L}^2\mathrm{KT}} = \mathrm{MLT}^{-3}\mathrm{K}^{-1}.$$

(d) $F = -\eta A\dfrac{v_2 - v_1}{x_2 - x_1}$

or, $\mathrm{MLT}^{-2} = [\eta]\mathrm{L}^2\dfrac{\mathrm{L/T}}{\mathrm{L}} = [\eta]\dfrac{\mathrm{L}^2}{\mathrm{T}}$

or, $[\eta] = \mathrm{ML}^{-1}\mathrm{T}^{-1}.$

2. *Test dimensionally if the equation $v^2 = u^2 + 2ax$ may be correct.*

Solution:

There are three terms in this equation v^2, u^2 and $2ax$. The equation may be correct if the dimensions of these three terms are equal.

$$[v^2] = \left(\frac{\mathrm{L}}{\mathrm{T}}\right)^2 = \mathrm{L}^2\,\mathrm{T}^{-2};$$

$$[u^2] = \left(\frac{\mathrm{L}}{\mathrm{T}}\right)^2 = \mathrm{L}^2\,\mathrm{T}^{-2};$$

$$[2ax] = [a]\,[x] = \left(\frac{\mathrm{L}}{\mathrm{T}^2}\right)\mathrm{L} = \mathrm{L}^2\,\mathrm{T}^{-2}.$$

Thus, the equation may be correct.