Lecture

# General Physics

Prepared by

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# UNITS

# &

# DIMENSIONS

# Physical Quantities

**Quantities by means of which we describe the laws of physics.**

## Types of physical quantities :

**1-Fundamental quantities**
**2-Derived quantities**

## Fundamental quantities

*These quantities are not defined in terms of other physical quantities like length, mass and time.*

## Derived quantities

*Physical quantities which dependent on Fundamental quantities or which can be derived from fundamental quantities e.g., velocity, acceleration, force, ...etc.*

*Table 1 showing the seven (7) Fundamental Quantities of the International System of Units.*

| Fundamental Quantity | | S.I. Unit | |
|---|---|---|---|
| **Name** | **Symbol** | **Name** | **Symbol** |
| Mass | m | kilogram | kg |
| Length | l | metre | m |
| Time | t | second | s |
| Current | I | ampere | A |
| Temperature | T | kelvin | K |
| Amount of Substance | n | mole | mol |
| Luminous Intensity | $I_v$ | candela | cd |

# Units:

Things in which quantity is measured.

# Systems of Units:

a) The ***French system*** (**cgs-system**), in which the fundamental units are the **centimeter, gram and second**.

b) The ***international system*** (**MKS-system**), in which the fundamental units are the **meter, kilogram and second**.

c) The ***British system*** (**fps-system**), in which the fundamental units are the **foot, pound and second**.

| System | Length | Mass | Time |
|---|---|---|---|
| F.P.S. | foot | pound | second |
| C.G.S. | centimetre | gram | second |
| M.K.S. | metre | kilogram | second |

# Dimensions

The way in which the derived quantity is related to the basic quantity can be shown by the dimensions of the quantity.
In considering dimensions we will restrict ourselves to the fundamental quantities.

**The dimensions of <u>mass</u> are written as [M]**
**The dimensions of <u>length</u> are written as [L]**
**The dimensions of <u>time</u> are written as [T]**

The square brackets round the letter to show that we are dealing with the dimensions of a quantity.

# EXAMPLES

$$\text{Velocity} = \frac{\text{distance}}{\text{time}} = \frac{L}{T} = [\,L.T^{-1}]$$

$$\text{Acceleration} = \frac{L}{T^2} = [L.T^{-2}\,]$$

$$\text{Force} = \text{mass} \times \text{acceleration} = [\,M.L.T^{-2}\,]$$

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{M.L.T^{-2}}{L^2} = [M.L^{-1}.\ T^{-2}]$$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = [M.L^{-3}]$$

# Applications of Dimensional Equations

1) To drive physical formula

2) To check the correctness of a formula

3) Conversion of units from one system to another system of units

# 1) To drive physical formula

let us derive the equation for the period of a simple pendulum.

Let the period (**T**), be the function of the length ($\ell$), mass of the suspended bob (**m**), and the acceleration due to gravity (**g**), thus

$T \propto \ell^x$ $\quad$ $T \propto m^y$ $\quad$ $T \propto g^z$

$$T \propto \ell^x m^y g^z$$

$$T = K \ell^x m^y g^z$$

Where the constant of proportionality **K**, **x**, **y** and **z** are constants to be determined and the constant of proportionality **K** is ***dimensionless***.

$$T = K\ L^{x}\, M^{y}\, (L\, T^{-2})^{z}$$

$$M^{0}\, L^{0}\, T^{1} = K\, L^{x+z}\, M^{y}\, T^{-2z}$$

By equating the indices of M, L and T on both sides, one gets:

$$X = \frac{1}{2} \quad , \quad y = 0 \quad \& \quad z = \frac{-1}{2}$$

Then

$$T = K\ \ell^{1/2}\, g^{-1/2}$$

$$T = K \sqrt{\frac{\ell}{g}}$$

The constant K may be found experimentally or theoretically, and its value is 2Π

$$\Rightarrow \quad T = 2\Pi \sqrt{\frac{\ell}{g}}$$

## *2) To check the correctness of a formula*

**For example, check the accuracy of the previous equation for the periodic time of a simple pendulum .**

$$T = 2\Pi \sqrt{\frac{\ell}{g}}$$

**Substitute in both sides of the equation by its dimensions:**

$$T = \sqrt{\frac{L}{L\,T^{-2}}} = \sqrt{T^2} = T$$

**Thus, the equation is *correct*.**

## 3) Conversion of units from one system to another system of units

To establish the relationship between two unites or force determined on the basic of Newton's second law:

$$F = mg$$

$$\Rightarrow [\,F\,] = M\,L\,T^{-2}$$

Where the basic unit cgs and fps of length & mass are :

1 Foot = 30.48 cm & 1 Pound = 453.6 gm

To convert the units of force between cgs & fps systems:

$$\frac{\textit{Units of fps system}}{\textit{Units of cgs system}} = 30.48 \times 453.6 = 1.382 \times 10^{-4}$$

**Force in fps = $1.382 \times 10^{-4}$ force (*dyne*) in cgs**

# Power-of-ten notation: Multiples and submultiples

When it is necessary to express a small fraction, or a large multiple of a unit, this is done by using powers of 10 and it is called standard form or scientific notation. Generally this is written $n \times 10^x$ where n is a number between 1 & 10 and x is a positive or negative whole number.

Using this method a mass of a mass of 0.00035 kg is expressed as $3.5 \times 10^{-4}$ kg and a mass of 354000 kg as $3.54 \times 10^5$ kg .

# Metric Conversion table

| Symbol | Prefix | 10n | Decimal |
|---|---|---|---|
| Y | yotta | $10^{24}$ | 1 000 000 000 000 000 000 000 000 |
| Z | zetta | $10^{21}$ | 1 000 000 000 000 000 000 000 |
| E | exa | $10^{18}$ | 1 000 000 000 000 000 000 |
| P | peta | $10^{15}$ | 1 000 000 000 000 000 |
| T | tera | $10^{12}$ | 1 000 000 000 000 |
| G | giga | $10^{9}$ | 1 000 000 000 |
| M | mega | $10^{6}$ | 1 000 000 |
| k | kilo | $10^{3}$ | 1 000 |
| h | hecto | $10^{2}$ | 1 00 |
| da | decca | $10^{1}$ | 1 0 |
| | none | 1 | base |
| d | deci | $10^{-1}$ | 0. 1 |
| c | centi | $10^{-2}$ | 0. 01 |
| m | milli | $10^{-3}$ | 0. 001 |
| μ | micro | $10^{-6}$ | 0. 000 001 |
| n | nano | $10^{-9}$ | 0. 000 000 001 |
| p | pico | $10^{-12}$ | 0. 000 000 000 001 |
| f | femto | $10^{-15}$ | 0. 000 000 000 000 001 |
| a | atto | $10^{-18}$ | 0. 000 000 000 000 000 001 |
| z | zepto | $10^{-21}$ | 0.000 000 000 000 000 000 001 |
| y | yocto | $10^{-24}$ | 0. 000 000 000 000 000 000 000 001 |

Vector Metric Conversion table EPS 10

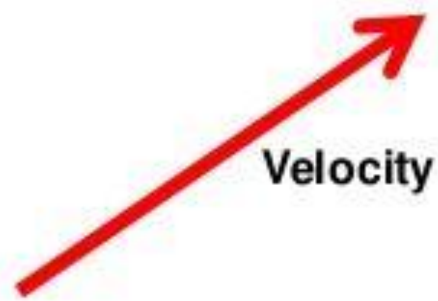
# Scalars and Vectors

A **scalar quantity** is a quantity that has only **magnitude**.

A **vector quantity** is a quantity that has both a **magnitude** and a **direction**.

**Scalar quantities**
Length, Area, Volume,
Speed,
Mass, Density
Temperature, Pressure
Energy, Entropy
Work, Power

**Vector quantities**
Displacement, Direction,
Velocity, Acceleration,
Momentum, Force,
Electric field, Magnetic field

# EXERCISES

***Q1 : Find the dimensions and SI units for the following quantities:***

1- **Pressure** 2- **Work** 3- **Kinetic energy**

| Quantity | Dimensions | SI Units |
|---|---|---|
| **Pressure** | $=\frac{[F]}{[A]} = \frac{[m][a]}{[A]} = \frac{M\,L\,T^{-2}}{L^2} = \mathrm{M}\,L^{-1}T^{-2}$ | $\mathrm{Kg}.m^{-1}\,S^{-2}$ |
| **Work** | $[\mathrm{W}] = [\mathrm{F}][\mathrm{x}] = \mathrm{M\,L}\,T^{-2}\,.\mathrm{L} = \mathrm{M}\,L^2\,T^{-2}$ | $\mathrm{Kg}\,m^2\,S^{-2}$ |
| **Kinetic energy** | $[\mathrm{K.E}] = \frac{1}{2}[\mathrm{m}]\,[v]^2 = \mathrm{M}(\mathrm{L}\,T^{-1})^2$ <br> $= \mathrm{M}\,L^2\,T^{-2}$ | $\mathrm{Kg}\,m^2\,S^{-2}$ |

**Q2 : Derive an equation for the speed of sound in a gas of density $\rho$ and pressure $P$ where constant $K = \Pi$.**

## Sol.

$$v_s = \Pi \, \rho^x \, P^y$$

$$[v_s] = \Pi \, [\rho^x] \, [P^y]$$

$$L\,T^{-1} = (M\,L^{-3})^x \,.\, (M\,L\,T^{-2}.\,L^{-2})^y$$

$$L\,T^{-1} = M^{x+y}.\, L^{-3x-y}\,.T^{-2y}$$

$\Rightarrow$ $y = \frac{1}{2}$ & $x = \frac{-1}{2}$

$$v_s = \Pi \, \rho^{-1/2} \, P^{1/2}$$

Or

$$v_s = \Pi \sqrt{\frac{P}{\rho}}$$

**Q3 : A sphere of radius r is moving through a fluid of density ρ with velocity v experiences a retarding force F giving by**

$$F = k\, r^x \rho^y v^z$$

"Where K is a dimensionless constant."

**Find x, y and z.**

## Sol.

$$[F] = [r]^x\ [\rho]^y\ [v]^z$$

$$[F] = L^x\ (ML^{-3})^y\ (LT^{-1})^z$$

$$M\,L\,T^{-2} = M^y\ L^{x-3y+z}\ T^{-z}$$

**y=1 , z=2 & x=2**

## Q4 : Check the correctness of the following equation:

$$P = \rho\, g\, h$$

**Sol.**

L.H.S. = [P] = $M\, L^{-1}\; T^{-2}$

R.H.S. = [ρ] [g] [h] = $M\, L^{-3} \,.\, L\, T^{-2} \,.\, L$

$= M\, L^{-1}\; T^{-2}$

L.H.S. = R.H.S.

The equation is ***correct***.

**Q5 : Convert the unit of *Energy* from *Joule* (M.K.S) system to erg (c.g.s) system.**

## Sol.

Joule = kg . $m^2$ . $s^{-2}$

erg = g . $cm^2$ . $s^{-2}$

J= $\frac{1\,kg\,.1\,m^2}{1s^2}$ = $\frac{1000\,g\,.\,(100)^2\,cm^2}{1s^2}$

= $\frac{10^7\;g.cm^2}{s^2}$

= $10^7$ g.$cm^2$ .$s^2$

= $10^7$ erg

# THANKS