UNIT-01

PHYSICAL WORLD, UNITS & MEASUREMENTS

INTRODUCTION

Physics is a branch of natural science which deals with the Physical world and laws governing its behaviour. The knowledge in this discipline is through observations followed by critical analysis and interpretation.

=> Any Physical Phenomenon can be described quantitatively which involves certain measurable quantities and are called OBSERVABLE OR PHYSICAL quantities.

The Physical quantity which can't be expressed in terms of any other quantity are called FUNDAMENTAL quantity

The Physical quantity which can be expressed in terms of any other quantity are called DERIVED quantity.

There are seven fundamental quantity which are as follows.

Sl no	Physical quantity	Name of unit	symbol
1	Mass	Kilogram	Kg
2	Length	Metre	m
3	Time	second	sec
4	Thermodynamic Temperature	Kelvin	K
5	Electric Current	Ampere	A
6	Amount of Substance	mole	mole
7	Luminous of intensity.	Candela	Cd

Systems of units are as follows.

1) CGS system (Centimetre, Gram, second)

2) FPS System. (Foot, Pound, second)

3) MKS System (Metre, Kilogram, second)

4) SI system (international system)

=> When a physical quantity is expressed in terms of fundamental quantity it is written as the Product of different Power of fundamental quantity. The Power of fundamental quantity in that expression is called DIMENSION.

=> DIMENSION FORMULA of a Physical quantity is the formula which express how and which of the fundamental quantities have been used for the measurement of that quantity.

Ex MASS $\lfloor M \rfloor$ Dimension formula.

Dimension of mass is 1 w.r.t M

Area =Length x breadth or L x L = $[M^0 L^2 T^0]$ Dimensional formula

Dimension of area is 0, 2 ,0 w.r.t Mass, Length & Time.

Velocity = Displacement/time = $\frac{L}{T}$= $[M^0 L^1 T^{-1}]$

Acceleration = velocity/Time = = $[M^0 L^1 T^{-2}]$

DIMENSIONAL FORMULA OF PHYSICAL QUANTITIES

Sl No	Physical Quantities	Relation	Dimensional Formula
1	Length	Fundamental quantity	$[M^0L^1T^0]$
2	Time	Fundamental quantity	$[M^0L^0T^1]$
3	Temperature	Fundamental quantity	$[M^0L^0T^0K^1]$
4	Current	Fundamental quantity	$[M^0L^0T^0K^1]$
5	Force	Mass X Displacement	$[M^1L^1T^{-2}]$
6	Work	Force X Displacement	$[M'L^2\ T\text{-}^2]$
7	energy	Mass X acceleration due to gravity X height	$[M'L^2\ T\text{-}^2]$
8	Pressure	Force/Area	$[M^1L^{-1}T^{-2}]$
9	Power	Work/Time	$[M^1L^2T^{-3}]$
10	Stress	Force/ Area	$[M^1L^{-1}T^{-2}]$
11	Charge	Current X Time	$[M^0L^0T^1A^1]$
12	Potential difference	Work/charge	$[M^1L^2T^{-3}A^{-1}]$
13	Resistance	Potential difference /current	$[M^1L^2T^{-3}A^{-2}]$
14	wave length	Velocity/frequency	$[M^0L^1T^0]$
15	Frequency	1 / time period	$[M^0L^0T^{-1}]$

PRINCIPLE OF HOMOGENEITY

It States that the dimensional formula of every term on the two sides of a correct relation must be homogeneous.

To convert the value of a Physical quantity from one system to another
Let us convent a work of 1 joule into erg.

M.KS	Work	CGS
M_1 = 1 Kg	$[M^1L^2T^{-2}]$	M_2 = 1 gm
L_1 =1met	a = 1	L_2=1 cm
T_1 = 1 sec	b = 2	T_2= 1 sec
n_1 = 1	C = -2	n_2= ?

n_1 [$M_1^a L_1^b\ T_1^C$] = $n_2[M_2^a L_2^b T_2^c]$

$n_2 = \frac{1000\ gm}{1gm}\ x\ \frac{100\ cm}{1cm}\ x\ \frac{100\ cm}{1cm}\ x\ \frac{1\ sec}{1\ sec}$

1 joule = 10^7erg.

PROBLEM

Convert 1 Newton into dyne (ANS I N = 10^5dyne).

=> To check the correctness of a given relation.

Consider the relation S = ut +$\frac{1}{2}at^2$

LHS $[M^0L^1T^0]$

R.HS $[M^0L^1T^{-1}][M^0L^0T^1]$ + [M°L'T -²] $[M^0L^0T^2]$ (1/2 has no Dimension)

= $[M^0L^1T^0]$ + $[M^0L^1T^0]$

Since the dimensional formula of all terms in LHS & RHS are homogeneous, equation is dimensionally connect.

PROBLEM

1) Check $V^2-u^2 = 2as$

2) Check F = MV/R

3) Check V = u + at

4) Check $T = 2\pi\sqrt{\frac{l}{g}}$

Ans (1, 3, 4 correct but 2 is not correct)

=>To derive the relation between various Physical quantities. Consider the case of a simple Pendulum. The time Period of simple pendulum (T) depends upon mass (m) effective length (L) and acceleration due to gravity (g).

T α M^a

α L^b

α g^c

$T = K M^a L^b g^c$ where. K-dimension less constant quantity

Dimensional formula of T, M, L & g are $[T^1]$ [M'] [L'] & $[L^1T^{-2}]$ respectively.

L·H·S of equation 1 is $[T^1]$

R. H.S of equation 1 is $[M^a]$ $[L^b][L^cT^{-2c}]$ b = $[m^aL^{b+c}T^{-2c}]$

From LHS & RHS a = 0, b + c =0 & -2c=1

Hence a=0 c = -1/2 & b = 1/2

using the value of a b & c in equation 1 we get

T = K $L^{1/2} g^{-1/2}$ or T = K √(l/g)

LIMITATIONS OF DIMENSIONAL ANALYSIS

1) It doesn't give information about the dimensional constant.
2) It doesn't give information about the trigonometric function.
3) It doesn't give information about the exponential function.
4) It doesn't give information about the logarithmic function.
5) It gives no information regarding whether a function is a scalar or vector quantity.

MEASUREMENT

The measurement of a physical quantity is the process of comparing this quantity with a standard amount of the physical quantity of the same kind, called its unit. To express the measurement of a physical quantity, we need to know two things:

(i) The unit in which the quantity is measured.

(ii) The numerical value or the magnitude of the quantity i.e., the number of times that unit is contained in the given physical quantity.

LEAST COUNT

The smallest measurement that can be done by an instrument accurately is called its least count.

MEASUREMENT OF LENGTH BY DIRECT METHODS

Length may be defined as the distance of separation between two points in space. The instruments used to measure length are Metre scale, Vernier callipers, Screw gauge or spherometer.

INDIRECT METHODS FOR MEASURING LARGE DISTANCES

Triangulation method for the height of an accessible object.

Let AB = h be the height of the tree or the tower to be measured. Let C be the point of observation at distance x from B. Place a sextant at C and measure the angle of elevation, angle ACB = θ. From right triangle ABC we have tan θ = (AB)/(CB) = h/x

h = x / tan θ

Knowing the distance x, the height h can be determined.

ERRORS IN A MEASUREMENT

The error in a measurement is equal to the difference between the true value and the measured value of the quantity.

Error = True value - Measured value

1) Systematic errors. The errors which tend to occur in one direction, either positive or negative, are called of systematic errors. These errors may be of the following types:

(i) Instrumental errors. These errors occur due to the inbuilt defect of the measuring instrument.

ii) Imperfections in experimental technique. These errors are due to the limitations of the experimental arrangement.

(iii) Personal errors. These errors arise due to individual's bias, lack of proper setting of apparatus or individual's carelessness in taking observations without observing proper precautions, etc.

(iv) Errors due to external causes. These errors arise due to the change in external conditions like pressure, temperature, wind, etc.

2) Random errors. The errors which occur irregularly and at random, in magnitude and direction, are called random errors.

3) Absolute error. The magnitude of the difference between the true value of the quantity measured and the individual measured value is called absolute error.

If we take arithmetic mean $\overline{a}$ as the true value, then the absolute errors in the individual measured values will be

$\Delta a_1 = \overline{a} - a_1 \;\; \Delta a_2 = \overline{a} - a_2$

$\Delta a_3 = \overline{a} - a_3 \;\; \Delta a_n = \overline{a} - a_n$

4) Relative error. The ratio of the mean absolute error to the true value of the measured quantity is called relative error.

Relative error, $\delta a = \frac{\Delta\overline{a}}{\overline{a}}$

SIGNIFICANT FIGURES

The significant figures are normally those digits in a measured quantity which is known reliably or about which we have confidence in our measurement plus one additional digit that is uncertain.

Rules for determining the number of significant figures:

(i) All non-zero digits are significant. So 13.75 have four significant figures.

(ii) All zeros between two non-zero digits are significant. Thus 100.05 km has five significant figures.

(iii) All zeros to the right of a non-zero digit but to the left of an understood decimal point are not significant. For example, 86400 have three significant figures. But such zeros are significant if they come from a measurement. For example, 86400 s has five significant figures.

(iv) All zeros to the right of a non-zero digit but to the left of a decimal point are significant. For example, 648700. has six significant figure.

(v) All zeros to the right of a decimal point are significant. So 161 cm, 161.0 cm and 161.00 cm have three, four and five significant figures respectively.

(vi) All zeros to the right of a decimal point but to the left of a non-zero digit are not significant. So 0.161 cm and 0.0161 cm, both have three significant figures. Moreover, zero conventionally placed to the left of the decimal point is not significant.

(vii) The number of significant figures does not depend on the system of units. So 16.4 cm, 0.164 m and 0.000164 km, all have three significant figures.

PROPAGATION AND ESTIMATIONS OF ERRORS

(i) Error in the sum of two quantities.

LetΔA and ΔB be the absolute errors in the two quantities A and B respectively. Then Measured value of A = A $\pm \Delta A$

Measured value of B = B $\pm \Delta B$ then consider the sum, Z = A + B

The error ΔZ in Z is then given by

Z $\pm$ΔZ = A $\pm$ΔA + B $\pm \Delta B$ = (A + B) $\pm (\Delta A \pm \Delta B)$

Z $\pm$ΔZ = Z $\pm (\Delta A \pm \Delta B)$

ΔZ = $\Delta A \pm \Delta B$

(ii) Error in the difference of two quantities.

LetΔA and ΔB be the absolute errors in the two quantities A and B respectively. Then

Measured value of A = A $\pm$ΔA

Measured value of B = B $\pm \Delta B$ then consider the difference,

Z = A - B

The error ΔZ in Z is then given by

Z $\pm$ΔZ = A $\pm$ΔA – (B $\pm \Delta B$) = (A - B) $\pm (\Delta A \mp \Delta B)$

Z $\pm$ΔZ = Z $\pm (\Delta A \mp \Delta B)$

ΔZ = $\Delta A \mp \Delta B$

(iii) Error in the product of two quantities.

Consider the product Z = AB

The error ΔZ in Z is given by Z $\pm$ΔZ = (A $\pm$ΔA)(B $\pm \Delta B$)

Or Z $\pm$ΔZ = AB $\pm A$ΔB $\pm B$ΔA $\pm$ ΔAΔB

Dividing L.H.S. by Z and R.H.S. by AB we get

$1 \pm \frac{\Delta Z}{Z} = 1 \pm \frac{\Delta B}{B} \pm \frac{\Delta A}{A} \pm \frac{\Delta A}{A}\frac{\Delta B}{B}$

Neglecting $\frac{\Delta A}{A}$ & $\frac{\Delta B}{B}$ we get $\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$

(iv) Error in the division or quotient.

Consider the quotient. Z = A/B

The error ΔZ in Z is given by $Z \pm \Delta Z = \frac{A \pm \Delta A}{B \pm \Delta B} = \left(\frac{1 \pm \frac{\Delta A}{A}}{1 \pm \frac{\Delta B}{B}} \right) \frac{A}{B}$

$Z \pm \Delta Z = \frac{A}{B} \left(1 \pm \frac{\Delta A}{A}\right) \left(1 \mp \frac{\Delta B}{B} \right)$

or $Z \pm \Delta Z = Z \left(1 \pm \frac{\Delta A}{A}\right) \left(1 \mp \frac{\Delta B}{B} \right)$

Dividing both sides by Z we get

$1 \pm \frac{\Delta Z}{Z} = \left(1 \pm \frac{\Delta A}{A}\right) \left(1 \mp \frac{\Delta B}{B} \right) = 1 \pm \frac{\Delta A}{A} \mp \frac{\Delta B}{B} \pm \frac{\Delta A}{A} \frac{\Delta B}{B}$

Neglecting $\frac{\Delta A}{A}$ & $\frac{\Delta B}{B}$ as very very small $\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$

(v) Error in the power of a quantity.

Consider the nth power of A that is Z = A^n

The error ΔZ in Z is given by

$Z \pm \Delta Z = (A \pm \Delta A)^n = A^n (1 \pm \Delta A / A)^n$

$= Z(1 \pm n \Delta A / A)$

Dividing both sides by Z, we get

$1 \pm \Delta Z / Z = 1 \pm n \Delta A / A$

Or $Z / Z = n \Delta A / A$

Short Answer Question

1 State the principle of homogeneity.

2 Define Dimension .

3 Write down the types of unit system .

4 Write the dimensional formula of force , power.

5 Write the dimensional formula energy , stress .

6 Write the dimensional formula current potential difference.

7 Write the dimensional formula resistance , wavelength .

8 Write the dimensional formula work , frequency .

9 State Systematic errors.

10 State Instrumental errors.

11 State Personal errors.

12 State Random errors.

13 State Absolute error.

14 Define Significant figures

15 Define least count.

Five mark questions

1) Check the correctness of the equation $V^2-u^2 = 2as$ using dimensional analysis .

2) Check the correctness of the equation F = MV^2/R using dimensional analysis .

3) Check the correctness of the equation $V = u+at$ using dimensional analysis .

4) Check the correctness of the equation $T = 2\pi \sqrt{l/g}$ using dimensional analysis .

5) Check the correctness of the equation S = ut + 1/2at using dimensional analysis .

6) Convert 1 joule into erg.

7) Convert 1 newton into dyne.

8) derive the expression of time period of a simple pendulum which depends upon its mass effective unit length & acceleration due to gravity.

9) Explain propagation of error.