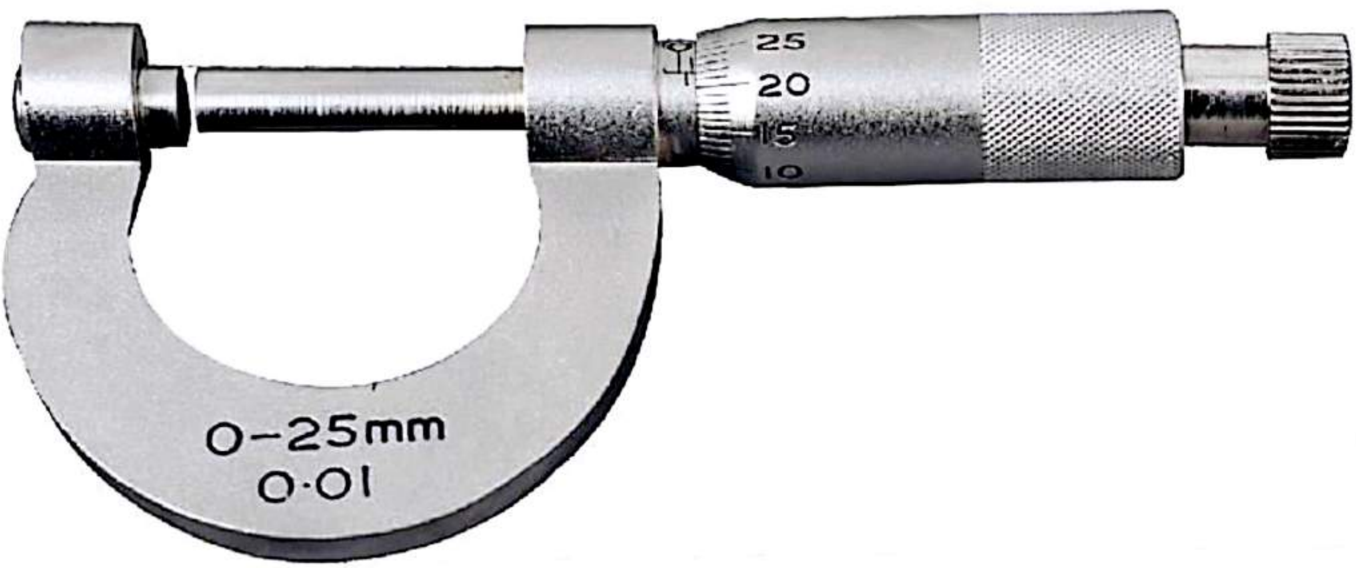
Chapter–1

Physical World and Measurement



CBSE CLASS XI NOTES

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Syllabus [course structure]

unit - I	Physical world and measurement	3
unit - II	Kinematics	10
unit - III	laws of motion	10
unit IV	Work, Energy & Power	6
unit V	motion of system of particles & Rigid body.	6
unit VI	Gravitation	5
unit - VII	Properties of Bulk matter	10
unit - VIII	Thermodynamics	5
unit - IX	Behavior of perfect gas & kinetic theory of gases	5
unit - X	Oscillation & Waves.	10

Simil...

Physics:- study of matter and energy. It is also the systematic study of the universe.

Classical physics (pre-1900)

Includes study of mechanics, gravitation, heat, sound, light, electricity and magnetism

Modern Physics [post-1900]

Includes the study of quantum mechanics, Atomic physics, Nuclear physics, molecular physics, Relativity, electronics, particle physics and plasma physics.

Scientific method

(i) Observation of relevant facts
(ii) proposal of theory based on these observations
(iii) Testing of the proposed theory by experiments.
(iv) Modification if necessary.

Physics Technology and society.

1, steam engine	laws of thermodynamics
2, Nuclear reactor	Nuclear fission.
3, Rocket propulsion	Newtons laws of motion
4, Radio & T.V	propagation of e.m waves
5, Aeroplane	Bernoulli's principle.
6, computer	Digital logic.

Fundamental forces in Nature.

1, **Gravitational force.**

It is the weakest force in nature and is always attractive.

$$F = \frac{G m_1 m_2}{r^2}$$

2, **Electromagnetic or electrostatic force.**

It is the force between electrically charged particles.

→ can be attractive or repulsive.

3, **Strong Nuclear force**

It is the streongest force. always attractive.

→ Force b/w nucleons

n-n

p-p.

p-n

→ charge Independent.

→ very short range

4, Weak Nuclear force.

come into play during β (Beta) decay of radio active nucleus.

conservation laws

1, law of conservation of linear momentum.

In the absence of an external force, the total linear momentum of a system remains constant.

2, law of conservation of Angular momentum

In the absence of an external torque, the total angular momentum of a system remains constant.

3, law of conservation of Energy.

Physical Quantity

The quantities in physics which can be measured directly or indirectly in terms of laws of physics

units

The measurement of physical quantity involves its comparison with a chosen standard of same kind. This reference standard is called a unit.

Fundamental physical Quantity

Quantities which cannot be defined in terms of other physical quantities.

The fundemental units are the units of fundemental quantities.

Eg; Length, Mass and Time.

Derived Units/physical Qnty.

Physical quantities which can be ~~derived~~ expressed in terms of fundamental quantities are called derived quantities

units :- Derived units

Eg; velocity, acceleration

systems of unit

(1) CGS systems - centimetre, gram second

(2) FPS - foot, Pound, second.

(3) MKS - Metre, kilogram second.

SI units

1, Mass	kg.
2, Length	m
3, Time	s
4, Temperature	K
5, Electric current	A
6, luminous Intensity	cd (candela)
7, amount of substance	mol

supplementary Units

1, Plane angle - radian (rad)

2, solid angle - steradian (sr)

Advtgs of SI

(1) It is comprehensive

(2) coherent

(3) International acceptance.

light year

$1\,ly = 9.46 \times 10^{15} m$

Astronomical unit (AU) $= 1.50 \times 10^{11} m$

Angstrom unit (Å) $= 10^{-10} m$

Fermi (fm) $= 10^{-15} m$

10^{12} tera - T	10^{-1} deci d
10^{9} giga - G	10^{-2} centi c
10^{6} mega - M	10^{-3} mili m
10^{3} kilo - k	10^{-6} micro - μ
10^{2} hecto - h	10^{-9} nano - n
10^{1} deka - da	10^{-12} pico - p
	10^{-15} femto - f
	10^{-18} atto a

some length measurements

(i) Measurement of large distance by angular measurement $x = r\theta$.

(ii) Parallax method. $\theta = \frac{x}{r}$

(iii) Reflection method.

→ SONAR [sound Navigation and Ranging]

→ RADAR [Radio detection and Ranging]

Dimensions

The dimension of a physical quantity are the powers to which the fundamental quantities (mass, length, time...) ~~can be~~ are to be raised.

eg; $k\, M^x L^y T^z$

$x, y, z \rightarrow$ How many times

$k \rightarrow$ constant.

Dimensional Equation

The expression which indicates the units of a physical quantity in terms of the fundemental units is called dimensional equation.

eg;

Area = Length × length
$= L \times L = L^2$
$= M^0 L^2 T^0$

Volume $= L^3 = M^0 L^3 T^0$

Density $= \frac{\text{Mass}}{\text{Volume}} = \frac{M}{L^3}$
$= M L^{-3} T^0$

Velocity $= \frac{\text{Disp}}{\text{Time}} = \frac{L}{T} = M^0 L T^{-1}$

Acceleration $= \frac{\text{Vel}}{\text{Time}} = \frac{LT^{-1}}{T} = LT^{-2}$
$= \underline{M^0 L T^{-2}}$

Force = Mass × acceleration
$= \underline{M L T^{-2}}$

Pressure $= \frac{\text{Force}}{\text{Area}} = \frac{MLT^{-2}}{L^2}$
$= \underline{M L^{-1} T^{-2}}$

pressure $= \frac{F}{A}$

work = Force × displacement
$= MLT^{-2} \times L = \underline{ML^2T^{-2}}$

Power $= \frac{\text{Work}}{\text{Time}} = \frac{ML^2T^{-2}}{T}$
$= \underline{ML^2T^{-3}}$

Gas Const $R = \frac{PV}{T}$
$= \frac{ML^{-1}T^{-2} \times L^3}{K}$
$= \underline{ML^2T^{-2}K^{-1}}$

Electric charge q = current × time
$= \underline{AT}$

Electric potential, V $= \frac{\text{work}}{\text{charge}}$
$= \frac{ML^2T^{-2}}{AT}$
$= \underline{ML^2T^{-3}A^{-1}}$
$= \underline{MA^{-1}L^2T^{-3}}$

note: ① Quantities such as number, angle and trigonometrical ratios are dimensionless.
② Angle has unit but no dimension

momentum = Mass × velocity

$= [M][LT^{-1}]$

$= [MLT^{-1}]$

Pressure, stress = $\frac{\text{Force}}{\text{Area}}$

$= \frac{MLT^{-2}}{L^2}$

$= [ML^{-1}T^{-2}]$

Mass density

$= \frac{\text{Mass}}{\text{Volume}} = \frac{M}{L^3}$

$= [ML^3T^0]$

frequency = $\frac{1}{\text{Time period}}$

$= [M^0L^0T^{-1}]$

acceleration due to gravity = $\frac{\text{change in velocity}}{\text{Time taken}}$

$= \frac{LT^{-1}}{T} = [LT^{-2}]$

$= [M^0LT^{-2}]$

wave length = distance

$= L$

$= [M^0LT^0]$

Impulse = Force × time

$= MLT^{-2} \times T$

$= [MLT^{-1}]$

strain = $\frac{\text{change in Dimension}}{\text{original Dimension}}$

$= \frac{L}{L} = [M^0L^0T^0]$

surface Tension = $\frac{\text{Force}}{\text{length}}$

$= \frac{MLT^{-2}}{L} = [ML^0T^{-2}]$

Electric current (I) = $[M^0L^0T^0A^1]$

Principle of Homogeneity of dimensions.

The dimensions of all the terms on the two sides of the equation are the same.

uses of Dimensional Analysis.

(1) To check the correctness of an equation

An equation is correct only if the dimensions of each term on either side of the equation are equal.

Eg; $S = ut + \frac{1}{2}at^2$.

$S = L$

$ut = LT^{-1} \times T = L$

$\frac{1}{2}at^2 = \frac{1}{2} LT^{-2} \times T^2 = L$

∴ all has same dimension. so the equation is dimensionally correct.

② $v = u + at$.

$v = LT^{-1}$.

$u = LT^{-1}$

$at = LT^{-2} \times T$

$= LT^{-1}$

∴ the equation is dimensionally correct.

③ $v^2 = u^2 + 2as$.

$v^2 = [LT^{-1}]^2 = [L^2T^{-2}]$

$[u^2] = [LT^{-1}]^2 = [L^2T^{-2}]$

$2as = \cancel{2}\, LT^{-2} \times L$

$= \underline{\underline{L^2T^{-2}}}$

∴ Formula is correct

④ $\frac{1}{2}mv^2 = mgh$

$M[LT^{-1}]^2 = [ML^2T^{-2}]$ ... ①

$mgh \Rightarrow MLT^{-2}L$

$= [ML^2T^{-2}]$. ②

∴ ① = ②

Formula is correct.

(ii) To derive the correct relationship b/w physical quantities.

(1) S.T $T = 2\pi\sqrt{\frac{l}{g}}$

The period of oscillation 't' of a simple pendulum may depend on (i) the length of pendulum l, (ii) Mass of bob m (iii) acceleration due to gravity g.

$t = k\, L^x M^y g^z$ -- ⓐ

$T = L^x M^y [LT^{-2}]^z$ [∵ k is dimensionless]

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

equating dimensions of L, M & T.

$x + z = 0$. - - ①

$y = 0$.

$-2z = 1$

$z = -1/2$ . . . ②

① ⇒ $x - 1/2 = 0$ ∴ $x = 1/2$

ⓐ ⇒

∴ $T = k\, l^{1/2} M^0 g^{-1/2}$

$T = k\sqrt{\frac{l}{g}}$ [$k = 2\pi$ const]

∴ $T = 2\pi\sqrt{\frac{l}{g}}$.

② The frequency 'n' of a streched string may depend upon (i) length of the vibrating segment l (ii) the tension in the string F and (iii) The mass per unit length m. S.T.

$\therefore \nu = \frac{k}{l}\sqrt{\frac{F}{m}}$

$\nu \propto l^x F^y m^z$

$\nu = k\, l^x F^y m^z$ -- (1)

taking Dimensions

$T^{-1} = L^x [MLT^{-2}]^y \left[\frac{M}{L}\right]^z$

$T^{-1} = L^x [M^y L^y T^{-2y}] \left[\frac{M}{L}\right]^z$

$T^{-1} = L^x [M^y L^y T^{-2y}][M^z L^{-z}]$

$T^{-1} = L^{x+y-z} M^{y+z} T^{-2y}$

$\therefore x+y-z=0$

$y+z=0$ $\quad \therefore \frac{1}{2}+z=0$

$-2y=-1$ $\quad z=-\frac{1}{2}$

$y=\frac{1}{2}$ $\quad \therefore x+\frac{1}{2}+\frac{1}{2}=0$

$x+1=0$

$x=-1$

$\therefore$ (1) $\Rightarrow \nu = k\, L^{-1} F^{1/2} m^{-1/2}$

$\therefore \boxed{\nu = \frac{k}{l}\sqrt{\frac{F}{m}}}$

(3) A body of mass 'm' is executing circular motion around a circle of radius r with speed v. It experiences centripetal force F. P.T $F = \frac{mv^2}{r}$ dimensionally.

$F = k\, m^x v^y r^z$ -- (1)

dimensions ⇒

$MLT^{-2} = M^x [LT^{-1}]^y [L]^z$

$MLT^{-2} = M^x L^{y+z} T^{-y}$

$x=1$ $\quad \therefore y+z=1$

$y+z=1$ $\quad 2+z=1$

$-y=-2$ $\quad z=-1$

$y=2$

$\therefore$ (1) $\Rightarrow F = m^1 v^2 r^{-1}$

$\therefore \boxed{F = \frac{mv^2}{r}}$

[ii] To convert from one system of units to another systems of units using dimesion.

(1) convert 1N to dynes.

They are units of force in SI & CGS respectively.

Force = MLT^{-2}

general formula

$n_1 M_1^a L_1^b T_1^c = n_2 M_2^a L_2^b T_2^c$

$\therefore n_2 = n_1 \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$

$$n_2 = n_1\left[\frac{M_1}{M_2}\right]^1\left[\frac{L_1}{L_2}\right]^1\left[\frac{T_1}{T_2}\right]^{-2}$$

$$n_2 = n_1\left[\frac{1kg}{1g}\right]^1\left[\frac{1m}{1cm}\right]^1\left[\frac{1sec}{1sec}\right]^{-2}$$

$[n_1 = 1]$

$$= \frac{1000g}{1g} \cdot \frac{100cm}{1cm} \cdot 1$$

$$= 1000 \cdot 100 = 10^5$$

$\therefore$ 1 newton = 10^5 dyne.

(2) 1 Joule to 1 erg.

* both are units of work

$$[W] = ML^2T^{-2}$$

$$n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$$

$$n_2 = n_1\left[\frac{M_1}{M_2}\right]^1\left[\frac{L_1}{L_2}\right]^2\left[\frac{T_1}{T_2}\right]^{-2}$$

$(n_1 = 1)$

$$= 1\left[\frac{kg}{g}\right]^1\left[\frac{m}{cm}\right]^2\left[\frac{sec}{sec}\right]^{-2}$$

$$= 1\left[\frac{1000g}{g}\right]\left[\frac{100cm}{1cm}\right]^2 \times 1$$

$$= 1\,[1000][100]^2$$

$$= 1\,[1000][10000]$$

$$= 1\,[10000000]$$

$$n_2 = 10^7$$

$$1J = 10^7 \text{ erg}$$

To find dimensional constants like a, b, c.

(1) In vander wall's equation $\left[P + \frac{a}{V^2}\right](V-b) = RT$ what are the dimensions of a & b? Here P is pressure, V is volume; 'T' is temperature and 'R' is a gas constant?

$$\left[P + \frac{a}{V^2}\right](V-b) = RT$$

As pressure can be added only to pressure

$$\therefore \frac{a}{V^2} = P$$

$$a = PV^2$$

$$a = ML^{-1}T^{-2}[L^3]^2$$

$$= ML^{-1}T^{-2}[L^6]$$

$$a = ML^5T^{-2}$$

again 'b' represents volume [Volume only can be subs tracted from vol]

$$b = V$$

$$b = [L^3]$$

$$b = M^0L^3T^0$$

[2] If $x = a + bt + ct^2$ where x is metres and t in sec. obtain the unit and dimension of a, b & c?

Dimension of LHS

$x = L^1$

Applying principle of Homogeneity

R.H.S = L.H.S

$\rightarrow x = a$

$a = \underline{\underline{L}}$

$bt = x$

$bT^1 = L$

$\rightarrow b = \frac{L}{T} = \underline{\underline{LT^{-1}}}$

$\rightarrow ct^2 = x$

$cT^2 = L$

$c = \frac{L}{T^2} = \underline{\underline{LT^{-2}}}$

(3) $V = at^2 + bt + c$

$V = m/s$

L.H.S = R.H.S

$LT^{-1} = at^2$

$LT^{-1} = aT^2$

$\therefore a = \frac{LT^{-1}}{T^2}$

$a = \underline{\underline{LT^{-3}}} = \underline{\underline{M^0LT^{-3}}}$

$LT^{-1} = bt$

$LT^{-1} = bT$

$b = \frac{LT^{-1}}{T}$ $\therefore \underline{\underline{b = LT^{-2}}}$

$b = \underline{\underline{M^0LT^{-2}}}$

$\underline{\underline{c = LT^{-1}}} = \underline{\underline{M^0LT^{-1}}}$

(4) If $V = at + \frac{b}{t+c}$, obtain a, b, c?

Dimension of $V = LT^{-1}$

$\therefore$ L.H.S = R.H.S

$V = at$

$LT^{-1} = aT$

$a = \frac{LT^{-1}}{T} = \underline{\underline{LT^{-2}}}$

$LT^{-1} = \frac{b}{t+c}$

$LT^{-1} = \frac{b}{T+c}$

$\frac{T+c}{b} = L^{-1}T^{+1}$

$\frac{T}{b} + \frac{c}{b} = L^{-1}T^{+1}$

$\frac{T}{b} + \frac{c}{b} = L^{-1}T^1$

$\frac{T}{b} = L^{-1}T^1$

$b = \frac{T}{L^{-1}T^1} = \underline{\underline{L}}$ $\therefore \underline{\underline{b = M^0L^1T^0}}$

$\rightarrow \frac{c}{b} = L^{-1}T^1$

$c = b\,L^{-1}T^1$

$c = L\,L^{-1}T^1$

$\underline{\underline{c = T^1}}$ $\therefore \underline{\underline{c = M^0L^0T^1}}$

LIMITATIONS OF DIMENSIONAL ANALYSIS

(1) In Mechanics, this method is not suitable if the physical quantity depend on more

than three other physical quantities

(2) This method does not tell us anything about dimensionless quantities

(3) This method cannot be employed if R.H.S of equation contains more than one term.

(4) Quite often it is difficult to guess parameters on which the physical quantity depends.

SIGNIFICANT FIGURES

The significant figures in a measured physical quantity indicates the number of digits in which we have confidence in respect of their accuracy.

* The greater the number of significant figures, the more accurate is the measurement.

Rules to determine significant figures

(1) All the non-zero digits are significant.

(2) The no of significant figures in a number is equal to the no of digits counted from the first non-zero digit on the left to the last digit on the right

eg; 18.45 → 4 sign fig

(3) All zero's occuring between two non-zero digits are significant

eg; 180.045 → 6 - significant figures

(4) If no starts with decimal all zeros on the left side are not significant, but on right side are significant

eg; 0.0001845 → 4 sig fig

0.004030 → 4 sign fig

(5) If a number has an Integral part and decimal part, all zeros in the number are significant

eg; 30.10 → 4 (sign fig)

30.00 → 4 (S.f)

(6) where there is no decimal part, the last zero's are not significant.

eg, 102000 → 3 [Sf]

Eg; [s.f]

$300 \rightarrow 1$

$3\times10^2 \rightarrow 1$

$3.0\times10^2 \rightarrow 2$

$3.00\times10^2 \rightarrow 3$

$403 \rightarrow 3$

$40.3 \rightarrow 3$

$4.03 \rightarrow 3$

$0.403 \rightarrow 3$

$0.0403 \rightarrow 3$

$0.04030 \rightarrow 4$

$403.0 \rightarrow 4$

$40.30 \rightarrow 4$

$1.02\times10^3 \rightarrow 3$

Errors In measurement.

when we take a measurement with an Instrument the measured value is usually different from the true value. There is always an uncertainity in the measurement. This uncertinity is called error.

accuracy - of a measurement is a measure of how close a measured value is to the true value of the quantity.

Absolute Error

magnitude of difference between the true value and a measured value is called the absolute error in the measurement.

$$\Delta a_i = |\bar{a} - a_i|$$

$\bar{a} \rightarrow$ True value

$\Delta a_i \rightarrow$ absolute error in the i^{th} measurement.

* It is expressed in the unit of measured values.

mean Absolute Error.

The arithemetic mean of the absolute errors in various measurements.

$$\overline{\Delta a} = \frac{\Delta a_1 + \Delta a_2 + \Delta a_3 + \ldots \Delta a_n}{n}$$

* $\Delta a_1, \Delta a_2, \Delta a_3 \ldots \rightarrow$ absolute errors
* measurement can have any value lying b/w $\bar{a} + \Delta a$ & $\bar{a} - \Delta a$

Relative error and percentage error

The relative error is defined as the ratio of mean absolute error to the true value.

$$\text{Relative error} = \frac{\overline{\Delta a}}{\bar{a}}$$

$$\text{Percentage error} = \left(\frac{\overline{\Delta a}}{\bar{a}}\right) \times 100\%$$

Eg (2.7) · We measure the period of oscillation of a simple pendulum. In successive measurements, the readings turn out to be 2.63 s, 2.56 s, 2.42 s, 2.71 s and 2.80 s. calculate absolute errors, relative error or percentage error.

$$T_{mean} = \frac{2.63+2.56+2.42+2.71+2.8}{5}$$

$$T_{mean} = \frac{13.12}{5} s = \underline{\underline{2.624 s}}$$

$$T_{mean} = \underline{\underline{2.62}}\ s$$

absolute errors (Δa)

$2.63 - 2.62 = 0.01\ s$

$2.56 - 2.62 = -0.06\ s$

$2.42 - 2.62 = -0.20\ s$

$2.71 - 2.62 = +0.09\ s$

$2.80 - 2.62 = +0.18\ s$

mean ~~Relative~~ Absolute error $(\bar{\Delta a}) = \frac{[(0.01+.06+.20+0.09+.18)]}{5}$

$\bar{\Delta a} = \underline{\underline{0.11 s}}$

percentage error $= \frac{0.11}{2.62} \times 100$

$= 4\ \%$

relative error $= \frac{0.11}{2.62} = \underline{\underline{0.04}}$

combination of errors

(i) error in sum
(ii) error in difference
(iii) error in product
(iv) error in a quotient
(v) error when a quantity is raised to power.

(1) Errors in a sum.

If 'z' be the sum of two observed quantities x and y.

$$z = x + y$$

$$\therefore z \pm \Delta z = (x \pm \Delta x) + (y \pm \Delta y)$$

$\therefore$ maximum possible error in z is

$$\boxed{\Delta z = \Delta x \pm \Delta y}$$

relative error in z is

$$\boxed{\frac{\Delta z}{z} = \frac{\pm(\Delta x \pm \Delta y)}{x+y}}$$

% error in z is

$$\boxed{\frac{\Delta z}{z} \times 100 =}$$

$$\boxed{\frac{\pm(\Delta x + \Delta y)}{(x+y)} \times 100}$$

(ii) Error in a difference

$$\boxed{z = x - y}$$

maximum possible error in 'z' is

$$\boxed{\Delta z = \Delta x \pm \Delta y}$$

relative error $= \boxed{\frac{\Delta z}{z} = \frac{\Delta x \pm \Delta y}{z}}$

$$\boxed{\frac{\Delta z}{z} = \frac{\pm(\Delta x \pm \Delta y)}{x-y}}$$

percentage error in z is

$$\frac{\Delta z}{z}\times 100 = \frac{\pm(\Delta x + \Delta y)}{x-y}\times 100$$

(iii) Error in a product

$\therefore z = xy.$

$$(z \pm \Delta z) = (x \pm \Delta x)(y \pm \Delta y)$$

max possible error

$$\pm\frac{\Delta z}{z} = \pm\left(\frac{\Delta x}{x}\right) \pm \left(\frac{\Delta y}{y}\right)$$

maximum relative error

$$\frac{\Delta z}{z} = \pm\left[\left(\frac{\Delta x}{x}\right) + \left(\frac{\Delta y}{y}\right)\right]$$

% error in z is

$$\left(\frac{\Delta z}{z}\right)\times 100 = \pm\left[\left(\frac{\Delta x}{x}\right) + \left(\frac{\Delta y}{y}\right)\right]\times 100\%$$

iv Error in a Quotient

Let $z = \frac{x}{y}$.

ma $$(z \pm \Delta z) = \frac{(x \pm \Delta x)}{(y \pm \Delta y)}$$

maximum possible error

$$\pm\frac{\Delta z}{z} = \pm\left(\frac{\Delta x}{x}\right) \pm \left(\frac{\Delta y}{y}\right)$$

• Relative error

$$\frac{\Delta z}{z} = \pm\left(\frac{\Delta x}{x} + \frac{\Delta y}{y}\right)$$

% error in z is

$$\left(\frac{\Delta z}{z}\right)\times 100 = \pm\left[\frac{\Delta x}{x} + \frac{\Delta y}{y}\right]\times 100\%$$

(v) Error when a Quantity is raised to a power.

let $z = \frac{x^a}{y^b}$

max $$\left(\frac{\Delta z}{z}\right) = \pm a\left(\frac{\Delta x}{x}\right) + b\left(\frac{\Delta y}{y}\right)$$

relative error $$\frac{\Delta z}{z} = \pm a\left(\frac{\Delta x}{x}\right) + b\left(\frac{\Delta y}{y}\right)$$

% error

$$\left(\frac{\Delta z}{z}\right)\times 100 = \left[\pm a\left(\frac{\Delta x}{x}\right) + b\left(\frac{\Delta y}{y}\right)\right]\times 100\%$$

Numericals.

(1) The resistance $R = \frac{V}{I}$ where $V = (100 \pm 5)V$ and $I = (10 \pm 0.2)A$. Find the % error in R?

sol:

% error in V = 5%

% error in I = 2%

$\therefore$ % in R = 5% + 2% = 7%

(2) Find the relative error in z, if $z = A^4 B^{1/3} / C D^{3/2}$?

relative error is Z is

$$\frac{\Delta Z}{Z} = 4\left(\frac{\Delta A}{A}\right)+\left(\frac{1}{3}\right)\left(\frac{\Delta B}{B}\right)+\left(\frac{\Delta C}{C}\right)+\left(\frac{3}{2}\right)\left(\frac{\Delta D}{D}\right)$$

(3) The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{l/g}$. Measured value of L is 20.0 cm known to 1mm accuracy and time for 100 oscillations of a pendulum is found to be 90s. using a wrist watch of 1s resolution. what is the accuracy in the determination of g?

given $L = 20cm$

$\Delta l = 1mm = 0.1cm$

$T = 90s$

$\Delta T = 1\ s$

$T = 2\pi\sqrt{l/g}$, $T^2 = 4\pi^2 \frac{l}{g}$

$g = 4\pi^2 \frac{l}{T^2}$

$$\frac{\Delta g}{g} = \left(\frac{\Delta l}{L}\right) + 2\left(\frac{\Delta T}{T}\right)$$

$$= \frac{0.1}{20} + 2\times\frac{1}{90}$$

$$= \frac{9+40}{1800} = \frac{49}{1800}$$

$$\frac{\Delta g}{g} = \underline{\underline{0.027}} \approx 0.03$$

% error $= 0.03 \times 100$

$= \underline{\underline{3\%}}$

* The physical quantity 'p' is related to a, b, c and d as follows.

$$P = \frac{a^3 b^2}{\sqrt{c}\, d}$$

The percentage error of measurement in a, b, c and d are 1%, 3%, 4% and 2% respectively what is the % error in the quantity P.

$$\frac{\Delta P}{P}\times 100 = 3\left(\frac{\Delta a}{a}\right)\times 100 + 2\left(\frac{\Delta b}{b}\right)\times 100 + \frac{1}{2}\left(\frac{\Delta c}{c}\right)\times 100 + \frac{\Delta d}{d}\times 100$$

$$\frac{\Delta P}{P}\times 100 = 3\times 1\% + 2\times 3\% + \frac{1}{2}\times 4\% + 2\%$$

$$= 3+6+2+2$$

$$= 13\%$$

$\therefore \frac{\Delta P}{P}\times 100 = 13\%$

$\therefore$ % error is $\underline{\underline{P = 13\%}}$

* The diameter of a wire measured by a screw gauge was found to be 1.328, 1.330, 1.325, 1.326, and 1.334, 1.336 cm. calculate the Absolute errors, relative errors and % error.

(1) True value.

$\bar{a} =$

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$$\bar{a} = \frac{1.328 + 1.330 + 1.325 + 1.326 + 1.334 + 1.336}{6}$$

$$= \frac{7.979}{6} = \underline{\underline{1.3298}}$$

$\bar{D} = \underline{1.330}$

(ii) Absolute errors (Δa)

$1.328 - 1.330 = 0.002$

$1.330 - 1.330 = 0.00$

$1.325 - 1.330 = 0.005$

$1.326 - 1.330 = 0.004$

$1.334 - 1.330 = 0.004$

$1.336 - 1.330 = 0.006$

(iii) Mean Absolute error.

$$\overline{\Delta a} = \frac{0.002 + 0.00 + 0.005 + 0.004 + 0.004 + 0.006}{6}.$$

$$\overline{\Delta a} = \frac{0.021}{6} = \underline{\underline{0.0035}} = 0.004$$

(iv) Relative error

$$= \frac{\overline{\Delta a}}{a} = \frac{0.004}{1.33} = \underline{\underline{0.003}}$$

(v) percentage error $= \frac{\overline{\Delta a}}{a} \times 100$

$= 0.003 \times 100$

$= \underline{\underline{0.3\%}}$

$\therefore D = \bar{D} \pm \Delta\bar{D}$

$= 1.330 \pm 0.004.$

$D = \underline{\underline{1.330 \pm 0.004 \text{ cm}}}$

Numericals for practice

1, Find the dimension of a/b in the relation

$F = a\sqrt{x} + bt^2.$

where $F \rightarrow$ force
$x \rightarrow$ distance
$t \rightarrow$ time

Ans: $[L^{-1/2}, T^2]$

2, Find the dimensions of a & b

$$E = \frac{b - x^2}{at}.$$

$E \rightarrow$ Energy
$x \rightarrow$ distance
$t \rightarrow$ time

Ans: $[M^{-1} L^2 T^1]$

3, Find the dimensions of a/b.

$$P = \frac{a - t^2}{bx}.$$

$P \rightarrow$ pressure, x - distance
$t \rightarrow$ time.

Ans: $[M T^{-2}]$

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