XI - CHAP: 1: UNITS AND MEASUREMENTS - PART-1

*** Physical Quantity:**
It is a quantity which can be measured.
eg. Length, mass, time, temperature, force, energy, pressure, distance, velocity etc.

*** Unit:** It is a standard used for the measurement of physical quantity.
eg. metre, kilogram, second, kelvin, newton, joule, pascal etc.

*** System of Units:**
1) CGS-system : Centimetre Gram Second system.
2) MKS-System : Metre Kilogram Second system.
3) FPS-System : Foot Pound Second system
4) SI-system : SI-System.

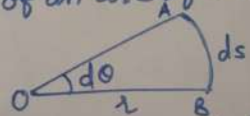
*** Fundamental Quantity:** It is a physical quantity which do not depends on any other physical quantity for its measurement.
eg. Length, mass, time, temperature, electric current, luminous intensity & amount of substance.

*** Fundamental unit:** It is the unit of fundamental quantity.
eg. metre (m), kilogram (kg), second (s), kelvin (K), ampere (A), candela (cd), mole (mol).

*** Derived Quantity:** - It is a physical quantity which depends upon one or more fundamental quantity for its measurement.
eg. Area, velocity, acceleration, density, force, pressure, energy, work etc.

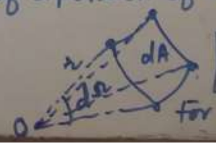
*** Derived unit:** It is the unit of derived quantity.
eg: m^2, m/s, m/s^2, kg/m^3, newton, pascal, joule etc.

*** Supplementary Quantities:-**
1) Plane angle ($d\theta$): It is the ratio of the length of an arc of a circle to the radius of circle.



$\boxed{d\theta = \frac{ds}{r}}$ unit of θ = radian (rad)

2) Solid angle ($d\Omega$): It is the ratio of the area of a portion of surface of a sphere to the square of radius of a sphere.



$\boxed{d\Omega = \frac{dA}{r^2}}$ unit of Ω = steradian (sr).

For entire sphere $\Omega = \frac{4\pi r^2}{r^2} = 4\pi$ sr.

XI - CHAP: 1: UNITS AND MEASUREMENTS - PART-2

* Conventions for the use of SI units.

1) Unit of every physical quantity should be represented by its symbol.

2) Full name of unit should start with small initial letter, even it is the name of person.
eg. newton, kilogram, joule **Not** Newton, Kilogram, Joule.

3) Symbol of unit which is the name of person should start with capital initial letter
eg. N, J, P **Not** n, j, p.

4) The symbol of other units (not name of person) shold start with small initial letter.
eg. m, kg, cd **Not** M, Kg, Cd.

5) Symbols for units do not take plural form.
eg. 10 N, 100 kg **Not** 10 Ns, 100 kgs.

6) Symbols of units do not contain any full stop or any punctuation mark.
eg. 2 m, 50 N **Not** 2 m., 50 'N'.

7) In numerator & denominator form it remains in one ratio
eg. m/s^2 or $m s^{-2}$ **Not** m/s/s.

8) Use of combination of units & symbols for units is avoided when physical quantity is expressed by combination of two.
eg J/kg K or joule/kg K.

9) A prefix symbol is used before the symbol of the unit
eg 1 ms = 1 millisecond = 10^{-3} s
1 μs = 1 microsecond = 10^{-6} s
1 ns = 1 nanosecond = 10^{-9} s
Not 10^{-6} s = 1 mms
10^{-9} s = 1 mμs.

10) Space or hypen must be introduced while indicating multiplication of two units.
eg m/s as $m\,s^{-1}$ or $m\text{-}s^{-1}$ **Not** ms^{-1}.

* Dimensions:-

The dimensions of a physical quantity are defined as the powers to which the fundamental units must be raised in order to obtain the unit of that quantity.

XI - CHAP:1: UNITS AND MEASUREMENTS - PART-2

6) density

$$\text{density} = \frac{\text{mass}}{\text{Volume}} = \frac{M}{V} \quad -- (V = L^3)$$

$$d = \frac{M}{L^3}$$

$$[d] = [L^{-3} M^1 T^0]$$

7) Electric charge

$$\text{Electric current} = \frac{\text{Charge}}{\text{Time}}$$

$$I = \frac{Q}{T}$$

$$\therefore Q = IT$$

$$[Q] = [L^0 M^0 T^1 I^1]$$

8) velocity gradient

$$\text{velocity gradient} = \frac{\text{velocity}}{\text{distance}} = \frac{V}{L}$$

$$(\because V = \frac{L}{T})$$

$$\therefore \text{velocity gradient} = \frac{\cancel{L}}{T\cancel{L}} = \frac{1}{T}$$

$$[\text{velocity gradient}] = [L^0 M^0 T^{-1}]$$

2) Area

$$\text{Area} = \text{Length} \times \text{breadth}$$

$$A = L \times L$$

$$A = L^2$$

$$[A] = [L^2 M^0 T^0]$$

3) volume

$$\text{Volume} = \text{length} \times \text{breadth} \times \text{height}$$

$$V = L \times L \times L$$

$$V = L^3$$

$$[V] = [L^3 M^0 T^0]$$

4) velocity

$$\text{velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{\text{length}}{\text{Time}}$$

$$v = \frac{L}{T}$$

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

5) Acceleration

$$\text{Acceleration} = \frac{\text{velocity}}{\text{Time}}$$

$$a = \frac{L}{T^2}$$

$$[a] = [L^1 M^0 T^{-2}]$$

XI - CHAP: 1: UNITS AND MEASUREMENTS - PART - 3

Uses of dimensional analysis

1) **To check the correctness of physical equations:**

The 2nd kinematical equation is

$$s = ut + \frac{1}{2}at^2 \quad \text{—— (1)}$$

s = displacement $= [s] = [L^1 M^0 T^0]$

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

t = Time $= [t] = [L^0 M^0 T^1]$

a = acceleration $= [a] = [L^1 M^0 T^{-2}]$

$\therefore$ From eq^n (1)

$$[s] = [u] \times [t] + \frac{1}{2}[a] \times [t]^2$$

$$[L^1 M^0 T^0] = [L^1 M^0 T^{-1}] \times [L^0 M^0 T^1] + \frac{1}{2}[L^1 M^0 T^{-2}] \times [L^0 M^0 T^1]^2$$

$$(a^m)^n = a^{mn}, \quad a^m \times a^n = a^{m+n}$$

$$[L^1 M^0 T^0] = [L^1 M^0 T^0] + \frac{1}{2}[L^1 M^0 T^{-2}] \times [L^0 M^0 T^2]$$

$$[L^1 M^0 T^0] = [L^1 M^0 T^0] + \frac{1}{2}[L^1 M^0 T^0]$$

Compare the powers of L M & T

$\therefore$ Dimensions of LHS = Dimensions of RHS

$\therefore$ $s = ut + \frac{1}{2}at^2$ is Correct.

2) **To establish the relationship between related physical quantities.**

The period (T) of Oscillation of simple Pendulum depends on length (l) & acc^n due to gravity (g).

$$\therefore T \propto l^a g^b$$

$$T = k\, l^a g^b \quad \text{—— (1)}$$

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

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

$[g] = [L^1 M^0 T^{-2}]$

From eq^n (1)

$$[L^0 M^0 T^1] = k[L^1 M^0 T^0]^a \times [L^1 M^0 T^{-2}]^b$$

$$[L^0 M^0 T^1] = k[L^a M^0 T^0] \times [L^b M^0 T^{-2b}]$$

$$\therefore [L^0 M^0 T^1] = k[L^{a+b} M^0 T^{-2b}]$$

Compare the powers

$\therefore a + b = 0$ —— (2)

$-2b = 1 \Rightarrow \boxed{b = -\frac{1}{2}}$ —— (3)

put (3) into (2)

$\therefore a - \frac{1}{2} = 0 \Rightarrow \boxed{a = \frac{1}{2}}$ —— (4)

put (3) & (4) into (1)

$$T = k\, l^{1/2} g^{-1/2}$$

$$\therefore T = k\frac{l^{1/2}}{g^{1/2}} = k\left(\frac{l}{g}\right)^{1/2}$$

$$\therefore \boxed{T = 2\pi\sqrt{\frac{l}{g}}} \quad \text{—— (5)}$$

By experiment $k = 2\pi$

3) **To find the conversion factor bet^n the units of the same physical quantity in two diff. systems of units**

For physical quantity force SI unit is (N) & CGS unit is (dyne).

$\therefore$ 1 N = x dyne —— (1)

$$[M_1^1 L_1^1 T_1^{-2}] = x[M_2^1 L_2^1 T_2^{-2}]$$

$$\therefore x = \frac{[M_1^1 L_1^1 T_1^{-2}]}{[M_2^1 L_2^1 T_2^{-2}]}$$

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

$$\therefore x = \left[\frac{kg}{g}\right]^1 \times \left[\frac{m}{cm}\right]^1 \times \left[\frac{s}{s}\right]^{-2}$$

XI - CHAP: 1: UNITS AND MEASUREMENTS - PART - 4

but $1\,kg = 1000\,g$, $1\,m = 100\,cm$.

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

$$\therefore x = 1000 \times 100$$

$$x = 10^3 \times 10^2$$

$$x = 10^5 \quad \text{--- (2)}$$

put (2) into (1)

$$\boxed{1\,N = 10^5\,dyne} \quad \text{--- (3)}$$

Limitations of dimensional analysis

1) The value of dimensional constant can be obtained with the help of experiments only.
2) It is not used to derive relations for trigonometric, exponential and logarithmic Funct[illegible] dimensionless.
3) It is not usefull if the constant of proportionality is not dimensional. ($F = G\frac{m_1 m_2}{r^2}$, G has some dimensions).
4) If the correct eqn. contains some more terms of the same dimensions, it is not possible to know about their presence.

eq. $s = ut + \frac{1}{2}at^2$ is the eqn.

but $s = ut$ as well as $s = \frac{1}{2}at^2$ are dimensionally correct.

3) To find the conversion factor betn the units of the same physical quantity in two diff. systems of units

For physical quantity force SI unit is (N) & CGS unit is (dyne).

$$\therefore 1\,N = x\,dyne \quad \text{--- (1)}$$

$$[M_1^1 L_1^1 T_1^{-2}] = x[M_2^1 L_2^1 T_2^{-2}]$$

$$\therefore x = \frac{[M_1^1 L_1^1 T_1^{-2}]}{[M_2^1 L_2^1 T_2^{-2}]}$$

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

$$\therefore x = \left[\frac{kg}{g}\right]^1 \times \left[\frac{m}{cm}\right]^1 \times \left[\frac{\cancel{s}}{\cancel{s}}\right]^{-2}$$

XI - CHAP: 1: UNITS AND MEASUREMENTS - PART-5

*Error: The uncertainties in the measurement of physical quantity is called as error.

The errors are introduced due to faulty measurements of physical quantity.

Types of errors:

A] Systematic errors: These errors are introduced by an inaccuracy either by observation or measurements. The sources of this error may be due to imperfect calibration of the instrument or by imperfect method of observation. It may be positive (+ve) or negative (-ve).

* The sources of systematic errors:

1) Instrumental Error:- This error arises due to defective calibration of an instrument (Incorrect zeroing of instrument).

eg. a) Zero of thermometer not mark at proper place.

b) pointer of weighting balance not show proper zero even no load is kept on it.

c) Ammeter showing some current even not connected in circuit.

2) Error due to imperfection in experimental technique.

This error is due to defective setting of an instrument.

eg. To measure the volume of liquid using measuring cylinder, if it is not held vertically this error is introduced in the measurement.

3) Personal Error:- This error is introduced due to faults of observer (carelessness).

eg. To measure the length of an object with a ruler (scale), it is necessary to look at the ruler directly above not from an angle; the measured length will be wrong due to parallax.

*Systematic errors can be minimized by

1) Using correct instrument.
2) Following proper experimental procedure.
3) Removing personal error.

B] Random Errors:- Taking all possible precautions to minimize systematic errors, the measuments contains some errors, called as random errors. These errors can not be eliminated completely but can be minimize by repeated observations & taking mean value. They are produced due to variation in conditions.

eg- Change in pressure, temp., voltage of Power supply etc.

XI - CHAP: 1: UNITS AND MEASUREMENTS - PART-6

* Estimation of errors:-

If a_1, a_2, a_3 - - - - a_n be the 'n' number of measurements for the same physical quantity.

*** Mean Value (a_m):** It is the arithmatic mean of all measured values.

$$a_{mean} = a_m = \frac{a_1 + a_2 + \cdots + a_n}{n}, \quad a_m = \frac{1}{n}\sum_{i=1}^{n} a_i$$

*** Absolute error:-**

It is the difference bet^n mean value & each measured value.

$$\Delta a_1 = |a_m - a_1|, \quad \Delta a_2 = |a_m - a_2| \; \cdots \; \Delta a_n = |a_m - a_n|$$

*** Mean absolute error (Δa_m):** It is the arithmatic mean of all absolute errors.

$$\Delta a_{mean} = \Delta a_m = \frac{\Delta a_1 + \Delta a_2 + \cdots + \Delta a_n}{n}, \quad \Delta a_m = \frac{1}{n}\sum_{i=1}^{n} \Delta a_i$$

*** Relative error:** It is the ratio of mean absolute error to the mean value.

$$\therefore \text{Relative error} = \frac{\Delta a_m}{a_m}$$

*** Percentage error:** It is the relative error expressed in percentage.

$$\therefore \text{Percentage error} = \%\,\text{error} = \frac{\Delta a_m}{a_m} \times 100.$$

* Significant figure:-

It is defined as a figure which is of some significant but it does not necessarily denote a certainty.

*** Rules for significant figures:**

1) All non zero digits are significant.
   eg. $579.24\ m^3 \Rightarrow$ No. of Significant figures = 5
2) All the zeros bet^n two non zero digits are significant.
   eg. $80.0049 \Rightarrow$ No. of Signi. Figures = 6
3) The zeros on the right of decimal point & to the left of 1st non zero digit are not significant.
   eg. $0.00023 \Rightarrow$ No. of Signi. Figures = 2
4) The zeros on the right hand side of the last non zero digit are significant.
   eg. $7.500 \Rightarrow$ No. of Signi. Figures = 4.

* If length of rod $L = \underline{100\ m} = 10000\ cm = 100\ 000\ mm$.
It has only 3 significant figures.

*** Order of magnitude:-** The magnitude of any physical quantity can be expressed as $A \times 10^n$ where A is number $(0.5 \le A < 5)$ & n is integer called as order of magnitude.

		Order of Mag.	Sign. Figure
1) Radius of earth $= R = 6400\ km = 6.4 \times 10^6\ m$	$\rightarrow$	7	2
2) Magnitude of charge of electron $= e = 1.6 \times 10^{-19}\ C$	$\rightarrow$	-19	2
3) Mass of electron $= m_e = 9.11 \times 10^{-31}\ kg$	$\rightarrow$	-30	3

XI - CHAP: 1: UNITS AND MEASUREMENTS - PART - N1

1) The masses of two bodies are measured to be 15.7 ± 0.2 kg & 27.3 ± 0.3 kg. What is the total mass of the two & the error in it?

$\Rightarrow$ Given:
$M_1 = 15.7$ kg, $\Delta M_1 = 0.2$ kg, $M_2 = 27.3$ kg, $\Delta M_2 = 0.3$ kg.

Total mass = ? . Error = ? .

Total mass $= M_1 + M_2$

$M = 15.7 + 27.3$

$\boxed{M = 43.0\text{ kg}}$

Error $= \Delta M_1 + \Delta M_2$

Error $= 0.2 + 0.3$

$\boxed{\text{Error} = 0.5\text{ kg}}$

2) The distance travelled by an object in time (100 ± 1) s is (5.2 ± 0.1) m. What is the speed & its error?

$\Rightarrow$ Given:- $t = 100$ s, $\Delta t = 1$ s, $S = 5.2$ m, $\Delta S = 0.1$ m.

$V = ?$, error in $V = ?$

ⓐ speed

Speed $= \dfrac{\text{Distance}}{\text{Time}}$

$V = \dfrac{S}{t}$

$V = \dfrac{5.2}{100}$

$\boxed{V = 0.052\text{ m/s}}$

ⓑ Error in speed

Error in $V = \left(\dfrac{\Delta S}{S} + \dfrac{\Delta t}{t}\right)$

$= \left(\dfrac{0.1}{5.2} + \dfrac{1}{100}\right)$

$= \dfrac{1}{52} + \dfrac{1}{100}$

$= 0.0192 + 0.01$

$\boxed{\text{Error in } V = 0.0292}$

3) An electron with charge e enters a uniform magnetic field $\vec{B}$ with a velocity $\vec{V}$. The velocity is perpendicular to magnetic field. The force on charge e is given by $|\vec{F}| = BeV$. Obtain the dimensions of $\vec{B}$.

$\Rightarrow$ $F = BeV \Rightarrow B = \dfrac{F}{eV} \Rightarrow [B] = \dfrac{[F]}{[e][V]}$

$\therefore [B] = \dfrac{[M^1 L^1 T^{-2}]}{[M^0 L^0 T^1 I^1][M^0 L^1 T^{-1}]} = \dfrac{[M^1 L^1 T^{-2}]}{[M^0 L^1 T^0 I^1]}$

$\therefore \boxed{[B] = [M^1 L^0 T^{-2} I^{-1}]}$

4) Nuclear radius R has a dependence on the mass number A as $R = 1.3 \times 10^{-16} A^{1/3}$ m. For a nucleus of mass number $A = 125$, obtain the order of magnitude of R in metre.

$\Rightarrow$ $R = 1.3 \times 10^{-16} \times A^{1/3}$ -- $[A = 125,\ A^{1/3} = (125)^{1/3} = 5]$

$\therefore R = 1.3 \times 10^{-16} \times 5$

$R = 6.5 \times 10^{-16}$ m.

$\therefore$ Order of magnitude of $R = -15$

XI - CHAP: 1: UNITS AND MEASUREMENTS - PART - N2

5) A large ball 2 m in radius is made up of a rope of square cross-section with edge length 4 mm. Neglecting the air gaps in the ball, what is the total length of the rope to the nearest order of magnitude ?

⇒ Given: $r = 2\,m$, Edge length $= l = 4\,mm = 4 \times 10^{-3}\,m$.

$\therefore$ Area of cross-section $= A = l^2 = 4 \times 10^{-3} \times 4 \times 10^{-3} = 16 \times 10^{-6}\,m^2$.

Volume of ball = vol^m enclosed by a rope

$\frac{4}{3}\pi r^3$ = Area of cross-section × length of rope.

$\therefore \frac{4}{3} \times 3.14 (2)^3 = 16 \times 10^{-6} \times L$.

$\frac{4}{3} \times 3.14 \times 8 = 16 \times 10^{-6} \times L \Rightarrow L = \frac{6.28}{3 \times 10^{-6}} = 2.093 \times 10^{6}\,m$

$\therefore$ $\boxed{\text{order of magnitude} = 10^{6}\,m}$

6) In Ohms experiment, the values of the unknown resistances were found to be $6.12\,\Omega$, $6.09\,\Omega$, $6.22\,\Omega$, $6.15\,\Omega$. Calculate mean absolute error, relative error & % error in these measurements.

⇒ Given: $R_1 = 6.12\,\Omega$, $R_2 = 6.09\,\Omega$, $R_3 = 6.22\,\Omega$, $R_4 = 6.15\,\Omega$.

(a) Mean Absolute error = ?, (b) Relative error = ? (c) % error = ?

Mean value is $R_m = \frac{R_1 + R_2 + R_3 + R_4}{4} = \frac{6.12 + 6.09 + 6.22 + 6.15}{4}$

$= 6.15\,\Omega$

(a) Absolute errors

$\Delta R_1 = |R_m - R_1| = |6.15 - 6.12| = |0.03| = 0.03\,\Omega$

$\Delta R_2 = |R_m - R_2| = |6.15 - 6.09| = |0.06| = 0.06\,\Omega$

$\Delta R_3 = |R_m - R_3| = |6.15 - 6.22| = |-0.07| = 0.07\,\Omega$

$\Delta R_4 = |R_m - R_4| = |6.15 - 6.15| = |0.00| = 0.00\,\Omega$

$\therefore$ Mean absolute error $= \Delta R_m = \frac{\Delta R_1 + \Delta R_2 + \Delta R_3 + \Delta R_4}{4}$

$\therefore \Delta R_m = \frac{0.03 + 0.06 + 0.07 + 0.00}{4} = \frac{0.16}{4} \Rightarrow \boxed{\Delta R_m = 0.04\,\Omega}$

(b) Relative error

Relative error $= \frac{\Delta R_m}{R_m} = \frac{0.04}{6.15} \Rightarrow \boxed{\text{Relative error} = 0.0065}$

(c) Percentage error

% error = Relative error × 100 = 0.0065 × 100

$\therefore$ $\boxed{\%\ \text{error} = 0.65\,\%}$

$\frac{20}{25}$ $\frac{4}{5}$ 0.8

7) Find the % error in the K.E. of a body having mass $60.0 \pm 0.3\,g$ with a velocity $25.0 \pm 0.1\,cm/s$.

⇒ Given: $M = 60.0\,g$, $\Delta M = 0.3\,g$, $V = 25.0\,cm/s$, $\Delta V = 0.1\,cm/s$

% error = ?

we have KE of a body is

$KE = \frac{1}{2} m V^2$

$\therefore$ % error in KE $= \left(\frac{\Delta m}{M} + 2\frac{\Delta V}{V}\right) \times 100$

$= \left(\frac{0.3}{60.0} + \frac{2 \times 0.1}{25.0}\right) \times 100$

% error $= \left(\frac{3}{600} + \frac{2}{250}\right) 100$

$= \left(\frac{300}{600} + \frac{200}{250}\right)\%$

$= (0.5 + 0.8)\%$

$\therefore$ $\boxed{\%\ \text{error} = 1.3\,\%}$

XI - CHAP: 1: UNITS AND MEASUREMENTS - PART - N 3

8) The length, breadth & thickness of a rectangular sheet of metal are 4.234 m, 1.005 m & 2.01 m respectively. Give the area & volume of the sheet to correct significant figures.

⇒ Given: $l = 4.234\,m$, $b = 1.005\,m$ & $t = 2.01\,m$.

Significant figures in Area & volume = ?

Area of meat sheet $= A = 2[lb + bt + tl]$

$\therefore A = 2[(4.234 \times 1.005) + (1.005 \times 2.01) + (2.01 \times 4.234)]$

$A = 8.721\,m^2$ → Correct significant figures in $\boxed{A = 8.72\,m^2}$

Volume of metal sheet $= V = l \times b \times t$

$\therefore V = 4.234 \times 1.005 \times 2.01 = 0.085528917\,m^3$

Correct significant figures in $\boxed{V = 0.086\,m^3}$.

9) If the length of a cylinder is $l = (4.00 \pm 0.001)\,cm$, radius $r = (0.0250 \pm 0.001)\,cm$ & mass $m = (6.25 \pm 0.01)\,g$. Calculate the % error in the determination of density.

⇒ Given: $l = 4\,cm$, $\Delta l = 0.001\,cm$, $r = 0.025\,cm$, $\Delta r = 0.001\,cm$.

$m = 6.25\,g$, $\Delta m = 0.01\,g$. % error in density = ?

density $= \frac{\text{mass}}{\text{Volume}} \Rightarrow \rho = \frac{m}{V}$ -- (but $V = \pi r^2 l$)

$\therefore \rho = \frac{m}{\pi r^2 l}$ % error in $\rho = \left(\frac{\Delta m}{m} + \frac{2\Delta r}{r} + \frac{\Delta l}{l}\right) \times 100$ — (1)

% error in $\rho = \left[\frac{0.01}{6.25} + 2 \times \frac{0.001}{0.025} + \frac{0.001}{4}\right] \times 100$

$= \left[\frac{1}{625} + \frac{2}{25} + \frac{1}{400}\right] \times 100 = 0.08185 \times 100$

$\therefore$ $\boxed{\%\text{ error in } \rho = 8.185\,\%}$

10) If the formula for a physical quantity is $x = \frac{a^4 b^3}{c^{1/3} d^{1/2}}$ & if the % error in the measurements of a, b, c & d are 2%, 3%, 3% & 4% respectively. Calculate % error in x.

⇒ Given $x = \frac{a^4 b^3}{c^{1/3} d^{1/2}}$. % error in a $= \frac{\Delta a}{a} \times 100 = 2\%$

% error in b $= \frac{\Delta b}{b} \times 100 = 3\%$.

% error in c $= \frac{\Delta c}{c} \times 100 = 3\%$, % error in d $= \frac{\Delta d}{d} \times 100 = 4\%$

% error in $x = \left[\frac{4\Delta a}{a} + \frac{3\Delta b}{b} + \frac{1}{3}\frac{\Delta c}{c} + \frac{1}{2}\frac{\Delta d}{d}\right] \times 100$

$= \left(4 \times \frac{\Delta a}{a} \times 100\right) + \left(3 \times \frac{\Delta b}{b} \times 100\right) + \left(\frac{1}{3} \times \frac{\Delta c}{c} \times 100\right) + \left(\frac{1}{2}\frac{\Delta d}{d} \times 100\right)$

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

$= [8 + 9 + 1 + 2]\,\%$

$\boxed{\%\text{ error in } x = 20\%}$