Unit 1
Units and Measurement

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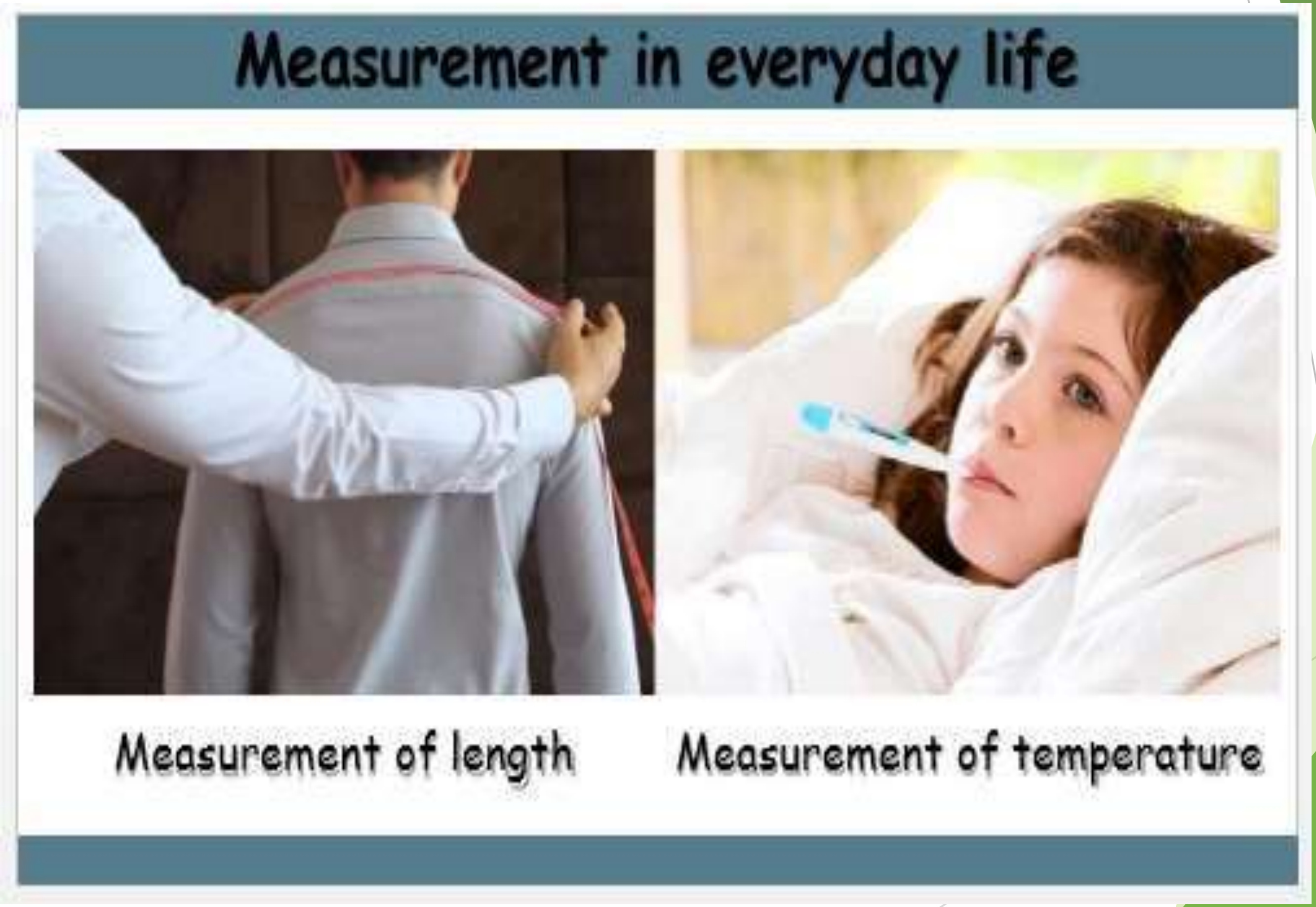
Course In charge

Measurement

It consists of comparison of unknown quantity with a known fixed quantity.



Weighing scale

Least count = 1 kg

Electronic balance

Least count = 1 g

Wrist watch

Least count = 1 s

Stopwatch

Least count = 0.01 s

Need of measurement

- To understand any phenomenon in physics we have to perform experiments.

- Experiments require measurements and we measure several physical properties like length, mass, time, temperature, pressure etc.

- Experimental verification of laws & theories also needs measurement of physical properties.

Measurement Depends on-

- Measuring instrument

- Method of measurement

Unit for measurement

The standard used for the measurementof a physical quantity is called aunit.

- Examples:
  - metre, foot, inch for length
  - kilogram, pound for mass
  - second, minute, hour for time
  - Fahrenheit, kelvin for temperature

Requirements of unit

- Well – defined
- Suitable size
- Reproducible
- Invariable
- Universally acceptable

Physical Quantity

- A physical property that can be measured and described by a number is called physical quantity.
- Examples:
  - Mass of a person is 70 kg.
  - Length of a table is 9 m.
  - Area of a hall is 190 m^2.
  - Temperature of a room is 300 ^0K

Types Of Physical quantities

- **1. Fundamental quantities:**
  - The physical quantities which do not depend on any other physical quantities for their measurements are known as fundamental quantities.
  - **Examples:**

- Mass
- Length
- Time
- Temperature

2. Derived quantities:

- The physical quantities which depend on two or more fundamental quantities for their measurements are known as derived quantities.

- **Examples:**

- Area
- Volume
- Pressure
- velocity

Fundamental unit

- The unit which is used for the measurement of fundamental physical quantity is known as fundamental unit.

FUNDAMENTAL QUANTITY	SI UNIT	SYMBOL
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Electric current	ampere	A
Luminous intensity	candela	cd
Amount of substance	mole	mol

Derived Unit

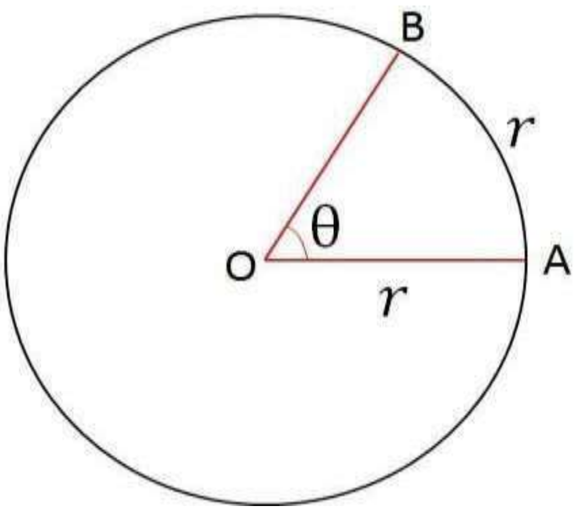
- The unit which is used for the measurement of derived physical quantity is known as derived unit.

Examples:

- Square meter (m^2) - Area
- Cubic meter (m^3) - Volume
- Kilogram/cubic meter (kg/m^3) - Density
- Meter/second (m/s) - Velocity

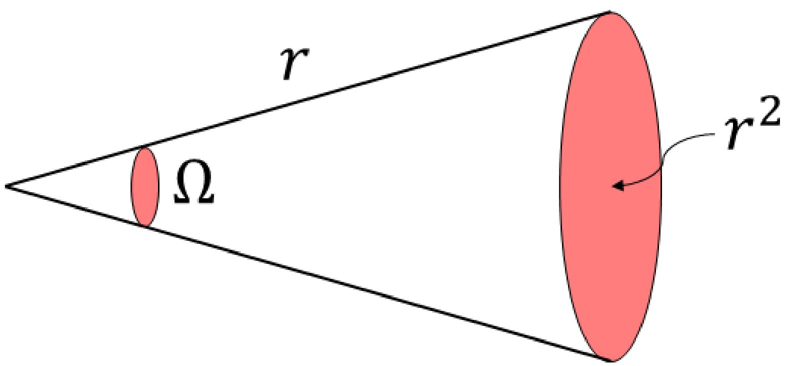
Two supplementary units

1. Radian: It is used to measure plane angle.



$\Theta = 1$ radian

2. Steradian: It is used to measure solid angle.



$\Omega = 1$ steradian

System of units

1.FPS system of units

2.CGS system of units

3.MKS system of units

SYSTEM OF UNITS	LENGTH	MASS	TIME
FPS	foot	pound	second
CGS	centimeter	gram	Second
MKS	meter	kilogram	second

International System of units (SI)

- In 1971, General Conference on Weight and Measures held its meeting and decided a system of units for international usage.
- This system is called international system of units and abbreviated as SI from its French name.
- The SI unit consists of seven fundamental units , two supplementary units and all the derived physical quantities.

Rules for writing SI units

1. Full name of unit always starts with small letter even if named after a person.

• **newton**		**Newton**
• **ampere**	**not**	**Ampere**
• **coulomb**		**Coulomb**

2. Symbol for unit named after a scientist should be in capital letter.

- **N for newton**
- **A for ampere**
- **K for kelvin**

3. Symbols for all other units are written in small letters.

- m for meter
- s for second

4. One space is left between the last digit of numeral and the symbol of a unit.

- 10 kg 10kg
- 5 N not 5N

5. The units do not have plural forms.

- 6 metre 6 metres
- 14 kg not 14 kgs

6.Full stop should not be used afterthe units.

- 6 metre 6 metres.
- 14 kg not 14 kgs.

7. No space is used between the symbols for units.

- 14 Nm not 14 N m

Multiples and submultiples of units

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	µ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deca	da	10^{-24}	yocto	y

Use of SI prefixes

Units of one system can be converted into units of other system with help of multiples and submultiples of units.

- 3 milliampere = 3 mA = 3 x 10^{-3} A
- 5 microvolt = 5 μV = 5 x 10^{-6} V
- 8 nanosecond = 8 ns = 8 x 10^{-9} s
- 6 picometre = 6 pm = 6 x 10^{-12} m
- 5 kilometre = 5 km = 5 x 10^{3} m
- 7 megawatt = 7 MW = 7 x 10^{6} W

Dimensions of a physical quantity

- The powers of fundamental quantities in a derived quantity are called dimensions of that quantity.
- Seven dimensions of the world
  - Fundamental quantities with dimension
    - Length [L]
    - Mass [M]
    - Time [T]
    - Temperature [K]
    - Current [I]
    - Amount of substance [mol]
    - Luminous intensity [C]

Example-

1. Area = length ×breadth = $[L] \times [L] = [M^0 L^2 T^0]$

2. Volume= length × breadth × height

$$= [L] \times [L] \times [L] = [M^0 L^3 T^0]$$

3. Velocity= $\dfrac{Distance}{Time} = \dfrac{[L]}{[T]} = [M^0 L^1 T^{-1}]$

4. Density = $\dfrac{Mass}{Volume}$

$$= \frac{[M]}{[L] \times [L] \times [L]} = [M^1 L^{-3} T^0]$$

5.Accerleration = $\frac{\text{Change in velocity}}{\text{time}}$

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

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

6. Force = mass X acceleration

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

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

7. Work = force x displacement

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

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

Uses Of Dimensional analysis

- To Verify the truth of physical equation ($V= u + at$).
- To derive the physical relation($P.E. = mgh$).
- To derive the conversion factor for units of same quantity into different systems of units ($1\ N= 10^5$ dyne).

Significant figures-

Significant figures or digits are the important digits that improve the accuracy of our measurement.

Mass = 6.11 g

3 significant figures

Speed = 67 km/h

2 significant figures

Rules for counting significant figures

- All non-zero digits(1,2,3,4,5,6,7,8,9) are significant.

Number	Significant figure
16	2
37.6	3
11296	5

- Zeros between non-zero digits are significant.

Number	Significant figure
106	3
3706	4
110.096	6

- Terminal zeros that are also to the right of a decimal point in a number are significant.

Number	Significant figure
1.60	3
40.00	4
25.050	5

- If the number is less than 1, all zeroes before the first non-zero digit are not significant.

Number	Significant figure
0.6	1
0.0082	2
0.05080	4

- During conversion of units use powers of 10 to avoid confusion.

Number	Significant figure
2.700 m	4
2.700 X 10^2 cm	4
2.700 X 10^{-3} km	4

Rules for rounding of approximate numbers-

1. If the first discarded number is less than 5 , leave the n th digit unchanged.

$$\text{Ex. } 1.12345678 \xrightarrow[\text{4 significant figures}]{\text{to round it to}} 1.123$$

Here first discarded digit is 4 which is less than 5 keep (n^{th}) 4^{th} digit (here 3) unchanged.

2. If the first discarded number is greater than 5 , increase the n^{th} digit by 1.

$$\text{Ex. } 6.124756 \xrightarrow[\text{4 significant figures}]{\text{to round it to}} 6.125$$

Here first discarded number is 7 which is greater than 5 hence increase (n^{th})4^{th} digit by 1 i.e 4 +1 =5.

3. If the first discarded digit is exact 5 ,then leave the n^{th} digit unchanged if it is an even and add one to it if it is odd.

Ex. 3.142519 $\xrightarrow[\text{4 significant figures}]{\text{To round it to}}$ 3.142

(Here nth digit is 2 i.e even hence keep unchanged)

Ex. 6.4475 $\xrightarrow[\text{4 significant figures}]{\text{to round it to}}$ 6.448

(Here n^{th} digit is 7i.e odd hence add 1)

Rules for arithmetic operations with significant figures-

Rule 1- In addition/ subtraction , final result should retain as many decimal places as are there in the number with the least decimal places.

Ex-

- 6.121 + 7.41 + 8.123 = 21.645 written as 21.64
- 19 – 1.567 -14.6 =2.833 written as 3

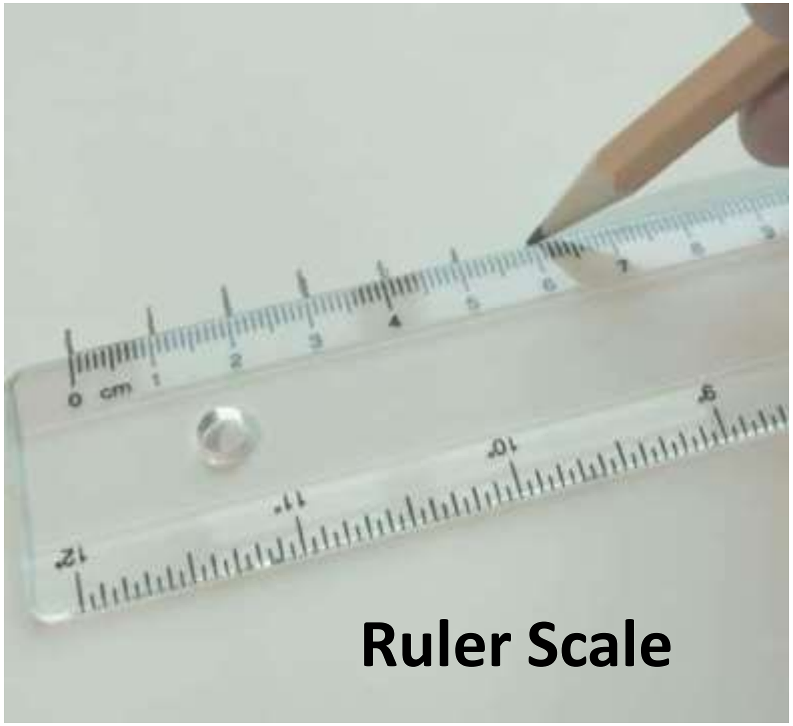
Rule 2-In multiplication/ division , final result should retain as many significant figures as are there in original number with the least significant figures.

Ex-

- 5.879 * 4.65 =27.33735 =27.3
- 6.579/4.56 =1.51

Least count (L.C.) of instruments

The smallest value that can be measured by the measuring instrument is called its least count or resolution.



Least count (L.C.) =1 mm
= 0.1 cm

Least count (L.C.) =0.02 mm

Micrometer screw gauge

L.C. = 0.01 mm

Milliameter

L.C. = 10 mA

Accuracy of measurement-

It refers to the closeness of a measurement to the true value of the physical quantity.

- **Example:**

- True value of mass = 25.67 kg
- Mass measured by student A = 25.61 kg
- Mass measured by student B = 25.65 kg
- The measurement made by student B is more accurate.

Accuracy depends on-

- Least count of an instrument
- Range of instrument
- Method of measurement
- Human limitations
- Environmental conditions

Errors in measurement-

Difference between the actual value of a quantity and the value obtained by a measurement is called an error.

OR

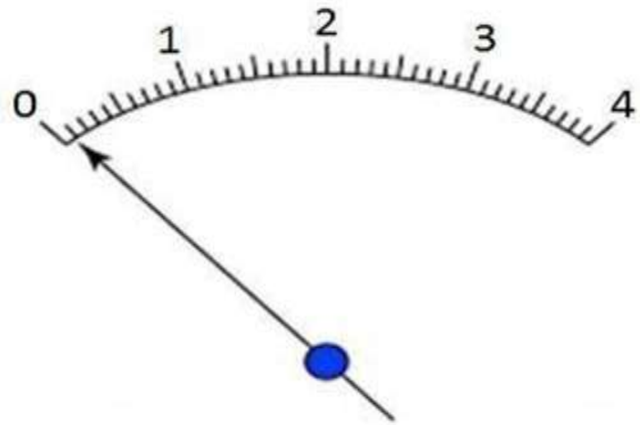
Error means fault which may occur even if in most careful observations.

Types Of Error

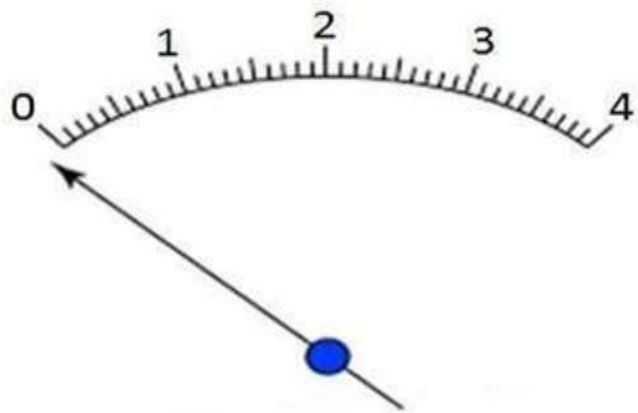
- Instrumental errors (Constant errors)
- Systematic errors (Personal errors)
- Random errors

1.Instrumental errors (Constant errors)-

- The errors which are caused due to the use of faulty measuring instruments are known as instrumental errors.



positive zero error

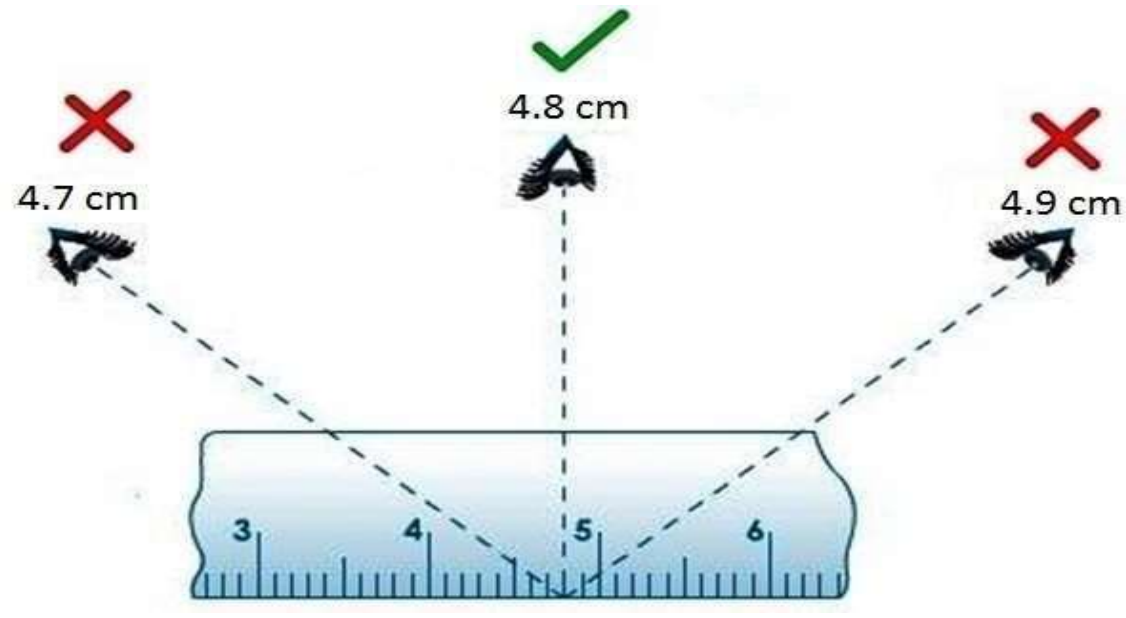


negative zero error

- If we use same faulty instrument again and again, then it will continuously introduce an error in the measurement . Hence these errors are also known as constant errors.
- These errors can be minimized by taking the same measurement with the help of correct instrument.

2. Systematic errors-

- The errors which are cause due to the defective setting or adjustment of the instrument by the experimenter are known as systematic errors.
- These errors can arise due to faulty procedures adopted by the person taking measurements, hence also known as personal error.



Parallex error

- These errors can be minimized by ,
  - Detecting sources of errors
  - Following the step wise procedure
  - taking proper care while performing the measurement

Random errors-

The errors which are cause due to changes in experimental conditions and human limitations are known as random errors.

For example –

While performing electrical experiments if there is voltage fluctuation then some error may be included.

Errors can be minimized by -

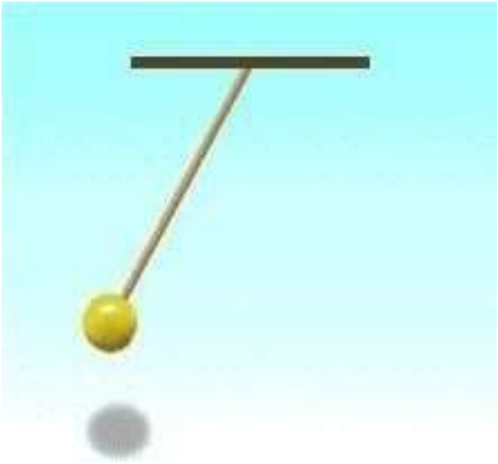
1. Taking large magnitude of the quantity which is to be measured.
2. Taking large number of readings.
3. Use smaller least count instrument.

Estimation Of Errors-

- Steps for estimation of errors-
  - Calculate mean reading
  - Calculate absolute error
  - Calculate mean absolute error.
  - Calculate relative error
  - Calculate percentage error.

To understand the process of estimation of errors and different steps involved in it we will go through one example.

For example, suppose you measure the oscillation period of a pendulum with a stopwatch five times.



Trial no (i)	**1**	**2**	**3**	**4**	**5**
Measured value (X_i)	3.9 (X_1)	3.5 (X_2)	3.6 (X_3)	3.7 (X_4)	3.5 (X_5)

1. Average or mean reading (X_m)-

To get mean or average add all the measured value and divide it by total number of readings.

$$X_m = \frac{X_1+X_2+X_3+X_4+X_5}{5}$$

$$= \frac{3.9 + 3.5 + 3.6 + 3.7 + 3.5}{5}$$

$$X_m = 3.64 = 3.6$$

2. Absolute error(δ_X) –

The magnitude of the difference between mean value and each individual value is called absolute error.

$$\delta_X = \left| X_m - X_i \right|$$

Hence, $\delta_{X1} = |X_m - X_1| = |3.6 - 3.9| = 0.3$

Similarly absolute error for each measurement will be,

Measured value (X_i)	3.9 (X_1)	3.5 (X_2)	3.6 (X_3)	3.7 (X_4)	3.5 (X_5)
(δ_X)	0.3	0.1	0	0.1	0.1

3.Average Absolute error (δ_{Xm})-

The mean of all the absolute errors is called mean absolute error.

$$\delta_{Xm} = \frac{\delta_{X1} + \delta_{X2} + \delta_{X3} + \delta_{X4} + \delta_{X5}}{5}$$

$$\delta_{Xm} = \frac{0.3 + 0.1 + 0 + 0.1 + 0.1}{5} = 0.1$$

4.Relative error (R) –

The relative error is defined as the ratio of the average absolute error (δ_{Xm}) to the average value (X_m).

$$R = \frac{\delta_{Xm}}{X_m}$$

$$= \frac{0.1}{3.6}$$

$$= 0.0277$$

$$=0.028$$

5.Percentage error –

The relative error multiplied by 100 is called as percentage error.

Percentage error = Relative error x 100

$$= \frac{\delta X_m}{X_m} \times 100$$

$$= 0.028 \times 100$$

$$= 2.8\ \%$$

Less is the percentage error more is the accuracy.

1. The mass of an object is 37.6 $\pm$ 0.02 gm. Estimate percentage error in the measurement.

- Percentage error = Relative error x 100

here , δxm = 0.02

X_m = 37.6

$$\% \text{ error} = \frac{\delta_{Xm}}{X_m} \times 100$$

$$= \frac{0.02}{37.6} \times 100$$

= 0.053%

2. The mass of an object is 179.5 ± 0.03gm. Estimate percentage error in the measurement.

3 . Which of the following is more accurate and why?

1) 2.33 ± 0.002 mm.

2) 2.55 ± 0.0015 mm.

Thank -you