ACCURACY, PRECISION OF INSTRUMENTS AND ERRORS IN MEASUREMENT

Error

The result of every measurement by any measuring instrument contains some **uncertainty**.

This uncertainty is called **error**

Errors are classified in to **systematic errors** and **random errors**

Accuracy and Precision

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

Precision tells us to what resolution or limit the quantity is measured

Systematic errors

The systematic errors are those errors that tend to be in one direction, either **positive** or **negative**

They are **Instrumental** errors, Imperfection in experimental technique or procedure (**Procedural** errors) and **Personal** errors

Random errors

These can arise due to random and unpredictable **fluctuations** in experimental conditions (e.g. unpredictable fluctuations in temperature, voltage supply, mechanical vibrations of experimental set-ups, etc)

Least count error

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

LC of Vernier Calipers is 0.01 cm

LC of Screw Gauge is 0.01 mm

It occurs with both systematic and random errors

Absolute Error

If a_1 , a_2 , a_3 .... a_n are the values obtained in different measurements of the same quantity.

The arithmetic mean of these values is taken as the best possible value (true value) of the quantity

$$a_{mean} = \frac{a_1 + a_2 + \ldots\ldots\ldots + a_n}{n} = \sum_{1}^{n} a_1$$

Errors on measurements

$$\Delta a_1 = a_1 - a_{mean}$$

$$\Delta a_2 = a_2 - a_{mean}$$

$$\Delta a_3 = a_3 - a_{mean}$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \Delta a_n = a_n - a_{mean}$$

Absolute Errors

$$|\Delta a_1| = |a_1 - a_{mean}|$$

$$|\Delta a_2| = |a_2 - a_{mean}|$$

$$|\Delta a_3| = |a_3 - a_{mean}|$$

.....

$$|\Delta a_n| = |a_n - a_{mean}|$$

Mean Absolute Error

The **arithmetic mean** of all the absolute errors is taken as the final or mean absolute error

$$\Delta a_{mean} = \frac{|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + \cdots\cdots\cdots + |\Delta a_n|}{n} = \frac{\sum_{1}^{n} |\Delta a_1|}{n}$$

Range of measured value

It is expected to be in between

$$a_{mean} - \Delta a_{mean} \quad \text{to} \quad a_{mean} + \Delta a_{mean}$$

Relative Error

The relative error is the ratio of the mean absolute error Δa_{mean} to the mean value a_{mean} of the quantity measured.

$$Relative\ Error = \frac{\Delta a_{mean}}{a_{mean}}$$

Percentage Error

Relative error can be expressed in **percent**

$$Percentage\ Error(\delta a) = \frac{\Delta a_{mean}}{a_{mean}} x\,100\%$$