Errors in Measurements

Dr.Jinchu.I

Errors in Measurements

▶ The measured value of the physical quantity is usually different from its true value.

▶ The result of every measurement by any measuring instrument is an approximate number, which contains some uncertainty.

▶ This uncertainty is called error.

▶ The difference between the true value and the measured value of a quantity is known as the error of measurement.

▶ Every calculated quantity, which is based on measured values, also has an error.

▶ Errors in measurements can be classified into two categories-- systematic errors and random errors.

1.Systamatic Errors

▶ Arises due to instrumental errors, incorrect experimental techniques, and personal errors.

▶ **Instrumental errors:** arise from the imperfect design or calibration of instruments, zero error of instruments, etc.

    ▶ Examples: Zero error in vernier calipers or screw gauge and error due to measurement of length using a scale broken at one end

▶ Error due to incorrect experimental technique: occur due to inaccurate experimental procedures as well as external factors like pressure, temperature, humidity, wind, etc.

    ▶ Eg.- measurement of body temperature by placing a thermometer under the armpit results in a lower temperature value than the actual value.

- **Personal errors:** arise due to personal bias, lack of proper setting of the apparatus, or individual's carelessness in taking observations. These types of errors are also known as observational errors.

- Eg- when an observer holds his head towards the right (by habit) while reading the position of a needle on the scale, he introduces an error due to parallax.

- This type of error can be minimized by using better instruments, improving experimental techniques, and avoiding personal bias

2.Random Errors

▶ Random errors come from unpredictable changes in experimental conditions. It makes to give different results for same measurements taken repeatedly.

▶ Random errors are present in all experiments and are unpredictable.The random errors can be reduced by taking a greater number of measurements.

▶ These errors are also called statistical errors and can be removed by statistical methods like averaging.

▶ For example, unpredictable temperature changes can affect the electrical properties of instruments in an experiment involving electrical instruments.

3. Least Count Error

- The least count error is the error associated with the resolution of the instrument.

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

- Least count may not be sufficiently small. The maximum possible error is equal to the least count. All readings or values are good only up to this value.

  - For example, a vernier caliper has the least count of 0.01 cm and a screw gauge has a least count of 0.001 cm.

  - Using instruments of higher precision, improving experimental techniques, etc., we can reduce the least count error.

  - Repeating the observations several times and taking the arithmetic mean of all the observations, the mean value would be very close to the true value of the measured quantity.

4. Absolute Error

- If $a_1, a_2, a_3, \ldots\ldots, a_n$ be the values obtained for a physical quantity 'a' in an experiment repeated 'n' times, then the arithmetic mean of the values is taken as the true value given by

$$a_0 = a_{mean} = \frac{a_1 + a_2 + \ldots\ldots + a_n}{n}$$

- The absolute error of a measurement is the difference between the individual measurement and the true value of that quantity denoted as $|\Delta a|$. The absolute errors in measurement values are

$$\left|\Delta a_1\right| = \left|a_0 - a_1\right|, \ \left|\Delta a_2\right| = \left|a_0 - a_2\right|, \ \left|\Delta a_3\right| = \left|a_0 - a_3\right|, \ldots\ldots, \left|\Delta a_n\right| = \left|a_0 - a_n\right|$$

Absolute error $|\Delta a|$ is always positive.

The arithmetic mean of all absolute errors of all the measurements is taken as the mean absolute error of the physical quantity 'a'.

$$\Delta a_{mean} = \frac{\Delta a_1 + \Delta a_2 + \ldots\ldots + \Delta a_n}{n}$$

- The value of a physical quantity

$$a = a_{mean} \pm \Delta a_{mean}$$

5. Relative Error

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

$$relative\ error = \frac{\Delta a_{mean}}{a_{mean}}$$

6. Percentage Error

The relative error of a physical quantity expressed in percentage is called percentage error.

$$percentage\ error = \frac{\Delta a_{mean}}{a_{mean}} \times 100$$

Problems

1. The measurement of length gives values of 2.54cm, 2.51cm, 2.48cm, 2.55cm, and 2.52cm. Find the absolute error, relative error, and percentage error.

2. The mean absolute error of a set of measurements is 0.85 and the mean value is 12.6. Find the relative error and percentage error.