ERRORS IN MEASUREMENT

XI- SCIENCE

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Errors in Measurement

- Errors are the deviations of observed values from true values.

ERROR = TV - MV

TV = true value

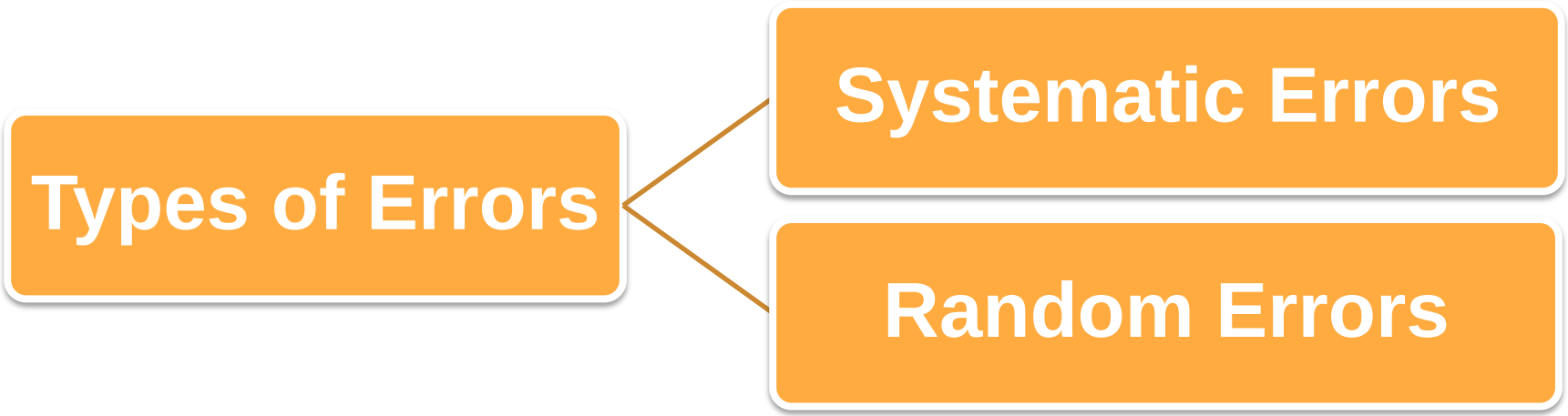
MV = measured value

Note: In absence of any other method of knowing true value, we consider arithmetic mean as the true value.

Types of Errors

In general, the errors in measurement can be broadly classified as

- Systematic errors
- Random errors



Types of Errors - Systematic Errors

Systematic Errors

The systematic errors are those errors that tend to be in one direction, either positive or negative. Some of the sources of systematic errors are:

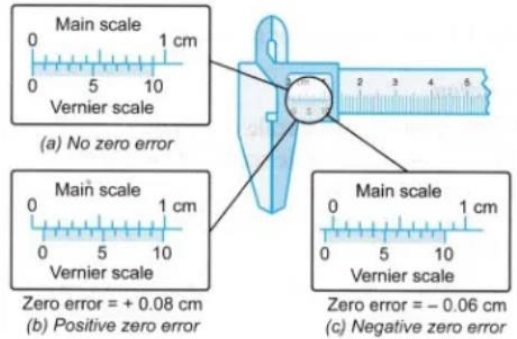
1. Instrumental errors:

The instrumental errors that arise from the errors due to imperfect design or calibration of the measuring instrument, zero error in the instrument, etc.

Example:

- The temperature graduations of a thermometer may be inadequately calibrated (it may read 104 °C at the boiling point of water at STP whereas it should read 100 °C);
- In a Vernier calipers the zero mark of Vernier scale may not coincide with the zero mark of the main scale;
- An ordinary metre scale may be worn off at one end.

Zero Errors in Vernier Callipers



Types of Errors - Systematic Errors

2. Imperfection in experimental technique or procedure

To determine the temperature of a human body, a thermometer placed under the armpit will always give a temperature lower than the actual value of the body temperature.

3. Personal errors

The personal errors arise due to an individual's bias, lack of proper setting of the apparatus or individual's carelessness in taking observations without observing proper precautions, etc.

Example: If you hold your head a bit too far to the right while reading the position of a needle on the scale, you will introduce an error due to parallax.

Systematic errors can be minimized by

- improving experimental techniques,
- selecting better instruments and
- removing personal bias as far as possible

Errors in Measurement

Random errors:

- These errors occur irregularly and hence random w.r.t sign and size.
- These may arise due to random and unpredictable fluctuations in experimental conditions.

Least count error :

- The least count error is the error associated with the resolution of the instrument.
- e.g. : If we are measuring by a slide caliper then least count = 0.01 cm. So various observation of a measurement can be ; 3.12 cm , 3.13 cm , 3.14 cm and so on. So error is arising in 2nd decimal place i.e. 0.01 cm. This is least count error.
- Least count error occurs with both systematic and random error.
- It can be reduced by using instruments of high resolutions or high precision.

Absolute Error, Relative Error and Percentage Error

Absolute error

The magnitude of the difference between the individual measured value and the true value of the quantity is called the absolute error of the measurement.

This is denoted by $|\Delta a|$.

Note: In absence of any other method of knowing true value, we consider arithmetic mean as the true value.

The errors in the individual measurement values from the true value are:

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

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

.

.

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

- The Δa calculated above may be positive or negative.
- But absolute error $|\Delta a|$ will always be positive.

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Absolute Error, Relative Error and Percentage Error

The arithmetic mean of all the absolute errors is taken as the final or mean absolute error of the value of the physical quantity .

It is represented by Δa_{mean}.

Thus, $\Delta a_{mean} = \frac{(|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + .. + |\Delta a_n|)}{n} = \sum_{i=1}^{n} |\Delta a_i|$

If we do a single measurement, the value we get may be in the range

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

This implies that any measurement of the physical quantity a is likely to lie between

$(a_{mean} + \Delta a_{mean})$ and $(a_{mean} - \Delta a_{mean})$

Absolute Error, Relative Error and Percentage Error

Relative error

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

$$\textbf{Relative error} = \frac{\textbf{Mean absolute error}}{\textbf{True value or Arithmetic Mean}}$$

$$\textbf{Relative error} = \frac{\Delta \boldsymbol{a_{mean}}}{\mathbf{a}_{\boldsymbol{mean}}}$$

Absolute Error, Relative Error and Percentage Error

Percentage error

When the relative error is expressed in percent, it is called the percentage error (δa).

$$\textbf{Percentage error} = \frac{\textbf{Mean absolute error}}{\textbf{True value or Arithmetic Mean}} \textbf{x100\%}$$

$$\textbf{Percentage error}(\delta a) = \frac{\Delta \mathbf{a_{mean}}}{\mathbf{a_{mean}}} \textbf{x100\%}$$

Numerical

Question: We measure the period of oscillation of a simple pendulum. In successive measurements, the readings turn out to be 2.63s, 2.56s, 2.42s, 2.71s, and 2.80s. Calculate the absolute errors, relative error or percentage error.

Solution: The mean period of oscillation is

$$\overline{\mathrm{T}} = \frac{2.63 + 2.56 + 2.42 + 2.71 + 2.80}{5} s = 2.62s$$

The absolute error are:

$\Delta \mathrm{T}_1 = |\overline{\mathrm{T}} - \mathrm{T}_1| = |2.62 - 2.63|s = 0.11s$

$\Delta \mathrm{T}_2 = 0.06s$

$\Delta \mathrm{T}_3 = 0.20s$

$\Delta \mathrm{T}_4 = 0.09s$

$\Delta \mathrm{T}_5 = 0.18s$

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Numerical

Solution:

The mean absolute error is

$$\overline{\Delta T} = \frac{0.01+.06+0.20+0.09+0.18}{5} s = 0.11s$$

So the period of the oscillation of simple pendulum is $(2.62 \pm 0.11)s$

The relative error is $\frac{0.11}{2.62} = 0.04$

The percentage error is $\left(\frac{0.11}{2.62} x100\right)\% = 4\%$

MCQ

1. Potential difference across a resistance measured by a voltmeter is found to be 20 V with 5% error. What is the maximum absolute error of the measurement?

   a) 1 V b) 2V c) 0.1 V d) 0.2 V

2. Length of a cylinder is measured by a slide caliper and found to be 2.5cm$\pm$0.03cm. Its percentage error is

   a) 3% b) 2.5% c) 1.2% d) 7.5 %

3. Least count error undergoes the category of

   a) systematic error b) Random error

   c) both random and systematic error d) non of the above

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THANKING YOU

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