Measurements and Instrumentations

Lecture 1: Measurement Errors and Characteristics

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Lecture Outline:

1. Types of Measurement Errors.
2. Measurements Characteristics.

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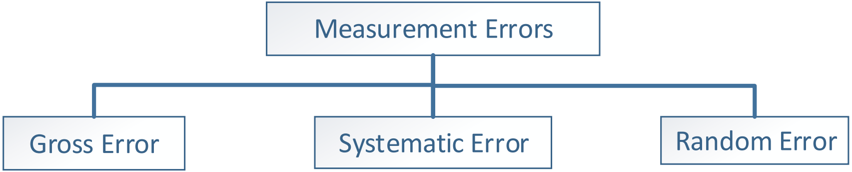
Measurement Errors:

- **No** electronic component or instrument is **perfectly accurate**; all have some error or inaccuracy.
- These errors are introduces due to either **defect in the instrument**, **wrong observance**, or **environmental factors**.
- These errors could combine to either:
  - Completely cancel each others.
  - Create greater errors in measurement (**Worst case**)
- **The worst case should always considered while performing measurement**, where these errors could combine to create larger error.

Measurement Errors:

Measurement errors can be categorized into three types:



Gross Error (Human Error)

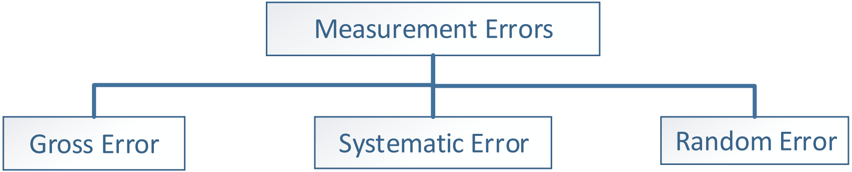
Errors due to **human mistakes** in using instruments, recording observations, and calculating measurement results.

Example

- Misunderstanding the unit in case of digital devices (21 V instead of 21 mV).
- A wrong scale may be chosen in analog instruments.
- Transpose of the readings while recording. (24.9 mV instead of 29.4 mV).

Measurement Errors:

Measurement errors can be categorized into three types:



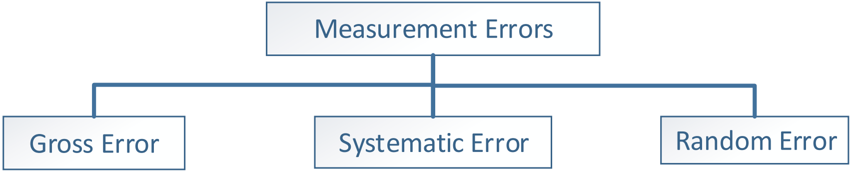
Systematic Error

Errors due to **problems with instruments**.

- **Instrument Errors**: May be due to incorrect device calibration.
- **Environmental Errors**: Change in environmental conditions may change some of device parameters.
- **Observational Errors**: Errors introduced by the observer as the **parallax error**.

Measurement Errors:

Measurement errors can be categorized into three types:



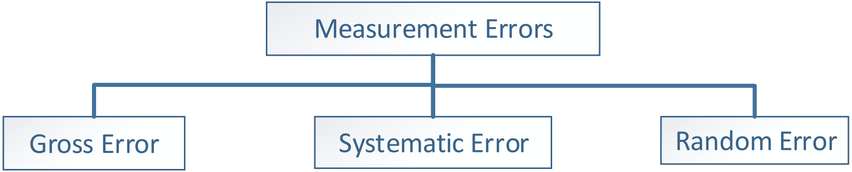
Systematic Error

Errors due to **problems with instruments**.

Parallax Error: Viewing measurement from different angles.

Measurement Errors:

Measurement errors can be categorized into three types:



Random Error

Errors due to **unknown factors**.

- These errors are **relatively small**.
- These errors can be reduced by **increasing the number of readings** and using arithmetic mean.

Measurement Errors:

Absolute and Relative Errors:

The error in measuring instruments can be represented in two ways: **Absolute** and **Relative**

Absolute Error (Δe)

It is defined as the difference between the true A_t and the measured A_m values.

$$\Delta e = A_m - A_t$$

Example

An ammeter reads 6.7 A and the true value of the current is 6.54 A. The absolute error is

$$\Delta e = A_m - A_t = 6.7 - 6.54 = 0.16\ A$$

Measurement Errors:

Absolute and Relative Errors:

Relative Error (e_r)

It is defined as the ratio of the absolute error Δe to the true value A_t of the quantity being measured.

$$e_r = \frac{\Delta e}{A_t}$$

Percentage error

$$\%e_r = e_r \times 100 = \frac{\Delta e}{A_t} \times 100$$

Example

The current through a resistor is 2.5 A, but the measurement yields a value of 2.45 A.
The absolute error is

$$\Delta e = A_m - A_t = 2.45 - 2.5 = -0.05A$$

The relative error

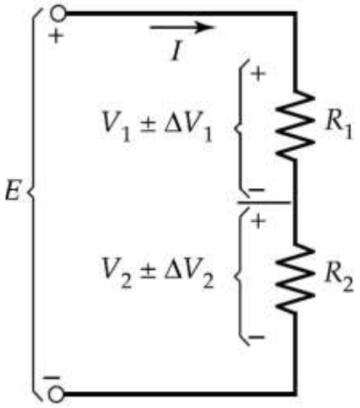
$$e_r = \frac{\Delta e}{A_t} = \frac{-0.05}{2.5} = -0.02$$

The percentage relative error

$$\%e_r = e_r \times 100 = -2\%$$

Errors in Sum of quantities

$$
\begin{aligned}
E &= V_1 + V_2 \\
&= (V_1 \pm \Delta V_1) + (V_2 \pm \Delta V_2) \\
&= (V_1 + V_2) \pm (\Delta V_1 + \Delta V_2)
\end{aligned}
$$



Error in Sum

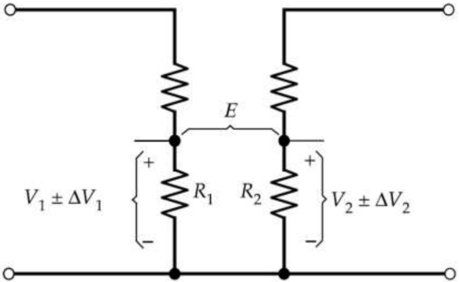
Error in the sum of quantities equals the sum of absolute errors.

Measurement Errors

Combination of Errors

Errors in Difference of quantities

$$
\begin{aligned}
E &= V_1 - V_2 \\
&= (V_1 \pm \Delta V_1) - (V_2 \pm \Delta V_2) \\
&= (V_1 - V_2) \pm (\Delta V_1 + \Delta V_2)
\end{aligned}
$$

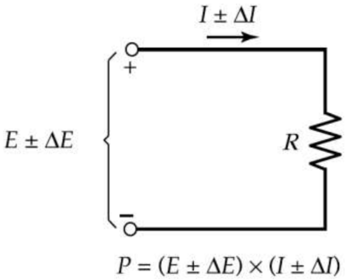


Error in Difference

Error in the difference of quantities equals the sum of absolute errors.

Errors in Product of quantities

$$\begin{aligned} P = EI &= (E \pm \Delta E) \times (I \pm \Delta I) \\ &= E.I \pm E.\Delta I \pm I.\Delta E \pm \Delta E.\Delta I \\ &\approx E.I \pm E.\Delta I \pm I.\Delta E \quad (\Delta E.\Delta I \text{ is very small}) \end{aligned}$$



Percentage error in P is

$$\begin{aligned} \%P &= \frac{E.\Delta I + I.\Delta E}{E.I} \times 100\% \\ &= \left(\frac{\Delta I}{I} + \frac{\Delta E}{E} \right) \times 100\% \\ &= (\% \text{ error in } I) + (\% \text{ error in } E) \end{aligned}$$

Percentage error in the product of quantities equals the sum of percentage errors

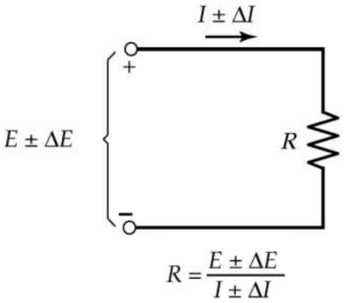
Errors in Quotient of quantities

$$R = \frac{E \pm \Delta E}{I \pm \Delta I}$$

Percentage error in R is

$$\%\text{error in } R = (\%\text{ error in } I) + (\%\text{ error in } E)$$

Percentage error in the quotient of quantities equals the sum of percentage errors



Quantity raised to a power:

$\%\text{error in } A^B = B(\%\text{ error in } A)$

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Measurements Characteristics:

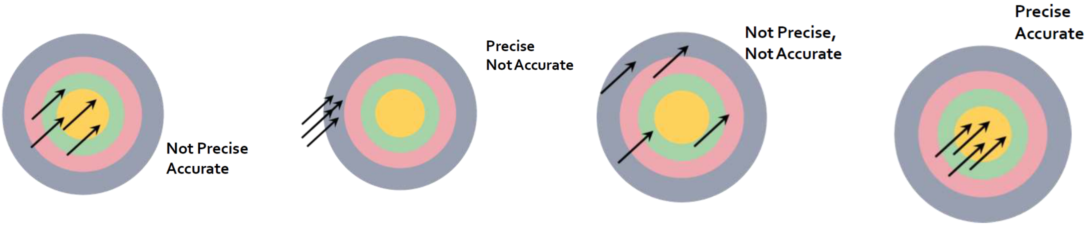
Accuracy and Precision:

Accuracy

Accuracy is defined as the **degree of closeness** of a measured value compared to the true value of the quantity to be measured.

Precision

Precision is defined as the **degree of similarity** of repeated measurements.



Measurements Characteristics:

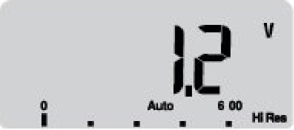
Resolution and Significant Figure:

Resolution

Resolution is defined as s the **smallest change in the measured quantity** to which an instrument will respond.

Significant Figure

Significant figure is defined as the **number of digits** used to represent a measured value. The more the number of significant figures, the more precise is the quantity.



End of Lecture

Best Wishes

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