ERRORS IN MEASUREMENT

- *Instrument* – a device or mechanism used to determine the present value of a quantity
- *Measurement* – a process of comparing an unknown quantity with an accepted standard quantity.
- *Standard* – an instrument or device having a recognized permanent (stable) value that is used as a reference.

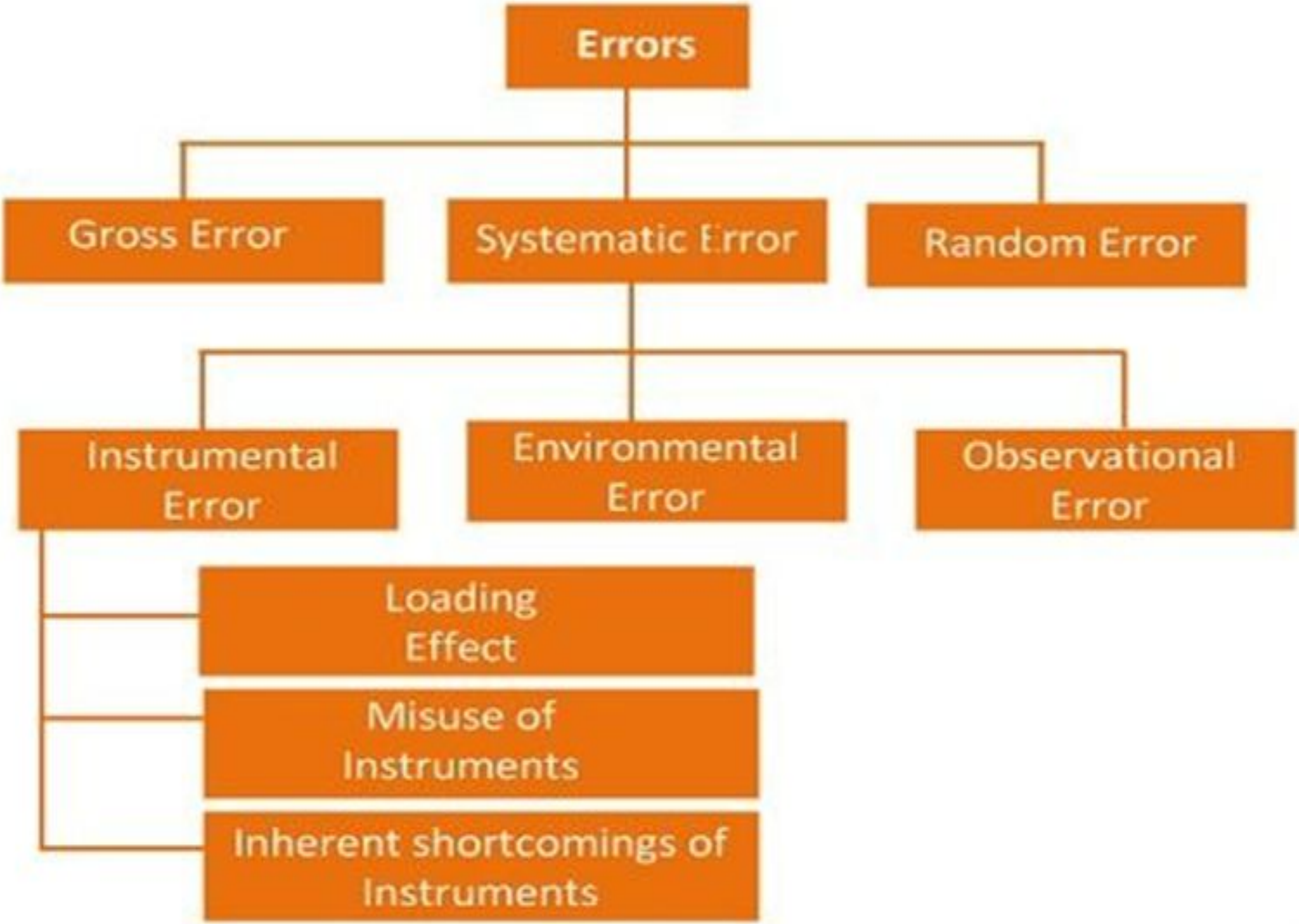
MEASUREMENT ERROR

Measurement Error:-The measurement error is defined as the difference between the true or actual value and the measured value.

ERRORS IN MEASUREMENT

There are various types of error in measurement:

- Gross error
- systematic error
- random error
- Absolute error
- Relative error


Errors
Gross Error
Systematic Error
Random Error
Instrumental Error
Environmental Error
Observational Error
Loading Effect
Misuse of Instruments
Inherent shortcomings of Instruments

Gross Errors

1.Gross Errors

The gross error occurs because of the human mistakes.

Example:-

1. Consider the person using the instruments takes the wrong reading, or they can record the incorrect data. Such type of error comes under the gross error.

2. The experimenter reads the 31.5ºC reading while the actual reading is 21.5Cº. This happens because of the oversights.

Elimination of Gross Errors

- The complete elimination of such type of error is not possible.
- Some of the gross error easily detected by the experimenter but some of them are difficult to find.
- **Three methods can remove the gross error.**

 The reading should be taken very carefully.

 Two or more readings should be taken of the measurement quantity.

  The readings are taken by the different experimenter and at a different point for removing the error.

2. Systematic Errors

The systematic errors are mainly classified into three categories.

Instrumental Errors

Environmental Errors

Observational Errors

Systematic Errors

1. **Instrumental Errors**

These errors mainly arise due to the three main reasons.

- (a) Inherent Shortcomings of Instruments
- (b) Misuse of Instrument
- (c) Loading Effect

Instrumental Errors

(a) Inherent Shortcomings of Instruments

- Such types of errors are inbuilt in instruments because of their mechanical structure.
- They may be due to manufacturing, calibration or operation of the device.
- These errors may cause the error to read too low or too high.
- For example – If the instrument uses the weak spring then it gives the high value of measuring quantity.
- The error occurs in the instrument because of the friction or hysteresis loss.

Instrumental Errors

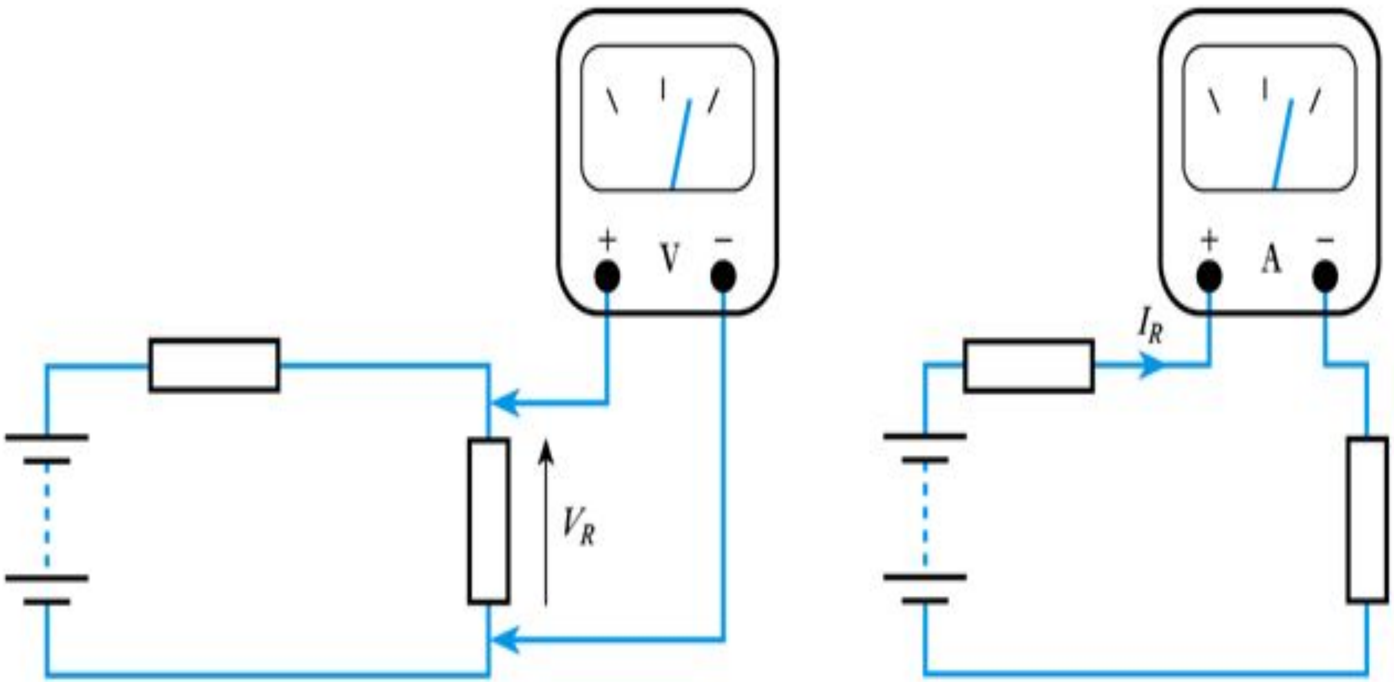
- **(b) Misuse of Instrument**
- The error occurs in the instrument because of the fault of the operator.
- A good instrument used in an unintelligent way may give an enormous result.
- For example – the misuse of the instrument may cause the failure to adjust the zero of instruments, poor initial adjustment.
- These improper practices may not cause permanent damage to the instrument, but all the same, they cause errors.

Instrumental Errors

- **(c) Loading Effect**
- It is the most common type of error which is caused by the instrument in measurement work.
- For example, when the voltmeter is connected to the high resistance circuit it gives a misleading reading, and when it is connected to the low resistance circuit, it gives the dependable reading.
- This means the voltmeter has a loading effect on the circuit.
- The error caused by the loading effect can be overcome by using the meters intelligently.
- For example, when measuring a low resistance by the ammeter-voltmeter method, a voltmeter having a very high value of resistance should be used.

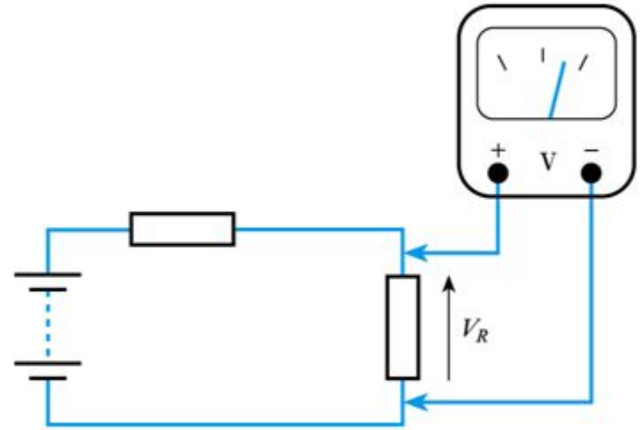
Loading effects

Measuring voltage and current in a circuit

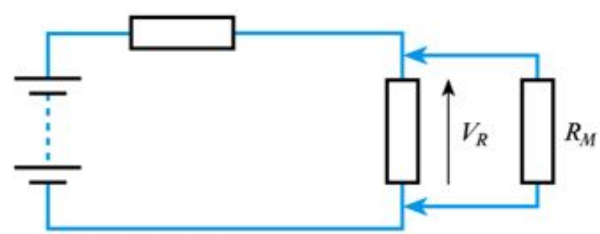


Loading effects – voltage measurement

Since voltage is a parallel measurement, the "loading" effect is minimized when the voltmeter resistance is much higher than the circuit resistance across which the measurement is being made.



It's the change of circuit parameter, characteristic, or behaviour due to instrument operation.



Example on Loading Effect

A voltmeter having a sensitivity of 1 kΩ/V is connected across an unknown resistance in series with a milliammeter reading 80 V on 150 V scale. When the milliammeter reads 10 mA, calculate the (i) Apparent resistance of the unknown resistance, (ii) Actual resistance of the unknown resistance, and (iii) Error due to the loading effect of the voltmeter.

if the milliammeter reads 600 mA and the voltmeter reads 30 V on a 150 V scale, calculate the following: (i) Apparent, resistance of the unknown resistance. (ii) Actual resistance of the unknown resistance. (iii) Error due to loading effect of the voltmeter.

A well calibrated voltmeter may give a misleading resistance when connected across two points in a high resistance circuit. The same voltmeter ,when connected in a low resistance circuit may give a more dependable reading

How to avoid Instrumental errors

(a) Selecting a suitable instrument for the particular measurement application.

(b) Applying correction factors after determining the amount of instrumental error.

(c) Calibrating the instruments against a standard.

Systematic Errors

2) Environmental errors

- Environmental errors arise as a result of environmental effects on instrument.

- It includes conditions in the area surrounding the instrument.

Environmental errors may be avoided by :

(a) Using the proper correction factor and information supplied by the manufacturer of the instrument.

(b) Using the arrangement which will keep the surrounding condition constant like use of air condition, temperature controlled enclosures etc.

Systematic Errors

2. Observational Errors

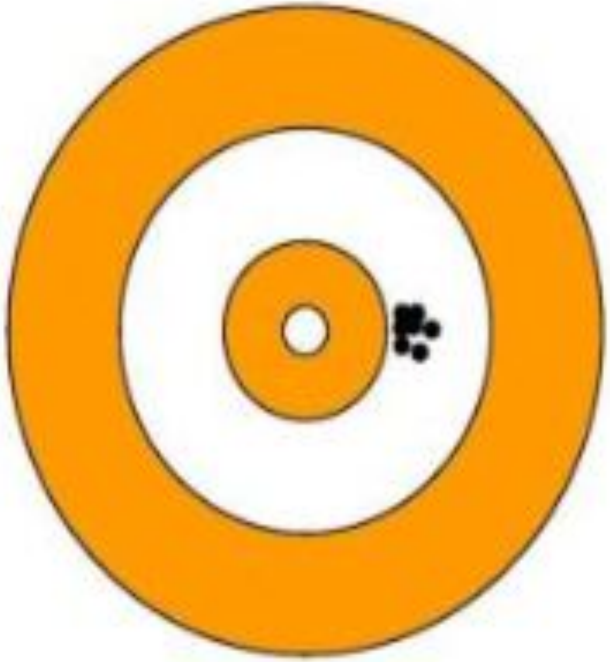
- Such types of errors are due to the wrong observation of the reading.
- There are many sources of observational error.
- For example, the pointer of a voltmeter resets slightly above the surface of the scale.
- Thus an error **occurs**(because of parallax) unless the line of vision of the observer is exactly above the pointer.
- To minimize the parallax error highly accurate meters are provided with mirrored scales.

Systematic Errors

Flaw in the device used to make the measurement.

Operator error in the use of the measuring device.

External condition that has not been taken into account.



Systematic errors affect the accuracy of the measurement.

Systematic Errors

3. Random Errors

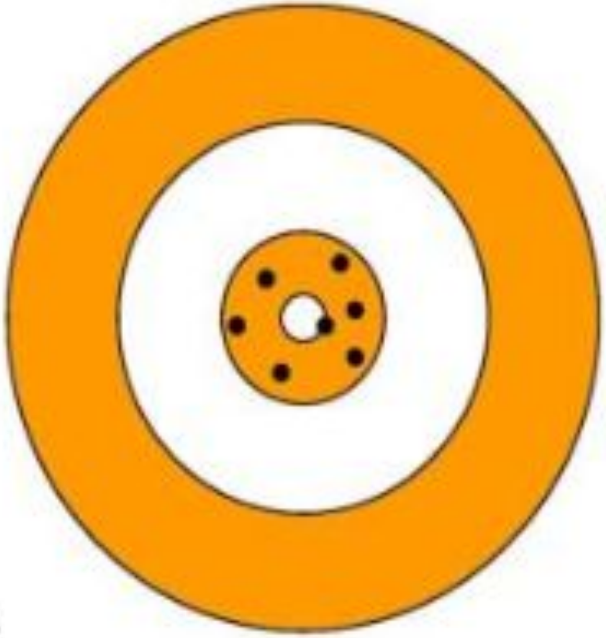
- These errors are due to unknown causes and occur even after the removal of the systematic error.
- These errors are due to friction in instrument movement, parallax errors between pointer and scale, mechanical vibrations, hysteresis in elastic members etc.
- Hence such type of error is also called residual error.

Random Errors

Distributed randomly around the average value.

They are inherent in any measurement and come from the same sources as systematic errors.

Because the errors are random, they can be corrected for by making many measurements and averaging the results.



Random errors affect the <u>precision</u> of a measurement.

Absolute Error

Absolute errors.

Absolute errors maybe defined as the *difference* between the *expected value* of the variable and the *measured value* of the variable, or

$$e = Yn - Xn$$

where:

e = absolute error.

Yn = expected value.

Xn = measured value

$$\% \text{ Error} = \frac{\text{Absolute value}}{\text{Expected value}} \times 100 = \frac{e}{Y_n} \times 100$$

$$\% \text{ Error} = \left(\frac{Y_n - X_n}{Y_n} \right) \times 100$$

It is more frequently expressed as a accuracy rather than error.

$$A = 1 - \left| \frac{Y_n - X_n}{Y_n} \right|$$

A is the relative accuracy

$$a = 100\% - \% \text{ error}$$

$$a = A \times 100\ \%$$

Accuracy is expressed as % accuracy

Example-1

The expected value of the voltage across a resistor is 80 V. However, the measurement gives a value of 79 V. Calculate (i) absolute error, (ii) % error, (iii) relative accuracy, and (iv) % of accuracy.

Solution

(i) Absolute error $e = Y_n - X_n = 80 - 79 = 1\ \text{V}$

(ii) % Error $= \dfrac{Y_n - X_n}{Y_n} \times 100 = \dfrac{80 - 79}{80} \times 100 = 1.25\%$

(iii) Relative Accuracy

$$A = 1 - \left|\frac{Y_n - X_n}{Y_n}\right| = 1 - \left|\frac{80 - 79}{80}\right|$$

$\therefore \quad A = 1 - 1/80 = 79/80 = 0.9875$

(iv) % of Accuracy $\quad a = 100 \times A = 100 \times 0.9875 = 98.75\%$

or $\quad a = 100\% - \%\text{ of error} = 100\% - 1.25\% = 98.75\%$

Example-2

The expected value of the current through a resistor is 20 mA. However the measurement yields a current value of 18 mA. Calculate (i) absolute error (ii) % error (iii) relative accuracy (iv) % accuracy

Solution

Step 1: Absolute error

$$e = Y_n - X_n$$

where e = error, Y_n = expected value, X_n = measured value

Given $Y_n = 20$ mA and $X_n = 18$ mA

Therefore $e = Y_n - X_n = 20\text{ mA} - 18\text{ mA} = 2\text{ mA}$

Step 2: % error

$$\%\text{ error} = \frac{Y_n - X_n}{Y_n} \times 100 = \frac{20\text{ mA} - 18\text{ mA}}{20\text{ mA}} \times 100 = \frac{2\text{ mA}}{20\text{ mA}} \times 100 = 10\%$$

Step 3: Relative accuracy

$$A = 1 - \left|\frac{Y_n - X_n}{Y_n}\right| = 1 - \left|\frac{20\text{ mA} - 18\text{ mA}}{20\text{ mA}}\right| = 1 - \frac{2}{20} = 1 - 0.1 = 0.90$$

Step 4: % accuracy

$$a = 100\% - \%\text{error} = 100\% - 10\% = 90\%$$

$$a = A \times 100\% = 0.90 \times 100\% = 90\%$$

Example-3

The expected value of the voltage across a resistor is 5.0 V. However, measurement yields a value of 4.9 V. Calculate:

a) absolute error

b) % error