Errors in Measurement

No measurement can be made with perfect accuracy, but it is important to find out what accuracy actually is and how different errors have entered into the measurement. A study of errors and their sources is a first step in finding ways to reduce them. Errors come from different sources and are usually classified as under in three main catagories.

(1) Gross Errors (2) Systematic errors (3) Random Errors.

(1) Gross Errors : (Human Errors)

This class of errors mainly covers human mistakes in reading instruments and recording as well as calculating measurement resuets. The error is on the experimeter or the user. Among them a/c of include :

* misreading due to oversight [may record 21.3 A instead of 31.3 A].
* error while transposing reading [may read 25.8 A but record 28.5 A].
* incorrect adjustment of instrument
* improper application of instrument

& so on.

Gross errors may be of any amount and therefore, their mathematical analysis is impossible. However, they can be avoided by :—

(i) Taking greater care in reading and recording the data.

(ii) two, three or even more readings should be taken for the quantity under measurement. These readings should be taken preferably by different experimenters and then taking an average of these readings to arrive at the best approx. value of the quantity under measurement.

(2) Systematic errors :-

They are further divided into three catagories

(i) Instrumental errors (ii) Environmental errors (iii) Observational errors.

(i) Instrumental errors

These errors rise due to three main reasons.

(a) Due to inherent short comings in the instrument

(b) Due to misuse of instrument

(c) Due to loading effects of Instrument.

(a) Inherent short comings of Instrument

These errors are inherent in instruments because of their mechanical structure. They may be due to construction, Calibration, or operation of the instruments or measuring device. These errors may cause the instruments to read too low or too high. Errors may be also because of friction, hysteresis or even gear backlash.

These can be avoided/minimised by

i) Carefully planning the measurement procedure
ii) Apply correction factors after determining the instrumental errors.
iii) Re-calibrating the instrument carefully.

(b) Misuse of Instrument

Too often, the errors caused in measurements are due to the fault of operator than that of instrument. A good instrument used in an unintelligent way may give erroneous results. e.g. faulty zero adjustment, poor adjustments, using leads of too high resistance, etc.

(C) Loading effects

This errors is most commonly committed by beginners. e.g. a well calibrated voltmeter may give a misleading voltage reading when connected across a high resistance circuit. The same voltmeter, when connected in a low resistance circuit, may give a more dependable reading. This is due to loading effect of voltmeter on the circuit. The voltmeter alters the actual circuit conditions when connected for purposes of measurement.

(Explained in example which follows at the end).

ii) Environmental Errors

These errors are due to conditions external to the measuring device including conditions in the area surrounding the instrument. These may be effects of temperature, pressure, humidity, dust, vibrations, or of external magnetic or electrostatic fields.

These can be avoided by

(a) Keep conditions external to instrument constant. e.g. temp can be kept constant by keeping the equipment / measuring device in temp controlled enclosure (Air-conditioning).

(b) Using equipment which is immune to these effects. e.g. use material with low α to prevent change in resistance with Temperature.

(c) Use hermetical seal to ~~[illegible]~~ eleminate effects of external disturbances like, humidity, dust, etc.

(d) Use Electromagnetic and Electrostatic shields to prevent interferance from nearby magnetic and electrostatic fields.

(e) Apply computed corrections.

(iii) observational errors

There are many sources of observational errors. e.g. parallax error, the pointer of a voltmeter rests slightly above the surface of scale. The error is incurred ~~if~~ unless the line of vision of observer is ~~not~~ exactly above the pointer.

To minimise this parallax, meters are provided by mirror backed scale, where in we ~~keep~~ overlap the pointer and its image in the mirror just below it so that there is no parallax error.

The sensing capability of ~~[illegible]~~ individual observers affect the accuracy of measurement.

③ Random Errors

It has been found than even after ~~taking~~ all systematic errors have been accounted for, the experimental results show variations from one reading to another. These errors are due to a multitude of small factors which change or fluctuate from one measurement to another. These errors are caused by unknown reasons. Sometimes present and at times not present. Due ~~the~~ to unknown reasons which leads errors in measurement are classified as Radom errors. Since their root cause is not known, we can not minimise them. Thus ~~[illegible]~~ how to minimise them?

The only method to minimise random errors is to get a good number of readings of the quantity under measurement and use different statistical techniques to arrive at the best approximate value.

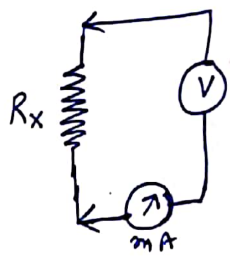
<u>Example:</u> A voltmeter having a sensitivity of 1000 Ω/V reads 100V on its 150V scale when connected across an unknown resistor in series with a milli-ammeter. When the milli-ammeter reads 5 mA, calculate:

(a) (i) apparent resistance of the unknown resistor

(ii) actual resistance of the unknown resistor &

(iii) error due to loading effect of voltmeter.

(b) Repeat the above example if the mill-ammeter reads 800 mA and the voltmeter reads 40V on its 150V scale.



(a) (i) Total circuit resistance

$$R_T = \frac{E_T}{I_T} = \frac{100}{5\times10^{-3}} = 20\,k\Omega$$

Neglecting the resistance of mA, the unknown resistance

$$\boxed{R_x = 20\,k\Omega}$$

(ii) Resistance of voltmeter = Sensitivity (Ω/V) × Voltage range (V)

$$R_V = 1000 \times 150 = 150\,k\Omega$$

~~Since~~ The voltmeter & unknown resistance R_x are in parallel.

∴ Total resistance $R_T = \frac{R_x R_V}{R_V + R_x}$

$$R_T R_V + R_T R_x = R_x R_V$$

$$R_x (R_V - R_T) = R_T R_V$$

$$R_x = \frac{R_T R_V}{R_V - R_T} = \frac{20\,k\Omega \times 150\,k\Omega}{(150\,k\Omega - 20\,k\Omega)} = 23.07\,k\Omega$$

$$\boxed{R_x = 23.07\,k\Omega}$$

(iii) Percentage error $= \frac{\text{measured value} - \text{true value}}{\text{True value}} \times 100$

$$= \frac{20 - 23.07}{23.07} \times 100$$

$$\boxed{\%\text{age error} = -13.33\%}$$

(b) (i) $R_T = \frac{40}{800 \times 10^{-3}} = 50\,\Omega$; $\boxed{R_T = 50\,\Omega}$

$R_V =$ same $= 150\,k\Omega$;

(ii) $R_x = \frac{R_T R_V}{R_V - R_T} = \frac{50 \times 150 \times 10^3}{150 \times 10^3 - 50} = 50.017\,\Omega$.

$$\boxed{R_x = 50.017\,\Omega}$$

(iii) Percentage error $= \frac{50.0 - 50.017}{50.017} \times 100$

$$\boxed{\%\text{age error} = -0.034\%}$$

Comments upon the Results

The ~~%~~ percentage error produced by the Same instrument under two different applications is quite different. ~~When a high resistance voltmeter is used~~ This is due to loading effect caused by the voltmeter when connected across unknown resistor.

~~In high resistance~~