Instrumentation

Tutorial 1
Topic: Measurement and Errors

1. A wheatstone bridge requires a change of 7Ω in the unknown arm to produce a change of 3mm deflection of galvanometer. Determine the sensitivity and deflection factor(scale factor).

Sulution:

$$\text{Sensitivity} = \frac{\text{magnitude of output response}}{\text{magnitude of input}}$$

$$= \frac{3\,\text{mm}}{7\Omega} = 0.429\ \text{mm}/\Omega$$

Inverse sensitivity or scale factor

$$= \frac{\text{magnitude of input}}{\text{magnitude of output response}} = \frac{7\Omega}{3\,\text{mm}}$$

$$= 2.33\ \Omega\,/\,\text{mm}.$$

2. A dead zone in a certain pyrometer is 0.125% of span. The calibration is 400ºC to 1000ºC. What temperature change might occur before it is detected?

Solution:

$$\text{Span} = 1000 - 400 = 600°\text{C}.$$

$$\therefore \text{ Dead zone} = \frac{0.125}{100} \times 600 = 0.75°$$

A change of 0.75°C must occur before it is detected.

3. A voltmeter can read out range from 0 to 200 counts. Determine the resolution of the instrument in volt when full scale reading is 1.21V.

Solution:

Total division= 200 divs.

FSR = 1.21V

Now,

200 divs = 1.21 V

1 div = 1.21/200 = 0.00605V

Therefore, the resolution of the instrument = 0.00605V.

4. A moving coil voltmeter has a uniform scale with 100 divisions, the full scale reading is 200V and 1/10 of a scale division can be estimated with fair degree of certainty. Determine the resolution of the instrument in volt.

Solution. 1 scale division $= \frac{200}{100} = 2\text{ V}$

$$\text{Resolution} = \frac{1}{10}\text{ scale division} = \frac{1}{10} \times 2 = 0.2\text{ V}$$

5. A voltmeter whose accuracy is 2% of the full scale reading is used on its 0 – 50V scale. The voltage measured by the meter is 15V and 42V. Calculate the possible percentage error of both readings. Comment upon your answer.

Solution:

Error = 2% of FSR = 0.02 × 50 = 1V

For 15V reading,

percent error = 1/15 × 100 = 6.67%

For 42V reading,

percent error = 1/42 × 100 = 2.38%

(Give comment)

6. 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.

Solution

(i) The total circuit resistance $R_T = \dfrac{V_T}{I_T} = \dfrac{80}{10\text{ mA}} = 8\text{ k}\Omega$

(Neglecting the resistance of the milliammeter.)

(ii) The voltmeter resistance equals $R_v = 1000\ \Omega/\text{V} \times 150 = 150\text{ k}\Omega$

∴ actual value of unknown resistance $R_x = \dfrac{R_T \times R_v}{R_v - R_T} = \dfrac{8\text{k} \times 150\text{k}}{150\text{k} - 8\text{k}}$

$$= \frac{1200\text{k}^2}{142\text{k}} = 8.45\ \Omega$$

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(iii) $$\% \text{ error} = \frac{\text{Actual value} - \text{Apparent value}}{\text{Actual value}} = \frac{8.45\text{k} - 8\text{k}}{8.45\text{k}} \times 100$$

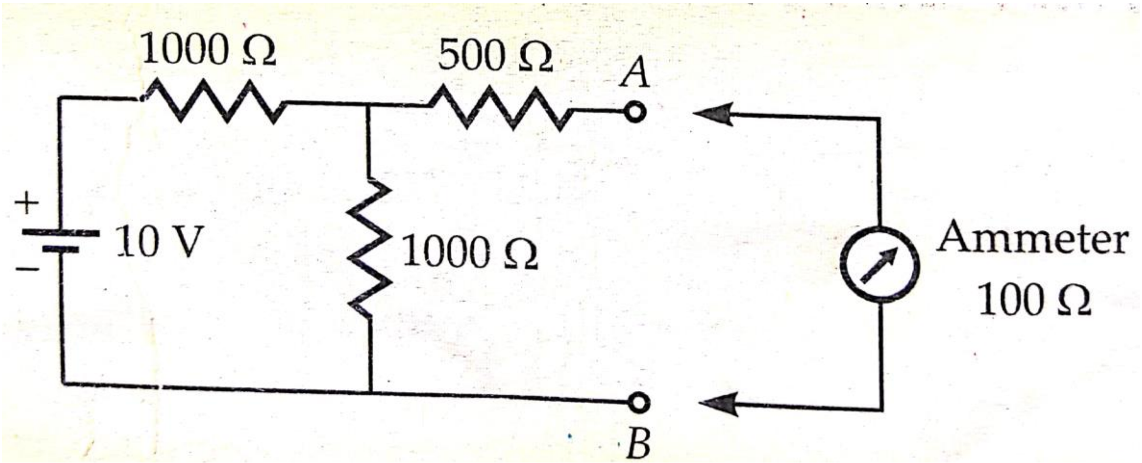
$$= 0.053 \times 100 = 5.3\%$$

7. It is desired to measure the value of current in the 500Ω resistor as shown in the figure by connecting a 100Ω ammeter. Find:

i) The actual value of current

ii) Measured value of current

iii) Percentage error in measurement.



Solution:

a) Let us reduce the circuit in to equivalent Thevenin's source:

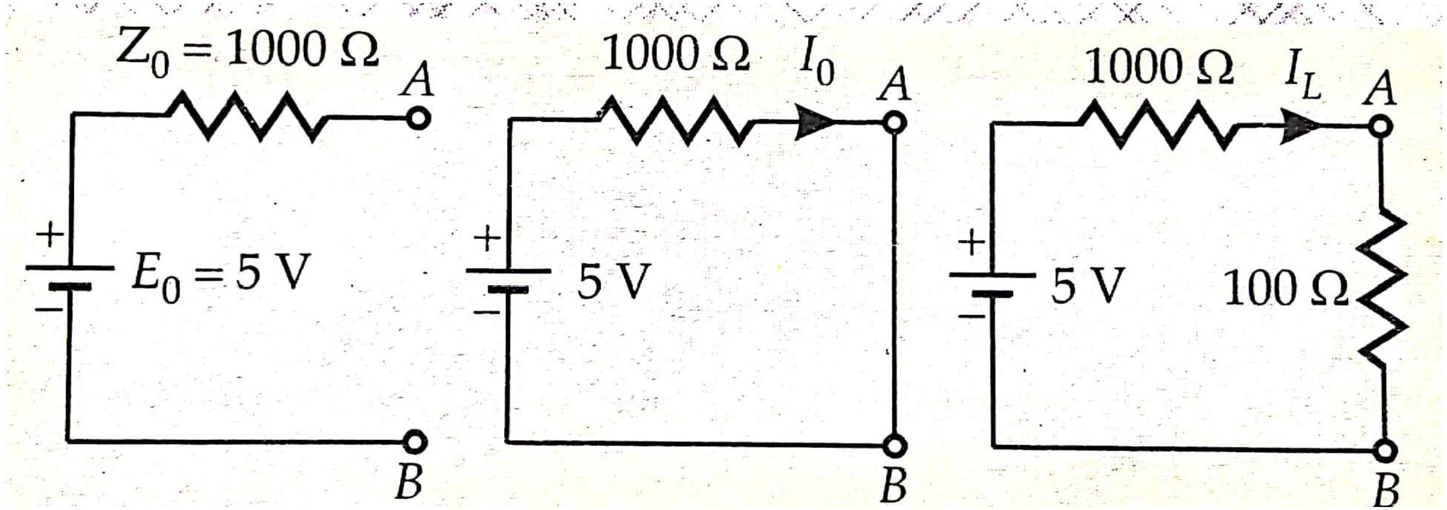
Open circuit voltage as applying at terminals A and B is,

$$E_0 = 10 - \frac{10}{1000+1000} \times 1000 = 5\ \text{V}.$$

Output impedance of source as looking into terminals A and B is,

$$Z_0 = \frac{1000 \times 1000}{1000+1000} + 500 = 1000\ \Omega$$

The Thevenin's equivalent circuit is shown below:



$\therefore$ Actual value of current $I_0 = \dfrac{E_0}{Z_0} = \dfrac{5}{1000}\text{ A} = 5\text{ mA}$

b) When the ammeter is introduced in to the ckt, the current is modified.

Measured value of current

$$I_L = \frac{E_0}{Z_0 + Z_L} = \frac{5}{1000 + 100} \text{ A} = 4.55 \text{ mA}.$$

$$(c)\ \text{Error} = \frac{4.55 - 5}{5} \times 100 = -9\% = 9\% \text{ low}$$

Accuracy of measurement $= 100 - 9 = 91\%$.

8. A voltmeter reading 70 V on its 100 V range and an ammeter reading 80 mA on its 150 mA range are used to determine the power dissipated in a resistor. Both these instruments are guaranteed to be accurate within ±1.5% at full scale defl ection. Determine the limiting error of the power.

Solution The magnitude of the limiting error for the voltmeter is

$$0.015 \times 100 = 1.5 \text{ V}$$

The limiting error at 70 V is

$$\frac{1.5}{70} \times 100 = 2.143 \text{ \%}$$

The magnitude of limiting error of the ammeter is

$$0.015 \times 150 \text{ mA} = 2.25 \text{ mA}$$

The limiting error at 80 mA is

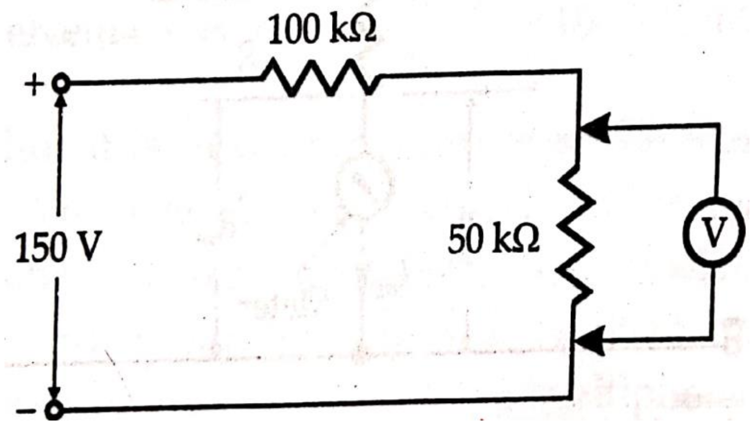
$$\frac{2.25 \text{ mA}}{80 \text{ mA}} \times 100 = 2.813 \text{ \%}$$

Therefore, the limiting error for the power calculation is the sum of the individual limiting errors involved.

Therefore, limiting error = 2.143 % + 2.813 % = 4.956 %

9. It is desired to measure voltage across 50Ω resistor in theb given circuit. Two voltmeters are available for this purpose.

Voltmeter A with a sensitivity of 1000 Ω/V and Voltmeter B with a sensitivity of 20,000 Ω/V.



Both meters have 0 – 50 V range. Calculate :

(a) The reading of each voltmeter ;

(b) The error in each reading expressed as a percentage of true value.

Solution:

Solution. True value of voltage across the 50 kΩ resistor $= 50/(100+50) \times 150 = 50$ V.

(a) ***Voltmeter A.*** Resistance of voltmeter

$$R_v = S_v V = 1000 \times 50\ \Omega = 50\ \text{k}\Omega.$$

Now this voltmeter is connected across the 50 kΩ resistor and therefore the resistance of parallel combination of voltmeter and resistor is

$$50 \times 50/(50+50) = 25\ \text{k}\Omega.$$

Voltage across the combination of voltmeter and resistor $= 25/(100+25) \times 150 = 30$ V.

Hence voltmeter *A* indicates a voltage of 30 V.

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Voltmeter B. **Resistance of voltmeter**

$$R_v = S_v V = 20{,}000 \times 50\ \Omega = 1000\ \text{k}\Omega$$

Resistance of combination of voltmeter in parallel with 50 kΩ resistor

$$= 1000 \times 50 / (1000 + 50) = 47.6\ \text{k}\Omega.$$

∴ Voltage across the combination of voltmeter and resistor

$$= 47.6 / (100 + 47.6) \times 150 = 48.37\ \text{V}.$$

Hence voltmeter *B* indicates a voltage of 48.37 V.

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(*b*) ***Voltmeter A.*** Percentage error

$$= \frac{\text{indicated voltage} - \text{true voltage}}{\text{true voltage}} \times 100$$

$$= \frac{30 - 50}{50} \times 100 = -40\%$$

Voltmeter B. Percentage error

The above results indicate that the meter with higher sensitivity or ohm per volt rating gives more reliable results. This is particularly true in the cases where voltage measurements are made in high resistance circuits.