ESE (Mains) 2019
Electronic Measurement & Instrumentation

Important Questions with Solutions

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1. A resistor has voltage drop of 110.2V and current of 5.5A. the uncertainties in the measurement of voltage and current are ± 0.5V and ±0.01 respectively calculate the uncertainty in power calculation.

Ans. Power (P) = voltage x current = V x I

= 110.2 × 5.5

= 606.1 w

Uncertainty in power =

$$\sqrt{\left(\frac{\partial P}{\partial V}\right)^2 w_v^2 + \left(\frac{\partial P}{\partial I}\right)^2 w_i^2} \qquad (i)$$

Where w_v and w_i are uncertainties in calculation of voltage and current respectively.

$$\frac{\partial P}{\partial V} = \frac{\partial}{\partial V} VI = I = 5.5 \qquad (ii)$$

$$\frac{\partial P}{\partial I} = \frac{\partial}{\partial I} VI = V = 110.2 \qquad (iii)$$

By i, ii, iii

Uncertainty in power =

$$\sqrt{[5.5]^2 \times 0.5 + [110.2]^2 \times 0.01}$$

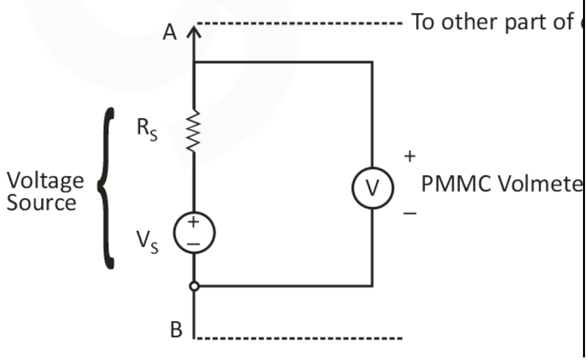
= ± 2.962 w

Uncertainty in power =

$$\pm \frac{2.962}{606.1} \times 100 = \pm 0.4888\%$$

2. A PMMC voltage has a reading of 9V when it is measuring a voltage source with an internal resistance of finite value on its scale of 10V. When scale of this is changed to 20v full scale then reading of 13 is obtained. Given sensitivity of voltmeter to be 50 kΩ/V. Find value of the voltage source and its internal resistance R.

Ans.



V_V = voltage across voltmeter =

$$V_s \frac{R_s}{R_s + R_v} \qquad ......(i)$$

V_s = voltage of source

R_s and R_v are resistance of source & voltmeter respectively.

<u>Case i</u>

V_v= 9V, V_s = ? R_s= ?

RV = sensitivity × range = 50 k Ω / V × 10 v

= 500 k/Ω

by (1)

∴9 = V_sR_v

$R_s + 500$

9 (R_s + 500) = V_sR_v

V_s. (500) = 9 (R_s + 500) ....(ii)

<u>Case ii</u>

V_V = 13V V_S= ?

R_S= ?

R_V = 50kΩ / V × 20v

R_V = 1000 kΩ

by (1)

$$13 = \frac{V_s\, R_v}{(R_s + 1000)}$$

V_s × (1000) = 1.5 (R_s + 1000) ......(iii)

by (ii) & (iii)

$$\frac{9(R_s + 500)}{500} = \frac{13(R_s + 1000)}{1000}$$

18 R_s + 9000 = 13 R_s + 13000

S0 5R_s = 4000

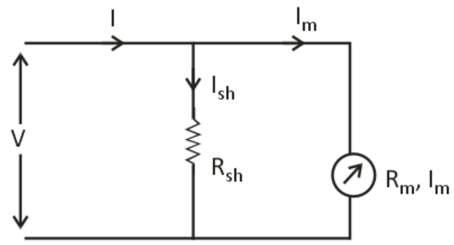
R_s = 800

3. Given a meter of range 0 – 1mA, having internal resistance of 5Ω. How do you extend the range of it to 10 mA?

Ans. To extend the range of ammeter a shunt resistance is applied to ammeter to bypass excess current through this shunt resistor.

Only rated current flours through ammeter. But now the dial of ammeter has to be recalibrated by multiplying the values with multiplication factor m. by following above steps the range of ammeter is extended.

<u>Numerical :</u>



R_m = internal meter resistance
R_{sh} = external shunt resistor to bypass excess current
I_m = meter current
I_{sh} = current in shunt arm
I = rated current of extended range meter
$\because V = I_m R_m = I_{sh}R_{sh}$ [KVL]
$I_m R_m = [I - I_m] R_{sh}$ ($\because I = I_m + I_{sh}$ KCL)

$$R_{sh} = \frac{R_m}{(m-1)} \quad where \left(m = \frac{I}{I_m} \right)$$

m = multiplication factor
I = 10mA, I_m = 1 mA, R_m = 5Ω,

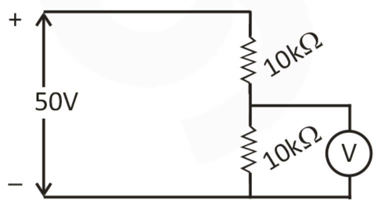
$$m = \frac{I}{I_m} = 10$$

$$\therefore R_{sh} = \frac{5}{10-1}$$

$$R_{sh} = \frac{5}{9} = 0.55\Omega$$

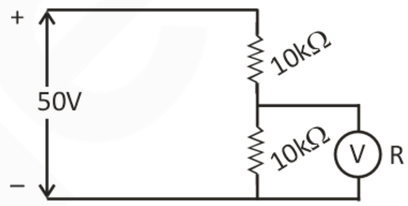
So, by connecting shunt resistance of 0.556Ω and multiplying dial value by m = 10 the range of ammeter will be extended from 1 mA to 10 mA.

4. A) explain the following terms with respect to measurement system:-
i) accuracy ii) precision iii) resolution
iv) sensitivity v) linearity
B) A voltmeter is connected across 10kΩ resistor as shown in figure



The voltmeter shows 24.5v, but it must have shown 25V. Why is his happening? Explain

Ans. i) Accuracy: The closeness with which instrument value or reading approaches the true value or quantity being measured. It means conformity to truth.
ii) Precision: It is measure of reproducibity of the measurements precision is a measure of degree of agreement within a group of measurements.
iii) Resolution: The smallest increment in the quantity being measured that can be measured with certainty by an instrument.
iv) Sensitivity: sensitivity of an instrument is ratio of magnitude of output signal / response to the magnitude of input signal / quantity being measured.
v) linearity: linearity is simply measure of maximum deviation of calibration points from the straight line.
B) The reduction in measured value of voltmeter is due to loading effect to voltmeter as voltmeter has some finite input resistance



Had the internal resistance of voltmeter infinite then no loading effect will occur and value shown by voltmeter will be true value itself
Let R_V be internal resistance of voltmeter
So, R_V is parallel to 10kΩ resistance and R_{eq} is equivalent
Resistance

$$R_{eq} = R_v \,||\, 10k\Omega = \frac{10R_v}{10+R_v}$$

∴ voltage shown by voltmeter =

$$50 \times \frac{R_{eq}}{R_{eq}+10K} \quad (KVL)$$

$$24.5 = \frac{50R_{eq}}{R_{eq}+10}$$

$24.5\, R_{eq} + 245 = 50\, R_{eq}$

$$R_{eq} = \frac{245}{25.5} = 9.60k\Omega$$

$$\boxed{R_{eq} = 9.60k\Omega}$$

$$R_{eq} = \frac{10R_v}{10+R_v} = 9.60$$

$10R_v = 96 + 9.6 R_v$

$0.4 R_v = 96$

$$R_v = \frac{96}{0.4} = 240k\Omega$$

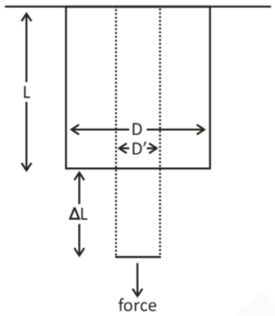
Therefore $\boxed{R_v = 240k\Omega}$ and this resistance of voltmeter causes the net voltage to reduce and is called loading effect

5. Define gauge factor for strain gauge and derive the expression for the same. Also explain the significance of piezo – resistivity in the expression.

Ans. If a metal is stretched or compressed, its resistance changes on account of fact that both the length and diameter / area of conductor changes. Also there is change in value of resistivity when strained.

Gauge factor derivation:

Consider a wise having initial length L and diameter D when stress or force is applied its length increases by ΔL and diameter decreases to D'



$$\because \text{Resistance } R = \rho\frac{L}{A}$$

ρ = resistivity

L = length of wire

A = area of wire $= \frac{\pi D^2}{4}$ $\quad (i)$

D = diameter of wire

$$R = \rho\frac{L}{A}$$

ln R = ln ρ + ln(L) – ln(A) [taking natural log both sides]

differentiate the above equation with respect to stress (σ)

$$\frac{1}{R}\frac{dR}{d\sigma} = \frac{1}{\rho}\frac{d\rho}{d\sigma} + \frac{1}{L}\frac{dL}{d\sigma} - \frac{1}{A}\frac{dA}{d\sigma} \quad (ii)$$

$$\therefore A = \frac{\pi D^2}{4}$$

$$\frac{dA}{d\sigma} = \frac{\pi(2D)}{4}\frac{dD}{d\sigma} = \frac{\pi D}{2}\frac{dD}{d\sigma}$$

$$\therefore \frac{1}{A}\frac{dA}{d\sigma} = \frac{4^2}{\pi D^2} \times \frac{\pi D}{2}\frac{dD}{d\sigma} = \frac{2}{D}\frac{dD}{d\sigma}$$

$$\boxed{\frac{1}{A}\frac{dA}{d\sigma} = \frac{2}{D}\frac{dD}{d\sigma}} \quad ......(iii)$$

by (ii) & (iii)

$$\frac{1}{R}\frac{\partial R}{d\sigma} = \frac{1}{\rho}\frac{d\rho}{d\sigma} + \frac{1}{L}\frac{dL}{d\sigma} - \frac{2}{D}\frac{dD}{d\sigma}$$

Rearranging above equation for small variation:-

$$\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} - 2\frac{dD}{D}$$

$$\frac{\Delta R}{R} = \frac{\Delta\rho}{\rho} + \frac{\Delta L}{L} - 2\frac{\Delta D}{D}$$

$$\frac{\Delta R/R}{\Delta L/L} = \left\{1 - 2\frac{\Delta D/D}{\Delta L/L} + \frac{\Delta\rho/\rho}{\Delta L/L}\right\}$$

$$Guage\ factor = \frac{\Delta R/R}{\Delta L/L} = \left\{1 - \frac{2\ \Delta D/D}{\Delta L/L} + \frac{\Delta\rho/\rho}{\Delta L/L}\right\} \quad ......$$

$$\therefore \left[\frac{\frac{-\Delta D}{D}}{\frac{\Delta L}{L}}\right] = poissons\ ratio = \vartheta$$

$$\therefore \boxed{Guage\ factor = \frac{\Delta R/R}{\Delta L/L} = \left\{1 + 2\vartheta + \frac{\Delta P/P}{\Delta L/L}\right\}}$$

→ for resistor made of metal resistivity is not changed so gauge factor depends on GF = (1+2ϑ) dimensions

→ For resistor mode of semiconductors so guage factor depends mainly on $\left(\frac{\Delta\rho/\rho}{\Delta L/L}\right)$. As resistivity changes sharply.