ELECTRICAL ENGINEERING

GATE | PSUs

ELECTRICAL & ELECTRONIC MEASUREMENTS

Volume - I : Study Material with Classroom Practice Questions

Electrical Measurements

1. Error Analysis

01. Ans: (a)

Sol: For 10V total input resistance

$R_v = \dfrac{V_{fsd}}{I_{m\,fsd}} = 10/100\mu A = 10^5\Omega$

Sensitivity = $R_v/V_{fsd} = 10^5/10$

$= 10k\Omega/V$

For 100V $R_v = 100/100\mu A = 10^6\Omega$

Sensitivity = $R_v/V_{fsd} = 10^6/100$

$= 10\ k\Omega/V$

(or)

Sensitivity = $\dfrac{1}{I_{fsd}} = \dfrac{1}{100\times10^{-6}}$

$= 10\ k\Omega/V$

02. Ans: (d)

Sol: Variables are measured with accuracy

x = ± 0.5% of reading 80 (limiting error)

Y = ± 1% of full scale value 100

(Guaranteed error)

Z = ± 1.5 % reading 50 (limiting error)

The limiting error for Y is obtained as Guaranteed

Error = 100×(± 1/100) = ± 1

Then % L.E in Y meter

$20\times\dfrac{x}{100} = \pm1$

x = 5%

Given $w = xy/z$, Add all %L.E s

Therefore =± (0.5% + 5% + 1.5%)

= ± 7%

03.

Sol: Mean$(\overline{X}) = \dfrac{\sum x}{n}$

$= \dfrac{41.7+42+41.8+42+42.1+41.9+42.5+42+41.9+41.8}{10}$

= 41.97

$SD = \sqrt{\dfrac{\Sigma d_n^2}{n-1}}$ for n < 20 $d_n = \overline{X} - X_n$

$$\sqrt{\frac{(0.27)^2+(-0.03)^2+(-0.17)^2+(-0.03)^2+(-0.13)^2+(0.07)^2+(-0.53)^2+(-0.03)^2+(-0.13)^2+(0.17)^2}{10-1}}$$

= 0.224

Probable error = ± 0.6745 × SD

= ± 0.1513

04.

Sol: Dial resistance of 1000 Ω

Error = $\pm\ 4000\times\dfrac{0.02}{100} = 0.8$

Dial resistance of 100 Ω

Error = $\pm\ 300\times\dfrac{0.05}{100} = 0.15\Omega$

Dial resistance of 10 Ω

Error = $\pm\ 20\times\dfrac{0.1}{100} = 0.02\Omega$

Dial resistance of 1 Ω

Error = $\pm\ 5\times\dfrac{0.2}{100} = 0.01\Omega$

Hence total error = ± (0.8+0.15+0.02 + 0.01)

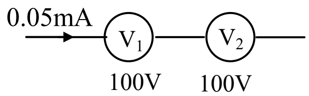
= ± 0.98 Ω

Relative limiting error

$$= \pm \frac{0.98}{4325} = \pm 2.26 \times 10^{-4}$$

05.

Sol:



V_1 :

$S_{dc_1} = 10\,k\Omega/V$

$I_{fsd} = \frac{1}{S_{dc1}}$

$= 0.1mA$

V_2 :

$S_{dc_2} = 20\,k\Omega/V$

$I_{fsd} = \frac{1}{S_{dc2}}$

$= 0.05\ mA$

The maximum allowable current in this combination is 0.05mA, since both are connected in series.

Maximum D.C voltage can be measured as

$= 0.05\ mA\ (10\ k\ \Omega/V \times 100 + 20\ k\Omega/V \times 100)$

$= 3000 \times 0.05 = 150\ V$

06.

Sol: Internal impedance of 1st voltmeter

$$= \frac{100V}{5\,mA} = 20\ k\Omega$$

Internal impedance of 2nd voltmeter

$= 100 \times 250\ \Omega/V = 25\ k\Omega$

Internal impedance of 3rd voltmeters,

$= 5\ k\Omega$

Total impedance across 120 V

$= 20 + 25 + 5 = 50\ k\Omega$

$$\text{Sensitivity} = \frac{50\,k\Omega}{120\,V} \Rightarrow 416.6\,\Omega/V$$

$\Rightarrow$ Reading of 1st voltmeter

$$= \frac{20\,k\Omega}{416.6\,\Omega/V} = 48\ V$$

Reading of 2nd voltmeter

$$= \frac{25\,k\Omega}{416.6\,\Omega/V} = 60\ V$$

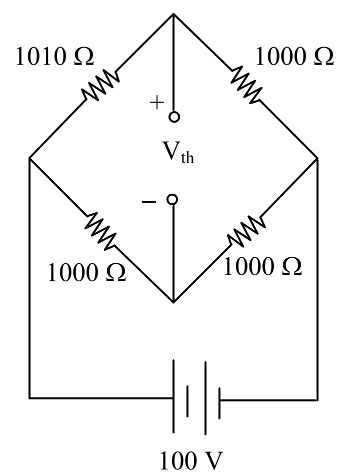
Reading of 3rd voltmeter

$$= \frac{5\,k\Omega}{4166\,\Omega/V} = 12\ V$$

07. Ans: (b)

Sol: $\text{Bridge sensitivity} = \frac{\text{Change in ouput}}{\text{Change in input}}$

$$= \frac{V_{th}}{10\,\Omega}$$



$$V_{th} = \frac{1010 \times 100}{2000} - \frac{1000 \times 100}{2000} = 0.25V$$

$$S_B = \frac{0.25\,V}{10\,\Omega} = 25\ mV/\Omega$$

08. Ans: (d)

Sol: $W_T = W_1 + W_2 = 100 - 50 = 50\ W$

$$\frac{\partial W_T}{\partial W_1} = \frac{\partial W_T}{\partial W_2} = 1$$

Error in meter 1 = $\pm \frac{1}{100} \times 100 = \pm 1$ W

Error in meter 2 = $\pm \frac{0.5}{100} \times 100 = \pm 0.5$ W

$W_T = W_1 + W_2 = 50 \pm 1.5$ W

$W_T = 50 \pm 3\%$

09. Ans: (b)

Sol: Resolution = $\frac{200}{100} \times \frac{1}{10} = 0.2$ V

10. Ans: (b)

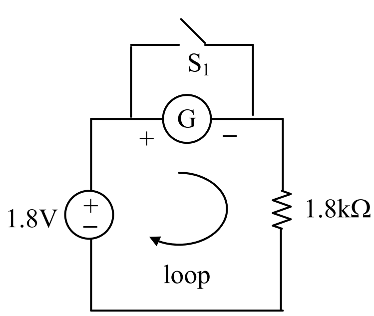
Sol: $\% \text{ LE} = \frac{\text{FSV}}{\text{true value}} \times \%\text{GAE}$

$= \frac{200\,\text{V}}{100\,\text{V}} \times \pm 2\% = \pm 4\%$

3. Electromechanical Indicating Instruments

01. Ans: (d)

Sol: The pointer swings to 1 mA and returns, settles at 0.9 mA i.e, pointer has oscillations. Hence, the meter is under-damped. Now the current in the meter is 0.9 mA.



Applying KVL to circuit,

$1.8 \text{ V} - 0.9 \text{ mA} \times R_m - 0.9 \text{ mA} \times 1.8 \text{ k}\Omega = 0$

$1.8 \text{ V} - 0.9\times10^{-3} R_m - 1.62 = 0$

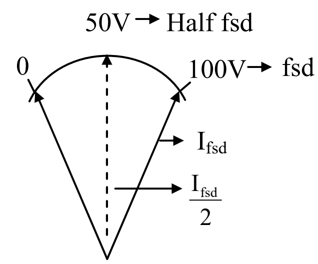
$R_m = \frac{0.18}{0.9\times10^{-3}} = 200\ \Omega$

02. Ans: (c)

Sol: $S = \frac{1}{1000}\ \Omega/\text{volt}$

$S = \frac{1}{I_{fsd}}\ \Omega/\text{V}$

$I_{fsd} = \frac{1}{S} = \frac{1}{1000} = 1$ mA



$100 \text{ V} \rightarrow 1 \text{ mA}$

$50 \text{ V} \rightarrow ?$

$= 0.5$ mA

03. Ans: (b)

Sol: $T_d = \frac{1}{2} I^2 \frac{dL}{d\theta}$

$K_c \theta = \frac{I^2}{2} \frac{dL}{d\theta}$

$25 \times 10^{-6} \times \theta = \frac{25}{2} \times \left(3 - \frac{\theta}{2}\right) \times 10^{-6}$

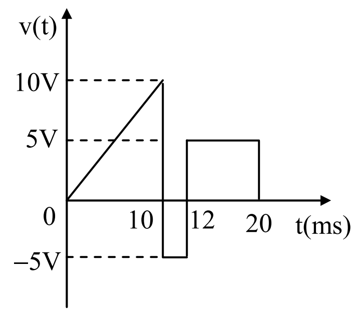
$2\theta = 3 - \frac{\theta}{2}$

$\frac{5}{2}\theta = 3$

$\theta = 1.2$ rad

04. Ans: (a)

Sol:



PMMC meter reads Average value

$$V_{avg} = \frac{\left(\frac{1}{2}\times10\times10ms\right)+(-5V\times2ms)+(5V\times8ms)}{20ms}$$

$$= \frac{50-10+40}{20} = 4V$$

(or)

$$\text{Avg. value} = \frac{1}{20}\left[\int_0^{10}(1)\,t\,dt - \int_{10}^{12}5\,dt + \int_{12}^{20}5\,dt\right]$$

$$= \frac{1}{20}\left[\left[\frac{t^2}{2}\right]_0^{10} - 5[t]_{10}^{12} + 5[t]_{12}^{20}\right]$$

$= 4$ V

05. Ans: (a)

Sol:

	1°C↑	10°C	T_c	θ
Spring stiffness(K_c)	0.04%↓	0.4%↓	0.4%↓	0.4%↑
			T_d	θ
Strength of magnet (B)	0.02%↓	0.2%↓	0.2%↓	0.2%↓

Net deflection (θ_{net}) = 0.4%↑ – 0.2%↓

= 0.2% ↑

Increases by 0.2%

06. Ans: 32.4° and 21.1°

Sol: $I_1 = 5$ A, $\theta_1 = 90°$; $I_2 = 3$ A, $\theta_2 = ?$

$\theta \propto I^2$ (as given in Question)

(i) Spring controlled

$\theta \propto I^2$

$$\frac{\theta_2}{\theta_1} = \left(\frac{I_2}{I_1}\right)^2$$

$$\Rightarrow \frac{\theta_2}{90} = \left(\frac{3}{5}\right)^2$$

$\theta_2 = 32.4°$

(ii) Gravity controlled

$\sin\theta \propto I^2$

$$\frac{\sin\theta_2}{\sin\theta_1} = \left(\frac{I_2}{I_1}\right)^2$$

$$\frac{\sin\theta_2}{\sin 90} = \left(\frac{3}{5}\right)^2$$

$$\Rightarrow \frac{\sin\theta_2}{1} = 0.36$$

$\theta_2 = \sin^{-1}(0.36) = 21.1°$

07. Ans: 3.6 MΩ

Sol: $V_m = (0 – 200)$ V ; S = 2000 Ω/V

V = (0 – 2000) V

$R_m = s \times V_m$

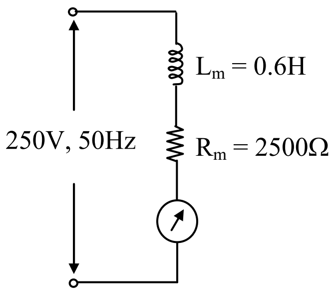
= 2000 Ω/V × 200 V = 400000 Ω

$$R_{se} = R_m\left(\frac{V}{V_m} - 1\right)$$

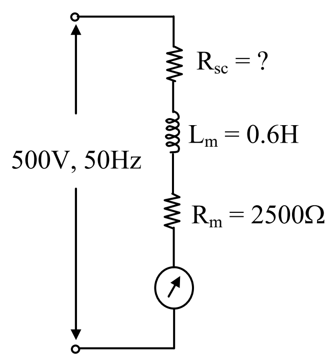
$$= 400000\left(\frac{2000}{200} - 1\right) = 3.6\ M\Omega$$

08. Ans: 2511.5 Ω

Sol:



(i)



(ii)

Current is same in case (i) & (ii)

In case (i),

$$I_m = \frac{250\,V}{\sqrt{R_m^2 + (\omega L_m)^2}}$$

$$= \frac{250\,V}{\sqrt{(2500)^2 + (2\pi\times 50\times 0.6)^2}}$$

$= 0.0997$ A

In case (ii),

$$I_m = \frac{250\,V}{\sqrt{(R_m + R_{se})^2 + (\omega L_m)^2}}$$

$$0.0997\,A = \frac{500\,V}{\sqrt{(2500 + R_{se})^2 + (2\pi\times 50\times 0.6)^2}}$$

$$\sqrt{(2500 + R_{se})^2 + 35.53\times 10^3} = \frac{500}{0.0997}$$

$$\sqrt{(2500 + R_{se})^2 + 35.53\times 10^3} = 5.015\times 10^3$$

$R_{se} = 2511.5\ \Omega$

09. Ans: 0.1025 μF

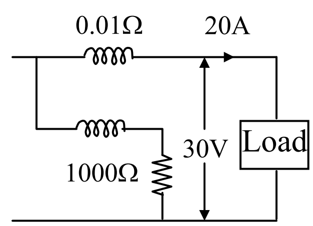
Sol: $C = \dfrac{0.41\,L_m}{R_{se}^2}$

$$C = \frac{0.41\times 1}{(2\,k\Omega)^2}$$

$= 0.1025\,\mu F$

10. Ans: (c)

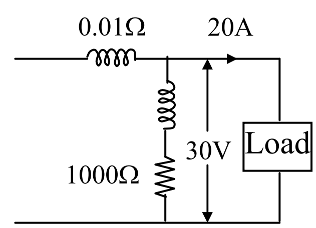
Sol: MC – connection



Error due to current coil

$$= \frac{20^2\times 0.01}{(30\times 20)}\times 100 = 0.667\%$$

LC – connection



Error due to potential coil

$$= \frac{(30^2/1000)}{(30\times 20)}\times 100 = 0.15\%$$

As per given options, 0.15% high

11. Ans: (b)

Sol: $\phi = \tan^{-1}\left[\frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}\right]$

Power factor = cos ϕ

= 0.917 lag (since load is inductive)

12. Ans: (c)

Sol: $R_{load} = \frac{V}{I} = \frac{200}{20} = 10\,\Omega$

For same error $R_L = \sqrt{R_C \times R_V}$

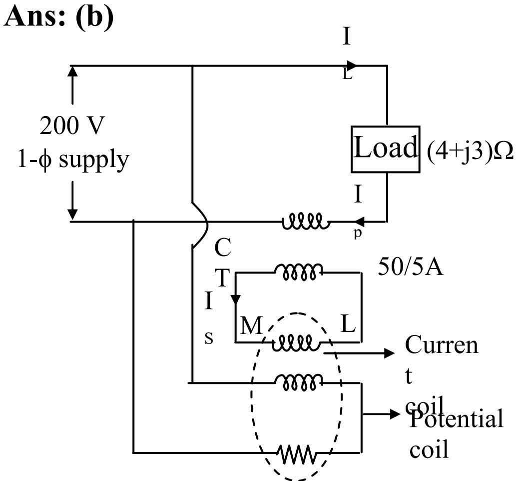
$\therefore\ 100 = 10 \times 10^3 \times R_C$

$\Rightarrow R_C = 0.01\ \Omega$

4. Measurement of Power and Energy

01. Ans: (b)

Sol:



Potential coil voltage = 200 V

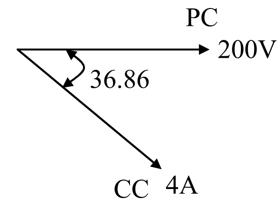
C.T. primary current (I_p)

$$I_P = I_L = \frac{200\,V}{\sqrt{4^2+3^2}\ \tan^{-1}\left(\frac{3}{4}\right)}$$

$$I_p = I_L = \frac{200\,V}{5\angle 36.86}$$

$I_p = 40\angle{-36.86}$

$$\frac{I_p}{I_S} = \frac{50}{5}$$



$$\frac{40}{I_S} = \frac{50}{5}$$

$$I_S = \frac{5}{50} \times 40 = 4\,A$$

C.T secondary (I_S) = $4\angle{-36.86°}$

Wattmeter current coil = I_C = $4\angle{-36.86°}$

Wattmeter reading

= 200 V × 4 × cos (36.86)

= 640.08 W

02. Ans: (a)

Sol: Energy consumed in 1 minute

$$= \frac{240 \times 10 \times 0.8}{1000} \times \frac{1}{60} = 0.032\,kWh$$

Speed of meter disc

= Meter constant in rev/kWhr × Energy consumed in kWh/minute

= 400 × 0.032

= 12.8 rpm (revolutions per minute)

03. Ans: (a)

Sol: Energy consumed (True value)

$$= \frac{230 \times 5 \times 1}{1000} \times \frac{3}{60} = 0.0575\ kWhr$$

Energy recorded (Measured value)

$$= \frac{\text{No. of rev (N)}}{\text{meter constant (k)}}$$

$$= \frac{90\ rev}{1800\ rev/kWh} = 0.05\ kWhr$$

$$\%Error = \frac{0.05 - 0.0575}{0.0575} \times 100$$

$= -13.04\% = 13.04\%$ (slow)

04. Ans: (c)

Sol: $W = \frac{E_1}{\sqrt{2}} \times \frac{I_1}{\sqrt{2}} \cos\phi_1 + \frac{E_3}{\sqrt{2}} \times \frac{I_3}{\sqrt{2}} \cos\phi_3$

$$W = \frac{1}{2}[E_1 I_1 \cos\phi_1 + E_3 I_3 \cos\phi_3]$$

05. Ans: (c)

Sol: $V = 220$ V, $\Delta = 85°$, $I = 5A$

Error = VI $[\sin(\Delta - \phi) - \cos\phi]$

(1) $\cos\phi$ = UPF, $\phi = 0°$

Error = $220\times5[\sin(85 - 0) - \cos 0]$

$= -4.185 \text{ W} \simeq -4.12 \text{ W}$

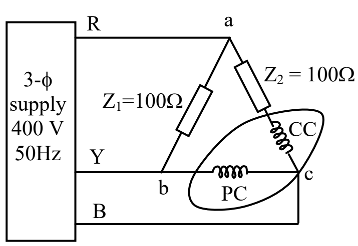
(2) $\cos\phi = 0.5$ lag, $\phi = 60°$

Error = $220\times5\ [\sin(85 - 60) - \cos 60]$

$= -85.12$ W

06. Ans: (c)

Sol:



Based on R-Y-B

Assume abc phase sequence

$V_{ab} = 400\angle0°$; $V_{bc} = 400\angle-120°$

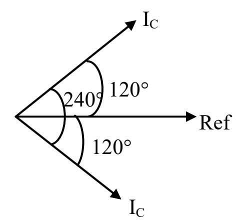
$V_{ca} = 400\angle-240°$ or $400\angle120°$

Current coil current $(I_c) = \frac{V_{ca}}{Z_2}$

$$= \frac{400\angle120^\circ}{100\,\Omega} = 4\angle120^\circ$$

Potential coil voltage $(V_{bc}) = 400\angle-120°$

$W = 400 \times 4 \times \cos(240) = -800$ W



07. Ans: (d)

Sol: $V_L = 400$ V, $I_L = 10$ A

$\cos\phi = 0.866$ lag, $\phi = 30°$

$W_1 = V_L I_L \cos(30 - \phi)$

$W_2 = V_L I_L \cos(30 + \phi)$

$W_1 = 400\times10\times \cos(30 - 30) = 4000$W

$W_2 = 400\times10\times \cos(30 + 30) = 2000$W

08. Ans: W = 519.61 VAR

Sol:

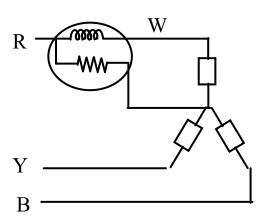


Fig. (a)

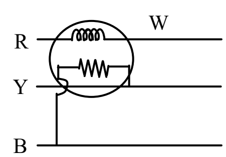


Fig. (b)

W = 400 watt ; $W = V_{ph} I_{ph} \cos\phi$

$V_{ph} I_{ph} = 400/0.8$

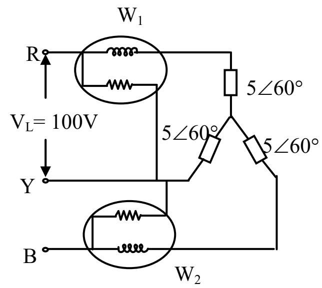
This type of connection gives reactive power

$$W = \sqrt{3} V_p I_p \sin\phi = \sqrt{3} \times \frac{400}{0.8} \times 0.6$$

$$= 519.6 \text{VAR}$$

09. Ans: 0 & 1000 W

Sol:



Y-phase is made common.

Hence wattmeter readings are

$W_1 = V_L I_L \cos(30+\phi)$

$W_2 = V_L I_L \cos(30-\phi)$

In star-connection

$I_L = I_{ph}$; $V_{ph} = \frac{V_L}{\sqrt{3}}$

$$I_L = I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{V_L/\sqrt{3}}{Z_{ph}}$$

$$I_L = I_{ph} = \frac{(100/\sqrt{3})}{5} = \frac{20}{\sqrt{3}} = 11.54A$$

$V_L = 100$ V, $I_L = 11.54$ A, $\phi = 60°$

$W_1 = 100 \times 11.54 \times \cos(30 + 60) = 0$ W

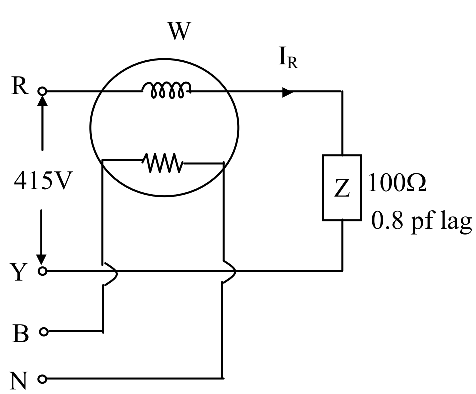
$W_2 = 100 \times 11.54 \times \cos(30 - 60)$

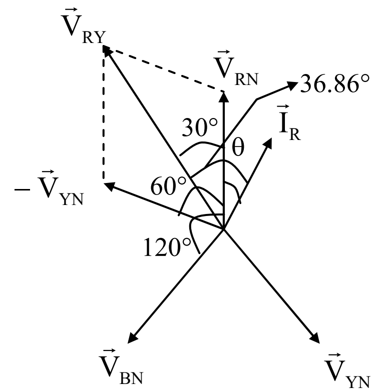
$= 999.393$ W $\simeq 1000$ W

$W_1 = 0$ W, $W_2 = 1000$ W

10. Ans: –596.46 W

Sol:





Current coil is connected in 'R_{phase}', it reads '$\vec{I}_R$' current.

Potential coil reads phase voltage i.e., $\vec{V}_{BN}$

$$W = \vec{V}_{BN} \times \vec{I}_R \times \cos(\vec{V}_{BN} . \vec{I}_R)$$

$$V_L = 415 \text{ V},\ V_{BN} = \frac{415}{\sqrt{3}} \text{ V}$$

$$I_R = \frac{V_{RY}}{Z} = \frac{415}{100} = 4.15 \text{ A}$$

$\cos\phi = 0.8$

$\Rightarrow \phi = 36.86$ between $\vec{V}_{RY}$ & $\vec{I}_R$

$\theta = 36.86° - 30° = 6.86°$

Now angle between $\vec{V}_{BN}$ and $\vec{I}_R$

$= 120 + 6.86 = 126.86°$

$$W = \frac{415}{\sqrt{3}} \times 4.15 \times \cos(126.86)$$

$= -596.467$ W

11. Ans: (c)

Sol: Meter constant = 14.4 A-sec/rev

$= 14.4 \times 250$W-sec/rev

$$= \frac{14.4 \times 250}{1000} \text{ kW} - \text{sec/rev}$$

$$= \frac{14.4 \times 250}{1000 \times 3600} \text{ kWhr/rev}$$

Meter constant = $\frac{1}{1000}$ kWhr/rev

Meter constant in terms of rev/kWhr = 1000

12. Ans: (d)

Sol: $R_p = 1000\ \Omega$, $L_p = 0.5$ H, f = 50 Hz,

$\cos\phi = 0.7$,

$X_{Lp} = 2 \times \pi \times f \times L$, $\tan\phi = 1$

$= 2 \times \pi \times 50 \times 0.5$

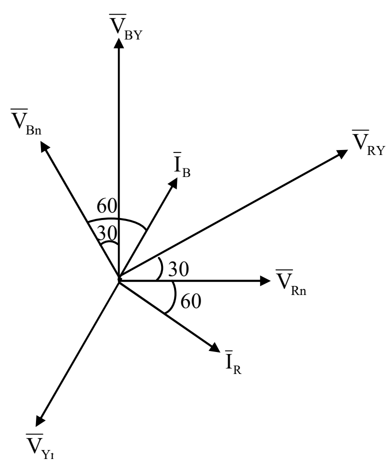
$= 157\ \Omega$

% Error = $\pm (\tan\phi \tan\beta) \times 100$

$$= \pm\left(1 \times \frac{157}{1000}\right) \times 100 = 15.7\% \simeq 16\%$$

13. Ans: (d)

Sol:



$P = W_1 + W_2 + W_3 = 1732.05$

Power factor, $\cos\phi = \frac{1732.05}{3464} = 0.5$ lag

$\sqrt{3} \times 400 \times I_L \times 0.5 = 1732.05$

$I_L = \frac{1732.05}{\sqrt{3} \times 400 \times 0.5} = 5$ A

When switch is in position N

$W_1 = W_2 = W_3 = 577.35$ W $\Rightarrow$ balanced load

$\therefore$ total power consumed by load is

$W = W_1 + W_2 + \omega_3$

W = 1732.05 W

Given load is inductive

And VA draw from source = 3464 VA

$\therefore$ power factor = $\frac{W}{VA}$

$= \frac{1732.05}{3464} = 0.5$ lag

$\Rightarrow$ Power factor angle = –60° ($\because$ lag)

When switch is connected in Y position pressure coil of W_2 is shorted

So $W_2 = 0$ and phasor diagrams for other two are as follows

$W_1 = V_{RY}\ I_R$ cos(angle between $\bar{V}_{RY}$ and $\bar{I}_R$)

$= 400 \times 5 \times \cos(90^\circ) = 0$ W

$W_3 = V_{BY}\ I_B$ cos(angle between $\bar{V}_{BY}$ and $\bar{I}_B$)

$= 400 \times 5 \times \cos(30^\circ)$

$= 400 \times 5 \times \frac{\sqrt{3}}{2} = 1732$ W

$W_1 = 0$, $W_2 = 0$, $W_3 = 1732$ W

5. Bridge Measurement of R, L &C

01. Ans: (a)

Sol: It is Maxwell Inductance Capacitance bridge

$R_x R_4 = R_2 R_3$

$$R_x = \frac{R_2 R_3}{R_4}$$

$$R_x = \frac{750 \times 2000}{4000}$$

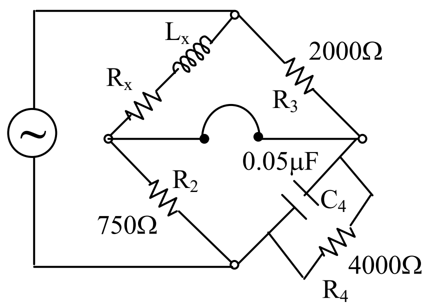
$R_x = 375\ \Omega$

$$\frac{L_x}{C_4} = R_2 R_3$$

$L_x = C_4 R_2 R_3$

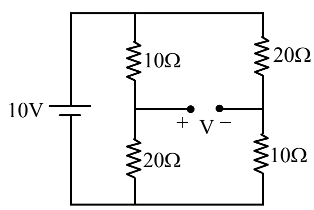
$L_x = 0.05 \times 10^{-6} \times 750 \times 2000$

$L_x = 75$ mH



02. Ans: (d)

Sol:



$V = V_+ - V_-$

$= 10\times\frac{20}{30} - 10\times\frac{10}{30}$

$= 6.66 - 3.33$

$= 3.33$ V

03. Ans: (c)

Sol: The voltage across R_2 is

$$= E\frac{R_2}{R_1+R_2} = \frac{E}{2}$$

The voltage across R_1 is

$$= E\frac{R_1}{R_1+R_2} = \frac{E}{2}$$

Now, $\frac{E}{2} = IR_3 + V$

$$I = \frac{E-2V}{2R_3} \Rightarrow I = \frac{E-2V}{2R}$$

and $\frac{E}{2} = IR_4$

$$\frac{E}{2} = \left(\frac{E-2V}{2R}\right)(R+\Delta R)$$

$$ER = (E-2V)(R+\Delta R)$$

$$R+\Delta R = \frac{ER}{(E-2V)}$$

$$\Delta R = \frac{ER}{(E-2V)} - R$$

$$= \frac{ER - ER + 2VR}{(E-2V)}$$

$$\Delta R = \frac{2VR}{(E-2V)}$$

04. Ans: (a)

Sol: The deflection of galvanometer is directly proportional to current passing through circuit, hence inversely proportional to the total resistance of the circuit.

Let S = standard resistance

R = Unknown resistance

G = Galvanometer resistance

θ_1 = Deflection with S

θ_2 = Deflection with R

$$\therefore \frac{\theta_1}{\theta_2} = \frac{R+G}{S+G}$$

$$\Rightarrow R = (S+G)\frac{\theta_1}{\theta_2} - G$$

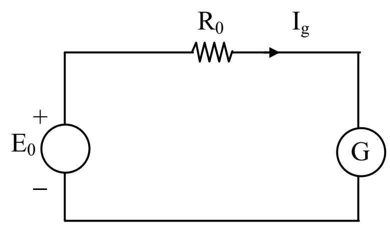
$$= \left(0.5\times10^{6}+10\times10^{3}\right)\left(\frac{41}{51}\right)-10\times10^{3}$$

$= 0.4 \times 10^{6}\ \Omega$

$= 0.4\ \text{M}\Omega$

05. Ans: (a)

Sol: Thevenin's equivalent of circuit is



R_0 = Resistance of circuit looking into terminals b & d with a & c short circuited.

$$= \frac{RS}{R+S}+\frac{PQ}{P+Q}=\frac{1\times5}{1+5}+\frac{1\times Q}{1+Q}$$

$$= 0.833+\frac{Q}{1+Q}\text{K}\Omega$$

$$\text{Now, } R_0+G=\frac{24\times10^{-3}}{13.6\times10^{-6}}$$

$= 1.765\ \text{k}\Omega$

(or) $R_0 = 1765 - 100 = 1665\ \Omega$

$$0.833+\frac{Q}{1+Q}=1.665$$

$\Rightarrow Q = 4.95\ \text{k}\Omega$

06. Ans: (c)

Sol: $$R = \frac{0.4343\ T}{C\ \log_{10}\left(\frac{E}{V}\right)}$$

$$= \frac{0.4343\times60}{600\times10^{-2}\times\log_{10}\left(\frac{250}{92}\right)}$$

$$= \frac{26.058}{260.49\times10^{-12}}$$

$R = 100.03 \times 10^{9}\ \Omega$

07. Ans: 0.118 μF, 4.26kΩ

Sol: Given

$R_3 = 1000\ \Omega$

$$C_1 = \frac{\varepsilon_0\varepsilon_r A}{d} = \frac{2.3\times4\pi\times10^{-7}\times314\times10^{-4}}{0.3\times10^{-2}}$$

$C_1 = 30.25\ \mu F$

$\delta = 9°$ for 50 Hz

$\tan\delta = \omega C_1 r_1 = \omega L_4 R_4$

$\Rightarrow r_1 = 16.67\ \Omega$

Variable resistor $(R_4) = R_3\left(\frac{C_1}{C_2}\right)$

$R_4 = 4.26\text{k}\ \Omega$

$C_4 = 0.118\ \mu F$

08.

Sol: Resistance of unknown resistor required for balance

R = (P/Q)S = (1000/100) × 200 = 2000 Ω.

In the actual bridge the unknown resistor has a value of 2005 Ω or the deviation from the balance conditions is Δ R = 2005 – 2000 = 5 Ω.

Thevenin source generator emf

$$E_0 = E\left[\frac{R}{R+S}-\frac{P}{P+Q}\right]$$

$$= 5\left[\frac{2005}{2005+200} - \frac{1000}{1000+100}\right]$$

$= 1.0307 \times 10^{-3}$V.

Internal resistance of bridge looking into terminals b and d.

$$R_0 = \frac{RS}{R+S} + \frac{PQ}{P+Q}$$

$$= \frac{2005\times200}{2005+200} + \frac{1000\times100}{1000+100}$$

$= 272.8\ \Omega$

Hence the current through the galvanometer

$$I_g = \frac{E_0}{R_0 + G}$$

$$= \frac{1.0307\times10^{-3}}{272.8+100} A = 2.77\ \mu A.$$

Deflection of the galvanometer

$\theta = S_i I_g = 10 \times 2.77$

$= 27.7$ mm/Ω.

Sensitivity of bridge

$$S_B = \frac{\theta}{\Delta R}$$

$$= \frac{27.7}{5} = 5.54\,\text{mm}/\Omega$$

6. Potentiometers & Instrument Transformers

01. Ans: (d)

Sol: Under null balanced condition the current flow in through unknown source is zero. Therefore the power consumed in the circuit is ideally zero.

02. Ans: (d)

Sol: Potentiometer is used for measurement of low resistance, current and calibration of ammeter.

03. Ans: (a)

Sol: Since the instrument is a standardized with an emf of 1.018 V with sliding contact at 101.8 cm, it is obvious that a length 101.8 cm represents a voltage of 1.018.

Resistance of 101.8 cm length of wire

= (101.8/200) × 400 = 203.6 Ω

∴ Working current

I_m = 1.018/203.6 = 0.005 A = 5 mA

Total resistance of the battery circuit

= resistance of rheostat + resistance of slide wire

∴ Resistance of rheostat

R_h = total resistance – resistance of slide wire

$$= \frac{3}{5\times10^{-3}} - 400 = 600 - 400 = 200\,\Omega$$

04. Ans: (b)

Sol: Voltage drop per unit length

$$= \frac{1.45\,V}{50\,cm} = 0.029\ V/cm$$

Voltage drop across 75 cm length

= 0.029 × 75 = 2.175 V

Current through resistor (I)

$$= \frac{2.175\,V}{0.1\ \Omega} = 21.75\ A$$

(or)

75 cm → 0.1 Ω

50 cm → ?

Slide wire resistance with standard cell

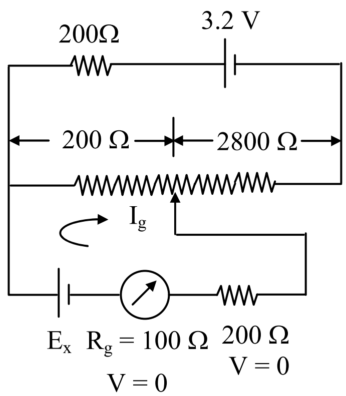
$$= \frac{50}{70} \times 0.1 = 0.067\ \Omega$$

Then $0.067 \times I_w = 1.45$ V

$$I_w = \frac{1.45}{0.067} = 21.75\ \text{A}$$

05. Ans: (a)

Sol:



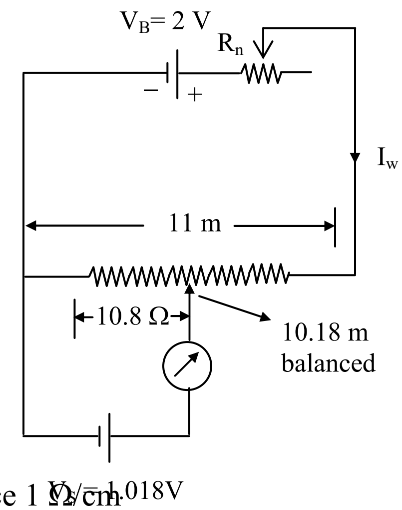
Under balanced, $I_g = 0$

$$E_x = 3.2\,\text{V} \times \frac{200}{(200+200+2800)} = 0.2\,\text{V}$$

$E_x = 200$ mV

06. Ans: (a)

Sol:



Resistance 1 Ω/cm

For 11 m → 11 Ω

For 10m + 18cm → 10.8Ω

$I_w \times 10.8\Omega = 1.018$ V

$$I_w = \frac{V_B}{R_n + l_r} \Rightarrow 0.1 = \frac{2}{R_n + 11\Omega}$$

$$R_n = \frac{2}{0.1} - 11 = 9\ \Omega$$

Electronic Measurements

7. Cathode Ray Oscilloscope

01. Ans: (b)

Sol: Time period of one cycle = $\frac{8.8}{2}\times 0.5$

$= 2.2$ msec

Therefore frequency = $\frac{1}{T} = \frac{1}{2.2\times 10^{-3}}$

$= 454.5$ Hz

The peak to peak Voltage = 4.6×100

$= 460$ mV

Therefore the peak voltage $V_m = 230$ mV

R.M.S voltage = $\frac{230}{\sqrt{2}} = 162.6$ mV

02. Ans: (c)

Sol: In channel 1

The peak to peak voltage is 5V and peak to peak divisions of upper trace voltage = 2

Therefore for one division voltage is 2.5V

In channel 2, the no. of divisions for unknown voltage = 3

Divisions = 3, voltage/division = 2.5

$\therefore$ voltage = $2.5 \times 3 = 7.5$ V

Similarly frequency of upper trace is 1kHz

So the time period T

(for four divisions) = $\frac{1}{f}$

$T = 1/10^3 \Rightarrow 1$ msec

i.e for four divisions time period = 1m sec

In channel 2, for eight divisions of unknown waveform time period = 2m sec.

03. Ans: (c)

Sol: No. of cycles of signal displayed

$= f_{signal} \times T_{sweep}$

$= 200\text{Hz} \times \left(10\,\text{cm}\times\frac{0.5\text{ms}}{\text{cm}}\right) = 1$

i.e, one cycle of sine wave will be displayed.

We know $V_{rms} = \frac{V_{p-p}}{2\sqrt{2}}$

$V_{rms} = \frac{N_v \times \text{Volt/div}}{2\sqrt{2}}$

$\Rightarrow N_v = \frac{2\sqrt{2}\times V_{rms}}{\text{Volt/div}}$

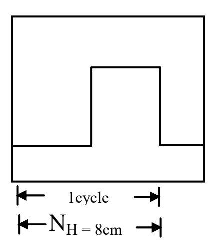
$\Rightarrow N_v = \frac{2\sqrt{2}\times 300\text{mV}}{100\text{mv/cm}}$

$\Rightarrow N_v = 8.485$cm

i.e 8.485cm required to display peak to peak of signal. But screen has only 8cm (vertical) As such, peak points will be clipped.

04. Ans: (b)

Sol:



→ Given data: Y input signal is a symmetrical square wave

$f_{signal} = 25KHz, \quad V_{pp} = 10V$

→ Screen has 10 Horizontal divisions & 8 vertical divisions which displays 1.25 cycles of Y-input signal.

→ $V_{PP} = N_V \times \dfrac{VOLT}{div}$

$\Rightarrow \dfrac{VOLT}{div} = \dfrac{V_{PP}}{N_V} = \dfrac{10V}{5cm} = 2$ Volt/ c.m

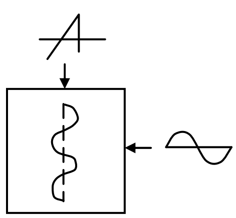
→ $T_{signal} = N_H \text{per cycle} \times \dfrac{TIME}{div}$

$\Rightarrow \dfrac{TIME}{div} = \dfrac{T_{signal}}{N_H \text{per cycle}}$

$= \dfrac{1}{25kHz \times 8cm} = 5\ \dfrac{\mu s}{cm}$

05. Ans: (a)

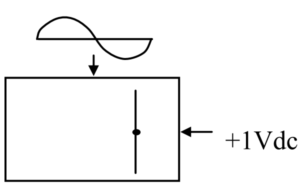
Sol: Frequency ratio is 2



∴ Two cycles of sine wave displayed on vertical time base

06. Ans: (a)

Sol:



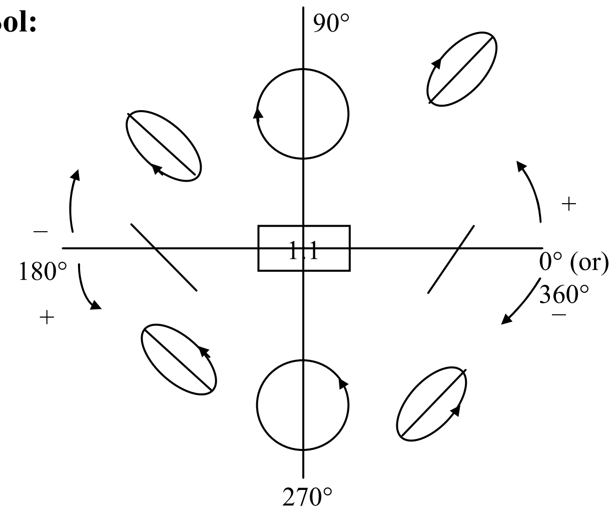
Vertical straight line

07. Ans: (a)

Sol: Since the coupling mode is set to DC the capacitance effect at the input side is zero. Therefore the waveform displayed on the screen is both DC and AC components.

08. Ans: (d)

Sol:

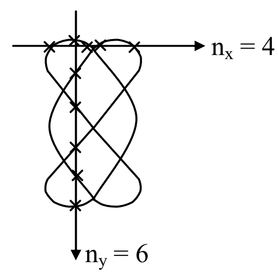


09. Ans: (b)

Sol: $f_y = \dfrac{n_x}{n_y} f_y$

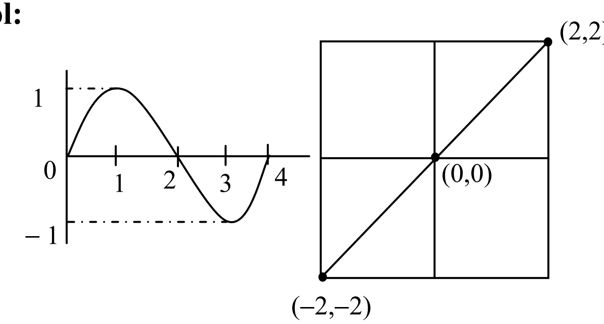
$= \dfrac{4}{6} \times 600Hz$

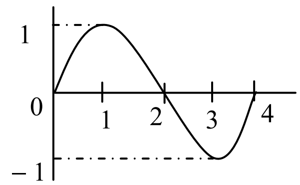
$= 400$ Hz



10. Ans: (d)

Sol:





Let $K_y = K_x = 2\ \text{Volt}/\text{div}$

t	V_y	V_x	$d_y = k_y V_y$	$d_x = k_x V_x$	points
0	0	0	0	0	(0,0)
1	1	1	2	2	(2,2)
2	0	0	0	0	(0,0)
3	-1	-1	-2	-2	(-2,-2)
4	0	0	0	0	(0,0)

By using these points draw the line which is a diagonal line inclined at 45° w.r.t the x-axis.

8. Digital Voltmeters

01. Ans: (a)

Sol: The type of A/D converter normally used in a $3\frac{1}{2}$ digit multimeter is Dual-slope integrating type since it offers highest Accuracy, Highest Noise rejection and Highest Stability than other A/D converters.

02. Ans: (d)

Sol: DVM measures the average value of the input signal which is 1 V.

$\therefore$ DVM indicates as 1.000 V

03. Ans: (c)

Sol: 0.2% of reading +10 counts → (1)

$$= 0.2 \times \frac{100}{100} + 10\,(\text{sensitivity} \times \text{range})$$

$$= 0.2 \times \frac{100}{100} + 10\left(\frac{1}{2\times10^4} \times 200\right)$$

$$= 0.2 + 0.1 = \pm\, 0.3\ \text{V}$$

$$\%\text{error} = \pm\frac{0.3}{100}\times 100 = 0.3\%$$

04. Ans: (d)

Sol: When $\frac{1}{2}$ digit is present voltage range becomes double. Therefore 1V can read upto 1.9999 V.

05. Ans: (d)

Sol: $\text{Resolution} = \frac{\text{full} - \text{scale reading}}{\text{maximum count}} = \frac{9.999\text{V}}{9999}$

$= 1\text{mV}$

06. Ans: (b)

Sol: Sensitivity = resolution × lowest voltage range

$$= \frac{1}{10^4}\times 100\ \text{mV} = 0.01\ \text{mV}$$

07. Ans: (a)

Sol: The DVM has $3\frac{1}{2}$ digit display

Therefore, the count range is from 0 to 1999 i.e., 2000 counts. The scale resolution is 0.001. And, the resolutions in each selected voltage Ranges of 2V, 20V & 200V are 1mV, 10mV & 100mV.

08. Ans: (a)

Sol: Resolution = $\dfrac{\text{max . voltage}}{\text{max . count}}$

$$= \frac{3.999}{3999} = 1\text{mV}$$

09. Ans: (b)

Sol: A and R are true, but R is not correct explanation for A.

10. Ans: (c)

Sol: When $\frac{1}{2}$ digit switched ON, then DVM will be able to read more than the selected range.

9. Q–Meter

01. Ans: (a)

Sol: $C_1 = 300\text{pF}$ $\quad C_2 = 200$ pF

$Q = 1/(\omega C_1 R)$ $\quad = 120 = 1/(C_2 + C_x)R$

$C_1 = C_2 + C_X$

$\therefore C_x = 100$ pF

02. Ans: (b)

Sol: %error = $-\dfrac{r}{r+R} \times 100$

$$= -\frac{0.02}{0.02+10} \times 100 = -0.2\%$$

03. Ans: (c)

Sol: Q-meter consists of R, L, C connected in series.

$\therefore$ Q-meter works on the principle of series resonance.

04. Ans: (b)

Sol: Given data: $C_d = 820$ pF,

$\omega = 10^6$rad/sec & C = 9.18nF

We know, $L = \dfrac{1}{\omega^2[C + C_d]}$

$$= \frac{1}{(10^6)^2[9.18\text{nF} + 820\text{pF}]} = 100\mu\text{H}$$

The inductance of coil tested with a Q-meter is 100μH.

05. Ans: (b)

Sol: A series RLC circuit exhibits voltage magnification property at resonance. i.e., the voltage across the capacitor will be equal to Q-times of applied voltage.

Given that V = applied voltage and

V_0 = Voltage across capacitor

There fore, $Q = \dfrac{V_{c\,max}}{V_{in}} \Rightarrow Q = \dfrac{V_0}{V}$

06. Ans: (b)

Sol: $f_1 = 500$ kHz ; $\quad f_2 = 250$kHz

$C_1 = 36$ pF ; $\quad C_2 = 160$ pF

$n = \dfrac{250\,\text{kHz}}{500\,\text{kHz}} \Rightarrow n = 0.5$

$$C_d = \frac{36\text{pF} - (0.5)^2 160\text{pF}}{(0.5)^2 - 1} = 5.33\text{pF}$$

07. Ans: (c)

Sol: $Q = \dfrac{\text{capacitor voltmeter reading}}{\text{Input voltage}}$

$$= \frac{10}{500 \times 10^{-3}} = 20$$

08. Ans: i → (c), ii → (a)

Sol: (i) $C_d = \dfrac{C_1 - n^2 C_2}{n^2 - 1} = \dfrac{360 - 288}{3} = 24\ \text{pF}$

(ii) $L = \dfrac{1}{\omega_1^2 [C_1 + C_d]}$

$$= \frac{1}{\left[2\pi \times 500 \times 10^3\right]^2 [24 + 360] \times 10^{-6}} = 264\mu\text{H}$$

09. Ans: (b)

Sol: $Q_{true} = Q_{meas}\left(1 + \dfrac{r}{R_{coil}}\right)$

$Q_{actual} = Q_{observed}\left[1 + \dfrac{R}{R_s}\right]$

10. Ans: (c)

Sol: $1 + \dfrac{C_d}{C} = \dfrac{Q_{true}}{Q_{measured}}$

$\Rightarrow \dfrac{C_d}{C} = \dfrac{245}{244.5} - 1$

$= 2.044 \times 10^{-3}$

$\Rightarrow \dfrac{C}{C_d} = 489$