ACE

ESE | GATE | PSUs

ELECTRICAL
ENGINEERING

ELECTRICAL AND ELECTRONIC MEASUREMENTS

Volume - 1 : Study Material with Classroom Practice Questions

Electrical Measurements

(Solutions for Volume-1 Class Room Practice Questions)

1. Error Analysis, Units & Standards

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. Ans: (i) 41.97 (ii) 0.224 (iii) ± 0.1513

(Update key)

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

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

= 41.97

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

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

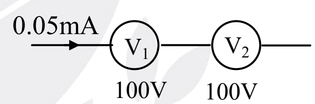
= 0.224

Probable error = ± 0.6745 × SD

= ± 0.1513

04. Ans: 150 V (Update key)

Sol:



V_1 : V_2 :

$S_{dc_1} = 10\,k\Omega/V$ $S_{dc_2} = 20\,k\Omega/V$

$I_{fsd} = \dfrac{1}{S_{dc1}}$ $I_{fsd} = \dfrac{1}{S_{dc2}}$

= 0.1mA = 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 Ω/V×100+20 kΩ/V × 100)

= 3000 × 0.05 = 150 V

05.

Sol: Internal impedance of 1st voltmeter

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

Internal impedance of 2nd voltmeter

$$= 100 \times 250\ \Omega/\text{V} = 25\ \text{k}\Omega$$

Internal impedance of 3rd voltmeters,

$$= 5\ \text{k}\Omega$$

Total impedance across 120 V

$$= 20 + 25 + 5 = 50\ \text{k}\Omega$$

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

⇒ Reading of 1st voltmeter

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

Reading of 2nd voltmeter

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

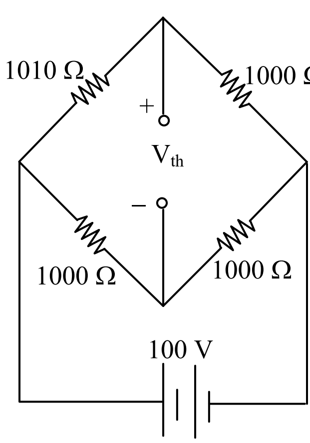
Reading of 3rd voltmeter

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

06. Ans: (b)

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

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



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

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

07. Ans: (d)

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

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

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

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

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

$W_T = 50 \pm 3\%$

08. Ans: (b)

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

09. Ans: (b)

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

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

10. Ans: (c)

Sol: Power = $I^2R = (2)^2\,(100)$

$= 400$ W

$$\%\ \text{Error} = \pm\left[2\left(\frac{\partial P}{\partial I}\right) + \frac{\partial P}{\partial R}\right]\times 100$$

$= \pm\, 2\,(1) \pm 0.2$

$= \pm\, 2.2\%$

$$\text{Error} = \pm\frac{2.2}{100}\times 400$$
$$= \pm 8.8\ \text{W}$$

11. Ans: (c)

Sol: $R_T = R_1 + R_2 = 36 + 75 = 111\ \Omega$

$$\Delta R_T = \left(\frac{5}{100}\times 36\right)+\left(\frac{5}{100}\times 72\right)$$
$$= 5.55\ \Omega$$
$$R_T = 111 \pm 5.55\ \Omega$$

12. Ans: (a)

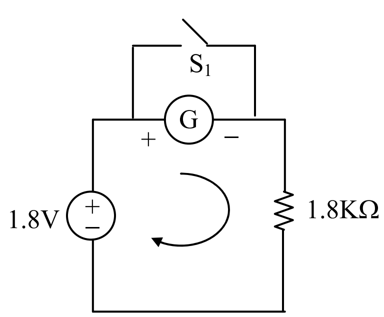
Sol: $R = \dfrac{V}{I}$

$$\frac{\Delta R}{R}\times 100 = \frac{\Delta V}{V}\times 100 + \frac{\Delta I}{I}\times 100$$
$$\frac{\Delta R}{R}\times 100 = 2\% + 1\%$$
$$= 3\%$$

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.

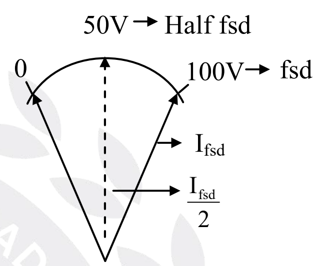


Applying KVL to circuit,

$$1.8\ \text{V} - 0.9\ \text{mA}\times R_m - 0.9\ \text{mA}\times 1.8\ \text{k}\Omega = 0$$
$$1.8\ \text{V} - 0.9\times 10^{-3}\,R_m - 1.62 = 0$$
$$R_m = \frac{0.18}{0.9\times 10^{-3}} = 200\ \Omega$$

02. Ans: (c)

Sol:



$$S = \frac{1}{1000}\ \Omega/\text{volt}$$
$$S = \frac{1}{I_{fsd}}\ \Omega/\text{V}$$
$$I_{fsd} = \frac{1}{S} = \frac{1}{1000}$$
$$= 1\ \text{mA}$$

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

$50\ \text{V} \rightarrow\ ?$

$= 0.5\ \text{mA}$

03. Ans: (c)

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

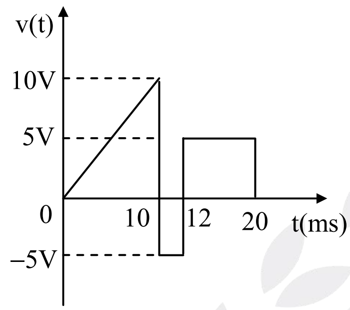
$$K_c\theta = \frac{I^2}{2}\frac{dL}{d\theta}$$
$$25\times 10^{-6}\times\theta = \frac{25}{2}\times\left(3-\frac{\theta}{2}\right)\times 10^{-6}$$
$$2\theta = 3-\frac{\theta}{2}$$

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

$$\theta = 1.2 \text{ rad}$$

04. Ans: (a) (Update Key)

Sol:



PMMC meter reads Average value

$$V_{avg} = \frac{\left(\frac{1}{2}\times 10\times 10\text{ms}\right)+(-5\text{V}\times 2\text{ms})+(5\text{V}\times 8\text{ms})}{20\text{ms}}$$

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

(or)

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

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

$$= 4\text{ V}$$

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° (Update Key)

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

$R_m = s \times V_m$

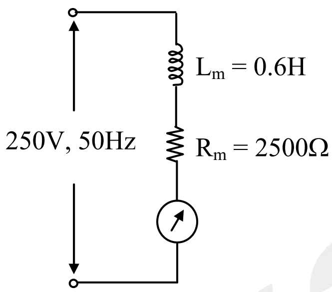
= 2000 Ω/V × 200 V = 400000 Ω

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

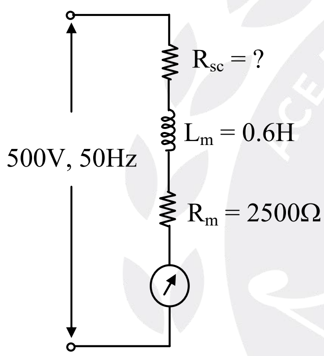
$$= 400000\left(\frac{2000}{200}-1\right) = 3.6\ \text{M}\Omega$$

08. Ans: 2511.5 Ω (Update Key)

Sol:



(i)



(ii)

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

In case (i),

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

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

= 0.0997 A

In case (ii),

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

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

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

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

R_{se} = 2511.5 Ω

09. Ans: 0.1025 μF

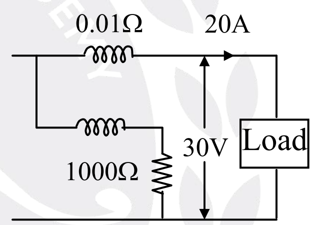
Sol: $C = \dfrac{0.41\,L_m}{R_{se}^2}$

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

$= 0.1025\,\mu\text{F}$

10. Ans: (c)

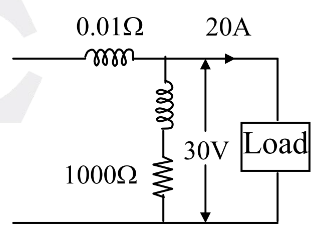
Sol: MC – connection



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 $R_L = \sqrt{R_C \times R_V}$

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

$\Rightarrow R_C = 0.01\ \Omega$

13. Ans: (a)

Sol: $i(t) = 3 + 4\sqrt{2}\sin 314t$

PMMC reads average value.

∴ Average value = 3A

14. Ans: (b)

Sol: Hot wire ammeter reads RMS value

$I_{rms} = \sqrt{2^2 + \left(\frac{4}{\sqrt{2}}\right)^2}$

$= 3.46\,A$

15. Ans: (d) (Update Key)

Sol: Moving Iron Ammeter, $\theta \propto I^2$

For 1 A dc → 20°

$I_1 = 1$ A, $\theta_1 = 20°$

For 3 sin 314 t → ?

MI Ammeter measures the rms value of AC current

$I_2 = \frac{I_m}{\sqrt{2}} = \frac{3}{\sqrt{2}}$, $I_2 = \frac{3}{\sqrt{2}}$, $\theta_2 = ?$

$\frac{\theta_2}{\theta_1} = \frac{I_2^2}{I_1^2}$

$\frac{\theta_2}{20} = \frac{(3/\sqrt{2})^2}{(1)^2}$

$\Rightarrow \theta_2 = 90^\circ$

16. Ans: (a)

Sol: $V_{dc} = I_{dc} \times 10\ \Omega$

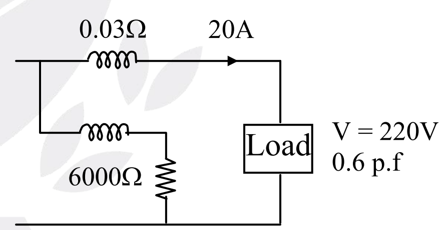
$= \left(\frac{12+5}{2}\right) \times 10$

$= 85\,V$

17. Ans: (b)

Sol: Given that,

$R_c = 0.03\ \Omega$, $R_P = 6000\ \Omega$



$\%\ \text{Error} = \frac{I_L^2 r_c}{VI\cos\phi} \times 100$

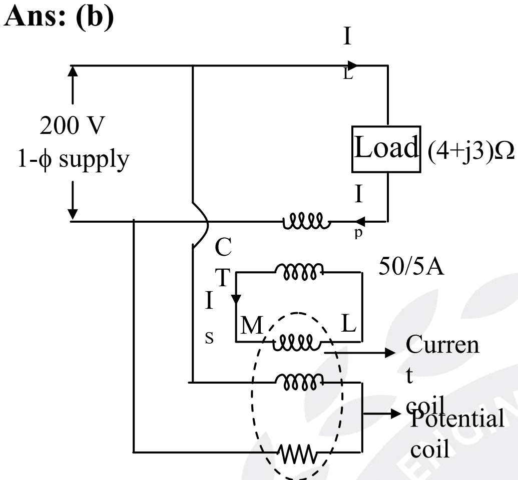
$= \frac{20^2 \times 0.03}{220 \times 20 \times 0.6} \times 100$

$= 0.45\%$

4. Measurement of Power and Energy

01. Ans: (b)

Sol:



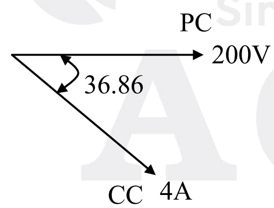
Potential coil voltage = 200 V

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

$$= \frac{240\times10\times0.8}{1000}\times\frac{1}{60} = 0.032\,\text{kWh}$$

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)

$$= \frac{230\times5\times1}{1000}\times\frac{3}{60} = 0.0575\ \text{kWhr}$$

Energy recorded (Measured value)

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

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

$$\%\text{Error} = \frac{0.05-0.0575}{0.0575}\times100$$

= – 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(Δ – ϕ) – cos ϕ]

(1) cos ϕ = UPF, ϕ = 0°

Error = 220×5[sin(85 – 0) – cos 0]

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

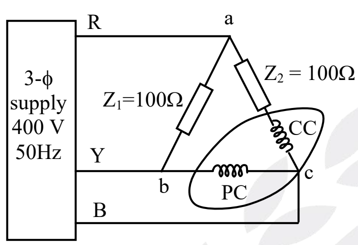
(2) $\cos\phi = 0.5$ lag, $\phi = 60°$

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

$= -85.12\text{ W}$

06. Ans: (c)

Sol:



Based on R-Y-B

Assume abc phase sequence

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

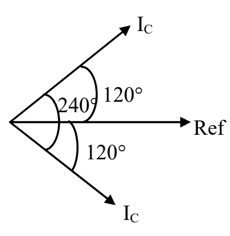
$V_{ca} = 400\angle-240°$ or $400\angle120°$

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

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

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

$W = 400\times4\times\cos(240) = -800\text{ W}$



07. Ans: (d)

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

$\cos\phi = 0.866$ lag, $\phi = 30°$

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

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

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

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

08. Ans: W = 519.61 VAR

Sol:

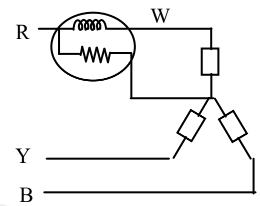


Fig. (a)

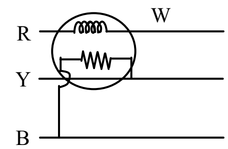


Fig. (b)

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

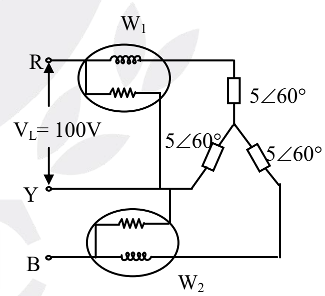
$V_{ph} I_{ph} = 400/0.8$

This type of connection gives reactive power

$$W = \sqrt{3}V_pI_p\sin\phi = \sqrt{3}\times\frac{400}{0.8}\times0.6 = 519.6\text{VAR}$$

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

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

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

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

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

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

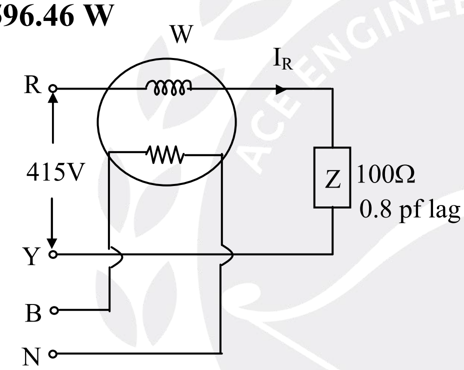
$W_2 = 100 \times 11.54 \times \cos(30 - 60)$

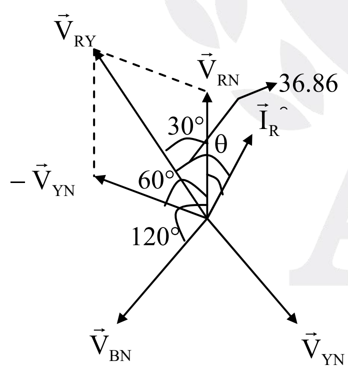
$= 999.393$ W $\simeq 1000$ W

$W_1 = 0$ 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., $\vec{V}_{BN}$

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

$V_L = 415$ V, $V_{BN} = \dfrac{415}{\sqrt{3}}$ 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 $= \dfrac{1}{1000}$ 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,

$\cos\phi = 0.7$,

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

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

$= 157\ \Omega$

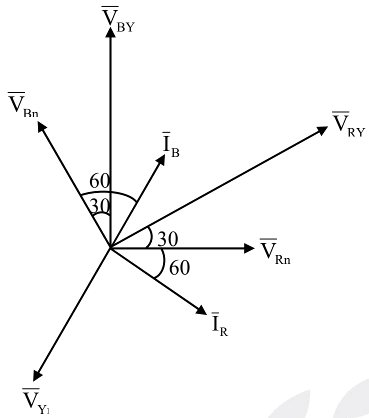
% Error $= \pm (\tan\phi \tan\beta) \times 100$

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

$= 15.7\% \simeq 16\%$

13. Ans: (d)

Sol:



$P = W_1 + W_2 + W_3 = 1732.05$

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

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

$I_L = \dfrac{1732.05}{\sqrt{3}\times 400\times 0.5} = 5$ 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 $= \dfrac{W}{VA}$

$= \dfrac{1732.05}{3464} = 0.5$ 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 $\bar{I}_B$)

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

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

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

14. Ans: (c)

Sol: Energy recorded (kWhr)

$= \dfrac{5\text{ rev}}{1200\text{ rev/kwhr}} = 4.1667\times 10^{-3}$ kwhr

Energy = 4.1667 Whr

Load power $= \dfrac{4.1667\text{ Whr}}{75\text{ sec}} = \dfrac{4.1667\text{ Whr}}{\frac{75}{3600}\text{ hr}}$

Load power = 200 W

15. Ans: (d)

Sol: Energy recorded (measured value)

$= \dfrac{51\text{ rev}}{360\text{ rev/kwhr}}$

$= 0.141667$ kwhr

Energy consumed (True value)

$= \dfrac{10\text{ kw}\times 50}{3600} = 0.13889$ kwhr

Error $= \dfrac{0.141667 - 0.13889}{0.13889}\times 100$

$= 1.999\% \simeq +2\ \%$

5. Bridge Measurement of R, L &C

01. Ans: (a)

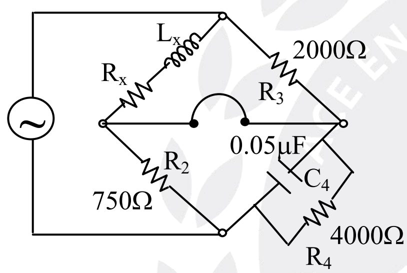
Sol: It is Maxwell Inductance Capacitance bridge

$R_x R_4 = R_2 R_3$

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

$$R_x = \frac{750\times2000}{4000}$$

$R_x = 375\ \Omega$



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

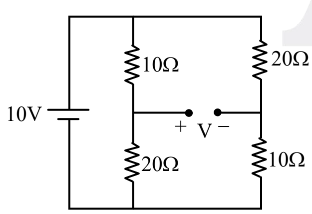
$L_x = C_4 R_2 R_3$

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

$L_x = 75$ 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

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

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

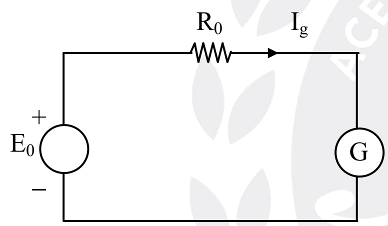
$$= (0.5\times10^6 + 10\times10^3)\left(\frac{41}{51}\right) - 10\times10^3$$

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

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

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 Ω

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

$\Rightarrow$ Q = 4. 95 kΩ

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 Ω

$$C_1 = \frac{\varepsilon_0\varepsilon_r A}{d}$$

$$= \frac{2.3\times4\pi\times10^{-7}\times314\times10^{-4}}{0.3\times10^{-2}}$$

C_1 = 30.25 μF

δ = 9° for 50 Hz

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

$\Rightarrow r_1$ = 16.67 Ω

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

R_4 = 4.26k Ω, C_4 = 0.118 μF

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

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

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

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

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

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

$$= \frac{1.0307\times10^{-3}}{272.8+100}\text{A}$$

$$= 2.77\ \mu\text{A}.$$

Deflection of the galvanometer

$$\theta = S_iI_g = 10 \times 2.77$$

$$= 27.7\ \text{mm}/\Omega.$$

Sensitivity of bridge

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

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

09. Ans: (d)

Sol: $R_1R_4 = R_2\,R_3$

$$R_4 = \frac{R_2\,R_3}{R_1}$$

$$= \frac{5\times100}{10} \pm (2\% + 5\% + 3\%)$$

$$= 50 \pm 10\%\ \Omega$$

10. Ans: (c)

Sol: Under balanced condition, current through Galvanometer is zero, then

$$R_{eq} = (120\Omega + 80\Omega)\ ||\ (120\Omega + 80\Omega)$$

$$= 100\ \Omega$$

$$I_B = \frac{1\text{V}}{100\Omega} = 10\ \text{mA}$$

11. Ans: (c)

Sol: $\text{Sensitivity} = \dfrac{\text{Change in output}}{\text{Change in input}}$

$$= \frac{3\ \text{mm}}{6\Omega} = 0.5\ \text{mm}/\Omega$$

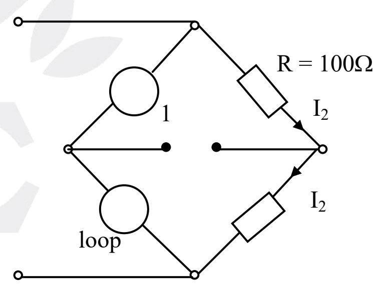
12. Ans: (d)

Sol: Changing the arms resistance by same value will not affect the Balance condition.

13. Ans: (a)

Sol: $V_1 = \sqrt{2}\cos(1000t)\ \text{V}$

$V_2 = 2\cos(1000t + 45^\circ)\ \text{V}$



Under balanced condition,

$V_1 = I_2\,R$

$$I_2 = \frac{V_1}{R} = \frac{\sqrt{2}\cos1000t}{100}$$

$$\left.\begin{aligned} I_2 &= 10^{-2}\times\sqrt{2}\cos(1000t) \\ V_2 &= 2\cos(1000t+45^\circ) \end{aligned}\right\}\ \text{At } Z_x$$

'I_2' lags 'V_2' by 45°. So, Z_x has 'R' and 'L' in series.

$$R = Z\cos\theta = \frac{2}{10^{-2}\times\sqrt{2}}\cos 45^\circ = 100\ \Omega$$

$X_L = Z \sin\theta$

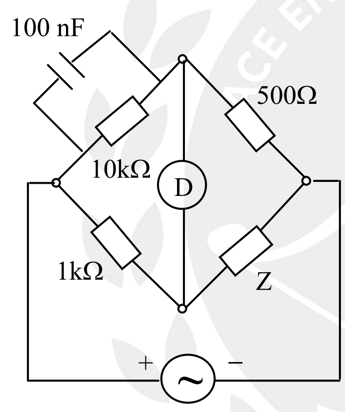
$$= \frac{2}{\sqrt{2}\times 10^{-2}}\sin 45^\circ = 100\ \Omega$$

$X_L = \omega L$

$$L = \frac{X_L}{\omega} = \frac{100}{1000} = 0.1\ H = 100\ mH$$

14. Ans: (b)

Sol:



$$R \parallel \frac{1}{j\omega C} = \frac{R}{1+j\omega RC}$$

$$\left(\frac{R}{1+j\omega RC}\right) Z = 1k\Omega \times 500\Omega$$

$$\left(\frac{10k\Omega}{1+j\omega\times10k\Omega\times100\times10^{-9}}\right) Z = 1k\Omega\times500\Omega$$

$$\frac{10^4\times Z}{1+j\omega\times10^{-3}} = 50\times10^4$$

$Z = 50 + j\omega \times 0.05$

$Z = R + j\,\omega L$

$R = 50\ \Omega$ in series with $L = 0.05$ H

7. 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

$= (101.8/200) \times 400$

$= 203.6\ \Omega$

∴ 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

$$= 0.029 \times 75 = 2.175\ V$$

Current through resistor (I)

$$= \frac{2.175\,V}{0.1\,\Omega} = 21.75\ A \quad \text{(or)}$$

75 cm → 0.1 Ω

50 cm → ?

Slide wire resistance with standard cell

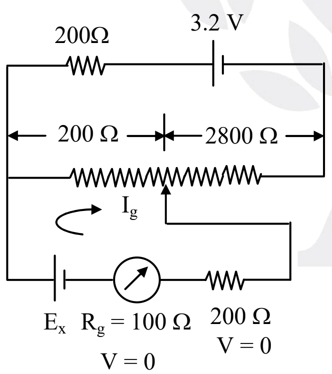
$$= \frac{50}{70} \times 0.1 = 0.067\ \Omega$$

Then $0.067 \times I_w = 1.45$ V

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

05. Ans: (a)

Sol:



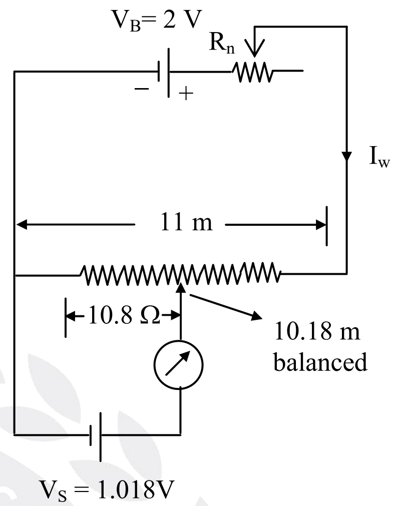
Under balanced, $I_g = 0$

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

$E_x = 200$ 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

$$I_w = \frac{V_B}{R_n + 1_r}$$

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

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

$$= 9\ \Omega$$

07. Ans: (a)

Sol: It is closed loop inverting amplifier

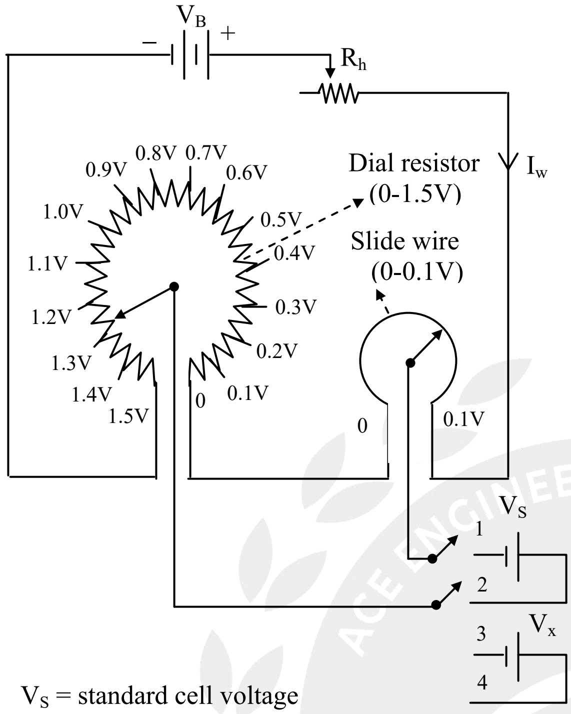
$$V_0 = -\frac{R_f}{R_i} V_{in}$$

$$= -\frac{15\,k\Omega}{10\,k\Omega} \times 1V$$

$$= -1.5\ V$$

08. Ans: (a)

Sol:



V_S = standard cell voltage

Dial resistor has 15 steps and each step is $10\ \Omega = 15 \times 10\ \Omega = 150\ \Omega$

Slide wire resistance = $10\ \Omega$

Total resistance = $150+10 = 160\ \Omega$

Working current (I_w) = 10 mA

Range of potentiometer

$= 10\text{mA} \times 160\ \Omega = 1.6$ V

Resolution of potentiometer

$$= \frac{\text{working current} \times \text{slide wire resistance}}{\text{slide wire length}}$$

$$= \frac{10\text{ mA} \times 10\ \Omega}{100\text{ cm}}$$

$= 0.001$ V/cm

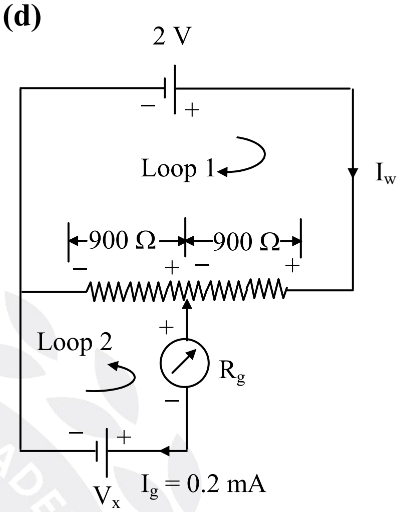
(1 div = 1 cm)

One fifth of a division can be read certainly.

$$\text{Resolution} = \frac{1}{5} \times 0.001 = 0.2\text{ mV}$$

09. Ans: (d)

Sol:



Write KVL for loop 1

$2V - 900\ I_w - 900(I_w - 0.2\text{mA}) = 0$

$I_w = 1.211$ mA

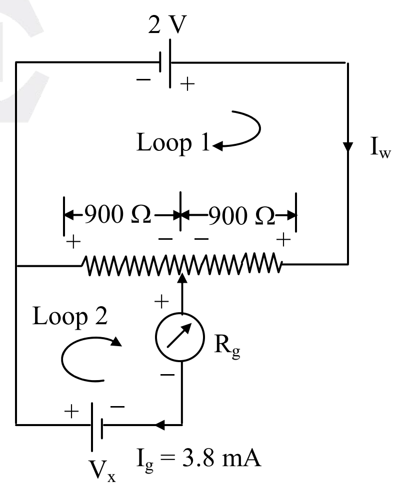
Write KVL for loop 2

$V_x + 0.2\text{ mA} \times R_g - 900(I_w - 0.2\text{mA}) = 0$

$V_x + 0.2\times10^{-3}R_g - 900(1.211\times10^{-3} - 0.2\times10^{-3}) = 0$

$V_x = 0.909 - 0.2\times10^{-3}\ R_g$ ……. (1)

When V_x is reversed, the circuit is



Write KVL for loop (1)

$2 - 900I_w - 900(I_w - 3.8mA) = 0$

$I_w = 3.011$ mA

Write KVL for loop (2)

$V_x - 900(3.8mA - I_w) - 3.8mA \times R_g = 0$

$V_x - 900(3.8\times10^{-3} - 3.011\times10^{-3}) - 3.8\times10^{-3} R_g = 0$

$V_x = 0.710 + 3.8\times10^{-3} R_g$ ………(2)

Substitute (2) in eqn (1)

$0.710 + 3.8\times10^{-3}R_g = 0.909 - 0.2\times10^{-3}R_g$

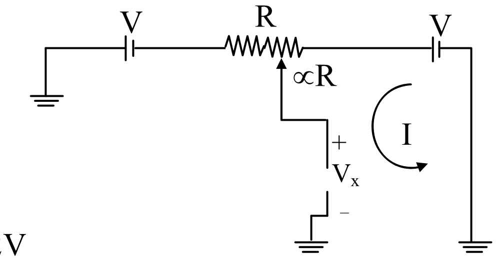
$R_g = 49.72\ \Omega \simeq 50\ \Omega$

Substitute 'R_g' value in eqn (2)

$V_x = 0.710 + 3.8 \times 10^{-3} \times 50 = 0.9001V$

10. Ans: (a)

Sol:



$I = \frac{2V}{R}$

Apply KVL in loop

$-V + I\alpha R + V_x = 0$

$-v + \frac{2v}{R} \times \alpha R + v_x = 0$

$V - 2V\alpha = Vx$

$V_x = [1 - 2\alpha]\ V$

Electronic Measurements

8. Cathode Ray Oscilloscope

01. Ans: (b)

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

= 2.2 msec

Therefore frequency = $\frac{1}{T} = \frac{1}{2.2\times10^{-3}}$

= 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

∴ voltage = 2.5 × 3 = 7.5 V

Similarly frequency of upper trace is 1kHz

So the time period T

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

$T = \frac{1}{10^3} \Rightarrow 1$ 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 $V_{rms} = \frac{V_{p-p}}{2\sqrt{2}}$

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

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

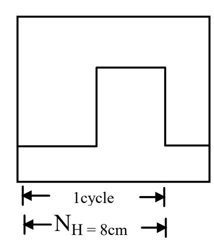
$\Rightarrow N_v = \frac{2\sqrt{2}\times 300\text{mV}}{100\text{mv/cm}}$

$\Rightarrow N_v = 8.485\text{cm}$

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

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

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

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

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

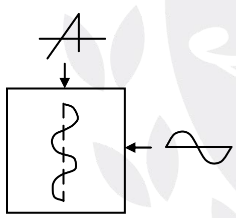
→ $T_{signal} = N_H \text{per cycle} \times \dfrac{\text{TIME}}{\text{div}}$

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

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

05. Ans: (a)

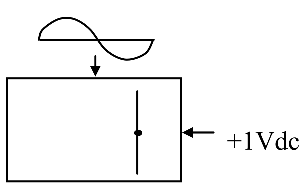
Sol: Frequency ratio is 2



∴ Two cycles of sine wave displayed on vertical time base

06. Ans: (a)

Sol:



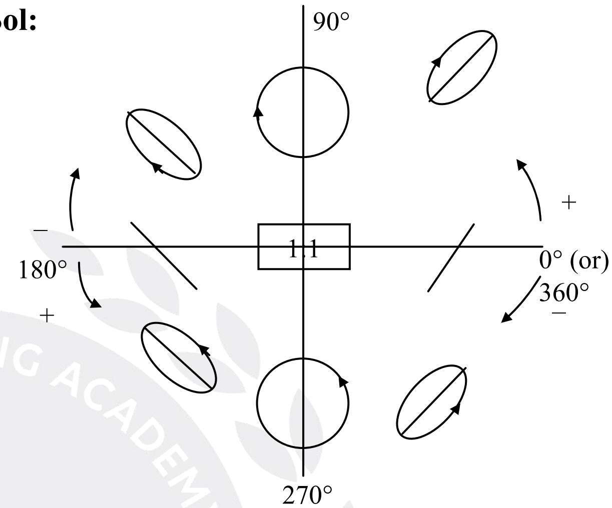
Vertical straight line

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:

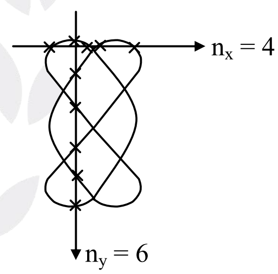


09. Ans: (b)

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

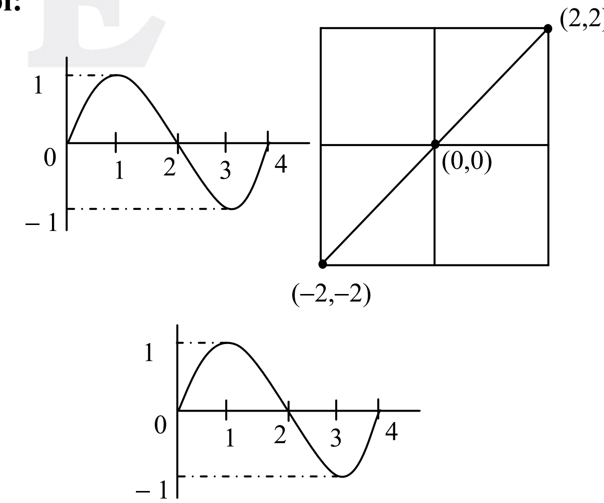
$= \dfrac{4}{6} \times 600\text{Hz}$

$= 400$ Hz



10. Ans: (d)

Sol:



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

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.

11. Ans: (d)

Sol: Voltage signal = 5 sin (314t + 45°)

$f_{signal} = \frac{314}{2\pi}$ Hz

$= 50$Hz

No.of cycles of signal displayed

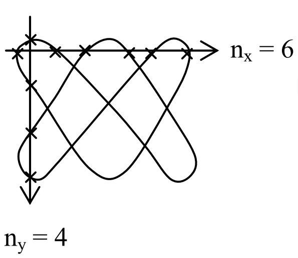
$= f_{signal} \times T_{sweep}$

$= 50\times10\times5$ ms/div

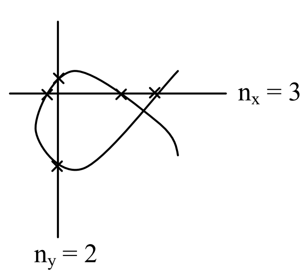
$= 2.5$

12. Ans: (d)

Sol:



$\frac{f_y}{f_x} = \frac{6}{4} \Rightarrow \frac{3}{2}$



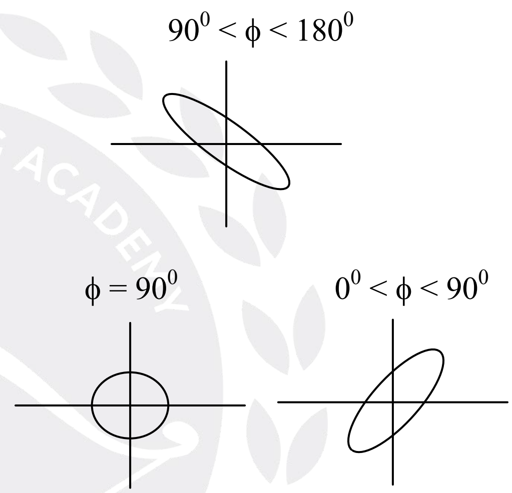
$\frac{f_y}{f_x} = \frac{3}{2}$

13. Ans: (a)

Sol: Lissajious figures are used for measurement of frequency and phase difference

14. Ans: (d)

Sol:



Because of phase difference only figures changes from ellipse to circle and back to ellipse.

15. Ans: (d)

9. 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 $\rightarrow$ (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: (c)

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

Therefore, the count range is from 0 to 1999 i.e., 2000 counts.

$$\text{Resolution} = \frac{\text{given voltage range}}{\text{Maximum count}}$$

$$= \frac{200\text{mV}}{2000} = 0.2\text{mV}$$

08. Ans: (a)

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

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

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.

11. Ans: (b)

Sol: Given , $3\frac{1}{2}$ digit, FSD value of 200 mV

Resolution $= \frac{200\text{mV}}{2000} = 0.1\text{mV}$

$$\therefore \text{Error} = \frac{0.5}{100}\times 100\text{mV} + 5\times 0.1\text{mV}$$

$$= \pm 1 \text{ mV}$$

$\therefore$ The value lies between 99.0 mV & 101.0 mV

12. Ans: (d)

Sol: • The DVM has $3\frac{1}{2}$ digit display. Therefore, its scale resolution is 0.001

- Its resolution in 200mV range is 100mV
- The maximum voltage that can be measured in this 200mV lowest Range: 199.9mV

13. Ans: (b)

Sol: For N-decade counter

Pulse width $_{(max)} = \frac{10^N}{f_{clk}}$

Resolution $\Rightarrow$ 1count $\Rightarrow$ $1.T_{clk}$

Resolution $= \frac{1}{f}$

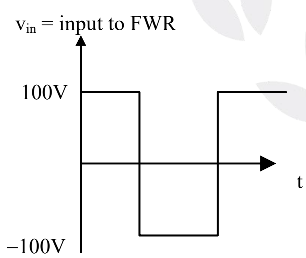
Range of pulse width

$\Rightarrow \frac{1}{f}$ to $\left(\frac{10^N - 1}{F}\right)$

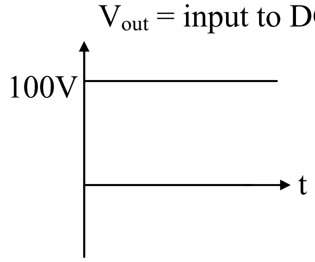
10. Analog Electronic Voltmeters

01. Ans: (d)

Sol:



V_{out} = input to DC voltmeter



The output of FWR is fed as input to DC volt meter. As such, the DC voltmeter measures average value of V_{out}.

V_{avg} of V_{out} = 100V

$V_{rms(ind)} = 1.11 \times V_{avg} = 1.11 \times 100$ V

$= 111$ V

02. Ans: (b)

Sol: $V_{measured}$ (rms) $= 1.11\times$ average value

$= 1.11 \times 75$

$= 83.25$V

$$V_{True}\,(rms) = \frac{V_m}{\sqrt{3}} = \frac{150}{\sqrt{3}} = 86.6V$$

$$\%\ \text{error} = \frac{V_{measured} - V_{True}}{V_{True}} \times 100$$

$$= \frac{83.25 - 86.6}{86.6} \times 100$$

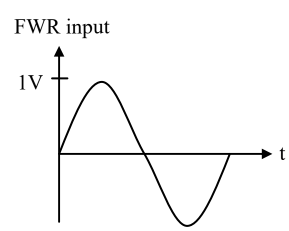
$= -3.87\%$

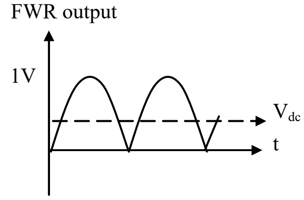
03. Ans: (a)

Sol: The full wave Rectifier type electronic AC voltmeter has a scale calibrated to read r.m.s value for square wave inputs. As such, the scale calibration factor used for deriving rms volt scale from DC volt scale is 1.

Reading = $1\times V_{dc}$ Where V_{dc} is Average voltage of output of full wave Rectifier for given input.

- This voltmeter is used to measure a sinusoidal voltage





DC. voltmeter measures V_{dc} of output of FWR

$$V_{dc} = \frac{2V}{\pi}$$

Therefore, reading = $1\times V_{dc}$

$$= \frac{2}{\pi}V$$

04. Ans: (b)

Sol: A rectifier moving coil instrument consists of a rectifier at primary stage whose output is fed to PMMC meter.

As such, it measures average value but indicates rms value since scale is calibrated in terms of rms.

05. Ans: (d)

Sol: Assertion is wrong since Fullwave rectifier AC voltmeter is a derived rms meter and reads true rms of only one wave form which meter scale is calibrated

06. Ans: (b) (Update Key)

Sol: $S_{AC} = 0.9\ S_{dc}$

$= 0.9\times 10\ k\Omega/V$

$= 9\ k\Omega/V$

Input resistance in 10V range

$= 9\ k\Omega/V \times 10$

$= 90\ k\Omega$

07. Ans: (c)

Sol: Given data: Full wave Bride Rectifier AC voltmeter's AC volt range is 0-100V. The PMMC ammeter used in the design has full scale current rating of 1mA and internal resistance of 100Ω & diodes are ideal

$$R_s = 0.9\times\frac{V_{rmsFSD}}{I_{dcFSD}} - 2R_d - R_m$$

$$= 0.9\times\frac{100V}{1mA} - 100\Omega$$

$= 90k\Omega - 100\Omega$

$= 89.9\ k\Omega$

08. Ans: (a)

Sol: we know, for FWBR type AC voltmeter

$V_{rms}=1.11\ (R_{v(fw)})\times I_{dc}$

$\Rightarrow 100kV=1.11\ [x_c]\times 45\times 10^{-3}A$

$$\Rightarrow X_c = \frac{100\times 10^3\,V}{1.11\times 45\times 10^3\,A}$$

$$\Rightarrow \frac{1}{2\pi fc} = \frac{100\times 10^3\,V}{1.11\times 45\times 10^{-3}\,A}$$

$$\Rightarrow C = \frac{1.11\times 45\times 10^{-3}\,A}{2\pi\times 50Hz\times 100\times 10^3\,V}$$

$\simeq 15.9\times 10^{-10}\ F$

09. Ans: (d)

Sol: Multimeter measure voltage (ac&dc), current (ac&dc), resistance

10. Ans: (c)

Sol: The meter reads full scale with 12v at M and range switch at B.

Now range switch is at D and meter reads full scale value.

Voltage at M is ?

At position B:

$$V_0 = V_s\left(\frac{1.2+0.6+0.12+0.06+0.02}{2+6+1.2+0.6+0.12+0.06+0.02}\right)$$

$= 12 \times 0.2 = 2.4$

At position D:

$$V_0 = V_s\left(\frac{0.12+0.06+0.02}{2+6+1.2+0.6+0.12+0.06+0.02}\right)$$

$2.4 = V_s \times 0.02$

$V_s = 120V$

11. Ans: (b)

Sol: Given data: Voltmeter sensitivity is 20kΩ/V

Reading of 4.5V on its 5V full scale

Reading of 6V on its 10V full scale

- Say, voltage source is V_s and its internal resistance is R_s.

5V range:

$$R_v = 20\frac{k\Omega}{V}\times 5 = 100\ k\Omega$$

$$\rightarrow \text{Reading} = V_s \times \frac{100k\Omega}{R_s + 100k\Omega}$$

$$4.5V = V_s \times \frac{100k\Omega}{R_s + 100k\Omega}$$

$$\therefore V_s = \frac{4.5V}{100k\Omega}(R_s + 100K\Omega) \quad \ldots\ldots\ldots (1)$$

10V Range:

$$\rightarrow R_v = 20\frac{k\Omega}{V}\times 10V$$

$$= 200k\Omega$$

$$\rightarrow \text{reading} = V_s \times \frac{200k\Omega}{R_s + 200k\Omega}$$

$$6V = V_s \times \frac{200k\Omega}{R_s + 200k\Omega}$$

$$\therefore V_s = \frac{6V}{200K\Omega}(R_s + 200k\Omega) \quad \ldots\ldots. (2)$$

Solving eq (1) & (2)

$$\frac{6V}{200k\Omega}(R_s + 200k\Omega) = \frac{4.5V}{100k\Omega}(R_s + 100k\Omega)$$

$$R_s + 200k\Omega = 1.5(R_s + 100k\Omega)$$

$0.5R_s = 50k\Omega$

$R_s = 100k\Omega$

Putting the value of R_s in eq (1)

$$V_s = \frac{4.5V}{100k\Omega}(100k\Omega + 100k\Omega)$$

$= 4.5V\times 2 = 9V$

Therefore, the voltage source is 9V and its internal resistance is 100kΩ

12. Ans: (b)

Sol: For the measurement of the voltage of the order of mv, an amplifier- rectifier type VTVM is best suitable where the low magnitude input signal (AC) is first amplified and then rectified and then driven to PMMC meter.

11. Q–Meter

01. Ans: (a)

Sol: $C_1 = 300pF$ $C_2 = 200\ pF$

$Q = 1/(\omega C_1R)$

$= 120 = 1/(C_2 + C_x)R$

$C_1 = C_2 + C_X$

$\therefore C_x = 100\ pF$

02. Ans: (b)

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

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

03. Ans: (c)

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

∴ 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, $L = \frac{1}{\omega^2[C+C_d]}$

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

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, $Q = \frac{V_{c\,max}}{V_{in}}$

$\Rightarrow Q = \frac{V_0}{V}$

06. Ans: (b)

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

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

$n = \frac{250\,\text{kHz}}{500\,\text{kHz}}$

$\Rightarrow n = 0.5$

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

$= 5.33$pF

07. Ans: (c)

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

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

$= 20$

08. Ans: i → (c), ii → (a)

Sol: (i) $C_d = \frac{C_1 - n^2 C_2}{n^2 - 1}$

$$= \frac{360-288}{3}$$

$= 24$ pF

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

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

09. Ans: (b)

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

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

10. Ans: (c)

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

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

$=2.044\times10^{-3}$

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

11. Ans: (b)

Sol: Q-meter works on the principle of series resonance

$V_c=Q\times V_{in}$

$\therefore$ Both A & R are individually true but R is not the correct explanation of A.

Transducers

12. Basics of Transducers

01. Ans: (d)

Sol: piezo electric transducer is an active transducer

02. Ans: (c)

Sol: Active transducers do not require an auxiliary power source to produce their output. From given options thermocouple & solar cell pair transducers are active transducers as they produce output with no auxiliary power source.

03. Ans: (d)

Sol: Pressure → Piezoelectric crystal

Temperature → Thermistor

Displacement → Capacitive transducer

Stress → Resistance strain gauge

04. Ans: (d)

Sol: Thermocuple → Cold junction compensation

Strain gauge → DC bridge

Piezoelectric crystal → Charge amplifier

LVDT → Phase sensitive detector

05. Ans: (b)

Sol: Usually from transducers we get small output which is not sufficient for further processing, so in order to amplify that output we require signal conditioning circuit. finally to read the output we require recorder.

06. Ans: (d)

Sol: Bolometer → measurement of power at 500 MHz

Hot wire anemometer → measurement of flow of air around an aeroplane.

C-type bourdon tube → measurement of high pressure

Optical pyrometer → measurement of temperature of furnace.

07. Ans: (d)

Sol: Charge amplifier with very low bias current and high input impedance → piezoelectric sensor for measurement of static force

Voltage amplifier with low bias current and very high input impedance → Glass electrode PH sensor

Voltage amplifier with very high CMRR sensing applications → strain gauge in unipolar DC wheatstone bridge.

08. Ans: (b)

Sol: Mcleod gauge → Pressure

Turbine meter → Flow

Pyrometer → Temperature

Synchros → Displacement

09. Ans: (a)

Sol: Variable capacitance device → Pressure transducer

Orifice meter → Flow measurement

Thermistors → Temperature measurement

10. Ans: (b)

Sol: From given options diaphragm and pivot torque are employed for displacement measurement while thermistor and thermocouple not related to displacement measurement.

11. Ans: (a)

Sol: Instrumentation amplifier is used to amplify signals from transducer

12. Ans: (a)

Sol: LVDT gives linear output & also very accurate compare to any other transducer given in options.

13. Ans: (b) (Update Key)

Sol: The lower limit of useful working range of a transducer is determined by transducer error and noise.

14. Ans: (d)

Sol: From given options, thermocouple and thermopile, piezoelectric pick-up, photovoltaic cellare a self generating type transducers.

13. Resistive, Capacitive, Inductive Transducers

01. Ans: (b)

Sol: **For resistive potentiometer**

output E_0 $= K \times E_i$

Where E_0 = output of the potentiometer

E_i = input of the potentiometer

02. Ans: (b)

Sol: In a resistance potentiometer, non linearity decreases with increase of load to potentiometer resistance because the output equation for potentiometer under loading condition is

$$E_0 = \frac{K}{1+K(1-K)\times\left(\frac{R_p}{R_m}\right)}$$

R_p = resistance of the potentiometer

R_m = resistance of the meter

03. Ans: (a)

Sol: In a resistance potentiometer high value of resistance lease to high value of sensitivity

04. Ans: (c)

Sol: Total temperature of POT = $T_{ambient} + T_{pot}$

$$T_{pot} = 30\left(\frac{°C}{W}\right)\times P$$

$$P = \frac{V^2}{R} = \frac{(10)^2}{100} = 1W$$

$$T_{pot} = 30\left(\frac{°C}{W}\right)\times 1W$$

$= 30$ °C

Total temperature of POT = 40 +30

= 70°C

05. Ans: (a)

Sol: Semiconductor strain gauge has a much higher gauge factor then that of a metal wire strain gauge because of piezo resistive effect.

06. Ans: (b)

Sol: We for quarter bridge strain measuring circuit the output $V_0 = \frac{V_i}{4} \times G_F \times \varepsilon$

Here, V_0 = 1 mV

Strain (ε) = 500×10^{-6}

V_i = 4 V

Now $G_F = 2$

07. Ans: (a)

Sol: For the given bending force we can say that configuration P is subjected to more tension compare to other two configurations.

08. Ans: (d)

Sol: $G_f = 1+2\times0.35$

$= 1.70$

09. Ans: (c)

Sol: for sinusoidal input output should have to be sinusoidal

10. Ans: (c)

Sol: Gauge factor $\frac{0.150/250}{1.5\times10^{-4}} = 4$

11. Ans: (b)

Sol: A gauge factor is a ratio of per unit change in resistance to per unit change in length

$$G.F = \frac{\Delta R / R}{\Delta L / L}$$

12. Ans: (b)

Sol: To receive the optimum output signal for shear strain, all the gauges should be placed at a position that is 45° in with respect to the longitudinal axis.

13. Ans: (c)

Sol: A strain gauge bridge sometimes excited with ac to avoid the power frequency pick-up.

14. Ans: (b)

Sol: GF = 2

$\varepsilon = 1\times 10^{-6}$

R = 120Ω

We know = $\frac{\Delta R}{R} = GF\varepsilon$

$\Delta R = GF\ \varepsilon\ R$

$= 2 \times 1 \times 10^{-6} \times 120$

$\Delta R = 240 \times 10^{-6}\Omega$

15. Ans: (c)

Sol: The piezoresistive effect is a change in the electrical resistivity of a semi conductor or metal when mechanical strain is applied. Semiconductor strain gauges have higher piezoresistive coefficient so higher gauge factor.

16. Ans: (a)

Sol: In given diagram of LVDT, two secondary coils are so connected that output will always be added. So output is constant voltage graph.

17. Ans: (d)

Sol: LVDT has one primary coil and two secondary coils are connected in opposition , so that output must difference between two secondary output voltage.

18. Ans: (a)

Sol: LVDT is an inductive transducer which translates the linear motion into electrical signals.

19. Ans: (b)

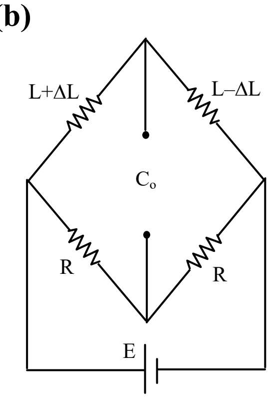
Sol: Air cored inductive transducers are suitable to use at higher frequencies

20. Ans: (d)

Sol: Inductive transducer in differential configuration of output is unaffected by External magnetic field temperature changes, variation of supply voltage & frequency.

21. Ans: (b)

Sol:



For push pull arrangement for L change change of inductance exhibited at output

$= L + \Delta L - (L - \Delta L) = 2\Delta L$

22. Ans: (d)

Sol: An LVDT exhibits linear characteristics up to a displacement of ± 5mm, linearly of 0.05 % has an infinite resolution and high sensitivity of the order of 40 V/mm.

23. Ans: (a)

Sol: To avoid the effect of fringing, the potential of the guard ring of a capacitance transducer hold at circuit potential. Ground is supposed to be a conduit to remove extraneous noise from the circuit.

24. Ans: (b)

Sol: The transfer function of capactive transducer is given as

$$\frac{Xo(s)}{X_i(s)} = \frac{1}{\sqrt{1+\left(\frac{1}{\tau\omega}\right)^2}}$$

So this resembles a high pass filter.

25. Ans: (a)

Sol: A strain gauge is an example of an electromechanical transducer in which displacement is used to vary the resistance. So we can say that both statement I & II are true as well as related.

26. Ans: (c)

Sol: Incase of strain gauge

Statement –I is true but

Statement –II is false.

14. Piezo Electric Transducers

01. Ans: (b) (Update Key)

Sol: For piezo electric transducer

$$\text{frequency} \propto \frac{1}{\text{cable length}}$$

$$f_{new} = \frac{f_{old}}{2} = \frac{2000}{2} = 1000\text{Hz}$$

02. Ans: (a)

Sol: The output piezo electric transducer is a zero for static pressure.

03. Ans: (a)

Sol: For signal conditioning of piezo electric type transducer we require a charge amplifier

04. Ans: (d)

Sol: Piezoelectric transducers is used to measure dynamic pressure measurement while for static its output is zero millivolts.

05. Ans: (a)

Sol: t = 2.5mm

$$G = 0.05 \times \frac{V_m}{N}$$

$P = 1.6 \times 10^5\ N/m^2$

We know $\varepsilon = gtp$

$= 0.05 \times 2.5 \times 10^{-3} \times 1.6 \times 10^6$

$e_0 = 200$ V

06. Ans: (c) (Update Key)

Sol: The piezoelectric transducers vibrate at ultrasonic frequencies. Piezoelectric material is a type of electro acoustic transducer that converts electrical energy into mechanical and vice versa.

07. Ans: (a)

Sol: Piezoelectric crystal can be shown as electrical equivalent circuit in interms L and C. Quartz, Rochelle salt, tour maline are piezoelectric crystal. Also piezoelectric crystal exhibits the reverse effect of electrostriction.

08. Ans: (c)

Sol: Piezoelectric transducer used for dynamic displacement only and it is useless for static displacement. Piezoelectric materials have low dielectric constant.
Quartz dielectric constant is 4.2

09. Ans: (a)

Sol: $BaTiO_3$ used in record player. Mechanical stress in piezoelectric material producer on electric polarization and application of electric field produces a mechanical strain.

15. Measurement of Temperature

01. Ans: (a)

Sol: Platinum resistance thermometer used to measure temperature in the range –200° C to 1000°C

Material	Minimum temperature	Maximum temperature

Platinum	–200°C	1000°C
Copper	–200°C	150°C
Nickel	–70°C	150°C
Tungsten	–200°C	850°C

02. Ans: (d)

Sol: RTD material must have

(i) High temperature coefficient of resistance

(ii) Higher resistivity

(iii) Linear relationship between R and T

(iv) Stability of the electrical characteristics of the material

03. Ans: (d)

Sol: Platinum has a constant volume of temperature coefficient in 0 to 100°C range.

Resistivity of platinum tends to increase less rapidly at higher temperatures.

Platinum has stability over higher range of temperature.

04. Ans: (a)

Sol: $\alpha_{45°C} = \left(\frac{R_2 - R_1}{T_2 - T_1}\right)\frac{1}{R_{45°C}}$

$R_{45°C} = \frac{R_1 + R_2}{2} = \frac{5 + 6.5}{2} = 5.75\Omega$

Here $R_1 = 5\Omega$ at $T_1 = 30°C$

$R_2 = 6.5\Omega$ at $T_2 = 60°C$

$\alpha_{45°C} = \left(\frac{6.5 - 5}{60 - 30}\right) \times \frac{1}{5.75}$

$= 0.0087\ (1/°C)$

05. Ans: (d)

Sol: The resistance temperature characteristics of a temperature transducer is related to positive temperature coefficient thermistor.

06. Ans: (d)

Sol: Thermistors are well suited to precision temperature measurement. It is used in range of –100°C to 300°C. It has higher negative temperature coefficient of resistance.

07. Ans: (c)

Sol: A thermistor can exhibit either a negative change of resistance (NTC) or positive change of resistance (PTC) with increase of temperature depending upon the type of material used.

08. Ans: (b)

Sol: $R = 5000\ \Omega$ at $T = 25°C$, $\alpha = 0.04\ (1/°C)$

$R_{lead} = R\,[1+\alpha\,(T_{lead} - T)]$

$10 = 5000\,[\,1+0.04\,(T-25)]$

$T = 0.05°C$

09. Ans: (b)

Sol: Thermistors are essentially semiconductor devices that behaves as resistors with high negative temperature coefficient and are atleast 10 times as sensitive as the platinum resistance thermometer.

10. Ans: (b)

Sol: $\beta = 3000$ K

$R = 1050\Omega$ at $T = 27\ °C$

$= 300$ K

So temperature coefficient of resistances for the thermistor $\alpha = \frac{-\beta}{T^2} = \frac{-3000}{(300)^2}$

$= -0.033$ (Ω/Ω/°C)

11. Ans: (d)

Sol: In case of thermocouple we required a reference junction compensation to get stable and reliable output. Also thermocouple output is very small.

12. Ans: (a)

Sol: V_0 = output of thermocouple = 50 mV

R_t = thermocouple internal resistance = 50Ω

R_{lead} = 10Ω

r = PMMC internal resistance = 120Ω

so output voltage indicated by PMMC V_{PMMC} is

$$V_{pmmc} = \frac{r}{r + R_t + R_{lead}} \times V_0$$

$$= \frac{120}{120 + 50 + 10} \times 50 \times 10^{-3}$$

$$= \frac{120 \times 50 \times 10^{-3}}{180}$$

$= 33.33$ mV

13. Ans: (d)

Sol:

Thermocouple	Temperature range(in°C)
Copper-constantan	–200 to 350
Iron – constantan	–200 to 850
Alumel-Chromel	–200 to 1100
Platinum Rhodium	450 to 1500

14. Ans: (b)

Sol: Iron-constantan thermocouple is most suitable for temperature measurement in the range of 700 °C to 800° C.

15. Ans: (a)

Sol: Time to reach equilibrium

Conditions 5T = 10 ⇒ T = 2 sec

$\theta = \theta_0\,[1 - e^{-t/T}]$

$0.5 = [1 - e^{-t/T}]$

T = 1.39 sec

16. Measurement of Flow, Viscosity, Humidity

01. Ans: (d)

Sol: In case of rotameter with increase in the flow rate, the float rises in the tube and there occurs an increase in the annular area between the float and the tube. So we can say that rotameter is a variable area device.

02. Ans: (a)

Sol: Flow rate in pitot tube is

$$Q = AV = A\sqrt{\frac{2P_d}{\rho}}$$

$$\theta \propto \sqrt{P_d}$$

03. Ans: (c)

Sol:

Restrictors	Discharge coefficient
Orifice tube	0.60
Venturi tube	0.98
Flow nozzle	0.80

04. Ans: (b)

Sol: Rotary vane type transducer is an example of positive displacement flow meter.

05. Ans: (b)

Sol: Venturimeter has the lowest pressure drop for a given range of flow because venturimeter has highest coefficient of discharge about 0.98 .

06. Ans: (a)

Sol: In Rota meter, flow rate is directly proportional to height

$Q \propto h$

$$\therefore \frac{Q_1}{Q_2} = \frac{h_1}{h_2} = \frac{70\,\text{mm}}{20\,\text{mm}} = \frac{7}{2} = 3.5$$

07. Ans: (d)

Sol: During the flow through an orifice meter, the fluid jet on leaving the orifice contracts to minimum area at a section called vena-contracta, area of fluid jet at vena contracta is less than areas of the orifice & the two are related as

area at vena contracta = C_d ×orifice area.

$$= 0.6\left(\frac{\pi d^2}{4}\right)$$

C_d of orifice = 0.6

Area of orifice = $\frac{\pi d^2}{4}$

08. Ans: (a)

Sol: Pressure at throat of a venturi tube is lower compare to upstream pressure. While velocity at throat of a venture tube is higher compare to velocity of flow at up stream.

09. Ans: (a)

Sol: In case of rotameter the weight of the float is balanced by the buoyancy and the drag force acting on the float. Volume flow rate sensitive to density changes of the fluid. By using rotameter volume flow rate of gas can be measured.

10. Ans: (c)

Sol: Flowing fluid density affected in orifice plate, rotameter, pitot static tube meter white flowing fluid density is not matter for measurement of flow in non obstruction type meter like electromagnetic flow meter.

11. Ans: (a)

Sol: When an electrically heated wire is placed in a flowing gas stream, heat is transferred from wire to the gas and hence the temperature of the wire reduces and due to this the resistance of the wire also changes. This change in resistance of the wire becomes a measure of flow rate.

12. Ans: (a)

Sol: Hot wire anemometer gives good result when the flowing fluid is exceptionally clean.

13. Ans: (c)

Sol: The turbine type flow meter used to measure totalisation of flow.

14. Ans: (b)

Sol: In case of electromagnectic flow meter the induced voltage is proportional to flow rate

as $e = \frac{B\ell VA}{A} = \frac{B\ell Q}{A}$

$e \propto Q$

17. Intermediate Quantity Measurements

01. Ans: (d)

Sol: In seismic vibration sensor for measuring amplitude of vibration $\omega_n << \omega$ & slightly less than 1.

02. Ans: (d)

Sol: $\omega_n = \sqrt{\frac{K}{M}}$

Decreasing the mass in case of a seismic acceleration sensor while keeping all other parameters constant will increase the natural frequency, without affecting steady state sensitivity.

03. Ans: (a)

Sol: $M = 100\ \mu gm$

$F_n = 1kHz$

04. Ans: (a)

Sol: $f = 100$ Hz

$X = 10$ mm

Peak acceleration of the seismicmass $= \omega^2 x$

$= (2\pi f)^2 x$

$= (2\pi\times 100)^2 \times 10 \times 10^{-3}$

$= 3947.84\ (m/sec^2)$

05. Ans: (a)

Sol: accelerometer input range

$= 0\ m/sec^2$ to $98.1\ (m/sec^2)$

$F = 30$ Hz

$M = 0.01$ kg

We know acceleration $= \omega^2\ x$

$x = \frac{\text{acceleration}}{\omega^2}$

$x_1 = 0mm$ to $x_2 = \frac{98.1}{(2\pi\times 30)^2}$

$= 2.76$ mm

06. Ans: (b)

Sol: In dc tachogenerators used for measurement of speed of a shaft, frequent calibration has to be done because the strength of permanent magnet decreases with age.

07. Ans: (c)

Sol: In a drag up type ac tachogenerator, the output voltage is modulated waveform.

08. Ans: (b) (Update Key)

Sol: $n_{teeth} = 60$

N = speed of shaft

N = 25 rps

We know

Speed of shaft in rps = $\frac{\text{pulse rate}}{n_{teeth}}$

$25 = \frac{\text{pulses per second}}{50}$

Pulses per second = 25 × 60

= 1500

09. Ans: (b)

Sol: f_r = rotating frequency of motor

$= \frac{1470}{60} = 24.5(\text{rps})$

F_f = stroboscope flashing frequency

= 12.5 (fps)

$F_r - nf_f = 24.5 - nf_f$

$n = 2\,f_r - nf_f = -30$ rpm

So star mark moves at a speed of 30 rpm against the direction of rotation.

10. Ans: (c)

Sol: $\text{rpm} = \frac{\text{pulses per second}}{\text{number of teeth}} \times 60$

$\text{rpm} = \frac{\text{flash per minute}}{\text{number of teeth}}$

$N = \frac{F}{n}$