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Electrical Engineering

ELECTRICAL & ELECTRONIC MEASUREMENTS

Text Book: Theory with worked out Examples and Practice Questions

Electrical Measurements

(Solutions for Text Book Practice Questions)

1. Error Analysis

01. Ans: (b)

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

$= \dfrac{200\text{ V}}{100\text{ V}} \times \pm 2\%$

$= \pm 4\%$

02. Ans: (d)

Sol: Variables are measured with accuracy

$x = \pm 0.5\%$ of reading 80 (limiting error)

$Y = \pm 1\%$ of full scale value 100

(Guaranteed error)

$Z = \pm 1.5\%$ reading 50 (limiting error)

The limiting error for Y is obtained as Guaranteed

Error $= 100\times(\pm 1/100)$

$= \pm 1$

Then % L.E in Y meter

$20 \times \dfrac{x}{100} = \pm 1$

$x = 5\%$

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

Therefore $= \pm (0.5\% + 5\% + 1.5\%)$

$= \pm 7\%$

03. Ans: (d)

Sol: $W_T = W_1 + W_2$

$= 100 - 50$

$= 50$ W

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

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

$= \pm 1$ W

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

$= \pm 0.5$ W

$W_T = W_1 + W_2$

$= 50 \pm 1.5$ W

$W_T = 50 \pm 3\%$

04. Ans: (a)

Sol: For 10V total input resistance

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

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

$= 10\text{k}\Omega/\text{V}$

For 100V $\quad R_v = 100/100\mu\text{A}$

$= 10^6\Omega$

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

$= 10\text{ k}\Omega/\text{V}$

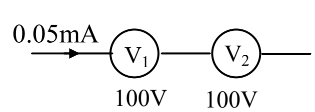
(or)

Sensitivity $= \dfrac{1}{I_{fsd}} = \dfrac{1}{100\times 10^{-6}}$

$= 10\text{ k}\Omega/\text{V}$

05.

Sol:



V_1: V_2:

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

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

= 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

06.

Sol: Internal impedance of 1st voltmeter

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

Internal impedance of 2nd voltmeter

= 100 × 250 Ω/V

= 25 kΩ

Internal impedance of 3rd voltmeters,

= 5 kΩ

Total impedance across 120 V

= 20 + 25 + 5

= 50 kΩ

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

= 416.6 Ω/V

⇒ 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: Voltmeter full scale = 10 V

Sensitivity of voltmeter = 100 kΩ/V

⇒ Internal resistance of voltmeter

= 100 kΩ × 10 = 1 MΩ

Internal resistance of photovoltaic cell

= 1 MΩ

Voltmeter reads = 5 V

$$\therefore\ V = V_{cell} \times \frac{R_V}{R_V + R_P}$$

$$5 = V_{cell} \times \frac{1M\Omega}{1M\Omega + 1M\Omega}$$

∴ The voltage generated by photovoltaic cell, V_{cell} = 5 × 2

= 10 V

08. Ans: (b)

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

= 0.2 V

2. Basics of Electrical Instruments

01. 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

$\sin\theta \propto I^2$

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

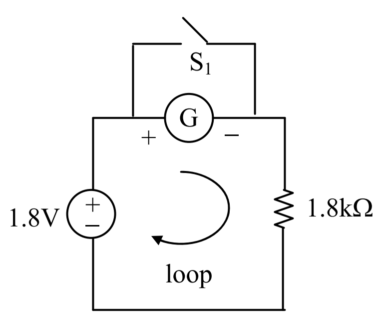
$$\frac{\sin\theta_2}{\sin 90} = \left(\frac{3}{5}\right)^2$$

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

$\theta_2 = \sin^{-1}(0.36) = 21.1°$

02. 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,

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

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

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

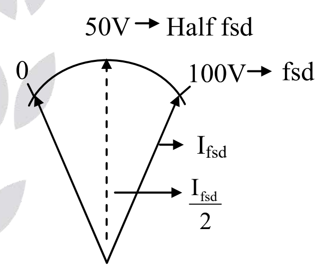
3. Electromechanical Indicating Instruments

01. Ans: (c)

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

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

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



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

$50\text{ V} \rightarrow ?$

$= 0.5$ mA

02. 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%↓

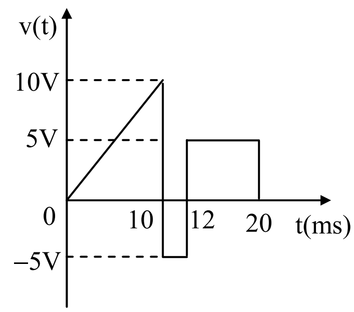
Net deflection (θ_{net}) = 0.4%↑ − 0.2%↓

= 0.2% ↑

Increases by 0.2%

03. Ans: (a)

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)

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

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

$= 4$ V

04. 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

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

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

$= 3.6$ MΩ

05. Ans: (c)

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

06. Ans: 0.1025 μF

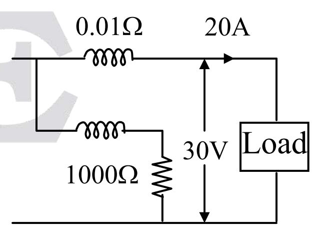
Sol: $C = \frac{0.41\,L_m}{R_{se}^2}$

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

$= 0.1025\,\mu$F

07. Ans: (c)

Sol: MC – connection

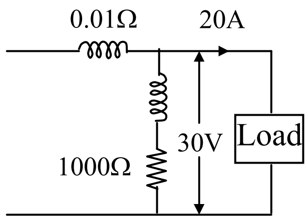


Error due to current coil

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

$= 0.667\%$

LC – connection



Error due to potential coil

$$= \frac{(30^2/1000)}{(30\times20)}\times100$$

$= 0.15\%$

As per given options, 0.15% high

08. Ans: (c)

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

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

$\therefore \quad 100 = 10\times10^3\times R_C$

$\Rightarrow \quad R_C = 0.01\ \Omega$

09. Ans: (d)

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

$\cos\phi = 0.7$,

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

$= 2\times\pi\times50\times0.5$

$= 157\ \Omega$

$\tan\beta = \frac{X_{LP}}{R_P}$

% Error $= \pm(\tan\phi\,\tan\beta)\times100$

$$= \pm\left(1\times\frac{157}{1000}\right)\times100$$

$= 15.7\% \simeq 16\%$

10. Ans: (a, b, c)

Sol: The sensitivity of galvanometer may be defined in several ways i.e., current, voltage and Megohm sensitivity.

11. Ans: (a, c)

Sol:

Electrodynamometer instruments are designed for accurate measurement of power and current in AC circuits.

To avoid core losses and frequency-dependent errors, air-core coils are used for both fixed and moving coils.

12. Ans: (a, b, d)

Sol:

(a) Small iron piece: Reduces the volume of material undergoing magnetization, thus lowering hysteresis effects.

(b) Low flux density: Keeps the iron in the linear region of its magnetization curve, avoiding saturation and reducing hysteresis.

(d) Narrow hysteresis loop alloy: Materials like Mu-metal or Permalloy have low coercivity and remanence, minimizing hysteresis loss.

(c) High flux density: This increases hysteresis error due to deeper magnetization cycles and possible saturation, so it's incorrect.

4. Measurement of Power

01. Ans: (c)

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

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

02. Ans: (d)

Sol: $V_L = 400$ V, $I_L = 10$ A and $\cos\phi = 0.866$ lag

$W_1 = V_L I_L \cos(30-\phi)$
$= 400 \times 10 \cos(30 - 30)$
$= 4000W$

$W_2 = V_L I_L \cos(30+\phi)$
$= 400 \times 10 \cos(30 + 30)$
$= 2000W$

03. Ans: (b)

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

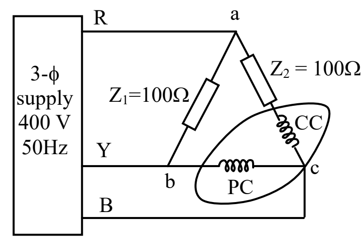
$$\phi = \tan^{-1}\left[\frac{\sqrt{3}\left(\frac{W_1}{W_2} - 1\right)}{\left(\frac{W_1}{W_2} + 1\right)}\right]$$

$$\phi = \tan^{-1}\left[\frac{\sqrt{3}\left(\frac{5}{3} - 1\right)}{\left(\frac{5}{3} + 1\right)}\right] = 23.41°$$

Power factor = $\cos\phi$
= 0.917 lag (since load is inductive)

04. Ans: (c)

Sol:



Based on R-Y-B

Assume abc phase sequence

$V_{ab} = 400\angle 0°$;

$V_{bc} = 400\angle -120°$

$V_{ca} = 400\angle -240°$ or $400\angle 120°$

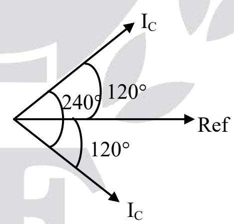
Current coil current $(I_c) = \frac{V_{ca}}{Z_2}$

$= \frac{400\angle 120°}{100\Omega}$

$= 4\angle 120°$

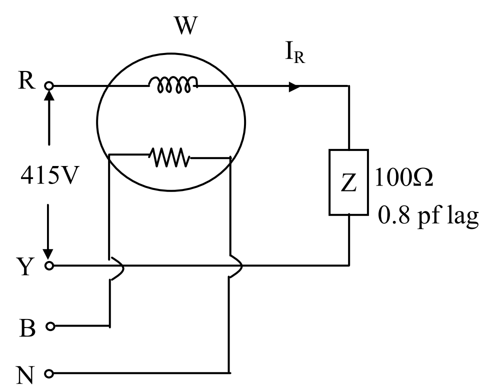
Potential coil voltage $(V_{bc}) = 400\angle -120°$

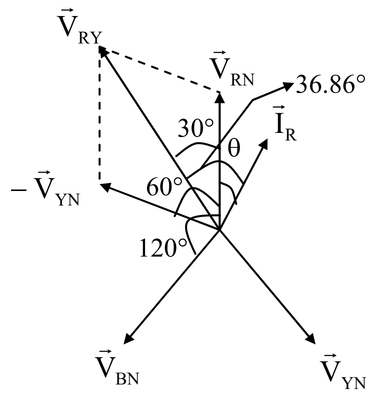
$W = 400 \times 4 \times \cos(240)$
$= -800$ W



05. 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

06. Ans: W = 519.61 VAR

Sol:

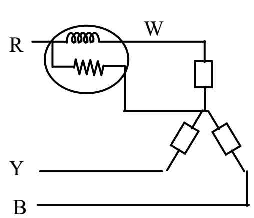


Fig. (a)

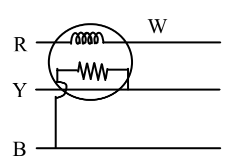


Fig. (b)

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

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

This type of connection gives reactive power

$$W = \sqrt{3} V_p I_p \sin\phi$$

$$= \sqrt{3} \times \frac{400}{0.8} \times 0.6$$

$= 519.6$VAR

07. Ans: (a, d)

Sol: Eddy currents in wattmeters introduce phase shifts that increase the deflecting torque, making the measured power appear higher than the true power.

This effect occurs for both lagging (inductive) and leading (capacitive) loads, hence both options are correct

08. Ans: (a, c)

Sol: Total Power in two wattmeter method is

$W = W_1 + W_2 = 1200 + 600 = 1800$ W

And we know that,

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

$$\phi = \tan^{-1}\left[\frac{\sqrt{3}(600)}{1800}\right] = 30°$$

Power factor = $\cos\phi = 0.866$

5. Measurement of Energy

01. 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)

02. 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)

03. Ans: (c)

Sol: V = 220 V, Δ = 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 W

≃ – 4.12 W

(2) cos ϕ = 0.5 lag, ϕ = 60°

Error = 220×5 [sin(85 – 60) – cos 60]

= – 85.12 W

04. Ans: (a, b)

Sol: The steady speed of the disc in an induction-type energy meter is achieved when the driving torque equals the braking torque. The steady speed is:

- Proportional to the resistance of the eddy current path
- Inversely proportional to the square of the flux of the permanent magnet.
- Inversely proportional to the effective radius of the disc from its axis.

Therefore, statements (a) and (b) are both correct

05. Ans: (a, d)

Sol: Recorded energy (meter reading)

$$E_{recorded} = \frac{\text{revolutions}}{K} = \frac{40}{0.4} = 100\text{ kWh}$$

Actual Energy, E_{actual} = VIcosϕ × t kWh

$$= \frac{20000\times400\times0.8\times0.6}{3600} = 106.67\text{ kWh}$$

$$\%\text{ error} = \frac{E_{recorder}-E_{actual(true)}}{E_{actual}}\times100$$

$$= \frac{100-106.67}{106.97}\times100$$

= – 6.27%

6. Bridge Measurement of R, L & C

01. Ans: (a, c)

Sol: Resistance of unknown resistor,

$$R = \frac{V_R}{V_s} \times S = \frac{0.525}{1.75} \times 0.2 = 0.06\ \Omega$$

Current through resistor $= \frac{V_s}{S} = \frac{1.75}{0.2}$

$= 8.75$ A

Power loss in the unknown resistor

$= (8.75)^2 \times 0.06$

$= 4.6$ W

02. 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

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

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

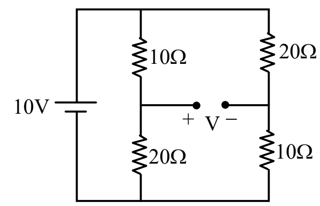
$$= (0.5 \times 10^6 + 10 \times 10^3)\left(\frac{41}{51}\right) - 10 \times 10^3$$

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

$= 0.4$ M Ω

03. Ans: (d)

Sol:



$V = V_+ - V_-$

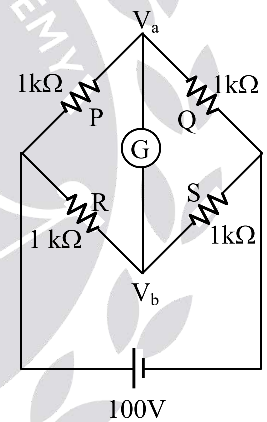
$$= 10 \times \frac{20}{30} - 10 \times \frac{10}{30}$$

$= 6.66 - 3.33$

$= 3.33$ V

04. Ans: (b)

Sol:



If bridge is balanced, the galvanometer reading is zero.

If S = 1010 Ω, then output voltage is $|V_a - V_b|$

$$V_a = 100 \times \frac{1000}{1000 + 1000} = 50\text{ V}$$

$$V_b = 100 \times \frac{1000}{1000 + 1010} = 50.248\text{ V}$$

Now output voltage of meter $= |V_a - V_b| = 0.2487$ V

For a change in resistance of $\Delta S = 10\ \Omega$

$$\text{Bridge sensitivity} = \frac{\Delta V_{out}}{\Delta S} = \frac{0.2487}{10}$$

$$= 0.0249\ V/\Omega$$

$$= 24.9\ mV/\Omega$$

05. Ans: (c)

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

$$= \frac{0.4343 \times 60}{600\times10^{-2}\times\log_{10}\left(\frac{250}{92}\right)}$$

$$= \frac{26.058}{260.49 \times 10^{-12}}$$

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

06. Ans: (a)

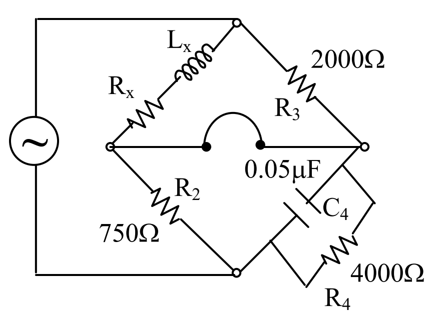
Sol: It is Maxwell Inductance Capacitance bridge

$$R_x R_4 = R_2 R_3$$

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

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

$$R_x = 375\ \Omega$$



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

$$L_x = C_4 R_2 R_3$$

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

$$L_x = 75\ mH$$

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

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

$$= \omega L_4 R_4$$

$$\Rightarrow r_1 = 16.67\ \Omega$$

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

$$R_4 = 4.26k\ \Omega$$

$$C_4 = 0.118\ \mu F$$

08. Ans: (a, d)

Sol: The given bridge is Wein's bridge.under balance,

$$R_4\left[R_1 + \frac{1}{j\omega C_1}\right] = R_2\left[\frac{R_3}{j\omega C_3 R_3 + 1}\right]$$

$$R_1R_4(j\omega C_3R_3 + 1) + \frac{R_4}{j\omega C_1}(j\omega C_3R_3 + 1)$$

$$= R_2R_3$$

Compare real and imaginary terms

$$\omega R_1 R_4 C_3 R_3 - \frac{R_4}{\omega C_1} = 0$$

$$\omega = \frac{1}{\sqrt{C_1 C_3 R_1 R_3}}$$

Frequency at which bridge is balanced is f =

$$\omega = \frac{1}{\sqrt{C_1 C_3 R_1 R_3}} \text{ rad/sec}$$

Compare real terms,

$$R_1 R_4 + + \frac{R_4 C_3 R_3}{C_1} = R_2 R_3$$

$$\frac{R_1}{R_3} + \frac{C_3}{C_1} = \frac{R_2}{R_4}$$

Therefore at balance, $\frac{R_1}{R_3} + \frac{C_3}{C_1} = \frac{R_2}{R_4}$

09. Ans: (a, c, d)

Sol: **(a)** Direct deflection method is commonly used for cable resistance measurement: This method is the standard for measuring high insulation resistance of cables.

(c) Kelvin double bridge eliminates error due to contact and lead wire resistance: This bridge is specifically designed for accurate measurement of very low resistances by using a four-terminal method.

(d) Earth electrode resistance must be of low value due to safety reasons: A low resistance path to the earth is crucial for electrical safety to ensure protective devices operate correctly during a fault.

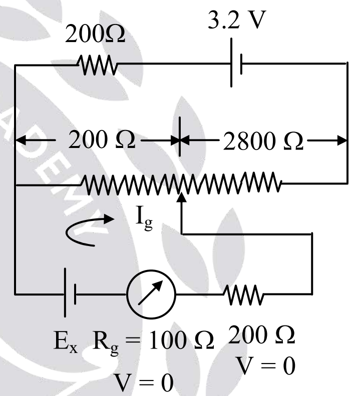
7. Potentiometers & Instrument Transformers

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: (a)

Sol:



Under balanced, $I_g = 0$

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

$$= 0.2 \text{ V}$$

$$E_x = 200 \text{ mV}$$

03. 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 $\rightarrow$ 0.1 Ω

50 cm $\rightarrow$?

Slide wire resistance with standard cell

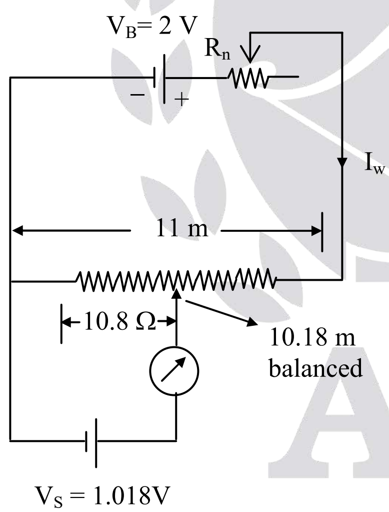
$$= \frac{50}{70} \times 0.1 = 0.067\ \Omega$$

Then $0.067 \times I_w = 1.45$ V

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

04. Ans: (a)

Sol:



Resistance 1 Ω/cm

For 11 m $\rightarrow$ 11 Ω

For 10m + 18cm $\rightarrow$ 10.8Ω

$I_w \times 10.8\Omega = 1.018$ V

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

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

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

05. Ans: (d)

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

06. Ans: (a, b, c)

Sol: True voltage across R_2 (without voltmeter)

$V_{true} = \frac{24}{2} = 12$ V (Since, $R_1 = R_2$)

Measured voltage for 90% accuracy,

$V_m = 0.9 \times 12 = 10.8$ V

Let R_S be the resistance added to the coil, now total meter resistance is R_m is parallel to the resistance 250 MΩ

$$\therefore\ R_P = \frac{R_m \times 250}{R_m + 250} \quad \text{........... (1)}$$

Now measured voltage,

$$10.8 = 24 \times \frac{R_P}{R_P + 250}$$

$\Rightarrow 0.45[R_P + 250] = R_P$

$\therefore\ R_P = 204.54$ MΩ

From (1),

$$204.54 = \frac{R_m \times 250}{R_m + 250}$$

$45.45R_m = 250 \times 204.54$

$R_m = 1125$ MΩ (Total meter resistance)

Now, additional resistance added to the meter

$R_s = R_m - 10M\Omega$

$= 1115\ M\Omega$

$\therefore$ Options (a), (b) & (c) are correct

07. Ans: (a, c, d)

Sol: CTs measure current, PTs measure voltage, both are essential in high-voltage systems for safe, scaled-down readings.

Circular (toroidal) cores avoid air gaps and joints, minimizing reluctance and improving accuracy.

Standard burden ratings for CTs are 2.5, 5, 7.5, 15 etc. These are standard burden values in VA (volt-ampere), defining the load CT can drive while maintaining accuracy.

08. Ans: (a,b,c,d)

Sol: (a)
- CTs are connected in series with the line so that the same current flows through the primary.
- They step down current for measurement and protection.

(b)
- PTs are connected in parallel across the line to measure voltage.
- They step down voltage to a safe measurable level.

(c)
- The ratio printed on CT/PT nameplate is the nominal ratio (ideal ratio).
- The actual ratio differs slightly due to errors.

(d)
- No-load (exciting) current causes ratio error and phase angle error in CTs and PTs.
- This is the primary source of inaccuracy in instrumentation transformers.

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

$= 454.5$ 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) = $\frac{1}{f}$

$$T = 1/10^3 = 1 \text{ msec}$$

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

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

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

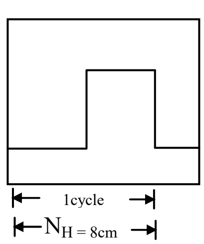
$$\Rightarrow N_v = \frac{2\sqrt{2} \times 300\text{mV}}{100\text{mv/cm}}$$

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

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.

$$\rightarrow V_{PP} = N_V \times \frac{\text{VOLT}}{\text{div}}$$

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

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

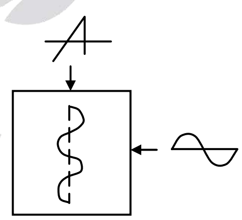
$$\Rightarrow \frac{\text{TIME}}{\text{div}} = \frac{T_{signal}}{N_H \text{per cycle}}$$

$$= \frac{1}{25\text{kHz} \times 8\text{cm}}$$

$$= 5\,\frac{\mu\text{s}}{\text{cm}}$$

05. Ans: (a)

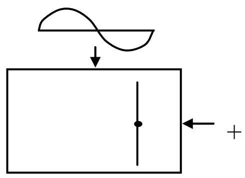
Sol: Frequency ratio is 2



∴ Two cycles of sine wave displayed on vertical time base

06. Ans: (a)

Sol:



Vertical straight line

07. Ans: (a)

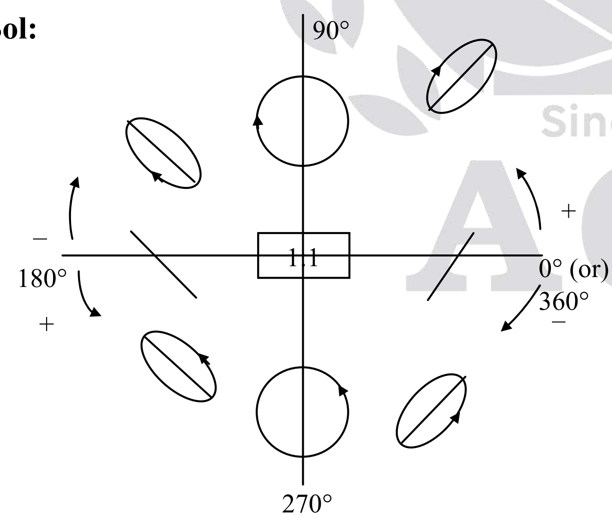
Sol: Since the coupling mode is set to DC the capacitance effect at the input side is zero. Therefore the waveform displayed on the screen is both DC and AC components.

08. Ans: (a)

Sol: In order to display correctly, a delay line of 150 ns has to be inserted in to the Y-channel between output of vertical amplifier and Y-input of CRT.

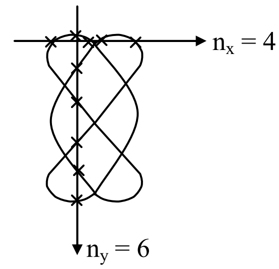
09. Ans: (d)

Sol:



10. Ans: (b)

Sol:



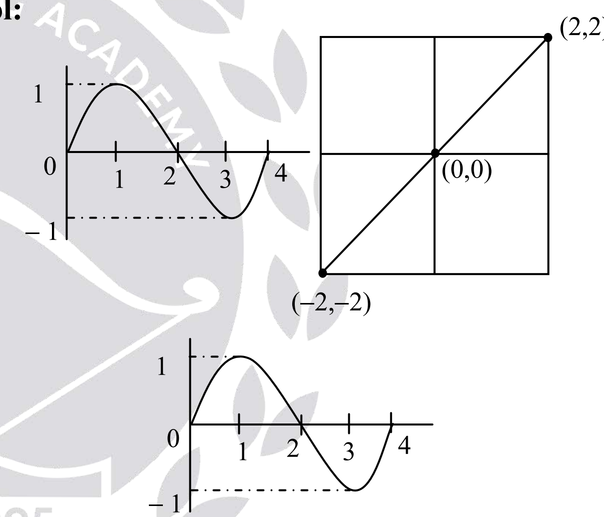
$$f_y = \frac{n_x}{n_y} f_y$$

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

$$= 400 \text{ Hz}$$

11. 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.

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 → (1)

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

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

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

$$\%\text{error} = \pm\frac{0.3}{100}\times100 = 0.3\%$$

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

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

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 & d)

Sol: 1. Digital voltmeters are generally more accurate due to better resolution, noise immunity, and calibration stability.

2. Electronic voltmeters often use operational amplifiers for buffering, amplification, and impedance matching.

3. R-2R DACs use only two resistor values (R and 2R), which simplifies design and improves precision.

4. Ramp-type digital voltmeters convert voltage into time duration, which is then measured digitally.

10. Q-Meter

01. Ans: (a)

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

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

$C_1 = C_2 + C_x$

$\therefore C_x = 100$ 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.

$\therefore$ 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, $L = \frac{1}{\omega^2[C + C_d]}$

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

$= 100\mu H$

The inductance of coil tested with a Q-meter is $100\mu H$.

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

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

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

= 5.33Pf

07. Ans: (c)

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

$= \dfrac{10}{500\times10^{-3}} = 20$

08. Ans: i → (c), ii → (a)

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

$= \dfrac{360-288}{3} = 24\text{ pF}$

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

$= \dfrac{1}{\left[2\pi\times500\times10^3\right]^2\left[24+360\right]\times10^{-6}} = 264\mu\text{H}$

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

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

$= 2.044\times10^{-3}$

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