1. Error Analysis

01. Ans: (a)
Sol: For 10V total input resistance
\[ R_v = \frac{V_{fsd}}{I_{mfsd}} = \frac{10}{100\mu A} = 10^5\Omega \]
Sensitivity = \( R_v/V_{fsd} = 10^5/10 \)
= 10kΩ/V
For 100V \( R_v = 100/100\mu A = 10^6\Omega \)
Sensitivity = \( R_v/V_{fsd} = 10^6/100 \)
= 100kΩ/V
(or)
Sensitivity = \( \frac{1}{I_{fsd}} = \frac{1}{100\times 10^{-6}} = 10kΩ/V \)

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 = 1000\times (\pm 1/100) = 1
Then % L.E in \( Y \) meter
\[ 20 \times \frac{x}{100} = \pm 1 \]
\( x = 5\% \)
Given \( w = xy/z \), Add all % L.E s
Therefore =\( + (0.5\% + 5\% + 1.5\%) \)
= \( \pm 7\% \)

03. Sol: Mean(\( \bar{X} \)) = \( \frac{\sum x}{n} \)
\[ = \frac{41.7 + 42 + 41.8 + 42 + 41.9 + 42.1 + 41.9 + 42.5 + 42 + 41.9 + 41.8}{10} \]
= 41.97
SD = \( \sqrt{\frac{\sum d^2}{n-1}} \) for \( n < 20 \)
\[ d_n = \bar{X} - X_n \]
= 0.224
Probable error = \( \pm 0.6745 \times SD \)
= \( \pm 0.1513 \)

04. Sol:
\[ V_1: V_2 \]
100V 100V
\[ V_1: V_2: \]
\[ S_{dc1} = 10kΩ/V \]
\[ S_{dc2} = 20kΩ/V \]
\[ I_{fsd} = \frac{1}{S_{dc1}} \]
\[ I_{fsd} = \frac{1}{S_{dc2}} \]
= 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
\[ = 0.05\text{ mA} (10kΩ/V \times 100 + 20kΩ/V \times 100) \]
= 3000 \times 0.05 = 150 V
05. Sol: Internal impedance of 1st voltmeter
\[ I = \frac{100V}{5mA} = 20 \text{ k}\Omega \]
Internal impedance of 2nd voltmeter
\[ = 100 \times 250 \Omega/V = 25 \text{ k}\Omega \]
Internal impedance of 3rd voltmeter,
\[ = 5 \text{ k}\Omega \]
Total impedance across 120 V
\[ = 20 + 25 + 5 = 50 \text{ k}\Omega \]
Sensitivity
\[ = \frac{50 \text{ k}\Omega}{120V} = 416.67 \text{ V/k}\Omega \]
\[ \Rightarrow \text{Reading of 1st voltmeter} \]
\[ = \frac{20 \text{ k}\Omega}{416.67 \text{ V/k}\Omega} = 48 \text{ V} \]
Reading of 2nd voltmeter
\[ = \frac{25 \text{ k}\Omega}{416.67 \text{ V/k}\Omega} = 60 \text{ V} \]
Reading of 3rd voltmeter
\[ = \frac{5 \text{ k}\Omega}{416.67 \text{ V/k}\Omega} = 12 \text{ V} \]

06. Ans: (b) Sol: Bridge sensitivity
\[ = \frac{\text{Change in output}}{\text{Change in input}} \]
\[ = \frac{V_{th}}{10\Omega} \]
\[ V_{th} = \frac{1010 \times 100}{2000} - \frac{1000 \times 100}{2000} = 0.25 \text{ V} \]
\[ S_B = \frac{0.25 \text{ V}}{10\Omega} = 25 \text{ mV/}\Omega \]

07. Ans: (d) Sol: \( W_T = W_1 + W_2 = 100 - 50 = 50 \text{ W} \)
\[ \frac{\partial W_T}{\partial W_1} = \frac{\partial W_T}{\partial W_2} = 1 \]
Error in meter 1
\[ \pm \frac{1}{100} \times 100 = \pm 1 \text{ W} \]
Error in meter 2
\[ \pm \frac{0.5}{100} \times 100 = \pm 0.5 \text{ W} \]
\[ W_T = 50 \pm 1.5 \text{ W} \]
\[ W_T = 50 \pm 3\% \]

08. Ans: (b) Sol: Resolution
\[ = \frac{200}{10} \times 1 = 0.2 \text{ V} \]

09. Ans: (b) Sol: \% LE
\[ = \frac{\text{FSV}}{\text{true value}} \times \% \text{GAE} \]
\[ = \frac{200 \text{ V}}{100 \text{ V}} \times \pm 2\% = \pm 4\% \]

3. Electromechanical Indicating Instruments

01. Ans: (d) Sol: The pointer swings to 1 mA and returns, settles at 0.9 mA i.e, pointer has oscillations. Hence, the meter is under-damped. Now the current in the meter is 0.9 mA.
Applying KVL to circuit,
1.8 V – 0.9 mA × R_m – 0.9 mA × 1.8 kΩ = 0
1.8 V – 0.9 × 10⁻³ R_m – 1.62 = 0
\( R_m = \frac{0.18}{0.9 \times 10^{-3}} = 200 \Omega \)

02. Ans: (c)
Sol: \( S = \frac{1}{1000} \) Ω/volt \( S = \frac{1}{I_{fsd}} \) Ω/V
\( I_{fsd} = \frac{1}{S} = \frac{1}{1000} = 1 \) mA

100 V → 1 mA
50 V → ?
= 0.5 mA

03. Ans: (b)
Sol: \( T_d = \frac{1}{2} I_{fsd}^2 \frac{dL}{d\theta} \)
\( K_c = \frac{I_{fsd}^2}{2} \frac{dL}{d\theta} \)
\( 25 \times 10^{-6} \times \theta = \frac{25}{2} \times \left(3 - \frac{\theta}{2}\right) \times 10^{-6} \)

04. Ans: (a)
Sol:
\[ V_{avg} = \frac{\left(\frac{1}{2} \times 10 \times 10 \text{ms}\right) + (-5 \times 2 \text{ms}) + (5 \times 8 \text{ms})}{20 \text{ms}} \]
\[ = \frac{50 - 10 + 40}{20} = 4 \text{ V} \]
(or)
\[ \text{Avg. value} = \frac{1}{20} \left[ \int_0^{10} (l) t \, dt - \int_{10}^{12} 5 \, dt + \int_{12}^{20} 5 \, dt \right] \]
\[ = \frac{1}{20} \left[ \frac{t^2}{2} \right]_0^{10} - 5[t]_{10}^{12} + 5[t]_{12}^{20} \]
\[ = 4 \text{ V} \]

05. Ans: (a)
Sol:
<table>
<thead>
<tr>
<th>1°C↑</th>
<th>10°C</th>
<th>( T_c )</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring stiffness( (K_c) )</td>
<td>0.04%↓</td>
<td>0.4%↓</td>
<td>0.4%↓</td>
</tr>
<tr>
<td>Strength of magnet ( (B) )</td>
<td>0.02%↓</td>
<td>0.2%↓</td>
<td>0.2%↓</td>
</tr>
</tbody>
</table>

\[ 2\theta = 3 - \frac{\theta}{2} \]
\[ \frac{5}{2} \theta = 3 \]
\[ \theta = 1.2 \text{ rad} \]
Net deflection (θ_{net}) = 0.4\% \uparrow - 0.2\% \downarrow 
= 0.2\% \uparrow 

Increases by 0.2% 

06. Ans: 32.4° and 21.1° 
Sol: \( I_1 = 5 \) A, \( \theta_1 = 90° \); \( I_2 = 3 \) A, \( \theta_2 = ? \)  
\( \theta \propto I^2 \) (as given in Question)  
(i) Spring controlled 
\( \theta \propto I^2 \) 
\[ \frac{\theta_2}{\theta_1} = \left( \frac{I_2}{I_1} \right)^2 \]  
\[ \Rightarrow \frac{\theta_2}{90} = \left( \frac{3}{5} \right)^2 \]  
\( \theta_2 = 32.4° \)  
(ii) Gravity controlled 
\( \sin \theta \propto I^2 \) 
\[ \sin \frac{\theta_2}{\sin 90} = \left( \frac{I_2}{I_1} \right)^2 \]  
\[ \Rightarrow \frac{\sin \theta_2}{1} = 0.36 \]  
\( \theta_2 = \sin^{-1} (0.36) = 21.1° \) 

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 \times 200 V = 400000 Ω  
\( R_{sc} = R_m \left( \frac{V}{V_m} - 1 \right) \)  
= 400000 \left( \frac{2000}{200} - 1 \right) = 3.6 \) MΩ 

08. Ans: 2511.5 Ω 
Sol: 
\[ \frac{V_m}{R_m} = 500 \] V 
\( R_m = 2500 \) Ω  
\( \omega = 2\pi \times 50 \times 0.6 \)  
\( \sqrt{(2500 + R_{sc})^2 + (\omega L_m)^2} \) 
\( R_{sc} = ? \)  
\( I_m = \frac{250 V}{\sqrt{R_m^2 + (\omega L_m)^2}} \) 
\( = \frac{250 V}{\sqrt{(2500 + R_{sc})^2 + (2\pi \times 50 \times 0.6)^2}} \) 
\( = 0.0997 \) A  
In case (ii), 
\( I_m = \frac{250 V}{\sqrt{(R_m + R_{sc})^2 + (\omega L_m)^2}} \) 
\( 0.0997 \) A 
\( \sqrt{(2500 + R_{sc})^2 + 35.53 \times 10^3} = \frac{500}{0.0997} \) 
\( \sqrt{(2500 + R_{sc})^2 + 35.53 \times 10^3} = 5.015 \times 10^3 \)  
\( R_{sc} = 2511.5 \) Ω
09. Ans: 0.1025 µF
Sol: 
\[ C = \frac{0.41 \times L_m}{R_{se}} \]
\[ = \frac{0.41 \times 1}{(2k\Omega)^2} \]
\[ = 0.1025 \text{µF} \]

10. Ans: (c)
Sol: MC – connection

[Diagram of MC connection]

Error due to current coil
\[ = \frac{20^2 \times 0.01}{(30 \times 20)} \times 100 = 0.667\% \]

LC – connection

[Diagram of 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 \phi
\[ = 0.917 \text{ lag (since load is inductive)} \]

12. Ans: (c)
Sol: 
\[ R_{load} = \frac{V}{I} = \frac{200}{20} = 10 \Omega \]

For same error \[ R_L = \sqrt{R_C \times R_V} \]
\[ : 100 = 10 \times 10^3 \times R_C \]
\[ \Rightarrow R_C = 0.01 \Omega \]
I_s = \frac{5}{50} \times 40 = 4 \text{ A}

C.T secondary (I_s) = 4 \angle -36.86^\circ

Wattmeter current coil = I_c = 4 \angle -36.86^\circ

Wattmeter reading
= 200 \text{ V} \times 4 \times \cos (36.86)
= 640.08 \text{ W}

02. Ans: (a)
Sol: Energy consumed in 1 minute
\[\frac{240 \times 10 \times 0.8}{1000} \times \frac{1}{60} = 0.032 \text{ kWh}\]

Speed of meter disc
= Meter constant in rev/kWhr \times Energy consumed in kWh/minute
= 400 \times 0.032
= 12.8 \text{ rpm} (revolutions per minute)

03. Ans: (a)
Sol: Energy consumed (True value)
\[\frac{230 \times 5 \times 1}{1000} \times \frac{3}{60} = 0.0575 \text{ kWh}\]

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{ kWh}

%Error = \frac{0.05 - 0.0575}{0.0575} \times 100
= -13.04\% = 13.04\% (slow)

04. Ans: (c)
Sol: \[W = \frac{1}{2} \left( E_1 I_1 \cos \phi_1 + E_3 I_3 \cos \phi_3 \right)\]

05. Ans: (c)
Sol: \[V = 220 \text{ V}, \Delta = 85^\circ, I = 5 \text{ A}\]

Error = VI \left[ \sin(\Delta - \phi) - \cos \phi \right]
(1) \cos \phi = \text{UPF}, \phi = 0^\circ
Error = 220 \times 5 \left[ \sin(85 - 0) - \cos 0 \right]
= -4.185 \text{ W} \approx -4.12 \text{ W}

(2) \cos \phi = 0.5 \text{ lag}, \phi = 60^\circ
Error = 220 \times 5 \left[ \sin(85 - 60) - \cos 60 \right]
= -85.12 \text{ W}

06. Ans: (c)
Sol:
Based on R-Y-B
Assume abc phase sequence
\[V_{ab} = 400 \angle 0^\circ, \ V_{bc} = 400 \angle -120^\circ\]
\[V_{ca} = 400 \angle -240^\circ \text{ or } 400 \angle 120^\circ\]

Current coil current (I_c) = \frac{V_{ca}}{Z_2}
= \frac{400 \angle 120^\circ}{100 \Omega} = 4 \angle 120^\circ

Potential coil voltage (V_{bc}) = 400 \angle -120^\circ
W = 400 \times 4 \times \cos (240) = -800 \text{ W}
07. Ans: (d)
Sol: \( V_L = 400 \text{ V}, I_L = 10 \text{ A} \)
\[ \cos \phi = 0.866 \text{ lag, } \phi = 30^\circ \]
\[ W_1 = V_L I_L \cos (30 - \phi) \]
\[ W_2 = V_L I_L \cos (30 + \phi) \]
\[ W_1 = 400 \times 10 \times \cos(30 - 30) = 4000 \text{ W} \]
\[ W_2 = 400 \times 10 \times \cos(30 + 30) = 2000 \text{ W} \]

08. Ans: \( W = 519.61 \text{ VAR} \)
Sol:
\[ W = 400 \text{ watt} ; \quad W = V_{ph} I_{ph} \cos \phi \]
\[ V_{ph} I_{ph} = 400/0.8 \]
This type of connection gives reactive power
\[ W=\sqrt{3}V_{I_p} \sin \phi = \sqrt{3} \times 400/0.8 \times 0.6 = 519.66 \text{ VAR} \]

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
\[ I_L = I_{ph} ; \quad V_{ph} = \frac{V_L}{\sqrt{3}} \]
\[ I_L = I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{V_L / \sqrt{3}}{Z_{ph}} \]
\[ I_L = I_{ph} = \frac{(100/\sqrt{3})}{5} = \frac{20}{\sqrt{3}} = 11.54 \text{A} \]
\[ V_L = 100 \text{ V}, I_L = 11.54 \text{ A}, \phi = 60^\circ \]
\[ W_1 = 100 \times 11.54 \times \cos(30 + 60) = 0 \text{ W} \]
\[ W_2 = 100 \times 11.54 \times \cos (30 - 60) \]
\[ = 999.393 \text{ W} \approx 1000 \text{ W} \]
\[ W_1 = 0 \text{ W}, W_2 = 1000 \text{ W} \]

10. Ans: –596.46 W
Sol:
Current coil is connected in ‘R_phase’, it reads ‘\( \bar{I}_R \)’ current.
Potential coil reads phase voltage i.e., \( \bar{V}_{BN} \)
\[ W = \bar{V}_{BN} \times \bar{I}_R \times \cos(\bar{V}_{BN}, \bar{I}_R) \]
\[ V_L = 415 \, \text{V}, \quad V_{BN} = \frac{415}{\sqrt{3}} \, \text{V} \]

\[ I_R = \frac{V_{RY}}{Z} = \frac{415}{100} = 4.15 \, \text{A} \]

\[ \cos \phi = 0.8 \]

\[ \Rightarrow \phi = 36.86^\circ \text{ between } \tilde{V}_{RY} \text{ & } \tilde{I}_R \]

\[ \theta = 36.86^\circ - 30^\circ = 6.86^\circ \]

Now angle between \( \tilde{V}_{BN} \) and \( \tilde{I}_R \)

\[ = 120 + 6.86 = 126.86^\circ \]

\[ W = \frac{415}{\sqrt{3}} \times 4.15 \times \cos(126.86^\circ) \]

\[ = -596.467 \, \text{W} \]

11. Ans: (c)

Sol: Meter constant = \( 14.4 \) A-sec/rev

\[ = 14.4 \times 250 \, \text{W}-\text{sec/rev} \]

\[ = \frac{14.4 \times 250}{1000} \, \text{kW-sec/rev} \]

\[ = \frac{14.4 \times 250}{1000 	imes 3600} \, \text{kWhr/rev} \]

Meter constant = \( \frac{1}{1000} \, \text{kWhr/rev} \)

Meter constant in terms of rev/kWhr = 1000

12. Ans: (d)

Sol: \( R_p = 1000 \, \Omega, \quad L_p = 0.5 \, \text{H}, \quad f = 50 \, \text{Hz}, \quad \cos\phi = 0.7, \)

\[ X_{Lp} = 2 \times \pi \times f \times L, \quad \tan\phi = 1 \]

\[ = 2 \times \pi \times 50 \times 0.5 \]

\[ = 157 \, \Omega \]

\[ \% \text{ Error} = \pm \left( \frac{\tan\phi \tan\beta}{1} \right) \times 100 \]

\[ = \pm \left( \frac{1 \times 157}{1000} \right) \times 100 = 15.7\% \]

\[ \approx 16\% \]

\[ P = W_1 + W_2 + W_3 = 1732.05 \]

Power factor, \( \cos \phi = \frac{1732.05}{3464} = 0.5 \, \text{lag} \)

\[ \sqrt{3} \times 400 \times I_L \times 0.5 = 1732.05 \]

\[ I_L = \frac{1732.05}{\sqrt{3} \times 400 \times 0.5} = 5 \, \text{A} \]

When switch is in position N

\[ W_1 = W_2 = W_3 = 577.35 \, \text{W} \Rightarrow \text{balanced load} \]

\[ \therefore \text{total power consumed by load is} \]

\[ W = W_1 + W_2 + W_3 \]

\[ W = 1732.05 \, \text{W} \]

Given load is inductive

And VA draw from source = 3464 VA

\[ \therefore \text{power factor} = \frac{W}{VA} \]

\[ = \frac{1732.05}{3464} \]

\[ = 0.5 \, \text{lag} \]

\[ \Rightarrow \text{Power factor angle} = -60^\circ \, (\because \text{lag}) \]

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
10. \[ W_1 = V_{RY} I_R \cos(\text{angle between } \vec{V}_{RY} \text{ and } \vec{I}_R) \]
\[ = 400 \times 5 \times \cos(90^\circ) = 0 \text{ W} \]
\[ W_3 = V_{BY} I_B \cos(\text{angle between } \vec{V}_{BY} \text{ and } \vec{I}_B) \]
\[ = 400 \times 5 \times \cos(30^\circ) \]
\[ = 400 \times 5 \times \frac{\sqrt{3}}{2} = 1732 \text{ W} \]
W_1 = 0, W_2 = 0, W_3 = 1732 W

14. Ans: (c)
Sol: Meter constant = 14.4 A-sec/rev

\[ = 14.4 \times 250 \text{W-sec/rev} \]
\[ = \frac{14.4 \times 250}{1000} \text{ kw-sec/rev} \]
\[ = \frac{14.4 \times 250}{1000 \times 3600} \text{ kwhr/rev} \]

Meter constant = \frac{1}{1000} \text{ kwhr/rev}

Meter constant in terms of rev/kwhr = 1000

5. Bridge Measurement of R, L & C

01. Ans: (a)
Sol: It is Maxwell Inductance Capacitance bridge

\[ R_x = \frac{R_2 R_3}{R_4} \]
\[ R_x = \frac{750 \times 2000}{4000} \]
\[ R_x = 375 \Omega \]

02. Ans: (d)
Sol: \[ V = V_+ - V_- \]
\[ = 10 \times \frac{20}{30} - 10 \times \frac{10}{30} = 6.66 - 3.33 = 3.33 \text{ V} \]

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, \[ \frac{E}{2} = I R_3 + V \]
\[ I = \frac{E - 2V}{2R_3} \Rightarrow I = \frac{E - 2V}{2R} \]
and \[ \frac{E}{2} = I R_4 \]
\[
\frac{E}{2} = \left(\frac{E-2V}{2R}\right)(R+\Delta R)
\]
\[
ER = (E-2V)(R+\Delta R)
\]
\[
R + \Delta R = \frac{ER}{E-2V}
\]
\[
\Delta R = \frac{ER}{E-2V} - R
\]
\[
= \frac{ER-ER+2VR}{E-2V}
\]
\[
\Delta R = \frac{2VR}{E-2V}
\]

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
\(\theta_1 = \) Deflection with \(S\)
\(\theta_2 = \) Deflection with \(R\)
\[
\therefore \frac{\theta_1}{\theta_2} = \frac{R+G}{S+G}
\]
\[
\Rightarrow R = (S+G)\frac{\theta_1}{\theta_2} - G
\]
\[
= \left(0.5 \times 10^6 + 10 \times 10^3\right)\left(\frac{41}{51}\right) - 10 \times 10^3
\]
\[
= 0.4 \times 10^6 \ \Omega
\]
\[
= 0.4 \ \text{M} \ \Omega
\]

05. Ans: (a)
Sol: Thevenin’s equivalent of circuit is
\[
R_0 = \text{Resistance of circuit looking into terminals b & d with a & c short circuited.}
\]
\[
= \frac{RS}{R+S} + \frac{PQ}{P+Q} = \frac{1 \times 5}{1+5} + \frac{1 \times Q}{1+Q}
\]
\[
= 0.833 + \frac{Q}{1+Q} \ \text{K} \ \Omega
\]
Now, \(R_0 + G = \frac{24 \times 10^{-3}}{13.6 \times 10^{-6}} = 1.765 \ \text{k} \ \Omega
\]
(or) \(R_0 = 1765 - 100 = 1665 \ \Omega
\]
\[
0.833 + \frac{Q}{1+Q} = 1.665
\]
\[
\Rightarrow Q = 4.95 \ \text{k} \ \Omega
\]

06. Ans: (c)
Sol: \(R = \frac{0.4343 \times T}{C \log_{10}\left(\frac{E}{V}\right)} = \frac{0.4343 \times 60}{600 \times 10^{-2} \times \log_{10}\left(\frac{250}{92}\right)}
\]
\[
= \frac{26.058}{260.49 \times 10^{-12}} = 100.03 \times 10^9 \ \Omega
\]

07. Ans: 0.118 \(\mu\)F, 4.26k\(\Omega\)
Sol: Given: \(R_3 = 1000 \ \Omega\)
\[ C_1 = \frac{\varepsilon_0 \varepsilon A}{d} = \frac{2.3 \times 4\pi \times 10^{-7} \times 314 \times 10^{-4}}{0.3 \times 10^{-2}} \]

\[ C_1 = 30.25 \, \mu F \]

\[ \delta = 9^\circ \text{ for } 50 \text{ Hz} \]

\[ \tan \delta = \omega C_1 r_1 = \omega L_4 R_4 \]

\[ \Rightarrow r_1 = 16.67 \, \Omega \]

Variable resistor \((R_4) = R_1 \left( \frac{C_1}{C_2} \right)\)

\[ R_4 = 4.26k \, \Omega \]

\[ C_4 = 0.118 \, \mu F \]

08.

**Sol:** Resistance of unknown resistor required for balance

\[ R = \frac{P}{Q} S = \frac{1000}{100} \times 200 = 2000 \, \Omega \]

In the actual bridge the unknown resistor has a value of 2005 \, \Omega or the deviation from the balance conditions is \(\Delta R = 2005 - 2000 = 5 \, \Omega\).

Thevenin source generator emf

\[ E_0 = E \left[ \frac{R}{R+Q} \right] \]

\[ = 0.5 \left[ \frac{2005}{2005 + 200} - \frac{1000}{1000 + 100} \right] \]

\[ = 1.0307 \times 10^{-3} \, V . \]

Internal resistance of bridge looking into terminals b and d.

\[ R_o = \frac{RS}{R+S} + \frac{PQ}{P+Q} \]

\[ = \frac{2005 \times 200 + 1000 \times 100}{2005 + 200 + 1000 + 100} \]

\[ = 272.8 \, \Omega \]

Hence the current through the galvanometer

\[ I_g = \frac{E_0}{R_o + G} \]

\[ = \frac{1.0307 \times 10^{-3}}{272.8 + 100} \]

Deflection of the galvanometer

\[ \theta = S I_g = 10 \times 2.77 \]

\[ = 27.7 \, \text{mm/} \, \Omega \]

Sensitivity of bridge

\[ S_B = \frac{\theta}{\Delta R} \]

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

09. **Ans:** (a)

**Sol:**

\[ V_1 = \sqrt{2} \cos(1000t) \, V \]

\[ V_2 = 2 \cos(1000(t+45^\circ)) \, V \]

Under balanced condition,

\[ V_1 = I_2 R \]

\[ I_2 = \frac{V_1}{R} = \frac{\sqrt{2} \cos 1000t}{100} \]

\[ I_2 = 10^{-2} \times \sqrt{2} \cos (1000t) \]

At \(Z_x\)

\[ V_2 = 2 \cos (1000(t+45^\circ)) \]

\[ 'I_2' \text{ lags 'V_2' by } 45^\circ \text{. So, } Z_x \text{ has 'R' and 'L' in series.} \]

\[ R = Z \cos \theta \]

\[ = \frac{2}{10^{-2} \times \sqrt{2}} \cos 45^\circ = 100 \, \Omega \]

\[ X_L = Z \sin \theta \]
13. Postal Coaching Solutions

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
\[ R = (101.8/200) \times 400 = 203.6 \, \Omega \]

\[ I_m = 1.018/203.6 = 0.005 \, A = 5 \, mA \]
Total resistance of the battery circuit
= resistance of rheostat + resistance of slide wire
\[ R_h = \frac{3}{5 \times 10^{-3}} - 400 = 600 - 400 = 200\Omega \]

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)
\[ = \frac{2.175 \, V}{0.1 \, \Omega} = 21.75 \, A \] (or)
75 cm → 0.1 Ω

---

6. Potentiometers & Instrument Transformers

01. Ans: (d)
Sol: Under null balanced condition the current flow in through unknown source is zero.
Measurements

50 cm → ?

Slide wire resistance with standard cell

\[ \text{Resistance} = \frac{50}{70} \times 0.1 = 0.067 \, \Omega \]

Then \[ 0.067 \times I_w = 1.45 \, V \]

\[ I_w = \frac{1.45}{0.067} = 21.75 \, A \]

05. Ans: (a)
Sol:

\[ \begin{array}{c}
\text{Dial resistor has 15 steps and each step is } 10 \, \Omega = 15 \times 10 \, \Omega = 150 \, \Omega \\
\text{Slide wire resistance} = 10 \, \Omega \\
\text{Total resistance} = 150 + 10 = 160 \, \Omega \\
\text{Working current} (I_w) = 10 \, mA \\
\text{Range of potentiometer} \\
= 10mA \times 160 \, \Omega = 1.6 \, V \\
\text{Resolution of potentiometer} \\
= \frac{\text{working current} \times \text{slide wire resistance}}{\text{slide wire length}} \\
\end{array} \]
\[
\frac{10 \text{ mA} \times 10 \Omega}{100 \text{ cm}} = 0.001 \text{ V/cm}
\]

(1 div = 1 cm)

One fifth of a division can be read certainly.

Resolution = \[\frac{1}{5} \times 0.001 = 0.2 \text{ mV/cm}\]

09. Ans: (a)
Sol:
Bar primary (\(N_p\)) = 1 turn
\(N_s = 500\) turns
\(I_s = 5 \text{ A}\)
\(Z_s = 1 \Omega\)
\(N_p I_m = 200\)
\(I_m = 200 \text{ A, } n = \frac{N_s}{N_p} = \frac{500}{1} = 500\)

Phase angle error (\(\theta\))
\[\frac{I_m}{n I_s} \times \frac{180}{\pi} \text{ degrees}\]
\[= \frac{200}{500 \times 5} \times \frac{180}{\pi} = 4.58^\circ\]
7. Cathode Ray Oscilloscope

01. Ans: (b)

Sol: Time period of one cycle = \( \frac{8.8}{2} \times 0.5 \)
\[ = 2.2 \text{ msec} \]
Therefore frequency = \( \frac{1}{T} \) = \( \frac{1}{2.2 \times 10^{-3}} \)
\[ = 454.5 \text{ Hz} \]
The peak to peak Voltage = 4.6 × 100
\[ = 460 \text{ mV} \]
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
\[ \therefore \text{ voltage} = 2.5 \times 3 = 7.5 \text{ V} \]
Similarly frequency of upper trace is 1kHz
So the time period \( T \)
\[ \text{(for four divisions)} = \frac{1}{f} \]
\[ T = \frac{1}{10^3} \Rightarrow 1 \text{ msec} \]
i.e for four divisions time period = 1m sec

03. Ans: (c)

Sol: No. of cycles of signal displayed
\[ = f_{\text{signal}} \times T_{\text{sweep}} \]
\[ = 200 \text{Hz} \times \left( 10 \text{cm} \times \frac{0.5 \text{ms}}{\text{cm}} \right) = 1 \]
i.e, one cycle of sine wave will be displayed.
We know \( V_{\text{rms}} = \frac{V_{p-p}}{2\sqrt{2}} \)
\[ V_{\text{rms}} = \frac{N_v \times \text{Volt/div}}{2\sqrt{2}} \]
\[ \Rightarrow N_v = \frac{2\sqrt{2} \times V_{\text{rms}}}{\text{Volt/div}} \]
\[ \Rightarrow N_v = \frac{2\sqrt{2} \times 300 \text{mV}}{100 \text{mv/cm}} \]
\[ \Rightarrow N_v = 8.485 \text{cm} \]
i.e 8.485 cm required to display peak to peak of signal. But screen has only 8 cm (vertical)
As such, peak points will be clipped.

04. Ans: (b)

Sol:
\[ \text{\rightarrow Given data: Y input signal is a symmetrical square wave} \]
\[ f_{\text{signal}} = 25 \text{KHz}, \quad V_{pp} = 10 \text{V} \]
→ Screen has 10 Horizontal divisions & 8 vertical divisions which displays 1.25 cycles of Y-input signal.

\[ V_{pp} = N_v \times \frac{VOLT}{\text{div}} \]

\[ \Rightarrow \frac{VOLT}{\text{div}} = \frac{V_{pp}}{N_v} = \frac{10V}{5cm} = 2 \text{ Volt/ c.m} \]

\[ \Rightarrow T_{\text{signal}} = N_n \text{per cycle} \times \frac{\text{TIME}}{\text{div}} \]

\[ \Rightarrow \frac{\text{TIME}}{\text{div}} = \frac{T_{\text{signal}}}{N_n \text{per cycle}} \]

\[ = \frac{1}{25kHz \times 8cm} \]

\[ = 5 \ \mu s \text{ cm}^{-1} \]

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:  

\[ f_y = \frac{n_x}{n_y} f_x \]

\[ = \frac{4}{6} \times 600Hz \]

\[ = 400 \text{ Hz} \]

10. Ans: (d)  
Sol:  

\[ +1Vdc \]

Vertical straight line

\[ n_x = 4 \]

\[ n_y = 6 \]
Measurements

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

<table>
<thead>
<tr>
<th>t</th>
<th>( V_y )</th>
<th>( V_x )</th>
<th>( d_y = k_y V_y )</th>
<th>( d_x = k_x V_x )</th>
<th>points</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(0,0)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>(2,2)</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(0,0)</td>
</tr>
<tr>
<td>3</td>
<td>-1</td>
<td>-1</td>
<td>-2</td>
<td>-2</td>
<td>(-2,-2)</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(0,0)</td>
</tr>
</tbody>
</table>

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

11. Ans: (a)
Sol: \( t_r = \frac{0.35}{10 \text{MHz}} \Rightarrow t_r = 35 \text{ nsec} \)

12. Ans: (a)
Sol: Given data: \( R_i = 1 \text{ M\Omega}, C_i = 45 \text{ pF} \)
Probe used is 10 : 1 attenuation probe
The probe offers 10 times attenuation i.e., \( V_i = \frac{1}{10} \times V_s \)
The input resistance increases by 10 times and the input capacitance decreases by 10 times
\( C_{eff} = \frac{C_i}{10} = \frac{45 \text{ pF}}{10} = 4.5 \text{ pF} \)

13. Ans: (d)
Sol: Given data
\( V_y(t) = 6 \cos (100\pi t) \text{V} \)

Means \( V_p = 6 \text{V}, V_{P-P} = 12 \text{V} \)
\( f = 50 \text{Hz} \Rightarrow T = \frac{1}{50 \text{Hz}} = 20 \text{ms} \)

We know:
\( V_{P-P} \) = Vertical division between 2 peaks \( \times \frac{\text{VOLT}}{\text{DIV}} \)
\( = 12 \text{V} = 6 \text{div} \times \frac{\text{VOLT}}{\text{DIV}} \)
\( \Rightarrow \frac{\text{VOLT}}{\text{DIV}} = \frac{12 \text{Volt}}{6 \text{div}} = 2 \text{ volt/div} \)
\( T = \) horizontal division with in 1 cycle \( \times \frac{\text{TIME}}{\text{DIV}} \)
\( 20 \text{msec} = 10 \text{division} \times \frac{\text{TIME}}{\text{DIV}} \)
\( \Rightarrow \frac{\text{TIME}}{\text{DIV}} = \frac{2 \text{ms}}{\text{div}} \)

14. Ans: (a)
Sol: Given data:
\( V_y(t) = 2\cos(100\pi t + 30^\circ) \text{V} \)
\( \frac{\text{Volt}}{\text{div}} \) is set as \( \frac{1 \text{V}}{\text{cm}} \) & \( \frac{\text{TIME}}{\text{div}} \) is set as \( \frac{2 \text{ms}}{\text{cm}} \)
Trigger voltage level is 0V & slope is negative. Screen dimensions are 10cm × 8cm
Number of cycles of signal displayed:
\( N = f_{signal} \times T_{sweep} \)
\( = 50 \text{Hz} \times 10 \text{cm} \times 2 \frac{\text{ms}}{\text{cm}} = 1 \text{cycle} \)
As trigger voltage level is set as 0V, the signal will be displayed from 0V onward and from falling side since slope is negative. Therefore option is (a)

15. Ans: (a)
Sol: Given data:
\[ V_y(t) = 4\cos(200\pi t - 45^\circ)V \]
Volt is set as \( \frac{1V}{div} \) & TIME is set as \( \frac{1ms}{div} \)

Internal triggering is chosen trigger voltage level is 0V & Slope is positive screen dimensions are 10div \( \times \) 8div

Number of cycles of signal displayed
\[ N = f_{signal} \times T_{sweep} = 100Hz \times 10div \times 1ms/div = 1 \text{ cycle} \]
The test signal is used as triggering signal since internal triggering is chosen. As the trigger voltage level is 0V the signal will be displayed from 0V onwards and from rising side since trigger slope, is positive. Therefore option is ‘a’

8. Digital Voltmeters

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

02. Ans: (d)
Sol: DVM measures the average value of the input signal which is 1 V. 
\[ \therefore \text{DVM indicates as 1.000 V} \]

03. Ans: (c)
Sol: 0.2% of reading +10 counts → (1)
\[ = 0.2 \times \frac{100}{100} + 10(\text{sensitivity} \times \text{range}) \]
\[ = 0.2 \times \frac{100}{100} + 10\left(\frac{1}{2 \times 10^4} \times 200\right) \]
\[ = 0.2 + 0.1 = \pm 0.3 \text{ V} \]
\[ \% \text{error} = \pm \frac{0.3}{100} \times 100 = 0.3\% \]

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: Resolution = \( \frac{\text{full scale reading}}{\text{maximum count}} \)
\[ = \frac{9.999V}{9999} = 1\text{mV} \]

06. Ans: (b)
Sol: Sensitivity = resolution \( \times \) lowest voltage range
\[ = \frac{1}{10^4} \times 100 \text{ mV} = 0.01 \text{ mV} \]

07. Ans: (a)
Sol: The DVM has 3\( \frac{1}{2} \) digit display

Therefore, the count range is from 0 to 1999 i.e., 2000 counts. The scale resolution is 0.001. And, the resolutions in each selected voltage Ranges of 2V, 20V & 200V are 1mV, 10mV & 100mV.
08. Ans: (a)
Sol: Resolution = $\frac{\text{max. voltage}}{\text{max. count}} = \frac{3.999}{3999} = 1\text{mV}$

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: (a)
Sol: Triangular wave of $V_m = 2 \times 10\text{V} = 20\text{V}$
rms meter reading for the same triangular wave input = $20/\sqrt{3} \text{ V}$

12. Ans: (a)
Sol: $4\frac{1}{2}$ digit is represented as

\[ \overline{1/2D} \overline{ID} \overline{ID} \overline{ID} \overline{ID} \]

$\frac{1}{2}D$ → half digit

$ID$ → full digit

For 1V range display is as:

\[ 0/1 \cdot X X X X \]

$X$ → any digit between 0 to 9

Reading 0.5245 V on 1V range is

So, option (a) is right.

13. Ans: (b)
Sol: For N-decade counter

\[ \text{Pulse width}_{\text{max}} = \frac{10^N}{f_{\text{clk}}} \]

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

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

Range of pulse width

$\Rightarrow 0$ to $\left(\frac{10^N - 1}{F}\right)$

9. Q–Meter

01. Ans: (a)
Sol: $C_1 = 300\text{pF}$

\[ Q = \frac{1}{\omega C_1 R} = 120 = \frac{1}{(C_2 + C_x)R} \]

\[ C_1 = C_2 + C_x \]

\[ C_x = 100 \text{ pF} \]

02. Ans: (b)
Sol: %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.

\[ \therefore \text{Q-meter works on the principle of series resonance.} \]

04. Ans: (b)
Sol: Given data: $C_d = 820 \text{ pF}$,

\[ \omega = 10^6\text{rad/sec} \& C = 9.18\text{nF} \]

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 100\mu\text{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 \( V = \text{applied voltage} \) and 
\[ V_0 = \text{Voltage across capacitor} \]
Therefore, 
\[ Q = \frac{V_{\text{max}}}{V_{\text{in}}} \Rightarrow Q = \frac{V_0}{V} \]

06. Ans: (b)
Sol: \( f_1 = 500 \text{kHz} \); \( f_2 = 250 \text{kHz} \)
\( C_1 = 36 \text{ pF} \); \( C_2 = 160 \text{ pF} \)
\[ n = \frac{250 \text{kHz}}{500 \text{kHz}} \Rightarrow n = 0.5 \]
\[ C_d = \frac{36 \text{ pF} - (0.5)^2 160 \text{ pF}}{(0.5)^2 - 1} = 5.33 \text{ pF} \]

07. Ans: (c)
Sol: 
\[ Q = \frac{\text{capacitor voltmeter reading}}{\text{Input voltage}} \]
\[ = \frac{10}{500 \times 10^{-3}} = 20 \]

08. Ans: i \(\rightarrow (c)\), ii \(\rightarrow (a)\)
Sol: (i) \[ C_d = \frac{C_1 - n^2 C_2}{n^2 - 1} \]
\[ = \frac{360 - 288}{3} = 24 \text{ pF} \]
(ii) \[ L = \frac{1}{\omega_1^2 [C_1 + C_d]} \]
\[ = \frac{1}{[2\pi 	imes 500 \times 10^3] \cdot [24 + 360] 	imes 10^{-6}} = 264 \mu\text{H} \]

09. Ans: (b)
Sol: 
\[ Q_{\text{true}} = Q_{\text{meas}} \left(1 + \frac{r}{R_{\text{coil}}} \right) \]
\[ Q_{\text{actual}} = Q_{\text{observed}} \left[1 + \frac{R}{R_s} \right] \]

10. Ans: (c)
Sol: 
\[ 1 + \frac{C_d}{C} = \frac{Q_{\text{true}}}{Q_{\text{measured}}} \]
\[ \Rightarrow \frac{C_d}{C} = \frac{245}{244.5} - 1 \]
\[ = 2.044 \times 10^{-3} \]
\[ \Rightarrow \frac{C}{C_d} = 489 \]

11. Ans: 1
Sol: \( \omega_1 = 10^6 \text{ rad/sec} \), \( C_1 = 990 \text{ pF} \)
\( \omega_2 = 2 \times 10^6 \text{ rad/sec} \), \( C_2 = 240 \text{ pF} \)
\( n = 2 \)
\[ C_d = \frac{C_1 - n^2 C_2}{n^2 - 1} \]
\[ = \frac{990 - 4(240)}{4 - 1} \]
\[ = \frac{30}{3} = 10 \text{ pF} \]
\[ L_{\text{coil}} = \frac{1}{(10^6)^2 (990 + 10) \text{pF}} \]
\[ = \frac{1}{10^{12} \times 1000 \times 10^{-12}} = 1 \text{ mH} \]
10. Analog Electronic Voltmeter

01. 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} \quad \text{Where } V_{dc} \text{ 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 = \( 1 \times V_{dc} = \frac{2V}{\pi} \)

02. Ans: (b)
Sol: The scale of a full wave rectifier type voltmeter is calibrated to read r.m.s for ideal sine wave i.e, reading =1.11V_{dc} where \( V_{dc} \) is average voltage of output of FWR for given input.

03. 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:

\[ R_v = \frac{20\ \text{kΩ}}{V} \times 5 \]

\[ = 100\text{kΩ} \]
Reading = \( V_s \times \frac{100k\Omega}{R_s + 100k\Omega} \)

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

\[ \therefore V_s = \frac{4.5V}{100k\Omega} (R_s + 100k\Omega) \rightarrow (1) \]

10V Range:

\[ R_v = 20 \frac{K\Omega}{V} \times 10V \]

\[ = 200k\Omega \]

Reading = \( V_s \times \frac{200k\Omega}{R_s + 200k\Omega} \)

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

\[ \therefore V_s = \frac{6V}{200k\Omega} (R_s + 200k\Omega) \rightarrow (2) \]

Solving equation (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 equation (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 100k\Ω