

**ESE GATE PSUs**

**State Engg. Exams**

**MADE EASY**  
**WORKBOOK 2027**



**Detailed Explanations of  
Try Yourself *Questions***

**ELECTRICAL ENGINEERING**  
Electrical & Electronic Measurements



# 1

## Error Analysis



### Detailed Explanation of Try Yourself Questions

#### T1 : Solution

(d)

Probable error,

$$\delta I = \sqrt{\left(\frac{\partial I}{\partial I_1}\right)^2 \delta I_1^2 + \left(\frac{\partial I}{\partial I_2}\right)^2 \delta I_2^2}$$

Here,

$$I = I_1 + I_2$$

So,

$$\frac{\partial I}{\partial I_1} = \frac{\partial I}{\partial I_2} = 1$$

$$\delta I = \sqrt{(1)^2(1)^2 + (1)^2(2)^2} = 2.24 \text{ A}$$

therefore,

$$I = 300 \pm 2.24 \text{ A}$$

# 2

## Indicating Meters



### Detailed Explanation of Try Yourself Questions

#### T1 : Solution

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$$S_{dc} = \frac{1}{I_{fs}} = \frac{1}{1 \times 10^{-3}} = 1000 \Omega/v$$

$$R_m = S_{dc} v = 1000 \times 1 = 1000 \Omega$$

$$R_s = 0.45 \times 1000 \times 10 - 1000$$

$$R_s = 3.5 \text{ k}\Omega$$

#### T2 : Solution

(d)

$$\text{Average value of rectangular current wave} = \sqrt{\frac{1}{2T} [(12^2 \times T) + (5^2 \times T)]} \approx 9.2$$

$$\text{Average volts} = 9.2 \times 10 = 92 \text{ V}$$

The MI meter will read 92 V.

#### T3 : Solution

For the range extension of electrostatic voltmeter the capacitor is connected in series with meter and its value is given by

$$C_s = \frac{C_v}{m-1}$$

Where 
$$m = \frac{V}{v} = \frac{20 \text{ kV}}{2 \text{ kV}} = 10$$

So, 
$$C_s = \frac{0.5}{10-1} = 0.05 \text{ pF}$$



# 3

## Power & Energy Measurement



### Detailed Explanation of Try Yourself Questions

#### T1 & T2 : Sol.

Total power in the circuit,  $P = W_1 + W_2 = 500 \text{ W} + (-100) \text{ W} = 400 \text{ W}$

Power factor of the circuit,  $\cos \phi = \cos \tan^{-1} \left\{ \left[ \frac{W_1 - W_2}{W_1 + W_2} \right] \cdot \sqrt{3} \right\}$

$$= \cos \tan^{-1} \left\{ \left[ \frac{0.5 - (-0.1)}{0.5 + (-0.1)} \right] \cdot \sqrt{3} \right\}$$

$$= \cos \tan^{-1} (1.5 \times \sqrt{3}) = 0.359$$

Load current per phase,  $I_p = \frac{P}{\sqrt{3} V_L \cos \phi} = \frac{400}{\sqrt{3} \times 440 \times 0.359} = 1.462 \text{ A}$

Load impedance per phase,  $Z_p = \frac{V_p}{I_p} = \frac{440 / \sqrt{3}}{1.462} = 173.76 \Omega$

Load resistance per phase,  $R_p = Z_p \cos \phi = 62.38 \Omega$

Load reactance per phase,  $X_p = Z_p \sin \phi = 162.18 \Omega$

Reading of wattmeter *B* will be zero when p.f. =  $\cos \phi' = 0.5$

or  $\phi' = 60^\circ$

Since there is no change in resistance,

Reactance in the circuit per phase,

$$X_p' = R_p \tan \phi'$$

$$X_p' = 62.38 \times \sqrt{3} = 108.045 \Omega$$

value of capacitive reactance to be introduced in each phase =  $X_p - X_p'$

$$= 162.18 \Omega - 108.045 \Omega$$

$$= 54.135 \Omega$$

**T3 : Solution**

Case-1:

$$\begin{aligned} \text{p.f.} &= 1 \Rightarrow \phi = 0^\circ \\ P_m &= V_L I_L \sin(\Delta - \phi) \\ P_m &= V_L I_L \sin(88^\circ - 0^\circ) \\ P_T &= V_L I_L \sin(90^\circ - 0^\circ) \\ \% \text{ error} &= \frac{P_m - P_T}{P_T} \times 100 \\ &= \frac{\sin(88^\circ) - \sin(90^\circ)}{\sin(90^\circ)} \times 100 = -0.061\% \end{aligned}$$

Case-2:

$$\begin{aligned} \text{p.f.} &= 0.5 \Rightarrow \phi = 60^\circ \\ P_m &= V_L I_L \sin(88^\circ - 60^\circ) \\ P_m &= V_L I_L \sin(28^\circ) \\ P_T &= V_L I_L \sin(90^\circ - 60^\circ) \\ P_T &= V_L I_L \sin(30^\circ) \\ \% \text{ error} &= \frac{\sin(28^\circ) - \sin(30^\circ)}{\sin(30^\circ)} \times 100 = -6.1\% \end{aligned}$$

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# 4

## Instrument Transformers



### Detailed Explanation of Try Yourself Questions

#### T1 : Solution

(c)

$$\text{Phase angle error for CT is} = \frac{180}{\pi} \left( \frac{I_m \cos \delta - I_e \sin \delta}{K_t I_s} \right) \text{ degree}$$

Here,

$$K_t = \frac{1000}{5} = 200, I_s = 5 \text{ A}$$

$$I_m = 11 \text{ A}$$

$$I_e = 6.5 \text{ A}$$

$$\delta = 30^\circ$$

$$\text{So, phase angle error} = \frac{180}{\pi} \left( \frac{11 \cos 30^\circ - 6.5 \sin 30^\circ}{200 \times 5} \right) = 0.359^\circ$$

#### T2 : Solution

(b)

$$\text{Secondary circuit phase angle, } \delta = \tan^{-1} \left( \frac{1}{1.5} \right) = 33.69^\circ$$

$$\cos \delta = \cos 33.39^\circ = 0.835$$

$$\text{or, } \sin \delta = \sin 33.69^\circ = 0.555$$

$$\text{Turn ratio, } K_t = \frac{N_s}{N_p} = \frac{300}{1} = 300$$

$$\text{Magnetizing current, } I_m = \frac{\text{Magnetising mmf}}{N_p} = \frac{100}{1} = 90 \text{ A}$$

$$\text{Secondary circuit burden impedance} = \sqrt{(1.5)^2 + (1.0)^2} = 1.8 \Omega$$

$$\text{Secondary induced voltage, } E_s = 5 \times 1.8 = 9 \text{ V}$$

$$\text{Primary induced voltage, } E_p = \frac{E_s}{300} = \frac{9 \text{ V}}{300}$$

$$\text{Loss component, } I_w = \frac{\text{iron loss}}{E_p} = \frac{1.2}{(9/300)} = 40 \text{ A}$$

$$\begin{aligned} \text{Phase angle, } \theta &= \frac{180}{\pi} \left( \frac{I_m \cos \delta - I_w \sin \delta}{K_t I_s} \right) \\ &= \frac{180}{\pi} \left( \frac{100 \times 0.835 - 40 \times 0.555}{300 \times 5} \right) = 2.34^\circ \end{aligned}$$



# 5

## Measurement of R, L, C Bridges



### Detailed Explanation of Try Yourself Questions

#### T1 : Solution

Schering bridge D-factor =  $\omega C_x R_x$  after substituting  $C_x$  and  $R_x$ .

$$\begin{aligned} \text{D-factor} &= \omega R_1 C_1 \\ &= 2\pi \times 10^3 \times 10^3 \times 0.5 \times 10^{-6} \\ &= 3.14 \end{aligned}$$

#### T2 : Solution

(b)

At balance,

$$Z_1 Z_4 = Z_2 Z_3$$

$$\frac{10 \times 10^3 \times X_C}{10 \times 10^3 + X_C} \times Z = 500 \times 10^3$$

as, 
$$X_C = \frac{1}{j\omega C} = \frac{1}{j \times 100\pi \times 100 \times 10^{-9}} = -j \frac{10^5}{\pi}$$

$$\therefore \frac{-j10^4 \times 10^5}{\pi \left( 10^4 - \frac{j \times 10^5}{\pi} \right)} \times 2 = 5 \times 10^5$$

$$\Rightarrow \frac{-j10^3}{1000\pi - j10^4} (R + jX) = 5$$

$$\Rightarrow -jR + X = 5\pi - j5 \times 10$$

$$\Rightarrow R = 50 \Omega$$

and 
$$L = \frac{5}{2 \times 50} = 50 \text{ mH}$$

**T3 : Solution**

$$\begin{aligned}R_3 &= 5 \Omega, \\C &= 1 \text{ mF}, \\R_1 &= 160 \Omega, \\R_2 &= 20 \Omega\end{aligned}$$

By using balance equation,

$$R = \frac{R_2 R_1}{R_3}$$

$$L = R_2 R_1 C$$

and

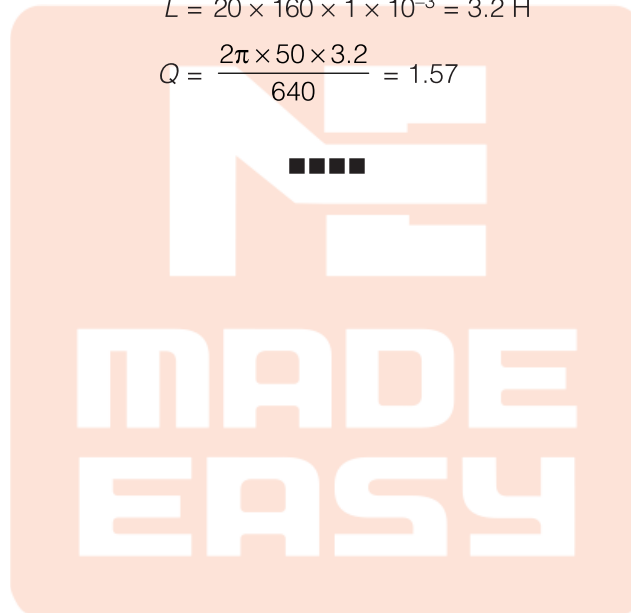
$$\text{quality factor} = Q = \frac{\omega L}{R}$$

So,

$$R = \frac{20 \times 160}{5} = 640 \Omega$$

$$L = 20 \times 160 \times 1 \times 10^{-3} = 3.2 \text{ H}$$

$$Q = \frac{2\pi \times 50 \times 3.2}{640} = 1.57$$





### Detailed Explanation of Try Yourself Questions

#### T1 : Solution

Using the equation,

$$V_{p-p} = \left( \frac{\text{volts}}{\text{div}} \right) \times \left( \frac{\text{no. of div}}{1} \right)$$

$$V_{p-p} = 0.5 \text{ V} \times 3 = 1.5 \text{ V}$$

#### T2 : Solution

The period of the signal is calculate using the equation

$$T = \left( \frac{\text{time}}{\text{div}} \right) \times \left( \frac{\text{no. of div}}{\text{cycle}} \right)$$

$$T = 2 \mu\text{s} \times 4 = 8 \mu\text{s}$$

Hence, frequency is

$$f = \frac{1}{T} = \frac{1}{8 \mu\text{s}} = 125 \text{ kHz}$$

