GATE

MADE EASY WORKBOOK 2024

Detailed Explanations of Try Yourself *Questions*

Instrumentation Engineering
Measurements

MADE EASY Publications

1   Error Analysis

T1. **Sol.**

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

T1. **(d)**

Average value of rectangular current wave $= \sqrt{\dfrac{1}{2T}\left[(12^2 \times T) + (5^2 \times T)\right]} \simeq 9.2$

Average volts $= 9.2 \times 10 = 92$ V

The MI meter will read 92 V.

■■■■

4 Instrument Transformers

Detailed Explanation
of
Try Yourself Questions

T1. (c)

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

Here, $K_t = \dfrac{1000}{5} = 200,\ I_s = 5$ A

$I_m = 11$ A
$I_e = 6.5$ A
$\delta = 30°$

So, phase angle error $= \dfrac{180}{\pi}\left(\dfrac{11\cos30° - 6.5\sin30°}{200\times5}\right) = 0.359°$

T2. (b)

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

$\cos\delta = \cos33.39° = 0.835$

or, $\sin\delta = \sin33.69° = 0.555$

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

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

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

Secondary induced voltage, $E_s = 5\times1.8 = 9$ V

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

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

Phase angle, $\qquad \theta = \dfrac{180}{\pi}\left(\dfrac{I_m \cos\delta - I_w \sin\delta}{K_t I_s}\right)$

$\qquad = \dfrac{180}{\pi}\left(\dfrac{100 \times 0.835 - 40 \times 0.555}{300 \times 5}\right) = 2.34°$

■■■■

Detailed Explanation
of
Try Yourself Questions

T1. Sol.

$$R_3 = 5\ \Omega,$$
$$C = 1\ mF,$$
$$R_1 = 160\ \Omega,$$
$$R_2 = 20\ \Omega$$

By using balance equation, $R = \dfrac{R_2 R_1}{R_3}$

$$L = R_2\, R_1 C$$

and   quality factor $= Q = \dfrac{\omega L}{R}$

So, $R = \dfrac{20 \times 160}{5} = 640\ \Omega$

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

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

T2. (b)

At balance,

$$Z_1\, Z_4 = Z_2\, Z_3$$

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

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

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

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

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

$$\Rightarrow \quad R = 50 \ \Omega$$

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

■■■■

6

CRO, Q-meter

T1. Sol.

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. Sol.

The period of the signal is calculate using the equation

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

$$T = 2\ \mu s \times 4 = 8\ \mu s$$

Hence, frequency is

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

■■■■