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Electrical Engineering

CLASS TEST
2016

EE

Electrical Measurement

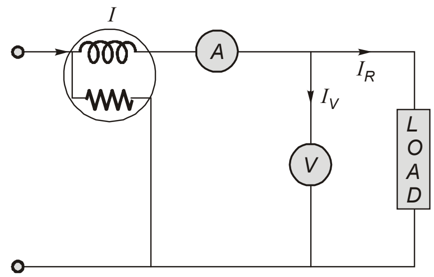
Date : 30/07/2016

ANSWERS

1.	(d)	7.	(a)	13.	(c)	19.	(c)	25.	(c)
2.	(a)	8.	(a)	14.	(c)	20.	(d)	26.	(b)
3.	(d)	9.	(b)	15.	(a)	21.	(c)	27.	(b)
4.	(a)	10.	(a)	16.	(c)	22.	(c)	28.	(a)
5.	(b)	11.	(b)	17.	(d)	23.	(c)	29.	(d)
6.	(c)	12.	(d)	18.	(b)	24.	(b)	30.	(d)

Explanation

1. (d)



$$V = (0.2 + 0.2) \times 5 + 200 = 202 \text{ V}$$

$$I = 5 \text{ A}$$

Wattmeter reading,

$$P = VI\cos\phi = 202 \times 5 \times 1 = 1010 \text{ Watt}$$

2. (a)

The overall uncertainty

$$\omega_x = \sqrt{\omega_{x_1}^2 + \omega_{x_2}^2 + \omega_{x_3}^2} = \sqrt{1^2 + 1^2 + 3^2} = \sqrt{11}\ \%$$

3. (d)

Phase shift between the inputs of the CRO = 0, so pattern will be a straight line.

4. (a)

In Maxwell bridge

$$L = CR_2R_3 = 20 \times 10^{-6} \times 250 \times 400 = 2 \text{ H}$$

5. (b)

In De-sauty's bridge

$$C_1 = C_2\frac{R_2}{R_1} = 200 \times 10^{-6} \times \frac{2000}{1000}$$

$$= 400\ \mu\text{F}$$

6. (c)

At balance condition,

$$\frac{1000}{R_x + j\omega L_x} = \frac{R_s}{(j\omega R_sC_s + 1) \times 1000}$$

or, $$10^6(j\omega R_sC_s + 1) = R_s(R_x + j\omega L_x)$$

equating real and imaginary terms,

$$10^6 = R_sR_x$$

$\Rightarrow$ $$R_x = \frac{10^6}{R_s} = 1000\ \Omega$$

and $$10^6\, C_s = L_x$$

$\Rightarrow$ $$L_x = 10^6 \times 0.5 \times 10^{-6}$$

$$= 0.5 \text{ H}$$

7. (a)

At balance condition,

$$Z_4 = \frac{150\angle 0° \times 250\angle -40°}{200\angle 30°}$$

$$= 187.5\angle -70°\ \Omega$$

8. (a)

At balance condition,

$$\frac{1000}{R_x + j\omega L_x} = \frac{R_s}{(j\omega R_s C_s + 1) \times 1000}$$

or, $$10^6(j\omega R_s C_s + 1) = R_s(R_x + j\omega L_x)$$

equating real and imaginary terms,

$$10^6 = R_x R_s$$

$$\Rightarrow \quad R_x = \frac{10^6}{R_s} = 1000\ \Omega$$

and $$10^6\, C_s = L_x$$

$$\Rightarrow \quad L_x = 10^6 \times 0.5 \times 10^{-6} = 0.5\ \text{H}$$

9. (b)

equivalent impedance,

$$Z = \frac{\left(\frac{1}{j\omega c}\right)(R + j\omega L)}{R + j\omega L + \left(\frac{1}{j\omega c}\right)} = \frac{R + j\omega(L - \omega^2 L^2 C - CR^2)}{1 + \omega^2 C^2 R^2 - 2\omega^2 LC + \omega^4 L^2 C^2}$$

So, the effective reactance,

$$X_{\text{eff}} = \frac{\omega\left\{L(1 - \omega^2 LC) - CR^2\right\}}{1 + \omega^2 C^2 R^2 - 2\omega^2 LC + \omega^4 L^2 C^2}$$

Since, X_{eff} is small, we have, $\omega^2 LC << 1$.

So, $\omega^2 LC$ can be neglected.

$$\therefore \quad X_{\text{eff}} = \frac{\omega(L - CR^2)}{1 + \omega^2 C(CR^2 - 2L)}$$

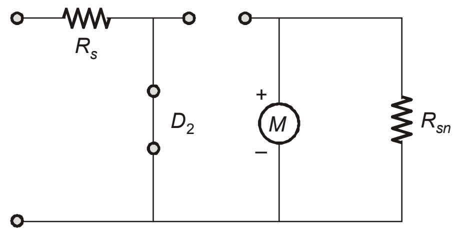
If the resistance is noninductive,

then, $$L - CR^2 = 0$$

$$\Rightarrow \quad R = \sqrt{\frac{L}{C}}$$

10. (a)

During negative half-cycle circuit can be redrawn as shown below



From above circuit it is clear that during negative half-cycle meter is open circuited due to diode D_2.
Reverse saturation current is the current that flows in diode when reverse voltage is applied without D_2, even though diode is open circuited, voltage across D_1 is AC voltage.
With diode D_2 ON, the voltage across diode D_1 is zero.

11. (b)

instantaneous value of voltage across 1 mH inductor is

$$V_L = L\frac{dI}{dt} = 1\times 10^{-3}\frac{d}{dt}(0.5 + 0.3\sin\omega t - 0.2\sin 2\omega t)$$

$$= 1\times 10^{-3}\times\omega(0.3\cos\omega t - 0.4\cos 2\omega t)$$

Put, $\omega = 10^6$ rad/sec then,

$$V_L = 300\cos\omega t - 400\cos 2\omega t$$

Hence, reading of electrostatic voltmeter across 1 mH inductor is

$$V_L = \sqrt{\left(\frac{300}{\sqrt{2}}\right)^2 + \left(\frac{400}{\sqrt{2}}\right)^2}$$

$$V_L = 354 \text{ V}$$

12. (d)

Inductance, $L = (200 + 40\theta - 4\theta^2 - \theta^3)\ \mu\text{H}$

∴ Rate of change of inductance,

$$\frac{dL}{d\theta} = (40 - 8\theta - 3\theta^2)\ \mu\text{H/rad}$$

For, $\theta = \frac{\pi}{2}$

$$\frac{dL}{d\theta} = 40 - 8\times\frac{\pi}{2} - 3\cdot\left(\frac{\pi}{2}\right)^2 = 20\ \mu\text{H/rad}$$

and deflection, $\theta = \frac{1}{2}\cdot\frac{I^2}{K}\cdot\frac{dL}{d\theta}$

with $I = 1.5$ A, we have $\theta = \frac{\pi}{2}$ and $\frac{dL}{d\theta} = 20\times 10^{-6}$ H/rad

$$\frac{\pi}{2} = \frac{1}{2}\times\frac{(1.5)^2}{K}\times 20\times 10^{-6}$$

or, $K = 14.32\times 10^{-6}$ Nm/rad

∴ spring constant, $K = 14.32 \times 10^{-6}$ Nm/rad

Deflection, $\theta = \frac{1}{2} \times \frac{I^2}{14.32 \times 10^{-6}} (40 - 8\theta - 3\theta^2) \times 10^{-6}$

or, $3\theta + 36.64\theta^2 - 40 = 0$

or, $\theta = 1.008$ radian

$= 57.8°$

13. (c)

Let,

L_C = length of capillary tube which would be occupied by mercury contained in the bulb when it is not heated; mm

$L_C + \Delta L_C$ = length of capillary tube which would be occupied by mercury contained in the bulb when heated, mm

A_C = Area of capillary tube; mm^2

α_V = coefficient of volumetric expansion/°C and $\Delta\theta$ = change in temperature; °C

It should be noted that there will be only a change in length of mercury column since it is given that the bulb has a zero expansion material and hence there will be no changes in its area and length. This is true of capillary tube as well.

Sensitivity,

$$S = \frac{(L_C + \Delta L_C) - L_C}{\Delta\theta} = \frac{\Delta L_C}{\Delta\theta} = 2.5 \text{ mm/°C}$$

Now, $A_C(L_C + \Delta L_C) = A_C(L_C + \alpha_V L_C \Delta\theta)$

∴ length of capillary tube,

$$L_C = \frac{1}{\alpha_V} \cdot \frac{\Delta L_C}{\Delta\theta} = \frac{1}{0.181 \times 10^{-3}} \times 2.5 = 13.8 \times 10^3 \text{ mm}$$

$$= 13.8 \text{ m}$$

14. (c)

from the modified De-Sauty bridge

$$\frac{R_2}{R_3} = \frac{r_1}{R_4 + r_4} = \frac{C_4}{C_1}$$

$$r_1 = \frac{R_2(R_4 + r_4)}{R_3} = \frac{2000 \times (4.8 + 0.4)}{2850}$$

$$= 3.65\ \Omega$$

and, $C_1 = \frac{R_3 C_4}{R_2} = \frac{2850 \times 0.5 \times 10^{-6}}{2000} = 0.7125\ \mu\text{F}$

and $\tan\delta_1 = \omega C_1 r_1 =$

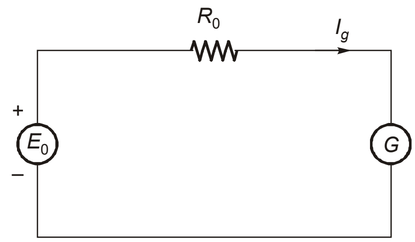
$= 2\pi \times 450 \times 0.7125 \times 10^{-6} \times 3.65 = 7353.1 \times 10^{-6}$

$= 0.007351$

$r_1 = \tan^{-1}(0.007351) = 0.42°$

15. (a)

The Thevenin equivalent circuit of the bridge is shown in figure below.



R_0 = resistance of circuit looking into terminals '*d*' and '*c*' with terminals '*a*' and '*b*' short circuits.

$$R_0 = \frac{RS}{R+S} + \frac{PQ}{P+Q}$$

$$R_0 = \frac{1\times 5}{1+5} + \frac{1\times Q}{1+Q}$$

$$R_0 = 0.833 + \frac{Q}{1+Q}\text{k}\Omega \quad ...(1)$$

Now,
$$R_0 + G = \frac{E_0}{I_g} = \frac{24\times 10^{-3}}{13.6\times 10^{-6}}$$

$$= 1.765\text{ k}\Omega = 1765\ \Omega$$

$$R_0 = 1765 - G$$

$$= (1765 - 100)\,\Omega$$

$$= 1665\ \Omega$$

$$= 1.665\text{ k}\Omega$$

Put, the value of R_0 = 1.665 kΩ in equation (1) then, we get

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

or,
$$\frac{Q}{1+Q} = 1.665 - 0.833$$

or,
$$\frac{Q}{1+Q} = 0.832$$

∴
$$Q = 4.95\text{ k}\Omega$$

16. (c)

For type - 1; error $= I^2R_C$

For type - 2; error $= \frac{V^2}{R_P}$

so,
$$I^2R_C = \frac{V^2}{R_P} = \frac{(200)^2}{10{,}000}$$

⇒
$$R_C = \frac{(200)^2}{10{,}000\times(20)^2} = 0.01\,\Omega$$

17. (d)

$$V = 230 \text{ Volt, I} = 5 \text{ A}, \cos\phi = pf = 0.1$$
$$R_p = 10 \text{ k}\Omega, L_p = 100 \text{ mH} = 0.1 \text{ H}$$
$$\therefore \quad \beta = \tan^{-1}\left(\frac{\omega L_p}{R_p}\right) = 0.18°$$
$$\phi = \cos^{-1}(0.1) = 84.26°$$

Method **I**

True power $= P_T = VI\cos\phi = 115$ Watt

Reading for lagging pf,

$$P_{read} = VI\cos(\phi - \beta)\cos\beta$$
$$= 118.6 \text{ watt}$$
$$\% \text{ error} = \frac{118.6 - 115.0}{115.0} \times 100$$
$$= 3.14\%$$

Method **II**

$$\% \text{ error} = \tan\phi \cdot \tan\beta \times 100$$
$$= \tan(84.26°) \times \tan(0.18°) \times 100$$
$$= 3.14\%$$

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

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

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

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

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

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

19. (c)

$$\text{units} = \pm 0.2\%$$
$$\text{Tens} = \pm 0.1\%$$
$$\text{Hundreds} = \pm 0.05\%$$
$$\text{Thousands} = \pm 0.02\%$$
$$400\ \Omega \text{ error} = \pm 4000 \times \frac{0.02}{100} = \pm 0.8\ \Omega$$

$$\text{For hundred error} = \pm 300 \times \frac{0.05}{100} = \pm\, 0.15\ \Omega$$

$$\text{For tenth error} = \pm 20 \times \frac{0.1}{100} = \pm 0.02\ \Omega$$

$$\text{For unit error} = \pm 5 \times \frac{0.2}{100} = \pm 0.01\ \Omega$$

Hence,
$$\text{total error} = \pm(0.8 + 0.15 + 0.02 + 0.01)$$
$$= \pm\, 0.98\ \Omega$$

$$\text{Limiting error} = \frac{0.98}{4325} \times 100 = 0.0226\%$$

20. (d)

Current through PMMC ammeter,

$$I = 0.9 \times 10^{-3} = \frac{1.8}{1.8 \times 10^3 + R_a}$$

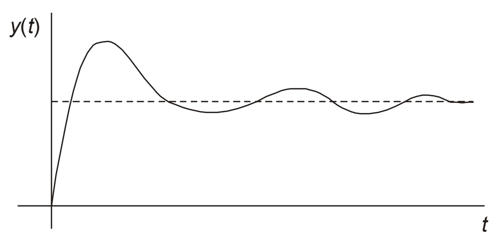
Where, R_a is the ammeter resistance

$$R_a + 1.8 \times 10^3 = 2 \times 10^3$$

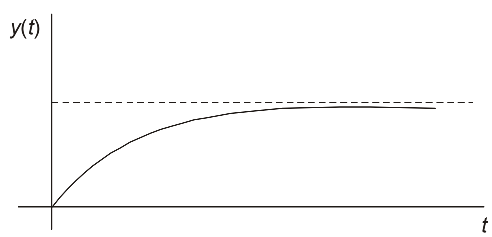
$$\Rightarrow \quad R_a = 200\ \Omega$$

Since, the pointer swings to 1 mA mark, it is under-damped.

Underdamped System:



Critically Damped System:



So, from the above, the system has shown a value higher than the steady state value, Hence it is underdamped system.

21. (c)

Reading of the true rms meter

$$V_{\text{rms(true)}} = \sqrt{\frac{1}{T_0}\int_0^{T_0} V^2(t)\,dt} = \sqrt{\frac{1}{2\pi}\left[\int_0^{T_0} V^2(t)\,dt\right]}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{\pi/2}(3V)^2\,dt + \frac{1}{2\pi}\int_{\pi/2}^{2\pi}(-1\,\text{V})^2\,dt}$$

$$= \sqrt{\frac{9}{2\pi}\times(t)_0^{\pi/2} + \frac{1}{2\pi}(t)_{\pi/2}^{2\pi}}\ \text{V}$$

$$= \sqrt{\frac{9}{2\pi}\times\frac{\pi}{2}+\frac{1}{2\pi}\times\frac{3\pi}{2}}\ V = \sqrt{\frac{9}{4}+\frac{3}{4}}$$

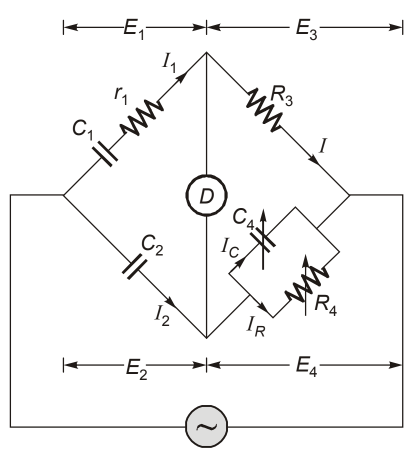
$$V_{\text{rms}} = \sqrt{\frac{12}{4}}\ \text{V}$$

$$V_{\text{rms}} = \sqrt{3}\ \text{V}$$

22. (c)

$$C_2 = 106\ \mu\text{F}$$
$$C_4 = 0.35\ \mu\text{F}$$
$$R_4 = 318\ \Omega$$
$$R_3 = 130\ \Omega$$

$$C_1 = C_2\left(\frac{R_4}{R_3}\right) = 259.29\ \mu\text{F}$$



Schering Bridge

23. (c)

Error in reading of first meter

$$= \text{FSD} \times \text{accuracy}$$

$$= 20 \times \frac{\pm 0.1}{100} = \pm 0.02$$

Error in reading of second meter

$$= 10 \times \frac{\pm 0.2}{100} = \pm 0.02$$

Error in reading of third meter

$$= 5 \times \frac{\pm 0.5}{100} = \pm 0.025$$

Error in reading of fourth meter

$$= 1 \times \frac{\pm 1.00}{100} = \pm 0.01$$

Third meter has maximum error.

24. (b)

$I = 0$, means the potential difference between 'AB' and 'AD' is same so the bridge is balanced.

At bridge balance condition.

so,
$$Z_1 Z_4 = Z_2 Z_3$$

$$(R_1 + j\omega_{L_1}).\left(R_4 + \frac{1}{j\omega C_4}\right) = R_2 R_3$$

$$R_1 R_4 + \frac{L_1}{C_4} = R_2 R_3$$

Similarly, for phase angles also equal for

$$\underline{|\theta_2 + \theta_3} = \underline{|\theta_1 + \theta_4}$$

$$\tan^{-1}\left(\frac{\omega L_1}{R_1}\right) - \tan^{-1}\left(\frac{1}{\omega C_4 R_4}\right) = 0 + 0$$

$$\tan^{-1}\left(\frac{\omega L_1}{R_1}\right) = \tan^{-1}\left(\frac{1}{\omega C_4 R_4}\right)$$

$$\frac{\omega L_1}{R_1} = \frac{1}{\omega C_4 R_4}$$

So,
$$2\,\omega L_1 = \frac{2R_1}{\omega C_4 R_4}$$

25. (c)

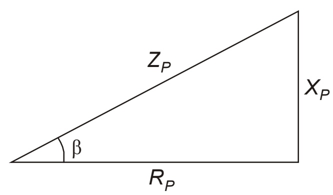
Since r is negligible and P, Q, p and q have large values, the effect of ratios arms can be neglected for the purpose of calculation of current,

$$\therefore \quad I = \frac{E}{R_b + R + S} \quad ...(1)$$

and
$$R = \frac{P}{Q}.S = \frac{1000}{1000} \times 0.001 = 0.001\Omega$$

From (1),
$$I = \frac{100}{5 + 0.001 + 0.001} \cong 20 \text{ A}$$

26. (b)



$$V_L = 220 \text{ V},$$
$$I_L = 4\text{A},$$
$$\cos\phi = 0.1,$$
$$R_p = 10{,}000\Omega$$
$$\text{True power} = V_L I_L \cos\phi = 220 \times 4 \times 0.1 = 88 \text{ W}$$

Error due to pressure coil inductance of 100 mH

$$L = 100 \text{ mH}$$
$$\Rightarrow \quad X_p = \omega L = 2\pi f L \text{ (Assume } f = 50 \text{ Hz)}$$
$$= \pi \times 50 \times 100 \times 10^{-3}$$
$$X_p = 31.415\ \Omega$$
$$R_p = 10{,}000\ \Omega$$

From impedance triangle of potential coil.

$$Z_p = \sqrt{X_p^2 + R_p^2}$$
$$\therefore \quad \tan\beta = \frac{X_P}{R_P}$$
$$\therefore \quad \beta = \tan^{-1}\left(\frac{X_P}{R_P}\right) = \tan^{-1}\left(\frac{31.415}{10000}\right) = 0.18°$$

$$\% \text{ error} = \tan\beta \,.\, \tan\phi \times 100$$
$$= \tan(0.18) \,.\, \tan[\cos^{-1}(0.1)] \times 100$$
$$= 3.141 \times 10^{-3} \times 9.949 \times 100$$
$$= 3.125$$

27. (b)

$$V_0 = \frac{V_R}{2^n}\left(a_{n-1}\,2^{n-1} + a_{n-2}\,2^{n-2} + \ldots.. + a_1 2^1 + a_0 2^0\right)$$

$$= \frac{6.5}{2^6}(2^4 + 2^3 + 2^2) = 6.5 \times \frac{28}{64}$$

$$= 2.84 \text{ V}$$

28. (a)

Steady deflection, $\theta = \frac{1}{2}\frac{V^2}{K}\cdot\frac{dc}{d\theta}$

When, $\theta = \frac{\pi}{2}$ rad,

$$\frac{dc}{d\theta} = \frac{2\theta K}{V^2} = \frac{2 \times \frac{\pi}{2} \times 5 \times 10^{-6}}{(2 \times 10^3)^2} = 3.93 \times 10^{-12} \text{ F/rad}$$

Change in capacitance when reading from 0 to 2000 V

$$= 3.93 \times 10^{-12} \times \frac{\pi}{2} = 6.17 \text{ pF}$$

Therefore, capacitance when reading is 2000 V

$$C = 15 + 6.17$$

$$= 21.17 \text{ pF}$$

29. (d)

$$\text{Velocity of beam} = V_{ox} = \left(\frac{2eE_a}{m}\right)^{\frac{1}{2}}$$

$$= \left[\frac{2 \times 1.6 \times 10^{-19} \times 2000}{9.1 \times 10^{-31}}\right]^{\frac{1}{2}}$$

$$V_{ox} = 26.5 \text{ m/s}$$

30. (d)

$r_d = 1000\ \Omega$, $I_{Fs} = 50 \times 10^{-6}$ A

The dc sensitivity,

$$S_{dc} = \frac{1}{50 \times 10^{-6}} = 20000\ \Omega/\text{V}$$

$$= 20\ \text{k}\Omega/\text{V}$$

For a full wave rectifier circuit,

ac sensitivity, $S_{ac} = 20000 \times 0.9 = 18000\ \Omega/\text{V} = 18\ \text{k}\Omega/\text{V}$

$\therefore$ Resistance of multiplier $= R_s = S_{ac} \times V_{rms} - R_m - 2r_d$

$$R_s = S_{ac} \times 10 - R_m - 2r_d$$

$$= 180000 - 1000 - 2000 = 177000\ \Omega$$

$$= 177\ \text{k}\Omega$$

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