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Measurement

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CLASS TEST 2019-2020

ELECTRICAL ENGINEERING

Date of Test : 20/09/2019

ANSWER KEY ➤ Measurement

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

Detailed Explanations

1. (d)

Probable error,

$$\sigma = \sqrt{\left(\frac{\partial I}{\partial I_1}\right)^2 \sigma_1^2 + \left(\frac{\partial I}{\partial I_2}\right)^2 \sigma_2^2}$$

Here, $I = I_1 + I_2$

So, $\dfrac{\partial I}{\partial I_1} = \dfrac{\partial I}{\partial I_2} = 1$

and $\sigma = \sqrt{(1)^2 (1)^2 + (1)^2 (2)^2} = 2.24$ A

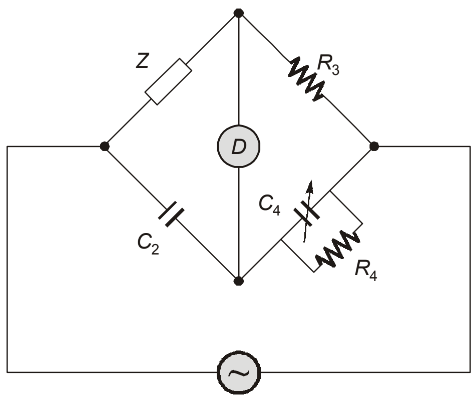
Therefore, $I = 300 \pm 2.24$ A

2. (d)

Wien bridge is balanced only for pure sinusoidal input supply and no harmonics in supply. So, no null indication is possible.

3. (c)

The given figure is shown below.



At balance condition,

$$Z\left(R_4 \parallel \frac{1}{j\omega C_4}\right) = R_3 \cdot \frac{1}{j\omega C_2}$$

$$\Rightarrow \quad Z\left(\frac{R_4}{1 + j\omega C_4 R_4}\right) = \frac{R_3}{j\omega C_2}$$

$$\Rightarrow \quad Z = \frac{R_3 + j\omega R_3 R_4 C_4}{j\omega C_2 R_4} = \frac{C_4}{C_2} R_3 + \frac{R_3}{j\omega C_2 R_4}$$

$$= R_{eq} + \frac{1}{j\omega c_{eq}}$$

So, it is combination of *R* and *C* in series.

4. (b)

Turning moment of the coil $= NBI\,A$

$N = 250,$

$B = 10 \text{ Wb/m}^2,$

$$A = 2\text{ cm} \times 3\text{ cm} = 6 \times 10^{-4}\text{ m}^2$$
$$I = 1 \times 10^{-3}\text{ A}$$
$$T = NBIA = 250 \times 10 \times 6 \times 10^{-4} \times 10^{-3}$$
$$T = 1.5 \times 10^{-3}\text{ N-m}$$

5. (c)

$X \rightarrow 0.5$ ms/cm;

$Y \rightarrow 100$ mV/cm

$$\text{Time occupied by wave} = 10\text{ cm} \times 0.5\text{ ms/cm} = 5\text{ ms}$$
$$\text{Time period of sine wave} = \frac{1}{200} = 5\text{ ms}$$
$$\text{No. of cycle occupied} = \frac{\text{time occupied wave}}{T} = \frac{5\text{ms}}{5\text{ms}} = 1\text{ cycle}$$
$$\text{RMS amplitude of wave} = 300\text{ mV}$$
$$\text{Maximum amplitude of wave} = 300\sqrt{2}\text{ mV}$$

Maximum amplitude occupied on screen

$$= 8\text{ cm} \times 100\text{ mV/cm} = 800\text{ mV}$$

Peak to peak amplitude of wave

$$= 2 \times 300\sqrt{2} = 600\sqrt{2}\text{ Volt}$$
$$= 848.53\text{ Volt}$$

So, wave will be clipped amplitude of one cycle.

6. (a)

In successive approximation type DVM conversion time is independent of applied voltage. It will remain constant i.e. nT_{clk}.

where n = number of bits

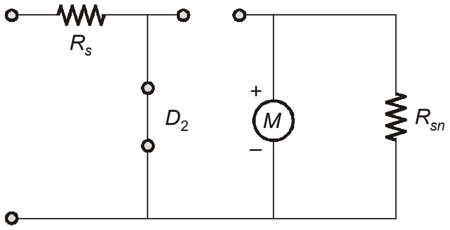
So, conversion time = 7 clock pulses.

7. (d)

$$P = I^2 R$$
$$\frac{\partial P}{\partial I} = 2IR,$$
$$\frac{\partial P}{\partial R} = I^2$$
$$W_P = \sqrt{\left(\frac{\partial P}{\partial I}\right)^2 W_I^2 + \left(\frac{\partial P}{\partial R}\right)^2 W_R^2}$$
$$\frac{W_P}{P} = \sqrt{4.\left(\frac{W_I}{I}\right)^2 + \left(\frac{W_R}{R}\right)^2}$$
$$\%\frac{W_P}{P} = \sqrt{4 \times (0.5)^2 + (0.2)^2}$$
$$= \sqrt{1.04} = 1.0198 \simeq 1.02$$

8. (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.

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,

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

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)

$$\text{Resolution} = \frac{1}{10^4} = 0.0001$$

Resolution on 1 V range $= 1 \times 0.0001$
$= 0.0001$

Therefore, on 1 V range, any reading can be displayed to 4th decimal place. Hence, 0.8245 will be displayed as 0.8245 on 1 V range.

11. (a)

Heaviside Campbell bridge method is commonly used for finding mutual inductance.

12. (d)

As moving iron volt meter reads rms value, therefore
rms value of rectangular current wave given in figure-2 is:

$$i_{\text{rms}} = \sqrt{\frac{1}{2T}\left[(12^2 \times T) + (5^2 \times T)\right]} \simeq 9.2$$

$\therefore$ rms value of voltage $= 9.2 \times 10 = 92$ V

Thus, *MI* meter will read 92 V.

13. (b)

In dynamometer type wattmeter, the fixed coil is current coil and moving coil is voltage coil or pressure coil.

14. (a)

As moving iron voltmeter measures rms value of voltage

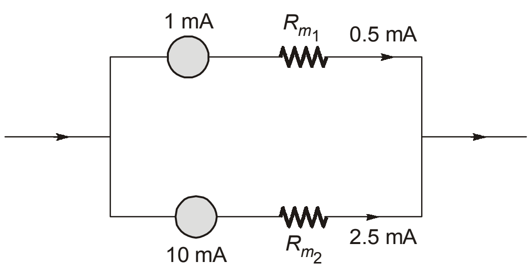
So, $$V_{\text{rms}} = \sqrt{\frac{1}{10}\int_0^T \{V(t)\}^2 dt}$$

From given waveform, $$v(t) = \begin{cases} 2t, & 0 < t < 5 \\ -10, & 5 < t < 10 \end{cases}$$

$\therefore$ $$V_{\text{rms}} = \sqrt{\frac{1}{10}\left[\int_0^5 (2t)^2 dt + \int_5^{10} (-10)^2 dt\right]} = \sqrt{\frac{1}{10}\left[4\left(\frac{t^3}{3}\right)_0^5 + 100[t]_5^{10}\right]}$$

$$= \sqrt{\frac{1}{10}\left[\frac{4}{3}(125-0) + 100(10-5)\right]} = 8.16 \text{ V}$$

15. (d)



Voltage across two meters are same.

$\therefore$ $$0.5R_{m_1} = 2.5R_{m_2}$$

or, $$\frac{R_{m_1}}{R_{m_2}} = \frac{2.5}{0.5} = \frac{5}{1}$$

16. (a)

Since deflecting torque varies as (current)^2, we have $T_d \propto I^2$

For spring control, $T_c \propto \theta$

$\therefore$ $\theta \propto I^2$ (Since $T_c = T_d$ at equilibrium)

For gavity control, $T_c \propto \sin\theta$

$\therefore$ $\sin\theta \propto I^2$

(i) For spring control, $90° \propto 5^2$ and $\theta \propto 3^2$

$$\theta = 90° \times \frac{3^2}{5^2} = 32.4°$$

(ii) For gravity control, $\sin 90° \propto 5^2$ and $\sin\theta \propto 3^2$

$$\sin\theta = \frac{9}{25} = 0.36\ ;$$

$$\theta = \sin^{-1}(0.36) = 21.1°$$

$$\therefore \quad \text{ratio} = \frac{32.4°}{21.1°} = 1.5355 \approx 1.54$$

17. (c)

Voltage, $v = 100\sin\omega t + 40\cos(3\omega t - 30°) + 50\sin(5\omega t + 45°)\text{V}$

$= 100\sin\omega t + 40\sin(3\omega t + 60°) + 50\sin(5\omega t + 45°)$

Current, $i = 8\sin\omega t + 6\cos(5\omega t - 120°)\text{A} = 8\sin\omega t + 6\sin(5\omega t - 30°)\text{A}$

Wattmeter reading, $P_{avg} = VI = V_o I_o + \frac{1}{2}\left[V_{m_1} I_{m_1}\cos(\phi_1 - \alpha_1) + V_{m_2} I_{m_2}\cos(\phi_2 - \alpha_2) + V_{m_3} I_{m_3}\cos(\phi_3 - \alpha_3)\right]$

$$= 0 + \frac{1}{2}[100 \times 8\cos(0 - 0) + 40 \times 0 + 50 \times 6\cos(45° - (-30°))]$$

$$= \frac{1}{2}[800 \times 1 + 300\cos 75°] = \frac{877.6457}{2} = 438.8228\text{ W} \approx 439\text{ W}$$

18. (b)

Primary current of C.T.,

$$I_P = \frac{10 \times 10^6}{\sqrt{3} \times 132 \times 10^3} = 43.738\text{ A}$$

Secondary current of C.T.,

$$I_s = I_p \times (\text{C.T. ratio}) = 43.738 \times \frac{1}{10} = 4.3738\text{ A}$$

Total VA on the secondary side

$$= (4.3738)^2 \times 3 + 5 = 62.39\text{ VA}$$

Hence VA rating or burden for CT should be 62.39 VA.

19. (a)

The total instantaneous current through ammeter is the vector sum of the three branch currents.

$$i_T = i_R + i_L + i_C$$

Now, $i_R = \frac{v}{R} = 100\sin\left(5000t + \frac{\pi}{4}\right)/25 = 4\sin\left(5000t + \frac{\pi}{4}\right)\text{ A}$

$$i_L = \frac{1}{L}\int v\,dt = \frac{10^3}{2}\int 100\sin\left(5000t + \frac{\pi}{4}\right)dt$$

$$= \frac{10^3 \times 100}{2}\left[\frac{-\cos\left(5000t + \frac{\pi}{4}\right)}{5000}\right] = -10\cos\left(5000t + \frac{\pi}{4}\right)$$

$$i_C = C\frac{dv}{dt} = C.\frac{d}{dt}\left[100\sin\left(5000t + \frac{\pi}{4}\right)\right]$$

$$= 30 \times 10^{-6} \times 100 \times 5000 \times \cos\left(5000t + \frac{\pi}{4}\right)$$

$$= 15\cos\left(5000t + \frac{\pi}{4}\right)$$

$$\therefore \quad i_T = 4\sin\left(5000t + \frac{\pi}{4}\right) - 10\cos\left(5000t + \frac{\pi}{4}\right) + 15\cos\left(5000t + \frac{\pi}{4}\right)$$

$$= 4\sin\left(5000t + \frac{\pi}{4}\right) + 5\cos\left(5000t + \frac{\pi}{4}\right)$$

Since moving iron ammeter reads rms value of current, therefore

$$\text{reading of ammeter, } i_{\text{rms}} = \sqrt{\frac{1}{2}\left(4^2 + 5^2\right)} = 4.52 \text{ A}$$

20. (a)

$$f_1 = 2 \text{ MHz}$$
$$C_1 = 210 \text{ pF},$$
$$Q = 100,$$
$$f_2 = 4 \text{ MHz}$$

and
$$C_2 = 45 \text{ pF}$$

$$n = \frac{4 \text{ MHz}}{2 \text{ MHz}} = 2$$

$$C_d = \frac{210 \text{ pF} - 2^2 \times 45 \text{ pF}}{2^2 - 1}$$

$$= 10 \text{ pF}$$

$$L = \frac{1}{(2\pi \times 2 \text{ MHz})^2 \cdot (210 \text{ pF} + 10 \text{ pF})}$$

$$= 0.287 \times 10^{-4} \text{ H}$$

21. (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.

22. (d)

Current through PMMC ammeter,

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

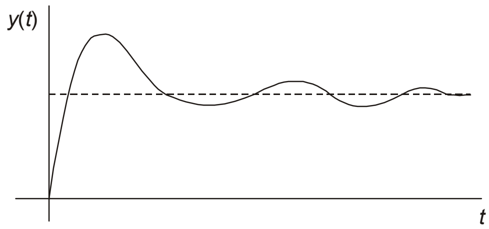
Where, R_a is the ammeter resistance

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

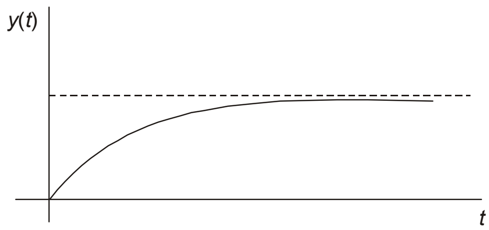
$$\Rightarrow \quad R_a = 200\ \Omega$$

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

Underdamped System:

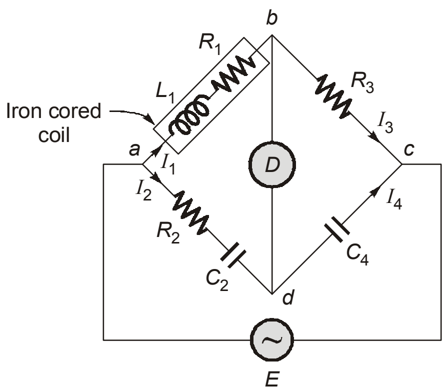


Critically Damped System:



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

23. (a)



At balance condition:

$$I_1 = I_3 \text{ and } I_2 = I_4$$

$$(R_1 + j\omega L_1)\left(\frac{1}{j\omega C_4}\right) = R_3\left(R_2 + \frac{1}{j\omega C_2}\right)$$

Separating the real and imaginary terms, we get

$$L_1 = R_2 R_3 C_4 \quad \text{and} \quad R_1 = \frac{R_3 C_4}{C_2}$$

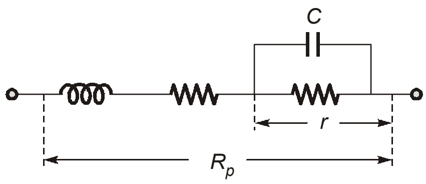
$$L_1 = R_2 R_3 C_4 = 842 \times 10 \times 1 \times 10^{-6} = 8.42 \text{ mH}$$

$$R_1 = \frac{R_3 C_4}{C_2} = \frac{10 \times 1 \times 10^{-6}}{0.135 \times 10^{-6}} = 74.074\ \Omega$$

Self inductance, $L_1 = 8.42$ mH

and effective resistance, $R_1 = 74.074\ \Omega \approx 74\ \Omega$

24. (a)



Total impedance of the circuit of pressure coil

$$Z_p = (R_p - r) + j\omega L + \frac{r - j\omega C r^2}{1 + \omega^2 C^2 r^2}$$

If the circuit constants are so chosen that for power frequency $\omega^2 C^2 r^2 << 1$.

We have approximately $Z_p = R_p - r + j\omega L + r - j\omega C r^2$

$$Z_p = R_p + j\omega(L - Cr^2)$$

If we make $L = Cr^2$ then $Z_p = R_p$ and $\beta = 0$.

Thus the error caused by pressure coil inductance is almost completely eliminated if

$$L = Cr^2$$

$$r = \sqrt{\frac{L}{C}} = \sqrt{\frac{4.2 \times 10^{-3}}{0.1 \times 10^{-6}}} = 204.939\ \Omega$$

Portion of the series resistance, $r = 204.939\ \Omega$

25. (a)

Given that,

number of revolution make by meter during given period,

$$N = 2208$$

Power, $P = VI \cos\phi \text{ kW} = 230 \times 4 \times 1.0 = 920 \text{ Watts} = 0.92 \text{ kW}$

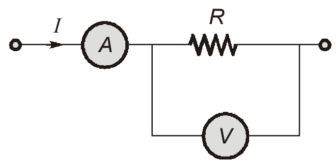
Time, $t = 6$ hour

$$\text{Energy recorded by meter} = \frac{920}{1000} \times 6 = 5.52 \text{ kWh}$$

Meter constant, $K = \dfrac{\text{Number of revolution}}{\text{Energy consumed by meter}} = \dfrac{2208}{5.52} = 400$

26. (a)

The circuit diagram is shown in figure



$$P = \frac{V^2}{R}$$

$$\frac{\partial P}{\partial V} = \frac{2V}{R} \text{ and } \frac{\partial P}{\partial R} = -\frac{V^2}{R^2}$$

Hence, uncertainty in power measurement

$$W_P = \sqrt{\left(\frac{\partial P}{\partial V}\right)^2 W_V^2 + \left(\frac{\partial P}{\partial R}\right)^2 W_R^2} = \sqrt{\left(\frac{2V}{R}\right)^2 W_V^2 + \left(-\frac{V^2}{R^2}\right)^2 W_R^2}$$

$\therefore$ Percentage uncertainty in measurement of power is calculated by putting $P = \frac{V^2}{R}$.

$$\frac{W_P}{P} \times 100 = \sqrt{4\left(\frac{W_V}{V}\right)^2 + \left(\frac{W_R}{R}\right)^2} \times 100$$

$$= \sqrt{4(0.01)^2 + (0.001)^2} \times 100 = 2.0025\% \approx 2\%$$

27. (a)

For 10 V, total input reinstance is:

$$R_V = \frac{V_{fsd}}{I_{fsd}} = \frac{10}{100\mu A} = 10^5\ \Omega$$

$$\therefore \quad \text{Sensitivity} = \frac{R_V}{V_{fsd}} = \frac{10^5}{10} = 10\ \text{k}\Omega/\text{V}$$

For 100 V,

$$R_V = \frac{100}{100\mu A} = 10^6\ \Omega$$

$$\text{Sensitivity} = \frac{R_V}{V_{fsd}} = \frac{10^6}{100} = 10\ \text{k}\Omega/\text{V}$$

28. (d)

At balance condition,

$$Z_1 Z_x = Z_2 Z_3$$

i.e.,

$$R_1\left(R_x - \frac{j}{\omega C_x}\right) = R_2\left(R_3 - \frac{j}{\omega C_3}\right)$$

$$\therefore \qquad R_1R_x - \frac{jR_1}{\omega C_x} = R_2R_3 - \frac{jR_2}{\omega C_3}$$

Equating the real and the imaginary parts,

$$R_1R_x = R_2R_3$$

$$\Rightarrow \qquad R_x = \frac{R_2R_3}{R_1} = \frac{30\times 25}{20} = 37.5\ \Omega$$

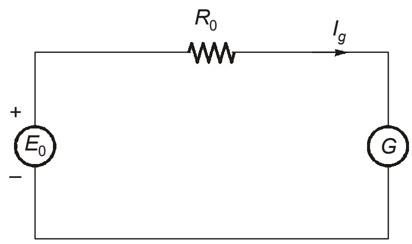
and

$$\frac{R_1}{\omega C_x} = \frac{R_2}{\omega C_3}$$

$$\Rightarrow \qquad C_x = \frac{C_3R_1}{R_2} = \frac{10\times 20}{30} = 20/3\ \text{pF}$$

29. (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.

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

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

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

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,

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

$$\therefore \qquad Q = 4.95\ \text{k}\Omega$$

30. (c)

$$\text{Resolution} = 0.01\% = \frac{0.01}{100} = \frac{1}{10000}$$

$$\frac{1}{2^n} = \frac{1}{10000}$$

$\therefore$ Minimum number of bits, $n = 14$ as $2^{14} = 16384$

(we cannot choose $n = 13$ as $2^{13} = 8192$. Which is less than 10000)

$$\text{Analog value of LSB} = \frac{1}{2^n} \times 10 = \frac{1}{2^{14}} \times 10$$

$$= \frac{1}{16384} \times 10\text{ V} = 610.4\ \mu\text{V}$$

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