BYJU'S
EXAM PREP

GATE 2023

Instrumentation Engineering

Questions & Solutions

Memory Based

GATE 2023 Instrumentation Engineering: Major Highlights

- **Overall Difficulty Level:** Moderate to Tough
- **Theoretical and Numerical weightage:** Equal weightage
- **MSQ weightage:** 1
- **NAT weightage:** 33
- **MCQ weightage:** 31
- **Questions from** Electrical Circuits was easy.
- **High Weightage for** Analog Electronics and Signals and Systems.

GATE 2023 Instrumentation Engineering: Comparison with last 3 Years' Data

GATE IN	2023	2022	2021	2020
MCQ	31	34	29	30
MSQ	1	5	3	0
NAT	33	26	33	35

GATE 2023 Instrumentation Engineering: Subject-Wise Question Distribution

S.No.	Subject	2023	2022	2021	2020
1	Digital Electronics	7	5	8	4
2	Signals & Systems	5	5	5	5
3	Electrical Circuits	7	5	0	3
4	Control Systems	7	5	5	10
5	Sensor & Industrial Instrumentation	2	7	8	8
6	Measurements	6	6	6	8
7	Communication Systems	1	3	3	0
8	Analog Electronics	6	6	3	4

9	Optical Instrumentation	2	2	2	2
10	Process Control Instrumentation	0	1	1	0
11	Electricity and Magnetism	1	1	4	0
12	Electric Machine	2	1	3	0
13	Engineering Mathematics	9	8	7	11
14	General Aptitude	10	10	10	10
Total Qs		**65**	**65**	**65**	**65**

GATE 2023 Instrumentation Engineering: Subject-Wise Question Distribution

Subject	NAT	MSQ	MCQ	Total
Digital electronics	0	0	7	7
Signals and Systems	2	0	3	5
Electric Circuits	7	0	0	7
Control Systems	4	1	2	7
Sensor & Industrial Instrumentation	2	0	0	2
Measurements	2	0	4	6
Communication Systems	1	0	0	1
Analog Electronics	5	0	1	6
Optical Instrumentation	1	0	1	2
Process Control Instrumentation	0	0	0	0
Electricity and Magnetism	1	0	0	1
Electrical Machines	2	0	0	2
Engineering Mathematics	2	0	7	9
General Aptitude	0	0	10	10
Total	**29**	**1**	**35**	**65**

Section-A: General Aptitude

1. Disagree: Protest :: Agree: ____.

A. Pretext
B. Refuse
C. Refute
D. Recommend

Ans. **

Sol: It your disagree by someone, you will protest him/her.

It you agree by someone, you will recommend him.

If you give pretext for any condition → given excuses.

When you refute some body, you disagree someone with very high intensity.

2. Residency is a famous housing complex with many well-established individuals among its residents. A recent survey conducted among the residents of the complex revealed that all of those residents who are well established in their respective fields happen to the academicians. The survey also revealed that most of these academicians are authors of some best-selling books. Based only on the information provided above, which one of the following statements can be logically inferred with certainty?

A. Some authors of best-selling books are residents of the complex who are well-established in their fields.

B. All academicians residing in the complex are well establishing in their fields.

C. Some residents of the complex who are well established in their fields are also authors of some best-selling books.

D. Some academicians residing in the complex are well established in their fields.

Ans. **

Sol:

Option D is the possible one.

Section-B: Technical

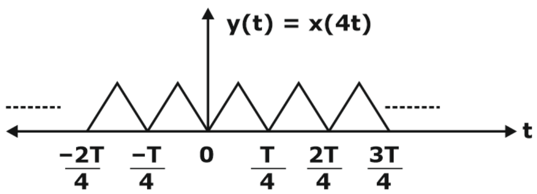
1. Let y(t) = x(4t), what x(t) is a continuous time periodic signal with fundamental period of 100 sec. The fundamental period of y(t) is _____ sec.

[NAT]

Ans. 25

Sol. y(t) = x(4t)

T = 100 sec



Fundamental period of

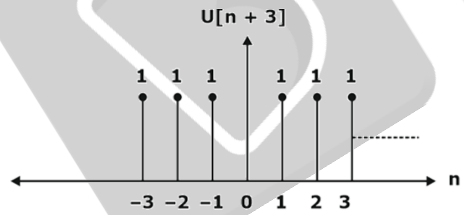
$$y(t) = \frac{T}{4} = \frac{100}{4} = 25 \text{ sec}$$

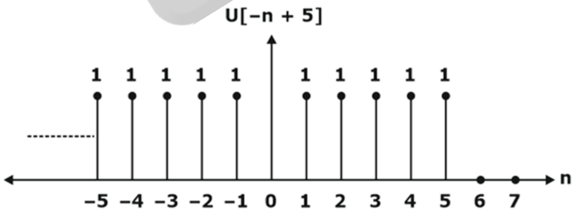
2. Consider the discrete time signal x(n) = U(−n + 5) − U(n + 3) where $U(n) = \begin{cases} 1; & n \ge 0 \\ 0; & n < 0 \end{cases}$ The smallest 'n' for which x(n) = 0 is _____ .

[NAT]

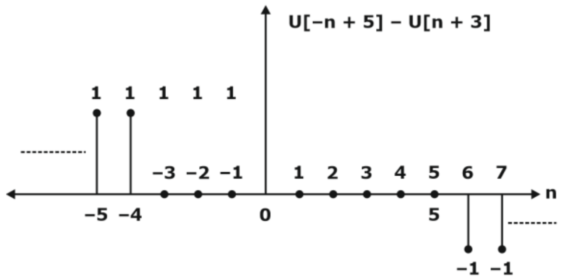
Ans. −3

Sol. x[n] = U[−n + 5] − U[n + 3]





$$U[n] \xrightarrow[5]{adv} U[n+5] \xrightarrow{fold} U[-n+5]$$



for smallest n = −3

⇒ x[n] = 0

3. The impulse response of an LTI system is h(t) = δ(t) + 0.5 δ(t − 4), where δ(t) is the continuous time unit impulse signal. If the input signal $x(t) = \cos\left(\frac{7\pi}{4}t\right)$ the output is

A. $0.5\sin\left(\frac{7\pi}{4}t\right)$

B. $1.5\sin\left(\frac{7\pi}{4}t\right)$

C. $0.5\cos\left(\frac{7\pi}{4}t\right)$

D. $10.5\cos\left(\frac{7\pi}{4}t\right)$

[MCQ]

Ans. C

Sol. h(t) δ(t) + 0.5 δ(t − 4)

& $x(t) = \cos\left(\frac{7\pi}{t}\right)$

⇒ y(t) = x(t) * h(t)

$$Y(t) = \cos\left(\frac{7\pi t}{4}\right) * \delta(t) + 0.5\cos\left(\frac{7\pi t}{4}\right) * \delta(t-4)$$

$$= \cos\left(\frac{7\pi t}{4}\right) + 0.5\cos\left(\frac{7\pi}{4}(t-4)\right)$$

$$= \cos\left(\frac{7\pi t}{4}\right) + 0.5\cos\left(\frac{7\pi t}{4} - 7\pi\right)$$

$$= \cos\left(\frac{7\pi t}{4}\right) + 0.5\left(-\cos\frac{7\pi t}{4}\right)$$

$$= 0.5\cos\left(\frac{7\pi t}{4}\right)$$

4. The Laplace transform of the continuous time signal $x(t) = e^{-3t}u(t-5)$ is _____ u(t) denotes the continuous time unit step signal

[MCQ]

A. $\frac{e^{-5s}}{s+3}, Real\{s\} > -3$

B. $\frac{e^{-5(s+3)}}{s+3}, Real\{s\} > -3$

C. $\frac{e^{-5(s-3)}}{s+3}, Real\{s\} > -3$

D. $\frac{e^{-5(s-3)}}{s-3}, Real\{s\} > -3$

Ans. B

Sol. $x(t)\ e^{-3t}\ u(t-5)$

$$e^{-3t} \cdot u(T) \longleftrightarrow \frac{1}{s+3}$$

$$e^{-3t(t-5)} \cdot u(t-5) \longleftrightarrow e^{-5s}\frac{1}{(s+3)}$$

$$e^{-3t} \cdot u(t-5) \longleftrightarrow \frac{e^{-5s}}{e^{15}}\frac{1}{s+3}$$

$$= \frac{e^{-5(s+3)}}{s+3}, Real\{s\} > -3$$

5. A system has transfer function $\frac{y(s)}{x(s)} = \frac{s-\pi}{s+\pi}$. Let u(t) be the unit step function. The input x(t) that result in a steady state output y(t) = sin πt is _____.

[MCQ]

A. x(t) = cos(πt + π/4)u(t)

B. x(t) = sin(πt − π/2)u(t)

C. x(t) = sin(πt + π/2)u(t)

D. x(t) = sinπt u(t)

Ans. B

Sol. Given output y(t) = sinπt

$$H(s) = \frac{y(s)}{X(s)} = \frac{s-\pi}{s+\pi}$$

$$\omega = \pi,\ H(j\omega) = \frac{j\omega-\pi}{j\omega+1} = \frac{-1+j}{1+j}$$

$|H(j\omega)| = 1$

$\angle H(j\omega) = 180 - \tan^{-1}(1) - \tan^{-1}(1)$

$= \pi/2$

So input $= \sin\left(\pi t - \frac{\pi}{2}\right)$

6. Number of zeros of polynomial $P(s) = s^3 + 2s + 5s + 80$ in right half plane is _____ .

[NAT]

Ans. 2

Sol.

s^2	1	5
s	2	80
s^1	−35	0
s^0	80	0

No. of sign changes = No. of zeros in right hand side = 2

7. The number of times the Nyquist plot of $G(s)\,H(s) = \frac{(s-1)(s-2)}{2(s+2)(s+1)}$ encircles the origin is _______ .

[NAT]

Ans. 2

Sol. $G(s)\,H(s) = \frac{2(s-1)(s-2)}{2(s+1)(s+2)}$

N, (0, 0) = Z − P (or) P − Z based as Nyquist contour

Z = zeroes of GH in right hand side = 2

P = poles of GH in right hand side = 0

N = 2 – 0

N = 2

8. The phase margin of the transfer function $G(s) = 2(1-s)/(1+s)^2$ is ______

[NAT]

Ans. 0

Sol. $G(s) = \frac{2(1-s)}{(1+s)^2}$

$$G(j\omega) = \frac{2(1+j\omega)}{(1+j\omega)^2}$$

$$|G(j\omega)| = \frac{2\sqrt{1+\omega^2}}{(1+\omega^2)} = \frac{2}{\sqrt{1+\omega^2}}$$

$$\omega_{gc} \Rightarrow \frac{2}{\sqrt{1+\omega^2}} = 1$$

$1 + \omega^2 = 4$

$\omega_{gc} = \sqrt{3}$

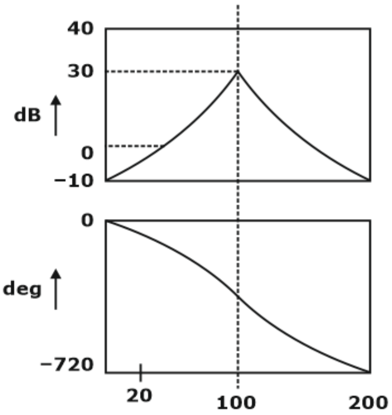
$\angle G(j\omega)$ – $\tan^{-1}(\omega)$ – $2\tan-1(\omega)$ = $-3\tan^{-1}(\omega)$

$\angle G(j\omega)$ at $\omega = \omega_{gc}$ = $-3\tan-1 - 3\tan^{-1}(\sqrt{3})$

= 180°

∴ So, phase margin = 180° – 180° = 0°

9. The magnitude and phase plot shown in figure match with the transfer function _______ .



[MCQ]

A. $\dfrac{100}{s^2 + 2s + 100}$

B. $\dfrac{10000}{s^2 + 2s + 10000}$

C. $\dfrac{10000}{s^2 + 2s + 10000} e^{-0.05s}$

D. $\dfrac{10000}{s^2 + 2s + 10000} e^{-0.05s \times 10^{-12s}}$

Ans. C

Sol. We can observe that, at ω = 100, there is a resonant peak and sudden drop of phase.

For 2nd order system, when we neglect exponential terms

$$\frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

At s = jω;

$$\frac{\omega_n^2}{(\omega_n^2 - \omega^2) + j2\xi\omega_n\omega}$$

$$\phi = -\tan^{-1}\left(\frac{2\xi\omega_n\omega}{\omega_n^2 - \omega^2}\right)$$

At $\omega \to 0$. $\phi = 0°$

$\omega \to \infty$ ϕ −180°

If we look into phase plot, plot goes till – ∞

This implies at $\omega \to \infty$, phase is not −180°

This happens due to the added exponential terms.

∴ Option A & C are only possible & they here same magnitude response.

At ω = 100, $e^{-30.05\times100} = e^{-35}$; $\phi \approx 280°$

Actually at $\omega = \omega_n$, Phase = 90°

∴ 90° + 280° = 370 approximately matching.

10. Induction of a coil is measured as 10 mH using are coil. The LCR meter uses a sinusoidal excitation at 10 kHz. If a pure copper sheet is brought near the coil, the same LCR meter will read ___?

[MCQ]

A. more than 10 mH

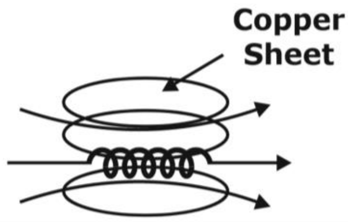
B. less than 10 mH

C. less than 10 mH initially and then stabilizes to more than 10 mH

D. 10 mH

Ans. A

Sol.



Due to presence of copper sheet, the reluctance around the coil reduces, which leads to increase in flux linkage and inductance too.

11. Capacitance C of a parallel plate structure is calculated as 20 pF using $C = \dfrac{\varepsilon_0\varepsilon_r A}{d}$ where ε_0 is permittivity of free space, ε_r is the relative permittivity of the dielectric. A is the area of overlapping of electrodes and d is measured using an LCR meter. If meter is assumed to be ideal and it introduces no error due to cable. Capacitance, which one of the following reading is likely to be correct ?

[MCQ]

A. 12.5 PF B. 20 PF

C. 20.5 PF D. 10 PF

Ans. B

Sol. Given the capacitance of a parallel plate capacitor is 20 pF.

Now, an LCR bridge is used to measured the capacitance of the above capacitor. Then the reading will be 20 pF only since, the meter is ideal and errors free.

12. Five measurements are made using a weighing machine, and the reading are 80 kg, 79 kg, 81 kg, 79 kg. The sample standard devaluation of measurement is _______ kg.

[NAT]

Ans. 1

Sol. mean $= \dfrac{80+79+81+79+81}{5} = 80$

deviation's

$d_1 = 80 - 80 = 0$

$d_2 = 79 - 80 = -1$

$d_3 = 81 - 80 = 1$

$d_4 = 79 - 80 = -1$

$d_5 = 81 - 80 = 1$

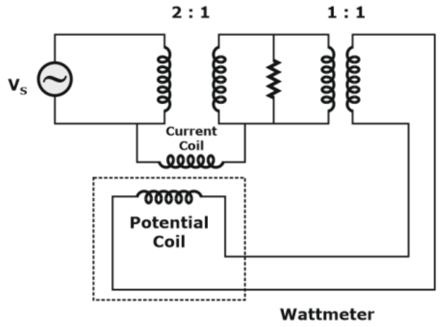
Standard deviation

$$S = \sqrt{\frac{d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2}{n-1}}$$

$$= \sqrt{\frac{0^2 + 1^2 + 1^2 + 1^2 + 1^2}{5-1}}$$

$$= \sqrt{\frac{4}{4}} = 1$$

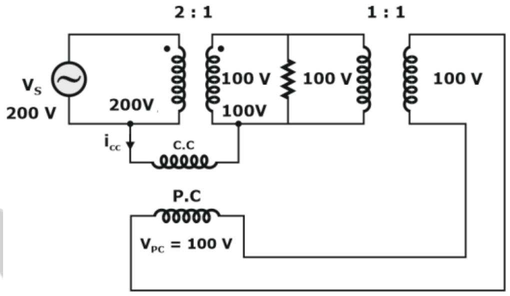
13. The full scale range of wattmeter shown in circuit is 100 W. The turn ratio of the individual transformer are indicated in figure. The rms value of AC source voltage V_s is 200 V. The wattmeter reading will be ______ W.



[NAT]

Ans. 0

Sol.



As the current coil does't have a closed path, there won't be any current [$i_{CC} = 0$] even though potential difference exists.

Wattmeter reading,

$W = V_{PC}\, i_{CC} \cos \angle V_{pc}\ \&\ i_{CC}$

$= 100 \times 0 \times \cos \phi$

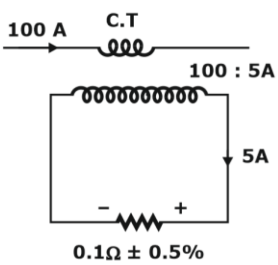
$= 0$

14. A 1.999 V true RMS 3½ digit multimeter has an accuracy of ± 0.1%. of reading ± 2 digit. It is used to measure 100 A (RMS) current flowing through a line using 100 : 5 ratio, class 1 current transformer with a burden of 0.1 Ω ± 5 %. The worst case absolute error in multimeter output is ______ mV.

[NAT]

Ans. 4

Sol.



$V_m = 5 \times [0.1 \pm 0.5\%]$

$V_m = 0.5 \pm 0.5\% = \pm 2.5$ mV

Sensitivity = Resolution × Range

$= \frac{1}{10^3} \times 2$

$= 2 \times 10^{-3}$

= 0.002 Volts.

The multimeter has an accuracy of ± 0.1% of reading ± 2 digits.

$\therefore \ \% \ \varepsilon = \left[\pm \frac{0.1}{100} \text{reading} \pm 2 \text{ dits} \right]$

$= \left[\pm \frac{0.1}{100} (0.5 \pm +0.5\%) \pm 2 \times 0.002 \right]$

$= \left[\pm \frac{2.5 \times 10^{-4}}{100} \pm \frac{0.4}{100} \right]$

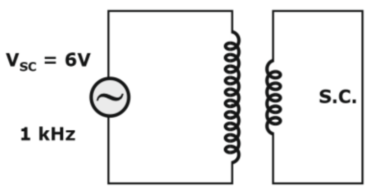
= ± 0.4% (or) 4 mV

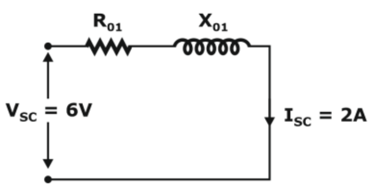
15. Short-circuit test is conducted on a single-phase transformer by shorting its secondary. The frequency of input voltage is 1 kHz. The corresponding wattmeter reading, primary current & primary voltage are 8w, 2A & 6V respectively. Assume that the no-load losses and the no-load currents are negligible, the core has linear magnetic characteristics. Keeping the secondary shorted the primary is connected to a 2V(rms), 1 kHz sinusoidal source in series with $\frac{2}{2\pi\sqrt{5}}$ mF capacitor. The primary current (rms) will be ______ A. (round off to 2 decimal)

[NAT]

Ans. 1

Sol.





Wattmeter reading, w = 8w = Cu. Losses

Ammeter reading, I_{SC} = 2A

Voltmeter reading, V_{SC} = 6 V

$W_{SC} = I_{SC}^2 \times R_{01}$

$8 = (2)^2 \times R_{01}$

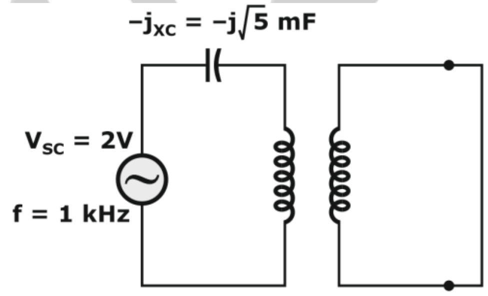
$R_{01} = 2 \ \Omega$

$Z_{01} = \frac{V_{SC}}{I_{SC}} = \frac{6}{2} 3\Omega$

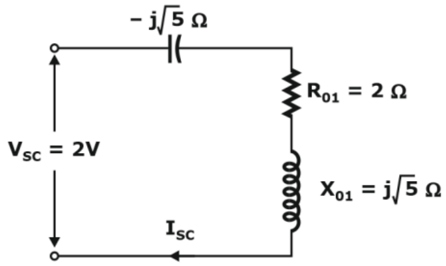
Now,

$X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} = \sqrt{3^3 - 2^2} = \sqrt{5} = 2.23 \ \Omega$

If, V_{SC} = 2V, f = 1 kHz (Unchanged) and a capacitor of $\frac{1}{2\pi\sqrt{5}}$ mF is connected in primary as shown below, Then the primary current will be



$\frac{1}{j\omega C} = \frac{-j}{2\pi \times 1 \times 10^3 \times \frac{1}{2\pi\sqrt{5} \times 10^{-3}}} = -j\sqrt{5}\Omega$



$I_{SC} = \frac{2}{2 - j\sqrt{5} \times j\sqrt{5}}$

= 1 Amp.

16. Force per unit length between two infinitely long parallel conductors, with a gap of 2cm between them is 10 μN/m, when the gap is doubled, force per unit length will be___ μN/m.

[NAT]

Ans. **

Sol: Force per unit length between two infinitely long parallel conductor is given by,

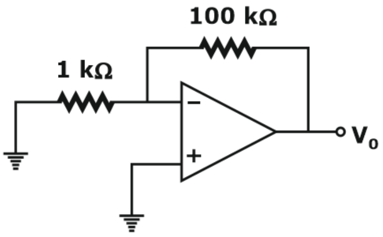
$$\frac{F}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

$$\left(\frac{F}{\ell}\right) \times \frac{1}{d}$$

If θ (gap between conductors) is doubled then force per unit length gets halved.

Hence answer is 5 μN/m.

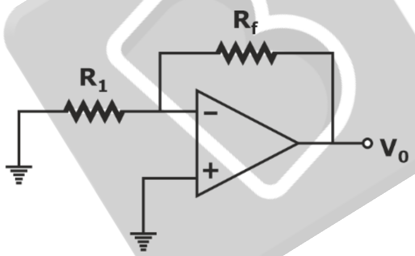
17. Ideal op-amp shown, except it has input bias current of 1 nA and input offset voltage 10 μV. Resulting worst case output voltage ± _____ μV



[NAT]

Ans. 1.01

Sol.



Input bias current

$V_{01} = R_f I_{B1}$

$= 100 \times 10^3 \times 1 \times 10^{-9}$

$= 1 \times 10^{-4}$ volt

Input offset voltage

$$V_{02} = \left(1 + \frac{R_f}{R_1}\right) V_{io}$$

$$= \left(1 + \frac{100}{1}\right) \times 10^3 \times 10 \times 10^{-6}$$

$= 1.01$ volt

Total

$V_0 = V_{01} + V_{02}$

$= 1.01 + 10^{-4}$

$\cong 1.01$ volt

18. An LED emits light when it is ____ biased. A photodiode provides maximum sensitivity to light when it is ______ biased.

A. Reverse, forward

B. Forward, forward

C. Forward, reverse

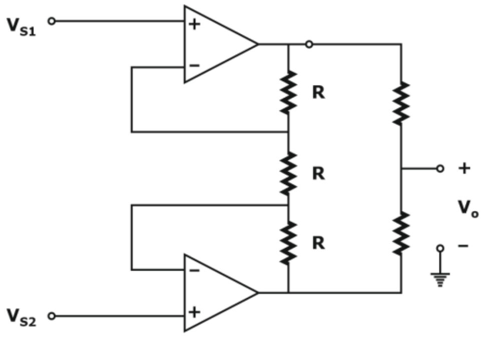
D. Reverse, reverse

[MCQ]

Ans. C

Sol. LED emits light when it is forward biased and photodiode provide maximum sensitivity when it is reverse biased.

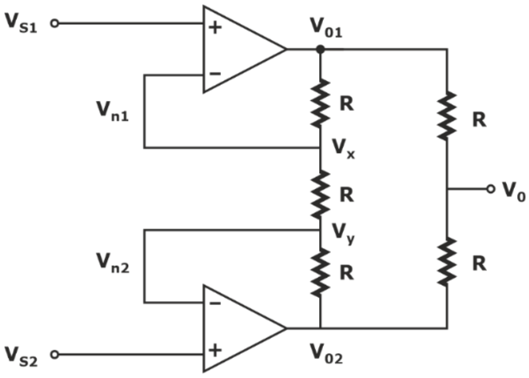
19. Om-amp in circuit is idea. The input signal are V_{S1} = 3+0.10sin(300t)V and V_{S2} = −2+0.11sin(300t)V. The average value of voltage V_o is _____ V.



[NAT]

Ans. 0.5

Sol.



$V_x = V_{n1} = V_{s1}$ $\quad V_y = V_{n2} = V_{s2}$

KCL as V_o $\quad \frac{V_o - V_{o1}}{R} + \frac{V_o - V_{o2}}{R} = 0$

$$\boxed{V_0 = \frac{V_{o1} + V_{o2}}{2}} \quad ...(1)$$

KCL at V_x

$$\frac{V_x - V_{o1}}{R} + \frac{V_x - V_y}{R} = 0$$

$2V_x - V_y - V_{o1} = 0$

$$\boxed{V_{o1} = 2V_x - V_y} \quad ...(2)$$

$V_{o1} = 2V_{S1} - V_{s2}$ $\quad ...(2)$

KCL at V_y.

$$\frac{V_y - V_x}{R} + \frac{V_y - V_{o2}}{R} = 0$$

$2V_y - V_x - V_{o2} = 0$

$V_{02} = 2V_y - V_x$ $\quad ...(3)$

Put (2) and (3) in (1)

$$V_o = \frac{2V_x - V_y + 2V_y - V_x}{2}$$

$$\boxed{V_o = \frac{V_x + V_y}{2}}$$

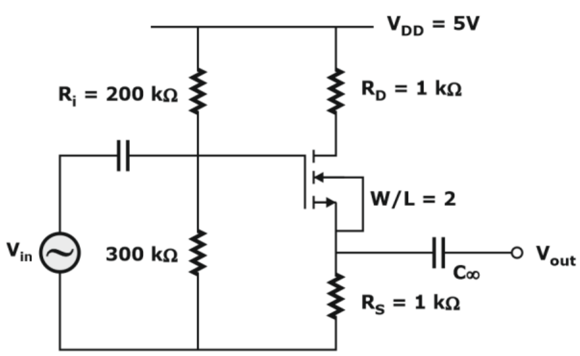
$$V_o = \frac{V_{s1} + V_{s2}}{2}$$

$$V_o = \frac{1}{2}\left[3 + 0.2\sin 300t + \left(-2 + 0.11\sin 300\right)\right]$$

$$= \frac{1}{2}\left[1 + 0.21\sin 300t\right]$$

$$\therefore V_{avg} = \frac{1}{2} = 0.5V$$

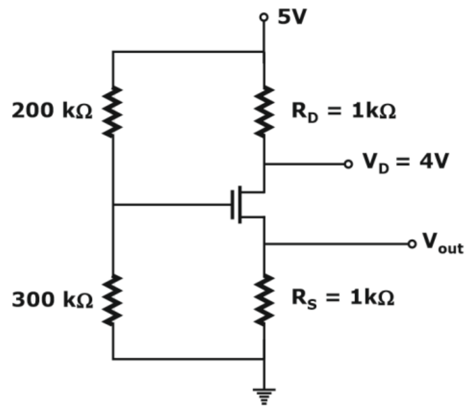
20. Figure below shows a feedback amplifier constructed using an nMOS transistor. Assume that $\mu_n C_{OX}$ = 1 mA/V^2, threshold voltage V_T = 1 V and W/L = 2. The bias voltage at the drain terminal is 4V. The capacitor C_∞ offer zero impedance once at signal frequency. The ratio V_{out}/V_{in} is _______ .



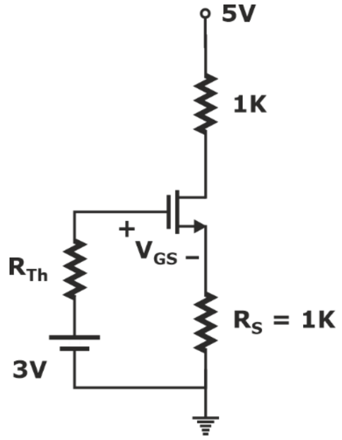
[NAT]

Ans. 0.90

Sol.



$$I_D = \frac{V_{DD} - V_D}{R_D} = \frac{5-4}{1} = 1\text{ mA}$$



$$V_{Th} = \frac{300}{200+300} \times 5 = 3V$$

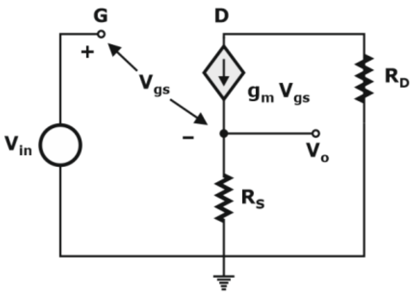
$3 = V_{GS} + I_D R_S$

$V_{GS} = 3 - I_D R_S = 3 - 1\times 1 = 2V$

$$\therefore g_m = K_n' \frac{W}{L}\left(V_{GS} - V_T\right)$$

$= 5\times 2\times[2-1]$

$= 10$ mA/V



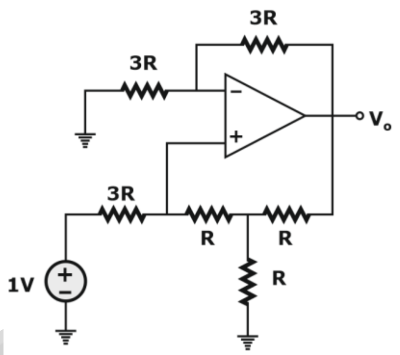
$V_{in} = V_{gs} + g_m V_{gs} R_s = (1+ g_m R_s) V_{gs}$

$V_o = I_m V_{gs} R_s$

$$\frac{V_o}{V_{in}} = \frac{g_m R_s}{1 + g_m R_s} = \frac{10 \times 1}{1 + 10 \times 1} = \frac{10}{11}$$

$$A_V = \frac{10}{11}$$

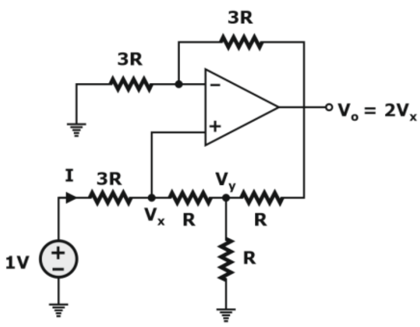
21. Op-amp is ideal find V_o = _____ V.



[NAT]

Ans. 2

Sol.



$$V_o = \left(1 + \frac{R_f}{R_1}\right) V_p \qquad ...(1)$$

$$\therefore V_o = \left(1 + \frac{3R}{3R}\right) V_x = 2V_x \qquad ...(2)$$

KCL at V_x

$$\frac{V_x - 1}{3R} + \frac{V_x - V_y}{R} = 0$$

$$\frac{V_x - 1 + 3V_x - 3V_y}{3R} = 0$$

$$\boxed{3V_y = 4V_x - 1} \qquad ...(3)$$

KCL at V_y.

$$\frac{V_y - V_x}{R} + \frac{V_y}{R} + \frac{V_y - 2V_x}{R} = 0$$

$3V_y = 3V_x$ ...(4)

from (3) and (4)

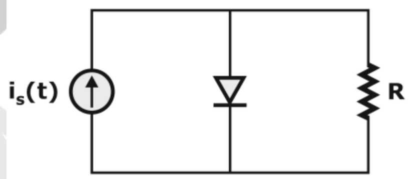
$3V_x = 4V_x - 1$

$4V_x - 3V_x = 1$

$V_x = 1$

$$\boxed{V_0 = 2V_x = 2V}$$

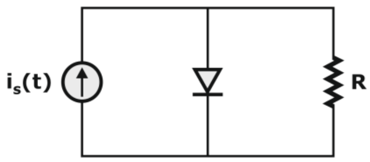
22. The diode in the circuit is ideal. The current source $i_s(t) = \pi\sin(3000\,\pi t)$. The magnitude of average current flowing through the resistor R is _____ mA.



[NAT]

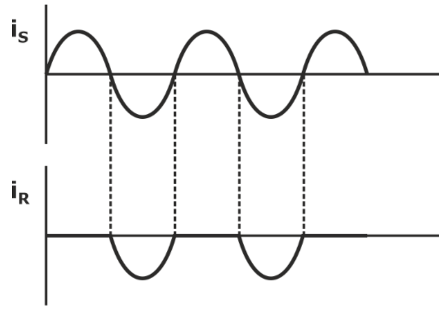
Ans. 1

Sol.



For $i_S > 0$, D is on $i_R = 0$

For $i_S < 0$, D is off.



$$i_{avg} = \frac{I_m}{\pi} = \frac{\pi}{\pi} = 1 \text{ mA}$$

23. A wire wound 'resistive potentiometer type' angle sensor with 72 turns is used in an application. The first turn of the potentiometer is connected to ground while its last turn is connected to 3.6 V. The width of the wiper cover two turns ensuring make before break. The output (wiper) voltage when the wiper on top of both the turns 35 and 36 is _____ V.

[NAT]

Ans. 0.1 V

Sol. Since wiper covers two turns, it spans over a total resistance of 2R.

(R is resistance of each turn)

Total resistance of the potentiometer can be $R_1 + R_2 + \ldots + R_n$

The first turn is connected to ground, so its resistance is zero. The last turn is connected to 3.6V. So, its resistance is

$$R_n = \frac{V}{I} = \frac{3.6}{I}\Omega$$

I is the current through potentiometer.

Since, potentiometer has 72 turns, the resistance of each turn can be calculated as

$$R = \frac{R_n}{72} = \frac{\frac{3.6}{I}}{72} = 0.05\ I$$

When wiper is on top of both turns 35 and 36, it spans over the resistance of turn 35 and 36, which is a total resistance of 2R.

The voltage at wiper is

$$V_{out} = \frac{2R}{\text{Total resistance}} \times 3.6V$$

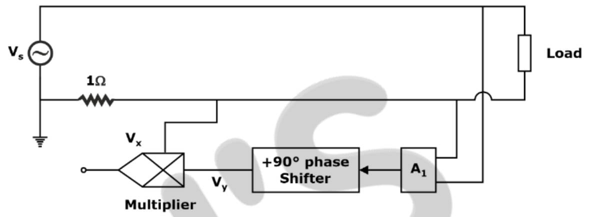
$$= \frac{2R}{R_1 + R_2 + \ldots + R_{72}} \times 3.6$$

$$V_{out} = \frac{2 \times 0.05I}{0.05I \times 72} \times 3.6$$

$$= 0.1\ V$$

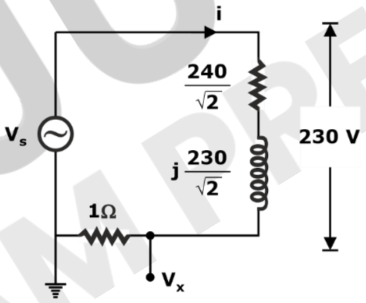
24. In the diagram shown, the freq. of the sinusoidal source voltage V_S is 50 Hz. The load voltage is 230 V (rms), & the load impedance is $\frac{230}{\sqrt{2}} + j\frac{230}{\sqrt{2}}\Omega$. The value of attenuator $A_1 = \frac{1}{50\sqrt{2}}$. The multiplier o/p voltage $V_0 = \frac{V_x V_y}{1V}$, where V_x & V_y are the inputs. The magnitude of the average value of the multiplier o/p V_0 is ______ V. (round off to 1 decimal)

[NAT]



Ans. 3.2 Volt

Sol.

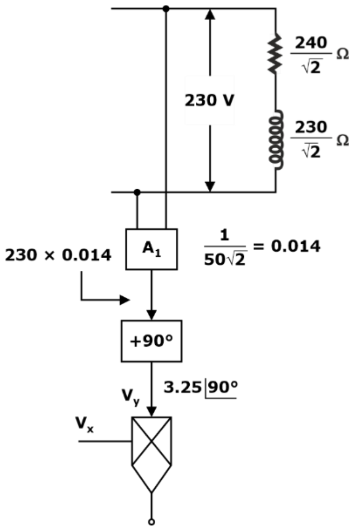


$$i = \frac{230}{\frac{230}{\sqrt{2}} + j\frac{230}{\sqrt{2}}}$$

$$i = 1\angle -45^\circ \text{ Amps}$$

$$V_x = i \times 1$$

$$= 4\angle -45^\circ \text{ volts}$$



$$V_0 = \frac{V_x\ V_y}{1}$$

$$= \frac{1\angle -45^\circ \times 3.25\angle 90^\circ}{1}$$

$$= 3.25\ \angle 45^\circ$$

$|V_0| = 3.25$ or 3.2 volts.

25. X is a discrete random variable which takes values 0, 1, 2. The probabilities are P(X = 0) = 0.25 and P(X = 1) = 0.5. with E[.] denoting the expectation operator, the value of E[X] – E[X^2] is ______.

[NAT]

Sol. Given:- X = {0, 1, 2}

p(X) = {0.25, 0.5, 0.25}

For a discrete random variable, mean value is given by,

$$E[X] = \sum_{i=0}^{\infty} X_i\ p(X_i)$$

$$= 0 \times \frac{1}{4} + 1 \times \frac{1}{2} + 2 \times \frac{1}{4}$$

$$= 1$$

For a discrete random variable, mean square value is given by,

$$E[X] = \sum_{i=0}^{\infty} X_i^2\ p(X_i)$$

$$= (0)^2 \times \frac{1}{4} + (1)^2 \times \frac{1}{2} + (2)^2 \times \frac{1}{4}$$

$$= \frac{3}{2}$$

The value of E[X] – E[X^2] $= 1 - \frac{3}{2}$

$$= -0.5$$

26. In a P-i-n photodiode, a pulse of light containing 8 × 10^{12} incident photous at wavelength γ_0 = 1.55 μm gives rise to an average 4 × 10^{12} electron collection at the terminals of the device. The quantum efficiency of the photodiode at this wavelength is _____ %.

A. 80

B. 62.5

C. 54.2

D. 50

[MCQ]

Ans. 50

Sol. % Quantum efficiency

$$= \frac{\text{No. of electrons collection}}{\text{No. of incident photons}} \times 100$$

$$= \frac{4 \times 10^{12}}{8 \times 10^{12}} \times 100$$

$$= 50\%$$

27. A silica glass fibre has a core refractive index of 1.47 and a cladding refractive index of 1.44. If the cladding is completely stripped out and core is dipped in water having a refractive index of 1.33, the numerical aperture of modified fiber is _____.

[NAT]

Ans. 0.458

Sol. Original numerical aperture of the fiber with cladding is:

$$NA = \sqrt{n_1^2 - n_2^2}$$

where, n_1 = Refractive index of core

n_2 = Refractive index of cladding

After the cladding is completely out and the core is dipped in water with a refractive index of 1.33, the new numerical aperture becomes:

$$NA = \sqrt{(1.47)^2 - (1.33)^2}$$

$$= 0.458$$

28. Match

I. $X \oplus x$	p. 1
II. $X \oplus \bar{X}$	q. 0
III. $X \oplus 0$	r. $\bar{x}$
IV. $X \oplus 1$	s. X

[MCQ]

Ans. I - q, II – p, III – s, IV - r

Sol. $X \oplus x = X\bar{X} + \bar{X}\,x = 0$

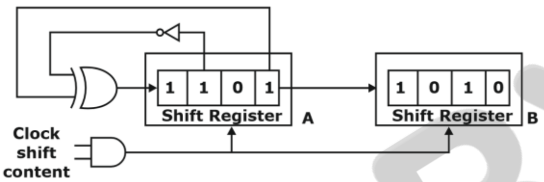
$X \oplus \bar{x} = XX + \bar{X}\,\bar{Y} = 1$

$X \oplus 0 = x.1 + \bar{X} \cdot 0 = x$

$X \oplus 1 = x.0 + \bar{X} \cdot 1 = \bar{x}$

29. In the circuit shown, the initial binary content of shift register A is 1101 and that of shift register B is 1010. The shift register are +ve edge triggered, and gates have no delay.

When the shift control is high, what will be the binary content of the shift register A and B after 4 clock pulse



[MCQ]

A. A = 1101, B = 1101

B. A = 0101, B = 1101

C. A = 1010, B = 1111

D. A = 1110, B = 1001

Ans. B

Sol. Content of shift register A → 1 1 0 1

Content of shift register B → 1 0 1 0

Serial input = $\bar{Q}_2 \oplus Q_0$

A Q_3	Q_2	Q_1	Q_0	B			
1	1	0	1	1	1	0	1
1	1	1	0	1	1	1	0
0	1	1	1	0	1	1	1
1	0	1	1	0	1	0	1
0	1	0	1	1	1	0	1

after 4 clock pulses.

∴ A = 0 1 0 1, B = 1 1 0 1

30. The simplified of Boolean Function F(W, X, Y, Z) = Σ(4, 5, 10, 11, 12, 13 14, 15) with minimum no. of terms and smallest number of literals in each term is _______

A. $WX + WY + X\bar{Y}$

B. $X\bar{Y} + WY$

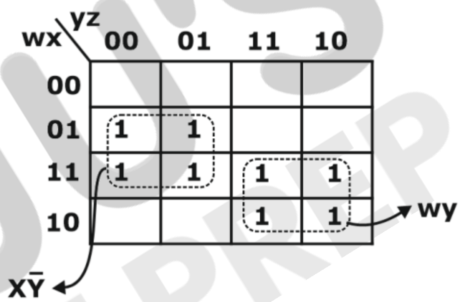
C. $\bar{X}Y + \bar{W}\bar{Y}$

D. $WX + \bar{W}X\bar{Y} + W\bar{X}Y$

[MCQ]

Ans. B

Sol. F(w, x, y, z) = Σm(4, 5, 10, 11, 12, 13, 14, 15)



Minimum expression $f = wy + x\bar{y}$

31. The table shows the Present state Q(t), next state Q(t + 1) and the control input in a flip flop Identify the flip flop

Q(t)	Q(t+1)	Input
0	0	0
0	1	1
1	0	1
1	1	0

[MCQ]

A. S R flip flop

B. T flip flop

C. D flip flop

D. JK flip flop

Ans. B

Sol.

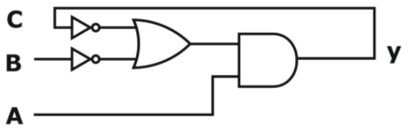
Q(t)	Q(t+1)	Input
0	0	0
0	1	1
1	0	1
1	1	0

When input = 1, $Q(t+1) = \bar{Q}(t)$

Input = 0, Q(t + 1) = Q(t)

This behaviour is of T-Flip flop

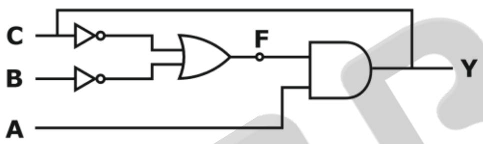
32. Given, A = B = 1, Assume AND, OR & NOT given have Propagation delay of 10 ns, 5 ns respectively, All lines have zero Propagation delay. Given that C = 1, when the circuit is turned on the frequency of steady state oscillation of output is



[NAT]

Ans. 20 MHz

Sol.



Given

A = B = 1; AND delay = 10 ns

C = Y OR delay = 10 ns

NOT delay = 5 ns

$f = \bar{B} + \bar{C} = \bar{Y}$

$Y = AF = \bar{Y}$

$t_{pd} = 25\text{ ns}$

Time period = 50 ns

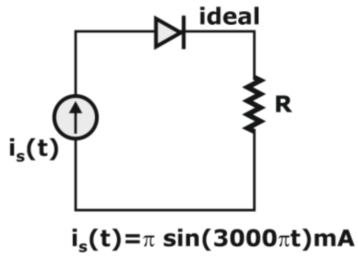
$\text{frequency} = \frac{10^3 \times 10^6}{50} = 20\text{ MHz}$

33. Diode in circuit is ideal. Current source $i_s(t)$ = π sin (300 πt) mA. The magnitude of the average current flowing through the resistor R is __________ mA.

[NAT]

Ans. 1

Sol.

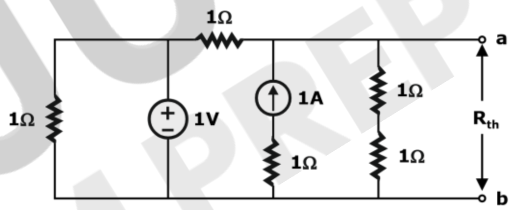


Average Current $\frac{I_m}{\pi}$

$= \frac{\pi}{\pi}$

= 1mA

34. Find Thevenin equivalent resistance across terminal 'a' and 'b' is __________ Ω.

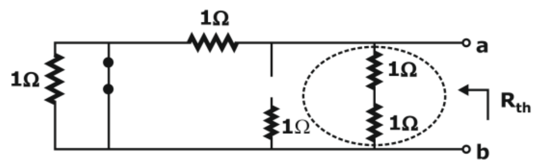


[NAT]

Ans. 0.67

Sol. Independent voltage source get short circuited

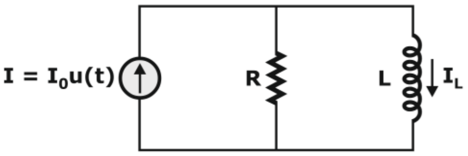
Independent current source get open circuited



$R_{th} = ((1+1)\Omega)\,||\,1\Omega$

$= (2\Omega)\ ||\ (1\Omega) = \frac{2 \times 1}{2+1} = \frac{2}{3}\Omega$

35. The R-L circuit with R = 10 kΩ & L = 1 mH is excited by a step current I_0 u(t), at t = 0^-, then is a current $I_L = \frac{I_0}{s}$ flowing through the inductor. The minimum then taken for the current through the inductor for reach 99% of its final value is ___________ μs.



[NAT]

Ans. 0.43

Sol. $i(0) = 0$

$i(\infty) = I_0$

$\tau = \frac{L}{R} = \frac{10^{-3}}{10^4} = 10^{-1}$

$i(\tau) = i(\infty) + [i(0) - i(\infty)]e^{-t/\tau}$

$i(t) = I_0 + \left[0 - \frac{I_0}{5}\right]e^{-t/\tau}$

For reaching i(t) to 99% of $i(\infty)$

$0.99 I_0 = I_0\left[1 - \frac{4e^{-t/\tau}}{5}\right]$

$\frac{4}{5}e^{-t/\tau} = 1 - 0.99$

$= 0.01$

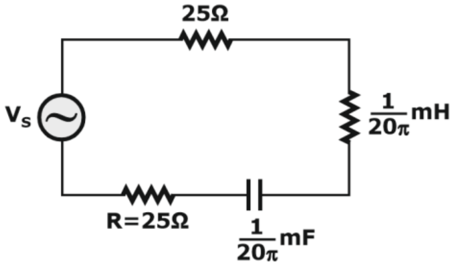
$+t = -\tau \ln\left[\frac{0.05}{4}\right]$

$t = 4.38\tau$

$= 4.38 \times 10^{-7}$

$t = 0.43$ μ sec

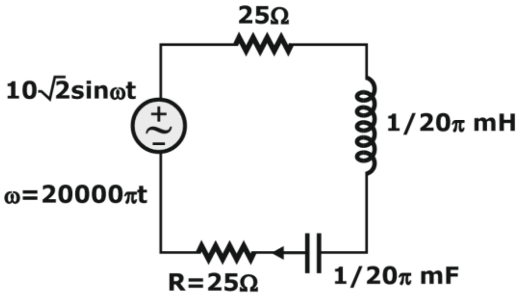
36. Voltage source $V_s = 10\sqrt{2}$ sin(210000πt) V has on internal resistance of 50 Ω. The RMS value of the current through R is _________ mA.



[NAT]

Ans. 0.1

Sol.



$\omega_0 = \frac{1}{\sqrt{LC}}$

$= \frac{1}{\sqrt{\left(\frac{1}{20\pi}10^{-3}\right)\left(\frac{1}{20\pi}\times 10^{-3}\right)}}$

$\omega_0 = 20\pi \times 10^3$

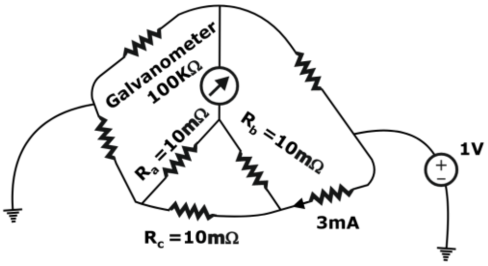
Given that $\omega = 20\pi \times 10^3$

So, R and L effect get nullified.

$V_{rms} = \frac{10\sqrt{2}}{\sqrt{2}} = 10V$

$I_{rms} = \frac{10}{100} = 0.1$

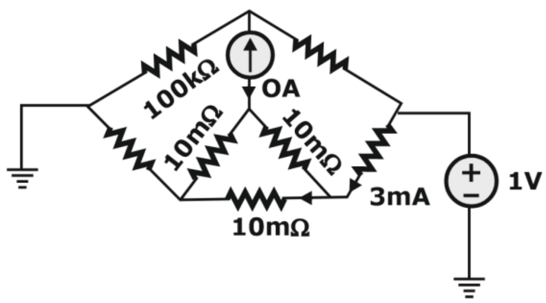
37. When the bridge given below is balanced, the current through resistor R_a is ________ mA.



[NAT]

Ans. 1

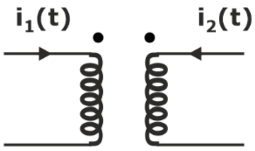
Sol.



Current through $R_a = 3mA\left[\frac{100m\Omega}{30m\Omega}\right]$

I = 1mA

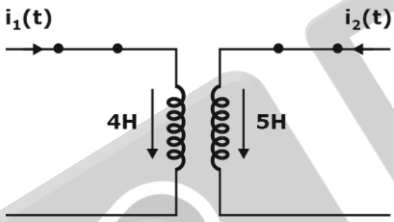
38. A sinusoidal current $i_1(t)$ = 1 sin (200 πt) mA is flowing through a 4H inductor which is mutually coupled to another 5H inductor carrying $i_2(t)$ = 2 sin(200 πt) mA as shown in fig. The coupling coefficient between the inductor is 0.6. The peak energy stored in the circuit is _____ μJ.



[NAT]

Ans. 17.37

Sol.



Given $i_1(t)$ = sin(200πt)mA

$I_2(t)$ = 2sin[200πt]mA

k = 0.6

Energy, E

$$= \frac{1}{2}L_1i_1^2(t) + \frac{1}{2}L_2i_2^2(t) + M\, i_1(t)\, i_2(t)$$

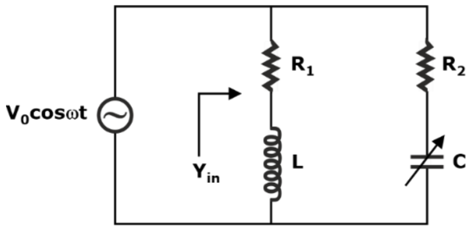
$$0.6 = \frac{M}{\sqrt{L_1L_2}}$$

$$M = 1.2\sqrt{5}$$

$$E = \frac{1}{2}(4)(1) + \frac{1}{2}(5)(4) + 1.2\sqrt{5}[2]$$

$$= [2 + 10 + 1.2\sqrt{2}]\ \mu J = 17.37\mu J$$

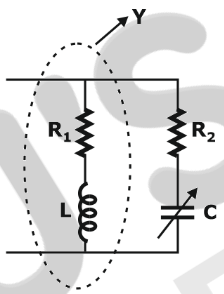
39. ω = 100 π rad/s, $R_1 = R_2 = 2.2\Omega$ & L = 7mH. the capacitance C for which Y_{in} is purely real is ______ μf.



[NAT]

Ans. 0.78

Sol.



Given that,

ω = 100π

$R_1 = R_2 = 2.2\Omega$

L = 7mH

Admittance

$$y = \frac{1}{2.2 + j(100\pi)[7\times10^{-3}]} + \frac{1}{2.2 - \frac{j}{100\pi(c)}}$$

Equating imaginary part = 0

$$0 = \frac{-j[100\pi\times7\times10^{-3}]}{\sqrt{(2.2)^2 + (0.1\pi(7))^2}} + \frac{j/100\pi c}{\sqrt{(2.2)^2 + \left(\frac{1}{100\pi c}\right)^2}}$$

let $x = \frac{1}{100\pi c}$

By solving we get

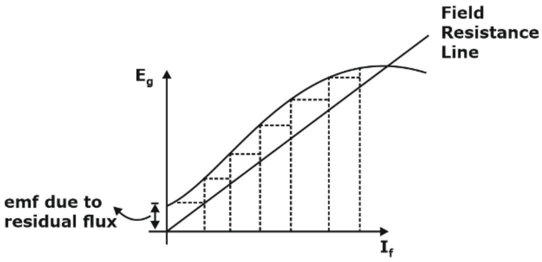
$$0.71 = \frac{1}{x^2(4.84 + x^2)} \Rightarrow \boxed{c = 0.78\,mF}$$

40. The no load steady state output voltage of a DC shunt generator is 200V when it is driven in clockwise direction at its rated speed. If the same machine is driven at the rated speed but in opposite direction, the steady state output voltage will be _______ V.

[NAT]

Ans. 0

Sol.



If the rotor is rotated in the opposite direction, the emf developed $\frac{L\, di_f}{dt}$ will neutralize the emf due to the residual flux. (Voltage buildup will be failed)
Hence, the steady state output Voltage will be zero.

41. What is line f(x), where $f(x) = x \sin \frac{1}{x}$.

A. Does not exist B. 1
C. 0 D. ∞

[MCQ, 1 Mark]

Ans. C

Sol. $\lim_{x \to 0} x \sin\left(\frac{1}{x}\right)$

Let $t = \frac{1}{x}$

$\lim_{t \to \infty} \frac{\sin t}{t} = \frac{\text{finite}}{\text{infinite}} = 0$

42. Consider the real valued function g(x) = max $\{(x - 2)^2, -2x + 7\}$
Where x ϵ (−∞, ∞). The minimum value attained by g(x) is _______

[NAT]

Ans. 1

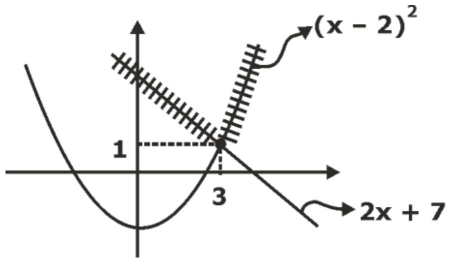
Sol. $(x - 2)^2 = -2x + 7$

$x^2 + 4 - 4x = -2x + 7$

$x^2 - 2x - 3 = 0$

$(x - 3)(x + 1) = 0$

$x = -1, +3$



$g(x) = \max\{(x - 2)^2, -2x + 7\}$

So, dotted/shaded area is curve of g(x)
So, minimum value = 1

43. $F(z) = \frac{1}{1 - Z}$, when expanded as a Power series around z = 2, would result in

$f(z) = \sum_{k=0}^{\infty} a_k (z - 2)^K$,

With the region of convergence (ROC) $|Z - 2| < 1$.
The coefficient a_K, k ≥ 0 re given by the expression.

[MCQ]

A. $\left(\frac{1}{2}\right)^K$ B. $(-1)^K$

C. $(-1)^{K+1}$ D. $\left(\frac{-1}{2}\right)^{K+1}$

Ans. B

Sol. $F(z) = \frac{1}{1 - z} = \frac{1}{1 - (z - 2 + 2)}$

$= \frac{1}{-1 - (z - 2)}$

$F(z) = -[1 + (z - 2)]^{-1}$

$F(z) = -[1 (z - 2) + (z - 2)^2 - (z - 2)^3 + ...]$

$= -1 + (z - 2) - (z - 2)^2 + (z - 2)^3 + ...$

For odd powers, coefficient is positive
Even powers, coefficient is negative
∴ $a_K = (-1)^{K+1}$

44. Choose solution set S corresponding to the system of 2 equations.
x − 2y + z = 0, x − z = 0. [R denote set or real numbers].

[MCQ]

A. $S = \left\{ \alpha \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} + \beta \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix} \middle| \alpha, \beta \in R \right\}$

B. $S = \left\{ \alpha \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \alpha \in R \right\}$

C. $S = \left\{ \alpha \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} + \beta \begin{pmatrix} 2 \\ 1 \\ 2 \end{pmatrix} \middle| \alpha, \beta \in R \right\}$

D. $S = \left\{ \alpha \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix} \alpha \in R \right\}$

Ans. B

Sol. x – z = 0

x = z

∴ from x – 2y + z = 0

x – 2y + x = 0

y = 0

let $x = \alpha$ then $y = \alpha, z = \alpha$

$\therefore \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \alpha \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$

45. Rank of matrix A is 1. The ratio $\frac{\alpha}{\beta}$ is ________.

$A = \begin{bmatrix} 1 & 4 \\ -3 & \alpha \\ \beta & 6 \end{bmatrix}$

[NAT]

Ans. –8

Sol. $A = \begin{bmatrix} 1 & 4 \\ -3 & \alpha \\ \beta & 6 \end{bmatrix}$

Rank of A = 1

Means all 2 × 2 minors' determinant = 0

$\therefore \begin{vmatrix} 1 & 4 \\ -3 & \alpha \end{vmatrix} = 0 \quad \Rightarrow \alpha + 12 = 0$

$\alpha = -12$

and $\therefore \begin{vmatrix} -3 & \alpha \\ \beta & 6 \end{vmatrix} = 0 \quad \Rightarrow -18 - \alpha\beta = 0$

– 18 = –12 (β)

$\beta = \frac{3}{2}$

$\therefore \frac{\alpha}{\beta} = \frac{-12}{\frac{3}{2}} = -8$

***

GATE 2023 Instrumentation Engineering: Expected Cut-Of

Category	2021	2022	Expected 2023
General	36	42.4	43
OBC	32.4	38.1	39.5
SC/ST	24	28.2	30

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Surya (CS)


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