



# GATE 2024

# ELECTRICAL ENGINEERING

Exam held on  
**11/02/2024**  
(Afternoon  
Session)

Memory based  
**Questions  
& Solutions**



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### SECTION - A

### GENERAL APTITUDE

Q.1 If  $\frac{x}{y} = \frac{a+1}{a-1}$ , then  $(x^2 - y^2) : (x^2 + y^2) = \underline{\hspace{2cm}}$ ?

Ans.  $\left(\frac{-2a}{a^2+1}\right)$

Given:  $\frac{x}{y} = \frac{a-1}{a+1}$

$$\begin{aligned} x^2 - y^2 : x^2 + y^2 &= \frac{\left(\frac{x}{y}\right)^2 - 1}{\left(\frac{x}{y}\right)^2 + 1} \\ &= \frac{\left(\frac{a-1}{a+1}\right)^2 - 1}{\left(\frac{a-1}{a+1}\right)^2 + 1} = \frac{(a-1)^2 - (a+1)^2}{(a-1)^2 + (a+1)^2} \\ &= \frac{-4a}{2a^2 + 2} = \frac{-2a}{a^2 + 1} \end{aligned}$$

End of Solution

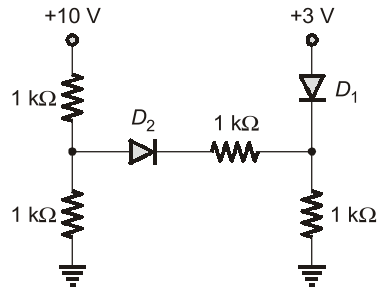


### SECTION - B

### TECHNICAL

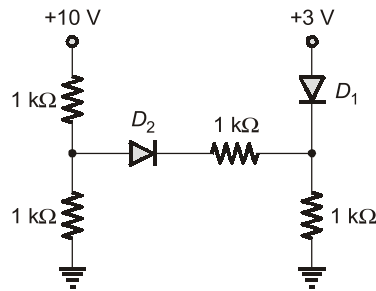
## Analog Electronics

Q.1 For the figure shown below, diodes are ideal

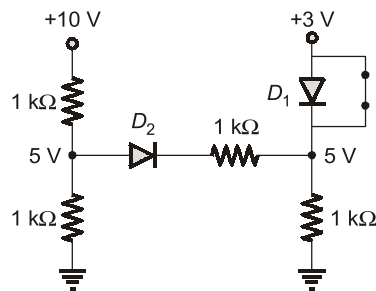


current flowing through diode  $D_1$  is \_\_\_\_mA.

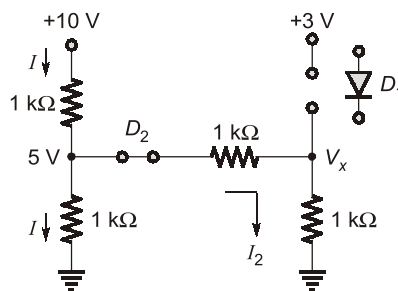
Ans. (1.67)

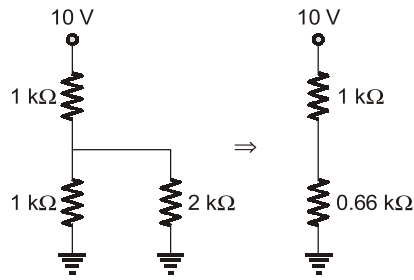


Assume  $D_2$  OFF



Tested :  $D_2$  ON  
Assume  $D_1$  OFF





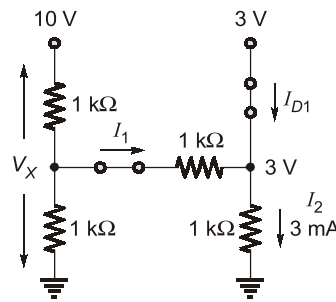
$$I = \frac{10}{1.66 \text{ K}} = 6.02 \text{ mA}$$

$$I_2 = I \times \frac{1 \text{ k}\Omega}{3 \text{ k}\Omega} = 6.02 \text{ mA} \times \frac{1}{3} = 2 \text{ mA}$$

Tested :  $D_1$  ON

$$V_x = 2 \text{ mA} \times 1 \text{ k}\Omega = 2 \text{ V}$$

States:  $D_1$  and  $D_2$  ON



$$\frac{V_x - 10}{1 \text{ k}\Omega} + \frac{V_x - 3}{1 \text{ k}\Omega} + \frac{V_x}{1 \text{ k}\Omega} = 0$$

$$3V_x = 13$$

$$V_x = \frac{13}{3} = 4.33 \text{ V}$$

$$I_1 + I_{D1} = I_2$$

$$\frac{4.33 - 3}{1 \text{ k}\Omega} + I_{D1} = 3 \text{ mA}$$

$$I_{D1} = 3 \text{ mA} - 1.33 \text{ mA} = 1.67 \text{ mA}$$

End of Solution





*Announcing*

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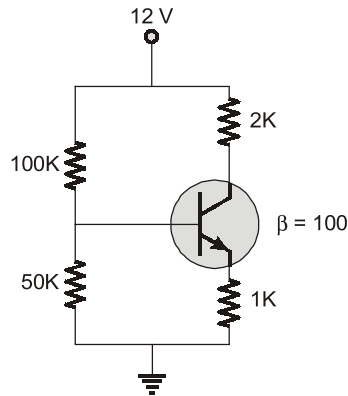
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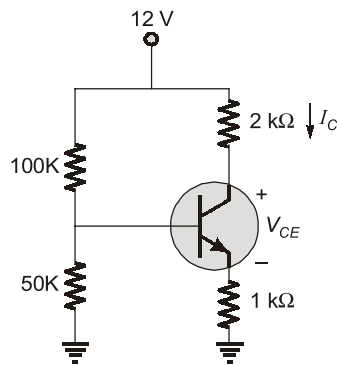
Q.2 Consider the circuit shown below :



$$V_{BE} = 0.7$$

Find Quiescent point  $V_{CE}$  and  $I_C$ .

Ans. (2.1)



$$V_{BE} = 0.7 \text{ V}$$

$$\beta = 100$$

As  $\beta$  is large,  $I_B$  neglected.

$$V_B = V_{CC} \times \frac{R_2}{R_1 + R_2} = 12 \times \frac{50 \text{ K}}{150 \text{ K}} = 4 \text{ V}$$

$$V_E = V_B - 0.7 \text{ V} = 4 - 0.7 = 3.3 \text{ V}$$

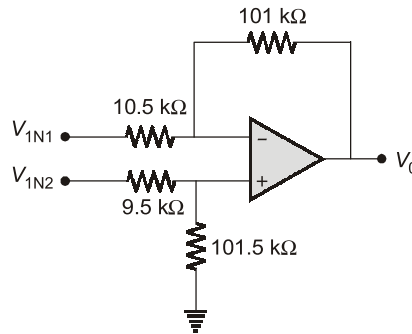
$$I_E = \frac{V_E}{R_E} = \frac{3.3 \text{ V}}{1 \text{ k}\Omega} = 3.3 \text{ mA}$$

$$I_C \approx I_E = 3.3 \text{ mA}$$

$$\begin{aligned} V_{CE} &= V_{CC} - I_C(R_C + R_E) \\ &= 12 - 3.3 \text{ mA} (3 \text{ K}) \\ &= 12 - 9.9 = 2.1 \text{ V} \end{aligned}$$

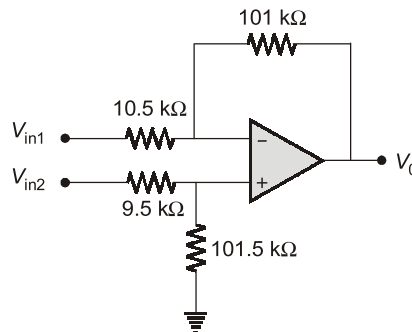
End of Solution

Q.3 Consider the circuit shown below :



Find CMRR (in dB)

Ans. (40.52)



$$V_o = \left(1 + \frac{101}{10.5}\right)V^+ + \frac{-101}{10.5}V_{in1}$$

$$= 10.62 \times V_{in2} \times \frac{101.5}{101.5 + 9.5} + \frac{-101}{10.5}V_{in1}$$

$$= \frac{9.71}{A_1}V_{in2} + \frac{-9.619}{A_2}V_{in1}$$

$$CMRR = \frac{A_d}{A_c}$$

$$A_d = \frac{A_1 - A_2}{2}$$

$$= \frac{9.71 + 9.619}{2} = 9.6645$$

$$A_c = A_1 + A_2$$

$$= 9.71 - 9.619 = 0.091$$

$$CMRR = \frac{9.6645}{0.091} = 106.20$$

$$CMRR = 20 \log(106.20) = 40.52 \text{ dB}$$

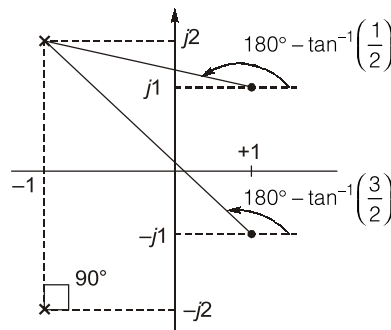
### Control Systems

Q.4 Consider the open loop system

$$G(s)H(s) = \frac{K(s^2 - 2s + 2)}{(s^2 + 2s + 5)}$$

The angle of departure at  $-1 + 2j$  is \_\_\_\_ (in degrees).

Ans. (7)



$$\phi_D = \pm(180 + \phi)$$

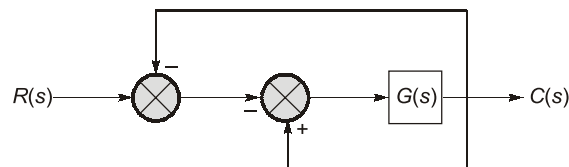
$$\phi = \sum \phi_z - \sum \phi_p$$

$$= \left\{ \left[ 180 - \tan^{-1}\left(\frac{1}{2}\right) \right] + \left[ 180 - \tan^{-1}\left(\frac{3}{2}\right) \right] - 90^\circ \right\}$$

$$\phi_D = \pm 7^\circ$$

End of Solution

Q.5 Consider the block diagram shown below :



Then the transfer function  $\frac{C(s)}{R(s)}$  is \_\_\_\_.

Ans.  $\left(\frac{G}{1-2G}\right)$

$$\text{Transfer function, } \frac{C(s)}{R(s)} = \frac{G}{1-G-G} = \frac{G}{1-2G}$$

End of Solution

**Q.6** Consider the stable close loop system shown in the figure. the asymptotic bode magnitude plot  $G(s)$  has a constant slope of  $-20$  dB/dec at least till  $100$  rad/sec with the gain crossover frequency being  $10$  rad/sec. The asymptotic bode phase plot remains constant at  $-90^\circ$  at least,  $\omega = 10$  rad/sec. The steady state error of the closed system for a unit ramp input is \_\_\_\_\_. (Rounded off to 2 decimal place).

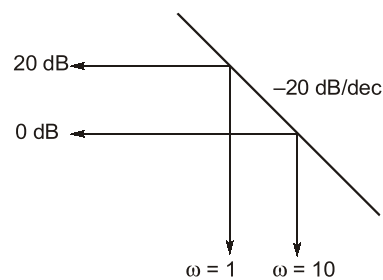
**Ans. (0.10)**

Initial slope =  $-20$  dB/sec

Open loop transfer function =  $\frac{k}{s}$

$$20 \log_{10} k = 20$$

$$k = 10$$

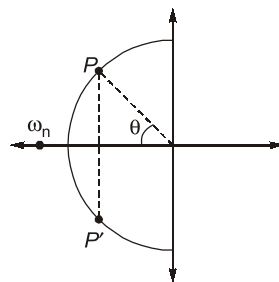


$e_{ss}$  for type -1 system for ramp input

$$e_{ss} = \frac{1}{k_v} = \frac{1}{10} = 0.1$$

End of Solution

**Q.7** For a second order system  $\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$ , diagram is shown



System (1) is given as  $\omega_n = 3$  rad/s,  $\theta = 60^\circ$

System (2) is given as  $\omega_n = 1$  rad/s,  $\theta = 70^\circ$

Which of the following is true?

- (a) System (1) has more settling time than system (2)
- (b) System (2) has more settling time than system (1)
- (c) Both have same settling time.
- (d) None of the above

Ans. (b)

In system -1

$$\xi_1 = \cos\theta = \cos 60^\circ = 0.5$$

$$\omega_{n1} = 3 \text{ rad/sec}$$

$$\text{Settling time} - t_{s1} = \frac{4}{\xi\omega_n} = \frac{4}{0.5 \times 3} = \frac{8}{3} = 2.67 \text{ sec}$$

In system -2

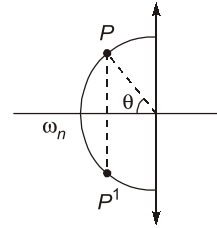
$$\xi_2 = \cos\theta_2 = \cos 70^\circ$$

$$\omega_{n2} = 1 \text{ rad/sec}$$

$$\text{Settling time} - t_{s2} = \frac{4}{\xi\omega_n} = \frac{4}{\cos 70^\circ \times 1} = 11.69 \text{ sec}$$

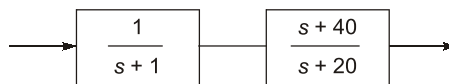
So,

$$t_{s2} > t_{s1}$$



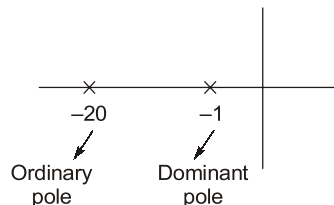
End of Solution

Q.8 Consider the cascaded system:



Which of the following option is the first order pole only approximation such a system having no effect of steady state value.

Ans.  $\left(\frac{2}{s+1}\right)$



$$\text{Transfer function} \rightarrow \frac{40\left(1 + \frac{s}{40}\right)}{20\left(1 + \frac{s}{40}\right)(1+s)}$$

$$\text{Answer} = \frac{2}{s+1}$$

End of Solution



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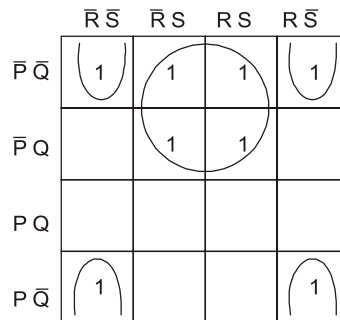
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### Digital Electronics

Q.9  $F(P, Q, R, S) = \bar{P}\bar{Q} + \bar{P}QS + P\bar{Q}\bar{R}\bar{S} + P\bar{Q}R\bar{S}$  minimize the function will be

- (a)  $\bar{P}Q + R\bar{S}$  (b)  $\bar{P}\bar{Q} + \bar{Q}\bar{S}$   
 (c)  $P\bar{S} + \bar{Q}\bar{R}$  (d)  $\bar{P}\bar{S} + \bar{Q}\bar{S}$

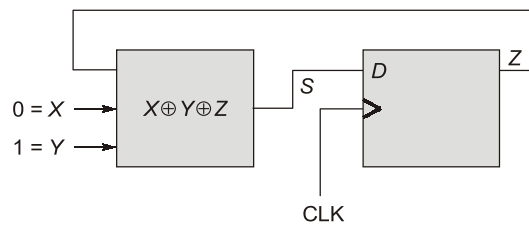
Ans. (d)



Minimize function =  $\bar{Q}\bar{S} + \bar{P}\bar{S}$

End of Solution

Q.10 Consider the digital logic circuit shown below,



Assume no transportation delay. After are cycle of clock, the value of Z and S is (Initially Z = 1)

Ans. (0)

Based on this trick

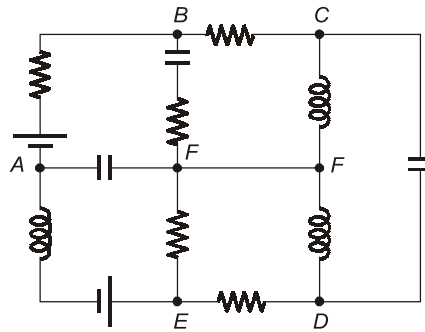
$$\begin{array}{l|l} x \oplus & x = 0 \\ x \oplus & \bar{x} = 1 \\ x \oplus & 1 = \bar{x} \\ x \oplus & 0 = x \end{array}$$

$$\overline{x \oplus y} = x \odot y = 0 \odot 1 = 0$$

End of Solution



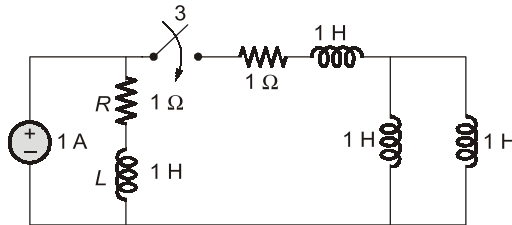




Number of junction = 6

End of Solution

Q.13 For the circuit shown below :



Switch is open for long time and closed at  $t = 0$ , then time constant is \_\_\_\_.

- (a) 1.25
- (b) 1.5
- (c) 0
- (d) #

Ans. (a)

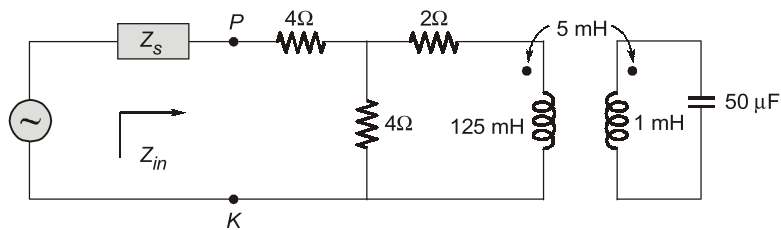
$$\text{Time constant, } \tau = \frac{L_{eq}}{R_{eq}} = \frac{2.5}{2} = 1.25$$

$$L_{eq} = 1 + 1 + 1 \parallel 1 = 2.5 \text{ H}$$

$$R_{eq} = 2 \Omega$$

End of Solution

Q.14 For the circuit shown below :



$\omega = 5000 \text{ rad/sec}$

$Z_{in}$  is \_\_\_\_.

Ans. (5)

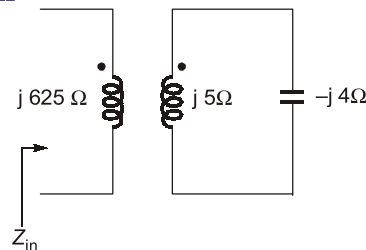
Given:  $\omega = 5000$  rad/sec

$$Z_{in} = jX_{L1} + \frac{(\omega m)^2}{jX_{L1} + Z_L}$$

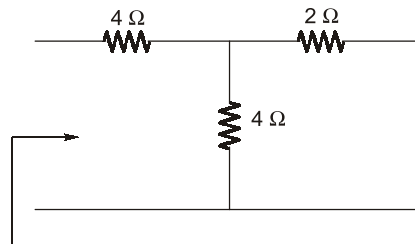
$$jX_{L1} = 125 \text{ mH} \times 5000 = j625 \Omega$$

$$\frac{j}{\omega C} = \frac{-j}{5000 \times 50 \times 10^{-6}} = -j4 \Omega$$

$$jX_{L2} = 1 \text{ mH} \times 5000 = +j5 \Omega$$



$$Z_{in} = j625 + \frac{(5000 \times 5 \times 10^{-3})^2}{j5 - j4} = j625 - j625 = 0 \Omega$$



$$Z_m = \frac{4 \times 2}{4 + 2} + 4 = \frac{16}{3} \Omega$$

End of Solution

## Electrical Machine

Q.15 A 3- $\phi$ , 50 Hz, 6 pole, induction motor runs at 960 rpm, neglected stator copper and stator core losses then, % efficiency is

- (a) 96% (b) 94%  
(c) 95% (d) 92%

Ans. (a)

$$s = \frac{1000 - 960}{1000} = 0.04$$

$$\frac{\text{Rotor output}}{\text{Rotor input}} = 1 - s$$

$$\eta = 1 - 0.04 = 0.96 \text{ or } 96\%$$

End of Solution



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**Q.16** A DC shunt motor 5 kW, 220 V. Armature resistance including brush drop is  $0.5 \Omega$ . The DC machine takes 3 A on no load the shunt current is 1 A. Neglect the rotational loss and current is independent of load. If machine is operating for rated current and rated power. Find the current drawn for best possible efficiency.

**Ans.** (37.276)

$$E_{b0} = 200 - 2(0.5) = 219$$

$$I_{a0} = 2$$

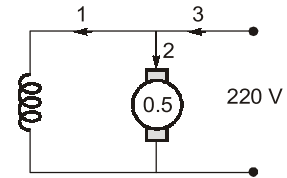
$$\text{Rotational loss} = 219 \times 2 = 438 \text{ W}$$

$$\text{Constant loss} = \text{Variable loss}$$

$$(438) + (220 \times 1) = I_a^2 (0.5)$$

$$\Rightarrow I_a = 36.27 \text{ A}$$

$$\therefore I_{\text{drawn}} = 37.27 + 1 = 37.27 \text{ A}$$



End of Solution

**Q.17** A 3-phase star connected slip ring induction motor has the following parameter referred to the stator.

$$R_s = 3 \Omega, X_s = 2 \Omega, X_r' = 2 \Omega, R_r' = 2.5 \Omega$$

the per phase stator to rotor effective turn ratio 3 : 1, the rotor winding is also star connected the magnetizers reactance and core loss of the motor can be neglected to have maximum torque at starting the value of the extra resistance in ohms (referred to rotor side) to be connected in series with each phase of the rotor winding is \_\_\_\_\_. [2 decimals]

**Ans.** (0.277)

Condition for the maximum torque

$$\frac{R_2'}{s} = \sqrt{3^2 + 4^2} = 5$$

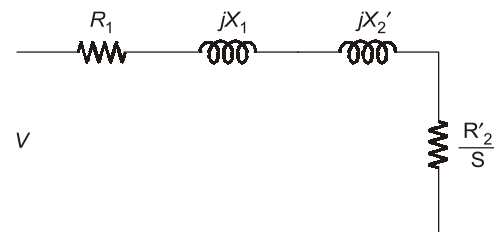
Substituting,  $s = 1$

As maximum torque at starting

$$R_2' + R_{\text{ext}}' = 5$$

$$R_{\text{ext}}' = 5 - 2.5 = 2.5 \Omega$$

$$\frac{2.5}{3^2} = 0.277 \Omega$$

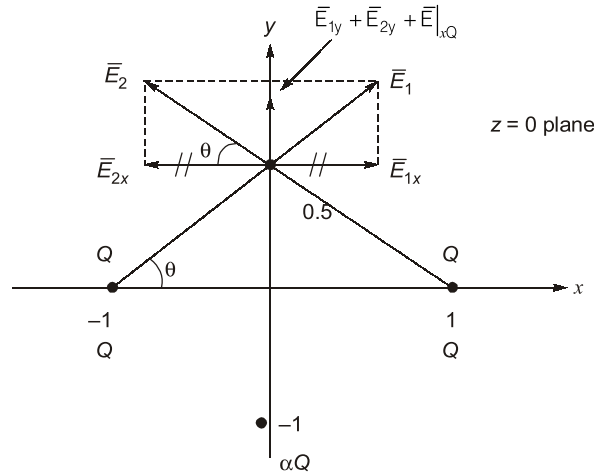


End of Solution

### EMT

**Q.18** Three charges,  $Q$ ,  $Q$ ,  $\alpha Q$  are placed at  $(-1, 0, 0)$ ,  $(1, 0, 0)$  and  $(0, -1, 0)$ . If electric field is zero at point  $(0, 0.5, 0)$  then value of  $\alpha$  is \_\_\_\_.

**Ans.**  $(-1.61)$



From the figure,

$$\vec{E}_{net} = \vec{E}_{1y} + \vec{E}_{2y} + \vec{E}_{\alpha Q} = 0 \text{ [as per question]}$$

Here,

$$\vec{E}_{1y} = \vec{E}_{2y} = \vec{E}_{|Q} \text{ (say)}$$

$\therefore$

$$\vec{E}_{net} = 2E_{|Q} + 2E_{\alpha Q} = 0$$

Now,

$$\vec{E}_{|Q} = \frac{kQ}{[\sqrt{1+0.5^2}]^2} \sin\theta \hat{a}_y; \quad k = \frac{1}{4\pi\epsilon_0}$$

$\Rightarrow$

$$\vec{E}_{|Q} = \frac{kQ}{1.25} \times \frac{0.5}{\sqrt{1+0.5^2}} \hat{a}_y = 0.357 kQ \hat{a}_y$$

Also,

$$\vec{E}_{\alpha Q} = \frac{k(\alpha Q)}{(1.5)^2} \hat{a}_y = 0.444k(\alpha Q) \hat{a}_y$$

Hence,

$$\vec{E}_{net} = 2 \times 0.357 kQ \hat{a}_y + 0.444k(\alpha Q) \hat{a}_y = 0$$

$\Rightarrow$

$$0.715kQ = -0.444 k(\alpha Q)$$

$\Rightarrow$

$$\alpha = \frac{-0.715}{0.444} = -1.61$$

$\therefore$

$$\alpha = -1.61$$

End of Solution

Q.19 For the  $\vec{H}(r, \theta, \phi) = \frac{1}{r^3}(P \cos \theta \hat{a}_r + \sin \theta \hat{a}_\theta)$ , then  $P = ?$

Ans. (2)

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \cdot \vec{H} = 0$$

Spherical coordinate system,

$$h_1 h_2 h_3 = r^2 \sin \theta$$

On substituting  $P = 2$ .

End of Solution

## Engg. Mathematics

Q.20 If  $A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}^2$ , the sum of eigen values of matrix  $A$  is \_\_\_\_.

Ans. (29)

$$A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} = \begin{bmatrix} 7 & 10 \\ 15 & 22 \end{bmatrix}$$

$$\begin{aligned} \lambda_1 + \lambda_2 &= \text{Trace (A)} \\ &= 22 + 7 \\ &= 29 \end{aligned}$$

End of Solution

Q.21  $f(z) = e^{z^2} + \cos z$ , find the coefficient of  $z^5$  in Taylor series?

Ans. (0)

$$f(z) = \left( 1 + z^2 + \frac{z^4}{2!} + \frac{z^6}{6} + \dots \right) + \left( 1 - \frac{z^2}{2!} + \frac{z^4}{4!} + \dots \right)$$

It is series is of even powers.

$\therefore$  Coefficient of  $z^5 = 0$ .

End of Solution

Q.22  $f = 2 \log(xy) + \log(yz) + 3 \log(xz)$ , find the directional derivative of 'f' in the direction of  $\vec{a} = 2\hat{i} + \hat{j} + 2\hat{k}$  at point (1, 1, 1)?

Ans. (7)

We know that: directional derivative of 'f' at P(1, 1, 1) in the direction of  $\vec{a}$  is given by

$$\text{Directional derivative} = \nabla f \cdot \frac{\hat{a}}{|\vec{a}|}$$

$$\nabla f = \hat{i} \frac{\partial f}{\partial x} + \hat{j} \frac{\partial f}{\partial y} + \hat{k} \frac{\partial f}{\partial z}$$

$$\nabla f = i \frac{5}{x} + j \frac{3}{y} + k \frac{4}{z}$$

$$(\nabla f)_{(1,1,1)} = 5i + 3j + 4k$$

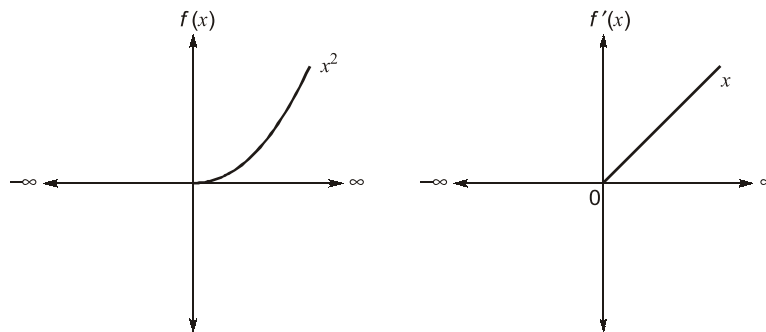
$$\therefore \text{Directional derivative} = \nabla f \cdot \frac{\vec{a}}{|\vec{a}|} = (5i + 3j + 4k) \cdot \frac{(2i + j + 2k)}{\sqrt{2^2 + 1^2 + 2^2}} = \frac{21}{3} = 7$$

End of Solution

**Q.23** Given  $f(x) = [\max(0, x)]^2$  in  $-\infty < x < \infty$ , then which of the following is/are true?

- (a)  $f(x)$  is differentiable but  $f'(x)$  is not continuous
- (b)  $f(x)$  is not differentiable but  $f'(x)$  is continuous
- (c)  $f(x)$  and  $f'(x)$  both differentiable
- (d)  $f(x)$  is differentiable and  $f'(x)$  is continuous

**Ans.** (d)



$\therefore f(x)$  is differential and  $f'(x)$  is continuous but  $f''(x)$  is not continuous.

End of Solution

**Q.24** Which of the following is analytic in entire complex plane?

- (a)  $f(z) = z^2 - z$
- (b)  $\text{Re}(z) = f(z)$
- (c)  $f(z) = i \text{Im}(z)$
- (d)  $f(z) = e^{|z|}$

**Ans.** (a)

Let us take (a),  $f(z) = z^2 - z$   
 $u + iv = x^2 - y^2 + i(2xy) - x - iy$   
 $\Rightarrow u = x^2 - y^2 - x, V = 2xy - y$

Now by C-R equation,

$$u_x = V_y \text{ and } u_y = -V_x$$

$$\Rightarrow (2x - 1) = (2x - 1) \text{ and } -2y = -(2y)$$

i.e. C-R equation are satisfied. Hence (a) is analytic rest are not analytic.

End of Solution





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**Q.25** If  $X = \{-10, -9, -8, \dots, 0, 1, 2, \dots, 9, 10\}$  is uniformly distributed RV then which of the following will also be uniformly distributed?

- (a)  $X^3$  (b)  $X^2$   
(c)  $(X + 10)^2$  (d)  $(X - 5)^2$

**Ans.** (a, c)

$$X^2 = \{100, 81, 64, \dots, 4, 1, 0, 1, 4, 9, \dots, 81, 100\}$$

$$P(\text{Choosing } 0) = \frac{1}{21}, P(\text{choosing } 1) = \frac{2}{21}$$

So,  $X^2$  is not uniformly distributed.

$$(X - 5)^2 = \{225, 199, \dots, 4, 1, 0, 1, 4, 9, 16, 25\}$$

Again probability of choosing any number is not equal so

$(X - 5)^2$  is also not uniformly - distributed.

$$(X + 10)^2 = \{0, 1, 4, 9, 16, \dots, 81, 100, 121, \dots, 400\}$$

$P(\text{Choosing any number}) = \frac{1}{21}$  so is it uniformly-distributed

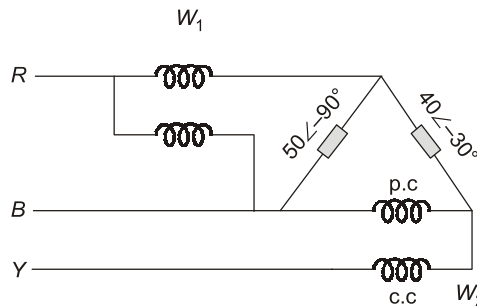
Now,  $X^3 = \{-1000, -729, -512, \dots, -8, -1, 0, 1, 8, \dots, 729, 1000\}$

Again  $P(\text{Choosing any number}) = \frac{1}{21} = \text{Constant}$

So, it is also uniformly-distributed.

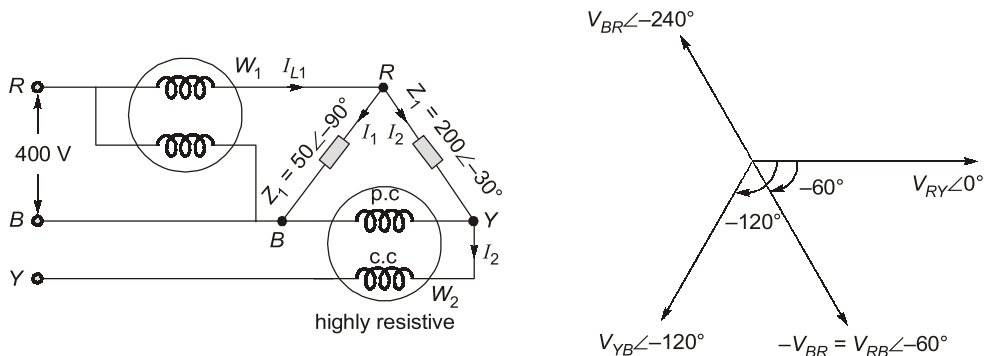
### Measurement

**Q.26** Supply is 400 V and phase sequence is RYB.



The difference between the readings of wattmeter  $W_1$  and  $W_2$  is

**Ans.** (692.8)



$W(1) \Rightarrow$

$$V_{RY} = 400\angle 0^\circ$$

$$V_{YB} = 400\angle -92^\circ$$

$$V_{BR} = 400\angle -240^\circ$$

$$V_{PC} = V_{RB} = 400\angle -60^\circ$$

$$I_1 = \frac{V_{RB}}{Z_1} = \frac{400\angle -60^\circ}{50\angle -90^\circ} = 8\angle 30^\circ$$

$$I_2 = \frac{V_{RY}}{Z_2} = \frac{400\angle 0^\circ}{200\angle -30^\circ} = 2\angle 30^\circ \Rightarrow I_{CC(2)}$$

$$I_{L1} = I_{CC(1)} = I_1 + I_2 = 8\angle 30^\circ + 2\angle 30^\circ = 10\angle 30^\circ \Rightarrow I_{CC(1)}$$

$$W = V_{RB} \times I_{2\theta} \cos(\angle V_{RB} \text{ and } I_{LO})$$

$$W_1 = 400 \times 10 \times \cos(-60^\circ - 30^\circ) = 0 \text{ Watt}$$

$$W_2 = V_{YB} \times I_2 \cos(\angle V_{YB} \text{ and } I_2)$$

$$= 400 \times 2 \times \cos(-120^\circ - 30^\circ) = -692.8 \text{ Watt}$$

$$W_1 - W_2 = 0 - (-692.8) = 692.8 \text{ Watt}$$

End of Solution

## Power Electronics

- Q.27** A 1- $\phi$  time based AC voltage controller feeds a series RL load, the i/P AC supply is 230 V, 50 Hz. The value of R and L are 10  $\Omega$  and 18.37 mH. The minimum triggering angle to obtain controllable output voltage is
- (a) 15° (b) 45°  
(c) 60° (d) 30°

**Ans. (d)**

Output voltage is controlled if

$$\alpha > \theta$$

Given:  $f = 50 \text{ Hz}$ ,  $R = 10 \Omega$ ,  $L = 18.37 \text{ mH}$

$$\theta = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

$$\theta = \tan^{-1}\left(\frac{2\pi \times 50 \times 18.37 \times 10^{-3}}{10}\right)$$

$$\theta = 29.989^\circ$$

So,  $\alpha_{\min}$  can be 30°. Hence answer is (d).

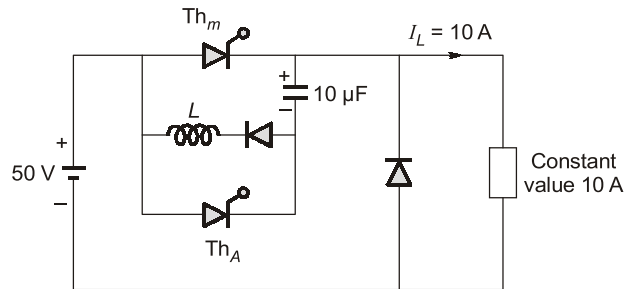
End of Solution

- Q.28** If the following switching devices have similar power ratings, then which of the following is fastest device?
- (a) Power mosfet (b) IGBT  
(c) GTO (d) SCR

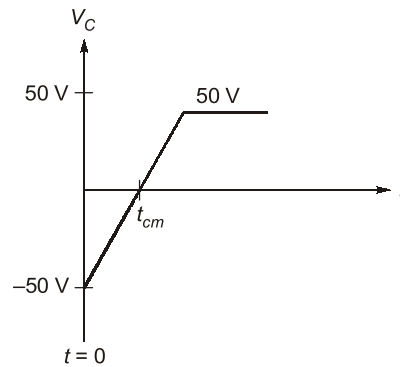
**Ans. (a)**

End of Solution

**Q.29** A load connected thyristorized step down chopper is in figure. Neglect on state drop across the power device. Assume the capacitor is initially charged to with polarity shown to 50 V. With polarity shown in figure. The load connected in is to constant of 10 A. Initially,  $Th_m$  is on and  $Th_A$  is OFF. The time to turn off to  $Th_m$  in milliseconds when  $Th_A$  is thyristorized is \_\_\_\_.



**Ans. (0.05)**



Given:  $V_s = 50$ ,

$T_A \rightarrow ON$

$$t_{cm} = \frac{C}{I_o} V_s = \frac{10 \times 10^{-6}}{10} \times 50$$

$$= 50 \mu\text{sec} = 0.05 \text{ msec}$$

**End of Solution**



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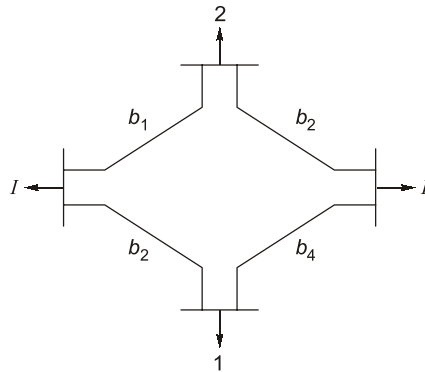
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### Power Systems

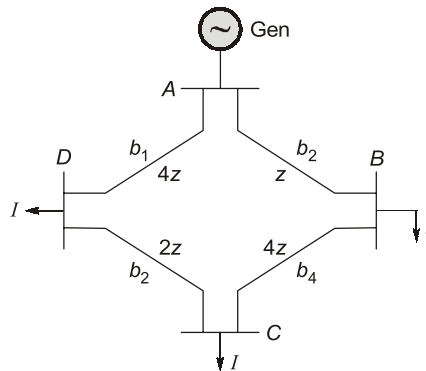
Q.30



The figure shows single line diagram of a 4-bar power N/ω. Branch  $b_1$ ,  $b_2$ ,  $b_3$  and  $b_4$  have Impedance of  $4z$ ,  $z$ ,  $2z$  and  $4z$  per unit (p.u.) respectively where  $z = r + jx$  with  $r > 0$ . The current drawn from loads (marked as arrow) is equal to 'I' p.u. were  $I \neq 0$ . It network is to operate with minimum loss, the branch should be opened is

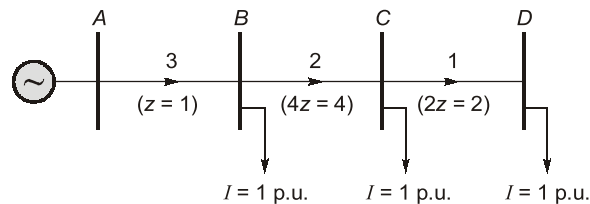
- (a)  $b_4$
- (b)  $b_3$
- (c)  $b_2$
- (d)  $b_1$

Ans. (b)



Assume,  $|z| = |r + jX| = 1$  p.u.,  
 $I = 1$  p.u.

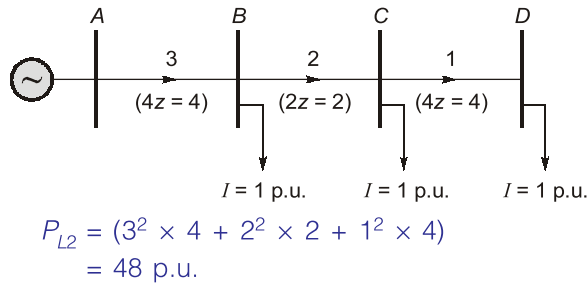
By opening branches ring becomes radial open  $b_1$



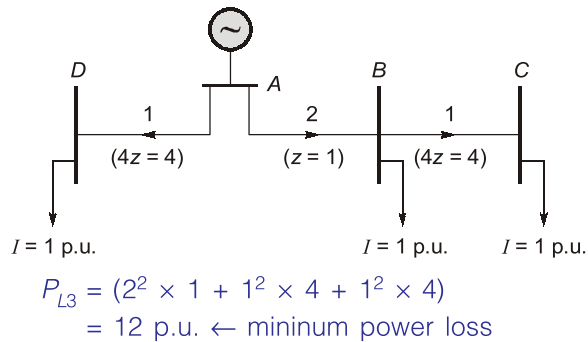
Total power loss,

$$P_{L1} = 1^2 \times 2 + 2^2 \times 4 + 3^2 \times 1 = 27 \text{ p.u.}$$

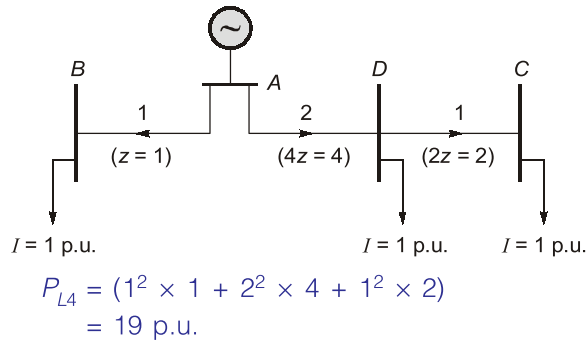
Open  $b_2$  :



Open  $b_3$  :



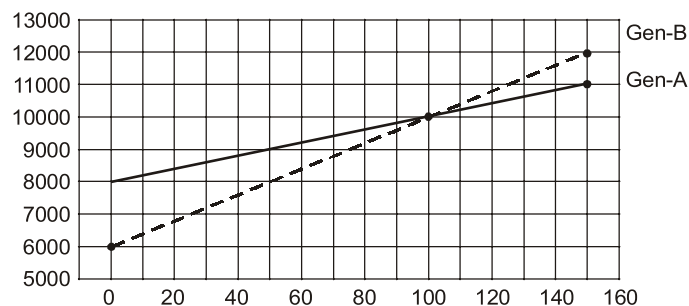
Open  $b_4$  :



By opening branch  $b_3$  Power loss is minimum.

End of Solution

- Q.31** The increments cost curves of the two generators (Gen-A and Gen-B) in a plant supplying a common load are shown in figure. If the increments cost of supplying the common load is Rs 7400 per Mwhr then common load in MW is \_\_\_\_\_. (Rounded off upto two decimal digit)



Ans. (35)

Given,

$$\lambda = 7400 \text{ Rs/MWhr}$$

$$I_{CA}(P_{GA}) = \frac{2000}{100} P_{GA} + 8000$$

$$I_{CB}(P_{GB}) = 40P_{GB} + 6000$$

$$\lambda = I_{CA} = I_{CB} = 7400$$

$$200P_{GA} + 8000 = 7400$$

$$P_{GA} = -600$$

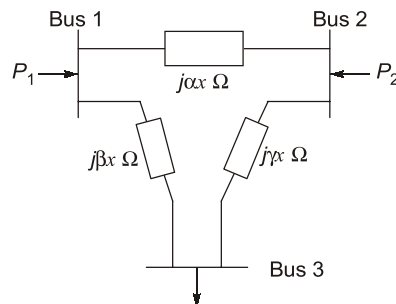
$$P_{GA} < 0$$

$$P_{GB} = \frac{7400 - 6000}{40} = 35$$

$$P_{GA} + P_{GB} = 35 \text{ MW}$$

End of Solution

**Q.32** For the 3 bus lossless power network shown in the figure the voltage magnitude at all the buses are equal to 1 per unit (PU) and the difference of the voltage phase angles are very small and the reactances are marked in the figure where  $\alpha$ ,  $\beta$ ,  $\gamma$  and  $x$  are strictly positive the bus injection  $P_1$  and  $P_2$  are in P.U. If  $P_1 = mP_2$  where  $m > 0$  and the real power flow from bus 1 to bus 2 is 0 p.u., then which one of the following options is correct?



(a)  $\alpha = m\beta$

(c)  $\beta = mr^2$

(b)  $\alpha = mr^2$

(d)  $\gamma = m\beta$

Ans. (d)

$$P_1 = mP_2$$

$$P_1 = \frac{1 \times 1}{\beta x} \sin\theta$$

$$P_2 = \frac{1 \times 1}{\gamma x} \sin\theta$$

$$\frac{1 \times 1}{\beta x} \sin\theta = m \frac{1 \times 1}{\gamma x} \sin\theta$$

$$\frac{1}{\beta} = \frac{m}{\gamma}$$

$$\gamma = m\beta$$

End of Solution





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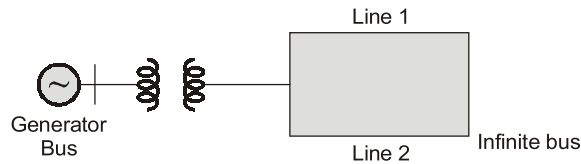
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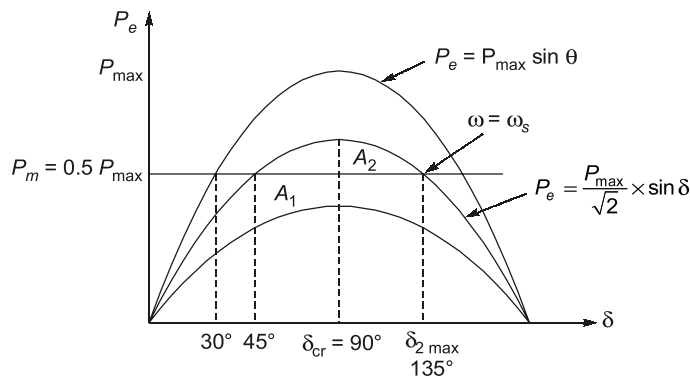
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**Q.33** The single line diagram of a loss less system is shown in the figure. The system is operating in steady state at a stable equilibrium point with the power output of the generator being  $P_{\max} \sin \delta$ , where  $\delta$  is the load angle and the mechanical power input is  $0.5P_{\max}$ . A fault occurs on line 2 such that the power output of the generator is less than  $0.5P_{\max}$  during the fault. After fault is cleared by opening line 2, the power output of the generation is  $(P_{\max}/\sqrt{2}) \sin \delta$ . If the critical fault clearing angle is  $\frac{\pi}{2}$  radians, the accelerating area on the power angle curve is \_\_\_\_\_ times  $P_{\max}$ .



**Ans. (0.1)**



$$A_1 = A_2$$

$$\int_{90^\circ}^{135^\circ} \left( \frac{P_{\max}}{\sqrt{2}} \sin \delta - 0.5 P_{\max} \right) d\delta = 0.1 P_{\max}$$

End of Solution

## Signals and Systems

**Q.34** Given signal  $x(t) = e^{t^2}[u(t-1) - u(t-10)]$ . ROC of the signal is \_\_\_\_\_.

- (a)  $-\infty < \sigma < \infty$
- (b)  $1 < \sigma < 10$
- (c)  $\sigma > 10$
- (d)  $\sigma < 1$

**Ans. (a)**

Since  $x(t)$  is finite duration signal. So ROC will be  $-\infty < \sigma < \infty$ .

End of Solution

**Q.35** If  $x(t)$  is signal  $y(t) = x(-t)$  then the convolution of  $x(t) * y(t)$  will be

- (a) even (b) odd  
(c) causal (d) anti-causal

**Ans. (a)**

$$z(n) = x[n] * y[n]$$

$$z(n) = x[n] * x[-n]$$

Replace  $n$  with  $-n$

$$z[-n] = x[-n] * x[n]$$

$$z[-n] = x[n] * x[-n]$$

$$z[-n] = z[n]$$

even function.

End of Solution

**Q.36**  $X(\omega)$  is fourier transform of  $e^{-t} \cos t$  then  $\left. \frac{dX(\omega)}{d\omega} \right|_{\omega=0} = ?$

**Ans. (0)**

$$tx(t) \Leftrightarrow j \frac{dX(\omega)}{d\omega}$$

$$f(t) = \frac{tx(t)}{j} \Leftrightarrow \frac{dX(\omega)}{d\omega} = F(\omega)$$

$$\left. \frac{dX(\omega)}{d\omega} \right|_{\omega=0} = F(\omega) \Big|_{\omega=0} = \text{area of } f(t)$$

$$= \int_{-\infty}^{\infty} \frac{tx(t)}{j} dt = \text{area of odd-function}$$

$$= 0$$

$$\left[ \begin{array}{l} \because x(t) = \text{even-function} \\ \therefore \frac{t}{j} x(t) = \text{odd-function} \end{array} \right]$$

End of Solution

**Q.37** The energy of  $x(t)$  is  $E$ , then the energy of  $2x(2t - 1)$  is  $CE$ , then the value of 'C' is \_\_\_\_.

**Ans. (2)**

$$x(t) \rightarrow E \text{ (energy)}$$

$$x(t - 1) \rightarrow E$$

$$2x(2t - 1) \rightarrow 2^2 \times \frac{E}{2} = 2E = CE, \quad x(2t - 1) \rightarrow \frac{E}{2}$$

$$C = 2$$

End of Solution



Put  $\tau - t_0 = k$ , then  $d\tau = dk$  and for  $\tau = t$ ,  $k = t - t_0$

$$= e^{-t} \int_{-\infty}^{t-t_0} e^{k+t_0} \cdot x(k) dk$$

$$= e^{-t} \times e^{t_0} \times \int_{-\infty}^{t-t_0} e^k \cdot x(k) dk = e^{-(t-t_0)} \times \int_{-\infty}^{t-t_0} e^k \cdot x(k) dk$$

$$= e^{-(t-t_0)} \times \int_{-\infty}^{t-t_0} e^\tau \cdot x(\tau) d\tau \quad \dots \text{(ii)}$$

Since,  $y(t) = y(t - t_0)$

So, the system is time-invariant.

**End of Solution**



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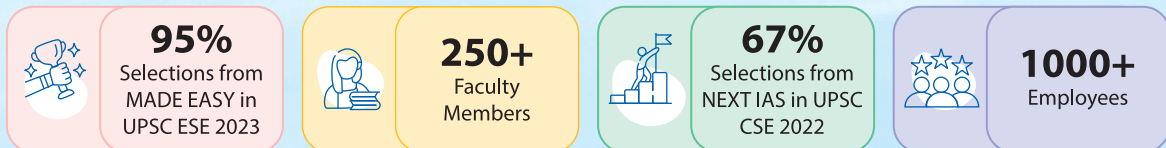
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