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# GATE 2017

## Electronics Engineering

(Afternoon Session : 05-02-2017)

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**ELECTRONICS ENGINEERING**

**Q.1** The general solution of the differential equation

$$\frac{d^2y}{dx^2} + 2\frac{dy}{dx} - 5y = 0$$

in terms of arbitrary constants  $K_1$  and  $K_2$  is

- (a)  $K_1e^{(-1+\sqrt{6})x} + K_2e^{(-1-\sqrt{6})x}$  (b)  $K_1e^{(-1+\sqrt{8})x} + K_2e^{(-1-\sqrt{8})x}$   
(c)  $K_1e^{(-2+\sqrt{6})x} + K_2e^{(-2-\sqrt{6})x}$  (d)  $K_1e^{(-2+\sqrt{8})x} + K_2e^{(-2-\sqrt{8})x}$

**Ans. (a)**

The general solution of the differential equation

$$\frac{d^2y}{dx^2} + 2\frac{dy}{dx} - 5y = 0$$

$$(D^2 + 2D - 5)y = 0$$

Auxillary equation is

$$m^2 + 2m - 5 = 0$$

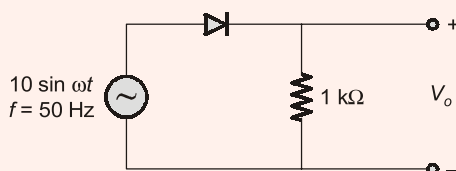
$$m = \frac{-2 \pm \sqrt{4+20}}{2} = \frac{-2 \pm \sqrt{24}}{2} = \frac{-2 \pm 2\sqrt{6}}{2} = -1 \pm \sqrt{6}$$

Solution is

$$y = K_1e^{(-1+\sqrt{6})x} + K_2e^{(-1-\sqrt{6})x}$$

• • • **End of Solution**

**Q.2** The output  $V_0$  of the diode circuit shown in the figure is connected to an averaging DC voltmeter. The reading on the DC voltmeter in Volts, neglecting the voltage drop across the diode, is



**Ans. (3.183)**

The given circuit is a halfwave rectifier.

Voltmeter reads the average value of  $V_0$ .

$$\text{Average value of } V_0 = \frac{V_m}{\pi}$$

$$V_m = \text{peak value of the applied sine wave} \\ = 10 \text{ V}$$

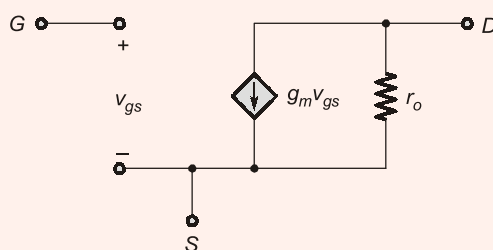
$$\text{So, Reading of meter} = \frac{10}{\pi} \text{ V} = 3.183 \text{ V}$$

• • • **End of Solution**

- Q.3** An  $n$ -channel enhancement mode MOSFET is biased at  $V_{GS} > V_{TH}$  and  $V_{DS} > (V_{GS} - V_{TH})$ , where  $V_{GS}$  is the gate-to-source voltage.  $V_{DS}$  is the drain-to-source voltage and  $V_{TH}$  is the threshold voltage. Considering channel length modulation effect to be significant, the MOSFET behaves as a
- voltage source with zero output impedance
  - voltage source with non-zero output impedance
  - current source with finite output impedance
  - current source with infinite output impedance

**Ans. (c)**

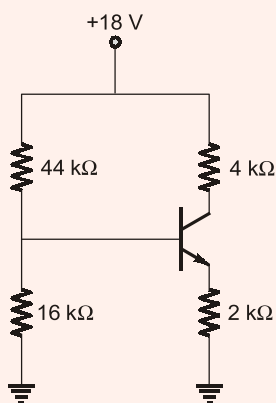
The small signal equivalent circuit of MOSFET in saturation is as given below.



So, when the channel length modulation effect is significant, the MOSFET can be modelled as a current source with finite output impedance.

• • • **End of Solution**

- Q.4** Consider the circuit shown in the figure. Assume base-to-emitter voltage  $V_{BE} = 0.8$  V and common-base current gain ( $\alpha$ ) of the transistor is unity.



The value of the collector-to-emitter voltage  $V_{CE}$  (in volt) is \_\_\_\_.

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**Ans. (6)**

By taking the Thevenin's equivalent between Base and Ground nodes, the given circuit can be reduced as follows:

$$V_{Th} = \frac{16}{16+44} \times 18 \text{ V} = 4.8 \text{ V}$$

$$I_E R_E = V_{Th} - V_{BE} - I_B R_{Th}$$

$$I_B = 0 \text{ A} \quad \because \alpha = 1$$

So,

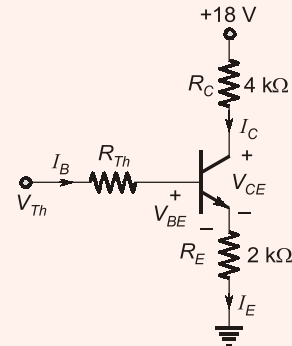
$$I_E R_E = 4.8 - 0.8 = 4 \text{ V}$$

$$I_E = \frac{4}{2} \text{ mA} = 2 \text{ mA}$$

$$I_C = I_E = 2 \text{ mA}$$

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

$$= 18 - (2 \times 4) - (2 \times 2) = 6 \text{ V}$$



$$\because \alpha = 1$$

• • • **End of Solution**

**Q.5** The smaller angle (in degrees) between the planes  $x + y + z = 1$  and  $2x - y + 2z = 0$  is \_\_\_\_\_.

**Ans. (54.73°)**

If  $\theta$  is the angle between

$$a_1x + b_1y + c_1z + d_1 = 0$$

$$a_2x + b_2y + c_2z + d_2 = 0 \text{ then}$$

$$\cos \theta = \frac{a_1a_2 + b_1b_2 + c_1c_2}{\sqrt{a_1^2 + b_1^2 + c_1^2} \sqrt{a_2^2 + b_2^2 + c_2^2}}$$

$$\begin{array}{llll} a_1 = 1 & b_1 = 1 & c_1 = 1 & d_1 = -1 \\ a_2 = 2 & b_2 = -1 & c_2 = 2 & d_2 = 0 \end{array}$$

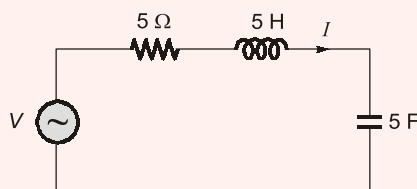
$$\cos \theta = \frac{(1)(2) + (1)(-1) + (1)(2)}{\sqrt{(1)^2 + (1)^2 + (1)^2} \sqrt{(2)^2 + (-1)^2 + (2)^2}}$$

$$= \frac{2-1+2}{\sqrt{3} \sqrt{9}} = \frac{3}{3\sqrt{3}} = \frac{1}{\sqrt{3}}$$

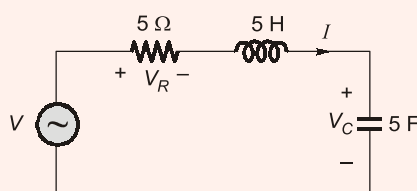
$$\theta = \cos^{-1}\left(\frac{1}{\sqrt{3}}\right) = 54.73^\circ$$

• • • **End of Solution**

- Q.6** In the circuit shown,  $V$  is a sinusoidal voltage source. The current  $I$  is in phase with voltage  $V$ . The ratio  $\frac{\text{amplitude of voltage across the capacitor}}{\text{amplitude of voltage across the resistor}}$  is \_\_\_\_\_.



**Ans. (0.2)**



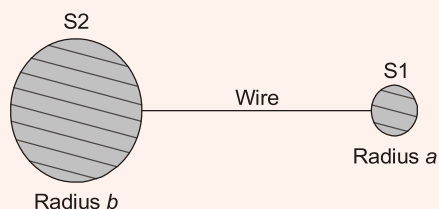
Given that,  $V$  and  $I$  have same phase. So, the circuit is in resonance.

At resonance,  $V_C = QV_R$

So, 
$$\frac{\text{Amplitude of } V_C}{\text{Amplitude of } V_R} = Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{5} \sqrt{\frac{5}{5}} = 0.2$$

• • • **End of Solution**

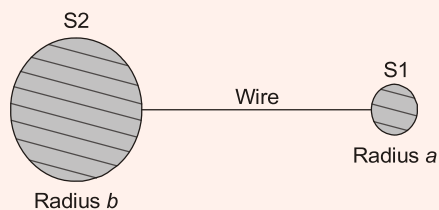
- Q.7** Two conducting spheres S1 and S2 of radii  $a$  and  $b$  ( $b > a$ ) respectively, are placed far apart and connected by a long, thin conducting wire, as shown in the figure.



For some charge placed on this structure, the potential and surface electric field on S1 are  $V_a$  and  $E_a$ , and that on S2 are  $V_b$  and  $E_b$  respectively. Then, which of the following is CORRECT?

- (a)  $V_a = V_b$  and  $E_a < E_b$                       (b)  $V_a > V_b$  and  $E_a > E_b$   
(c)  $V_a = V_b$  and  $E_a > E_b$                       (d)  $V_a > V_b$  and  $E_a = E_b$

**Ans. (c)**



- When charge is placed on this structure, equilibrium is established such that both spheres are at same potential i.e.

$$V_a = V_b$$

- $V_a = V_b$

$$\text{So, } \frac{Q_a}{4\pi\epsilon_0 a} = \frac{Q_b}{4\pi\epsilon_0 b}$$

$$\frac{Q_b}{Q_a} = \frac{b}{a}$$

- Now, surface electric fields,

$$\frac{E_a}{E_b} = \left[ \frac{Q_a / 4\pi\epsilon_0 a^2}{Q_b / 4\pi\epsilon_0 b^2} \right] = \frac{Q_a \times b^2}{Q_b \times a^2} = \frac{b}{a} > 1 \quad \left( \because \frac{Q_b}{Q_a} = \frac{b}{a} \text{ and } b > a \right)$$

$$\text{So, } E_a > E_b.$$

● ● ● End of Solution

**Q.8** An *npn* bipolar junction transistor (BJT) is operating in the active region. If the reverse bias across the base-collector junction is increased, then

- the effective base width increases and common-emitter current gain increases
- the effective base width increases and common-emitter current gain decreases
- the effective base width decreases and common-emitter current gain increases
- the effective base width decreases and common-emitter current gain decreases

**Ans. (c)**

When a BJT is in active region, as the reverse bias voltage across collector-base junction increased, the width of depletion region increases, which results in decrease of effective base width. This decrease in effective base width reduces the recombinations in base region, hence, common-emitter current gain will increase.

● ● ● End of Solution

**Q.9** The input  $x(t)$  and the output  $y(t)$  of a continuous-time system are related as

$$y(t) = \int_{t-T}^t x(u) du$$

The system is

- linear and time-variant
- linear and time-invariant
- non-linear and time-variant
- non-linear and time-invariant

**Ans. (b)**

Given that, 
$$y(t) = \int_{t-T}^t x(u) du$$

- Since the given system satisfies both homogeneity and additivity properties, the system is linear.
- Check for time invariance:**

$$y(t - t_0) = \int_{t-t_0-T}^{t-t_0} x(u) du$$

- When the applied input is  $x(t - t_0)$ ,

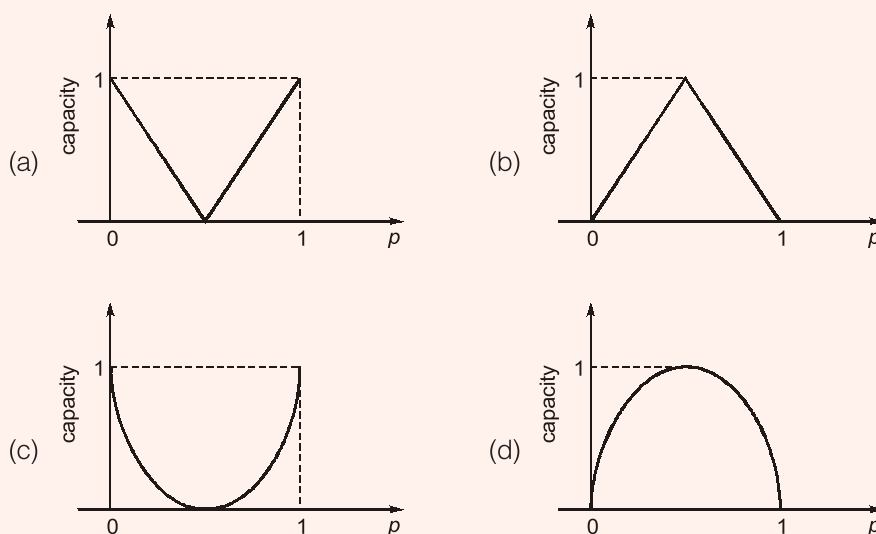
$$y_1(t) = \int_{t-T}^t x(u - t_0) du = \int_{t-t_0-T}^{t-t_0} x(\tau) d\tau$$

$$= y(t - t_0) \Rightarrow \text{System is time invariant}$$

Hence, option (b) is correct.

• • • End of Solution

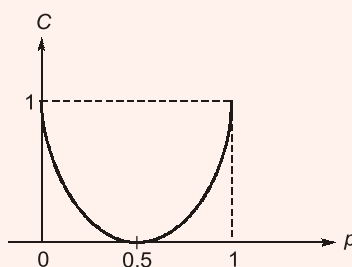
**Q.10** Which one of the following graphs shows the Shannon capacity (Channel capacity) in bits of a memoryless binary symmetric channel with crossover probability  $p$ ?



**Ans. (c)**

The channel capacity of a memoryless binary symmetric channel can be expressed as,

$$C = 1 + p \log_2 p + (1 - p) \log_2 (1 - p)$$



• • • End of Solution



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**Q.11** The rank of the matrix

$$\begin{bmatrix} 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 \\ 0 & 1 & -1 & 0 & 0 \\ -1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & -1 \end{bmatrix}$$

is \_\_\_\_\_.

**Ans. (4)**

$$A = \begin{bmatrix} 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 \\ 0 & 1 & -1 & 0 & 0 \\ -1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & -1 \end{bmatrix}$$

$$R_4 \rightarrow R_4 + R_1$$

$$= \begin{bmatrix} 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 \\ 0 & 1 & -1 & 0 & 0 \\ 0 & -1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & -1 \end{bmatrix}$$

$$R_4 \rightarrow R_4 + R_3$$

$$= \begin{bmatrix} 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 \\ 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & 1 & -1 \end{bmatrix}$$

$$R_4 \rightarrow R_4 + R_2$$

$$= \begin{bmatrix} 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 \\ 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 \\ 0 & 0 & 0 & 1 & -1 \end{bmatrix}$$

$$R_2 \leftrightarrow R_3 \text{ and } R_5 \rightarrow R_5 + R_4$$

$$= \begin{bmatrix} 1 & -1 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & -1 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

From here,

$$\therefore \rho(A) = 4$$

● ● ● **End of Solution**

**Q.12** Consider an  $n$ -channel MOSFET having width  $W$ , length  $L$ , electron mobility in the channel  $\mu_n$  and oxide capacitance per unit area  $C_{ox}$ . If gate-to-source voltage  $V_{GS} = 0.7$  V, drain-to-source voltage  $V_{DS} = 0.1$  V.  $(\mu_n C_{ox}) = 100 \mu\text{A/V}^2$ , threshold voltage  $V_{TH} = 0.3$  V and  $(W/L) = 50$ , then the transconductance  $g_m$  (in mA/V) is \_\_\_\_.

**Ans. (0.5)**

Given that,

$$V_{GS} = 0.7 \text{ V}, V_{TH} = 0.3 \text{ V}, V_{DS} = 0.1 \text{ V}$$

$$V_{GS} - V_{TH} = 0.4 > V_{DS} \Rightarrow \text{MOSFET is in linear region.}$$

In linear region, 
$$I_D = K_n \left[ 2(V_{GS} - V_{TH})V_{DS} - V_{DS}^2 \right]$$

Transconductance, 
$$g_m = \frac{\partial I_D}{\partial V_{GS}} = 2 K_n V_{DS}$$

$$K_n = \frac{K'_n}{2} \left( \frac{W}{L} \right) = \frac{\mu_n C_{ox}}{2} \left( \frac{W}{L} \right)$$

So, 
$$g_m = 2K_n V_{DS} = \mu_n C_{ox} \left( \frac{W}{L} \right) V_{DS}$$

$$= 100 \times 50 \times 0.1 \mu\text{A/V}$$

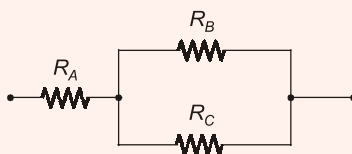
$$= 0.5 \text{ mA/V}$$

• • • **End of Solution**

**Q.13** A connection is made consisting of resistance  $A$  in series with a parallel combination of resistances  $B$  and  $C$ . Three resistors of value  $10 \Omega$ ,  $5 \Omega$ ,  $2 \Omega$  are provided. Consider all possible permutations of the given resistors into the positions  $A$ ,  $B$ ,  $C$  and identify the configurations with maximum possible overall resistance, and also the ones with minimum possible overall resistance. The ratio of maximum to minimum values of the resistances (up to second decimal place) is \_\_\_\_.

**Ans. (2.143)**

The connection of resistors is as shown below:



Given resistor values are :  $10 \Omega$ ,  $5 \Omega$ ,  $2 \Omega$

The maximum resistance possible is,

$$R_{T(\max)} = 10 \Omega + (5 \Omega \parallel 2 \Omega)$$

$$= \left( 10 + \frac{10}{7} \right) \Omega = \frac{80}{7} \Omega$$

The minimum resistance possible is,

$$R_{T(\min)} = 2 \Omega + (10 \Omega \parallel 5 \Omega)$$

$$= \left(2 + \frac{10}{3}\right) \Omega = \frac{16}{3} \Omega$$

$$\frac{R_{T(\max)}}{R_{T(\min)}} = \frac{80/7}{16/3} = \frac{15}{7} = 2.143$$

• • • End of Solution

**Q.14** Consider the state space realization

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & -9 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 45 \end{bmatrix} u(t), \text{ with the initial condition } \begin{bmatrix} x_1(0) \\ x_2(0) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix},$$

where  $u(t)$  denotes the unit step function. The value of  $\lim_{t \rightarrow \infty} \sqrt{x_1^2(t) + x_2^2(t)}$  is \_\_\_\_\_.

**Ans. (5)**

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & -9 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 45 \end{bmatrix} u(t)$$

By applying Laplace transform on both sides, we get

$$sX_1(s) - x_1(0) = 0$$

$$X_1(s) = \frac{x_1(0)}{s} = 0 \quad \because x_1(0) = 0$$

So,  $x_1(t) = 0$

and  $sX_2(s) - x_2(0) = -9X_1(s) + \frac{45}{s}$

$$X_2(s) = \frac{45}{s(s+9)} \quad \because x_2(0) = 0$$

$$\text{Required value} = \lim_{t \rightarrow \infty} \sqrt{x_1^2(t) + x_2^2(t)}$$

$$= \left| \lim_{t \rightarrow \infty} x_2(t) \right| \quad \because x_1(t) = 0$$

$$\lim_{t \rightarrow \infty} x_2(t) = \lim_{s \rightarrow 0} sX_2(s) = \frac{45}{9} = 5$$

So, Required value =  $|5| = 5$

• • • End of Solution

**Q.15** An LTI system with unit sample response  $h[n] = 5\delta[n] - 7\delta[n-1] + 7\delta[n-3] - 5\delta[n-4]$  is a

- |                      |                      |
|----------------------|----------------------|
| (a) low-pass filter  | (b) high-pass filter |
| (c) band-pass filter | (d) band-stop filter |



Ans. (c)

$$h[n] = 5\delta[n] - 7\delta[n-1] + 7\delta[n-3] - 5\delta[n-4]$$

Now,

$$H(e^{j\omega}) = 5 - 7e^{-j\omega} + 7e^{-3j\omega} - 5e^{-4j\omega}$$

Now for  $\omega = 0$ ,

$$H(e^{j0}) = 5 - 7 + 7 - 5 = 0$$

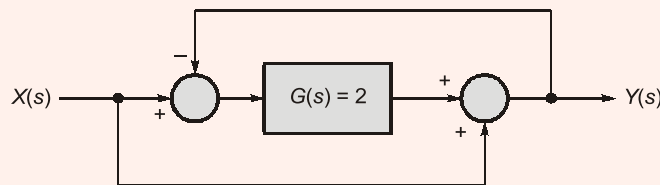
and for  $\omega = \pi$ ,

$$H(e^{j\pi}) = 5 - 7(-1) + 7(-1) - 5(1) \\ = 5 + 7 - 7 - 5 = 0$$

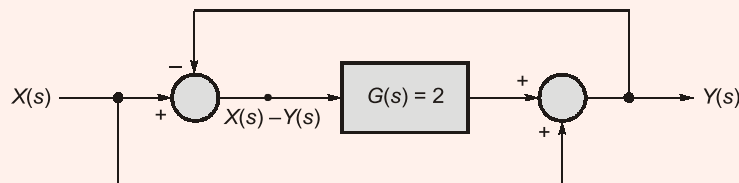
System is attenuating low and high frequencies whereas passing the mid frequencies. So, its a BPF.

• • • End of Solution

Q.16 For the system shown in the figure,  $Y(s)/X(s) = \underline{\hspace{2cm}}$ .



Ans. (1)



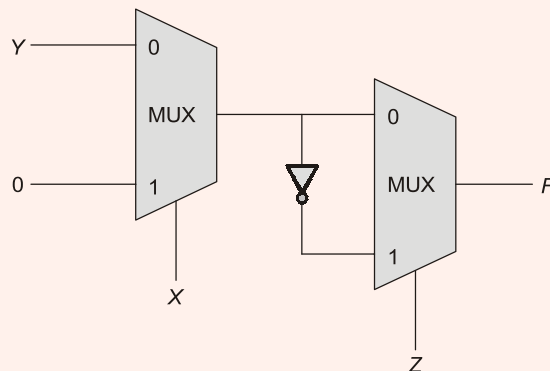
$$Y(s) = [X(s) - Y(s)]G(s) + X(s)$$

$$[1 + G(s)]Y(s) = [G(s) + 1]X(s)$$

$$\frac{Y(s)}{X(s)} = 1$$

• • • End of Solution

Q.17 Consider the circuit shown in the figure.





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<b>ME</b> 9 Selections in Top 10	<b>AIR-1</b>  Mohd Idul Ahmad	<b>AIR-3</b>  Chirag Srivastav	<b>AIR-4</b>  Taronjot Singh	<b>AIR-5</b>  Deepak Vijay	<b>AIR-6</b>  Dheeraj Kumar	<b>AIR-7</b>  Tarun Kumar	<b>AIR-8</b>  JGMV Pramod	<b>AIR-9</b>  Gaurav Kant	<b>AIR-10</b>  Jivitesh Anand	
<b>EE</b> 10 Selections in Top 10	<b>AIR-1</b>  Gaurav	<b>AIR-2</b>  B Venkatesh	<b>AIR-3</b>  Tanuj K Sharma	<b>AIR-4</b>  Varsha	<b>AIR-5</b>  Ashish Verma	<b>AIR-6</b>  Mufeed Khan	<b>AIR-7</b>  Shyamji D.	<b>AIR-8</b>  Sk Taushifur R.	<b>AIR-9</b>  Arvind Biswal	<b>AIR-10</b>  Gaurav Tyagi
<b>E&amp;T</b> 10 Selections in Top 10	<b>AIR-1</b>  Naveen B. Sharma	<b>AIR-2</b>  Amit Rawat	<b>AIR-3</b>  Aswathy S.	<b>AIR-4</b>  Thaduri Naveen	<b>AIR-5</b>  Vinit Ranjan	<b>AIR-6</b>  Harshit Jain	<b>AIR-7</b>  Akash Chhikara	<b>AIR-8</b>  Vivek Jain	<b>AIR-9</b>  Jadugurta N.	<b>AIR-10</b>  Prabhakar

**39** Selections  
in Top 10

**76** Selections  
in Top 20

**505** Selections out of  
total 604 vacancies

<b>CE</b>	Selections in Top 10 <b>10</b>	MADE EASY Selections <b>182</b> Out of <b>225</b> Vacancies	MADE EASY Percentage <b>81%</b>
<b>ME</b>	Selections in Top 10 <b>9</b>	MADE EASY Selections <b>159</b> Out of <b>179</b> Vacancies	MADE EASY Percentage <b>89%</b>
<b>EE</b>	Selections in Top 10 <b>10</b>	MADE EASY Selections <b>86</b> Out of <b>106</b> Vacancies	MADE EASY Percentage <b>81%</b>
<b>E&amp;T</b>	Selections in Top 10 <b>10</b>	MADE EASY Selections <b>78</b> Out of <b>94</b> Vacancies	MADE EASY Percentage <b>83%</b>

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The Boolean expression  $F$  implemented by the circuit is

- (a)  $\bar{X}\bar{Y}\bar{Z} + XY + \bar{Y}Z$  (b)  $\bar{X}Y\bar{Z} + XZ + \bar{Y}Z$   
(c)  $\bar{X}Y\bar{Z} + XY + \bar{Y}Z$  (d)  $\bar{X}\bar{Y}\bar{Z} + XZ + \bar{Y}Z$

Ans. (b)

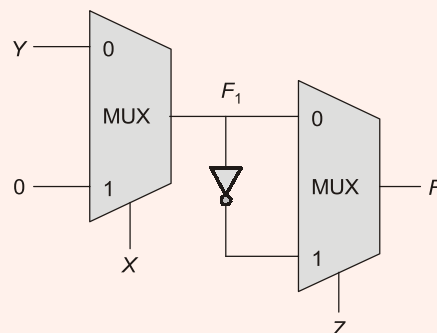
$$F_1 = \bar{X}Y$$

$$F = \bar{Z}F_1 + Z\bar{F}_1$$

$$= (\bar{X}Y)\bar{Z} + (\bar{X}\bar{Y})Z$$

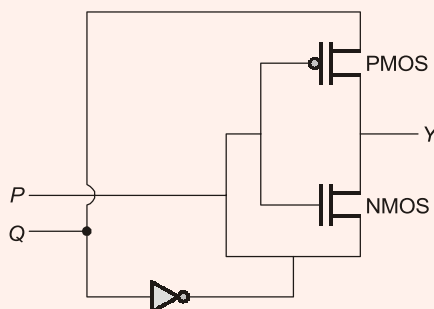
$$= \bar{X}Y\bar{Z} + (X + \bar{Y})Z$$

$$F = \bar{X}Y\bar{Z} + XZ + \bar{Y}Z$$



End of Solution

Q.18 For the circuit shown in the figure.  $P$  and  $Q$  are the inputs and  $Y$  is the output.



The logic implemented by the circuit is

- (a) XNOR (b) XOR  
(c) NOR (d) OR

Ans. (\*)

The given circuit is wrong

End of Solution

Q.19 In a DRAM,

- (a) periodic refreshing is not required  
(b) information is stored in a capacitor  
(c) information is stored in a latch  
(d) both read and write operations can be performed simultaneously

Ans. (b)

In a DRAM, data is stored in the form of charge on capacitor and periodic refreshing is needed to restore the charge on capacitor.

End of Solution

**Q.20** Consider the random process

$$X(t) = U + Vt,$$

where  $U$  is a zero-mean Gaussian random variable and  $V$  is a random variable uniformly distributed between 0 and 2. Assume that  $U$  and  $V$  are statistically independent. The mean value of the random process at  $t = 2$  is \_\_\_\_\_.

**Ans. (2)**

$$X(t) = U + Vt$$

$$\text{At } t = 2, \quad X(t) = X(2) = U + 2V$$

$$\begin{aligned} E[X(t)] &= E[U + 2V] \\ &= E[U] + 2E[V] \end{aligned}$$

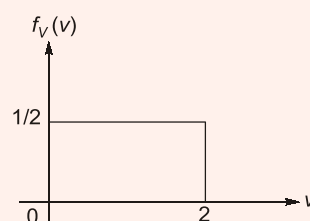
$$\text{Given that,} \quad E[U] = 0$$

Also given that,

$V$  is uniformly distributed between 0 and 2

$$\text{So,} \quad E[V] = \int_{-\infty}^{\infty} f_V(v) dv = \int_0^2 \left(\frac{1}{2}\right) dv = 1$$

$$\text{So,} \quad E[X(t)] = 0 + 2(1) = 2$$



● ● ● **End of Solution**

**Q.21** Which of the following statements is incorrect?

- (a) Lead compensator is used to reduce the settling time.
- (b) Lag compensator is used to reduce the steady state error.
- (c) Lead compensator may increase the order of a system.
- (d) Lag compensator always stabilizes an unstable system.

**Ans. (d)**

In case of high type systems Lag compensator fails to give stability.

● ● ● **End of Solution**

**Q.22** A two-wire transmission line terminates in a television set. The VSWR measured on the line is 5.8. The percentage of power that is reflected from the television set is \_\_\_\_\_.

**Ans. (49.83)**

Given that, VSWR (or)  $s = 5.8$

$$s = \frac{1+|\rho|}{1-|\rho|} = 5.8$$

$\rho$  = Reflection coefficient of television set

$$\rho = \frac{s-1}{s+1} = \frac{4.8}{6.8} = 0.70588$$

$$\frac{P_{\text{reflected}}}{P_{\text{incident}}} = \rho^2 = 0.4983 \text{ or } 49.83\%$$

● ● ● **End of Solution**

**Q.23** The residues of a function

$$f(z) = \frac{1}{(z-4)(z+1)^3}$$

are

(a)  $\frac{-1}{27}$  and  $\frac{-1}{125}$

(b)  $\frac{1}{125}$  and  $\frac{-1}{125}$

(c)  $\frac{-1}{27}$  and  $\frac{1}{5}$

(d)  $\frac{1}{125}$  and  $\frac{-1}{5}$

**Ans. (b)**

$$\text{Residue at } z = 4 \text{ is } = \lim_{z \rightarrow 4} (z-4) \frac{1}{(z-4)(z+1)^3} = \frac{1}{(4+1)^3} = \frac{1}{125}$$

$$\begin{aligned} \text{Residue at } z = -1 \text{ is } &= \lim_{z \rightarrow -1} \frac{1}{2!} \frac{d^2}{dz^2} \left( (z+1)^3 \frac{1}{(z-4)(z+1)^3} \right) \\ &= \lim_{z \rightarrow -1} \frac{1}{2!} \left( \frac{2}{(z-4)^3} \right) = \frac{1}{(-1-4)^3} = \frac{-1}{125} \end{aligned}$$

• • • **End of Solution**

**Q.24** A sinusoidal message signal is converted to a PCM signal using a uniform quantizer. The required signal to quantization noise ratio (SQNR) at the output of the quantizer is 40 dB. The minimum number of bits per sample needed to achieve the desired SQNR is \_\_\_\_.

**Ans. (7)**

For sinusoidal input is applied to a PCM system,

$$\text{SQNR} = 6n + 1.8 ; \quad n = \text{number of bits per sample}$$

Given that, the required SQNR = 40 dB

$$\text{so, } 6n + 1.8 \geq 40$$

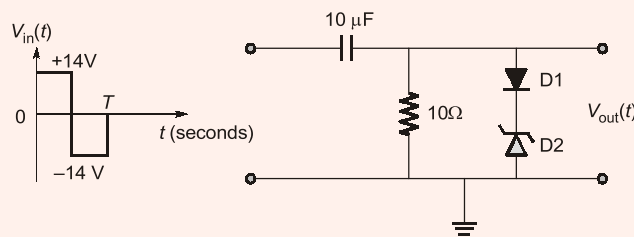
$$n \geq \frac{38.2}{6}$$

$$n_{\min} = 7$$

$\therefore n$  is always an integer value

• • • **End of Solution**

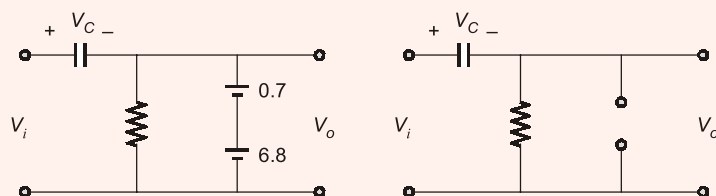
**Q.25** In the figure, D1 is a real silicon *pn* junction diode with a drop of 0.7 V under forward bias condition and D2 is a Zener diode with breakdown voltage of -6.8 V. The input  $V_{in}(t)$  is a periodic square wave of period  $T$ , whose one period is shown in the figure.



Assuming  $10 \tau \ll T$ , where  $\tau$  is the time constant of the circuit, the maximum and minimum values of the output waveform are respectively.

- (a) 7.5 V and – 20.5 V                      (b) 6.1 V and – 21.9 V  
(c) 7.5 V and – 21.2 V                      (d) 6.1 V and – 22.6 V

**Ans. (a)**



When  $V_i = 14$  V:

$$V_o = 7.5 \text{ V}$$

$$V_C = V_i - V_o = 6.5 \text{ V}$$

When  $V_i = -14$  V:

$$\text{Minimum } V_o = V_i - V_C$$

$$= -14 - 6.5 = -20.5 \text{ V}$$

$$\text{Maximum } V_o = 7.5 \text{ V}$$

$$\text{Minimum } V_o = -20.5 \text{ V}$$

End of Solution

**Q.26** The signal  $x(t) = \sin(14000\pi t)$ , where  $t$  is in seconds is sampled at a rate of 9000 samples per second. The sampled signal is the input to an ideal lowpass filter with frequency response  $H(f)$  as follows :

$$H(f) = \begin{cases} 1, & |f| \leq 12 \text{ kHz} \\ 0, & |f| > 12 \text{ kHz} \end{cases}$$

What is the number of sinusoids in the output and their frequencies in kHz?

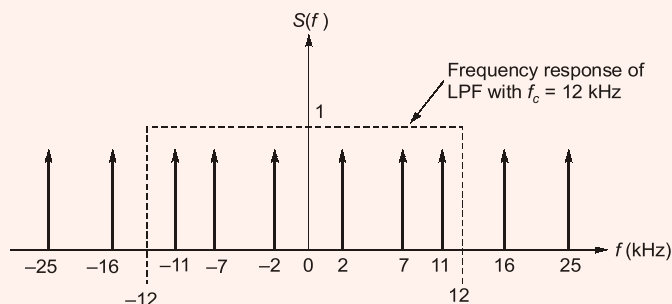
- (a) Number = 1, frequency = 7                      (b) Number = 3, frequencies = 2, 7, 11  
(c) Number = 2, frequencies = 2, 7                      (d) Number = 2, frequencies = 7, 11

**Ans. (b)**

$$x(t) = \sin(14000\pi t) ; f_m = 7 \text{ kHz}$$

$$f_s = 9000 \text{ samples per second} = 9 \text{ kHz}$$

The spectrum of the sampled signal can be given as shown below:

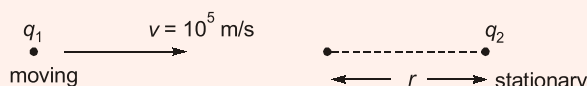


So, three sinusoids will be there at the output of the LPF and the frequencies of those sinusoids are 2 kHz, 7 kHz and 11 kHz.

● ● ● **End of Solution**

- Q.27** An electron ( $q_1$ ) is moving in free space with velocity  $10^5$  m/s towards a stationary electron ( $q_2$ ) far away. The closest distance that this moving electron gets to the stationary electron before the repulsive force diverts its path is  $\_\_\_\_ \times 10^{-8}$  m.  
[Given, mass of electron  $m = 9.11 \times 10^{-31}$  kg, charge of electron  $e = -1.6 \times 10^{-19}$  C, and permittivity  $\epsilon_0 = (1/36\pi) \times 10^{-9}$  F/m]

**Ans. (5.058)**



$r$  is the distance at which kinetic energy of  $q_1$  becomes zero (because kinetic energy (KE) is converted into potential energy (PE)).

When  $q_1$  reaches ' $r$ ', it starts diverting.

Kinetic energy,  $KE = \frac{1}{2}mv^2$  and work done in moving  $q_1$  charge to distance ' $r$ ' is

$$q_1 V_2 = q_1 \frac{q_2}{4\pi\epsilon_0 r}, \quad (q_1 = q_2 = -1.6 \times 10^{-19} \text{ C})$$

now 
$$\frac{1}{2}mv^2 = \frac{q_1 q_2}{4\pi\epsilon_0 r}$$

$$\Rightarrow r = \frac{2 \times -1.6 \times 10^{-19} \times -1.6 \times 10^{-19}}{4\pi \times \frac{10^{-9}}{36\pi} \times 9.11 \times 10^{-31} \times (10^5)^2} = 5.058 \times 10^{-8} \text{ m}$$

● ● ● **End of Solution**

- Q.28** A unity feedback control system is characterized by the open-loop transfer function

$$G(s) = \frac{2(s+1)}{s^3 + Ks^2 + 2s + 1}$$

The value of  $K$  for which the system oscillates at 2 rad/s is  $\_\_\_\_$ .

**Ans. (0.75)**

The given open loop transfer function is,

$$G(s) = \frac{2(s+1)}{s^3 + Ks^2 + 2s + 1}$$

The closed loop transfer function is,

$$T(s) = \frac{G(s)}{1+G(s)} = \frac{2(s+1)}{s^3 + Ks^2 + 4s + 3}$$

When system oscillates, i.e., when system is marginally stable,

$$(1)(3) = K(4)$$

So, 
$$K = 0.75$$

● ● ● **End of Solution**

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**Q.29** Consider an LTI system with magnitude response

$$|H(f)| = \begin{cases} 1 - \frac{|f|}{20}, & |f| \leq 20 \\ 0, & |f| > 20 \end{cases}$$

and phase response

$$\arg \{H(f)\} = -2f$$

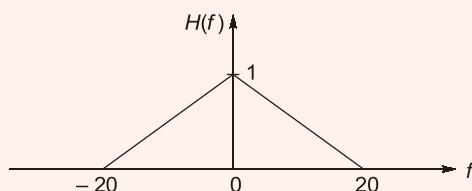
If the input to the system is

$$x(t) = 8 \cos\left(20\pi t + \frac{\pi}{4}\right) + 16 \sin\left(40\pi t + \frac{\pi}{8}\right) + 24 \cos\left(80\pi t + \frac{\pi}{16}\right)$$

then the average power of the output signal  $y(t)$  is \_\_\_\_.

**Ans. (8)**

Since,



So,

$$y(t) = \frac{1}{2} \times 8 \cos(20\pi t + \phi) = 4 \cos(20\pi t + \phi)$$

So,

$$P_y = \frac{4^2}{2} = 8 \text{ W.}$$

• • • **End of Solution**

**Q.30** A second order LTI system is described by the following state equations

$$\frac{d}{dt}x_1(t) - x_2(t) = 0$$

$$\frac{d}{dt}x_2(t) + 2x_1(t) + 3x_2(t) = r(t)$$

where  $x_1(t)$  and  $x_2(t)$  are the two state variables and  $r(t)$  denotes the input. The output  $c(t) = x_1(t)$ . The system is

- |                            |                 |
|----------------------------|-----------------|
| (a) undamped (oscillatory) | (b) underdamped |
| (c) critically damped      | (d) overdamped  |

**Ans. (d)**

Given state variable equations are as follows :

$$\frac{d}{dt}x_1(t) - x_2(t) = 0 \quad \dots (i)$$

$$\frac{d}{dt}x_2(t) + 2x_1(t) + 3x_2(t) = r(t) \quad \dots (ii)$$

Also given that, input =  $r(t)$  and output =  $x_1(t)$

By applying Laplace transform to equation (i), we get,

$$sX_1(s) = X_2(s) \quad \dots (iii)$$

By applying Laplace transform to equation (ii), we get,

$$sX_2(s) + 2X_1(s) + 3X_2(s) = R(s)$$

$$X_2(s) = \frac{R(s) - 2X_1(s)}{s+3} \quad \dots (iv)$$

By substituting equation (iv) in equation (iii), we get,

$$sX_1(s) = \frac{R(s) - 2X_1(s)}{s+3}$$

$$(s^2 + 3s + 2)X_1(s) = R(s)$$

So, the transfer function of the given system is,

$$\frac{X_2(s)}{R(s)} = \frac{1}{s^2 + 3s + 2}$$

$$\omega_n^2 = 2$$

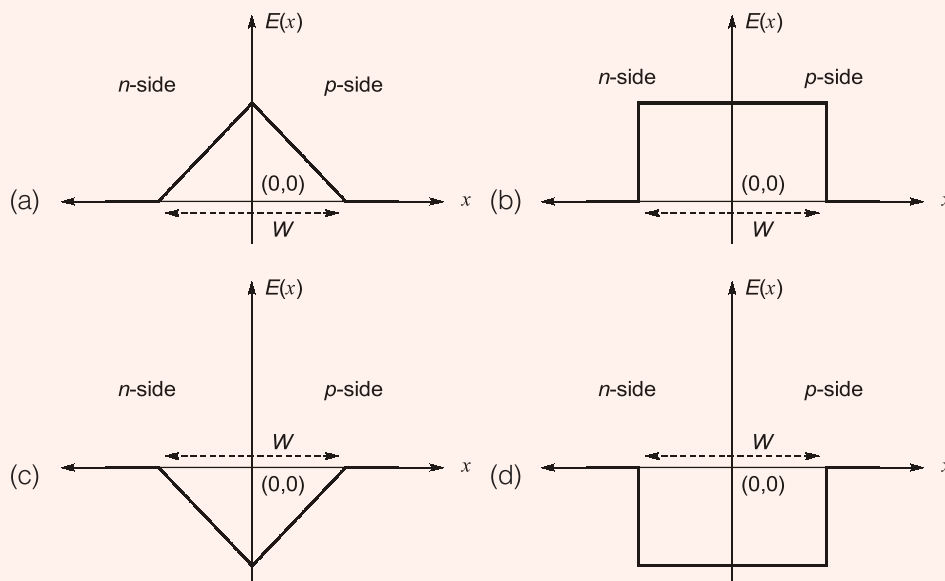
$$2\zeta\omega_n = 3$$

$$\zeta = \frac{3}{2\omega_n} = \frac{3}{2\sqrt{2}} = 1.06$$

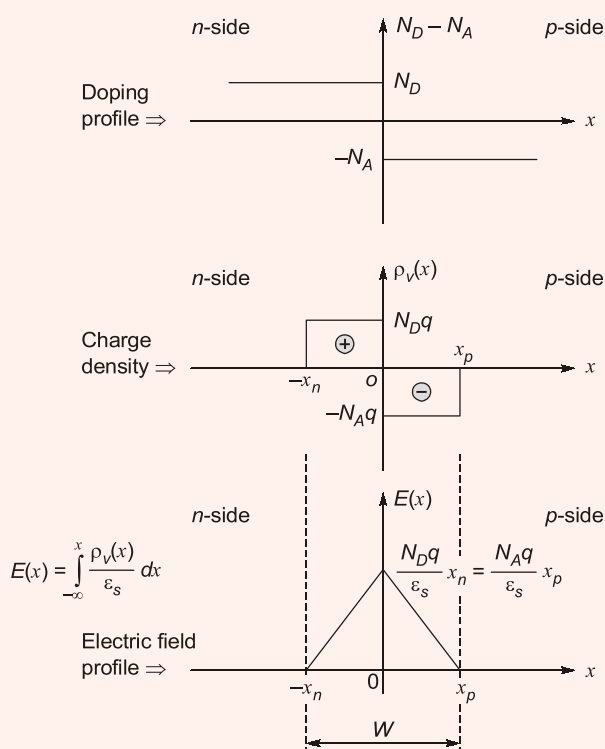
As  $\zeta > 1$ , the given system is overdamped.

● ● ● End of Solution

- Q.31** An abrupt  $pn$  junction (located at  $x = 0$ ) is uniformly doped on both  $p$  and  $n$  sides. The width of the depletion region is  $W$  and the electric field variation in the  $x$ -direction is  $E(x)$ . Which of the following figures represents the electric field profile near the  $pn$  junction?



Ans. (a)



End of Solution

**Q.32** A modulating signal given by  $x(t) = 5 \sin(4\pi 10^3 t - 10\pi \cos 2\pi 10^3 t)$  V is fed to a phase modulator with phase deviation constant  $k_p = 5$  rad/V. If the carrier frequency is 20 kHz, the instantaneous frequency (in kHz) at  $t = 0.5$  ms is \_\_\_\_.

Ans. (70)

Given that, the modulating signal is,

$$x(t) = 5 \sin(4000\pi t - 10\pi \cos 2000\pi t) \text{ V}$$

The standard phase modulated signal can be given as,

$$s(t) = A_c \cos(\omega_c t + k_p x(t))$$

Instantaneous angle of the modulated signal is,

$$\theta(t) = \omega_c t + k_p x(t)$$

Instantaneous frequency is,

$$\omega_i(t) = \frac{d\theta(t)}{dt}$$

$$= \omega_c + k_p \frac{dx(t)}{dt}$$

$$f_i(t) = f_c + \frac{25}{2\pi} \left[ \cos(4000\pi t - 10\pi \cos 2000\pi t) (4000\pi + 20000\pi^2 \sin 2000\pi t) \right]$$

At  $t = 0.5$  ms,

$$\begin{aligned} f_i(t) &= f_c + \frac{25}{2\pi} \left[ \cos(2\pi - 10\pi \cos(\pi)) \right] (4000\pi + 20000\pi^2 \sin(\pi)) \\ &= f_c + \frac{25}{2\pi} [\cos(12\pi)] (4000\pi) \\ &= f_c + 50 \text{ kHz} \\ &= 70 \text{ kHz} \end{aligned}$$

$\therefore$  Given that,  $f_c = 20 \text{ kHz}$

• • • End of Solution

**Q.33** For a particular intensity of incident light on a silicon *pn* junction solar cell, the photocurrent density ( $J_L$ ) is  $2.5 \text{ mA/cm}^2$  and the open-circuit voltage ( $V_{oc}$ ) is  $0.451 \text{ V}$ . Consider thermal voltage ( $V_T$ ) to be  $25 \text{ mV}$ . If the intensity of the incident light is increased by 20 times, assuming that the temperature remains unchanged,  $V_{oc}$  (in volts) will be \_\_\_\_.

**Ans. (0.526)**

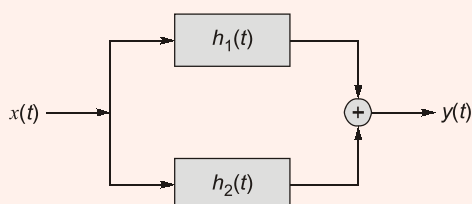
$$V_{OC} = V_T \ln \frac{J_L}{J_S} \quad J_L \propto \text{Light intensity}$$

$$V_{OC2} - V_{OC1} = V_T \ln \frac{J_{L2}}{J_{L1}}$$

$$\begin{aligned} V_{OC2} - V_{OC1} &= 25 \ln 20 \approx 75 \text{ mV} = 0.075 \text{ V} \\ V_{OC2} &= 0.451 \text{ V} + 0.075 \text{ V} = 0.526 \text{ V} \end{aligned}$$

• • • End of Solution

**Q.34** Consider the parallel combination of two LTI systems shown in the figure,



The impulse responses of the systems are

$$h_1(t) = 2\delta(t+2) - 3\delta(t+1)$$

$$h_2(t) = \delta(t-2)$$

If the input  $x(t)$  is a unit step signal, then the energy of  $y(t)$  is \_\_\_\_.

**Ans. (7)**

Given that,

$$h_1(t) = 2\delta(t+2) - 3\delta(t+1)$$

$$h_2(t) = \delta(t-2)$$

Overall impulse response is,

$$h(t) = h_1(t) + h_2(t) = 2\delta(t+2) - 3\delta(t+1) + \delta(t-2)$$

If input,  $x(t) = u(t)$ , then the output will be,

$$\begin{aligned} y(t) &= x(t) * h(t) \\ &= u(t) * [2\delta(t+2) - 3\delta(t+1) + \delta(t-2)] \\ &= 2u(t+2) - 3u(t+1) + u(t-2) \end{aligned}$$



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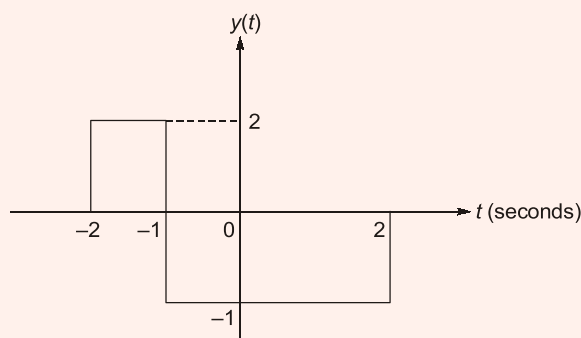
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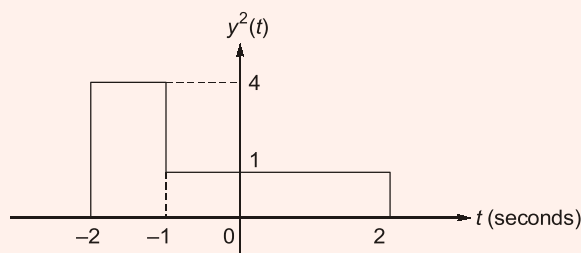
By plotting  $y(t)$ , we get,



The energy of  $y(t)$  can be given as,

$$E_y = \int_{-\infty}^{\infty} y^2(t) dt$$

By plotting  $y^2(t)$ , we get,



$$\begin{aligned} E_y &= \text{Area under the plot of } y^2(t) \\ &= (4 \times 1) + (3 \times 1) = 7 \end{aligned}$$

● ● ● End of Solution

**Q.35** The minimum value of the function  $f(x) = \frac{1}{3}x(x^2 - 3)$  in the interval  $-100 \leq x \leq 100$  occurs at  $x = \underline{\hspace{2cm}}$ .

**Ans.** (-100)

$$f(x) = \frac{1}{3}x(x^2 - 3)$$

$$= \frac{1}{3}(x^3 - 3x)$$

$$f'(x) = \frac{1}{3}(3x^2 - 3) = x^2 - 1$$

$$f'(x) = x^2 - 1 = 0$$

$$\Rightarrow x = \pm 1$$

$$f''(x) = 2x$$

$$\text{At } x = 1, \quad f''(1) = 2 = 0 \quad \Rightarrow \text{minima}$$

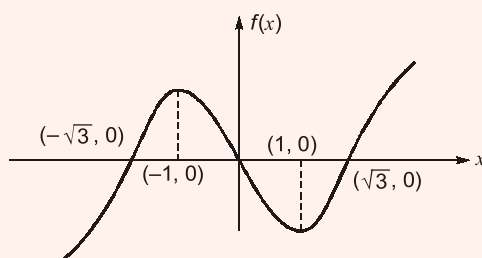
At  $x = -1$ ,  $f''(-1) = -2 < 0 \Rightarrow \text{maxima}$

Minimum value of  $f(x)$  in  $[-100, 100]$  is given by Minimum  $\{f(-100), f(100), f(1)\}$

Minimum  $\{-333433.3, 333233.3, -0.666\}$   
 $= -3335433.3$

Hence the minimum value occurs at  $x = -100$

Also graph of the function will be like



• • • End of Solution

**Q.36** The values of the integrals

$$\int_0^1 \left( \int_0^1 \frac{x-y}{(x+y)^3} dy \right) dx \quad \text{and} \quad \int_0^1 \left( \int_0^1 \frac{x-y}{(x+y)^3} dx \right) dy$$

are

- (a) same and equal to 0.5                      (b) same and equal to -0.5  
(c) 0.5 and -0.5 respectively              (d) -0.5 and 0.5 respectively

**Ans. (c)**

$$\begin{aligned} \text{Integral } I_1 &= \int_0^1 \int_0^1 \frac{x-y}{(x+y)^3} dy dx \\ &= \int_0^1 \left[ \int_0^1 \left( \frac{2x}{(x+y)^3} - \frac{1}{(x+y)^2} \right) dy \right] dx \\ &= \int_0^1 \left[ 2x \left( \frac{-1}{2(x+y)^2} \right) \Big|_0^1 + \left( \frac{1}{x+y} \right) \Big|_0^1 \right] dx \\ &= \int_0^1 \frac{1}{(x+1)^2} dx = - \left[ \frac{1}{x+1} \right]_0^1 = 0.5 \end{aligned}$$

$$\begin{aligned} \text{and Integral } I_2 &= \int_0^1 \left( \int_0^1 \frac{x-y}{(x+y)^3} dx \right) dy = \int_0^1 \left( \int_0^1 \frac{1}{(x+y)^2} - \frac{2y}{(x+y)^3} dx \right) dy \\ &= \int_0^1 \left[ \frac{-1}{(x+y)} + \frac{2y}{2(x+y)^2} \right]_0^1 dy = \int_0^1 \frac{-1}{(1+y)^2} dy = - \left[ \frac{-1}{y+1} \right]_0^1 = -0.5 \end{aligned}$$

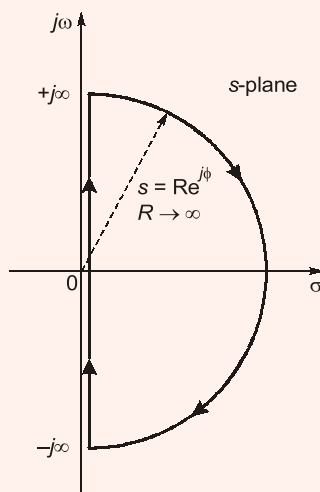
Option (c) is correct.

• • • End of Solution

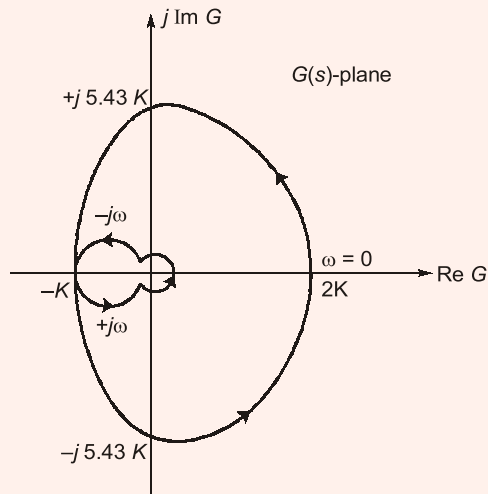
**Q.37** A unity feedback control system is characterized by the open-loop transfer function

$$G(s) = \frac{10K(s+2)}{s^3 + 3s^2 + 10}$$

The Nyquist path and the corresponding Nyquist plot of  $G(s)$  are shown in the figures below.



Nyquist path for  $G(s)$



Nyquist plot for  $G(s)$

If  $0 < K < 1$ , then the number of poles of the closed-loop transfer function that lie in the right-half of the  $s$ -plane is

- (a) 0 (b) 1  
(c) 2 (d) 3

**Ans. (c)**

Given that, the open loop transfer function of a unity feedback system is,

$$G(s) = \frac{10k(s+2)}{s^3 + 3s^2 + 10}$$

From the given Nyquist plot, for  $0 < k < 1$ , the encirclements about the point  $(-1 + j0)$  is,

$$N = 0$$

$$N = P - Z$$

$P$  = number of open loop poles in the right half of  $s$ -plane

$Z$  = number of closed loop poles in the right half of  $s$ -plane

**To determine the value of  $P$ :**

Applying R-H criteria to  $G(s)$ ,

$$G(s) = \frac{10k(s+2)}{s^3 + 3s^2 + 10}$$



$s^3$	1	0
$s^2$	3	10
$s^1$	$-10/3$	0
$s^0$	10	0

Two sign changes are there in the first column of the RH table. So, two open loop poles are there in right half of s-plane.

$$\begin{aligned}\text{So, } P &= 2 \\ N &= P - Z \\ 0 &= 2 - Z \\ Z &= 2\end{aligned}$$

$Z = 2$  indicates, there are two closed loop poles in right half of s-plane.

● ● ● End of Solution

**Q.38** The unmodulated carrier power in an AM transmitter is 5 kW. This carrier is modulated by a sinusoidal modulating signal. The maximum percentage of modulation is 50%. If it is reduced to 40%, then the maximum unmodulated carrier power (in kW) that can be used without overloading the transmitter is \_\_\_\_.

**Ans. (5.208)**

Given that,  $P_C = 5 \text{ kW}$  for  $\mu_{(\max)} = 0.5$

$$\begin{aligned}\text{So, } P_{t(\max)} &= P_c \left[ 1 + \frac{(0.5)^2}{2} \right] \\ &= 5 \left[ 1 + \frac{0.25}{2} \right] \text{ kW} = 5.625 \text{ kW}\end{aligned}$$

For  $\mu = 0.4$ ,

$$\begin{aligned}P_{C(\max)} \left( 1 + \frac{\mu^2}{2} \right) &= P_{t(\max)} \\ P_{C(\max)} &= \frac{5.625}{1 + \frac{(0.4)^2}{2}} \text{ kW} = 5.208 \text{ kW}\end{aligned}$$

● ● ● End of Solution

**Q.39** Standard air-filled rectangular waveguides of dimensions  $a = 2.29 \text{ cm}$  and  $b = 1.02 \text{ cm}$  are designed for radar applications. It is desired that these waveguides operate only in the dominant  $TE_{10}$  mode with the operating frequency at least 25% above the cutoff frequency of the  $TE_{10}$  mode but not higher than 95% of the next higher cutoff frequency. The range of the allowable operating frequency  $f$  is \_\_\_\_.

- (a)  $8.19 \text{ GHz} \leq f \leq 13.1 \text{ GHz}$       (b)  $8.19 \text{ GHz} \leq f \leq 12.45 \text{ GHz}$   
(c)  $6.55 \text{ GHz} \leq f \leq 13.1 \text{ GHz}$       (d)  $1.64 \text{ GHz} \leq f \leq 10.24 \text{ GHz}$

Ans. (b)

$$a = 2.29 \text{ cm}, b = 1.02 \text{ cm}$$

Waveguide is operating in  $(\text{TE}_{10})$  dominant mode

- $$f_c(\text{TE}_{10}) = \frac{c}{2a} = \frac{3 \times 10^{10}}{2 \times 2.29} = 6.55 \text{ GHz}$$

$$\Rightarrow 25\% \text{ above cut-off frequency} = 1.25 \times 6.55 \text{ GHz} = 8.1875 \text{ GHz}$$
- Next higher order mode is  $\text{TE}_{20}$  ( $\because a > 2b$ )

$$f_c(\text{TE}_{20}) = \frac{c}{a} = \frac{3 \times 10^{10}}{2.29} = 13.1 \text{ GHz}$$

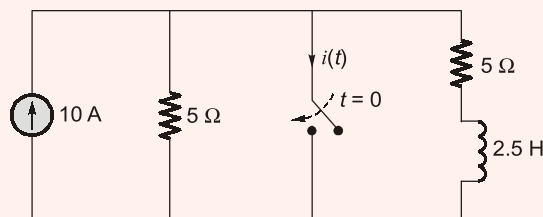
$$\Rightarrow 95\% \text{ of } f_c(\text{TE}_{20}) = 0.95 \times 13.1 = 12.445 \text{ GHz}$$

- Range of allowable operating frequency  $f$  is  

$$8.19 \text{ GHz} \leq f \leq 12.45 \text{ GHz}$$

• • • End of Solution

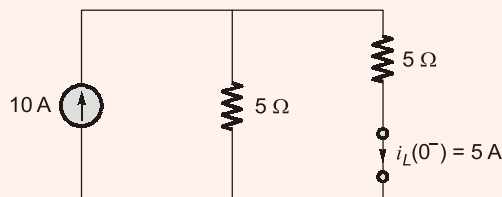
**Q.40** The switch in the circuit, shown in the figure, was open for a long time and is closed at  $t = 0$ .



The current  $i(t)$  (in ampere) at  $t = 0.5$  seconds is \_\_\_\_.

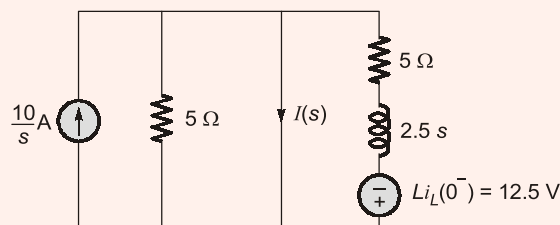
Ans. (8.16)

- The equivalent circuit at  $t = 0^-$  is as follows:



$$i_L(0^-) = i_L(0^+) = 5 \text{ A}$$

- The Laplace transform model of the circuit for  $t > 0$  is as follows:



$$I(s) = \frac{10}{s} - \frac{12.5}{5 + 2.5s} = \frac{10}{s} - \frac{5}{s + 2}$$

- By taking inverse Laplace transform,  
 $i(t) = (10 - 5e^{-2t}) u(t) \text{ A}$
- At  $t = 0.5$  seconds,

$$i(t) = \left(10 - \frac{5}{e}\right) \text{A} = 8.16 \text{ A}$$

• • • End of Solution

**Q.41** An integral  $I$  over a counter-clockwise circle  $C$  is given by

$$I = \int_C \frac{z^2 - 1}{z^2 + 1} e^z dz.$$

If  $C$  is defined as  $|z| = 3$ , then the value of  $I$  is

- (a)  $-\pi i \sin(1)$  (b)  $-2\pi i \sin(1)$   
(c)  $-3\pi i \sin(1)$  (d)  $-4\pi i \sin(1)$

**Ans. (d)**

Poles are  $z^2 + 1 = 0$   
 $z = \pm i$

$z = i$  lies inside  $|z| = 3$

$z = -i$  lies inside  $|z| = 3$

Residue at  $z = i$  is  $= \lim_{z \rightarrow i} (z - i) \frac{z^2 - 1}{(z - i)(z + i)} e^z = \frac{-1 - 1}{2i} e^i = ie^i$

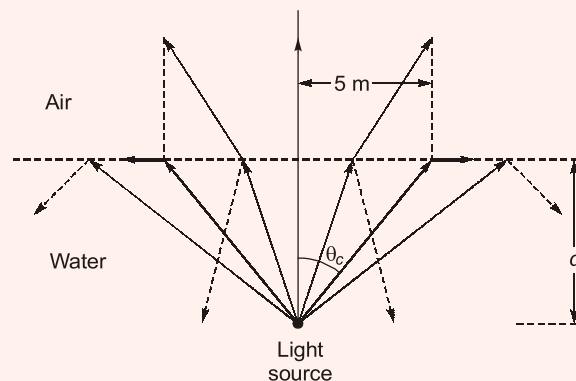
Residue at  $z = -i$  is  $= \lim_{z \rightarrow -i} (z + i) \frac{z^2 - 1}{(z - i)(z + i)} e^z = \frac{-1 - 1}{-2i} e^{-i} = \frac{1}{i} e^{-i} = -ie^{-i}$

By Residues theorem

$$\begin{aligned} I &= 2\pi i (ie^i - ie^{-i}) \\ &= -2\pi (e^i - e^{-i}) = -2\pi (\cos 1 + i \sin 1 - \cos 1 + i \sin 1) \\ &= -2\pi (2i \sin 1) = -4\pi i \sin 1 \end{aligned}$$

• • • End of Solution

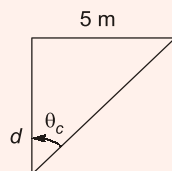
**Q.42** The permittivity of water at optical frequencies is  $1.75 \epsilon_0$ . It is found that an isotropic light source at a distance  $d$  under water forms an illuminated circular area of radius 5 m as shown in the figure. The critical angle is  $\theta_c$ .



The value of  $d$  (in meter) is \_\_\_\_.

Ans. (4.33)

- Critical angle,  $\theta_c = \sin^{-1} \sqrt{\frac{\epsilon_2}{\epsilon_1}} = \sin^{-1} \sqrt{\frac{\epsilon_0}{1.75 \epsilon_0}} = 49.1^\circ$

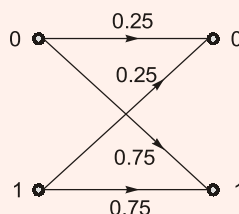


$$\tan 49.1 = 1.547 = \frac{5}{d}$$

$$\Rightarrow d = \frac{5}{1.547} = 4.33 \text{ m}$$

• • • End of Solution

**Q.43** Consider a binary memoryless channel characterized by the transition probability diagram shown in the figure.



The channel is

- (a) lossless
- (b) noiseless
- (c) useless
- (d) deterministic

Ans. (c)

Given that,

$$\left[ P\left(\frac{Y}{X}\right) \right] = \begin{bmatrix} 0.25 & 0.75 \\ 0.25 & 0.75 \end{bmatrix}$$

If mutual information  $I(X; Y) = 0$  for every possible input distribution, then the channel is called as useless (or) zero-capacity channel.

Let  $[P(X)] = [\alpha \quad (1 - \alpha)]$

Then,  $H(X) = -\alpha \log_2 \alpha - (1 - \alpha) \log_2 (1 - \alpha)$  bits/ symbol

$$[P(Y)] = [P(X)] \left[ P\left(\frac{Y}{X}\right) \right] = [0.25 \quad 0.75]$$

$$[P(X, Y)] = \begin{bmatrix} \frac{\alpha}{4} & \frac{3\alpha}{4} \\ \frac{(1-\alpha)}{4} & \frac{3(1-\alpha)}{4} \end{bmatrix}$$

$$\left[ P\left(\frac{X}{Y}\right) \right] = \frac{[P(X, Y)]}{[P(Y)]_d} = \begin{bmatrix} \alpha & \alpha \\ (1-\alpha) & (1-\alpha) \end{bmatrix}$$

$$H\left(\frac{X}{Y}\right) = -\sum_i \sum_j P(x_i, y_j) \log_2 P\left(\frac{x_i}{y_j}\right) \text{ bits/symbol}$$

$$= -\alpha \log_2 \alpha - (1-\alpha) \log_2 (1-\alpha) \text{ bits/symbol}$$

$$I(X; Y) = H(X) - H\left(\frac{X}{Y}\right) = 0$$

So, the given binary memoryless channel is a "useless" channel.

• • • End of Solution

- Q.44** If the vector function  $F = \hat{a}_x(3y - k_1z) + \hat{a}_y(k_2x - 2z) - \hat{a}_z(k_3y + z)$  is irrotational, then the values of the constants  $k_1$ ,  $k_2$  and  $k_3$ , respectively, are
- (a) 0.3, -2.5, 0.5                      (b) 0.0, 3.0, 2.0  
(c) 0.3, 0.33, 0.5                      (d) 4.0, 3.0, 2.0

**Ans. (b)**

$$F = \hat{a}_x(3y - k_1z) + \hat{a}_y(k_2x - 2z) - \hat{a}_z(k_3y + z)$$

$$\nabla \times F = 0 \quad (\text{irrotational})$$

$$\nabla \times F = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 3y - k_1z & k_2x - 2z & -(k_3y + z) \end{vmatrix}$$

$$= \hat{a}_x \left[ \frac{\partial}{\partial y} [-(k_3y + z)] - \frac{\partial}{\partial z} (k_2x - 2z) \right] - \hat{a}_y \left[ \frac{\partial}{\partial x} [-(k_3y + z)] - \frac{\partial}{\partial z} (3y - k_1z) \right]$$

$$+ \hat{a}_z \left[ \frac{\partial}{\partial x} (k_2x - 2z) - \frac{\partial}{\partial y} (3y - k_1z) \right]$$

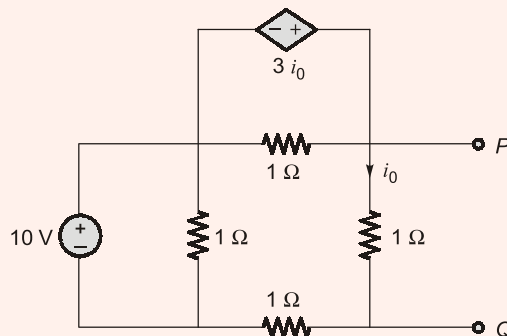
$$\hat{a}_x [-k_3 + 2] - \hat{a}_y [k_1] + \hat{a}_z [k_2 - 3] = 0$$

$$\Rightarrow \quad k_3 = 2, \quad k_1 = 0, \quad k_2 = 3$$

or  $k_1 = 0, \quad k_2 = 3, \quad k_3 = 2$

• • • End of Solution

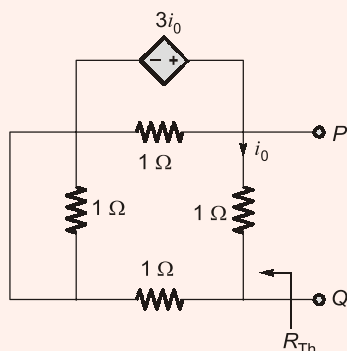
- Q.45** Consider the circuit shown in the figure.



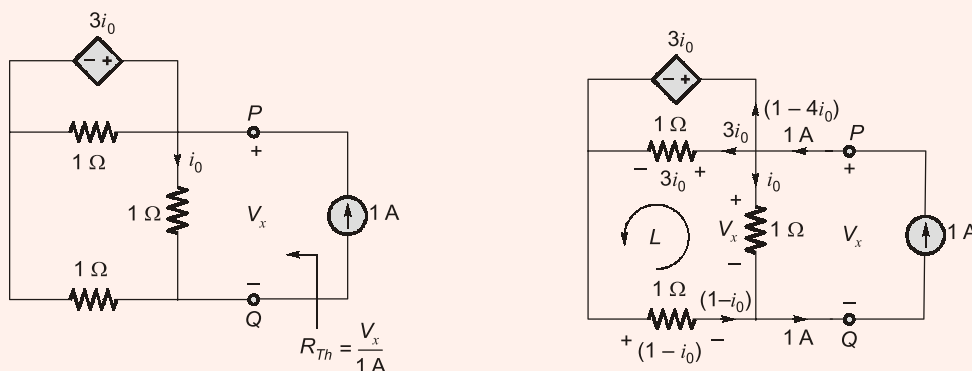
The Thevenin equivalent resistance (in  $\Omega$ ) across P-Q is \_\_\_\_\_.

Ans. (-1)

- The equivalent circuit to calculate the Thevenin equivalent resistance ( $R_{Th}$ ) is as follows:



- It can be further reduced as follows:



- By applying KVL in the Loop L,

$$V_x = 3i_0 + (1 - i_0) = 2i_0 + 1$$

Also,

$$V_x = i_0(1 \Omega)$$

- So,

$$2i_0 + 1 = i_0$$

$$i_0 = -1 \text{ A}$$

And

$$V_x = -1 \text{ V}$$

So,

$$R_{Th} = \frac{V_x}{1 \text{ A}} = -1 \Omega$$

End of Solution

**Q.46** Figure I shows a 4-bit ripple carry adder realized using full adders and Figure II shows the circuit of a full-adder (FA). The propagation delay of the XOR, AND and OR gates in Figure II are 20 ns, 15 ns and 10 ns, respectively. Assume all the inputs to the 4-bit adder are initially reset to 0.

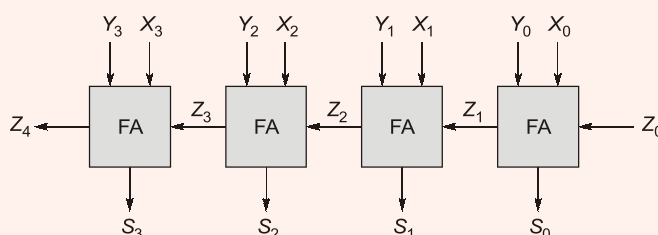


Figure I

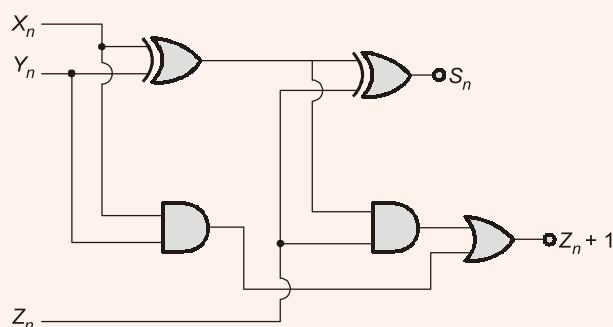


Figure II

At  $t = 0$ , the inputs to the 4-bit adder are changed to  $X_3X_2X_1X_0 = 1100$ ,  $Y_3Y_2Y_1Y_0 = 0100$  and  $Z_0 = 1$ . The output of the ripple carry adder will be stable at  $t$  (in ns) = \_\_\_\_\_.

**Ans. (50)**

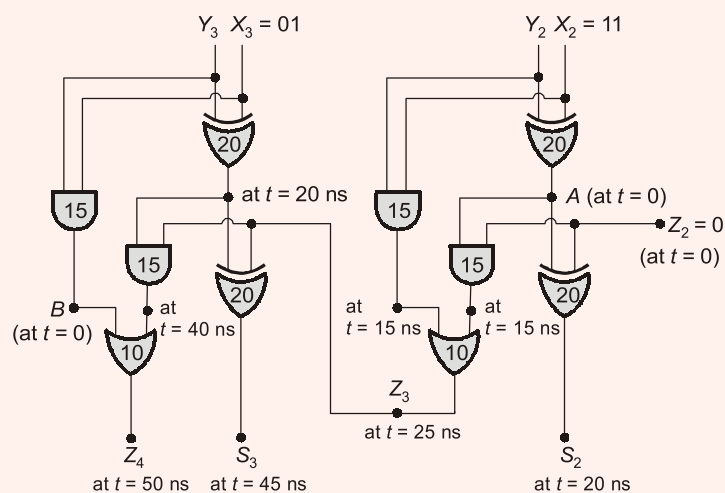
In this question inputs to be added are :

$$X_3X_2X_1X_0 = 1100$$

$$Y_3Y_2Y_1Y_0 = 0100 \text{ and } Z_0 = 1$$

For this combination of addition, total minimum delay depends on the addition of most-significant two bits (since least significant two bits are zeros they do not cause any change in  $Z_1$  and  $Z_2$ ).

So, in the process of addition of given two digits, waveforms at  $Z_1$  and  $Z_2$  become stable at  $t = 0$  itself.



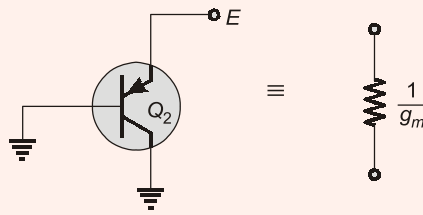
In the above diagram the waveform at  $A$  and  $B$  become stable at  $t = 0$  itself, as the applied input combinations do not cause any change.

So, for the given combination of inputs, output will settle at  $t = 50$  ns.

● ● ● End of Solution







Computer AC equivalent circuit in as shown below:

It is a CE amplifier with unbypassed  $R_E$ .

$$A_v = \frac{-g_m R'_L}{1 + g_m R_E}$$

where,

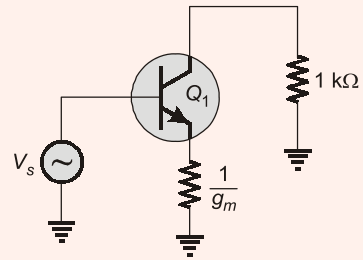
$$g_m = \frac{I_C}{V_T} = \frac{2.6}{26} = 100 \text{ m}$$

$$R'_L = 11 \Omega$$

$$R_E = \frac{1}{g_m}$$

$$A_v = \frac{-100 \times 1}{1 + 1} = -50$$

$$|A_v| = 50$$



● ● ● End of Solution

**Q.49** The transfer function of a causal LTI system is  $H(s) = 1/s$ . If the input to the system is  $x(t) = [\sin(t)/\pi t] u(t)$ , where  $u(t)$  is a unit step function, the system output  $y(t)$  as  $t \rightarrow \infty$  is \_\_\_\_\_.

**Ans. (0.5)**

$$h(t) = u(t)$$

$$x(t) = \frac{\sin t}{\pi t} \cdot u(t)$$

So,

$$y(t) = \int_0^t \frac{\sin \tau}{\pi \tau} d\tau$$

$$y(t)_{t \rightarrow \infty} = \frac{1}{\pi} \int_0^\infty \frac{\sin \tau}{\tau} d\tau$$

Since,

$$\int_0^\infty \frac{\sin \tau}{\tau} d\tau = \frac{\pi}{2}$$

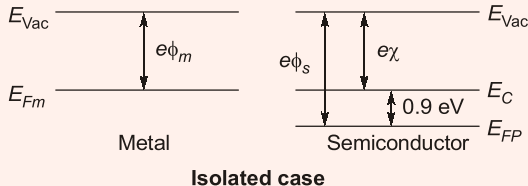
So,

$$y(t)_{t \rightarrow \infty} = \frac{1}{\pi} \cdot \frac{\pi}{2} = \frac{1}{2}$$

● ● ● End of Solution

- Q.50** A MOS capacitor is fabricated on  $p$ -type Si (Silicon) where the metal work function is 4.1 eV and electron affinity of Si is 4.0 eV.  $E_C - E_F = 0.9$  eV, where  $E_C$  and  $E_F$  are the conduction band minimum and the Fermi energy levels of Si respectively. Oxide  $\epsilon_r = 3.9$ ,  $\epsilon_o = 8.85 \times 10^{-14}$  F/cm, oxide thickness  $t_{ox} = 0.1 \mu\text{m}$  and electronic charge  $q = 1.6 \times 10^{-19}$  C. If The measured flat band voltage of this capacitor is  $-1$  V, then the magnitude of the fixed charge at the oxide-semiconductor interface, in nC/cm<sup>2</sup> is \_\_\_\_.

**Ans. (6.903)**

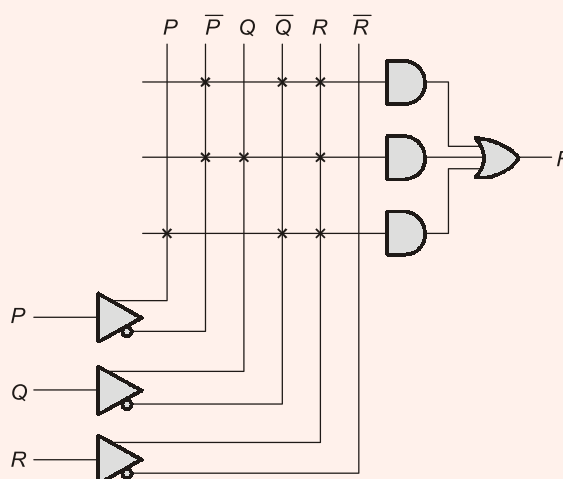
$$\begin{aligned}
 e\phi_m &= 4.1 \text{ eV} \\
 e\chi &= 4 \text{ eV} \\
 E_C - E_{FP} &= 0.9 \text{ eV} \\
 e\phi_s &= e\chi + 0.9 \\
 &= 4.9 \text{ eV} \\
 \phi_m &= 4.1 \text{ V}, \quad \phi_s = 4.9 \text{ V} \\
 \phi_{ms} &= \phi_m - \phi_s = 4.1 - 4.9 = -0.8 \text{ V}
 \end{aligned}$$


**Isolated case**

$$\begin{aligned}
 C_{ox} &= \frac{\epsilon_{ox}}{t_{ox}} = \frac{3.9 \times 8.85 \times 10^{-14}}{0.1 \times 10^{-4}} \\
 &= 34.515 \times 10^{-9} \text{ F/cm}^2 \\
 V_{FB} &= \phi_{ms} - \frac{\phi'_{ox}}{C_{ox}} \\
 \frac{\phi'_{ox}}{C_{ox}} &= -0.8 + 1 = 0.2 \text{ V} \\
 \phi'_{ox} &= 0.2 \times C_{ox} = 0.2 \times 34.515 \times 10^{-9} \text{ C/cm}^2
 \end{aligned}$$

● ● ● **End of Solution**

- Q.51** A programmable logic array (PLA) is shown in the figure.



The Boolean function  $F$  implemented is

(a)  $\bar{P}\bar{Q}R + \bar{P}QR + P\bar{Q}\bar{R}$

(b)  $(\bar{P} + \bar{Q} + R)(\bar{P} + Q + R)(P + \bar{Q} + \bar{R})$

(c)  $\bar{P}\bar{Q}R + \bar{P}QR + P\bar{Q}R$

(d)  $(\bar{P} + \bar{Q} + R)(\bar{P} + Q + R)(P + \bar{Q} + R)$

Ans. (c)

$$F = \bar{P}\bar{Q}R + \bar{P}QR + P\bar{Q}R$$

• • • End of Solution

**Q.52** Passengers try repeatedly to get a seat reservation in any train running between two stations until they are successful. If there is 40% chance of getting reservation in any attempt by a passenger, then the average number of attempts that passengers need to make to get a seat reserved is \_\_\_\_.

52. (3)

Probability of getting success =  $\frac{4}{10}$

Probability of failure =  $\frac{6}{10}$

$$H(X) = \sum x_i P(x_i)$$

$$H(X) = 1 \times \frac{4}{10} + 2 \times \frac{4}{10} \times \frac{6}{10} + 3 \times \frac{4}{10} \left(\frac{6}{10}\right)^2 + \dots \quad \dots(i)$$

$$\frac{6}{10} H(X) = 1 \times \frac{4}{10} \times \frac{6}{10} + 2 \times \frac{4}{10} \times \left(\frac{6}{10}\right)^2 \dots \quad \dots(ii)$$

subtracting (ii) from (i), we get

$$\frac{4}{10} H(X) = \frac{4}{10} + \frac{4}{10} \times \frac{6}{10} + \frac{4}{10} \times \left(\frac{6}{10}\right)^2 \dots$$

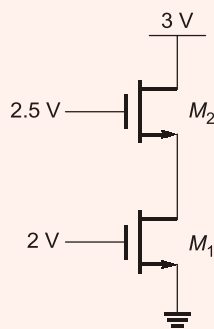
$$\frac{4}{10} H(X) = \frac{\frac{4}{10}}{1 - \frac{6}{10}} = 1$$

$$H(X) = \frac{10}{4} = 2.5$$

To ensure his success, he requires on an average 3 attempts.

• • • End of Solution

**Q.53** Assuming that transistors  $M_1$  and  $M_2$  are identical and have a threshold voltage of 1 V, the state of transistors  $M_1$  and  $M_2$  are respectively



- (a) Saturation, Saturation                      (b) Linear, Linear  
(c) Linear, Saturation                            (d) Saturation, Linear

**Ans. (c)**

$$\begin{aligned} V_{GS1} &= 2 \text{ V} \\ V_{GS2} &= 2.5 - V_x \\ V_{DS1} &= V_x \\ V_{DS2} &= 3 - V_x \end{aligned}$$

Assume both MOSFETs in saturation and equate their currents

$$I_{DS1} = I_{DS2}$$

$$\frac{k_n}{2} (2 - 1)^2 = \frac{k_n}{2} (2.5 - V_x - 1)^2$$

After solving,  $V_x = 0.5 \text{ V}, 2.5 \text{ V}$

$V_x$  cannot be 2.5 V. Because this will make  $M_2$  OFF.

Hence  $V_x$  may be 0.5 V

$\Rightarrow M_1$  is in linear region.

$\Rightarrow M_2$  is in saturation region.

To verify further,

$$I_{DS1} = I_{DS2}$$

$$k_n \left[ (2 - 1)V_x - \frac{V_x^2}{2} \right] = \frac{k_n}{2} (2.5 - V_x - 1)^2$$

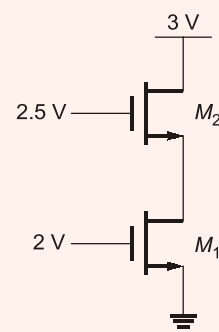
After solving,  $V_x = 0.588 \text{ V}, 1.91 \text{ V}$

Hence correct value of  $V_x = 0.588 \text{ V}$

This verifies above conclusion i.e.

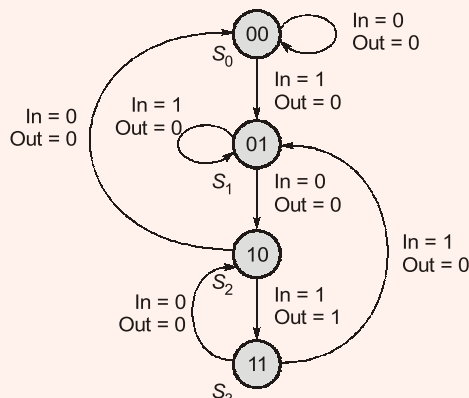
$M_1 \rightarrow$  Linear region

$M_2 \rightarrow$  Saturation region



• • • **End of Solution**

- Q.54** The state diagram of a finite state machine (FSM) designed to detect an overlapping sequence of three bits is shown in the figure. The FSM has an input 'In' and an output 'Out'. The initial state of the FSM is  $S_0$ .



If the input sequence is 10101101001101, starting with the left-most bit, then the number of times 'Out' will be 1 is \_\_\_\_.

**Ans. (4)**

By observing the given state diagram, it is clear that, the FSM can be used to detect the sequence '101'.

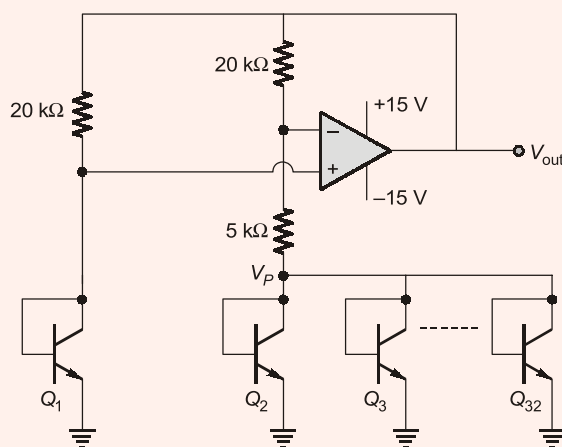
It is given in the question that, the FSM detects overlapping sequences also.

The given input sequence is,

10101101001101  $\Rightarrow$  So, output will be 1 for 4 times.

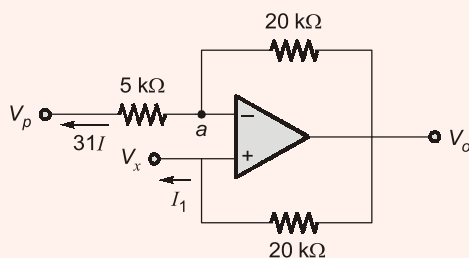
● ● ● End of Solution

- Q.55** In the voltage reference circuit shown in the figure, the op-amp is ideal and the transistors  $Q_1, Q_2, \dots, Q_{32}$  are identical in all respects and have infinitely large values of common-emitter current gain ( $\beta$ ). The collector current ( $I_C$ ) of the transistors is related to their base-emitter voltage ( $V_{BE}$ ) by the relation  $I_C = I_S \exp(V_{BE}/V_T)$ , where  $I_S$  is the saturation current. Assume that the voltage  $V_P$  shown in the figure is 0.7 V and the thermal voltage  $V_T = 26$  mV.



The output voltage  $V_{out}$  (in volts) is \_\_\_\_.

Ans. (1.145)



KCL at  $a$

$$\frac{V_o - V_x}{20} = \frac{V_x - 0.7}{5}$$

$$V_o - V_x = 4 V_x - 2.8$$

$$V_o = 5 V_x - 2.8$$

$$I_1 = 31I$$

...(i)

Now,

$$I_s e^{V_x/V_T} = 31 I_s e^{V_P/V_T}$$

$$\frac{V_x}{V_T} = \ln 31 + \frac{V_P}{V_T}$$

$$\frac{V_x - V_P}{V_T} = \ln 31$$

⇒

$$V_x = 0.789 \text{ V}$$

From equation (i)

$$V_o = 5 \times 0.789 - 2.8 = 1.145 \text{ V}$$

End of Solution

■■■■

**SECTION : GENERAL APTITUDE**

- Q.1** It is \_\_\_\_\_ to read this year's textbook \_\_\_\_\_ the last year's.  
(a) easier, than (b) most easy, than  
(c) easier, from (d) easiest, from

**Ans. (a)**

It is easier to read this year's textbook than the last year's.

Use of comparative degree adjectives is made for comparing two nouns.

Comparative adjectives take 'than'.

● ● ● **End of Solution**

- Q.2** A rule states that in order to drink beer, one must be over 18 years old. In a bar there are 4 people. *P* is 16 years old, *Q* is 25 years old, *R* is drinking milkshake and *S* is drinking a beer. What must be checked to ensure that the rule is being followed?  
(a) Only *P*'s drink (b) Only *P*'s drink and *S*'s age  
(c) Only *S*'s age (d) Only *P*'s drink. *Q*'s drink and *S*'s age

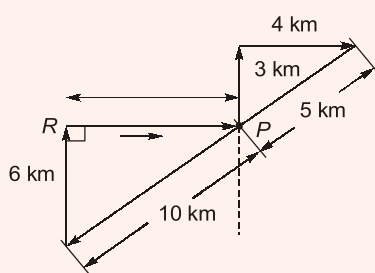
**Ans. (b)**

For rules to be followed, we need to check *P*'s drink and *S*'s age.

● ● ● **End of Solution**

- Q.3** Fatima starts from point *P*, goes North for 3 km and then East for 4 km to reach point *Q*. She then turns to face point *P* and goes 15 km in that direction. She then goes North for 6 km. How far is she from point *P* and in which direction should she go to reach point *P*?  
(a) 8 km, East (b) 12 km, North  
(c) 6 km, East (d) 10 km, North

**Ans. (a)**



● ● ● **End of Solution**

- Q.4** 500 students are taking one or more courses out of Chemistry, Physics and Mathematics. Registration records indicate course enrolment as follows: Chemistry (329), Physics (186), Mathematics (295), Chemistry and Physics (83), Chemistry and Mathematics (217) and Physics and Mathematics (63). How many students are taking all 3 subjects?  
(a) 37 (b) 43  
(c) 47 (d) 53

**Ans. (d)**

$$n(C) = 329$$

$$n(P) = 186$$

$$n(M) = 295$$

$$n(C \cap P) = 83$$

$$n(C \cap M) = 217$$

$$n(P \cap M) = 63$$

$$n(P \cup C \cup M) = n(C) + n(P) + n(M) - n(C \cap P) - n(C \cap M) - n(P \cap M) + n(P \cap C \cap M)$$

$$500 = 329 + 186 + 295 - 83 - 217 - 63 + n(P \cap C \cap M)$$

$$\Rightarrow n(P \cap C \cap M) = 500 - 447 = 53$$

● ● ● End of Solution

**Q.5** The ninth and the tenth of this month are Monday and Tuesday \_\_\_\_.

- (a) figuratively (b) retrospectively  
(c) respectively (d) rightfully

**Ans. (c)**

The ninth and tenth of this month are Monday and Tuesday respectively.

Respectively refers to separately or individually in the order already mentioned.

● ● ● End of Solution

**Q.6** "If you are looking for a history of India, or for an account of the rise and fall of the British Raj or for the reason of the cleaving of the subcontinent into two mutually antagonistic parts and the effects this mutilation will have in the respective sections, and ultimately on Asia, you will not find it in these pages: for though I have spent a lifetime in the country. I lived too near the seat of events, and was too intimately associated with the actors, to get the perspective needed for the impartial recording of these matters."

Which of the following statements best reflects the author's opinion?

- (a) An intimate association does not allow for the necessary perspective.  
(b) Matters are recorded with an impartial perspective.  
(c) An intimate association offers an impartial perspective.  
(d) Actors are typically associated with the impartial recording of matters.

**Ans. (c)**

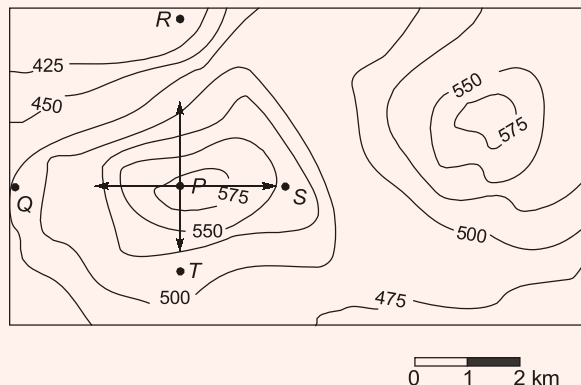
An intimate association offers impartial perspective.

Author states that he was too intimately associated with the actors to set the perspective needed for impartial recording.

● ● ● End of Solution



- Q.7** A contour line joins locations having the same height above the mean sea level. The following is a contour plot of a geographical region. Contour lines are shown at 25 m intervals in this plot.



Which of the following is the steepest path leaving from P?

- (a) P to Q (b) P to R  
(c) P to S (d) P to T

**Ans. (b)**

The steepest path will be the path which is deepest from sea level. So, P to R is the steepest path.

● ● ● **End of Solution**

- Q.8** 1200 men and 500 women can build a bridge in 2 weeks, 900 men and 250 women will take 3 weeks to build the same bridge. How many men will be needed to build the bridge in one week?

- (a) 3000 (b) 3300  
(c) 3600 (d) 3900

**Ans. (c)**

Let a man can build the bridge in  $x$  weeks and a woman can build the bridge in  $y$  weeks.

$$\text{So, } \frac{1200}{x} + \frac{500}{y} = \frac{1}{2} \quad \dots(i)$$

$$\frac{900}{x} + \frac{250}{y} = \frac{1}{3} \quad \dots(ii)$$

By equation (i) and (ii), we get

$$x = 3600 \text{ and } y = 3000$$

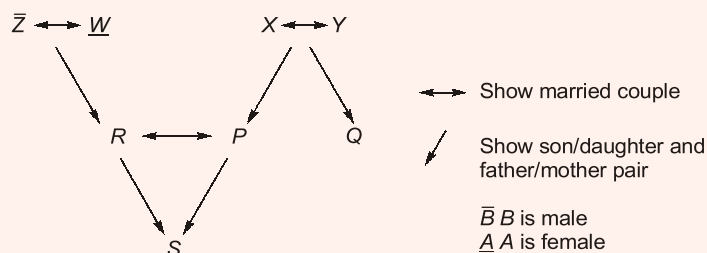
⇒ A man build the bridge in 3600 weeks.

● ● ● **End of Solution**

**Q.9** Each of  $P, Q, R, S, W, X, Y$  and  $Z$  has been married at most once.  $X$  and  $Y$  are married and have two children  $P$  and  $Q$ .  $Z$  is the grandfather of the daughter  $S$  of  $P$ . Further,  $Z$  and  $W$  are married and are parents of  $R$ . Which one of the following must necessarily be FALSE?

- (a)  $X$  is the mother-in-law of  $R$  (b)  $P$  and  $R$  are not married to each other  
(c)  $P$  is a son of  $X$  and  $Y$  (d)  $Q$  cannot be married to  $R$

**Ans. (b)**



From here,  
 $P$  and  $R$  are married couple. So option (b) is necessarily false.

● ● ● **End of Solution**

**Q.10** The number of 3-digit numbers such that the digit 1 is never to the immediate right of 2 is

- (a) 781 (b) 791  
(c) 881 (d) 891

**Ans. (c)**

Total number of three digit number are =  $9 \times 10 \times 10 = 900$

Number with 2 is immediate right of 1 are

$$= \begin{array}{|c|c|c|} \hline 1 & 2 & x \\ \hline \end{array} + \begin{array}{|c|c|c|} \hline x & 1 & 2 \\ \hline \end{array} = 19$$

$1 \times 1 \times 10 \quad + \quad 9 \times 1 \times 1$

So number with 2 is not immediate right of 1 are

$$= 900 - 19 = 881$$

● ● ● **End of Solution**

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