MADE EASY

GATE 2026

Electronics Engineering

Forenoon Session

Detailed Solutions

Exam held on 15-02-2026

MADE EASY Corporate Office:

44-A/1, Kalu Sarai, Near Hauz Khas Metro Station, New Delhi-110016

Centres : Delhi, Hyderabad, Jaipur, Bhopal, Pune | **www.madeeasy.in** | **Ph: 9021300500**

Q.1 Among the following options, the antonym of the word 'nocturnal' is ________.

(a) normal
(b) diurnal
(c) abnormal
(d) exceptional

Ans. (b)

- Nocturnal-means active at night.
- Diurnal-means active during the day.

End of Solution

Q.2 The statements (S1), (S2), and (S3) pertain to the scores obtained by students in an exam. The maximum possible marks in the exam is 150.

(S1) The highest score is 100.

(S2) The fourth highest score is 76.

(S3) There are at least four students whose scores are within 25 of each other.

Which one of the following options is necessarily correct?

(a) (S1) and (S2) together imply (S3)
(b) (S1) and (S3) together imply (S2)
(c) (S2) and (S3) together imply (S1)
(d) (S1) implies (S3)

Ans. (a)

(S1) : Highest score = 100

(S2) : Fourth Highest Score = 76

So, the maximum difference among these four students is

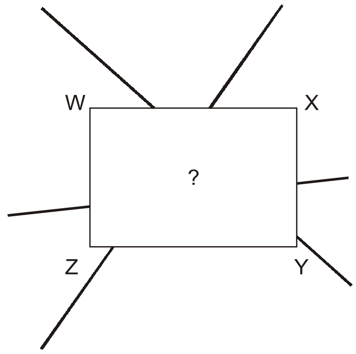
$$100 - 76 = 24$$

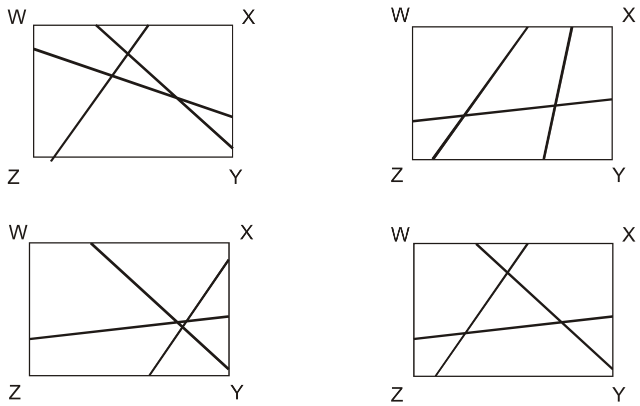
Since, $24 \leq 25$, these four students are within 25 marks of each other.

Hence, (S3) must be true.

End of Solution

Q.3 The figure below has exactly three intersecting line segments with a rectangular portion WXYZ missing. Which one of the following options P, Q, R, and S is the missing portion WXYZ?

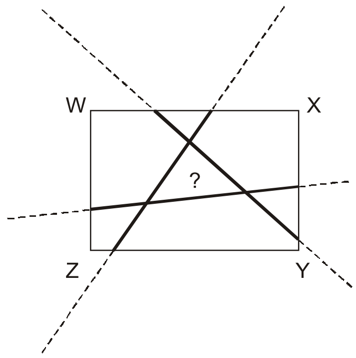




(a) P
(b) Q
(c) R
(d) S

Ans. (d)

The missing portion WXYZ shown below:



End of Solution

Q.4 Real numbers y, p, and n (all greater than 1) satisfy

$$(\log_{p^{1/n}} y)(\log_{y^{1/n}} p) = 16,$$

where the logarithms are taken to the bases $p^{1/n}$ and $y^{1/n}$

The value of n is ________

(a) 2
(b) 4
(c) 8
(d) 16

Ans. (b)

$$\log_{p^{1/n}} y \times \log_{y^{1/n}} p = 16$$

$$\frac{\log y}{\frac{1}{n}\log p} \times \frac{\log p}{\frac{1}{n}\log y} = 16$$

$$\frac{1}{\frac{1}{n^2}} = 16$$

$$n^2 = 16 \quad \Rightarrow \quad n = 4$$

End of Solution

Q.5 The following observation is made about the scores obtained by 100 students in an exam: 'For each student, there exists another student in the class such that their scores are at most ten marks away.'

If the above statement is **false**, which one of the following statements is necessarily true?

(a) For each student, the scores of all the other students are more than 10 marks away.

(b) There exists at least one student in the class for whom the scores of all the other students are more than 10 marks away.

(c) There is exactly one student in the class for whom the scores of some students are more than 10 marks away.

(d) For each student, the score of exactly one other student is more than 10 marks away.

Ans. (b)

End of Solution

Q.6 Each one of the following clues contains a keyword that is partially filled.

Clue 1: Synonym of recognize (8 letters): _ D _ NT_ FY

Clue 2: A story long enough to fill a book (5 letters): _ _ _ EL

Clue 3: Two of something (6 letters): _ _ _ PLE

Clue 4: A fraction of something, split equally into two parts (4 letters): _ _ _ F

The first letter of each of the keywords can be rearranged to form a four-letter word. Which one of the options below is a possible choice for the four-letter word?

(a) CHIN (b) COIN

(c) ITCH (d) NOSE

Ans. (a)

Ⓘ D E N T Ⓘ F Y	First leter **I**
Ⓝ Ⓞ Ⓥ E L	First leter **N**
Ⓒ Ⓞ Ⓤ P L E	First leter **C**
Ⓗ Ⓐ Ⓛ F	First leter **H**

Hence, option (a) CHIN is correct.

End of Solution

Q.7 Three children P, Q, R and two grown-ups X, Y play a badminton doubles tournament. X and Y are parents to two of the children playing. The child of X is not the same as the child of Y. Exactly one of the children does not have a parent playing in the tournament. The following rules are followed:

(i) A parent and his/her child cannot be on the same team.

(ii) A match can feature at most one parent and his/her child, that is, a maximum of one parent-child pair can play in a match.

The following matches were played:

	TEAM 1	TEAM2
MATCH 1	P and X	Q and R
MATCH 2	P and R	X and Y
MATCH 3	R and X	Q and Y

Which one of the following options is correct?

(a) P does not have any parent playing
(b) Q does not have any parent playing
(c) R does not have any parent playing
(d) X does not have a child playing

Ans. **(c)**

From Match 1 and Match 3

P and X are together so, P is not child of X.

R and X are together so R is not child of X

Therefore, Q must be child of X.

Since, exactly one child has no parent playing and X already has Q as child, Y must be parent of either P or R.

Checking all only option (c) is possible.

End of Solution

Q.8 Let P_k represent the perimeter of a square with sides of length k. The value of the expression $P_1 + P_2 + P_3 + \ldots + P_{10}$ is ________.

(a) 55
(b) 110
(c) 220
(d) 440

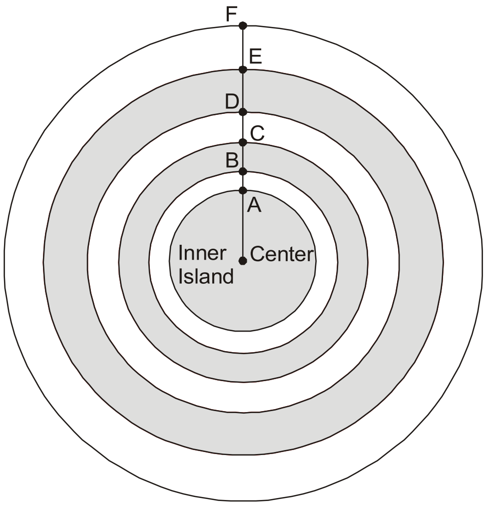
Ans. **(c)**

$$P_1 = 4$$
$$P_2 = 8$$
$$P_3 = 12$$
$$P_1 + P_2 + P_3 + \ldots + P_{10} = 4 + 8 + 12 + \ldots + 40$$
$$= 4(1 + 2 + 3 + \ldots + 10)$$
$$= 4 \times \frac{10 \times 11}{2} = 220$$

End of Solution

Q.9 The city of Atlantis was crafted by the God of the seas, Poseidon. It was made of alternating concentric circular rings of land (shaded) and water (not shaded) as represented in the figure (not to scale). The radius of Inner Island was 2.5 stades (a unit of length used in ancient Greece). The water surrounding Inner Island was one stade wide (length AB). This was surrounded by two pairs of alternating rings of land and water. The first pair of land and water was two stades wide each (lengths BC and CD), and the outer pair is three stades wide each (lengths DE and EF).

The ratio of the surface area of the land to that of the water in the city of Atlantis is ________ (round off to two decimal places).



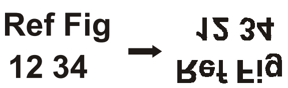
(a) 0.45 (b) 0.60
(c) 0.75 (d) 0.90

Ans. (c)

$$AB = r_1 = 2.5, \quad AC = r_2 = 3.5$$
$$AD = r_3 = 5.5, \quad AE = r_4 = 7.5$$
$$AF = r_5 = 10.5, \quad AG = r_6 = 13.5$$
$$L = L_1 + L_2 + L_3$$
$$= \pi r_1^2 + \pi\left(r_3^2 - r_2^2\right) + \pi\left(r_5^2 - r_4^2\right)$$
$$= \pi(2.5)^2 + \pi(5.5^2 - 3.5^2) + \pi(10.5^2 - 7.5^2)$$
$$= 78.25\pi$$
$$W = W_1 + W_2 + W_3$$
$$= \pi\left(r_2^2 - r_1^2\right) + \pi\left(r_4^2 - r_3^2\right) + \pi\left(r_6^2 - r_5^2\right)$$
$$= \pi(3.5^2 - 2.5^2) + \pi(7.5^2 - 5.5^2) + \pi(13.5^2 - 10.5^2)$$
$$= 104\pi$$
$$\frac{L}{W} = \frac{78.25\pi}{104\pi} = 0.75$$

End of Solution

Q.10 If



Then

GATE - 2026
Aptitude Test → ?

(a) 

(b) 

(c) 

(d) 

Ans. (c)

GATE - 2026
Aptitude Test → 

End of Solution

Q.11 Consider the differential equation $\dot{\vec{w}} = A\vec{w}$, with $\vec{w}(t=0) = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$.

If $\vec{w}(t) = e^t \vec{u}_x + e^{-2t}\vec{u}_y$ be the solution to the equation where $\vec{u}_x$ and $\vec{u}_y$ are unit vectors along the positive x and y axes respectively, then which of the following options is the correct matrix representing A?

(a) $\begin{bmatrix} 1 & 0 \\ 0 & -2 \end{bmatrix}$

(b) $\begin{bmatrix} -1 & 0 \\ 0 & 2 \end{bmatrix}$

(c) $\begin{bmatrix} 0 & -2 \\ 1 & 0 \end{bmatrix}$

(d) $\begin{bmatrix} 0 & 2 \\ -1 & 0 \end{bmatrix}$

Ans. (a)

The problem gives the solution as

$$\vec{w}(t) = e^t \vec{u}_x + e^{-2t}\vec{u}_y$$

Since $\vec{u}_x$ and $\vec{u}_y$ are unit vectors along the x and y axis, we can write them in vector form.

Substituting these into the solution:

$$\vec{w}(t) = e^t \begin{bmatrix} 1 \\ 0 \end{bmatrix} + e^{-2t} \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$\vec{w}(t) = \begin{bmatrix} e^t \\ e^{-2t} \end{bmatrix}$$

The differential equation is given as

$$\dot{\vec{w}} = A\vec{w} \quad \text{...(i)}$$

$$\dot{\vec{w}} = \frac{d}{dt}\begin{bmatrix} e^t \\ e^{-2t} \end{bmatrix} = \begin{bmatrix} e^t \\ -2e^{-2t} \end{bmatrix}$$

Putting the value of $\vec{w}(t)$ and $\dot{\vec{w}}$ in equation (i)

$$\begin{bmatrix} e^t \\ -2e^{-2t} \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} e^t \\ e^{-2t} \end{bmatrix}$$

This gives us two linear equations:

$$e^t = ae^t + be^{-2t} \quad \text{...(ii)}$$

$$-2e^{-2t} = ce^t + de^{-2t} \quad \text{...(iii)}$$

For these equations to hold time for all value of t.

- From (2) : $a = 1$ and $b = 0$
- From (3) : c = 0 and $d = -2$

The resulting matrix A is:

$$A = \begin{bmatrix} 1 & 0 \\ 0 & -2 \end{bmatrix}$$

End of Solution

Q.12 A surface is given by $z^2 = 2x^2 - y^2$ and $\vec{n}$ and $-\vec{n}$ are unit normal vectors to the surface at the point $\vec{P} = \hat{i} + \sqrt{2}\,\hat{k}$.

Which of the following vectors can be $\vec{n}$, where $\hat{i}, \hat{j}$ and $\hat{k}$ and are the unit vectors along x, y and z axes, respectively?

(a) $\hat{i} - \sqrt{2}\,\hat{k}$

(b) $\frac{2}{3}\hat{i} - \frac{1}{3}\hat{k}$

(c) $\sqrt{2}\hat{i} - \sqrt{3}\hat{k}$

(d) $\frac{\sqrt{2}\,\hat{i} - \hat{k}}{\sqrt{3}}$

Ans. (d)

The given surface equation is $z^2 = 2x^2 - y^2$.

Rewriting this as a scalar function

$$f(x, y, z) = 0$$

$$f(x, y, z) = 2x^2 - y^2 - z^2$$

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

$$\nabla f = 4x\hat{i} - 2y\hat{j} - 2z\hat{k} \quad \text{...(i)}$$

The point is $\vec{P} = \hat{i} + \sqrt{2}\,\hat{k}$, which corresponds to $(x, y, z) = (1, 0, \sqrt{2})$.

Substituting these values into ∇f (i.e. equation (i))

$$\nabla f = 4(1)\,\hat{i} - 2(0)\hat{j} - 2(\sqrt{2})\,\hat{k}$$

$$\nabla f = 4\hat{i} - 2\sqrt{2}\,\hat{k}$$

The unit normal vector $\vec{n}$ is given by

$$|\nabla f| = \sqrt{4^2 + (-2\sqrt{2})^2} = \sqrt{16+8} = \sqrt{24} = 2\sqrt{6}$$

$$\vec{n} = \frac{4\hat{i} - 2\sqrt{2}\hat{k}}{2\sqrt{6}} = \frac{2\hat{j} - \sqrt{2}\hat{k}}{\sqrt{6}}$$

$$\vec{n} = \frac{\sqrt{2}\,\hat{i} - \hat{k}}{\sqrt{3}}$$

End of Solution

Q.13 The Laplace Transform of the signal $x(t) = u(t-2) * (tu(t))$ is given by which of the following expressions?

["$*$" represents convolution operator]

(a) $\dfrac{e^{-2s}}{s^2(s-2)}$ (b) $\dfrac{e^{-2(s-2)}}{s^3}$

(c) $\dfrac{se^{-2s}}{(s-2)^2}$ (d) $\dfrac{e^{-2s}}{s^3}$

Ans. **(d)**

$$x(t) = r(t) * u(t-2) = p(t-2) = \frac{(t-2)^2}{2}u(t-2) \quad \text{...(i)}$$

$$p(t) = \frac{t^2}{2}u(t) \rightleftharpoons P(s) = \frac{1}{s^3}$$

From (i), $$X(s) = P(s)e^{-2s} = \frac{1}{s^3}\cdot e^{-2s}$$

End of Solution

Q.14 Consider carrier transport in a Zener diode in the breakdown region. Which is the dominant transport mechanism for current flow in this case?

(a) Drift (b) Diffusion

(c) Tunneling (d) Ballistic transport

Ans. **(c)**

In Zener breakdown (heavily doped junction, low breakdown voltage), the strong electric field across the thin depletion region causes quantum mechanical tunneling of electrons from the valence band of p-side to the conduction band of n-side, dominating the current flow.

End of Solution

Q.15 Two analog signals $x_1(t)$ and $x_2(t)$ (t in second), are sampled at a rate F_s = 40 Hz, where $x_1(t) = \cos(20\pi t)$, $t \ge 0$, and $x_2(t) = \cos(100\pi t)$, $t \ge 0$.

The first ten samples (starting from $t = 0$) are considered for the analysis.

Which of the following statements is TRUE?

(a) All of the first three samples of $x_1(t)$ are greater than the corresponding samples of $x_2(t)$.

(b) All of the last three samples of $x_1(t)$ are greater than the corresponding samples of $x_2(t)$.

(c) All of the samples of $x_2(t)$ are greater than the corresponding samples of $x_1(t)$.

(d) All of the fourth to seventh samples of $x_1(t)$ are equal to the corresponding samples of $x_2(t)$.

Ans. (d)

$$x_1(t) = \cos 20\pi t$$

On sampling $t = nT_s = \frac{n}{f_s} = \frac{n}{40}$

$$x_1(n) = x_1(nT_s) = \cos\left(20\pi \times \frac{n}{40}\right) = \cos\frac{\pi}{2}n$$

Similarly, for $x_2(t)$

$$x_2(t) = \cos 100\pi t$$

On sampling $t = nT_s = \frac{n}{40}$

$$x_2(n) = x_2(nT_s) = \cos\left(100\pi \frac{n}{40}\right) = \cos\left(\frac{5\pi}{2}n\right)$$

$$= \cos\left[\left(2\pi + \frac{\pi}{2}\right)n\right] = \cos\frac{\pi}{2}n$$

Therefore, $x_1(n) = x_2(n)$

Hence, all of the fourth to seventh samples of $x_1(t)$ are equal to the corresponding samples of $x_2(t)$.

End of Solution

Q.16 The response of a discrete time system y[n] obeys the following relation:

$$y[n] = \frac{5}{6}y[n-1] - \frac{1}{6}y[n-2] + x[n].$$

The input to the system is $x[n] = \delta[n] - \frac{1}{3}\delta[n-1]$.

Which of the following options is TRUE for $y[n]$?

(a) Stable and causal response
(b) Stable and non-causal response
(c) Unstable and causal response
(d) Unstable and non-causal response

Ans. (a)

The given difference equation is:

$$y(n) = \frac{5}{6}y(n-1) - \frac{1}{6}y(n-2) + x(n)$$

Taking the z-transform on both sides:

$$Y(z) = \frac{5}{6}z^{-1}Y(z) = \frac{1}{6}z^{-2}Y(z) + X(z)$$

$$Y(z)\left(1 - \frac{5}{6}z^{-1} + \frac{1}{6}z^{-2}\right) = X(z)$$

$$H(z) = \frac{Y(z)}{X(z)} = \frac{1}{1-\frac{5}{6}z^{-1}+\frac{1}{6}z^{-2}}$$

On factoring the denominator, we get,

$$H(z) = \frac{1}{\left(1-\frac{1}{2}z^{-1}\right)\left(1-\frac{1}{3}z^{-1}\right)}$$

The input is given as

$$x[n] = \delta[n]-\frac{1}{3}\delta[n-1]$$

Its z-transform is: $X(z) = 1-\frac{1}{3}z^{-1}$

The response $Y(z)$,

$$Y(z) = H(z)\cdot X(z)$$

$$Y(z) = \frac{1-\frac{1}{3}z^{-1}}{\left(1-\frac{1}{2}z^{-1}\right)\left(1-\frac{1}{3}z^{-1}\right)}$$

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

On taking inverse z-transform of $Y(z)$, we get

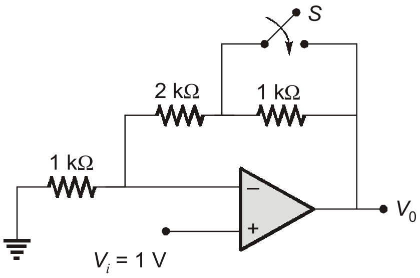
$$y(n) = \left(\frac{1}{2}\right)^n u(n)$$

- Since $y(n) = 0$ for $n < 0$. Hence, the response is causal.
- The pole of $Y(z)$ is at $z=\frac{1}{2}$. Since the magnitude of the pole $\left(\text{i.e. } \frac{1}{2}\right)$ i.e. less than 1, the pole lies inside the unit circle in the z-plane, making the response stable.
- Hence, the response $y[n]$ is stable and causal.

End of Solution

Q.17 The ideal OP-AMP circuit shown in the Figure produces output voltage $V_o = x$ when the Switch, S, is open.

Which of the options represents the output voltage when S is closed?



(a) x (b) $\frac{2}{3}x$

(c) $\frac{3}{4}x$ (d) $\frac{1}{2}x$

Ans. **(c)**

Given, $V_{01} = x$

$$\text{Switch open} = V_{01} = \left(1+\frac{3}{1}\right)\times 1 = 4\text{ V} = x$$

$$\text{Switch open} = V_{02} = \left(1+\frac{2}{1}\right)\times 1 = 3\text{ V}$$

$$\frac{V_{02}}{V_{01}} = \frac{3}{4}$$

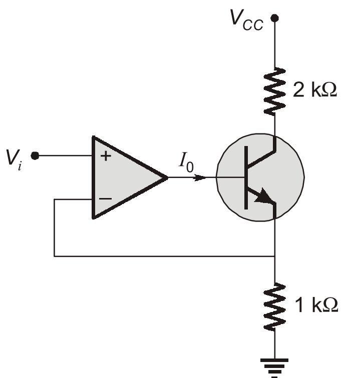
$$V_{02} = \frac{3}{4}\times V_{01}$$

$$V_{02} = \frac{3}{4}x$$

End of Solution

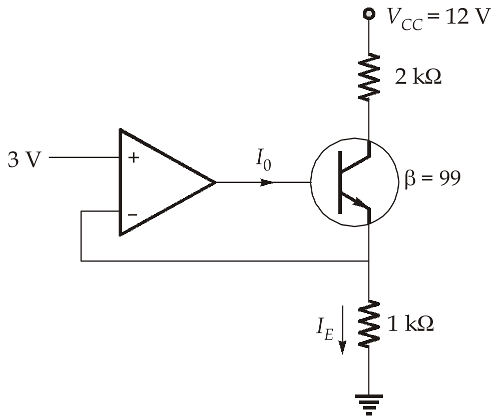
Q.18 Consider the circuit shown in the Figure with V_i = 3 V and V_{cc} = 12 V. Assume V_{BE} = 0.7 V and β_{dc} = 99 for the BJT.

Which of the following options is the correct value of the current I_o?



(a) 60 μA (b) 6 μA
(c) 3 μA (d) 30 μA

Ans. (d)



$$V^- = V^+ = 3\text{ V}$$

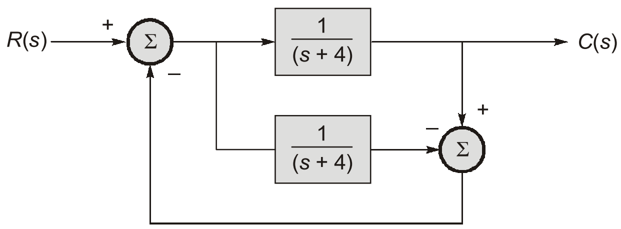
$$I_E = \frac{3}{1\text{k}\Omega} = 3\text{ mA}$$

$$I_0 = I_B - \frac{I_E}{1+\beta} = \frac{3}{100} = 0.03\text{ mA}$$

Hence, $I_0 = 30\ \mu\text{A}$

End of Solution

Q.19 A control system is shown in the Figure.
Which option represents the correct transfer function of the system?



(a) $\dfrac{1}{(s+4)^2}$ (b) $\dfrac{1}{(s+4)}$

(c) $\dfrac{2}{(s+4)}$ (d) $\dfrac{1}{(s^2+8s+17)}$

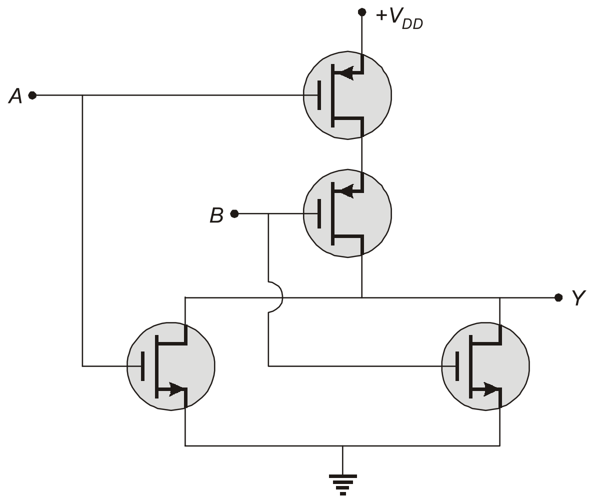
Ans. (b)

Using Mason's gain formula, we get

$$\frac{C(s)}{R(s)} = \frac{\dfrac{1}{s+4}}{1-\left[-\dfrac{1}{s+4}+\dfrac{1}{s+4}\right]} = \frac{1}{s+4}$$

End of Solution

Q.20 In the circuit shown in the Figure, A and B are logic inputs and Y is the logic output. Which of the following logic operations is realized by the circuit?



(a) NOR
(b) OR
(c) XOR
(d) AND

Ans. (a)

A	B	F
0	0	1
0	1	0
1	0	0
1	1	0

$\therefore$ The given circuit performs NOR operation.

End of Solution

Q.21 Consider the Friis' transmission equation $P_R = (P_T G_T G_R \lambda^2)/(4\pi D)^2$, where P_R and P_T are the received and the transmitted powers, respectively.

G_T and G_R are the gain of transmitting and receiving antennas, respectively, D is the distance between the transmitting and receiving antennas, and λ is the wavelength in free space.

Given: $G_T = G_R = 1.0$, $\lambda = 0.30$ m and $P_T = +10$ dBm.

Choose the distance (D), in km, from the following options at which the received power, $P_R = -90$ dBm?

(a) $\frac{15}{4\pi}$
(b) $\frac{15}{2\pi}$
(c) $\frac{75}{2\pi}$
(d) $\frac{3}{4\pi}$

Ans. (b)

Given data: $G_t = G_r = 1$; $\lambda = 0.30$; $P_t = 10$ dBm ; $P_r = -90$ dBm ; $r = ?$ (km)

From Friis' transmission formula,

$$P_r = \frac{P_t G_{dt} G_{dr}}{\left(\frac{4\pi r}{\lambda}\right)^2}$$

$$\because \qquad P_r|_{dBm} = 10\log_{10}\left(\frac{P_r}{1\text{mW}}\right)$$

$$\Rightarrow \qquad -90 = 10\log_{10}\left(\frac{P_r}{1\times 10^{-3}}\right)$$

$$\Rightarrow \qquad P_r = 10^{-12}\ \text{W}$$

Similarly, for P_t

$$10 = 10\log_{10}\left(\frac{P_t}{1\times 10^{-3}}\right)$$

$$\Rightarrow \qquad P_t = 0.01\ \text{W}$$

On substituting, we get,

$$\left(\frac{4\pi r}{\lambda}\right)^2 = \frac{P_t G_{dt} G_{dr}}{P_r}$$

$$\Rightarrow \qquad r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_{dt} G_{dr}}{P_r}}$$

$$r = \frac{0.30}{4\pi}\sqrt{\frac{0.01\times 1\times 1}{1\times 10^{-12}}} = \frac{15}{2\pi}\text{km}$$

End of Solution

Q.22 Consider a discrete memoryless source with an alphabet of four source symbols. $s(t)$ is a multi-level (–1, 0, +1, +2) signal representing a long sequence of random symbols from the above source which is generating 10^4 symbols per second.

Which of the following options is the correct value of equivalent Nyquist bandwidth of $s(t)$?

(a) 10 kHz
(b) 64 kHz
(c) 5 kHz
(d) 20 kHz

Ans. (c)

Number of given symbols $\Rightarrow M = 4$

$$\text{Symbol rate } (R_s) = 10^4 \frac{\text{symbols}}{\text{sec}}$$

$$\text{Nyquist Bandwidth} = \frac{R_b}{2\log_2 M}$$

$$\text{Symbol rate, } (R_s) = \frac{R_b}{\log_2 M}$$

$$\text{Nyquist Bandwidth} = \frac{R_s}{2} = \frac{10^4}{2} = 5\,\text{kHz}$$

End of Solution

Q.23 The relation between the input current (I) and the output voltage (V) of a circuit is governed by the equation: $C\frac{dV}{dt} = I(t) - m(t)$. The circuit is excited by $I(t) = q\delta(t)$, where q is a real valued constant. V at $t = 0^-$ is V_0.

Which of the following is an equivalent representation of the above case?

(a) $C\frac{dV}{dt} = -m(t)$, with $V(t = 0^-) = V_0 + q/C$

(b) $C\frac{dV}{dt} = -m(t)$, with $V(t = 0^-) = V_0 + q/C + m(t = 0^-)$

(c) $C\frac{dV}{dt} = -m(t)$, with $V(t = 0^-) = V_0 - q/C + m(t = 0^-)$

(d) $C\frac{dV}{dt} = -m(t)$, with $V(t = 0^-) = q/C$

Ans. **(a)**

The circuit is governed by the equation

$$C\frac{dV}{dt} = I(t) - m(t) \quad ...(i)$$

The given conditions are:

Initial current: $I(t) = q\delta(t)$

Initial voltage: V at $t = 0^-$ is V_o

To understand the effect of impulse $q\delta(t)$,

Integrating equation (i)

From $t = 0^-$ to $t = 0^+$

$$\int_{0^-}^{0^+} C\frac{dV}{dt} = \int_{0^-}^{0^+} [q\delta(t) - m(t)] \cdot dt$$

$$\Rightarrow \quad C\left[V(0^+) - V(0^-)\right] = q$$

$$\Rightarrow \quad V(0^+) - V_o = \frac{q}{C}$$

$$\Rightarrow \quad V(0^+) = V_o + \frac{q}{C}$$

After the impulse has occured (for $t > 0$), the input $I(t)$ become zero.

The behaviour of system is then described by the original equation without the impulse term, but starting from the new initial state at $t = 0^+$

i.e. $$C\frac{dV}{dt} = -m(t) \text{ with } V(t = 0^+) = V_o + \frac{q}{C}$$

So, the equivalent representation shifts the effect of the impulse into the initial condition of the system. Hence, option (a) is correct.

End of Solution

Q.24 The electric field of a monochromatic plane wave travelling in a lossless isotropic and homogenous medium is given by

$$\vec{E}(z,t) = E_0\left[\hat{x}\cos(\omega t - kz) + \hat{y}\sin(\omega t - kz)\right]$$

in a right-handed orthogonal co-ordinate system.

Which of the following is the correct polarization of the electromagnetic wave?

(a) Right-handed circularly polarized
(b) Left-handed circularly polarized
(c) Linearly polarized
(d) Linearly polarized with –45° angle to $\hat{x}$

Ans. (a)

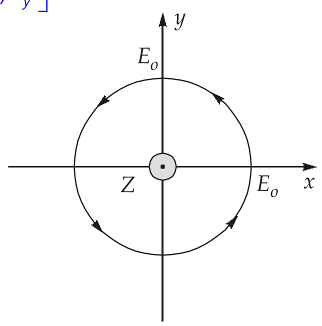
Given, $\bar{E}(z,t) = E_0\left[\cos(\omega t - kz)\hat{a}_x + \sin(\omega t - kz)\hat{a}_y\right]$

at $z = 0$,

$$\bar{E}(t) = E_0\cos\omega t\,\hat{a}_x + E_0\sin\omega t\,\hat{a}_y$$

As $|E_{x0}| = |E_{y0}| = E_0$

$$|\phi| = 90°$$



∴ it is a circularly polarized wave.

Now, at $t = 0$, $\omega t = 0$, $\bar{E} = E_0\hat{a}_x$

at $t = T/4$, $\omega t = \pi/2$, $\bar{E} = E_0\hat{a}_y$

Hence it is Right-handed circularly polarized.

End of Solution

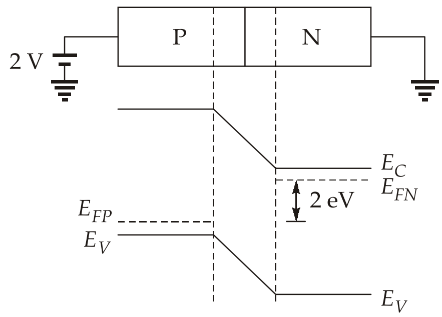
Q.25 Consider a p-n junction diode when it is forward biased with 2 V.

Which of the following is/are the correct magnitude(s) of the energy difference between quasi Fermi-levels, E_{fn} in the n-side and E_{fp} in the p-side?

(a) 2 eV
(b) 1 eV
(c) 2 V
(d) 1 V

Ans. (a)

In a forward-biased p-n junction, the separation (magnitude of difference) between the quasi-Fermi levels E_{FN} (electron quasi-Fermi level) and E_{FP} (hole quasi-Fermi level) equals qV (i.e., applied forward bias voltage), so for $V = 2$ V, $|E_{FN} - E_{FP}| = 2$ eV.



End of Solution

Q.26 Consider the matrix $M = \begin{bmatrix} 2 & 1 & 1 \\ 1 & 3 & 0 \\ -1 & a & b \end{bmatrix}$.

Which of the following options is/ are TRUE if det(M) ≠ 0?

(a) $a = -\frac{1}{2}$ and $b = -\frac{1}{2}$
(b) $a = \frac{1}{2}$ and $b = \frac{1}{2}$
(c) $a = -3$ and $b = 0$
(d) $a = \frac{1}{2}$ and $b = -3$

Ans. **(b, d)**

$2(3b) - 1(b) + (a + 3)$

$6b - b + a + 3$

$$5b + a + 3 \neq 0$$

$$a = b = -\frac{1}{2}$$

and $a = -3,\ b = 0$ are not correct rest two are correct.

End of Solution

Q.27 A binary ripple counter is designed to count $(0)_{10}$ to $(64)_{10}$.

Which of the following is/are the number of flip-flops required to design the counter?

(a) 6
(b) 7
(c) 4
(d) 5

Ans. **(b)**

A counter that counts from 0 to 64 must be able to represent a total of 65 distinct states. The maximum number of states (or the MOD number) that can be represented by n-flip-flops is given by:

$$\text{Total states} = 2^n$$

To accommodate 65 states, it must satisfy the following inequality:

$$2^n \geq 65$$

i.e. $$n \geq \log_2^{65}$$

$$n \geq 6.022$$

Hence, the minimum number of flip-flops required to design this counter is 7.

End of Solution

Q.28 Which option(s) represents/ represent the dielectric loss tangent of a substrate?

(a) Ratio of the real to imaginary parts of the total displacement current

(b) $\frac{(\omega \in'' + \sigma)}{(\omega \in')}$

(c) Ratio of the electric susceptibility to permittivity

(d) Ratio of the polarization vector $\vec{P}$ to the displacement vector $\vec{D}$

Ans. (a, b)

The dielectric loss tangent (tan δ) measures energy loss in a dielectric substrate under AC fields. In electromagnetics it includes both polarization losses and conduction losses.

According to standard definition:

$$\tan\delta = (\omega\varepsilon'' + \sigma) / (\omega\varepsilon')$$

(where ε' = real permittivity, ε'' = imaginary part from dielectric loss, σ = conductivity, ω = angular frequency)

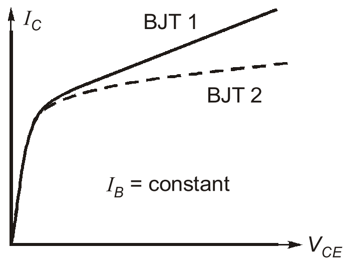
Hence, option (b) is correct.

Dielectric loss tangent of a substrate is the ratio of the real to imaginary parts of the total displacement current. Hence, option (a) is correct.

End of Solution

Q.29 Figure shows the output characteristics of two different Bipolar Junction Transistors (BJT), BJT 1 with magnitude of Early voltage $|V_{A1}|$, and BJT 2 with magnitude of Early voltage $|V_{A2}|$.

Which of the following options is/are correct regarding the Early voltages?



(a) $|V_{A1}| > |V_{A2}|$

(b) $|V_{A1}|$ is infintely large

(c) $|V_{A1}| < |V_{A2}|$

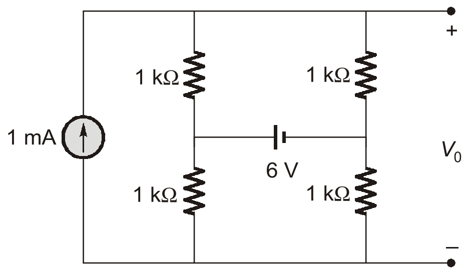
(d) $|V_{A2}|$ is infinte

Ans. (c, d)

BJT 2 has a smaller slope in the active region (flatter I_C vs V_{CE} curve). Hence $|V_{A_2}|$ is greater than $|V_{A_1}|$, so option (c) is correct, and since BJT 2 curve shows finite slope (not perfectly flat), V_{A_2} is finite (and not ∞), so option (d) is also correct.

End of Solution

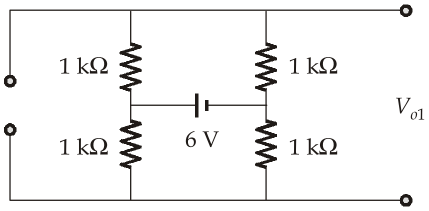
Q.30 The output voltage V_o (in Volt) for the network given in the Figure is _______. (rounded off to two decimal places)



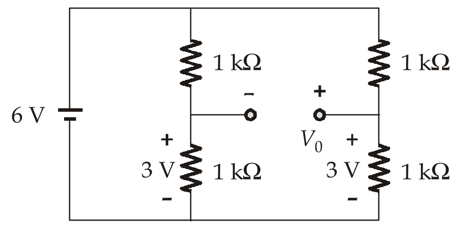
Ans. (1) (0.95 to 1.05)

By using superposition theorem.

If 6 V source is active and 1 mA current source is open circuit.

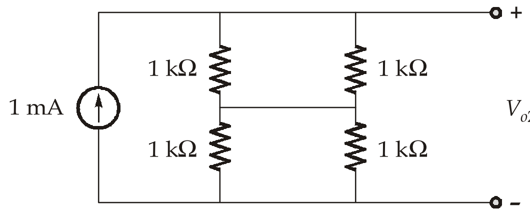


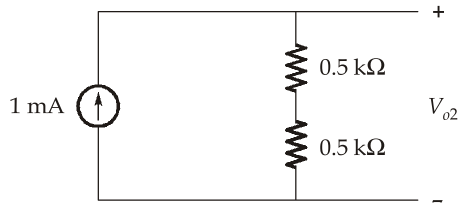
or



∴ $V_{o1} = 3 - 3 = 0$ V

If 1 mA current source is active and 6 V voltage source is short circuited.





∴ $V_{o2} = |\text{max}|\ 1\ \text{k}\Omega = 1$ V

By superposition theorem,

$$V_0 = V_{o1} + V_{o2}$$

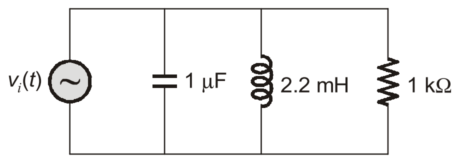
∴ $V_0 = 0 + 1 = 1$ V

End of Solution

Q.31 Consider the circuit shown in the Figure, where the input $v_i(t)$ is in Volt.

The average power (in mW) dissipated in the load resistance of 1 kΩ at the resonant frequency is ______.

(rounded off to two decimal places)



$v_i(t) = 12 \sin(\omega t)$

Ans. (72) (71.50 to 72.50)

$$P = \frac{V^2}{R} = \frac{\left(\frac{12}{\sqrt{2}}\right)^2}{1 \times 10^3} = 72 \text{ mW}$$

End of Solution

Q.32 A wireless digital transmission scheme is using 16-QAM over an additive white Gaussian noise channel and a maximum-likelihood receiver. Consider the information bit rate from source to be 4×10^6 bits per second.

The minimum transmission bandwidth (in MHz) of the modulated signal necessary for optimum recovery of information at the receiver is ________.

(rounded off to two decimal places)

Ans. (1) (0.95 to 1.05)

Given modulation scheme is 16 QAM

$$M = 16$$

$$\text{Information bit rate } (R_b) = 4 \times 10^6 \frac{\text{bits}}{\text{sec}}$$

$$\text{Minimum transmission B.W} = \frac{R_b}{\log_2 M}$$

$$= \frac{4 \times 10^6}{\log_2 16} = 10^6$$

$$= 1 \text{ MHz}$$

End of Solution

Q.33 The cutoff frequency (in GHz) for the dominant TE_{10} mode of an air-filled rectangular waveguide of inner dimension 0.28 inch × 0.14 inch is _______.

(rounded off to two decimal places).

Ans. (21.09) (20.50 to 21.50)

$$f_C\big|_{TE_{10}} = \frac{c}{2a} = \frac{3 \times 10^{10}}{2 \times 0.28 \times 2.54} \qquad [\because \text{ 1 inch} = 2.54 \text{ cm}]$$

$$= 21.09 \text{ GHz}$$

End of Solution

Q.34 For a lossless passive two-port network, $|S_{11}|$ and $|S_{21}|$ intersect at –3 dB.
For a lossy passive two-port network, $|S_{11}|$ and $|S_{21}|$ intersect at – 4 dB..

The percentage of power dissipated in the lossy network at the intersection frequency is ________.
(rounded off to two decimal places)

Ans. (20.38) (20.00 to 21.00)
Given for the lossy passive two port network, at the intersection

$$|S_{11}| = |S_{21}| = -4\text{ dB}$$

$\therefore$ $$\text{Power ratio} = 10^{-0.4} = 0.3981$$

$\therefore$ $$|S_{11}|^2 = |S_{21}|^2 = 0.3981$$

Further, $$P_{in} = |S_{11}|^2 + |S_{21}|^2 + P_{loss}$$

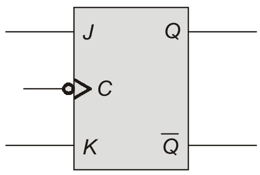
$\Rightarrow$ $$1 = 0.3981 + 03981 + P_{loss}$$

$\Rightarrow$ $$P_{loss} = 0.2038$$

$\therefore$ $$\%P_{loss} = 20.38$$

End of Solution

Q.35 The negative edge triggered *JK* flip-flop in the Figure has *J* and *K* inputs tied to Logic High and a square wave of 10 cycles/second is applied to its clock (*C*) input. The frequency of the output *Q* (in cycles/second) is ________.
(rounded off to two decimal places)



Ans. (5) (4.90 to 5.10)
When, $J = K = 1$,
Then, JK-FF operate in toggle mode.

$\therefore$ $$f_{out} = \frac{f_{in}}{2} = 5\text{ Hz}$$

End of Solution

Q.36 Consider the two series, S_A and S_B, where

$$S_A = \sum_{n=1}^{\infty} \frac{n^2}{2^n}$$

$$S_A = 1 + \frac{1}{2} + \frac{1}{8} + \frac{1}{16} + \frac{1}{64} + \frac{1}{128} + \frac{1}{512} + \ldots$$

Which of the following statements is correct for the two given series?

(a) Both S_A and S_B converge.
(b) Neither S_A nor S_B converges.
(c) S_A converges but S_B does not converge.
(d) S_B converges but S_A does not converge.

Ans. (a)

Case I :

$$S_A = \sum \frac{n^2}{2^n}$$

By n^{th} root test

$$= \lim_{n\to\infty}\left(\frac{n^2}{2^n}\right)^{1/n}$$

$$= \lim_{n\to\infty}\frac{n^{2/n}}{2} = \frac{1}{2} < 1$$

Hence, S_A is convergent

Case II :

Given $$S_B = \sum_{n=1}^{\infty}\frac{1}{2^n} \text{ is GP series.}$$

$$= 1+\frac{1}{2}+\frac{1}{4}+....+\frac{1}{512}$$

$$S_\infty = \frac{1}{1-\frac{1}{2}} = 2$$

$\therefore$ S_B is also convergent.

End of Solution

Q.37 The continuous time signal x(t) is real, periodic with period T and satisfies the Dirichlet conditions.

The Fourier series representation of $x(t) = \sum_{n=-\infty}^{\infty} a_n e^{j\left(\frac{2\pi nt}{T}\right)}$ and $x(t)$ satisfies the following:

$$x\left(t-\frac{T}{2}\right) = -x(t).$$

For any integer m, which of the following options is correct?

(a) $a_{2m} = 0$
(b) $a_{2m} = 1$
(c) $a_{2m} = a_{2m+1}$
(d) $a_{2m} = -1$

Ans. (a)

Given that, $x\left(t-\frac{T}{2}\right) = -x(t)$ where 'T' is FTP.

Thus, $x(t)$ is half-wave symmetric signal.
For HWS: Even harmonics will be absent
i.e. $a_n = 0$ if n is even-integer.
$\Rightarrow a_{2m} = 0$ where m = integer

End of Solution

Q.38 Let X, N, Y and Z be random variables. The variables X and N are independent of each other. X is uniformly distributed between –1 and 1; N follows Normal distribution with zero mean and unity variance.

Y and Z are defined as, $Y = X + N$ and $Z = X^2 + N$.

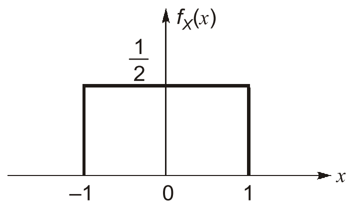
Which of the following pairs represents the values of correlation between X and Y and that between X and Z?

(a) 1/3 and 0
(b) 1/3 and 1/9
(c) 1/3 and 1/3
(d) 1 and 0

Ans. (a)

Given,

$$X = U(-1, 1)$$
$$E[X] = 0$$
$$\text{var}[X] = \frac{1}{3}$$
$$E[X^2] = \frac{1}{3}$$
$$N = N(0, 1)$$
$$E[N] = 0$$
$$\text{var}[N] = 1$$
$$E[N^2] = 1$$



X and N are independent random variables.
Given $Y = X + N$ and $Z = X^2 + N$
Correlation between X and $Y \rightarrow$ Cov (X, Y)
$\because$ Co-variance is measure of correlation between two random variables.

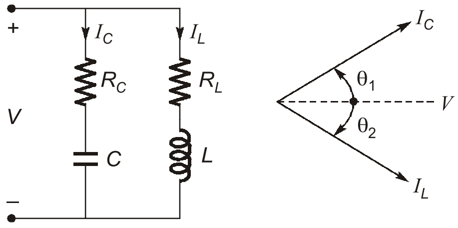
$$\text{Cov}(X, Y) = E[XY] - E[X] \cdot E[Y]$$
$$= E[X^2 + XN] - E[X] \cdot E[X + N]$$
$$= E[X^2] + E[X] \cdot E[N] - E[X] \cdot \{E[X] + E[N]\}$$
$$= \frac{1}{3} + 0 - 0 = \frac{1}{3}$$

Correlation between X and Z

$$\text{Cov}(X, Z) = E[XZ] - E[X] \cdot E[Z]$$
$$= E[X^3 + XN] - E[X] \cdot E[X^2 + N]$$
$$= E[X^3] + E[XN] - 0$$
$$= E[X^3]$$
$$= \int_{-1}^{1} x^3 f_X(x) dx = 0$$

End of Solution

Q.39 In the given circuit, L = 1 μH and C = 1 μF. The phasor diagram for I_C and I_L is also shown. Assume that the phase $(\theta_1 + \theta_2)$ is 90° at a frequency of 159.15 kHz. Among the following options, what is the nearest integer value of $R_C \times R_L$?



(a) 0
(b) 1
(c) 2
(d) 10

Ans. (b)

$$\theta_1 = \tan^{-1}\left(\frac{X_C}{R_C}\right) + \tan^{-1}\left(\frac{X_L}{R_L}\right) = 90°$$

$$\tan(A + B) = \frac{\tan A + \tan B}{1 - \tan A \tan B}$$

Here, $\tan A \cdot \tan B = 1$

i.e. $$\tan^{-1}\left(\frac{X_C}{R_C}\right) \cdot \tan\left(\frac{X_L}{R_L}\right) = 1$$

$$\frac{X_C}{R_C} \cdot \frac{X_L}{R_L} = 1$$

$$\frac{1}{\omega C R_C} \cdot \frac{\omega L}{R_L} = 1$$

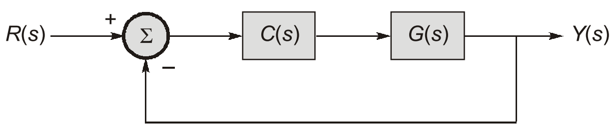
i.e. $$R_L \cdot R_C = \frac{L}{C}$$

∴ $$R_L \cdot R_C = 1$$

End of Solution

Q.40 For the control system shown in the Figure, the transfer function of a plant, $G(s) = \frac{1}{(s+1)(s+2)}$ is connected in cascade with a compensator $C(s) = K(s + \alpha)$, where K and α are positive real valued constants.

Which of the following pairs (K, α) represent the correct values for the closed loop system to have poles at $(-3 \pm j\sqrt{5})$?



(a) 2, 3
(b) 3, 4
(c) 2, 4
(d) 3, 3

Ans. (b)

We know that the characteristics equation is given as,

$$1 + G(s)\,H(s) = 1+\frac{K(s+\alpha)}{(s+1)(s+2)}$$

or characteristics equation,

$$q(s) = s^2 + s(K + 3) + (2 + \alpha K) \quad ...(1)$$

For $S = -3 \pm j\sqrt{5}$,

$$q(s) = (s+3)^2 + (\sqrt{5})^2 \quad ...(2)$$

$$= s^2 + 14 + 6s$$

On comparing (1) and (2) we get,

$$K = 3 \text{ and } \alpha = 4$$

End of Solution

Q.41 The state and output equations for a control system are:

$$\dot{x} = \begin{bmatrix} -4 & -1.5 \\ 4 & 0 \end{bmatrix} x + \begin{bmatrix} 2 \\ 0 \end{bmatrix} u$$

$$y = [1.5 \quad 0.625]x$$

Which of the following expressions correctly represents the transfer function $\frac{Y(s)}{U(s)}$ of the system with zero initial conditions?

(a) $\frac{3s}{s^2 + 4s - 6}$

(b) $\frac{3s+5}{s^2 + 4s - 6}$

(c) $\frac{3s+5}{s^2 + 4s + 6}$

(d) $\frac{3s}{s^2 + 4s + 6}$

Ans. (c)

We know that,

Transfer Function of system, TF = $C[(sI - A)^{-1} B] + D$

On solving, we get

$$\text{TF} = \frac{3s+5}{s^2 + 4s + 6}$$

End of Solution

Q.42 The address of the first location of a 256 kilo byte (KB) memory is $(2500)_H$. Choose the correct address of the last location of the memory.

(a) $(2FFF)_H$

(b) $(124FF)_H$

(c) $(424FF)_H$

(d) $(324FF)_H$

Ans. (c)

Given, Memory capacity = 256 kB

Starting address = 2500 H

Final address = ?

Final address – Initial address + 1 = Capacity of memory

$x - 2500\text{ H} + 1 = 40000\text{ H}$

$x = 40000\text{ H} - 1 + 2500\text{ H}$

$$x = \begin{array}{r} 3FFFFH \\ +2500H \\ \hline 424FFH \\ \hline \end{array}$$

Hence, the final address location is 424FFH.

End of Solution

Q.43 Consider a real signal $x(t)$, $-\infty < t < \infty$, such that
$x(t) = 0$ for $t < 0$, $x(t) = 2$ for $0 \le t < 1$ and $x(t) = 0$ for $t \ge 1$.

Let $E[x(t)] = \int_{-\infty}^{\infty} [x(t)]^2\, dt$.

Which of the following options correctly represents the ratio, $E[x(t)]/E[3x(-3t+)]$?

(a) 3 (b) 1
(c) 1/3 (d) 1/9

Ans. (c)

Energy of signal, $x(t)$ = E joule

$$x(-3t + 5) \rightarrow \frac{E}{3} \text{ joule}$$

$$3x[-3t + 5] \rightarrow 3^2 \times \frac{E}{3} = 3E \text{ joule}$$

$$\frac{E[x(t)]}{E[3x(-3t+5)]} = \frac{E}{3E} = \frac{1}{3}$$

End of Solution

Q.44 A QPSK modulated signal from an additive white Gaussian noise (AWGN) channel is received with an E_b/N_o = 8.4 dB at the input of a coherent QPSK demodulator. A maximum-likelihood reception method is used in the demodulator.
Assume the complimentary error function

$$\text{erfc}(u) \cong \left[\frac{1}{(u\sqrt{\pi})}\right]\exp(-u^2).$$

Which is the nearest bit error rate (BER) at the output of the demodulator?

(a) 10^{-3} (b) 10^{-4}
(c) 10^{-5} (d) 10^{-6}

Ans. (b)

Given, $$\frac{E_b}{N_0} = 8.4 \text{ dB} = 10^{0.84}$$

$$erfc(u) \simeq \frac{1}{u\sqrt{\pi}} e^{-u^2}$$

$$\text{BER of QPSK} = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$
$$= \frac{1}{2}erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$
$$= \frac{1}{2}erfc\left(\sqrt{6.91}\right)$$
$$= \frac{1}{2}erfc(2.63)$$
$$= \frac{1}{2}\times\frac{1}{2.63\sqrt{\pi}}e^{-(2.63)^2}$$
$$= 0.0001 \simeq 10^{-4}$$

End of Solution

Q.45 What is the 10's complement of $(47)_{10}$?

(a) 52 (b) 53
(c) 54 (d) 55

Ans. (b)

Using r's complement = $(r-1)$'s complement + 1

∴ 9's compliment of $(47)_{10}$

$$\begin{array}{r} 99 \\ -47 \\ \hline 52 \end{array} \quad \text{i.e., (9's complement)}$$

∴ 10's complement

$$\begin{array}{r} 52 \\ +1 \\ \hline 53 \end{array}$$

Hence, the 10's complement of $(47)_{10}$ is 53.

End of Solution

Q.46 Consider a real baseband signal $x(t) = e^{-2t}$, for t (in seconds) ≥ 0.
If 99% of energy of $x(t)$ lies within B Hz, then which of the following options is TRUE for the value of B?

(a) $B > 1$ kHz (b) $63/\pi$ Hz $< B < 64/\pi$ Hz
(c) $126/\pi$ Hz $< B < 128/\pi$ Hz (d) $B < 1$ Hz

Ans. (b)

$$x(t) \rightleftharpoons X(\omega) = \frac{1}{2+j\omega}$$
$$|X(\omega)| = \frac{1}{\sqrt{4+\omega^2}}$$

For $x(t)$: Energy $\quad \frac{1}{2\times 2} = \frac{1}{4}$

Given that energy contained in the frequency range "$2\pi B$" rad/sec is 99% of energy of $x(t)$.

i.e. $$\frac{1}{2\pi}\int_{-2\pi B}^{2\pi B}|X(\omega)|^2 d\omega = \frac{0.99}{4}$$

$$\Rightarrow \quad \frac{1}{2\pi}\times 2\times\int_0^{2\pi B}\frac{1}{4+\omega^2}d\omega = \frac{0.99}{4}$$

$$\Rightarrow \quad \frac{1}{\pi}\left[\frac{1}{2}\tan^{-1}\left(\frac{w}{2}\right)\right]_0^{2\pi B} = \frac{0.99}{4}$$

$$\frac{1}{\pi}\tan^{-1}\left[\frac{2\pi B}{2}\right] = \frac{0.99}{2}$$

$$\Rightarrow \quad \tan^{-1}(\pi B) = \frac{0.99\pi}{2}$$

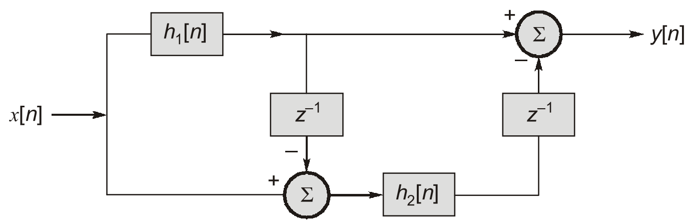
$$\Rightarrow \quad \pi B = \tan\left(\frac{0.99\pi}{2}\right) = 63.56$$

$$\Rightarrow \quad B = \frac{63.56}{\pi} = 20.26 \text{ Hz}$$

End of Solution

Q.47 Consider the discrete time system (S) with input $x[n]$ and output $y[n]$ as shown in the Figure. The two sub-systems represented by their impulse responses $h_1[n]$ and $h_2[n]$ are linear and time invariant.

Which of the following statements is necessarily TRUE?



(a) S is causal.
(b) S is linear and time invariant.
(c) S is linear and time varying.
(d) S is non-linear.

Ans. (b)

The overall system S is composed of two sub-systems with impulse response $h_1[n]$ and $h_2[n]$.

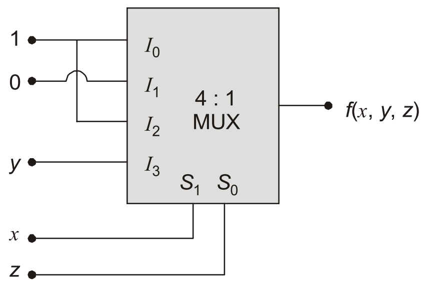
- Given $h_1[n]$ and $h_2[n]$ is LTI system.
- The system uses adders (Σ), which are linear operation.
- The system uses unit delays (z^{-1}), which are linear and time-invariant operations.
- The sub-systems are connected in a combination of parallel and cascode (series) configuration.

- Hence, the combination of linear sub-systems through linear operations (addition and scaling) results in an overall system that is linear.
- Since all components (h_1, h_2, adders, and delays) are time-invariant, their interconnection is also time-invariant.
- Because the system is built entirely from LTI components and linear interconnections, the overall system S must be linear and time invariant.

End of Solution

Q.48 A Boolean function, $f(x, y, z)$ with x as MSB and z as LSB is realized by 4 : 1 multiplexer (MUX) with select lines, S_1 and S_0 (S_1 is MSB, S_0 is LSB) and inputs, I_0, I_1, I_2, I_3 as shown in the Figure.

Which of the following options is the correct expression of $f(x, y, z)$?

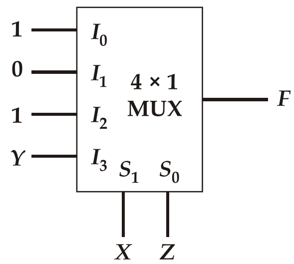


(a) $xz + y$ (b) $x\bar{y} + z$

(c) $xy + \bar{z}$ (d) $\bar{x}y + \bar{z}$

Ans. (c)

Given,



$$F = \bar{S}_1\bar{S}_0 I_0 + \bar{S}_1 S_0 I_1 + S_1\bar{S}_0 I_2 + S_1 S_0 I_3$$

$$= \bar{X}\,\bar{Z}(1) + \bar{X}Z(0) + X\bar{Z}(1) + XZY$$

$$= \bar{X}\,\bar{Z} + X\bar{Z} + XZY$$

$$= \bar{Z}[X + \bar{X}] + XYZ$$

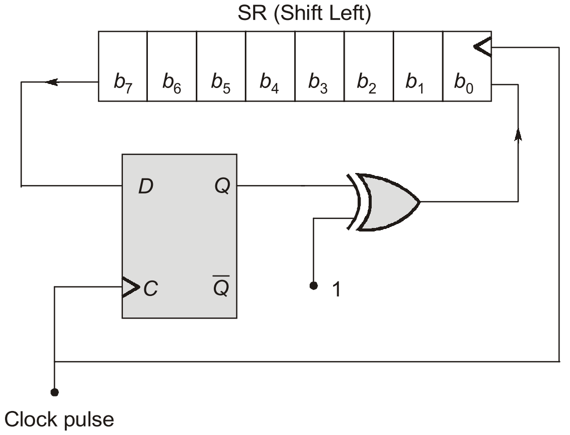
$$F = \bar{Z} + XYZ$$

$$F = XY + \bar{Z}$$

End of Solution

Q.49 A shift-left Shift Register (SR) and a *D* flip-flop are connected to a synchronized clock as shown in the Figure. Assume that the SR and D flip-flops are initially cleared and the XOR gate has no propagation delay.

Which of the following options gives the correct binary representation ($b_7\, b_6\, b_5\, b_4\, b_3\, b_2\, b_1\, b_0$) of the content of the shift register immediately after the 5th clock transition (positive edge)?



(a) 00011111 (b) 10111111
(c) 00111111 (d) 11000011

Ans. (a)

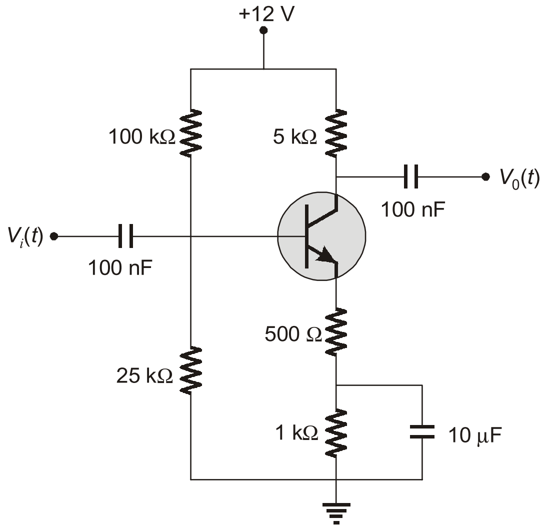
CLK	Q	B_7	B_6	B_5	B_4	B_3	B_2	B_1	B_0
0	0	0	0	0	0	0	0	0	0
1st	0	0	0	0	0	0	0	0	1
2nd	0	0	0	0	0	0	0	1	1
3rd	0	0	0	0	0	0	1	1	1
4th	0	0	0	0	0	1	1	1	1
5th	0	0	0	0	1	1	1	1	1

Hence, the output after 5 clock pulses is 0 0 0 1 1 1 1 1.

End of Solution

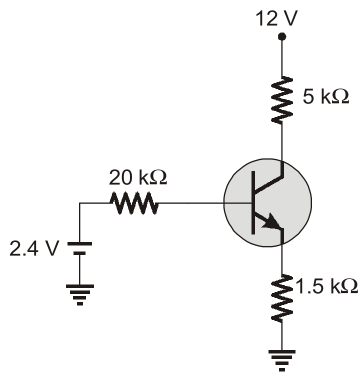
Q.50 A small signal source, $V_i(t) = A\cos(10^5 t) + B\sin(10^7 t)$ is applied to a BJT circuit as shown in the Figure.

Assume zero source resistance, $V_{BE} = 0.7$ V, $\beta_{dc} = 99$, Early voltage = 100 V and Thermal voltage = 25 mV. Effect of internal parasitic capacitances of the BJT may be neglected. Which expression is the best approximation of the output voltage $V_o(t)$?



(a) $-9.1\left[A\cos(10^5 t)+B\sin(10^7 t)\right]$
(b) $9.1\left[A\cos(10^5 t)+B\sin(10^7 t)\right]$
(c) $-190.4\left[A\cos(10^5 t)+B\sin(10^7 t)\right]$
(d) $190.4\left[A\cos(10^5 t)-B\sin(10^7 t)\right]$

Ans. (a)



For DC Analysis,

$$V_{th} = \frac{12\times 25}{100+25} = 2.4 \text{ V}$$

$$R_{th} = 100 \,||\, 25 = 20 \text{ k}\Omega$$

$$I_B = \frac{V_{th}-V_{BE}}{R_{th}+(1+\beta)R_E}$$

$$I_B = 0.01 \text{ mA}$$

$$I_C = \beta I_B = 0.99 \text{ mA}$$

$$V_{CE} \cong V_{CC} - I_C(R_C + R_E) = 5.56 \text{ V}$$

$$g_m = \frac{I_C}{V_T} = 39.6 \text{ m}\mho$$

$$r_\pi = \frac{\beta}{g_m} = 2.5 \text{ k}\Omega$$

$$r_0 = \frac{V_A+V_{CE}}{I_C} = 106.6 \text{ k}\Omega$$

If we neglect the effect of r_0 then voltage gain expression is,

$$A_V \cong \frac{-g_m R_C}{1+g_m R_{E1}}, \quad R_{E1} = 0.5 \text{ k}\Omega$$

$$A_V \cong -9.5$$

100 nF capacitors provide negligible reactance at given input frequencies. Hence both frequencies will appear in the output.

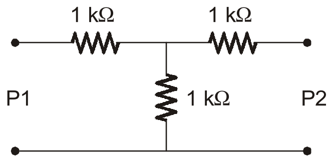
$$V_0 = A_V \times V_i$$

$$V_0 \cong -9.5\,(A\cos 10^5 t + B\sin 10^7 t)$$

End of Solution

Q.51 Consider the two-port network as shown in the Figure.

Which of the following options provides the correct set of values of A, B, C and D parameters?



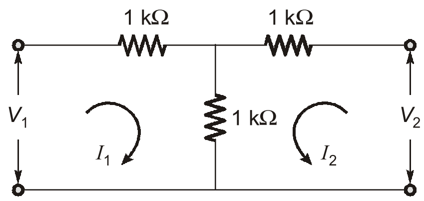
(a) $A = \frac{1}{2}, B = 3 \times 10^3\ \Omega, C = 10^{-3}\ \Omega^{-1}, D = \frac{1}{2}$

(b) $A = 2,\ B = 3\ \Omega,\ C = 1\ \Omega^{-1},\ D = 2$

(c) $A = 2,\ B = 6 \times 10^3\ \Omega,\ C = 2 \times 10^{-3}\ \Omega^{-1},\ D = 2$

(d) $A = 2,\ B = 3 \times 10^3\ \Omega,\ C = 10^{-3}\ \Omega^{-1},\ D = 2$

Ans. (d)



BY KVL1

$$V_1 = 2 \times 10^3 I_1 + 10^3 I_2 \quad \text{...(1)}$$

BY KVL2

$$V_2 = 10^3 I_1 + 2 \times 10^3 I_2 \quad \text{...(2)}$$

From eq. (2)

$$I_1 = \frac{V_2}{10^3} - \frac{2 \times 10^3}{10^3} I_2$$

$$I_1 = 10^{-3} V_2 - 2 I_2 \quad \text{...(3)}$$

$$I_1 = C V_2 - D I_2 \quad \text{...(4)}$$

By comparing eq. (3) and eq. (4)

$$C = 10^{-3},\ D = 2$$

Substituting eq. (3) in eq. (1)

$$V_1 = 2 \times 10^3 \left(10^{-3} V_2 - 2 I_2\right) + 10^3 I_2$$

$$V_1 = 2V_2 - 3 \times 10^3 I_2 \quad \text{...(5)}$$

$$V_1 = AV_2 - BI_2 \quad \text{...(6)}$$

By comparing eq. (5) and eq. (6)

$$A = 2,\ B = 3 \times 10^3$$

End of Solution

Q.52 A complex load (in Ω) is represented as $\Gamma_L = 0.5\angle 30°$ on the Smith chart. A co-axial cable with a characteristic impedance of 50 Ω is connected to the load. The new input impedance of the load now moves to a diametrically opposite point on the same Γ circle on the Smith chart.

Which option is the nearest input impedance of the cable connected load (in Ω)?

(a) $20.7 - j5.1$
(b) $17.7 - j11.8$
(c) $97.5 - j65.0$
(d) $97.5 + j65.0$

Ans. (b)

Given: $\Gamma_L = 0.5\angle 30°$; $Z_o = 50\ \Omega$

As point moves to a diametrically opposite point. So, there will be a phase change of 180°, the magnitude

$$\therefore \quad \Gamma_L\big|_{new} = 0.5[\angle 30° + \angle 180°] = 0.5\angle 210° = 0.5\angle -150°$$

So,
$$\Gamma_L\big|_{new} = \frac{Z_{in} - Z_o}{Z_{in} + Z_o}$$

$$\Rightarrow \quad Z_{in} = Z_o\left[\frac{1+\Gamma_L\big|_{new}}{1-\Gamma_L\big|_{new}}\right]$$

$$\Rightarrow \quad Z_{in} = 50\left[\frac{1+0.5\angle -150°}{1-0.5\angle -150°}\right] = 50 \times 0.426\ \angle -33.7°$$

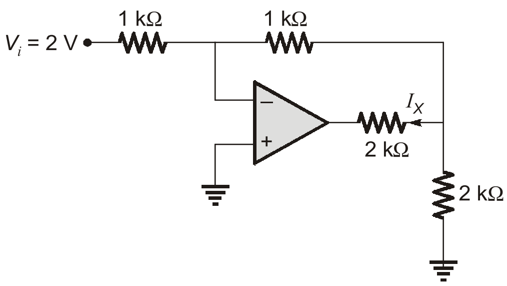
$$\Rightarrow \quad Z_{in} = 21.3\angle 33.7°$$

$$\Rightarrow \quad Z_{in} = 17.72 - j11.82\ \Omega$$

End of Solution

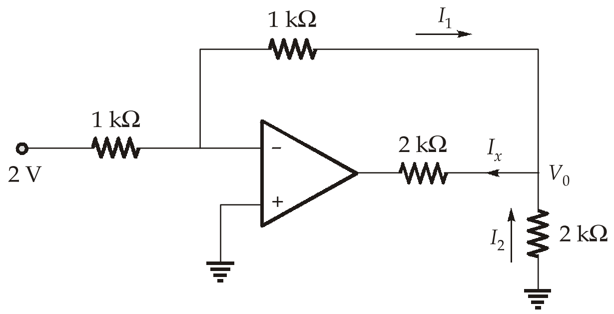
Q.53 A circuit using an ideal OP-AMP is shown in the Figure.

Which of the following options gives the correct value of the current I_X?



(a) 2.0 mA
(b) 1.5 mA
(c) 3.0 mA
(d) 0 mA

Ans. (c)



$$V_0 = \frac{-1}{1}\times 2 = -2 \text{ V}$$

KCL :

$$I_x = I_1 + I_2$$

$$I_x = \frac{0-V_0}{1} + \frac{0-V_0}{2}$$

$$I_x = \frac{2}{1} + \frac{2}{2} = 3 \text{ mA}$$

End of Solution

Q.54 Consider an LED based on a direct bandgap semiconductor material with energy bandgap 1.3 eV.

Given: Plank's constant, h = 6.63 × 10^{-34} J s and speed of light in free space is 3 × 10^8 m s^{-1}.

In which of the following wavelength ranges the LED will NOT emit?

(a) 1410 ± 20 nm
(b) 1090 ± 20 nm
(c) 950 ± 20 nm
(d) 510 ± 20 nm

Ans. (a, b, d)

Wave length is absorbed if

$$\lambda \le \frac{1.24}{E_G}\mu\text{m}$$

$$\lambda \le \frac{1.24}{1.3}\mu\text{m}$$

$$\lambda \le 0.953\ \mu\text{m}$$

$$\lambda \le 953 \text{ nm}$$

$$\lambda \approx 953 \text{ nm}$$

Hence, the LED will emits light centered around 954 nm.

So, option (a), (b) and (d) does not fall in this range and hence does not emit and the LED will emit in the range of 930 nm to 970 nm.

End of Solution

Q.55 Let the relevant bandwidth (B) of a digital communication system be 1 MHz and kT = –174 dBm/Hz, where k is Boltzmann's constant and 'T' is equivalent noise temperature of the receiver. The power (S) of signal received through an additive Gaussian channel is –80 dBm.

Which of the following options is/are TRUE about Shannon capacity (C) of the channel?

(a) $C = B$ (b) $C = 2B$

(c) $C > 3B$ (d) $C < B$

Ans. **(c)**

Given, bandwidth (B) = 1 MHz

$$KT = -174 \text{ dBm/Hz} = 10^{-17.4} \times 10^{-3} \text{ W/Hz}$$

Signal power → S = –80 dBm = $10^{8} \times 10^{-3}$ W

$$C = B\log_2\left(1+\frac{S}{N}\right)$$

Noise power, (N) = KTB

$$= [10^{-17.4} \times 10^{-3}] \times 10^{6}$$

$$C = B\log_2\left(1+\frac{10^{-11}}{10^{-14.4}}\right)$$

$$= B\log_2(1 + 10^{3.4})$$

$$C = 11.29\, B$$

∴ $C > 3B$ would satisfy the above result.

End of Solution

Q.56 Consider the four-variable Boolean function,

$f(w, x, y, z) = \Sigma m$ (0, 2, 5, 7, 8, 10, 13, 14, 15) with 'w' as MSB and 'z' as LSB.

Which of the following expressions is/are the valid form(s) of $f(w, x, y, z)$?

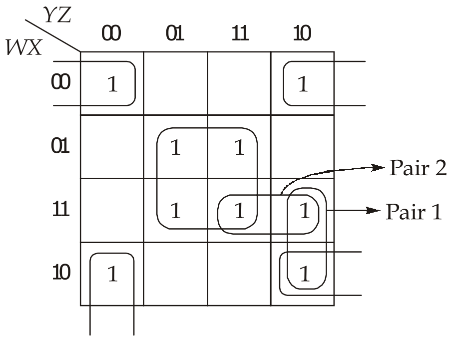
(a) $\bar{x}\bar{z} + xz + wxy$ (b) $xz + wxy + w\bar{x}\bar{z} + \bar{w}xy\bar{z}$

(c) $\bar{x}\bar{z} + wxy + w\bar{x}\bar{z} + \bar{w}xy\bar{z}$ (d) $\bar{x}\bar{z} + xz + wy\bar{z}$

Ans. **(a, d)**

Given, $f(W, X, Y, Z) = \Sigma m(0, 2, 5, 7, 8, 10, 13, 14, 15)$

By using 4-variable K-map



By forming pair 1, $f = XZ + \bar{X}\bar{Z} + WY\bar{Z}$

If we form pair (2), $f = XZ + \bar{X}\bar{Z} + WXY$

End of Solution

Q.57 Consider a real, narrowband signal $x(t) = A(t)\cos[2\pi f_c t + \theta(t)]$ where the maximum frequency components of $A(t)$ and $\theta(t)$ are f_M and f_c (= 1000 f_M), respectively.

Which of the following statements is/are correct for $-\infty < t < \infty$?

(a) $x(t)$ represents a PSK modulated signal for suitable choices of $A(t)$ and $\theta(t)$.

(b) $x(t)$ represents an amplitude modulated signal for suitable choices of $A(t)$ and $\theta(t)$.

(c) $x(t)$ represents a band-limited Gaussian noise process.

(d) $x(t)$ never represents a narrowband FM signal.

Ans. (a, b, c)

Given Narrow band signal

$$x(t) = A(t)\cos[2\pi f_c t + \theta(t)]$$

- For suitable choices of $A(t)$ and $\theta(t)$; $x(t)$ represents an AM signals.

  Ex.: Let $A(t) = 1 + m(t)$
  $$\theta(t) = 0$$
  $$x(t) = [1 + m(t)]\cos 2\pi f_c t;$$

  It represents an AM signal.

- For suitable choices of $A(t)$ and $\theta(t)$; $x(t)$ represents PSK signal.

  Ex.: Let $A(t)$ is a constant, $\theta(t)$ is 45°, 135°, 225°, 315°;

  Hence, $x(t)$ represents PSK signal.

- $x(t)$ represents a bandlimited Gaussian Noise process.
  $$x(t) = x_c(t)\cos 2\pi f_c t - x_q(t)\sin 2\pi f_c t$$
  where,
  $$x_c(t) = A(t)\cos\theta(t)$$
  $$x_q(t) = A(t)\sin\theta(t)$$

  If $x_1(t)$ and $x_q(t)$ are Gaussian processes then $x(t)$ also represents Gaussian Process.

  Hence, option (a, b, c) are correct.

- $x(t)$ can represents NBFM signal.

  Ex:
  $$x(t) = A(t)\cos\underbrace{[2\pi f_c t + \theta(t)]}_{\theta_i(t)}$$

  $x(t)$ represents an angle modulated signal. So, can be considered as NBFM signal also. Hence option (d) is incorrect.

End of Solution

Q.58 Let $x_1(t) = \cos(2\pi nt)$ and $x_2(t) = 2\sin(4\pi nt)$ represent two sinusoids for a positive integer n and $-\infty < t < \infty$.

Which of the following statements about $x_1(t)$ and $x_2(t)$is/are valid?

(a) $x_1(t)$ and $x_2(t)$ are orthogonal to each other over $0 \le t < 1/n$.

(b) $x_1(t)$ and $x_2(t)$ are orthonormal to each other over $0 \le t < 1/n$.

(c) $x_2(t)$ is a harmonic of $x_1(t)$.

(d) $x_1(t)$ and $x_2(t)$ are non-orthogonal to each other over $0 \le t < 1/(2n)$.

Ans. (a, c, d)

$$x_1(t) = \cos 2\pi nt,\ x_2(t) = 2\sin 4\pi nt$$

$$\int_0^{1/n} x_1(t)\cdot x_2(t)dt = \int_0^{1/n} \cos 2\pi nt \cdot 2\sin 4\pi nt\,dt$$

$$= \int_0^{1/n} (\sin 6\pi nt + \sin 2\pi nt) dt$$

$$= \left[\frac{-\cos 6\pi nt}{6\pi n} - \frac{\cos 2\pi nt}{2\pi n}\right]_0^{1/n}$$

$$= \left[\frac{-\cos 6\pi + \cos 0}{6\pi n}\right] + \left[\frac{-\cos 2\pi + \cos 0}{2\pi n}\right]$$

$$= \frac{-1+1}{6\pi n} + \frac{-1+1}{2\pi n} = 0$$

i.e., $x_1(t)$ and $x_2(t)$ are orthogonal over $0 \le t < 1/n$.

Energy of $x_1(t)$ over $\left(0, \frac{1}{n}\right)$ interval is $\frac{1}{2n}$.

So, $x_1(t)$ and $x_2(t)$ are not orthonormal over $0 \le t < 1/n$.

$$\int_0^{1/2n} x_1(t) \cdot x_2(t) dt = \int_0^{1/2n} \cos 2\pi nt \cdot 2\sin 4\pi nt \, dt$$

$$= \left[\frac{-\cos 6\pi nt}{6\pi n} - \frac{\cos 2\pi nt}{2\pi n}\right]_0^{1/2n}$$

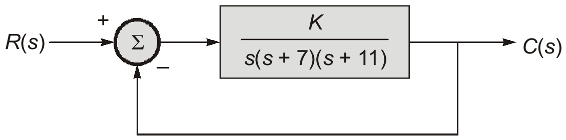
$$= \left(\frac{-\cos 3\pi + \cos 0}{6\pi n}\right) + \left(\frac{-\cos \pi + \cos 0}{2\pi n}\right)$$

$$= \frac{2}{6\pi n} + \frac{2}{2\pi n} = \frac{8}{6\pi n} = \frac{4}{3\pi n} \neq 0$$

i.e, $x_1(t)$ and $x_2(t)$ are non-orthogonal over $0 \le t < \frac{1}{2n}$.

End of Solution

Q.59 Consider the unity negative feedback control system shown in the Figure.
The value of gain K (>0) at which the given system will remain marginally stable is ______.
(Answer in integer)



Ans. (1386 to 1386)

We know that the characteristics equation is given as,

$$1 + G(s)\,H(s) = 1 + \frac{K}{s(s+7)(s+11)}$$

or $\quad s(s^2 + 18s + 77) + K = 0$

or $\quad s^3 + 18s^2 + 77s + K = 0$

Now using RH criteria we get

s^3	1	77
s^2	18	L
s^1	$\frac{18\times 77 - K}{1s}$	
s^0	K	

For marginally stable system

$$18 \times 77 - K = 0$$

$$K = 18 \times 77 = 1386$$

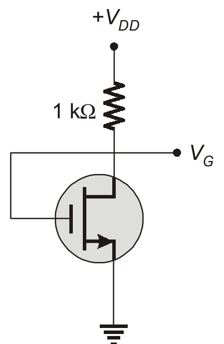
End of Solution

Q.60 An n-channel MOSFET is connected as shown in the Figure.

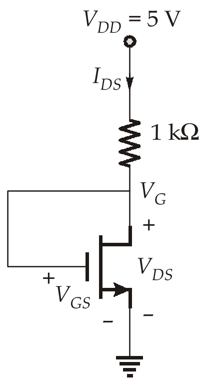
Assume V_{TH} = 1 V, V_{DD} = 5 V, and $\mu C_{ox}\left(\frac{W}{L}\right) = 2\text{ mA V}^{-2}$ and neglect channel length modulation effects.

The gate voltage (V_G) of the n-channel MOSFET (in Volt) is ______.

(rounded off to two decimal places)



Ans. (2.56) (2.50 to 2.60)

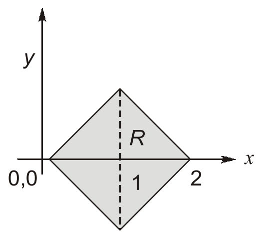


$$V_{GS} = V_{DS} = 5 - 1 \times I_{DS}$$
$$I_{DS} = 5 - V_{GS} \quad ...(1)$$
$$I_{DS} = \frac{\mu_N C_{ox}}{2} \times \frac{W}{L}(V_{GS} - V_T)^2$$
$$5 - V_{GS} = \frac{2}{2}(V_{GS} - 1)^2$$
$$10 - 5V_{GS} = V_{GS}^2 + 1 - 2V_{GS}$$
$$V_{GS}^2 - V_{GS} - 4 = 4$$
$\Rightarrow$ $$V_{GS} = 2.56 \text{ V}$$
Hence, $$V_G = V_{GS} = 2.56 \text{ V}$$

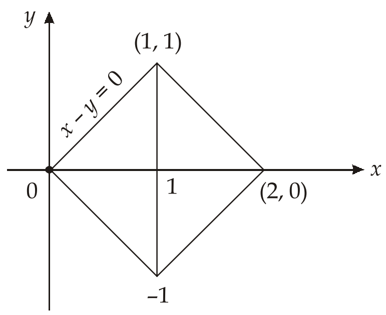
End of Solution

Q.61 Consider the square region R in the X-Y plane as shown with the dark shading in the Figure. The value of $\iint_R (x^2 + y^2 - 1)\, dx\, dy$ is ____.

(rounded off to two decimal places)



Ans. (0.66) (0.60 to 0.70)



$$I = \iint_R (x^2 + y^2 dx)dy - \iint_R dy dx$$
$$I = I_1 - I_2$$
$$I_1 = \int_0^1 \int_{-x}^{x} (x^2 + y^2) dy\, dx + \int_1^2 \int_{-(2-x)}^{(2-x)} (x^2 + y^2) dy\, dx$$
$$= 2\int_0^1 \left(x^2 y + \frac{y^3}{3} \right)_0^x dx + 2\int_1^2 \left(x^2 y + \frac{y^3}{3} \right)_0^{(2-x)} dx$$

$$= 2\int_0^1 \frac{4}{3}x^3 + 2\int_1^2 \left(x^2(2-x) + \frac{(2-x)^3}{3} \right) dx$$

$$= \frac{8}{3}\left(\frac{1}{4}\right) + 2\left[\frac{2x^3}{3} - \frac{x^4}{4} + \frac{1}{3}\frac{(2-x)^4}{-4}\right]_1^2$$

$$= \frac{8}{12} + 2\left[\left(\frac{16}{3} - 4 - \frac{1}{2}(0)\right) - \left(\frac{2}{3} - \frac{1}{4} - \frac{1}{12}\right)\right]$$

$$= \frac{2}{3} + 2\left[\left(\frac{4}{3} - \frac{1}{3}\right)\right]$$

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

$$I_1 = \frac{8}{3}$$

I_2 = Area of square

$\therefore \quad I = I_1 - I_2$

$$I = \frac{8}{3} - \sqrt{2} \times \sqrt{2}$$

$$I = \frac{8}{3} - 2$$

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

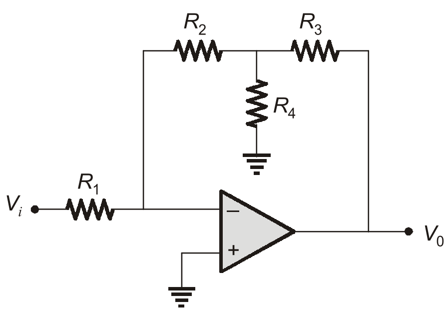
End of Solution

Q.62 Consider an ideal OP-AMP circuit as shown in the Figure.

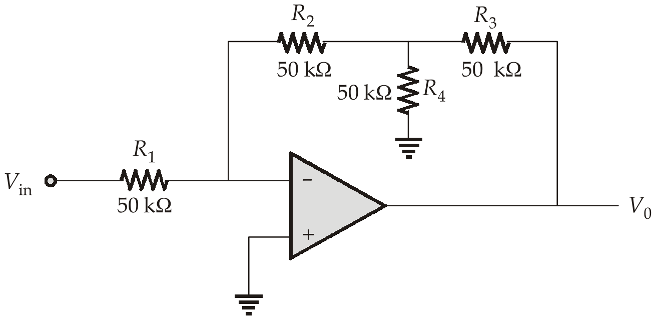
The resistances $R_1 = R_2 = R_3 = R_4 = 50\ \text{k}\Omega$.

The magnitude of the closed loop gain is ________.

(rounded off to two decimal places)



Ans. (2.90 to 3.10)



$$\frac{V_0}{V_i} = \frac{-R_2}{R_1}\left[1+\frac{R_3}{R_2}+\frac{R_3}{R_4}\right]$$

$$= \frac{-50\text{ k}\Omega}{50\text{ k}\Omega}\left[1+\frac{50\text{ k}\Omega}{50\text{ k}\Omega}+\frac{50\text{ k}\Omega}{50\text{ k}\Omega}\right]$$

$$= -1[1 + 1 + 1]$$

$$= -3$$

Hence, $\left|\frac{V_0}{V_i}\right| = 3$

End of Solution

Q.63 The average bit error rate at the input of a (7, 4, 1) Hamming decoder is 0.10. The probability that the decoder will fail to decode a received word correctly is ______. (rounded off to two decimal places)

Ans. (0.15) (0.10 to 0.20)

Hamming code can correct upto one error only.

Probability of decoding received code word properly will be

$\Rightarrow$ $$P_c = P\text{ (no error)} + P\text{(1-bit error)}$$

$$= {}^7C_0(0.1)^0(0.9)^7 + {}^7C_1(0.1)^1(0.9)^6$$

$\because$ When n-bits transmitted, probability of getting error in r-bits will be ${}^nC_r\, P^r(1-P)^{n-r}$

$\therefore$ $$P_c \cong 0.85$$

Probability of decoder failed to decode received codeword properly will be

$$P_e = 1 - P_c$$

$$= 1 - 0.85$$

$$= 0.15$$

End of Solution

Q.64 Consider that the concentration of electrons in a semiconductor bar varies linearly from 2×10^{17} cm^{-3} at x = 1 μm to 1×10^{16} cm^{-3} at x = 4 μm along the x-direction. Assume that the concentration of electrons is not varying along other directions (that is along y and z-directions).

[Given: the mobility of electron is 1400 cm^2 V^{-1} s^{-1}, thermal voltage is 25 mV and electronic charge is 1.6×10^{-19} Coulomb.]

The density of electron diffusion current (in A/mm^2) is _____.
(rounded off to two decimal places)

Ans. (35.47) (34.50 to 36.50)

$$D_N = \mu_N \times V_T = 35 \text{ cm}^2/\text{sec}$$

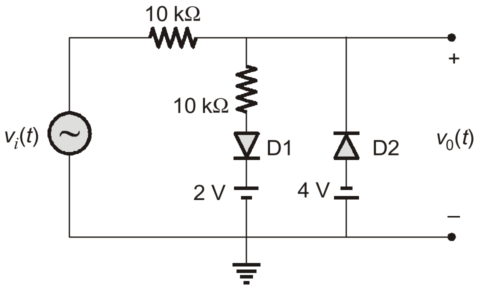
$$\frac{dn}{dx} = \frac{\Delta n}{\Delta x} = \frac{2\times10^{17} - 1\times10^{16}}{3\times10^{-4}\,cm} = 6.33\times10^{20}\,cm^{-4}$$

$$J_{\text{Diff}} = qD_N \times \frac{dn}{dx} = 1.6\times10^{-19}\times35\times6.33\times10^{20}$$

$$= 3547 \text{ A/cm}^2 = 35.47 \text{ A/mm}^2$$

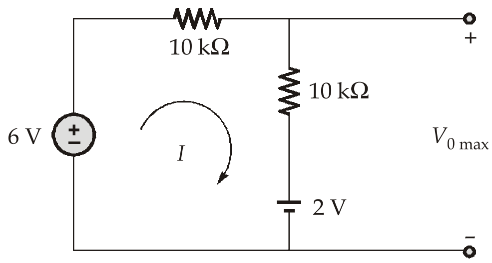
End of Solution

Q.65 Consider the ideal diodes D1 and D2 as shown in the Figure with cut-in voltage V_γ = 0 Volt and $v_i(t)$ is in Volt.
The maximum voltage (Volt) of the output $v_o(t)$ is __.
(rounded off to two decimal places)



$v_i(t) = 6\sin(\omega t)$

Ans. (4) (3.70 to 4.30)
For maximum V_0
D_1 ON and D_2 OFF



$$I = \frac{6-2}{20\,k\Omega} = \frac{4}{20\,k\Omega} = 0.2\,mA$$

$$V_{0\,max} = I \times 10\text{ K} + 2\text{ V}$$
$$= 0.2\text{ mA} \times 10\text{ K} + 2\text{ V}$$
$$= 4\text{ V}$$

End of Solution

■■■■