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GATE 2020

Electronics and Communication Engineering

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SECTION A : GENERAL APTITUDE

Q.1 The Canadian constitution requires that equal importance be given to English and French. Last year, Air Canada lost a lawsuit, and had to pay a six-figure fine to a French-speaking couple after they filed complaints about formal in-flight announcements in English lasting 15 seconds, as opposed to informal 5 second messages in French.

The French-speaking couple were upset at __________.

(a) equal importance being given to English and French.
(b) the in-flight announcements being made in English.
(c) the English announcements being longer than the French ones.
(d) the English announcements being clearer than the French ones.

Ans. (c)

End of Solution

Q.2 A superadditive function $f(\cdot)$ satisfies the following property

$$f(x_1 + x_2) \geq f(x_1) + f(x_2)$$

Which of the following functions is a superadditive function for $x > 1$?

(a) $\sqrt{x}$ (b) e^{-x}
(c) e^x (d) $1/x$

Ans. (c)

Verify with options

Option (a):
$$\frac{1}{x_1 + x_2} > \frac{1}{x_1} + \frac{1}{x_2}$$
$$\frac{1}{2+3} > \frac{1}{2} + \frac{1}{3}$$
$$\frac{1}{5} > \frac{5}{6}$$
$0.2 > 0.8$ which is wrong.

Option (b):
$$\sqrt{x_1 + x_2} > \sqrt{x_1} + \sqrt{x_2}$$
$$\sqrt{2+3} > \sqrt{2} + \sqrt{3}$$
$$\sqrt{5} > 1.414 + 1.732$$
$2.23 > 3.146$ which is wrong.

Option (c):
$$e^{x_1 + x_2} > e^{x_1} + e^{x_2}$$
$$e^{1+2} > e^1 + e^2$$
$20.085 > 2.718 + 7.389$ Satisfying.

End of Solution

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Q.3 Select the word that fits the analogy:

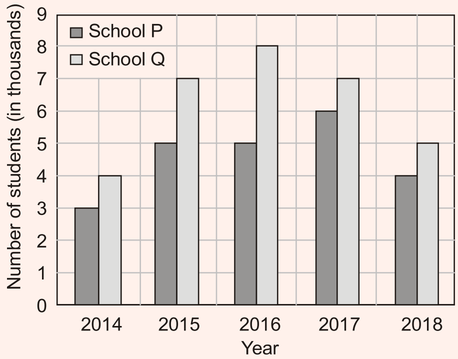
Explicit : Implicit : : Express : ________

(a) Repress (b) Suppress
(c) Compress (d) Impress

Ans. (a)

End of Solution

Q.4 The following figure shows the data of students enrolled in 5 years (2014 to 2018) for two schools P and Q. During this period, the ratio of the average number of the students enrolled in school P to the average of the difference of the number of students enrolled in schools P and Q is ________.



(a) 8 : 23 (b) 23 : 8
(c) 23 : 31 (d) 31 : 23

Ans. (b)

Average number of students in school,

$$P = \frac{3+5+5+6+4}{5} = \frac{23}{5}$$

Average number of students in school,

$$Q = \frac{4+7+8+7+5}{5} = \frac{31}{5}$$

Difference of the number of students enrolled in school P and Q

$$= \frac{31-23}{5} = \frac{8}{5}$$

Ratio of the average number of the students enrolled in school P to the average of the difference of the number of students enrolled in schools P and Q is

$$= 23 : 8$$

End of Solution

Q.5 a, b, c are real numbers. The quadratic equation $ax^2 - bx + c = 0$ has equal roots, which is β, then

(a) $\beta^2 = ac$
(b) $\beta^3 = bc/(2a^2)$
(c) $\beta = b/a$
(d) $b^2 \neq 4ac$

Ans. (b)

End of Solution

Q.6 The untimely loss of life is a cause of serious global concern as thousands of people get killed _______ accidents every year while many other die _______ diseases like cardio vascular disease, cancer, etc.

(a) during, from
(b) in, of
(c) from, from
(d) from, of

Ans. (b)

End of Solution

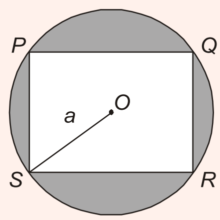
Q.7 It is quarter past three in your watch. The angle between the hour hand and the minute hand is __________.

(a) 22.5°
(b) 7.5°
(c) 0°
(d) 15°

Ans. (b)

End of Solution

Q.8 A circle with centre O is shown in the figure. A rectangle PQRS of maximum possible area is inscribed in the circle. If the radius of the circle is a, then the area of the shaded portion is ___________.



(a) $\pi a^2 - 2a^2$
(b) $\pi a^2 - 3a^2$
(c) $\pi a^2 - \sqrt{2}a^2$
(d) $\pi a^2 - a^2$

Ans. (a)

Area of shaded portion = Area of circle – area of rectangle

Maximum possible area of rectangle inscribed in the circle = $2a^2$

So, Required shaded area = $\pi a^2 - 2a^2$

End of Solution

Q.9 The global financial crisis in 2008 is considered to be the most serious world-wide financial crisis, which started with the sub-prime lending crisis in USA in 2007. The sub-prime lending crisis led to the banking crisis in 2008 with the collapse of Lehman Brothers in 2008. The sub-prime lending refers to the provision of loans to those borrowers who may have difficulties in repaying loans, and it arises because of excess liquidity following the East Asian crisis.

Which one of the following sequences shows the correct precedence as per the given passage?

(a) Subprime lending crisis → global financial crisis → banking crisis → East Asian crisis.
(b) Banking crisis → subprime lending crisis → global financial crisis → East Asian crisis.
(c) East Asian crisis → subprime lending crisis → banking crisis → global financial crisis.
(d) Global financial crisis → East Asian crisis → banking crisis → subprime lending crisis.

Ans. (c)

End of Solution

Q.10 He was not only accused of theft ________ of conspiracy.

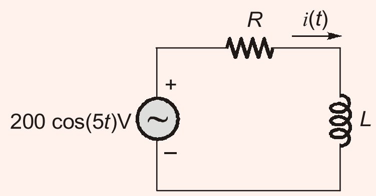
(a) rather
(b) rather than
(c) but also
(d) but even

Ans. (c)

End of Solution

SECTION B : TECHNICAL

Q.1 The current in the RL-circuit shown below is $i(t) = 10\cos(5t - \pi/4)A$. The value of the inductor (rounded off to two decimal places) is ________ H.



Ans. (2.828)

$$Z = \frac{V}{I} = \frac{200\angle 0^\circ}{10\angle -45^\circ} = 20\angle 45^\circ$$

$$Z = 10\sqrt{2} + j10\sqrt{2}$$

$$X_L = 10\sqrt{2}$$

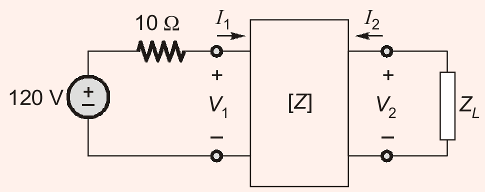
$$\omega L = 10\sqrt{2}$$

$$L = \frac{10\sqrt{2}}{5} = 2.828\ H$$

End of Solution

Q.2 In the given circuit, the two-port network has the impedance matrix $[Z] = \begin{bmatrix} 40 & 60 \\ 60 & 120 \end{bmatrix}$.

The value of Z_L for which maximum power is transferred to the load is ________ Ω.



Ans. **(48)**

From maximum power transfer theorem

$$Z_L = Z_{th}$$

$$Z_{th} = Z_{22} - \frac{Z_{12} \times Z_{21}}{R_S + Z_{11}}$$

For given data,
$$Z_{th} = 120 - \frac{60 \times 60}{10 + 40} = 48\,\Omega$$

$$Z_L = 48\Omega$$

End of Solution

Q.3 If v_1, v_2, ..., v_6 are six vectors in R^4, which one of the following statements is False?

(a) If $\{v_1, v_3, v_5, v_6\}$ spans R^4, then it forms a basis for R^4.
(b) These vectors are not linearly independent.
(c) It is not necessary that these vectors span R^4.
(d) Any four of these vectors form a basis for R^4.

Ans. **(d)**

End of Solution

Q.4 The loop transfer function of a negative feedback system is

$$G(s)H(s) = \frac{K(s+11)}{s(s+2)(s+8)}$$

The value of K, for which the system is marginally stable, is ________.

Ans. **(160)**

Characteristic equation $q(s)$ for the given open loop system will be

$$q(s) = s^3 + 10s^2 + 16s + Ks + 11K = 0$$

Using R-H criteria,

$$\begin{array}{c|cc} s^3 & 1 & 16+K \\ s^2 & 10 & 11K \\ s^1 & \dfrac{10(16+K)-11K}{10} & 0 \\ s^0 & 11K & 0 \end{array}$$

For system to be marginally stabled

$$\frac{10(16+K)-11K}{10} = 0$$

$$160 + 10K - 11K = 0$$

$$K = 160$$

End of Solution

Q.5 The partial derivative of the function

$$f(x,y,z) = e^{1-x\cos y} + xze^{-1/(1+y^2)}$$

with respect to x at the point (1, 0, e) is

(a) −1 (b) 1

(c) 0 (d) $\frac{1}{e}$

Ans. (c)

Given $f(x, y, z) = e^{1-x\cos y} + xze^{-1/(1+y^2)}$

$$\frac{\partial f}{\partial x} = e^{1-x\cos y}(0-\cos y) + ze^{-1/1+y^2}$$

$$\left(\frac{\partial f}{\partial x}\right)_{(1,0,e)} = e^0(0-1) + e \cdot e^{-1/(1+0)}$$

$$= -1 + 1 = 0$$

End of Solution

Q.6 The random variable

$$Y = \int_{-\infty}^{\infty} W(t)\phi(t)dt, \text{ where } \phi(t) = \begin{cases} 1; & 5 \le t \le 7 \\ 0; & \text{otherwise} \end{cases}$$

and $W(t)$ is a real white Gaussian noise process with two-sided power spectral density $S_W(f)$ = 3 W/Hz, for all f. The variance of Y is ________.

Ans. (6)

Given: $\phi(t) = \begin{cases} 1 & 5 \le t \le 7 \\ 0 & \text{Otherwise} \end{cases}$

$$S_\omega(f) = 3 \text{ Watts/Hz}$$

$$R_\omega(\tau) = 3\delta(\tau) = 3\delta(t_1 - t_2)$$

$$\text{Var}[y] = E[y^2] - \{E[y]\}^2$$

$$\{E[W(t)]\}^2 = \text{DC power} = \text{Area under PSD at } f = 0$$

$$\{E[W(t)]\}^2 = 0$$

$$E[W(t)] = 0$$

$$y = \int_{-\infty}^{\infty} W(t)\,\phi(t)\,dt$$

$$E[y] = \int_{-\infty}^{\infty} E[W(t)]\,\phi(t)dt = 0$$

$$y = \int_{-\infty}^{\infty} W(t)\,\phi(t)dt \rightarrow E[y^2] = S_{\omega}(f)\cdot \text{Energy }[\phi(t)]$$

$$= 3 \times 2 = 6$$

$$\text{Var}[y] = 6 - 0 = 6$$

Detailed explanations for :

$$y = \int_{-\infty}^{\infty} W(t)\,\phi(t)\,dt$$

$$E(y^2) = E[y \cdot y] = E\left[\int_{-\infty}^{\infty} W(t_1)\,\phi(t_1)dt_1 \int_{-\infty}^{\infty} W(t_2)\phi(t_2)dt_2\right]$$

$$= E\left[\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} W(t_1)\,W(t_2)\,\phi(t_1)\,\phi(t_2)\,dt_1\cdot dt_2\right]$$

$$= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E[W(t_1)\,W(t_2)]\cdot\phi(t_1)\,\phi(t_2)\,dt_1\,dt_2$$

$$= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} R_W(t_1 - t_2)\,\phi(t_1)\,\phi(t_2)\,dt_1\,dt_2$$

$$= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} 3\delta(t_1 - t_2)\,\phi(t_1)\,\phi(t_2)\,dt_1\,dt_2$$

Above integration exists provided

$$t_1 = t_2 = t$$

$$= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} 3\delta(0)\,\phi(t)\,\phi(t)\,dt\,dt$$

$$= 3\int_{-\infty}^{\infty}\delta(0)\,dt\int_{-\infty}^{\infty}\phi^2(t)\,dt$$

$$= 3 \times 1 \times \text{Energy }[\phi(t)]$$

$$E[y^2] = 6$$

End of Solution

Q.7 For a vector field $\vec{A}$, which one of the following is False?

(a) $\nabla \times \vec{A}$ is another vector field.

(b) $\vec{A}$ is solenoidal if $\nabla \cdot \vec{A} = 0$.

(c) $\vec{A}$ is irrotational if $\nabla^2 \vec{A} = 0$.

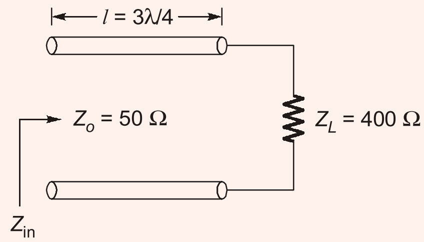
(d) $\nabla \times (\nabla \times \vec{A}) = \nabla(\nabla \cdot \vec{A}) - \nabla^2 \vec{A}$

Ans. (c)

End of Solution

Q.8 A transmission line of length $3\lambda/4$ and having a characteristic impedance of 50 Ω is terminated with a load of 400 Ω. The impedance (rounded off to two decimal places) seen at the input end of the transmission line is ________ Ω.

Ans. (6.25)



$$Z_{in} \text{ for } (l = \lambda/4) = \frac{Z_0^2}{Z_L} = \frac{50^2}{400} = \frac{25}{4} = 6.25\ \Omega$$

End of Solution

Q.9 A 10-bit D/A converter is calibrated over the full range from 0 to 10 V. If the input to the D/A converter is 13A (in hex), the output (rounded off to three decimal places) is ________ V.

Ans. (3.069)

Given, $n = 10$

$V_{FS} = 10$ V

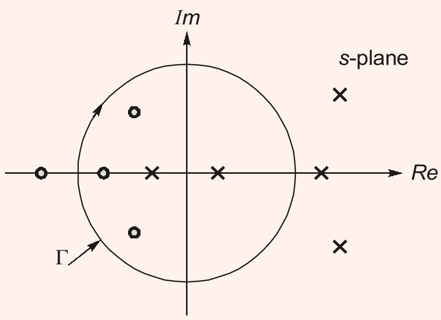
Input voltage $= (13A)_{16} = (314)_{10}$

Output voltage = Resolution × Decimal equivalent of input

$$V_o = \frac{10}{2^{10}-1} \times 314 = 3.069 \text{ V}$$

End of Solution

Q.10 The pole-zero map of a rational function $G(s)$ is shown below. When the closed counter Γ is mapped into the $G(s)$-plane, then the mapping encircles.



(a) the point $-1 + j0$ of the $G(s)$-plane once in the counter-clockwise direction.
(b) the origin of the $G(s)$-plane once in the clockwise direction.
(c) the origin of the $G(s)$-plane once in the counter-clockwise direction.
(d) the point $-1 + j0$ of the $G(s)$-plane once in the clockwise direction.

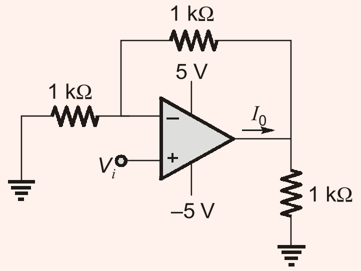
Ans. (b)

s-plane contour is encircling 2-poles and 3-zeros in clockwise direction hence the corresponding $G(s)$ plane contour encircles origin 2-times in anti-clockwise direction and 3-times in clockwise direction.

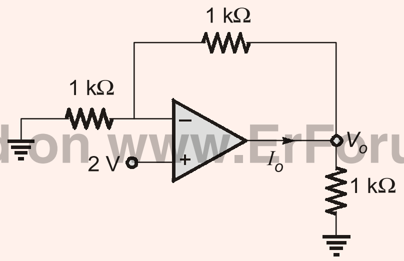
$\therefore$ Effectively once in clockwise direction.

End of Solution

Q.11 In the circuit shown below, all the components are ideal. If V_i is +2 V, the current I_0 sourced by the op-amp is ________ mA.



Ans. (6)



$$V_o = (1 + 1) \times 2 = 4 \text{ V}$$

$$\frac{2-4}{1\text{k}\Omega} + I_o + \frac{0-4}{1\text{k}\Omega} = 0 \qquad \text{(KCL at node } V_o\text{)}$$

$$-2 + I_o - 4 = 0$$

$$\Rightarrow \quad I_o = 6 \text{ mA}$$

End of Solution

Q.12 The two sides of a fair coin are labelled as 0 and 1. The coin is tossed two times independently. Let M and N denote the labels corresponding to the outcomes of those tosses. For a random variable X, defined as $X = \min(M, N)$, the expected value $E(X)$ (rounded off to two decimal places) is ________.

Ans. (0.25)

$$s = \{(\text{H, H}), (\text{H, T}), (\text{T, H}), (\text{T, T})\}$$

$$M = \begin{bmatrix} 1 & 1 & 0 & 0 \\ \text{H} & \text{H} & \text{T} & \text{T} \end{bmatrix} \text{ of first toss}$$

$$N = \begin{bmatrix} \text{H} & \text{T} & \text{H} & \text{T} \\ 1 & 0 & 1 & 0 \end{bmatrix} \text{ of second toss}$$

Now, $X = \text{Min}\{M, N\}$

$\therefore$ $X = \text{Min}\{H, H\} = \text{Min}\{(1, 1)\} = 1$

$X = \text{Min}\{H, T\} = \text{Min}\{1, 0\} = 0$

$X = \text{Min}\{T, H\} = \text{Min}\{0, 1\} = 0$

$X = \text{Min}\{T, T\} = \text{Min}\{0, 0\} = 0$

$\therefore$ $P(X = 1) = \frac{1}{4}, \quad P(X = 0) = \frac{3}{4}$

We know that, $E(X) = \sum_i X_i P(x_i) = 1 \times \frac{1}{4} + 0 \times \frac{3}{4} = \frac{1}{4} = 0.25$

End of Solution

Q.13 A single crystal intrinsic semiconductor is at a temperature of 300 K with effective density of states for holes twice that of electrons. The thermal voltage is 26 mV. The intrinsic Fermi level is shifted from mid-bandgap energy level by

(a) 13.45 meV (b) 18.02 meV
(c) 26.90 meV (d) 9.01 meV

Ans. (d)

$$\frac{E_C + E_V}{2} - E_{F_i} = \frac{kT}{2}\ln\left(\frac{N_C}{N_V}\right) \qquad \left(\because N_C = \frac{N_V}{2}\right)$$

$$= \frac{0.026}{2}\ln 0.5 = -9.01\,\text{meV}$$

End of Solution

Q.14 The output $y[n]$ of a discrete-time system for an input $x[n]$ is

$$y[n] = \max_{-\infty \le k \le n} |x[k]|$$

The unit impulse response of the system is

(a) 0 for all n. (b) 1 for all n.
(c) unit step signal $u[n]$. (d) unit impulse signal $\delta[n]$.

Ans. (c)

End of Solution

Q.15 A binary random variable X takes the value +2 or –2. The probability $P(X = +2) = \alpha$. The value of α (rounded off to one decimal place), for which the entropy of X is maximum, is ________.

Ans. (0.5)

Given that $P(X = 2) = \alpha$

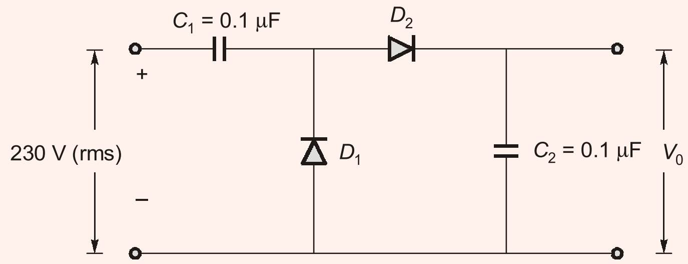
Entropy will be maximum; provided probabilities are equal.

i.e. $P(X = 2) = P(X = -2) = \alpha = \frac{1}{2}$

$$\alpha = \frac{1}{2} = 0.5$$

End of Solution

Q.16 In the circuit shown below, all the components are ideal and the input voltage is sinusoidal. The magnitude of the steady-state output V_0 (rounded off to two decimal places) is ________ V.



Ans. (650.40)

Voltage doubles, $V_o = 2\ V_m = 2 \times 230\sqrt{2} \cong 650.4$ V

End of Solution

Q.17 Consider the recombination process via bulk traps in a forward biased pn homojunction diode. The maximum recombination rate is U_{max}. If the electron and the hole capture cross-section are equal, which one of the following is False?

(a) With all other parameters unchanged, U_{max} decreases if the intrinsic carrier density is reduced.
(b) With all other parameters unchanged, U_{max} increases if the thermal velocity of the carriers increases.
(c) U_{max} occurs at the edges of the depletion region in the device.
(d) U_{max} depends exponentially on the applied bias.

Ans. (c)

End of Solution

Q.18 The general solution of $\frac{d^2y}{dx^2} - 6\frac{dy}{dx} + 9y = 0$ is

(a) $y = C_1e^{3x} + C_2e^{-3x}$
(b) $y = (C_1 + C_2x)e^{3x}$
(c) $y = C_1e^{3x}$
(d) $y = (C_1 + C_2x)e^{-3x}$

Ans. (b)

Taking $\frac{d}{dx} = D$

Given, $D^2 - 6D + 9 = 0$

$(D-3)^2 = 0$

$D = 3, 3$

So, solution of the given differential equation

$y = (c_1 + c_2\,x)\,e^{3x}$

End of Solution

Q.19 In an 8085 microprocessor, the number of address lines required to access a 16 K byte memory bank is __________.

Ans. (14)

$$2^n = N$$

$n \rightarrow$ Number of address lines

$N \rightarrow$ Number of Memory locations

$\therefore \quad 2^n = 16 \text{ kB}$

$= 2^4 (2^{10}) \qquad [\because 1 \text{ kB} = 2^{10}]$

$= 2^{14}$

$n = 14$

End of Solution

Q.20 The impedances $Z = jX$, for all X in the range $(-\infty, \infty)$, map to the Smith chart as

(a) a circle of radius 0.5 with centre at (0.5, 0).

(b) a point at the centre of the chart.

(c) a line passing through the centre of the chart.

(d) a circle of radius 1 with centre at (0, 0),

Ans. (d)

For given impedance Normalized impedance is

$$\frac{Z}{Z_0} = \frac{jX}{Z_0}$$

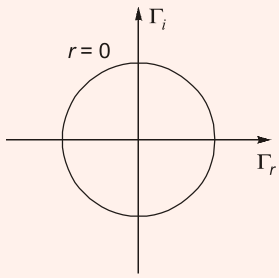
$$Z = jX$$

$\Rightarrow \quad Z = 0 + jX$

Normalized resistance $= 0 \Rightarrow r = 0$

$X = -\infty$ to ∞

$r = 0$ and X from $-\infty$ to ∞ is a unit circle (radius 1) and centre (0, 0) on a complex reflection coefficient plane:



End of Solution

Q.21 A digital communication system transmits a block of N bits. The probability of error in decoding a bit is α. The error event of each bit is independent of the error events of the other bits. The received block is declared erroneous if at least one of the its bits is decoded wrongly. The probability that the received block is erroneous is

(a) $N(1 - \alpha)$

(b) $1 - (1 - \alpha)^N$

(c) $1 - \alpha^N$

(d) α^N

Ans. (b)

Probability of error in decoding single bit = α

Then probability of no error will be $1 - \alpha$.

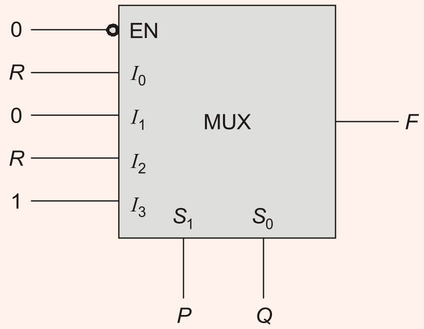
Total N-bits transmitted, so that probability of no error in received block

$$= (1 - \alpha)(1 - \alpha) \ldots N \text{ times}$$
$$= (1 - \alpha)^N$$

The probability of received block is erroneous is $= 1 - (1 - \alpha)^N$

End of Solution

Q.22 The figure below shows a multiplexer where S_1 and S_0 are the select lines. I_0 to I_3 are the input data lines, EN is the enable line, and $F(P, Q, R)$ is the output. F is



(a) $\bar{Q} + PR$.
(b) $P + Q\bar{R}$.
(c) $PQ + \bar{Q}R$.
(d) $P\bar{Q}R + \bar{P}Q$.

Ans. (c)

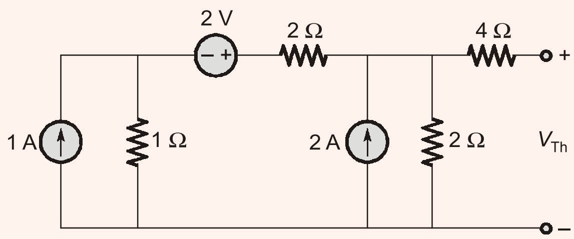
P \ QR	00	01	11	10
0	0	1	0	0
1	0	1	1	1

Output, $F = \bar{P}\bar{Q}R + P\bar{Q}R + PQ$

$F = \bar{Q}R + PQ$

End of Solution

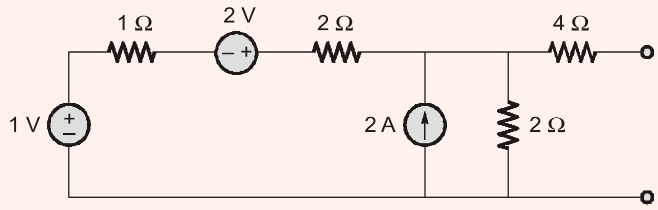
Q.23 In the circuit shown below, the Thevenin voltage V_{Th} is

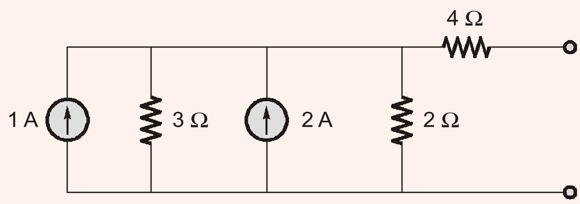


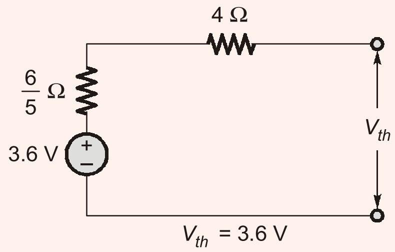
(a) 2.8 V
(b) 3.6 V
(c) 2.4 V
(d) 4.5 V

Ans. (b)

By applying source transformation





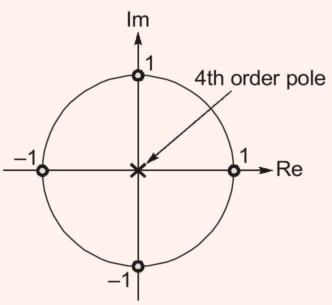


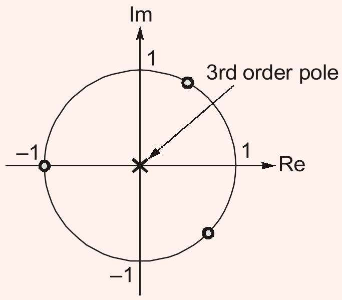
$V_{th} = 3.6$ V

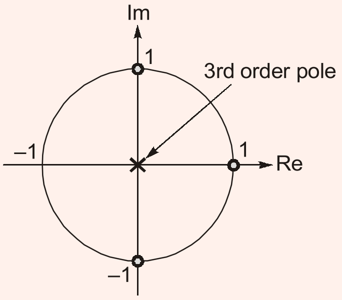
End of Solution

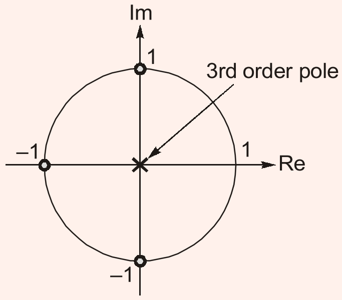
Q.24 Which one of the following pole-zero corresponds to the transfer function of an LTI system characterized by the input-output difference equation given below?

$$y[n] = \sum_{k=0}^{3} (-1)^k x[n-k]$$

(a)


(b)


(c)


(d)


Ans. **(c)**

$$y(n) = \sum_{K=0}^{3} (-1)^K x(n-K)$$

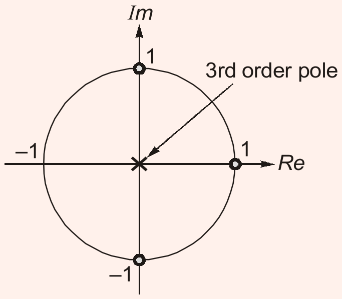
$$= x(n) - x(n-1) + x(n-2) - x(n-3)$$

$\Rightarrow$ $$Y(z) = X(z) - z^{-1} X(z) + z^{-2} X(z) - z^{-3} X(z)$$

$\Rightarrow$ $$H(z) = \frac{Y(z)}{X(z)} = 1 - z^{-1} + z^{-2} - z^{-3}$$

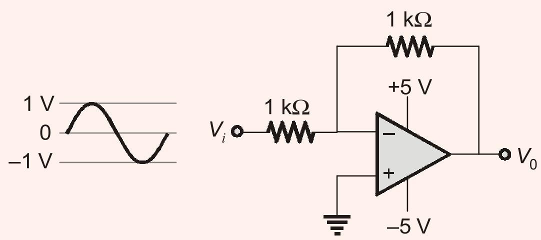
$$= \frac{z^3 - z^2 + z - 1}{z^3} = \frac{(z-1)(z^2+1)}{z^3}$$

Pole zero plot:



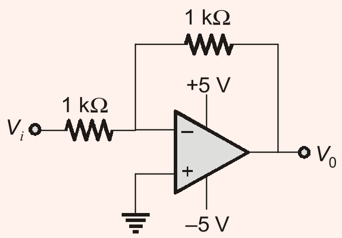
End of Solution

Q.25 The components in the circuit shown below are ideal. If the op-amp is in positive feedback and the input voltage V_i is a sine wave of amplitude 1 V, the output voltage V_o is



(a) a square wave of 5 V amplitude
(b) an inverted sine wave of 1 V amplitude
(c) a non-inverted sine wave of 2 V amplitude
(d) a constant of either +5 or –5 V

Ans. **(d)**



Given circuit is a Schmitt trigger of non-inverting type.

$$V_o = \pm 5 \text{ V}$$

$$V^+ = \frac{V_o \times 1 + V_i \times 1}{1+1} = \frac{V_o + V}{2}$$

Let, $V_o = -5$ V, $\quad V^+ = \dfrac{-5 + V_i}{2}$

V_o can change from –5 V to +5 V if $V^+ > 0$ i.e. $\dfrac{-5+V_i}{2} > 0 \Rightarrow V_i > 5$ V.

Similarly V_o can change from +5 V to –5 V if $V_i < -5$ V

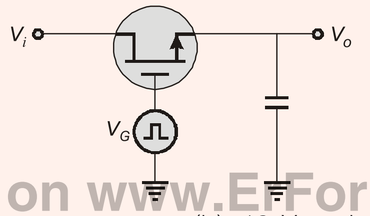
But given input has peak value 1 V. Hence output cannot change from +5 V to –5 V or –5 V to +5 V.

$\therefore$ Output remain constant at +5 V or –5 V.

Correct answer is option (d)

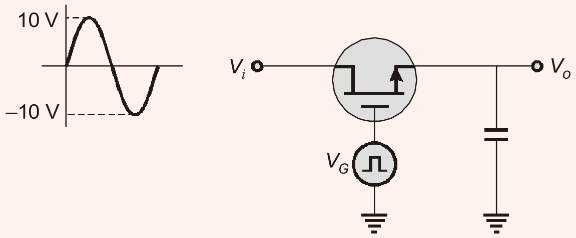
End of Solution

Q.26 An enhancement MOSFET of threshold voltage 3 V is being used in the sample and hold circuit given below. Assume that the substrate of the MOS device is connected to –10 V. If the input voltage V_i lies between ±10 V. the minimum and the maximum values of V_G required for proper sampling and holding respectively, are



(a) 10 V and –13 V
(b) 13 V and –7 V
(c) 10 V and –10 V
(d) 3 V and –3 V

Ans. (b)



for holding MOSFET should be OFF.

$$V_{1\,min} \rightarrow -10 \text{ V}$$
$$V_G - V_{1\,min} < 3$$
$$V_G < 3 - 10 \text{ V} \Rightarrow -7 \text{ V}$$

For sampling,
$$V_G - V_{i\,max} > 3$$
$$V_G > 3 + V_{i\,max}$$
$$V_G > 13$$

End of Solution

Q.27 P, Q, and R are the decimal integers corresponding to the 4-bit binary number 1100 considered in signed magnitude, 1's complement, and 2's complement representations, respectively. The 6-bit 2's complement representation of $(P + Q + R)$ is

(a) 111101 (b) 110101
(c) 110010 (d) 111001

Ans. **(b)**

Given, binary number 1100

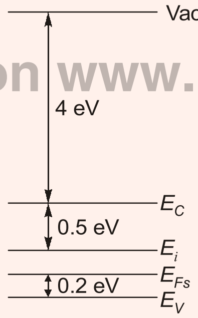
1's complement of 1100 = –3
Sign magnitude of 1100 = –4
2's complement of 1100 = –4

$\therefore \quad P + Q + R = -4 - 3 - 4 = -11$

The 6 digit 2's complement of (–11) = 110101

End of Solution

Q.28 The band diagram of a *p-type* semiconductor with a band-gap of 1 eV is shown. Using this semiconductor, a MOS capacitor having V_{Th} of –0.16 V, C'_{ox} of 100 nF/cm^2 and a metal work function of 3.87 eV is fabricated. There is no charge within the oxide. If the voltage across the capacitor is V_{Th}, the magnitude of depletion charge per unit area (in C/cm^2) is



(a) 0.52×10^{-8} (b) 0.93×10^{-8}
(c) 1.41×10^{-8} (d) 1.70×10^{-8}

Ans. **(d)**

MOS capacitance

$$\phi_m = 3.87, \quad \phi_s = 4.8, \quad \phi_{ms} = -0.93$$

$$V_T = \phi_{ms} - \frac{Q'_{ox}}{C_{ox}} - \frac{Q'_d}{C_{ox}} + 2\phi_{Fp}$$

$$\phi_{Fp} = E_i - E_F = 0.5 - 0.2 = 0.3$$

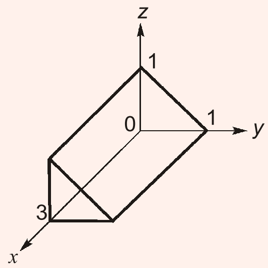
$$-0.16 = -0.93 - 0 - \frac{Q'_d}{C_{ox}} + 2 \times 0.3$$

$$\frac{Q'_d}{C_{ox}} = 0.6 + 0.16 - 0.93 = -0.17$$

$$Q_b = -0.17 \times C_{ox} = -0.17 \times 100 \times 10^{-9} = -1.7 \times 10^{-8} \text{ C/cm}^2$$

End of Solution

Q.29 For the solid S shown below, the value of $\iiint\limits_S x\,dx\,dy\,dz$ (rounded off to two decimal places) is ______.



Ans. (2.25)

x : 0 to 3
y : 0 to 1
z : 0 to $1 - y$

$$= \int_{y=0}^{1}\int_{z=0}^{1-y}\int_{x=0}^{3} x\,dx\,dy\,dz = \int_{y=0}^{1}\int_{0}^{1-y}\left(\frac{x^2}{2}\right)_0^3 dz\,dy$$

$$= \int_0^1 \frac{9}{2}(z)_0^{1-y}\,dy = \frac{9}{2}\int_0^1 (1-y)\,dy = \frac{9}{2}\left(y - \frac{y^2}{2}\right)_0^1$$

$$= \frac{9}{2}\left(1-\frac{1}{2}\right) = \frac{9}{4}$$

End of Solution

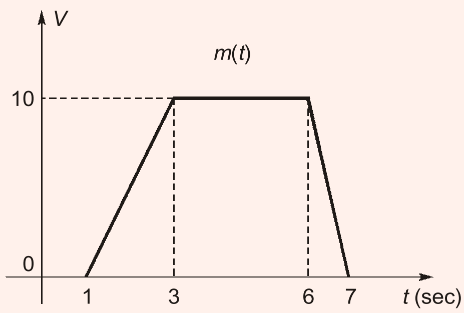
Q.30 $S_{PM}(t)$ and $S_{FM}(t)$ as defined below, are the phase modulated and the frequency modulated waveforms, respectively, corresponding to the message signal $m(t)$ shown in the figure.

$$S_{PM}(t) = \cos(1000\pi t + K_p\, m(t))$$

and

$$S_{FM}(t) = \cos\left(1000\pi t + K_f \int_{-\infty}^{t} m(\tau)\,d\tau\right)$$

where K_p is the phase deviation constant in radians/volt and K_f is the frequency deviation constant in radians/second/volt. If the highest instantaneous frequencies of $S_{PM}(t)$ and $S_{FM}(t)$ are same, then the value of the ratio $\frac{K_p}{K_f}$ is ______ seconds.

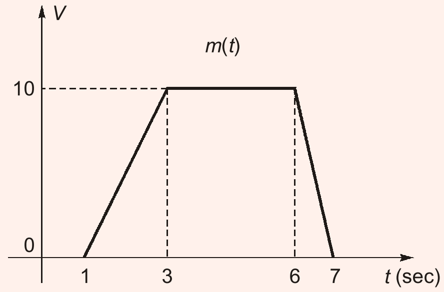


Ans. **(2)**

$$S(t)_{pm} = A_c \cos[2\pi f_c t + k_p m(t)]$$

$$S(t)_{Fm} = A_c \cos\left[2\pi f_c t + k_f \int_0^{\infty} m(t) dt\right]$$

Instantaneous frequency are equal



$$f_i = \frac{1}{2\pi}\frac{d}{dt}\theta(t)$$

$$f_{iPM} = f_c + \frac{K_p}{2\pi}\frac{d}{dt}m(t)$$

$$f_{iFM} = f_c + \frac{K_f}{2\pi}m(t)$$

Given that, $(f_{iPM})_{max} = (f_{iFM})_{max}$

$$f_c + \frac{k_p}{2\pi}\left[\frac{d}{dt}m(t)\right]_{max} = f_c + \frac{k_f}{2\pi}[m(t)]_{max}$$

$$\frac{k_p}{2\pi}\frac{d}{dt}m(t)\bigg|_{max} = \frac{k_f}{2\pi}m(t)\bigg|_{max}$$

$$\frac{d}{dt}m(t)\bigg|_{max} = 5, \quad m(t)\big|_{max} = 10$$

$$5k_p = 10k_f$$

$$\frac{k_p}{k_f} = 2$$

End of Solution

Q.31 Which one of the following options contains two solutions of the differential equation $\frac{dy}{dx} = (y-1)x$?

(a) $\ln|y-1| = 0.5x^2 + C$ and $y = -1$
(b) $\ln|y-1| = 2x^2 + C$ and $y = 1$
(c) $\ln|y-1| = 2x^2 + C$ and $y = -1$
(d) $\ln|y-1| = 0.5x^2 + C$ and $y = 1$

Ans. **(d)**

Given differential equation: $\frac{dy}{dx} = (y-1)x$

By variable separable method:

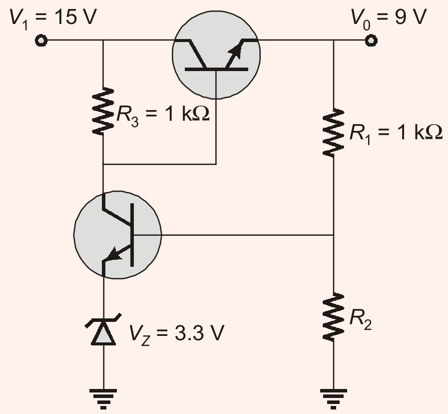
$$\int \frac{dy}{y-1} = \int x\,dx$$

$$\ln|y-1| = \frac{x^2}{2} + c \quad (\text{where } y \neq 1)$$

and the second solution is for $y = 1$.

End of Solution

Q.32 In the voltage regulator shown below, V_t is the unregulated at 15 V. Assume V_{BE} = 0.7 V and the base current is negligible for both the BJTs. If the regulated output V_o is 9 V, the value of R_2 is ________ Ω.



Ans. (800)

$$9 \times \frac{R_2}{R_2 + 1\,\text{k}\Omega} = 4$$

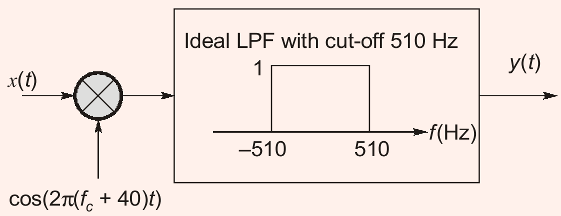
$$9R_2 = 4R_2 + 4\ \text{k}\Omega$$

$$5R_2 = 4K$$

$$R_2 = \frac{4000}{5} = 800\,\Omega$$

End of Solution

Q.33 For the modulated signal $x(t) = m(t)\cos(2\pi f_c t)$, the message signal $m(t) = 4\cos(1000\pi t)$ and the carrier frequency f_c is 1 MHz. The signal $x(t)$ is passed through a demodulator, as shown in the figure below. The output $y(t)$ of the demodulator is



(a) $\cos(1000\pi t)$
(b) $\cos(540\pi t)$
(c) $\cos(920\pi t)$
(d) $\cos(460\pi t)$

Ans. (c)

Output of multiplier

$= x(t)\cos 2\pi(f_c + 40)t = m(t)\cos 2\pi f_c t \cdot \cos 2\pi(f_c + 40)t$

$$= \frac{m(t)}{2}\left[\cos 2\pi(2f_c + 40)t + \cos 2\pi(40)t\right]$$

Given, $m(t) = 4\cos 1000\pi t$

So, output of multiplier $= 2\cos 2\pi(500)t\,[\cos 2\pi(2f_c + 40)t + \cos 2\pi(40)t]$

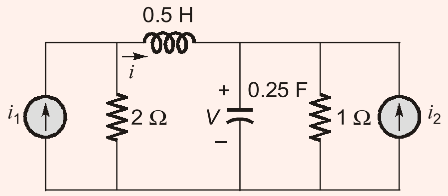
$$= \cos 2\pi(2f_c + 540)t + \cos 2\pi(2f_c - 460)t + \cos 2\pi(540)t + \cos 2\pi(460)t$$

Output of Low pass filter

$$= \cos\,[2\pi\,(460)]t$$
$$= \cos\,920\,\pi t$$

End of Solution

Q.34 For the given circuit, which one of the following is the correct state equation?

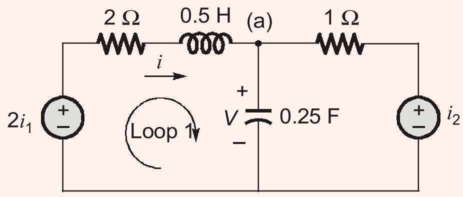


(a) $\frac{d}{dt}\begin{bmatrix} V \\ i \end{bmatrix} = \begin{bmatrix} -4 & 4 \\ -2 & -4 \end{bmatrix}\begin{bmatrix} V \\ i \end{bmatrix} + \begin{bmatrix} 0 & 4 \\ 4 & 0 \end{bmatrix}\begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$ (b) $\frac{d}{dt}\begin{bmatrix} V \\ i \end{bmatrix} = \begin{bmatrix} -4 & -4 \\ -2 & -4 \end{bmatrix}\begin{bmatrix} V \\ i \end{bmatrix} + \begin{bmatrix} 4 & 0 \\ 0 & 4 \end{bmatrix}\begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$

(c) $\frac{d}{dt}\begin{bmatrix} V \\ i \end{bmatrix} = \begin{bmatrix} -4 & -4 \\ -2 & 4 \end{bmatrix}\begin{bmatrix} V \\ i \end{bmatrix} + \begin{bmatrix} 4 & 4 \\ 4 & 0 \end{bmatrix}\begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$ (d) $\frac{d}{dt}\begin{bmatrix} V \\ i \end{bmatrix} = \begin{bmatrix} 4 & -4 \\ -2 & -4 \end{bmatrix}\begin{bmatrix} V \\ i \end{bmatrix} + \begin{bmatrix} 0 & 4 \\ 4 & 4 \end{bmatrix}\begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$

Ans. **(a)**

From source transformation,



KVL in loop 1,

$$2i_1 = 2i + 0.5\frac{di}{dt} + V$$

$$\frac{di}{dt} = -2V - 4i + 4i_1 \quad \text{(i)}$$

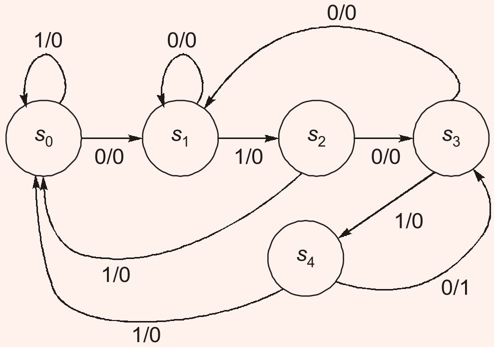
KCL at node (a), $\quad i = 0.25\frac{dV}{dt} + \frac{V - i_2}{1}$

$$\frac{dv}{dt} = -4V + 4i + 4i_2 \quad \text{(ii)}$$

$$\frac{d}{dt}\begin{bmatrix} V \\ i \end{bmatrix} = \begin{bmatrix} -4 & 4 \\ -2 & -4 \end{bmatrix}\begin{bmatrix} V \\ i \end{bmatrix} + \begin{bmatrix} 0 & 4 \\ 4 & 0 \end{bmatrix}\begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

End of Solution

Q.35 The state diagram of a sequence detector is shown below. State S_0 is the initial state of the sequence detector. If the output is 1, then



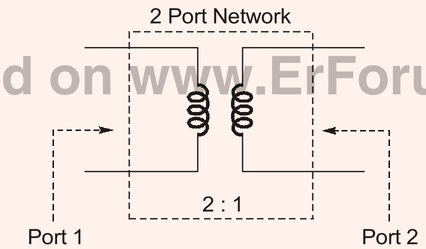
(a) the sequence 01010 is detected
(b) the sequence 01011 is detected
(c) the sequence 01001 is detected
(d) the sequence 01110 is detected

Ans. (a)

The sequence detected is 01010.

End of Solution

Q.36 For a 2-port network consisting of an ideal lossless transformer, the parameter S_{21} (rounded off to two decimal places) for a reference impedance of 10 Ω, is _____.



Ans. (0.8)

For ideal transformer of n : 1, the scattering matrix is

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} \dfrac{n^2-1}{n^2+1} & \dfrac{2n}{n^2+1} \\ \dfrac{2n}{n^2+1} & \left(\dfrac{1-n^2}{1+n^2}\right) \end{bmatrix}$$

$$S_{21} = \frac{2n}{n^2+1} = \frac{2(2)}{2^2+1} = \frac{4}{5} = 0.8$$

End of Solution

Q.37 The characteristic equation of a system is

$$s^3 + 3s^2 + (K+2)s + 3K = 0$$

In the root locus plot for the given system, as K varies from 0 to ∞, the break-away or break-in point(s) lie within

(a) (–2, –1)
(b) (–1, 0)
(c) (–3, –2)
(d) (–∞, –3)

Ans. (b)

$$Q(s) = 1 + G(s)\,H(s) = 0$$

$$s^3 + 3s^2 + 2s + ks + 3k = 0$$

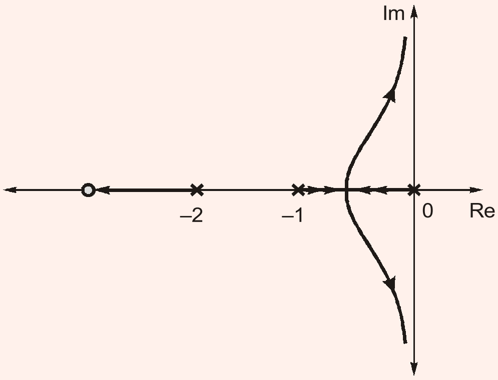
$$-k = \frac{s^3 + 3s^2 + 2s}{s+3}$$

$$-\frac{dk}{ds} = \frac{(s+3)(3s^2+6s+2) - (s^3+3s^2+2s)}{(s+3)^2} = 0$$

$$3s^3 + 6s^2 + 2s + 9s^2 + 18s + 6 - s^3 - 3s^2 - 2s = 0$$

$$2s^3 + 12s^2 + 18s + 6 = 0$$

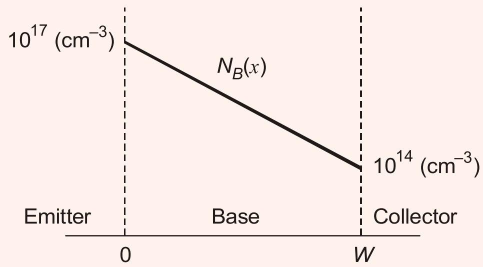
$$s = -0.46,\ -3.87,\ -1.65$$



$\therefore$ Break-away point lies between (0, –1), i.e. (–1, 0).

End of Solution

Q.38 The base of an npn BJT T1 has a linear doping profile $N_B(x)$ as shown below. The base of another npn BJT T2 has a uniform doping N_B of 10^{17} cm^{-3}. All other parameters are identical for both the devices. Assuming that the hole density profile is the same as that of doping, the common-emitter current gain of T2 is



(a) approximately 0.3 times that of T1
(b) approximately 0.7 times that of T1
(c) approximately 2.5 times that of T1
(d) approximately 2.0 times that of T1

Ans. (*)

$$\frac{\beta_1}{\beta_2} = \frac{\int_0^W N_{A_2}(x)dx}{\int_0^W N_{A_1}(x)dx} = \frac{W \times 10^{17}}{\frac{1}{2} \times W \times (10^{17} - 10^{14})} = \frac{2 \times 10^{17}}{10^{17} + 10^{14}} \simeq 2$$

$$\beta_2 = 0.5\beta_1$$

Hence no option is matching.

End of Solution

Q.39 Consider the following system of linear equation.

$$x_1 + 2x_2 = b_1\ ;\quad 2x_1 + 4x_2 = b_2\ ;\ 3x_1 + 7x_2 = b_3\ ;\ 3x_1 + 9x_2 = b_4$$

Which one of the following conditions ensures that a solution exists for the above system?

(a) $b_3 = 2b_1$ and $3b_1 - 6b_3 + b_4 = 0$ (b) $b_2 = 2b_1$ and $3b_1 - 6b_3 + b_4 = 0$

(c) $b_2 = 2b_1$ and $6b_1 - 3b_3 + b_4 = 0$ (d) $b_3 = 2b_1$ and $3b_1 - 3b_3 + b_4 = 0$

Ans. (c)

Given:
$$x_1 + 2x_2 = b_1 \quad ...(i)$$
$$2x_1 + 4x_2 = b_2 \quad ...(ii)$$
$$3x_1 + 7x_2 = b_3 \quad ...(iii)$$
$$3x_1 + 9x_2 = b_4 \quad ...(iv)$$

From equations (ii) and (i)

We can write, $b_2 = 2[x_1 + 2x_2] = 2b_1$

From option (b):

$$3b_1 - 6b_3 + b_4 = 3[x_1 + 2x_2] - 6[3x_1 + 7x_2] + 3x_1 + 9x_2 \neq 0$$

From option (c):

$$b_2 = 2b_1$$

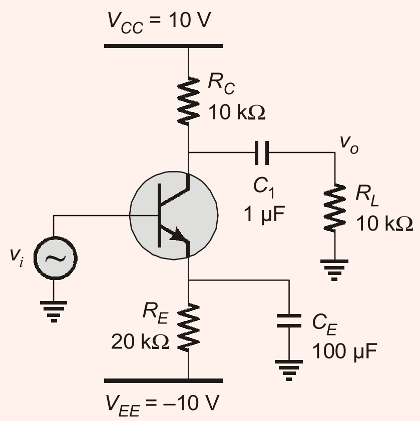
and $b_1 - 3b_3 + b_4 = 6[x_1 + 2x_2] - 3[3x_1 + 7x_2] + [3x_1 + 9x_2] = 0$

$$6b_1 - 3b_3 + b_4 = 0$$

Hence, answer is option (c).

End of Solution

Q.40 For the BJT in the amplifier shown below. V_{BE} = 0.7 V, kT/q = 26 mV. Assume the BJT output resistance (r_o) is very high and the base current is negligible. The capacitors are also assumed to be short circuited at signal frequencies. The input v_i is direct coupled. The low frequency gain v_o/v_i of the amplifier is



(a) –178.85 (b) –256.42

(c) –128.21 (d) –89.42

Ans. (d)

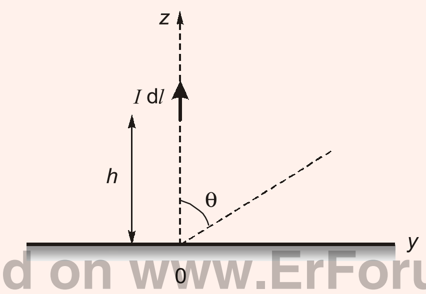
$$I_{EQ} = \frac{10-0.7}{20} = 0.465 \text{ mA}$$

$$g_m = \frac{I_{EQ}}{V_T} = \frac{0.465}{26} \text{ A/V}$$

$$\frac{V_{out}}{V_{in}} = -g_m (R_e \| R_L) = \frac{0.465}{26} \times 5000 = -89.423$$

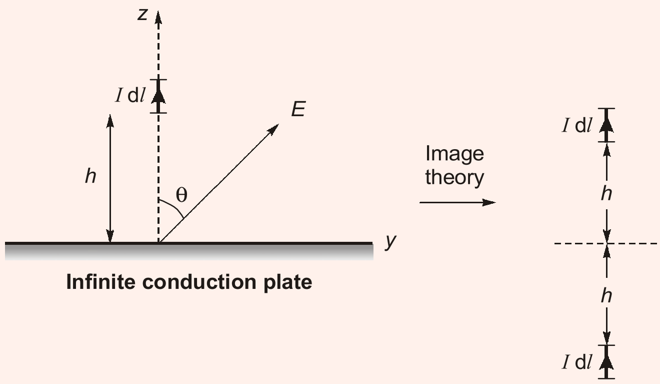
End of Solution

Q.41 For an infinitesimally small dipole in free space, the electric field E_θ in the far field is proportional to $(e^{-jkr}/r)\sin\theta$, where $k = 2\pi/\lambda$. A vertical infinitesimally small electric dipole ($\delta l << \lambda$) is placed at a distance $h (h > 0)$ above an infinite ideal conducting plane, as shown in the figure. The minimum value of h, for which one of the maxima in the far field radiation pattern occurs at $\theta = 60°$. is



(a) 0.75λ
(b) λ
(c) 0.25λ
(d) 0.5λ

Ans. (b)



$$|\text{Total E}| = |(E_{\text{single element}})||(\text{A.F.})|$$

$$|(\text{A.F.})| = \frac{\sin\left(N\frac{\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)} = \frac{\sin\left(2\frac{\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)} = \frac{2\sin\left(\frac{\psi}{2}\right)\cos\left(\frac{\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)} = 2\cos\left(\frac{\psi}{2}\right)$$

$$|A.F_N| = \frac{A.F}{A.F_{max}} = \frac{2\cos\left(\frac{\psi}{2}\right)}{2} = \left|\cos\left(\frac{\psi}{2}\right)\right|$$

where, $\psi = \beta d\cos\theta = \frac{2\pi}{\lambda}(2h)\cos\theta$

$$\left|A.F_N|_{\theta=60°}\right| = \left|\cos\left(\frac{2\pi}{\lambda}h\cos 60°\right)\right| = \left|\cos\left(\frac{\pi h}{\lambda}\right)\right|$$

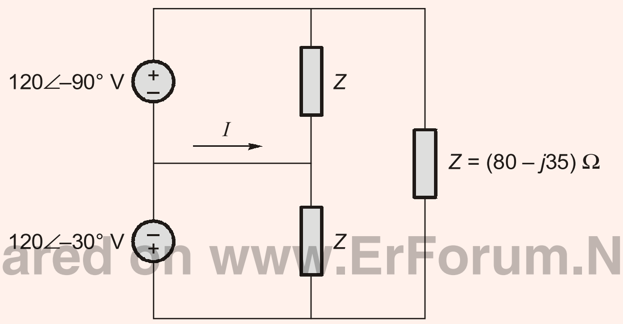
$\cos\theta$ is maximum, whenever $\theta = n\pi$; n = 0, 1, 2 ...

$$\frac{\pi h}{\lambda} = n\pi \quad \Rightarrow h = n\lambda$$

$\Rightarrow$ For $n = 1$, $\quad h_{min} = \lambda$

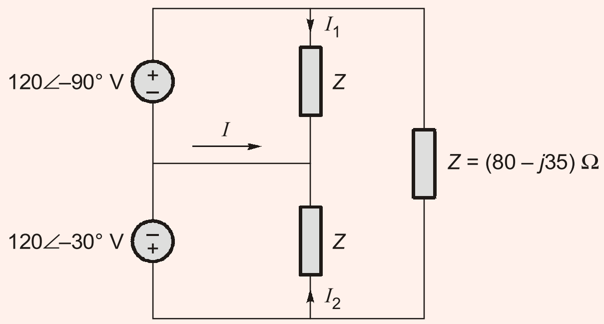
End of Solution

Q.42 The current I in the given network is



(a) 2.38 ∠–23.63° A
(b) 0 A
(c) 2.38 ∠–96.37° A
(d) 2.38 ∠143.63° A

Ans. (d)



$$I = -[I_1 + I_2]$$

$$I = -\left[\frac{120\angle-90°}{80-j35} + \frac{120\angle-30°}{80-j35}\right]$$

$$I = 2.38\angle 143.7°$$

End of Solution

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Q.43 A system with transfer function $G(s) = \dfrac{1}{(s+1)(s+a)}$, $a > 0$ is subjected an input $5\cos 3t$. The steady state output of the system is $\dfrac{1}{\sqrt{10}}\cos(3t - 1.892)$. The value of a is ____.

Ans. (4)

Given that, $G(j\omega) = \dfrac{1}{(1+j\omega)(\alpha+j\omega)}$; $|G(j\omega)| = \dfrac{1}{\sqrt{(\omega^2+1)(\omega^2+\alpha^2)}}$

According to question,

$$|G(j\omega)|_{\omega=3} = \frac{1}{5\sqrt{10}}$$

$$\Rightarrow \quad \frac{1}{\sqrt{(\omega^2+1)(\omega^2+\alpha^2)}} = \frac{1}{5\sqrt{10}}$$

$$\Rightarrow \quad \frac{1}{\sqrt{10(a^2+9)}} = \frac{1}{5\sqrt{10}}$$

$$\alpha^2 + 9 = 25$$

$$\alpha^2 = 16$$

$$\alpha = 4$$

End of Solution

Q.44 A finite duration discrete-time signal $x[n]$ is obtained by sampling the continuous-time signal $x(t) = \cos(200\pi t)$ at sampling instants $t = n/400$, $n = 0, 1, \ldots, 7$. The 8-point discrete Fourier transform (DFT) of $x[n]$ is defined as

$$X[k] = \sum_{n=0}^{7} x[n]\, e^{-j\frac{\pi k n}{4}},\quad k = 0, 1, \ldots, 7$$

Which one of the following statements is true?

(a) Only $X[2]$ and $X[6]$ are non-zero
(b) Only $X[3]$ and $X[5]$ are non-zero
(c) All $X[k]$ are non-zero
(d) Only $X[4]$ is non-zero

Ans. (a)

$$x(t) = \cos 200\pi t$$

$$t = \frac{n}{400}$$

$$x(n) = \cos\left(200\pi\frac{n}{400}\right) = \cos\left(\frac{\pi}{2}n\right);\quad n = 0, 1, \ldots, 7$$

$$= \left\{\cos 0, \cos\frac{\pi}{2}, \cos\pi, \cos\frac{3\pi}{2}, \cos 2\pi, \cos\frac{5\pi}{2}, \cos 3\pi, \cos\frac{7\pi}{2}\right\}$$

$$= \{1, 0, -1, 0, 1, 0, -1, 0\} \xrightleftharpoons{\text{DFT}} X(k)$$

Suppose, $y(n) = \{1, -1, 1, -1\} \xrightleftharpoons{\text{DFT}} Y(k)$

$$[Y(k)] = [W_N]\big|_{N=4}[y(n)] = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix}\begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \end{bmatrix} = [0,\ 0,\ 4,\ 0]$$

Now, as we know,

If for $\{a, b, c, d\} \xrightleftharpoons{\text{DFT}} \{A, B, C, D\}$

Then for $\{a, 0, b, 0, c, 0, d, 0\} \xrightleftharpoons{\text{DFT}} \{A, B, C, D, A, B, C, D\}$

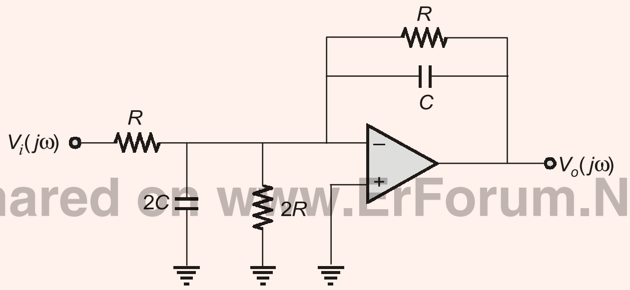
Similarly, for $y(n) = \{1, -1, 1, -1\} \xrightleftharpoons{\text{DFT}} Y(k) = \{0, 0, 4, 0\}$

Here, for $x(n) = \{1, 0, -1, 0, 1, 0, -1, 0\}$

$$X(k) = \{\underset{\uparrow}{0}, 0, 4, 0, 0, 0, 4, 0\}$$

End of Solution

Q.45 The components in the circuit given below are ideal. If R = 2 kΩ and C = 1 μF, the –3 dB cut-off frequency of the circuit in Hz is



(a) 34.46
(b) 79.58
(c) 59.68
(d) 14.92

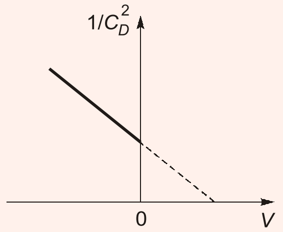
Ans. **(b)**

Op-amp active filter (LPF) inverting type 3 dB cut-off frequency,

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 2 \times 10^3 \times 10^{-6}} = \frac{500}{2\pi} = 79.58 \text{ Hz}$$

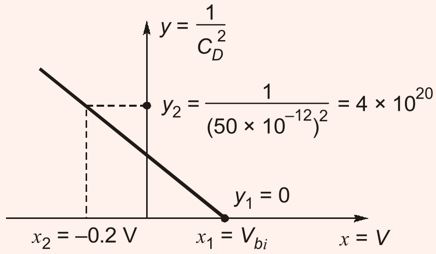
End of Solution

Q.46 A one-sided abrupt pn junction diode has a depletion capacitance C_D of 50 pF at a reverse bias of 0.2 V. The plot of $1/C_D^2$ versus the applied voltage V for this diode is a straight line as shown in the figure below. The slope of the plot is ____ $\times 10^{20}$ $F^{-2}\ V^{-1}$.



(a) –1.2
(b) –5.7
(c) –3.8
(d) –0.4

Ans. **(*)**



Depletion or transition capacitance is,

$$C_D = \frac{A\epsilon}{W}$$

For one-sided PN junction (Ex : P^+ N junction)

$$W = \sqrt{\frac{2\epsilon V_B}{eN_D}} = \sqrt{\frac{2\epsilon(V_{bi} - V)}{eN_D}}$$

where V is anode to cathode applied potential.

$$\Rightarrow \qquad C_D = \frac{A\epsilon}{\sqrt{\frac{2\epsilon(V_{bi} - V)}{eN_D}}}$$

$$\Rightarrow \qquad \frac{1}{C_D^2} = \frac{2}{A^2 \epsilon e N_D}(V_{bi} - V)$$

$\frac{1}{C_D^2}$ becomes zero at $V = V_{bi}$

From above graph, $y = \frac{1}{C_D^2} = 0$ at $x_1 = V_{bi}$

And $\qquad y_2 = \frac{1}{C_D^2} = 4 \times 10^{20}$ at $x_2 = -0.2$ V

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{4 \times 10^{20} - 0}{-0.2 - V_{bi}}$$

$\because$ V_{bi} is not provided, slope cannot be found.

End of Solution

Q.47 A pn junction solar cell of area 1.0 cm^2, illuminated uniformly with 100 mW cm^{-2}, has the following parameters: Efficiency = 15%, open circuit voltage = 0.7 V, fill factor = 0.8, and thickness = 200 μm, The charge of an electron is 1.6×10^{-19} C. The average optical generation rate (in cm^{-3} S^{-1}) is

(a) 1.04×10^{19}
(b) 83.60×10^{19}
(c) 0.84×10^{19}
(d) 5.57×10^{19}

Ans. **(c)**

$$\eta = \frac{(FF)V_{OC}I_{SC}}{P_{in}}$$

$$0.15 = \frac{0.8 \times 0.7 \times I_{SC}}{100 \text{ mW}}$$

$$\Rightarrow \qquad I_{SC} = \frac{15}{0.56}\text{mA}$$

$$G_L = \frac{I_{SC}}{q \times \text{Area} \times \text{thickness}} = \frac{15 \times 10^{-3}}{0.56 \times 1.6 \times 10^{-19} \times 1 \times 200 \times 10^{-4}}$$

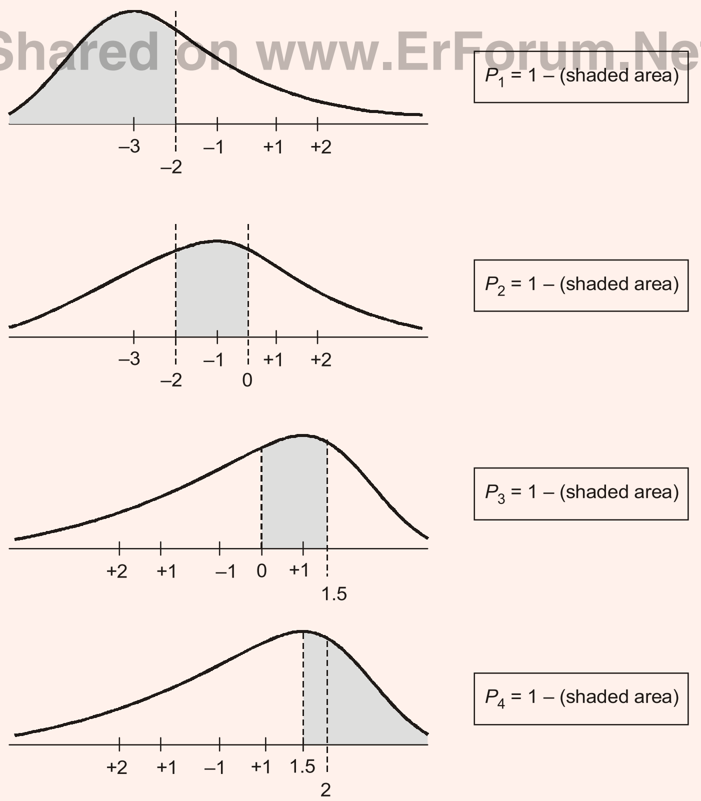
$$= \frac{15}{0.56 \times 32} \times 10^{19} = 0.837 \times 10^{19} \ / \ \text{cm}^3/\text{second}$$

End of Solution

Q.48 In a digital communication system, a symbol S randomly chosen from the set (s_1, s_2, s_3, s_4) is transmitted. It is given that $s_1 = -3$, $s_2 = -1$, $s_3 = +1$ and $s_4 = +2$. The received symbol is $Y = S + W$. W is a zero-mean unit-variance Gaussian random variable and is independent of S. P_i is the conditional probability of symbol error for the maximum likelihood (ML) decoding when the transmitted symbol $S = s_i$. The index i for which the conditional symbol error probability P_i is the highest is ______.

Ans. **(3)**

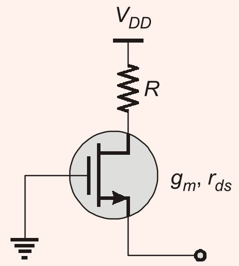
Since the noise variable is Gaussian with zero mean and ML decoding is used, the decision boundary between two adjacent signal points will be their arithmetic mean. In the following graphs, the shaded area indicates the conditional probability of decoding a symbol correctly when it is transmitted.



By comparing the above graphs, we can conclude that P_3 is larger among the four.

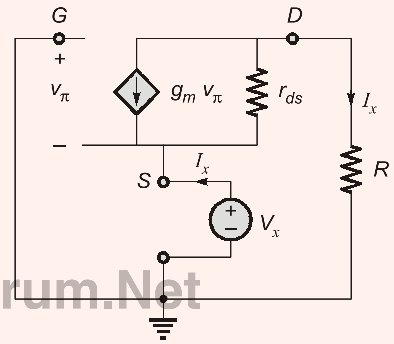
End of Solution

Q.49 Using the incremental low frequency small-signal model of the MOS device, the Norton equivalent resistance of the following circuit is



(a) $r_{ds} + R + g_m r_{ds} R$
(b) $r_{ds} + \frac{1}{g_m} + R$
(c) $r_{ds} + R$
(d) $\frac{r_{ds} + R}{1 + g_m r_{ds}}$

Ans. **(d)**



$$v_\pi = -V_x$$

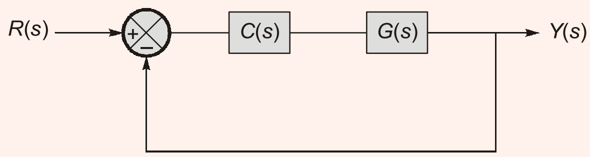
$$V_x = (I_x - g_m V_x) r_{ds} + I_x R$$

$$V_x(1 + g_m r_{ds}) = (r_{ds} + R) I_x$$

$$R_N = \frac{V_x}{I_x} = \frac{R + r_{ds}}{1 + g_m r_{ds}}$$

End of Solution

Q.50 Consider the following closed loop control system



where $G(s) = \frac{1}{s(s+1)}$ and $C(s) = K\frac{s+1}{s+3}$. If the steady state error for a unit ramp input is 0.1, then the value of K is _______.

Ans. **(30)**

Open loop transfer function for the system = $C(s) \times G(s) = \frac{K(s+1)}{(s+3)} \times \frac{1}{s(s+1)}$

Since the system is type-1 so far a given unit ramp input steady state

$$e_{ss} = \frac{1}{K_V}$$

where, $K_V = \lim_{s \to 0} s \times \frac{K}{s(s+3)} = \frac{K}{3}$

So, $$e_{ss} = \frac{1}{K/3} = \frac{3}{K}$$

Given that, $e_{ss} = 0.1$

So, $$0.1 = \frac{3}{K} \Rightarrow K = 30$$

End of Solution

Q.51 X is a random variable with uniform probability density function in the interval [–2,10]. For $Y = 2X - 6$, the conditional probability $P(Y \le 7 \mid X \ge 5)$ (rounded off to three decimal places) is _____.

Ans. (0.3)

x follows uniform distribution over [–2, 10]

$$\therefore \quad f(x) = \frac{1}{b-a} = \frac{1}{10-(-2)} = \frac{1}{12}$$

Given: $y = 2x - 6$

$$\Rightarrow \quad x = \frac{y+6}{2}$$

For $y = 7$

$$x = \frac{7+6}{2} = \frac{13}{2} = 6.5$$

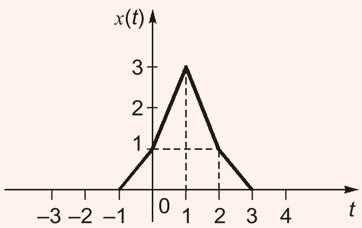
$$P\left[\frac{y<7}{x>5}\right] = P\left[\frac{x<6.5}{x>5}\right] = \frac{P[x>5 \text{ and } x<6.5]}{P[x>5]}$$

$$= \frac{P[5<x<6.5]}{P[x>5]} = \frac{\int_5^{6.5} f(x)\,dx}{\int_5^{10} f(x)\,dx} = \frac{\int_5^{6.5} \frac{1}{12}\,dx}{\int_5^{10} \frac{1}{12}\,dx}$$

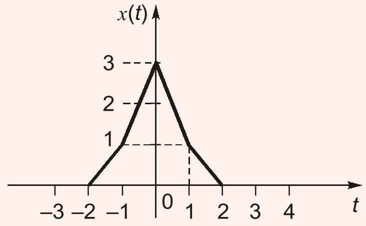
$$= \frac{(x)_5^{6.5}}{(x)_5^{10}} = \frac{1.5}{5} = 0.3$$

End of Solution

Q.52 $X(\omega)$ is the Fourier transform of $x(t)$ shown below. The value of $\int_{-\infty}^{\infty} |X(\omega)|^2 d\omega$ (rounded off to two decimal places) is ______.



Ans. (58.61)



$$\int_{-\infty}^{\infty} |X(\omega)|^2 d\omega = 2\pi \int_{-\infty}^{\infty} |x(t)|^2 dt = 2\pi \int_{-\infty}^{\infty} |y(t)|^2 dt$$

$$= 2 \times 2\pi \int_{-2}^{0} |y(t)|^2 dt$$

$$= 2 \times 2\pi \left[\int_{-2}^{-1} (t+2)^2 dt + \int_{-1}^{0} (2t+3)^2 dt \right]$$

$$= 4\pi \left[\left\{ \frac{(t+2)^3}{3} \right\}_{-2}^{-1} + \left\{ \frac{(2t+3)^3}{3 \times 2} \right\}_{-1}^{0} \right]$$

$$= 4\pi \left[\frac{1-0}{3} + \frac{3^3-1}{6} \right] = 4\pi \left[\frac{1}{3} + \frac{26}{6} \right]$$

$$= 4\pi \times \left[\frac{1}{3} + \frac{26}{6} \right] = 4\pi \times \left[\frac{1}{3} + \frac{13}{3} \right]$$

$$= 4\pi \times \frac{14}{3} = \frac{56\pi}{3}$$

End of Solution

Q.53 The transfer function of a stable discrete-time LTI system is $H(z) = \dfrac{K(z-\alpha)}{z+0.5}$, where K and α are real numbers. The value of α (rounded off to one decimal place) with $|\alpha| > 1$, for which the magnitude response of the system is constant over all frequencies, is _____.

Ans. (–2)

System is all-pass filter.

For digital all-pass filter, condition is

$$\text{Zero} = \frac{1}{\text{Pole}^*} \qquad \text{...(i)}$$

By given transfer function,

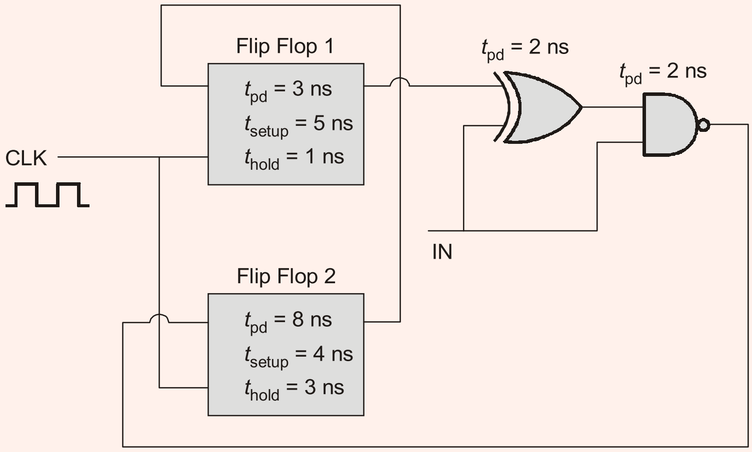
$$\text{Zero} = \alpha$$

$$\text{Pole} = -0.5$$

Using condition (i), $\alpha = \dfrac{1}{-0.5} = -2$

End of Solution

Q.54 For the components in the sequential circuit shown below, t_{pd} is the propagation delay, t_{setup} is the setup time, and t_{hold} is the hold time. The maximum clock frequency (rounded off to the nearest integer), at which the given circuit can operate reliably, is ____ MHz.



Ans. (76.92)

Total propagation delay = $(t_{pd} + t_{\text{set-up}})_{max}$ = 8ns + 5 ns = 13 ns

$\therefore$ Frequency of operations = $\frac{1000}{13}$ MHz = 76.92 MHz

End of Solution

Q.55 The magnetic field of a uniform plane wave in vacuum is given by

$$\vec{H}(x, y, z, t) = (\hat{a}_x + 2\hat{a}_y + b\hat{a}_z)\cos(\omega t + 3x - y - z).$$

The value of b is ____.

Ans. (1)

For uniform plane wave

$$\hat{a}_H \cdot \hat{a}_p = 0$$

$\hat{a}_H$ is unit vector in magnetic field direction $\hat{a}_p$ is unit vector in power flow direction

$$\hat{a}_H = \frac{1\hat{a}_x + 2\hat{a}_y + b\hat{a}_z}{\sqrt{1^2 + 2^2 + b^2}}$$

$$\hat{a}_p = \frac{-3\hat{a}_x + \hat{a}_y + \hat{a}_z}{\sqrt{3^2 + 1^2 + 1^2}}$$

$$\hat{a}_H \cdot \hat{a}_p = 0$$

$$(\hat{a}_x + 2\hat{a}_y + b\hat{a}_z)\cdot(-3\hat{a}_x + \hat{a}_y + \hat{a}_z) = 0$$

$$-3 + 2 + b = 0$$

$$b = 1$$

End of Solution

■■■■