GATE 2019

Electronics Engineering

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Date of Exam : 9/2/2019

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SECTION A : GENERAL APTITUDE

Q.1 When he did not come home, she _______ him lying dead on the roadside somewhere.

(a) notice (b) looked

(c) concluded (d) pictured

Ans. (d)

When he did not come home, she pictured him lying dead on the roadside somewhere. "pictured" is the most appropriate option in this situation as she is imagining or creating an image of somebody/something in her mind.

End of Solution

Q.2 The strategies that the company ____ to sell its products ______ house-to-house marketing.

(a) used, includes (b) uses, includes

(c) use, includes (d) uses, including

Ans. (b)

"Company" is singular, hence, "uses" would be the correct option in blank 1. "products" is plural, hence, "include" would be the correct option in blank 2.

End of Solution

Q.3 It would take one machine 4 hours to complete a production order and another machine 2 hours to complete the same order. If both machines work simultaneously at their respective constant rates, the time taken to complete the same order is ____ hours.

(a) 7/3 (b) 3/4

(c) 2/3 (d) 4/3

Ans. (d)

Machine X = 4 hours

Machine Y = 2 hours

In 1 hour X can work $= \frac{1}{4}$

In 1 hour Y can work $= \frac{1}{2}$

In 1 hour $(X + Y)$ can work $= \frac{1}{4} + \frac{1}{2} = \frac{3}{4}$

$(X + Y)$ together $= \frac{4}{3}$ hours

End of Solution

Q.4 The boat arrived ______ dawn.

(a) on (b) at

(c) in (d) under

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CE	B	21-Feb-2019	Kalu Sarai Centre	3:00 PM to 9:00 PM
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Ans. (b)

Option 1 i.e. "on" is used when one is talking about a day of the week e. g. on Thursday, or a particular part of a date e.g. on Sunday evening, or a particular date e.g. on 9th March.

Option 3 i.e. "in" is used when one is talking about a month e.g. in June, or a season e.g. in winter, or a specific year e.g. in 2019.

Option 4 i.e. "under" is absurd in this situation.

Option 2 i.e. "at" is used when one is referring to a particular time e.g. at dawn, or a calendar festival season e.g. at Christmas.

End of Solution

Q.5 Five different books (P, Q, R, S, T) are to be arranged on a shelf. The books R and S are to be arranged first and second, respectively from the right side of the shelf. The number of different orders in which P, Q and T may be arranged is _____.

(a) 12
(b) 2
(c) 120
(d) 6

Ans. (d)

Here R and S are fixed in 1st and 2nd places from right.

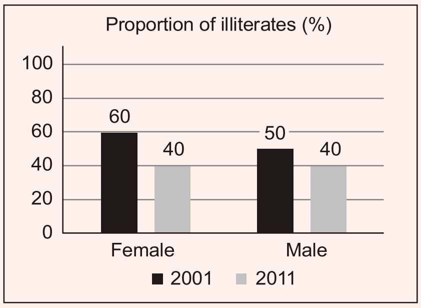
P Q T [S] [R]

Therefore arrangement of

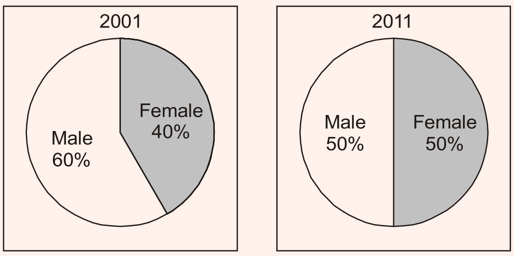
$$P, Q, T = {}^3P_3 = 3! = 6$$

End of Solution

Q.6 The bar graph in Panel (a) shows the proportion of male and female illiterates in 2001 and 2011. The proportions of males and females in 2001 and 2011 are given in Panel (b) and (c), respectively. The total population did not change during this period. The percentage increase in the total number of literates from 2001 to 2011 is ____.



Panel (a)



Panel (b) Panel (c)

(a) 35.43
(b) 34.43
(c) 30.43
(d) 33.43

Ans. **(c)**

Let total population

in 2001 = 100

in 2011 = 100

In 2001, males = 60, females = 40

illiterates,

50% of 60 = 30

50% of 60 = 24

54

literates = 100 − 54 = 46

In 2011, males = 50, females = 50

illiterates,

40% of 50 = 20

40% of 50 = 20

40

literates = 100 − 40 = 60

Percentage of increase literates from 2001 to 2011 = $\frac{60-46}{46} \times 100 = 30.43$.

End of Solution

Q.7 Two design consultants, P and Q, started working from 8 AM For a client. The client budgeted a total of USD 3000 for the consultants. P stopped working when the hour hand moved by 210 degrees on the clock. Q stopped working when the hour hand moved by 240 degrees. P took two lea breaks of 15 minutes each during her shift, but took no lunch break. Q took only one lunch break for 20 minutes, but no tea breaks. The market rate for consultants is USD 200 per hour and breaks are not paid. After paying the consultants, the client shall have USD ________ remaining in the budget.

(a) 433.33
(b) 000.00
(c) 300.00
(d) 166.67

Ans. **(d)**

P and *Q* started 8 am

1 hour = 30

$$P = \frac{210}{30} = 7 \text{ hours}$$

$$Q = \frac{240}{30} = 8 \text{ hours}$$

After break time, P = 7:30 min = 6 hours 30 min

After break time, Q = 8:20 min = 7 hours40 min

Total time = 6 hours 30 min + 7 hour 40 min

= 14 hours 10 min

$$= 14 \text{ hour} + \frac{10}{16} \text{ hour}$$

$$= 14 \text{ hour} + \frac{1}{6} \text{ hour} = \frac{85}{6} \text{ hours}$$

In every 1 hour USD 200

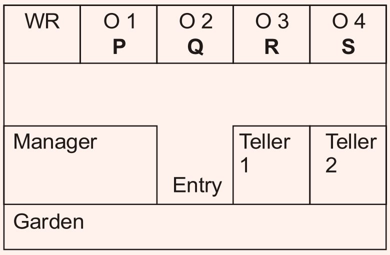
$$\therefore \qquad \frac{85}{6} \text{ hours} = \frac{85}{6} \times 200 = 2833.33$$

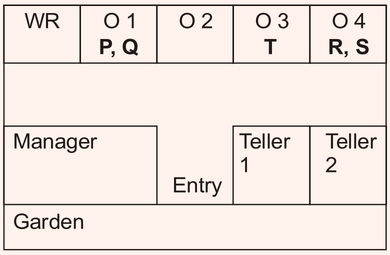
$$\text{Remaining} = 3000 - 2833.33 = 166.666666 = 166.67$$

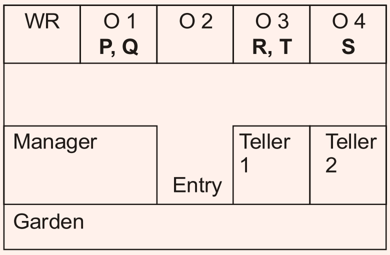
End of Solution

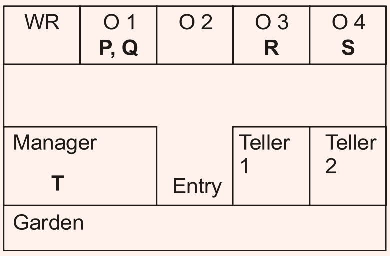
Q.8 Five people P, Q, R, S and T work in a bank. P and Q don't like each other but have to share an office till T gets a promotion and moves to the big office next to the garden. R, who is currently sharing an office with T wants to move to the adjacent office with S, the handsome new intern. Given the floor plan, what is the current location of Q, R and T?

(O = Office, WR = Washroom)

(a)


(b)


(c)


(d)


Ans. (c)

Only option (c) shows P and Q in same office, R and T in same office with S being in the adjacent office. Thus, option (c) is correct.

End of Solution

Q.9 Four people are standing in a line facing you. They are Rahul, Mathew, Seema and Lohit. One is an engineer, one is a doctor, one a teacher and another a dancer. You are told that:

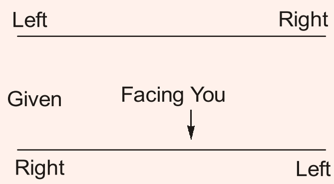
1. Mathew is not standing nest to Seema.
2. There are two people standing between Lohit and the engineer.
3. Rahul is not a doctor.
4. The teacher and the dancer are standing next to each other.
5. Seema is turning to her right to speak to the doctor standing next to her.

Who among them is an engineer?

(a) Lohit
(b) Rahul
(c) Seema
(d) Mathew

Ans. (d)

According to given conditions sequence is
Lohit, Seema, Rahul, Mathew,
↓ ↓
Doctor Engineer
∴ Engineer = Mathew



End of Solution

Q.10 "Indian history was written by British historians-extremely well documented and researched, but not always impartial. History had to serve its purpose: Everything was made subservient to the glory of the Union Jack. Latter-day Indian scholars presented a contrary picture."

From the text above, we can infer that:

Indian history written by British historians _______.

(a) was well documented and researched but was sometimes biased
(b) was well documented and not researched but was always biased
(c) was not well documented and researched and was sometimes biased
(d) was not well documented and researched and was always biased

Ans. (a)

The passage says" extremely well documented and researched, but not always impartial". This suggests that Indian history written by British historians was well documented and researched but was sometimes biased. hence option (a) is the correct answer.

End of Solution

SECTION B : TECHNICAL

Q.1 The families of curves represented by the solution of the equation

$$\frac{dy}{dx} = -\left(\frac{x}{y}\right)^n$$

for $n = -1$ and $n = +1$, respectively, are

(a) Hyperbolas and Parabolas
(b) Hyperbolas and Circles
(c) Parabolas and Circles
(d) Circles and Hyperbolas

Ans. (b)

$$\frac{dy}{dx} = -\left(\frac{x}{y}\right)^n$$

$n = -1$,

$$\frac{dy}{dx} = -\frac{y}{x}$$

$$\frac{dy}{y} = -\frac{dx}{x}$$

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

$$\ln y = -\ln x + \ln c$$

$$\ln(yx) = \ln c$$

$$xy = c$$ Represents rectangular hyperbola

$n = 1$,

$$\frac{dy}{dx} = -\frac{x}{y}$$

$$y dy = -x dx$$

$$\int y dy = -\int x dx$$

$$\frac{y^2}{2} = -\frac{x^2}{2} + c$$

$$x^2 + y^2 = 2c$$ Represents family of circles

End of Solution

Q.2 In the table shown, List-I and List-II, respectively, contain terms appearing on the left-hand side and the right-hand side of Maxwell's equations (in their standard form). Match the left-hand side with the corresponding right-hand side.

List-I		List-II	
1.	$\nabla \cdot \vec{D}$	P.	0
2.	$\nabla \times \vec{E}$	Q.	ρ
3.	$\nabla \cdot \vec{B}$	R.	$-\frac{\partial \vec{B}}{\partial t}$
4.	$\nabla \times \vec{H}$	S.	$\vec{J} + \frac{\partial \vec{D}}{\partial t}$

(a) 1-R, 2-Q, 3-S, 4-P
(b) 1-Q, 2-S, 3-P, 4-R
(c) 1-P, 2-R, 3-Q, 4-S
(d) 1-Q, 2-R, 3-P, 4-S

Ans. (d)

$$\nabla \cdot \vec{D} = \rho_v$$
$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$
$$\nabla \cdot \vec{B} = 0$$
$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

End of Solution

Q.3 Radiation resistance of a small dipole current element of length l at a frequency of 3 GHz is 3 ohms. If the length is changed by 1%, then the percentage change in the radiation resistance, rounded off to two decimal places, is_____________%.

Ans. (2.01)

Radiation resistance of a small dipole current element of length 'l' is

$$R_{rad} = 80\pi^2\left(\frac{l}{\lambda}\right)^2 \Rightarrow R \propto l^2$$
$$\frac{R_2}{R_1} = \left(\frac{l_2}{l_1}\right)^2$$

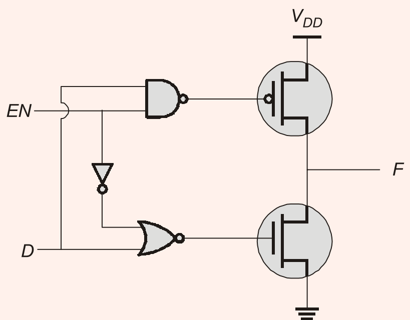
If length is changed by 1% then percentage change in the radiation resistance.

$$\frac{R_2}{R_1} = \left(\frac{1.01l}{l}\right)^2 = 1.0201$$

Percentage change in radiation resistance = $\frac{R_2 - R_1}{R_1} \times 100 = 0.0201 \times 100 = 2.01\%$

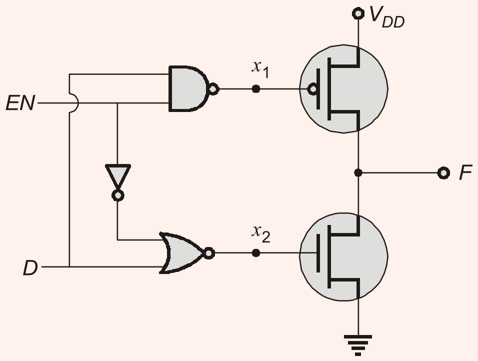
End of Solution

Q.4 In the circuit shown, what are the values of F for $EN = 0$ and $EN = 1$, respectively?



(a) 0 and 1
(b) Hi-Z and D
(c) Hi-Z and $\bar{D}$
(d) 0 and D

Ans. (b)



When $EN = 0$: $x_1 = \overline{(D \cdot 0)} = 1 \Rightarrow$ PMOS is in OFF state

$x_2 = \overline{(1 + D)} = 0 \Rightarrow$ NMOS is in OFF state

Both the transistors are in OFF state, which offers high impedance.

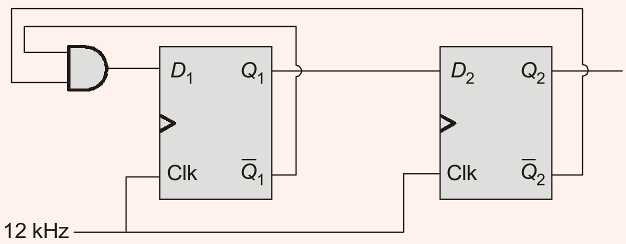
When $EN = 1$: $x_1 = \overline{(D \cdot 1)} = \bar{D}$

$x_2 = \overline{(0 + D)} = \bar{D}$

$F = D$

End of Solution

Q.5 In the circuit shown, the clock frequency, i.e., the frequency of the Clk signal, is 12 kHz. The frequency of the signal at Q_2 is ________ kHz.



Ans. (4)

$D_1 = \bar{Q}_2\bar{Q}_1 = \overline{Q_2 + Q_1}$

PS		D_2	D_1	NS	
Q_2	Q_1			Q_2^+	Q_1^+
0	0	0	1	0	1
0	1	1	0	1	0
1	0	0	0	0	0

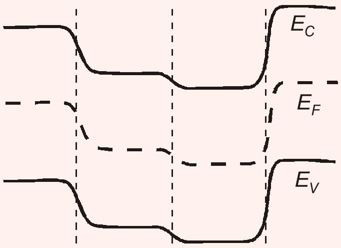
MOD = 3

$$f_{Q2} = \frac{f_{clk}}{3} = \frac{12}{3}\text{ kHz} = 4\text{ kHz}$$

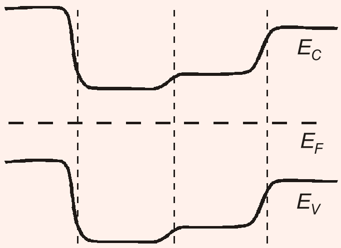
End of Solution

Q.6 Which one of the following options describes correctly the equilibrium band diagram at T = 300 K of a Silicon pnn^+p^{++} configuration shown in the figure?

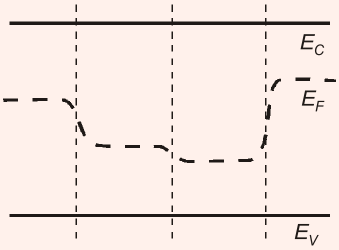
(a)



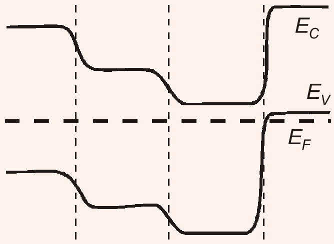
(b)



(c)



(d)



Ans. (d)

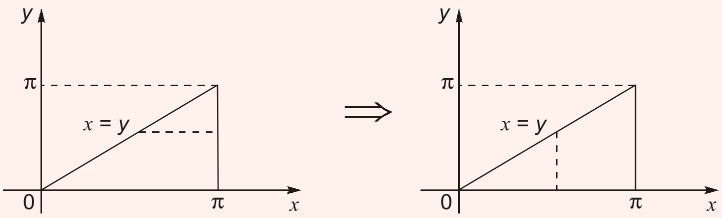
End of Solution

Q.7 The value of integral $\int_0^{\pi}\int_y^{\pi} \frac{\sin x}{x} dx\, dy$, is equal to ________.

Ans. (2)

$x = y\,; \quad x = \pi$

$y = 0\,; \quad y = \pi$



$$\therefore \quad = \int_0^{\pi}\int_y^{\pi} \frac{\sin x}{x} dx\, dy = \int_0^{\pi} \frac{\sin x}{x} (y)\Big|_0^x dx$$

$$= \int_0^{\pi} \frac{\sin x}{x} (x) dx = \int_0^{\pi} \sin x\, dx = (-\cos x)\Big|_0^{\pi}$$

$$= -\cos\pi + \cos 0 = 1 + 1 = 2$$

End of Solution

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Q.8 If X and Y are random variables such that $E[2X + Y] = 0$ and $E[X + 2Y] = 33$, then $E[X] + E[Y] =$ ________.

Ans. (11)

$$E[2X + Y] = 0 \text{ and } E[X + 2Y] = 33$$

then,
$$2E[X] + E[Y] = 0 \text{ and } E[X] + 2E[Y] = 33$$
$$3E[X] + 3E[Y] = 0 + 33 = 33$$
$$E[X] + E[Y] = 11$$

End of Solution

Q.9 A linear Hamming code is used to map 4-bit messages to 7-bit codewords. The encoder mapping is linear. If the message 0001 is mapped to the codeword 0000111, and the message 0011 is mapped to the codeword 1100110, then the message 0010 is mapped to

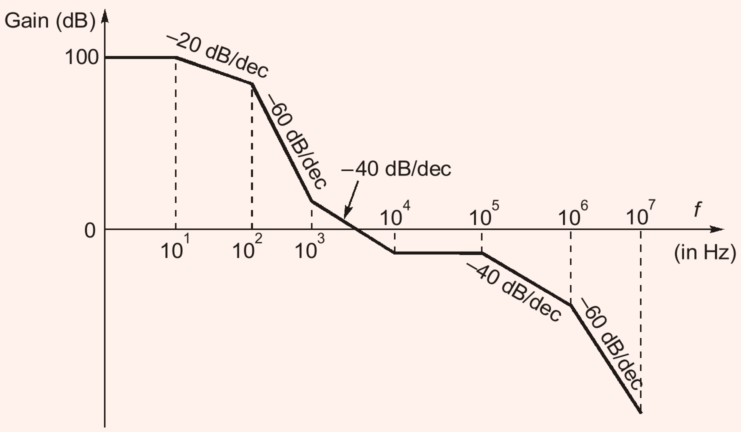
(a) 0010011
(b) 1100001
(c) 1111000
(d) 1111111

Ans. (b)

0 0 0 1 ⟶ 0 0 0 0 1 1 1
⊕ ⊕
0 0 1 1 ⟶ 1 1 0 0 1 1 0
0 0 1 0 ⟶ 1 1 0 0 0 0 1

End of Solution

Q.10 For an LTI system, the Bode plot for its gain is as illustrated in the figure shown. The number of system poles N_p and the number of system zeros N_z in the frequency range $1 \text{ Hz} \le f \le 10^7$ Hz is



(a) $N_p = 6, N_z = 3$
(b) $N_p = 7, N_z = 4$
(c) $N_p = 5, N_z = 2$
(d) $N_p = 4, N_z = 2$

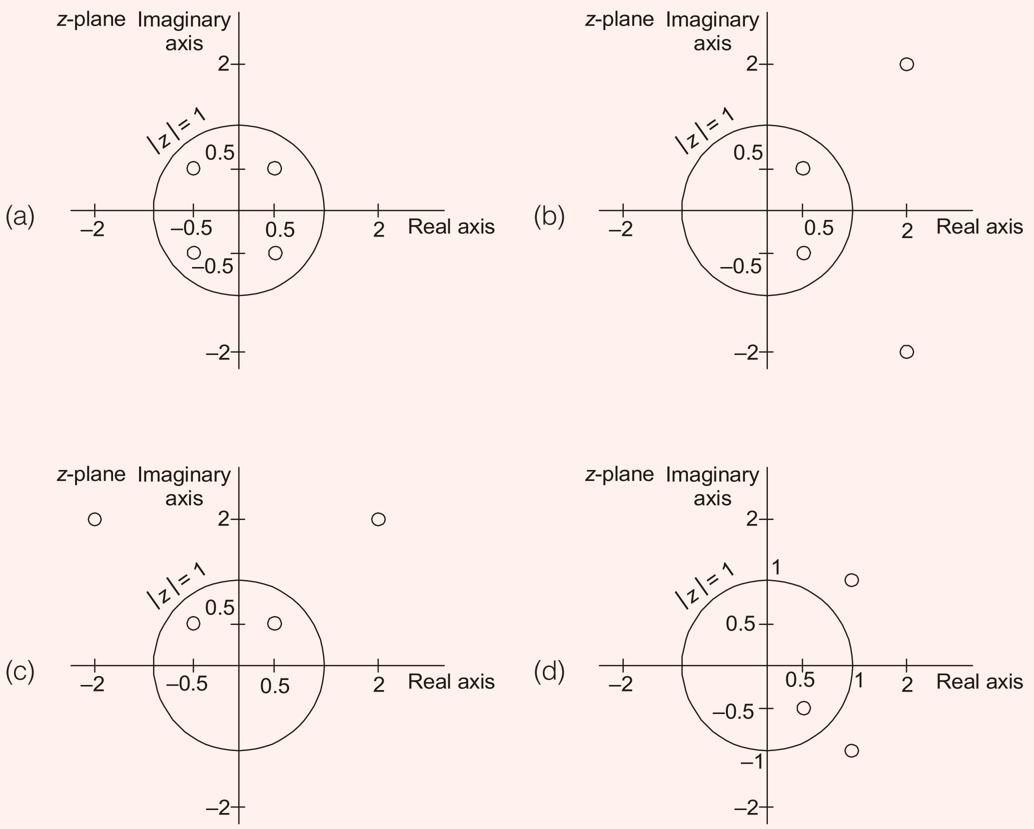
Ans. (a)

Corner frequency (in Hz)	No. of poles (or) zeros
10	1 pole
10^2	2 poles
10^3	1 zero
10^4	2 zeros
10^5	2 poles
10^6	1 pole

Number of poles (N_p) = 6
Number of zeros (N_z) = 3

End of Solution

Q.11 Let $H(z)$ be the z-transform of a real-valued discrete-time signal $h[n]$. If $P(z) = H(z)H\left(\frac{1}{z}\right)$ has a zero at $z = \frac{1}{2} + \frac{1}{2}j$, and $P(z)$ has a total of four zeros, which one of the following plots represents all the zeros correctly?



Ans. (d)

$$P(Z) = H(z)H\left(\frac{1}{z}\right)$$

(i) $h(n)$ is real. So, $p(n)$ will be also real

(ii) $P(z) = P(z^{-1})$

From (i): If z_1 is a zero of $P(z)$, then z_1^* will be also a zero of $P(z)$.

From (ii): If z_1 is a zero of $P(z)$, then $\frac{1}{z_1}$ will be also a zero of $P(z)$.

So, the 4 zeros are,

$$z_1 = \frac{1}{2}+\frac{1}{2}j$$

$$z_2 = z_1^* = \frac{1}{2}-\frac{1}{2}j$$

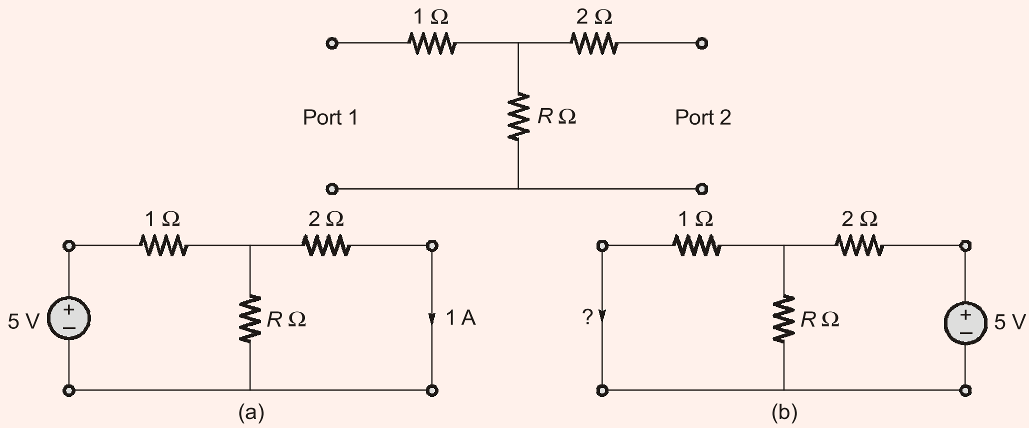
$$z_3 = \frac{1}{z_1} = \frac{1}{\frac{1}{2}+\frac{1}{2}j} = 1-j$$

$$z_4 = \left(\frac{1}{z_1}\right)^* = z_3^* = 1+j$$

So, option (d) is correct.

End of Solution

Q.12 Consider the two-port resistive network shown in the figure. When an excitation of 5 V is applied across Port 1, and Port 2 is shorted, the current through the short circuit at Port 2 is measured to be 1 A (see (a) in the figure).
Now, if an excitation of 5 V is applied across Port 2, and Port 1 is shorted (see (b) in the figure), what is the current through the short circuit at Port 1?



(a) 0.5 A
(b) 2.5 A
(c) 1 A
(d) 2 A

Ans. (c)

According to reciprocity theorem,

In a linear bilateral single source network the ratio of response to excitation remains the same even after their positions get interchanged.

$$\therefore \qquad \frac{I}{5} = \frac{1}{5} \Rightarrow I = 1 \text{ A}$$

End of Solution

Q.13 Consider the signal $f(t) = 1 + 2\cos(\pi t) + 3\sin\left(\frac{2\pi}{3}t\right) + 4\cos\left(\frac{\pi}{2}t + \frac{\pi}{4}\right)$, where t is in seconds. Its fundamental time period, in seconds, is _______.

Ans. (12)

$$f(t) = 1 + 2\cos(\pi t) + 3\sin\left(\frac{2\pi}{3}t\right) + 4\cos\left(\frac{\pi}{2}t + \frac{\pi}{4}\right)$$

$$\omega_1 = \pi$$

$$\omega_2 = \frac{2\pi}{3}$$

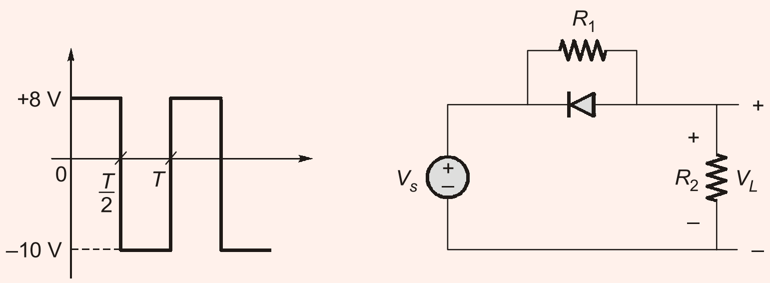
$$\omega_3 = \frac{\pi}{2}$$

$$\omega_0 = \text{GCD}\left(\pi, \frac{2\pi}{3}, \frac{\pi}{2}\right) = \frac{\pi}{6}$$

Fundamental period, $N = \frac{2\pi}{\omega_o} = \frac{2\pi}{(\pi/6)} = 12$

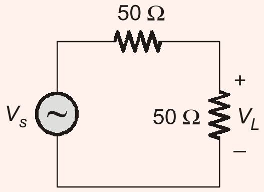
End of Solution

Q.14 In the circuit shown, V_s is a square wave of period T with maximum and minimum values of 8 V and –10 V, respectively. Assume that the diode is ideal and $R_1 = R_2 = 50\ \Omega$. The average value of V_L is ________ volts (rounded off to 1 decimal place).



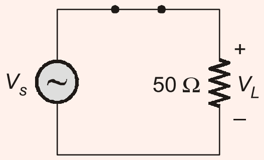
Ans. (–3)

When $V_s = 8$ V $\Rightarrow$ diode is in reverse bias



$$V_L = \frac{8 \times 50}{50 + 50} = 4 \text{ V}$$

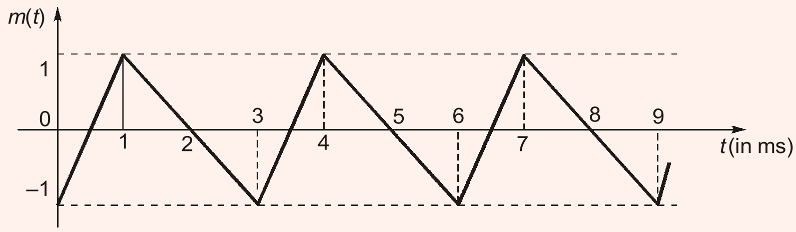
If $V_s = -10$ V, diode is in forward bias



$$\text{Average value of } V_L = \frac{\text{Area}}{\text{Time period}} = \frac{4 \times 0.5T + (-10) \times 0.5T}{T} = -3 \text{ V}$$

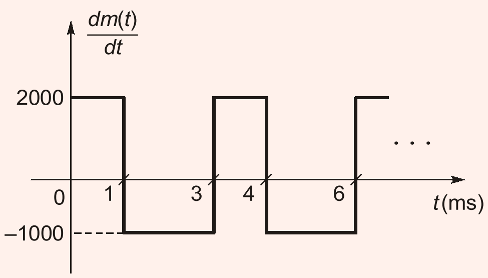
End of Solution

Q.15 The baseband signal $m(t)$ shown in the figure is phase-modulated to generate the PM signal $\phi(t) = \cos(2\pi f_c t + km(t))$. The time t on the x-axis in the figure is in milliseconds. If the carrier frequency is $f_c = 50$ kHz and $k = 10\pi$, then the ratio of the minimum instantaneous frequency (in kHz) to the maximum instantaneous frequency (in kHz) is _______ (rounded off to 2 decimal places).



Ans. (0.75)

$$f_i = \frac{1}{2\pi}\frac{d\theta(t)}{dt} = f_c + \frac{k}{2\pi}\frac{dm(t)}{dt} = f_c + 5\frac{dm(t)}{dt}$$



So, $f_{i\,(min)} = 50 \text{ kHz} - (5 \times 1000 \text{ Hz}) = 45 \text{ kHz}$

$f_{i\,(max)} = 50 \text{ kHz} + (5 \times 2000 \text{ Hz}) = 60 \text{ kHz}$

$$\frac{f_{i(min)}}{f_{i(max)}} = \frac{45}{60} = 0.75$$

End of Solution

Q.16 The number of distinct eigen values of the matrix

$$A = \begin{bmatrix} 2 & 2 & 3 & 3 \\ 0 & 1 & 1 & 1 \\ 0 & 0 & 3 & 3 \\ 0 & 0 & 0 & 2 \end{bmatrix}$$

is equal to ________.

Ans. (3)

$$A = \begin{bmatrix} 2 & 2 & 3 & 3 \\ 0 & 1 & 1 & 1 \\ 0 & 0 & 3 & 3 \\ 0 & 0 & 0 & 2 \end{bmatrix}$$

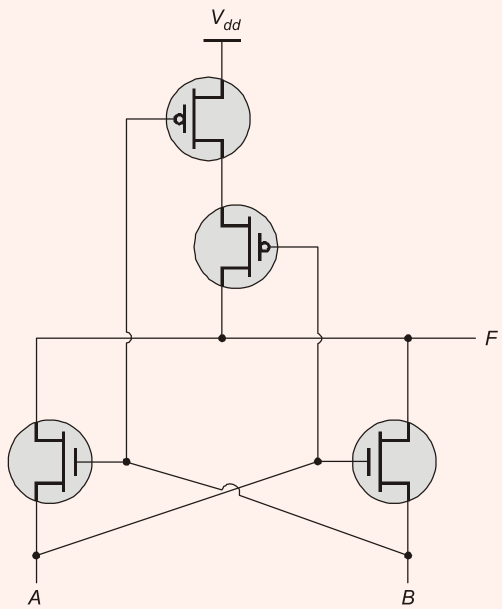
Eigen values are 2, 1, 3, 2

Distinct eigen values are 2, 1, 3

∴ Number of distinct eigen values = 3

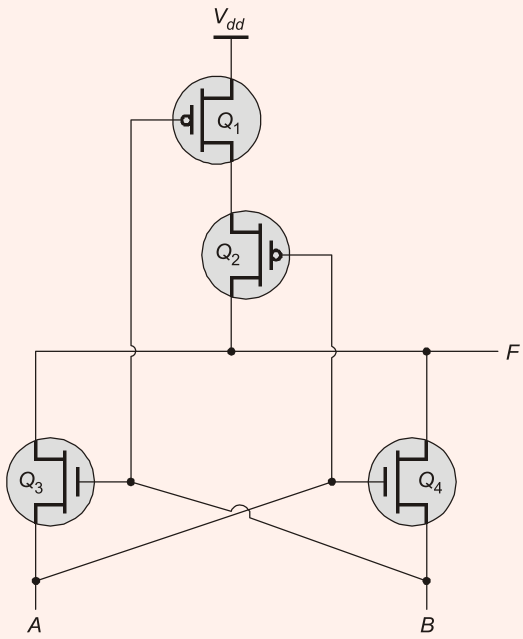
End of Solution

Q.17 In the circuit shown, A and B are the inputs and F is the output. What is the functionality of the circuit?



(a) XNOR
(b) SRAM Cell
(c) XOR
(d) Latch

Ans. (a)



A	B	Q_1	Q_2	Q_3	Q_4	F
0	0	ON	ON	OFF	OFF	1
0	1	OFF	ON	ON	OFF	0
1	0	ON	OFF	OFF	ON	0
1	1	OFF	OFF	ON	ON	1

So, the given logic circuit acts as an XNOR gate.

End of Solution

Q.18 Let $Y(s)$ be the unit-step response of a causal system, having a transfer function

$$G(s) = \frac{3-s}{(s+1)(s+3)}$$

that is, $Y(s) = \frac{G(s)}{s}$. The forced response of the system is

(a) $u(t)$
(b) $2u(t)$
(c) $u(t) - 2e^{-t}u(t) + e^{-3t}u(t)$
(d) $2u(t) - 2e^{-t}u(t) + e^{-3t}u(t)$

Ans. (c)

Given, $$G(s) = \frac{3-s}{(s+1)(s+3)}$$

$\therefore$ $$Y(s) = \frac{G(s)}{s} = \frac{3-s}{s(s+1)(s+3)}$$

Using partial fractions, we get,

$$Y(s) = \frac{A}{s} + \frac{B}{(s+1)} + \frac{C}{(s+3)}$$

$$A(s^2 + 4s + 3) + B(s^2 + 3s) + C(s^2 + s) = 3 - s$$

$$A + B + C = 0$$

$$4A + 3B + C = -1$$

and $$3A = 3$$

Therefore, we get,

$$A = 1,\ B = -2 \text{ and } C = 1$$

So, $$Y(s) = \frac{1}{s} - \frac{2}{(s+1)} + \frac{1}{(s+3)}$$

and $$y(t) = u(t) - 2e^{-t}u(t) + e^{-3t}u(t)$$

End of Solution

Q.19 Which one of the following functions is analytic over the entire complex plane?

(a) $\cos(z)$ (b) $e^{1/z}$

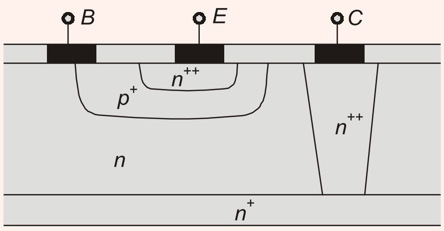
(c) $\ln(z)$ (d) $\frac{1}{1-z}$

Ans. **(a)**

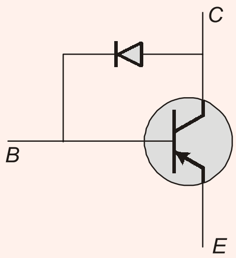
$f(z) = \cos z$ is analytic every where.

End of Solution

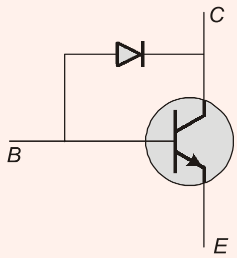
Q.20 The correct circuit representation of the structure shown in the figure is



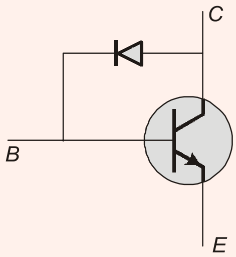
(a)



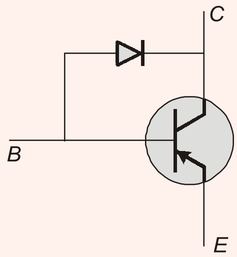
(b)



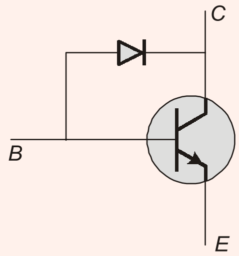
(c)



(d)



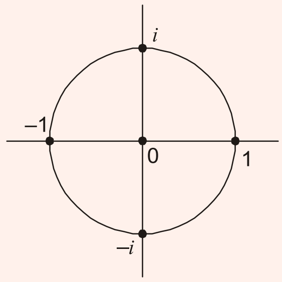
Ans. (b)



End of Solution

Q.21 The value of the contour integral $\frac{1}{2\pi j}\oint\left(z+\frac{1}{z}\right)^2 dz$ evaluated over the unit circle $|z| = 1$ is ___________.

Ans. (0)



$\frac{1}{2\pi j}\oint\left(z+\frac{1}{z}\right)^2 dz$ where C is $|z| = 1$

$$I = \frac{1}{2\pi j}\int_c \frac{(z^2+1)^2}{z^2}dz$$

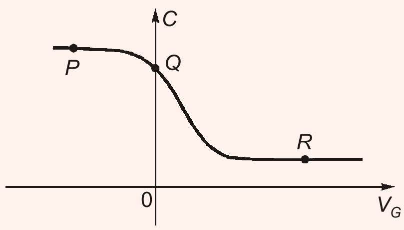
$z = 0$ lies inside the circle,

$$I = \frac{1}{2\pi j}\left[\frac{2\pi j}{1!}\frac{d}{dz}(z^2+1)^2\right]_{z=0} = \left[\frac{d}{dz}(z^2+1)^2\right]_{z=0}$$

$$= \left[2(z^2+1)\times 2z\right]_{z=0} = 0$$

End of Solution

Q.22 The figure shows the high-frequency C-V curve of a MOS capacitor (at T = 300 K) with ϕ_{ms} = 0 V and no oxide charges. The flat-band, inversion, and accumulation conditions are represented, respectively, by the points



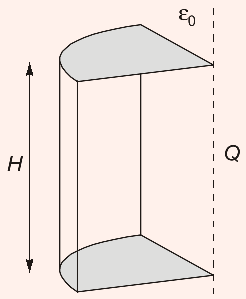
(a) Q, R, P
(b) P, Q, R
(c) Q, P, R
(d) R, P, Q

Ans. **(a)**

Since $\phi_{ms} = 0$, the MOS-capacitor is ideal.
Point P Represents accumulation
Point Q Represents flat band
Point R Represents Inversion

End of Solution

Q.23 What is the electric flux $\left(\int \vec{E} \cdot d\hat{a}\right)$ through a quarter-cylinder of height H (as shown in the figure) due to an infinitely long line charge along the axis of the cylinder with a charge density of Q?



(a) $\dfrac{4H}{Q\varepsilon_0}$
(b) $\dfrac{H\varepsilon_0}{4Q}$
(c) $\dfrac{HQ}{\varepsilon_0}$
(d) $\dfrac{HQ}{4\varepsilon_0}$

Ans. **(d)**

Electric field intensity $(\vec{E})$ at 'ρ' distance due to infinite long line having line charge density Q is

$$\vec{E} = \frac{Q}{2\pi\varepsilon_0\rho}\hat{a}_\rho$$

$$\int \vec{E} \cdot \vec{da} = \iint \frac{Q}{2\pi\varepsilon_0\rho}\hat{a}_\rho \cdot \rho\, d\phi\, dz\, \hat{a}_\rho$$

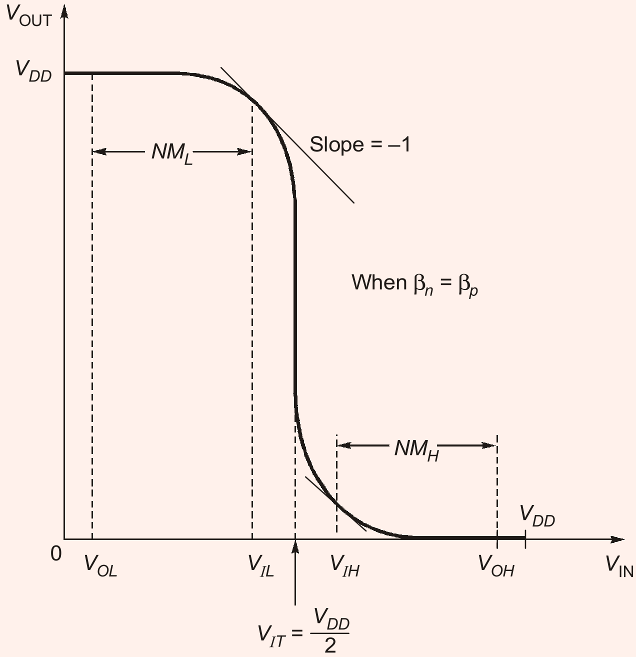
$$= \frac{Q}{2\pi\varepsilon_0}\int_{<\pi/2>} d\phi \int_{z=0}^{H} dz = \frac{Q}{2\pi\varepsilon_0}\left(\frac{\pi}{2}\right)H = \frac{HQ}{4\varepsilon_0}$$

End of Solution

Q.24 A standard CMOS inverter is designed with equal rise and fall times ($\beta_n = \beta_p$). If the width of the pMOS transistor in the inverter is increased, what would be the effect on the LOW noise margin (NM_L) and the HIGH noise margin NM_H?

(a) NM_L decreases and NM_H increases.
(b) No change in the noise margins.
(c) Both NM_L and NM_H increase.
(d) NM_L increases and NM_H decreases.

Ans. (d)



Making PMOS wider, shifts input transition point (V_{IT}) towards V_{DD}.
Making NMOS wider, shifts input transition point (V_{IT}) towards zero.
So, as PMOS made wider, NM_L increases and NM_H decreases.

End of Solution

Q.25 Let Z be an exponential random variable with mean 1. That is, the cumulative distribution function of Z is given by

$$F_Z(x) = \begin{cases} 1 - e^{-x} & \text{if } x \geq 0 \\ 0 & \text{if } x < 0 \end{cases}$$

Then $\Pr(Z > 2 \mid Z > 1)$, rounded off to two decimal places, is equal to ______.

Ans. (0.37)

Sol. Required probability $= \dfrac{P[(z>2) \cap (z>1)]}{P[z>1]} = \dfrac{P[z>2]}{P[z>1]}$

$$P(z \leq 2) = 1 - e^{-2} \Rightarrow P(z > 2) = e^{-2}$$
$$P(z \leq 1) = 1 - e^{-1} \Rightarrow P(z > 1) = e^{-1}$$

So, Required probability $= \dfrac{e^{-2}}{e^{-1}} = e^{-1} \simeq 0.37$

End of Solution

Q.26 Consider a differentiable function $f(x)$ on the set of real numbers such that $f(-1) = 0$ and $|f'(x)| \le 2$. Given these conditions, which one of the following inequalities is necessarily true for all $x \in [-2, 2]$?

(a) $f(x) \le 2|x+1|$

(b) $f(x) \le \frac{1}{2}|x|$

(c) $f(x) \le 2|x|$

(d) $f(x) \le \frac{1}{2}|x+1|$

Ans. (a)

Given that, $|f'(x)| \le 2$; $f(-1) = 0$

$$-2 \le f'(x) \le 2$$

$x \in [-2, 2] \rightarrow 2 \le x \le 2$

$\therefore$ By applying mean value theorem in $[-1, 2]$

$$-2 \le f'(x) \le 2$$

$$-2 \le \frac{f(2) - f(-1)}{2 - (-1)} \le 2$$

$$-2 \le \frac{f(2) - f(-1)}{3} \le 2$$

$$-6 \le f(2) - 0 \le 6$$

$$-6 \le f(2) \le 6$$

It is satisfied by only option (a).

End of Solution

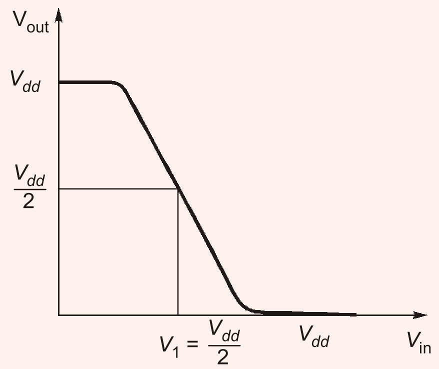
Q.27 A CMOS inverter, designed to have a mid-point voltage V_1 equal to half of V_{dd}, as shown in the figure, has the following parameters:

$V_{dd} = 3$ V

$\mu_n C_{ox} = 100\ \mu A/V^2$; $V_{tn} = 0.7$ V for nMOS

$\mu_n C_{ox} = 40\ \mu A/V^2$; $|V_{tp}| = 0.9$ V for pMOS

The ratio of $\left(\frac{W}{L}\right)_n$ to $\left(\frac{W}{L}\right)_p$ is equal to ________ (rounded off to 3 decimal places).



Ans. (0.225)

$I_{Dn} = I_{Dp}$ and both will be in saturation.

$$\text{If } V_{IN} = \frac{V_{DD}}{2} = 1.5\text{ V} = V_{GSN} = V_{SGP}$$

$$\Rightarrow \frac{1}{2}(\mu_n C_{ox})\left(\frac{W}{L}\right)_n [V_{GSN} - V_{TN}]^2 = \frac{1}{2}(\mu_p C_{ox})\left(\frac{W}{L}\right)_p [V_{GSP} + V_{TP}]^2$$

$$100 \times 10^{-6}\left(\frac{W}{L}\right)_n [1.5 - 0.7]^2 = 40 \times 10^{-6}\left(\frac{W}{L}\right)_p [1.5 - 0.9]^2$$

$$\Rightarrow \frac{\left(\frac{W}{L}\right)_n}{\left(\frac{W}{L}\right)_p} = \frac{40}{100} \times \frac{(0.6)^2}{(0.8)^2} = 0.225$$

End of Solution

Q.28 In an ideal *pn* junction with an ideality factor of 1 at T = 300 K, the magnitude of the reverse-bias voltage required to reach 75% of its reverse saturation current, rounded off to 2 decimal places, is________ mV.

[$k = 1.38 \times 10^{-23}$ JK^{-1}, $h = 6.625 \times 10^{-34}$ J-s, $q = 1.602 \times 10^{-19}$C]

Ans. (35.83)

$$V_T = \frac{kT}{q} = \frac{1.38 \times 10^{-23} \times 300}{1.602 \times 10^{-19}}\text{ V} = 25.843\text{ mV}$$

$$I = I_0\left(e^{V/V_T} - 1\right) = -\frac{3}{4}I_0$$

$$\Rightarrow V = V_T \ln 0.25 = -35.83\text{ mV}$$

$$V_R = |V| = 35.83\text{ mV}$$

End of Solution

Q.29 It is desired to find a three-tap causal filter which gives zero signal as an output to an input of the form

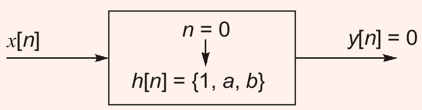
$$x[n] = c_1 \exp\left(-\frac{j\pi n}{2}\right) + c_2 \exp\left(\frac{j\pi n}{2}\right),$$

where c_1 and c_2 are arbitrary real numbers. The desired three-tap filter is given by

$$h[0] = 1, \quad h[1] = a, \quad h[2] = b$$

and $$h[n] = 0 \text{ for } n < 0 \text{ or } n > 2$$

What are the values of the filter taps a and b if the output $y[n]$ = 0 for all n, where $x[n]$ is as given above?



(a) $a = 0,\ b = -1$ (b) $a = 1,\ b = 1$
(c) $a = -1,\ b = 1$ (d) $a = 0,\ b = 1$

Ans. (d)

$$x(n) = c_1 e^{-j\frac{\pi}{2}n} + c_2 e^{j\frac{\pi}{2}n}$$

$$\omega_o = \frac{\pi}{2}\text{ rad/s}$$

$$H(e^{j\omega}) = 1 + ae^{-j\omega} + be^{-j2\omega}$$

To get $y(n) = 0$,

$$H(e^{j\omega_o}) = H(e^{j\omega})\Big|_{\omega=\frac{\pi}{2}} = 0$$

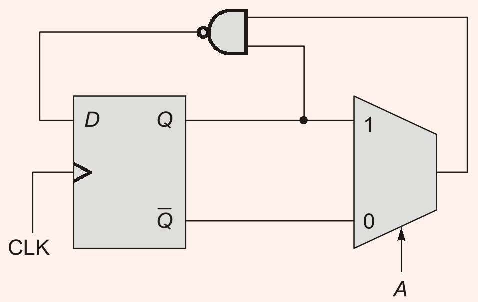
$$1 + ae^{-j\frac{\pi}{2}} + be^{-j2\frac{\pi}{2}} = 0$$

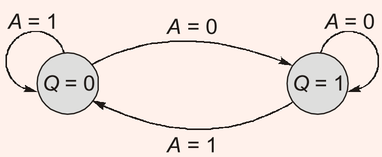
$$1 - ja - b = 0$$

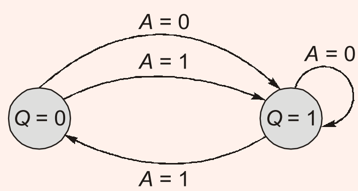
From the given options, $a = 0$ and $b = 1$.

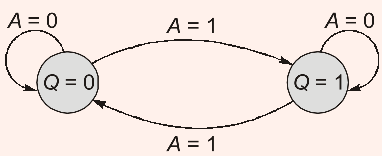
End of Solution

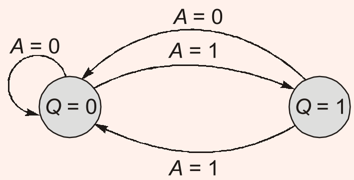
Q.30 The state transition diagram for the circuit shown is



(a)


(b)


(c)


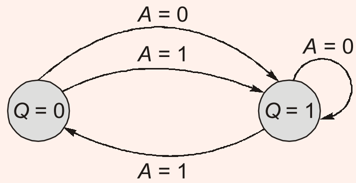
(d)


Ans. (b)

When $A = 0$, $Q_{n+1} = 1$

When $A = 1$, $Q_{n+1} = \bar{Q}_n$

So, the correct state transition diagram is,



End of Solution

Q.31 Let the state-space representation of an LTI system be $\dot{X}(t) = AX(t) + Bu(t)$, $y(t) = CX(t) + du(t)$ where A, B, C are matrices, d is a scalar, $u(t)$ is the input to the system, and $y(t)$ is its output. Let $B = [0\ \ 0\ \ 1]^T$ and $d = 0$. Which one of the following options for A and C will ensure that the transfer function of this LTI system is

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

(a) $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -3 & -2 & -1 \end{bmatrix}$ and $C = [0\ \ 0\ \ 1]$

(b) $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -2 & -3 \end{bmatrix}$ and $C = [0\ \ 0\ \ 1]$

(c) $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -2 & -3 \end{bmatrix}$ and $C = [1\ \ 0\ \ 0]$

(d) $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -3 & -2 & -1 \end{bmatrix}$ and $C = [1\ \ 0\ \ 0]$

Ans. (c)

$$X(t) = Ax(t) + Bu(t)$$
$$y(t) = Cx(t)$$
$$B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$
$$\frac{Y(s)}{U(s)} = \frac{Y(s)}{X_1(s)} \times \frac{X_1(s)}{U(s)} = 1 \times \frac{1}{s^3 + 3s^2 + 2s + 1}$$

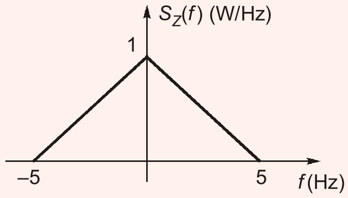
$$X_1(s)[s^3 + 3s^2 + 2s + 1] = U(s)$$

$$x_2 = \dot{x}_1(t) \Rightarrow X_2(s) = sX_1(s)$$
$$x_3 = \dot{x}_2(t) \Rightarrow X_3(s) = sX_2(s) = s^2X_1(s)$$

So,
$$sX_3(s) = -X_1(s) - 2X_2(s) - 3X_3(s) + U(s)$$
$$\dot{x}_3(t) = -x_1(t) - 2x_2(t) - 3x_3(t) + u(t)$$
$$y(t) = x_1(t)$$
$$\dot{x}(t) = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -2 & -3 \end{bmatrix} x(t) + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u(t)$$
$$y(t) = [1\ \ \ 0\ \ \ 0]\, x(t)$$

End of Solution

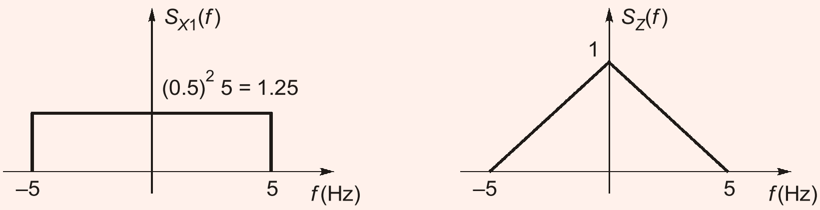
Q.32 Let a random process $Y(t)$ be described as $Y(t) = h(t) * X(t) + Z(t)$, where $X(t)$ is a white noise process with power spectral density $S_X(f) = 5$ W/Hz. The filter $h(t)$ has a magnitude response given by $|H(f)| = 0.5$ for $-5 \leq f \leq 5$, and zero elsewhere. $Z(t)$ is a stationary random process, uncorrelated with $X(t)$, with power spectral density as shown in the figure. The power in $Y(t)$, in watts, is equal to W _____ (rounded off to two decimal places).



Ans. **(17.5)**

Let, $$X_1(t) = h(t) * X(t)$$

$$S_{X1}(f) = |H(f)|^2 \, S_X(f)$$



Given that, $Z(t)$ and $X(t)$ are uncorrelated.

So, $$S_Y(f) = S_{X1}(f) + S_z(f)$$

Power in $y(t)$, $$P_Y = [\text{Area under } S_{X1}(f)] + [\text{Area under } S_z(f)]$$
$$= (10 \times 1.25) + (5 \times 1) = 17.5 \text{ W}$$

End of Solution

Q.33 Consider the homogeneous ordinary differential equation

$$x^2 \frac{d^2y}{dx^2} - 3x\frac{dy}{dx} + 3y = 0, \quad x > 0$$

with $y(x)$ as a general solution. Given that

$$y(1) = 1 \text{ and } y(2) = 14$$

the value of $y(1.5)$, rounded off to two decimal places, is ______.

Ans. **(5.25)**

$$(x^2D^2 - 3xD + 3) = 0$$

$$(\theta(\theta - 1) - 3\theta + 3)y = 0$$

$$(\theta^2 - 4\theta + 3)y = 0$$

AE is $m^2 - 4m + 3 = 0$

$$m = 1, 3$$

$$\text{CF} = C_1e^z + C_2e^{3z}$$

Solution is $$y = C_1x + C_2x^3 \quad \text{...(i)}$$

$y(1) = 1 \qquad 1 = C_1 + C_2 \qquad \text{...(ii)}$

$y(2) = 14 \qquad 14 = 2C_1 + 8C_2 \qquad \text{...(iii)}$

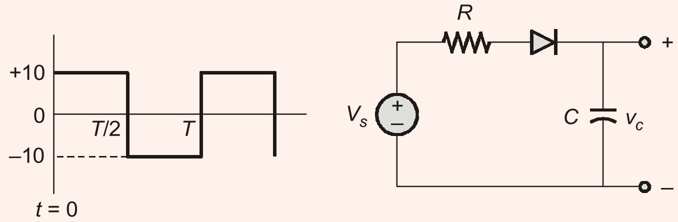
From (ii) and (iii), $C_1 = -1, \quad C_2 = 2$

$\therefore \qquad y = -x + 2x^3$

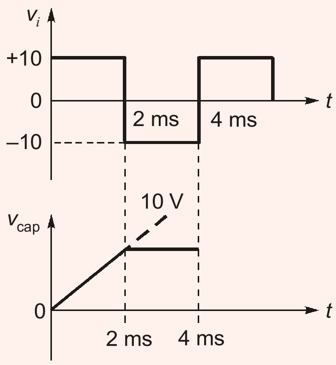
$$y(1.5) = -1.5 + 2(1.5)^3 = 5.25$$

End of Solution

Q.34 In the circuit shown. V_s is a 10 V square wave of period, T = 4 ms with R = 500 Ω and C = 10 μF. The capacitor is initially uncharged at t = 0, and the diode is assumed to be ideal. The voltage across the capacitor (V_c) at 3 ms is equal to _____ volts (rounded off to one decimal place).



Ans. (3.3)



$$\tau = RC = 500 \times 10 \times 10^{-6} = 5 \text{ ms}$$

$0 < t < \frac{t}{2}$: $\qquad v_{cap} = v_f + (v_i - v_f)e^{-t/\tau}$

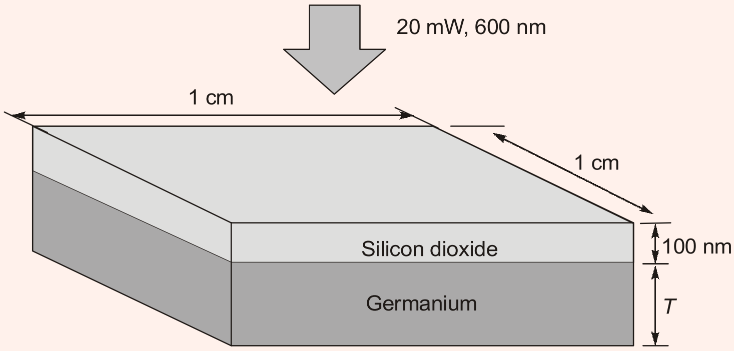
$$= 10 + (0 - 10)e^{-t/RC}$$

At t = 2 msec, $\qquad v_{cap} = 10 - 10e^{\frac{-2\times10^{-3}}{5\times10^{-3}}} = 3.296 \text{ V} \simeq 3.3 \text{ V}$

For 2 ms < t < 4 ms, diode is OFF and capacitor has no path to discharge. Hence, at t = 3 ms, V_{cap} = 3.3 V.

End of Solution

Q.35 A Germanium sample of dimensions 1 cm × 1 cm is illuminated with a 20 mW. 600 nm laser light source as shown in the figure. The illuminated sample surface has a 100 nm of loss-less Silicon dioxide layer that reflects one-fourth of the incident light. From the remaining light, one-third of the power is reflected from the Silicon dioxide- Germanium interface, one-third is absorbed in the Germanium layer, and one-third is transmitted through the other side of the sample. If the absorption coefficient of Germanium at 600 nm is 3×10^4 cm^{-1} and the bandgap is 0.66 eV, the thickness of the Germanium layer, rounded off to 3 decimal places, is ________ μm.



Ans. (0.231)

$$P_{absorbed} = P_{incident}(1 - e^{-\alpha T})$$

$$\frac{1}{3} = \frac{2}{3}(1 - e^{-\alpha T})$$

$$\frac{2}{3}e^{-\alpha T} = \frac{1}{3}$$

where $\alpha = 3 \times 10^4$ cm^{-1}, absorption coefficient of Ge sample.

$$\therefore \quad T = \frac{1}{\alpha}\ln(2) = \frac{1}{3 \times 10^4}\ln(2) \text{ cm} = 0.231\,\mu\text{m}$$

End of Solution

Q.36 A rectangular waveguide of width w and height h has cut-off frequencies for TE_{10} and TE_{11} modes in the ratio 1 : 2. The aspect ratio w/h, rounded off to two decimal places, is _____.

Ans. (1.732)

$$f_{cmn} = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

For TE_{10} mode, $$f_{c10} = \frac{c}{2w} \qquad \text{...(i)}$$

and For TE_{11} mode, $$f_{c11} = \frac{c}{2}\sqrt{\left(\frac{1}{w}\right)^2 + \left(\frac{1}{h}\right)^2} = \frac{c}{2w}\sqrt{1 + \left(\frac{w}{h}\right)^2} \qquad \text{...(ii)}$$

given, $$\frac{f_{c10}}{f_{c11}} = \frac{1}{2} \qquad \text{...(iii)}$$

put (i), (ii) in (iii)

$$\Rightarrow \qquad \frac{\dfrac{c}{2w}}{\dfrac{c}{2w}\sqrt{1+\left(\dfrac{w}{h}\right)^2}} = \frac{1}{2} \Rightarrow \sqrt{1+\left(\frac{w}{h}\right)^2} = 2$$

On solving above equation, we get,

$$\frac{w}{h} = \sqrt{3} = 1.732$$

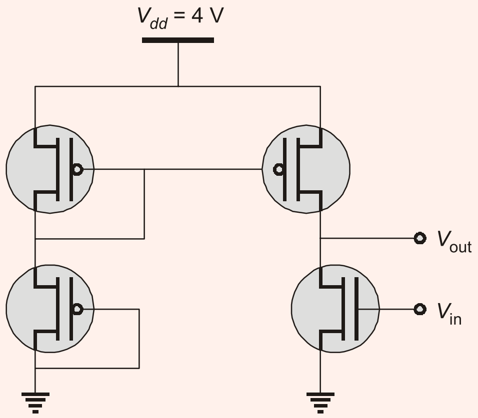
End of Solution

Q.37 In the circuit shown, the threshold voltages of the pMOS ($|V_{tp}|$) and nMOS (V_{tn}) transistors are both equal to 1 V. All the transistors have the same output resistance r_{ds} of 6 MΩ. The other parameters are listed below:

$$\mu_n C_{ox} = 60\,\mu A/V^2 \;;\; \left(\frac{W}{L}\right)_{nMOS} = 5$$

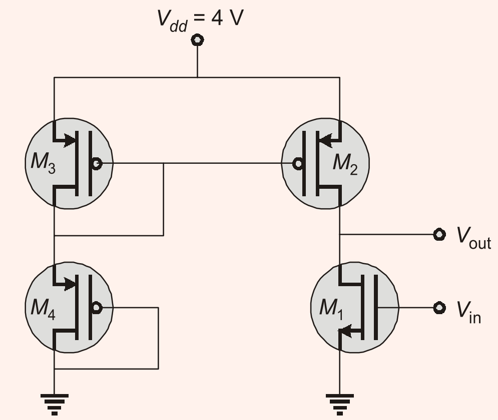
$$\mu_p C_{ox} = 30\,\mu A/V^2 \;;\; \left(\frac{W}{L}\right)_{pMOS} = 10$$

μ_n and μ_p are the carrier mobilities, and C_{ox} is the oxide capacitance per unit area. Ignoring the effect of channel length modulation and body bias, the gain of the circuit is _____ (rounded off to 1 decimal place).



Ans. **(–900)**

M_3 and M_4 are identical PMOS transistor and they have equal current.
Hence their V_{SG} should be equal.



$$V_{SG3} = V_{SG4} = \frac{V_{DD}}{2} = 2\text{ V}$$

$$I_{SD} = \frac{\mu_p C_{ox}}{2}\left(\frac{W}{L}\right)_p (V_{SG} - |V_T|)^2$$

$$= \frac{30}{2} \times 10(2-1)^2 = 150\ \mu\text{A}$$

now, by using current mirror property all transistor should have equal current.

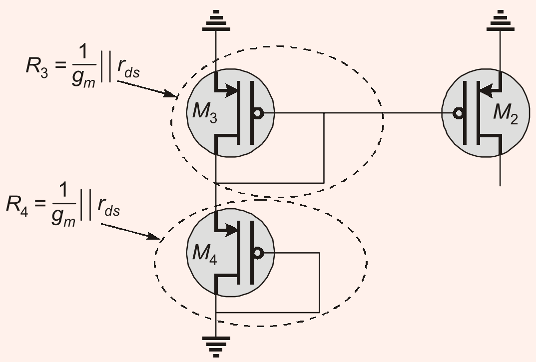
$$I_{DSN} = I_{SDP} = 150\ \mu\text{A}$$

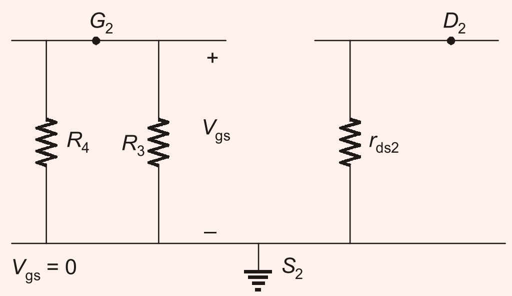
For M_1

$$g_{m1} = \sqrt{2\mu_n C_{ox}\frac{W}{L} \times I_{DS}}$$

$$= \sqrt{2\mu_n C_{ox}\frac{W}{L} \times I_{DS}} = \sqrt{2 \times 60 \times 5 \times 150} = 300\ \mu℧$$

M_2, M_3 and M_4 from active load for M_1. This active load in equivalent to resistance r_{ds2} i.e. 6 MΩ.





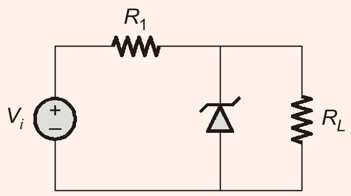
M_1 is common source amplifier.

$$\therefore \quad \frac{V_{out}}{V_{in}} = A_v = -g_{m1} \times (r_{ds2} \parallel r_{ds1})$$

$$= -300\ \text{M℧} \times 3\ \text{M}\Omega = -900$$

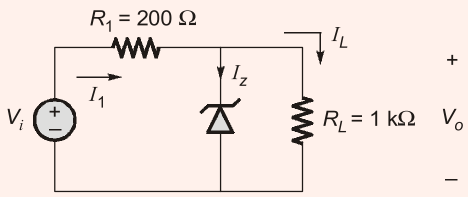
End of Solution

Q.38 In the circuit shown, the breakdown voltage and the maximum current of the Zener diode are 20 V and 60 mA. respectively. The values of R_1 and R_L are 200 Ω and 1 kΩ. respectively. What is the range of V_i that will maintain the Zener diode in the 'on' state?



(a) 20 V to 28 V
(b) 24 V to 36 V
(c) 18 V to 24 V
(d) 22 V to 34 V

Ans. (b)



$$V_z = 20\ \text{V}$$

$$I_{z\,max} = 60\ \text{mA}$$

Set zener diode be OFF

$$V_o = \frac{V_i \times 1}{0.2+1} = \frac{V_i}{1.2}$$

Zener diode can become ON i.e. it goes into breakdown, when

$$\frac{V_i}{1.2} > 20\ \text{V}$$

$$V_i > 24\ \text{V}$$

When Zener diode is in breakdown region,

$$I_1 = \frac{V_i - 20}{0.2\ \text{k}\Omega} = \frac{V_i - 20}{0.2}\ \text{mA}$$

$$I_L = \frac{V_o}{R_L} = \frac{20}{1\ \text{k}\Omega} = 20\ \text{mA}$$

$$I_z = I_1 - I_L = \frac{V_i - 20}{0.2} - 20$$

For safe operation, $I_z \le I_{z\,max}$

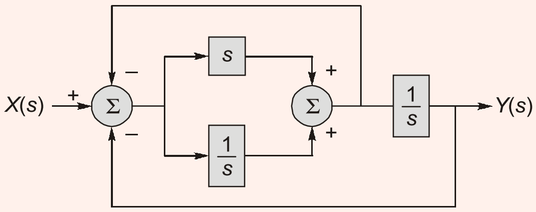
$$\frac{V_i - 20}{0.2} - 20 \le 60$$

$$\Rightarrow \quad V_i \le 36\ \text{V}$$

Hence, $\quad 24 < V_i < 36\ \text{V}$

End of Solution

Q.39 The block diagram of a system is illustrated in the figure shown, where $X(s)$ is the input and $Y(s)$ is the output. The transfer function $H(s) = \frac{Y(s)}{X(s)}$ is



(a) $H(s) = \frac{s^2+1}{2s^2+1}$

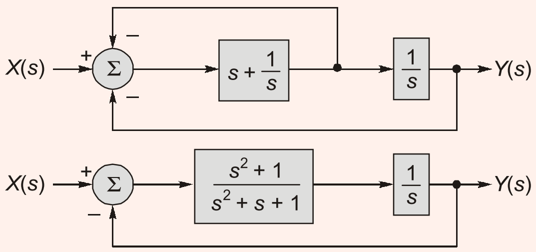
(b) $H(s) = \frac{s^2+1}{s^3+2s^2+s+1}$

(c) $H(s) = \frac{s+1}{s^2+s+1}$

(d) $H(s) = \frac{s^2+1}{s^3+s^2+s+1}$

Ans. (b)

Using block diagram reduction, we get,



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

End of Solution

Q.40 A single bit, equally likely to be 0 and 1, is to be sent across an additive white Gaussian noise (AWGN) channel with power spectral density $N_o/2$. Binary signaling, with $0 \rightarrow p(t)$ and $1 \rightarrow q(t)$, is used for the transmission, along with an optimal receiver that minimizes the bit-error probability.

Let $\varphi_1(t), \varphi_2(t)$ form an orthonormal signal set.

If we choose $p(t) = \varphi_1(t)$ and $q(t) = -\varphi_1(t)$, we would obtain a certain bit-error probability P_b.

If we keep $p(t) = \varphi_1(t)$, but take $q(t) = \sqrt{E}\,\varphi_2(t)$, for what value of E would we obtain the same bit-error probability P_b?

(a) 0

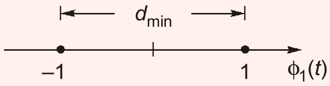
(b) 3

(c) 1

(d) 2

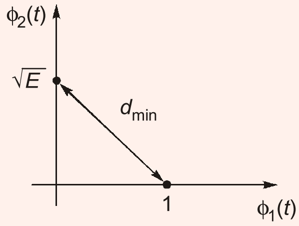
Ans. (b)

When $p(t) = \phi_1(t)$ and $q(t) = -\phi_1(t)$:



$$d_{min} = 2$$

When $p(t) = \phi_1(t)$ and $q(t) = \sqrt{E}\,\phi_2(t)$:



$$d_{min} = \sqrt{(\sqrt{E})^2 + 1} = \sqrt{E+1}$$

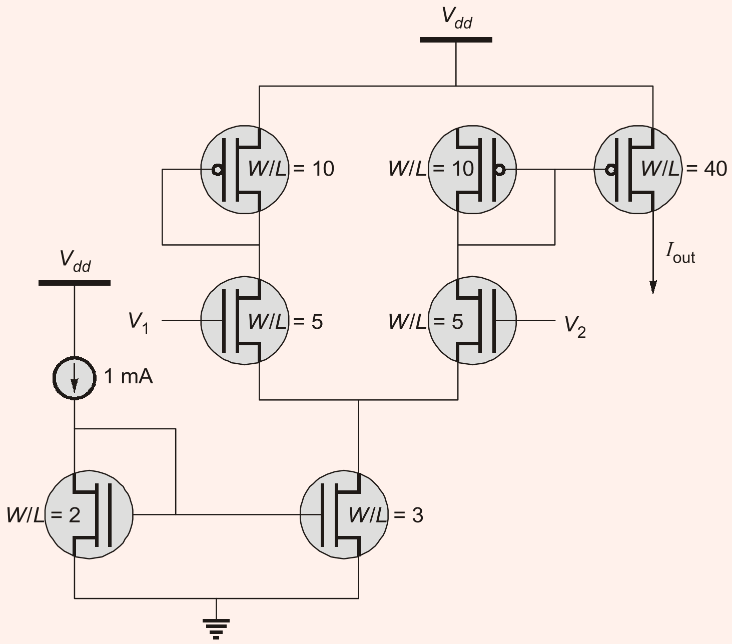
To obtain same bit-error probability, d_{min} should be same.

So, $\sqrt{E+1} = 2$

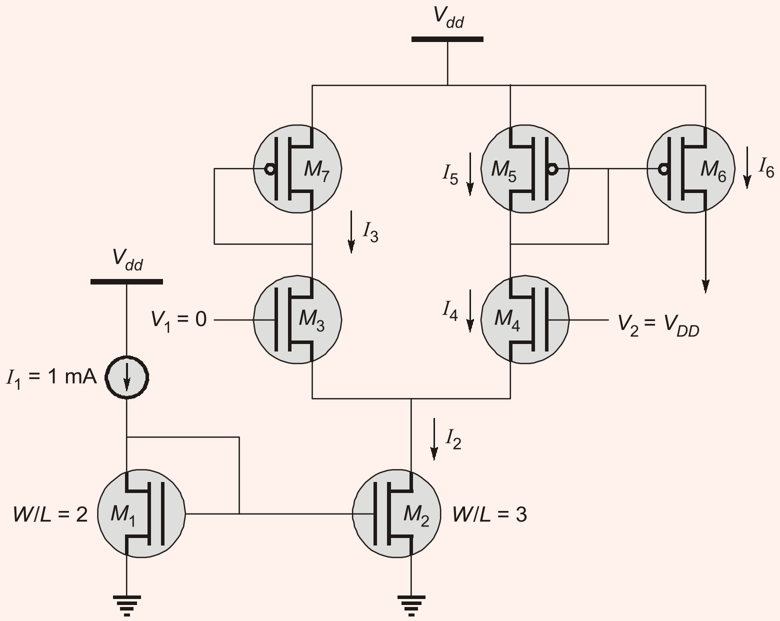
$$E = 3$$

End of Solution

Q.41 In the circuit shown. $V_1 = 0$ and $V_2 = V_{dd}$. The other relevant parameters are mentioned in the figure. Ignoring the effect of channel length modulation and the body effect, the value of I_{out} is _______ mA (rounded off to 1 decimal place).



Ans. (6)



$$\frac{I_2}{I_1} = \frac{(W/L)_2}{(W/L)_1} = \frac{3}{2}$$

$$I_2 = \frac{3}{2} \times I_1 = 1.5 \text{ mA}$$

M_3 is OFF because $V_1 = 0 \Rightarrow I_3 = 0$

M_4 is ON because $V_2 = V_{DD}$

$$I_5 = I_4 = I_2 = 1.5 \text{ mA}$$

$$\frac{I_6}{I_5} = \frac{(W/L)_6}{(W/L)_5} = \frac{40}{10} = 4$$

$$I_6 = 4I_5 = 4 \times 1.5 = 6 \text{ mA}$$

$\therefore$ $I_{out} = I_6 = 6$ mA

End of Solution

Q.42 Consider a causal second-order system with the transfer function

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

with a unit-step $R(s) = \frac{1}{s}$ as an input. Let $C(s)$ be the corresponding output. The time taken by the system output $c(t)$ to reach 94% of its steady-state value $\lim_{t \to \infty} c(t)$, rounded off to two decimal places, is

(a) 5.25
(b) 4.50
(c) 2.81
(d) 3.89

Ans. (b)

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

$$R(s) = \frac{1}{s}$$

$$C(s) = G(s)R(s) = \frac{1}{s(s+1)^2}$$

Using partial fraction expansion, we get,

$$C(s) = \frac{A}{s} + \frac{B}{(s+1)} + \frac{C}{(s+1)^2}$$

$$A(s^2 + 2s + 1) + B(s^2 + s) + Cs = 1$$

$$A = 1$$

$$A + B = 0 \Rightarrow B = -1$$

$$2A + B + C = 0 \Rightarrow C = -1$$

$\therefore$ $$C(s) = \frac{1}{s} - \frac{1}{(s+1)} - \frac{1}{(s+1)^2} \quad \text{and} \quad c(t) = (1 - e^{-t} - te^{-t})\ u(t)$$

$$\lim_{t \to \infty} c(t) = 1$$

In order to reach 94% of its steady-state value,

$$(1 - e^{-t} - te^{-t}) = 0.94$$

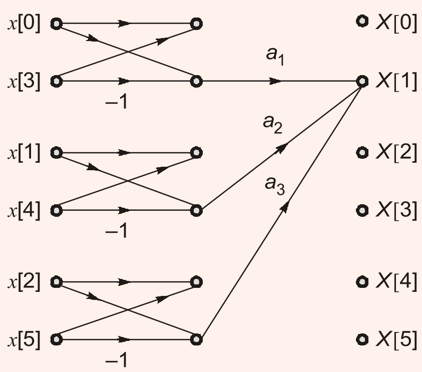
By trial and error, we get,

$$t \approx 4.50 \text{ sec}$$

End of Solution

Q.43 Consider a six-point decimation-in-time Fast Fourier Transform (FFT) algorithm, for which the signal-flow graph corresponding to $X[1]$ is shown hi the figure. Let $W_6 = \exp\left(-\frac{j2\pi}{6}\right)$.

In the figure, what should be the values of the coefficients a_1, a_2, a_3 in terms of W_6 so that $X[1]$ is obtained correctly?



(a) $a_1 = 1, a_2 = W_6^2, a_3 = W_6$

(b) $a_1 = -1, a_2 = W_6^2, a_3 = W_6$

(c) $a_1 = -1, a_2 = W_6, a_3 = W_6^2$

(d) $a_1 = 1, a_2 = W_6, a_3 = W_6^2$

Ans. (d)

$$X(k) = \sum_{n=0}^{N-1} x(n)\, e^{-j\frac{2\pi}{N}kn} \quad ; \quad X(1) = \sum_{n=0}^{5} x(n) W_6^n$$

$$= x(0) + x(1)W_6 + x(2)W_6^2 + x(3)W_6^3 + x(4)W_6^4 + x(5)W_6^5 \quad ...(i)$$

From the given flow graph,

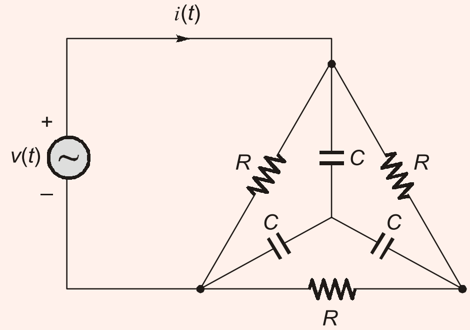
$$X(k) = [x(0) - x(3)]a_1 + [x(1) - x(4)]a_2 + [x(2) - x(5)]a_3$$

By comparing equations (i) and (ii), we get,

$$a_1 = 1,\ a_2 = W_6,\ a_3 = W_6^2$$

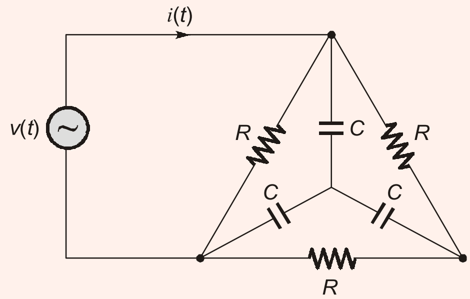
End of Solution

Q.44 In the circuit shown, if $v(t) = 2\sin(1000t)$ volts. $R = 1$ kΩ and $C = 1$ μF. then the steady-state current $i(t)$, in milliamperes (mA), is



(a) $3\sin(1000t) + \cos(1000t)$
(b) $\sin(1000t) + \cos(1000t)$
(c) $\sin(1000t) + 3\cos(1000t)$
(d) $2\sin(1000t) + 2\cos(1000t)$

Ans. (a)



Here,

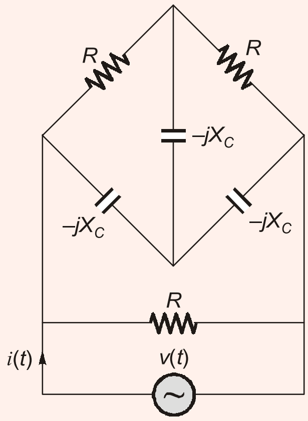
$$X_C = \frac{1}{\omega C} = \frac{1}{10^3 \times 10^{-6}} = \frac{1}{10^{-3}}$$

$$X_C = 10^3\ \Omega$$

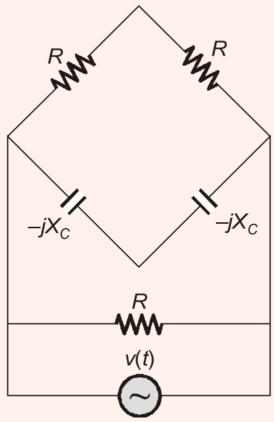
$$R = 10^3\ \Omega \quad \text{(Given)}$$

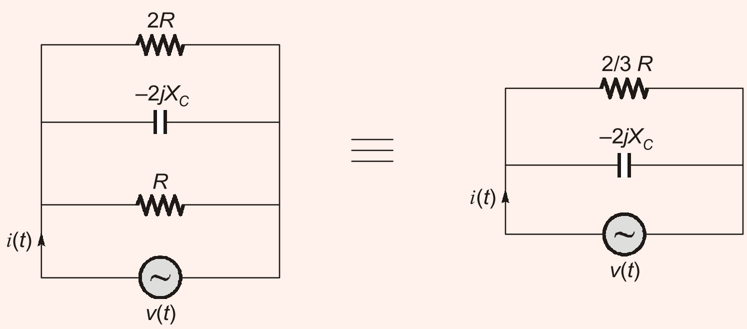
$$v(t) = 2\sin 1000t \text{ V} = 2\angle 0° \text{ V}$$

Redrawing the given network, we get,



As the bridge is balanced, it can be redrawn as





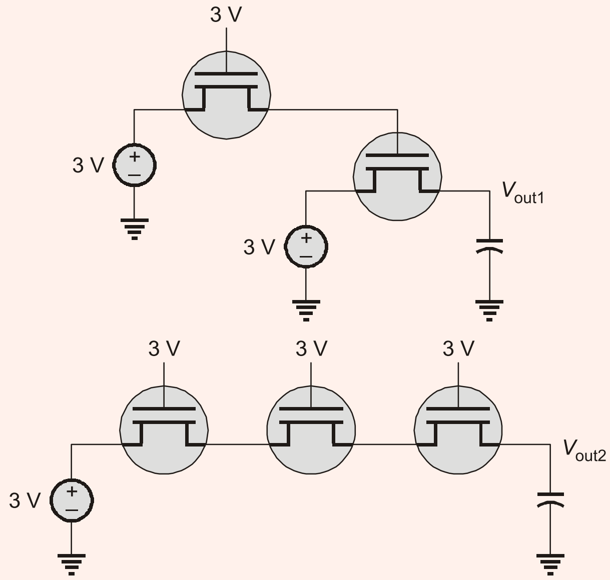
$$\therefore \qquad Y_{eq} = Y_1 + Y_2 = \frac{3}{2}R + \frac{1}{-2jX_C} = \frac{3}{2}\times 10^{-3} + j\frac{1}{2}\times 10^{-3}$$

$$\therefore \qquad i(t) = v(t) \times Y_{eq} = 2\angle 0^\circ\left[\frac{3}{2} + j\frac{1}{2}\right]\text{mA}$$

$$= (3 + j1)\text{ mA} = 3\sin(1000t) + \cos(1000t)\text{ mA}$$

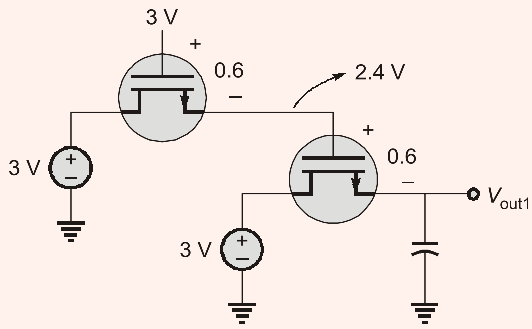
End of Solution

Q.45 In the circuits shown, the threshold voltage of each nMOS transistor is 0.6 V. Ignoring the effect of channel length modulation and body bias, the values of V_{out1} and V_{out2}, respectively, in volts, are

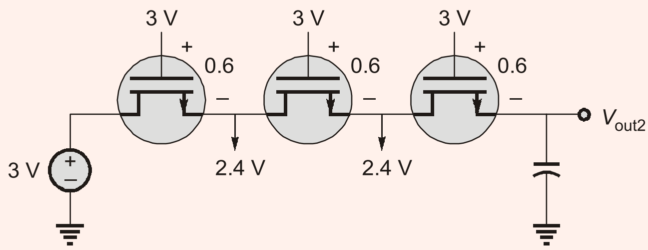


(a) 1.8 and 2.4
(b) 2.4 and 1.2
(c) 1.8 and 1.2
(d) 2.4 and 2.4

Ans. (a)



$$V_{out\ 1} = 3 - 0.6 - 0.6 = 1.8 \text{ V}$$



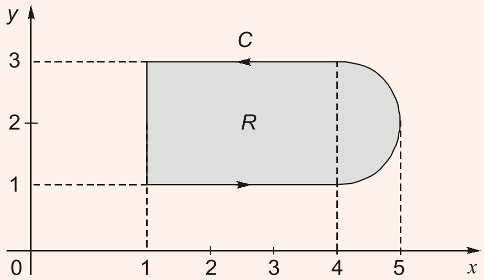
$$V_{out\ 2} = 2.4 \text{ V}$$

End of Solution

Q.46 Consider the line integral

$$\int_c (xdy - ydx)$$

the integral being taken in a counterclockwise direction over the closed curve C that forms the boundary of the region R shown in the figure below. The region R is the area enclosed by the union of a 2×3 rectangle and a semi-circle of radius 1. The line integral evaluates to



(a) $12 + \pi$
(b) $16 + \pi$
(c) $6 + \pi/2$
(d) $8 + \pi$

Ans. (a)

Given, $\int -ydx + xdy$

here, $F_1 = -y$ and $\frac{\partial F_1}{\partial y} = -1$

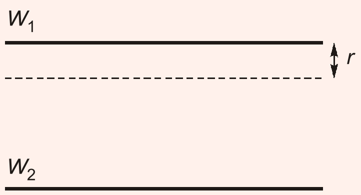
$F_2 = x$ and $\frac{\partial F_2}{\partial x} = 1$

$\therefore \quad \int F_1 dx + F_2 dy = \iint \left(\frac{\partial F_2}{\partial x} - \frac{\partial F_1}{\partial y} \right) dx\, dy$

$\int -ydx + xdy = \iint 1 - (-1) dx\, dy = 2(\text{Area of region } R) = 2\left(6 + \frac{\pi}{2}\right) = 12 + \pi$

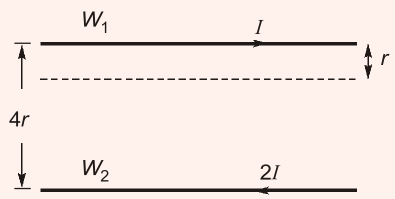
End of Solution

Q.47 Two identical copper wires W_1 and W_2 placed in parallel as shown in the figure, carry currents I and $2I$, respectively, in opposite directions. If the two wires are separated by a distance of $4r$, then the magnitude of the magnetic field $\vec{B}$ between the wires at a distance r from W_1 is



(a) $\frac{\mu_0^2 I^2}{2\pi r^2}$
(b) $\frac{6\mu_0 I}{5\pi r}$
(c) $\frac{\mu_0 I}{6\pi r}$
(d) $\frac{5\mu_0 I}{6\pi r}$

Ans. (d)



Magnetic flux density ($\vec{B}$) at r distance due to infinite line carrying current I is $\left|\vec{B}\right| = \dfrac{\mu_0 I}{2\pi\rho}$.

- $\vec{B}$ at r distance due to W_1 wire = $\left|\vec{B}_1\right| = \dfrac{\mu_0 I}{2\pi r}$ ...(i)
- $\vec{B}$ at $3r$ distance due to W_2 wire = $\left|\vec{B}_2\right| = \dfrac{\mu_0 (2I)}{2\pi(3r)}$ ...(ii)

From right hand thumb rule, $\vec{B}$ due to both lines add in between conductors.

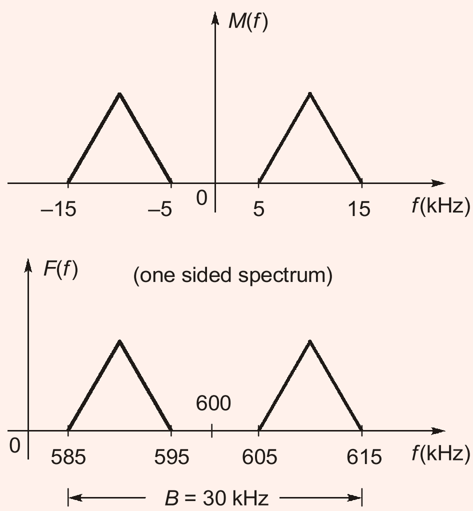
So, $$\left|\vec{B}\right| = \left|\vec{B}_1\right| + \left|\vec{B}_2\right|$$

$$\therefore \quad \left|\vec{B}\right| = \frac{\mu_0 I}{2\pi r} + \frac{2\mu_0 I}{6\pi r} = \frac{5\mu_0 I}{6\pi r}$$

End of Solution

Q.48 A voice signal $m(t)$ is in the frequency range 5 kHz to 15 kHz. The signal is amplitude-modulated to generate an AM signal $f(t) = A(1 + m(t)) \cos 2\pi f_c t$, where f_c = 600 kHz. The AM signal $f(t)$ is to be digitized and archived. This is done by first sampling $f(t)$ at 1.2 times the Nyquist frequency, and then quantizing each sample using a 256-level quantizer. Finally, each quantized sample is binary coded using K bits, where K is the minimum number of bits required for the encoding. The rate, in Megabits per second (rounded off to 2 decimal places), of the resulting stream of coded bits is ____ Mbps.

Ans. (0.59)



$$\text{Nyquist rate} = \frac{2f_H}{\lfloor f_H/B \rfloor} = \frac{2\times 615}{\lfloor 615/30 \rfloor}\ \text{kHz}$$

$$= \frac{2\times 615}{\lfloor 20.5 \rfloor} = \frac{2\times 615}{20} = 61.5 \text{ kHz}$$

$$f_s = 1.2 \times 61.5 = 73.8 \text{ kHz}$$

Bits/sample, $n = \log_2(256) = 8$

So, $R_b = nf_s = 8 \times 73.8$ kbps

$$= 590.4 \text{ kbps} = 0.5904 \text{ Mbps} \simeq 0.59 \text{ Mbps}$$

Note: If band-pass sampling is not considered by the examiner, then

$$f_s = 1.2 \times 2 \times 615 = 1476 \text{ kHz}$$

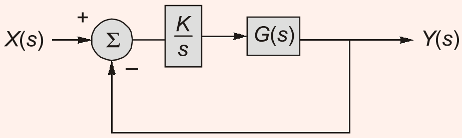
$$R_b = 8 \times 1.476 = 11.808 \simeq 11.81 \text{ Mbps}$$

End of Solution

Q.49 Consider a unity feedback system, as in the figure shown, with an integral compensator $\frac{K}{s}$ and open-loop transfer function

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

where $K > 0$. The positive value of K for which there are exactly two poles of the unity feedback system on the $j\omega$ axis is equal to _____ (rounded off to two decimal places).



Ans. (6)

$$\frac{Y(s)}{X(s)} = \frac{K}{s^3 + 3s^2 + 2s + K}$$

Two poles of this system lie on the $j\omega$ axis when the system is marginally stable.

$$k_{mar} = 3 \times 2 = 6$$

End of Solution

Q.50 Let $h[n]$ be a length-7 discrete-time finite impulse response filter, given by

$$h[0] = 4, \quad h[1] = 3, \quad h[2] = 2, \quad h[3] = 1$$
$$h[-1] = -3, \quad h[-2] = -2, \quad h[-3] = -1,$$

and $h[n]$ is zero for $|n| \geq 4$. A length-3 finite impulse response approximation $g[n]$ of $h[n]$ has to be obtained such that

$$E(h, g) = \int_{-\pi}^{\pi} \left| H(e^{j\omega}) - G(e^{j\omega}) \right|^2 d\omega$$

is minimized, where $H(e^{j\omega})$ and $G(e^{j\omega})$ are the discrete-time Fourier transforms of $h[n]$ and $g[n]$, respectively. For the filter that minimizes $E(h, g)$, the value of $10g[-1] + g[1]$, rounded off to 2 decimal places, is ________ .

Ans. **(–27)**

From Parseval's theorem,

$$\sum_{n=-\infty}^{\infty} |x[n]|^2 = \frac{1}{2\pi}\int_{-\pi}^{\pi} |X(e^{j\omega})|^2 d\omega$$

So, $$\int_{-\pi}^{\pi} |H(e^{j\omega}) - G(e^{j\omega})|^2 d\omega = 2\pi \sum_{n=-3}^{3} |h(n) - g(n)|^2$$

The solution of $g(n)$ that minimizes $E(h, g)$ also minimizes $\sum_{n=-3}^{3} |h(n) - g(n)|^2$.

$$\sum_{n=-3}^{3} |h(n) - g(n)|^2 = |4 - g(0)|^2 + |3 - g(1)|^2 + |-3 - g(-1)|^2 + 10$$

The solution of $g(n)$ that minimizes the above equation is

$$g(n) = \{-3, \underset{\uparrow}{4}, 3\}$$

So, $$10g(-1) + g(1) = 10(-3) + 3 = -27$$

End of Solution

Q.51 Consider a long-channel MOSFET with a channel length 1 μm and width 10 μm. The device parameters are acceptor concentration N_A = 5 × 10^{16} cm^{-3}, electron mobility μ_n = 800 cm^2/V-s, oxide capacitance/area C_{ox} = 3.45 × 10^{-7} F/cm^2, threshold voltage V_T =0.7 V. The drain saturation current (I_{Dsat}) for a gate voltage of 5 V is ____ mA (rounded off to two decimal places). [ε_0 = 8.854 X 10^{-14} F/cm, ε_{Si} = 11.9]

Ans. **(25.52)**

$$I_{D\,(sat)} = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(V_{GS} - V_T)^2$$

$$= \frac{1}{2} \times 800 \times 3.45 \times 10^{-7} \times \frac{10}{1}(5 - 0.7)^2 \text{ A}$$

$$= 25.5162 \text{ mA} \simeq 25.52 \text{ mA}$$

End of Solution

Q.52 A random variable X takes values –1 and +1 with probabilities 0.2 and 0.8. respectively. It is transmitted across a channel which adds noise N, so that the random variable at the channel output is $Y = X + N$. The noise N is independent of X, and is uniformly distributed over the interval –2 , 2]. The receiver makes a decision

$$\widehat{X} = \begin{cases} -1, & \text{if } Y \le \theta \\ +1, & \text{if } Y < \theta \end{cases}$$

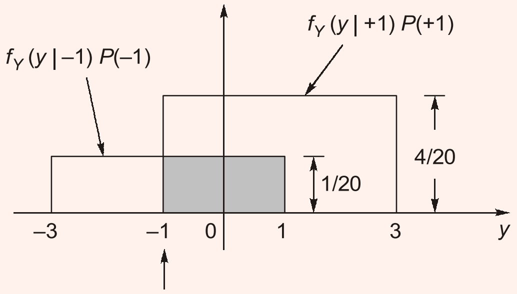
where the threshold $\theta \in [-1, 1]$ is chosen so as to minimize the probability of error $\Pr[\hat{X} \neq X]$. The minimum probability of error, rounded off to 1 decimal place, is ____.

Ans. (0.10)

MAP criteria should be used to minimise the probability of error.

$$f_Y(y \mid +1)\ P(+1) \underset{-1}{\overset{+1}{\gtrless}} f_Y(y \mid -1)\ P(-1)$$

$$P(+1) = 0.80 \text{ and } P(-1) = 0.20$$



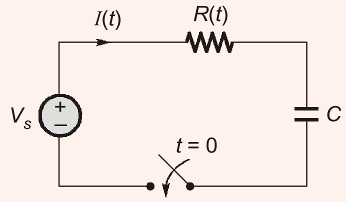
$$P_{e\,(\text{min})} = \text{Shaded area} = 2 \times \frac{1}{20} = 0.10$$

End of Solution

Q.53 The RC circuit shown below has a variable resistance *R(t)* given by the following expression:

$$R(t) = R_o\left(1 - \frac{t}{T}\right) \text{ for } 0 \le t < T$$

where R_o = 1 Ω, and C = 1 F. We are also given that $T = 3R_oC$ and the source voltage is V_s = 1 V. If the current at time t = 0 is 1 A. then the current $I(t)$, in amperes, at time t = $T/2$ is __________ (rounded off to 2 decimal places).



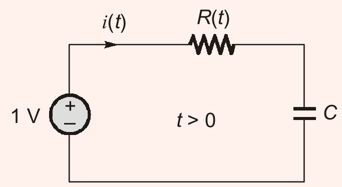
Ans. (0.25)

$$T = 3R_oC = 3\text{sec}$$

$$R(t) = \left(1 - \frac{t}{3}\right) ; \ 0 \le t \le 3 \text{ sec}$$

$$R(t)\ i(t) + \frac{1}{C}\int i(t)dt = 1$$

$$\left(1 - \frac{t}{3}\right) i(t) + \int i(t)dt = 1$$



Differentiating both sides, we get,

$$\left(1 - \frac{t}{3}\right)\frac{di}{dt} - \frac{i}{3} + i = 0$$

$$(3 - t)\frac{di}{dt} + 2i = 0$$

$$\frac{di}{i} = -\frac{2}{(3-t)}dt$$

Integrating on both sides, we get,

$$\ln(i) = 2\ln(3-t) + \ln(c)$$

$$i(t) = c(3-t)^2 \;;\; t \geq 0$$

Given that, $i(0) = 1$ A.

So, $c(3-0)^2 = 1$ A

$$c = \frac{1}{9}\text{ A}$$

$$i(t) = \frac{1}{9}(3-t)^2 \text{ A}$$

At $t = \frac{T}{2} = 1.5\text{ sec}$, $\quad i(1.5) = \frac{1}{9}(1.5)^2 = 0.25\text{ A}$

End of Solution

Q.54 The dispersion equation of a waveguide, which relates the wave-number k to the frequency ω, is

$$k(\omega) = \left(\frac{1}{c}\right)\sqrt{\omega^2 - \omega_0^2}$$

where the speed of light $c = 3 \times 10^8$ m/s, and ω_0 is a constant. If the group velocity is 2×10^8 m/s, then the phase velocity is

(a) 2×10^8 m/s
(b) 3×10^8 m/s
(c) 1.5×10^8 m/s
(d) 4.5×10^8 m/s

Ans. (d)

By definition $v_p = \frac{\omega}{\beta} = \frac{\omega}{k}$

where, $k(\omega) = \left(\frac{1}{c}\right)\sqrt{\omega^2 - \omega_0^2}$ (given)

$$\therefore \quad v_p = \frac{c}{\sqrt{1-\left(\frac{\omega_0}{\omega}\right)^2}}$$

by definition, $\quad v_g = \frac{d\omega}{d\beta} = \frac{d\omega}{dk} \Rightarrow \frac{dk}{d\omega} = \frac{1}{c}\frac{1}{2\sqrt{\omega^2-\omega_0^2}} \times 2\omega$

or $\quad v_g = c\sqrt{1-\left(\frac{\omega_0}{\omega}\right)^2}$

$$\because \quad v_p \cdot v_g = c^2$$

$$\therefore \quad v_p = \frac{c^2}{v_g} = \frac{(3\times10^8)^2}{2\times10^8} = 4.5\times10^8 \text{ m/sec}$$

End of Solution

Q.55 The quantum efficiency (η) and responsivity (R) at a wavelength λ (in μm) in a p-i-n photodetector are related by

(a) $R = \frac{1.24 \times \lambda}{\eta}$

(b) $R = \frac{\eta \times \lambda}{1.24}$

(c) $R = \frac{\lambda}{\eta \times 1.24}$

(d) $R = \frac{1.24}{\eta \times \lambda}$

Ans. **(b)**

$$\eta = \frac{I_{out}}{q} \times \frac{hf}{P_{in}}$$

$$R = \frac{I_{out}}{P_{in}}$$

So,
$$R = \eta \times \frac{q}{hf} = \eta \times \frac{q\lambda}{hc}$$

If λ is given in μm, then

$$R = \eta\lambda \times \frac{q \times 10^{-6}}{hc}$$

$$\frac{hc}{q \times 10^{-6}} \simeq 1.24$$

So,
$$R = \frac{\eta\lambda}{1.24}$$

End of Solution

■■■■