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ISRO

ELECTRONICS ENGINEERING

Written Test of Scientist/Engineer Examination

Date of Test : 12-01-2020

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ISRO (Scientist/Engineer) Examination
Electronics Engineering : Paper Analysis
Exam held on 12.01.2020

Sl.	Subjects	No. of Qs.	Level of Difficulty
1	Electromagnetics	13	Difficult
2	Communication Systems	5	Moderate
3	Network Theory	10	Easy
4	Control Systems	9	Moderate
5	Signals and Systems	3	Easy
6	Digital Electronics	12	Easy
7	Electronic Devices and Circuits	11	Moderate
8	Analog Electronics	12	Moderate
9	Power Electronics	3	Difficult
10	Mathematics	2	Difficult

Q.1 The plane wave propagating through the dielectric has the magnetic field component as $H = 20e^{-ax}\cos(\omega t - 0.25x)\ a_y$ A/m (a_x, a_y, a_z are unit vectors along x, y and z axis respectively).

Determine the polarization of the wave

(a) a_x
(b) $-a_z$
(c) $\dfrac{(a_x + a_y)}{\sqrt{2}}$
(d) a_y

Ans. **(b)**

$$\vec{H} = 20\,e^{-ax}\cos(\omega t - 0.25\pi)\hat{a}_y$$

Electric field direction is called polarization of wave

$$\hat{a}_E = \hat{a}_H \times \hat{a}_p$$

$$= (+\hat{a}_y) \times (+\hat{a}_x)$$

$$\hat{a}_E = -\hat{a}_z$$

End of Solution

Q.2 In free space, $H = 0.1\cos(\omega t - \beta x)\ a_z$ A/m (a_x, a_y, a_z are unit vectors along x, y and z axis respectively). The total power passing through a square plate of side 10 cm on plane $x + 2y = 1.0$, is approximately:

(a) 42.12 mW
(b) 16.85 mW
(c) 18.84 mW
(d) 8.425 mW

Ans. **(d)**

In free space, $\vec{H} = 0.1\cos(\omega t - \beta x)\hat{a}_z$ (A/ m)

Power crossing through a square plate of side 10 cm on plane $x + 2y = 10$

$$\vec{P}_{avg} = \frac{1}{2}H_o^2\eta_0\hat{a}_p$$

$$= \frac{1}{2}(0.1)^2(120\pi)\hat{a}_x = 0.6\pi\hat{a}_x\left(\frac{\text{Watt}}{\text{m}^2}\right) \quad \text{...(i)}$$

$$\vec{S} = (\text{area})\hat{a}_N$$

$$\vec{S} = (0.10)^2\hat{a}_N = 10^{-2}\left(\frac{\hat{a}_x + 2\hat{a}_y}{\sqrt{5}}\right) \quad \text{...(ii)}$$

average power crossing the surface

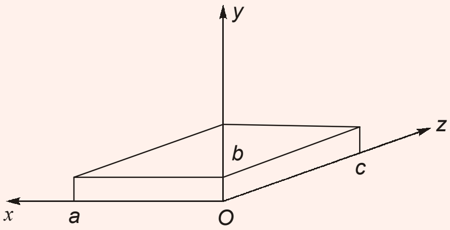
$$P_{avg} = \vec{P}_{avg}\cdot\vec{S}$$

$$= (0.6\pi\,\hat{a}_x)\cdot\left(\frac{10^{-2}}{\sqrt{5}}\right)(\hat{a}_x + 2\hat{a}_y)$$

$$= \frac{10^{-2}}{\sqrt{5}}(0.6\pi) = 8.429 \times 10^{-3}\ \text{Watt} = 8.429\ \text{mW}$$

End of Solution

Q.3 Consider the rectangular cavity as shown below:
If $a = c > b$, the dominant mode of resonance corresponding to the above rectangular cavity is



(a) TE_{011}
(b) TE_{101}
(c) TM_{110}
(d) TM_{011}

Ans. (b)

Rectangular cavity

having $a = c > b$

$$f_{c\,mnp} = \frac{v}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{c}\right)^2}$$ where, m, n, p are integers

Given that b is smaller. So select $n = 0$, to get least cut-off frequency f_{C101}

$$m = 1;\ n = 0;\ p = 1$$

End of Solution

Q.4 A video camera generates data at a rate of 5 Mbps. The data is channel coded at rate 1/3 and 8 PSK modulated. Which of the following statements is correct?

(a) Information rate: 15 Mbps; Symbol rate: 5 Msps
(b) Information rate: 5 Mbps; Symbol rate: 5 Msps
(c) Information rate: 15 Mbps; Symbol rate: 15 Msps
(d) Information rate: 5 Mbps; Symbol rate: 5 Msps

Ans. (a)

Given code rate $= \frac{1}{3} = \frac{k}{n}$

i.e., For every k bits of message bits 'n' number of total bits will be generated.
From given data, for every 1 bit of message bits total 3 number of total bits will be generated.
Given data rate = 5 Mbps
after channel encoding information rate will become 5 Mbps × 3 = 15 Mbps

$$\text{symbol rate} = \frac{\text{Information rate}}{\log_2 m}$$

Given 8-PSK
$$\text{Symbol rate} = \frac{15\text{ Mbps}}{\log_2 8} = \frac{15}{3}$$
$$= 5\text{ Mega symbols/sec} = 5\text{ Msps}$$

End of Solution

Q.5 Evaluate $\int_{-\infty}^{\infty} x^4 f(x)\, dx$, where, $f(x) = \frac{1}{\sqrt{2\pi}} e^{(-x^2/2)}$, $x \in (-\infty, \infty)$

(a) 3
(b) $3\sqrt{\pi}$
(c) $\sqrt{3}\pi$
(d) 3π

Ans. (a)

$$I = \int_{-\infty}^{\infty} x^4 f(x) dx = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} x^4 e^{-x^2/2} dx$$

$$I = \sqrt{\frac{2}{\pi}} \int_0^{\infty} x^4 e^{-x^2/2} dx$$

Let, $\frac{x^2}{2} = y \Rightarrow x\,dx = dy$

So, $I = \sqrt{\frac{2}{\pi}} \int_0^{\infty} 2y\sqrt{2y}\, e^{-y} dy$

$$= \frac{4}{\sqrt{\pi}} \int_0^{\infty} (y)^{3/2} e^{-y} dy = \frac{4}{\sqrt{\pi}} \Gamma\left(\frac{3}{2}+1\right)$$

$$\Gamma\left(\frac{3}{2}+1\right) = \frac{3}{2}\Gamma\left(\frac{3}{2}\right) = \frac{3}{4}\Gamma\left(\frac{1}{2}\right) \qquad \left[\because \Gamma(n+1) = n\Gamma(n)\right]$$

$$I = \frac{4}{\sqrt{\pi}} \times \frac{3}{4} \times \Gamma\left(\frac{1}{2}\right) = \frac{4}{\sqrt{\pi}} \times \frac{3}{4} \times \sqrt{\pi} = 3$$

End of Solution

Q.6 Consider a transformation $T: R^3 \rightarrow R^2$ where R^3 and R^2 represent three and two dimensional real column vectors respectively. Also, $T(x) = Ax$ for some matrix A and for each x in R^3. How many rows and columns does A have and what is the its maximum possible rank?

(a) Rows : 3; Columns : 2; Rank : 3
(b) Rows : 3; Columns : 2; Rank : 2
(c) Rows : 2; Columns : 3; Rank : 2
(d) Rows : 2; Columns : 3; Rank : 3

Ans. (c)

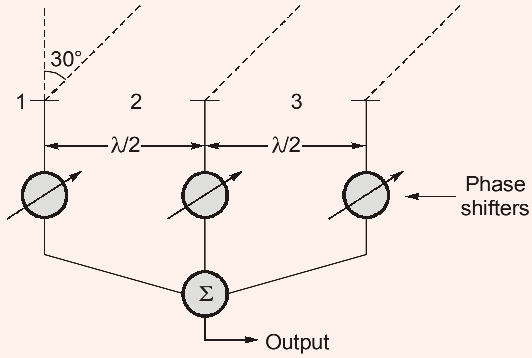
$$T : R^3 \rightarrow R^2$$

$$T(x) = A_{2\times 3} X_{3\times 1}$$

Number of rows = 2
Number of columns = 3
Maximum possible rank = 2

End of Solution

Q.7 The output of a three element co-linear antenna array operating in a free space environment is combined (after appropriate phase shifting) to maximize the signal received from a particular direction as shown in figure.



If the inter-element spacing is half of the signal wavelength and direction of maximum response is 30° from the perpendicular to the array, what are the phases to be applied to each element? Consider the first element as the reference.

(a) $\left[-\frac{\pi}{3} \;\; 0 \;\; \frac{\pi}{3}\right]$

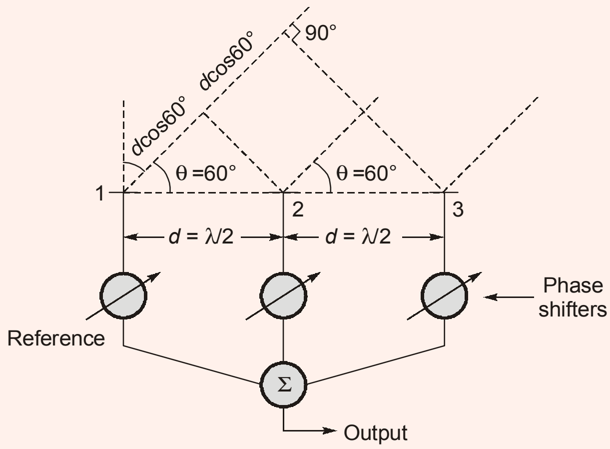
(b) $\left[-\frac{\pi}{4} \;\; 0 \;\; \frac{\pi}{4}\right]$

(c) $\left[0 \;\; \frac{\pi}{2} \;\; \pi\right]$

(d) $\left[0 \;\; \frac{\pi}{4} \;\; \frac{\pi}{2}\right]$

Ans. **(c)**

The angle between array axis and maximum electric field response is 90° – 30° = 60°



Distance phase difference between 1st, 2nd is $\beta d \cos\theta$

$$= \beta d \cos 60°$$

$$= \frac{2\pi}{\lambda}\left(\frac{\lambda}{2}\right)\left(\frac{1}{2}\right) = \frac{\pi}{2} \text{ (lag)}$$

Distance phase differences between 1st and 3rd is

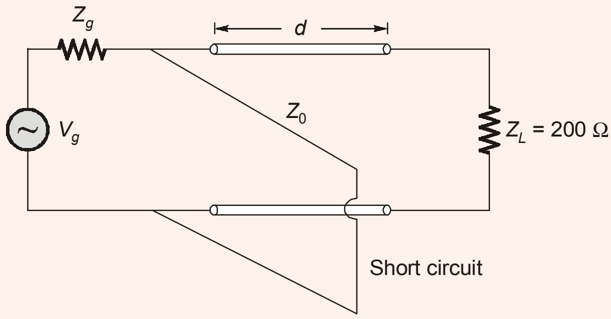
$$= \beta\,(2d \cos 60°)$$

$$= \frac{2\pi}{\lambda} \cdot 2\frac{\lambda}{2}\left(\frac{1}{2}\right) = \pi \text{ (lag)}$$

To get maximum output, we have to take $\left[0 \quad \frac{\pi}{2} \quad \pi\right]$ phases respectively at phase shifters.

End of Solution

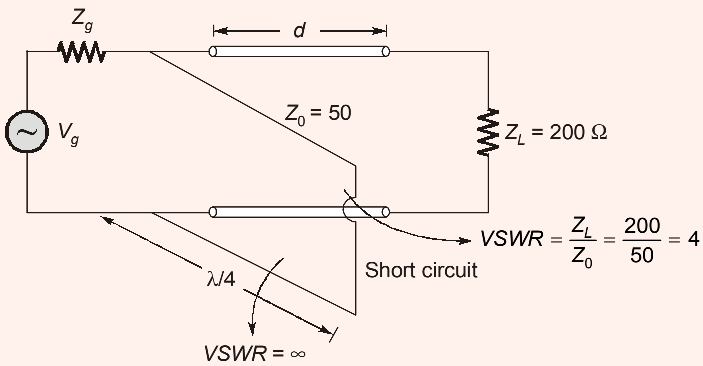
Q.8 The transmission line of characteristic impedance 50 Ω and feeding a purely resistive load of 200 Ω uses single quarter wavelength long short-circuit stub which is placed at a distance *d* from the load. The VSWR on the transmission line section of length d and VSWR on the stub respectively are



(a) 0 and 0 respectively
(b) 1 and 1 respectively
(c) 4 and 1 respectively
(d) 4 and ∞ respectively

Ans. (d)

$$Z_0 = 50\ \Omega;\ Z_L = 200\ \Omega$$



End of Solution

Q.9 The plane $Y = 0$ carries a uniform current density of $-20\hat{k}$ mA/m. The magnetic field intensity at $X = 1$, $Y = 10$ and $Z = -2$ is

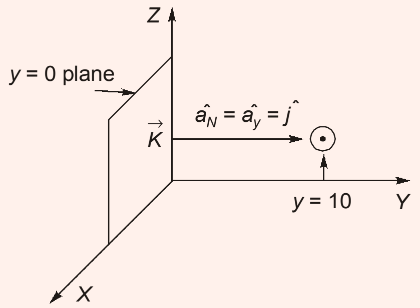
(a) $-10\hat{i}$ mA/m
(b) $10\hat{i}$ mA/m
(c) $-20\hat{i}$ mA/m
(d) $20\hat{i}$ mA/m

Ans. (b)

Plane $y = 0$ has uniform current density of $\vec{K} = -20\hat{k}$ mA/m

To find $\vec{H}$ at

$$X = 1;\ Y = 10 \text{ and } Z = -2$$



$$\vec{H} = \frac{1}{2}\vec{K} \times \hat{a}_N = \frac{1}{2}\left(-20 \times \hat{k} \times 10^{-3}\right) \times \hat{j}$$

$$= -10 \times 10^{-3}(-\hat{i})$$

$$\vec{H} = 10\hat{i} \text{ mA/m}$$

End of Solution

Q.10 A charge of 2 Coulombs is placed near a grounded conducting plate at a distance of 1 m. The force acting between the charge of 2 C and ground conducting plate in Newton is

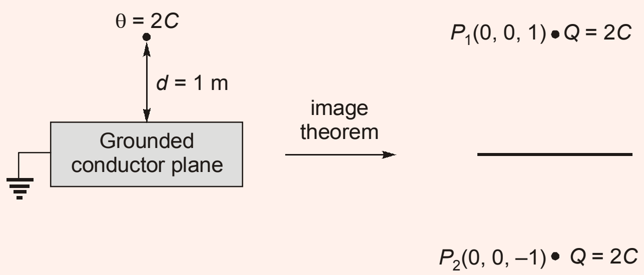
(a) $\frac{1}{4\pi\varepsilon}$

(b) $\frac{1}{8\pi\varepsilon}$

(c) $\frac{1}{16\pi\varepsilon}$

(d) $4\pi\varepsilon$

Ans. (a)



$$P_1(0,\ 0,\ 1) \cdot Q = 2C\ \vec{F}$$

$$P_2(0,\ 0,\ -1) \cdot Q = -2C$$

$$\vec{F} = \frac{Q_1 Q_2 \vec{R}_{12}}{4\pi\varepsilon_0 \left|\vec{R}_{12}\right|^3} = \frac{(2)(-2)2\hat{a}_z}{4\pi\varepsilon_0 (2)^3}$$

$$\vec{F} = \frac{-\hat{a}_z}{4\pi\varepsilon_0}$$

$$\Rightarrow \quad |\vec{F}| = \frac{1}{4\pi\varepsilon}$$

Where,

$$\vec{R}_{12} = \text{(Force point)} - \text{(Other charge point)}$$
$$= (0, 0, 1) - (0, 0, -1)$$
$$\vec{R}_{12} = 2\hat{a}_z$$
$$\vec{R}_{12} = \sqrt{2^2}$$

End of Solution

Q.11 A data sequence $x[n] = \{1, 2, 3, 4, 5\}$ passes through a linear time-invariant system with impulse response $h[n] = \{5, 4, 3, 2, 1\}$. The output of the filter will be

(a) {6, 6, 6, 6, 6}
(b) {5, 8, 9, 8, 5}
(c) {5, 14, 26, 40, 55, 40, 26, 14, 5}
(d) {1, 4, 10, 20, 35, 44, 46, 40, 25}

Ans. (c)

$h(n)$ \ $x(n)$	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

$$y(n) = \{5, 14, 26, 40, 55, 40, 26, 14, 5\}$$

End of Solution

Q.12 Consider a signal $v(t)$ with Fourier transform $V(f)$. If $V'(f)$ represents the Fourier transform of $v(2f)$, what is the relation of $V'(f)$ to $V(f)$?

(a) Magnitude scaled by 0.5 and bandwidth compressed
(b) Magnitude scaled by 0.5 and bandwidth expanded
(c) Magnitude scaled by 2 and bandwidth compressed
(d) Magnitude scaled by 2 and bandwidth expanded

Ans. (b)

$$v'(t) = v(2t) \Longleftrightarrow V'(f) = \frac{1}{2}V\left(\frac{f}{2}\right)$$

Magnitude scaled by 0.5 and bandwidth expanded.

End of Solution

Q.13 If one of the code words of a Hamming (7, 4) code is 0001011, which of the following cannot be the valid code word in the same group?

(a) 0011101 (b) 0101100
(c) 0011010 (d) 1110100

Ans. (c)

Given (7, 4) Hamming code

One of the code word given = 0001011

Hamming code is a single error correcting code : i.e. $t = 1$

To correct upto 't' errors

$$d_{min} \geq 2t + 1$$
$$d_{min} \geq 2 \times 1 + 1$$
$$d_{min} \geq 3$$

i.e., d_{min} should be at least of equals to 3.

Option 'c' given → 0011010

Given codeword = 0001011

Hamming distance between above codewords = 2

So that 0001011 is not a valid codeword for the given code.

End of Solution

Q.14 Which of the following digital modulations can be decoded non-coherently?

(a) QAM (b) APSK
(c) BPSK (d) BFSK

Ans. (d)

End of Solution

Q.15 A mobile antenna receives two copies of the signal transmitted by the base station. The first copy is the line-of-sight component and the other is a reflected component which is 20 dB weaker in terms of Power than the LoS component and delayed by 100 ns. If the signal is sufficiently wideband, causing constructive and destructive interference at different frequency points within the signal bandwidth. What will be the ratio of maximum to minimum signal level variation across bandwidth and what will be the frequency separation between two consecutive maxima or minima?

(a) $\frac{101}{99}$, 10 MHz (b) $\frac{121}{81}$, 10 MHz
(c) $\frac{101}{99}$, 5 MHz (d) $\frac{121}{81}$, 5 MHz

Ans. (a)

Given that reflected component is weaker in terms of power than the LoS component by 20 dB.

$$\text{Return loss} = 10\log_{10}\frac{1}{|\tau|} = 20 \text{ dB}$$

$$\frac{1}{|\tau|} = 100$$

$$|\tau| = 0.01$$

$$\text{VSWR} = \frac{V_{max}}{V_{min}} = \frac{1+|\tau|}{1-|\tau|} = \frac{1+0.01}{1-0.01} = \frac{1.01}{0.99} = \frac{101}{99}$$

$$\text{VSWR} = \frac{V_{max}}{V_{min}} = \frac{101}{99}$$

Given, delay = 100 nsec
Total delay = 200 nsec

$$f = \frac{1}{200 \times 10^{-9}} = 5 \text{ MHz}$$

Maximum to maximum gap is $\lambda/2$
So $f = 5 \times 2 = 10$ MHz

End of Solution

Q.16 An antenna with an efficiency of 90% has a maximum radiation intensity of 0.5 W/Steradian. Calculate the directive gain of the antenna when the input power to the antenna when the input power to the antenna is 0.4 W

(a) 18.23
(b) 17.4
(c) 11.2
(d) 21.6

Ans. **(b)**

$\eta_r \% = 90\%$
$U_{max} = 0.5$ W/Steradian
$P_{in} = 0.4$ Watt;

Find G_d

$$\Rightarrow \quad \eta_r = \frac{P_{rad}}{P_{in}} \Rightarrow P_{rad} = (0.9)(0.4) = 0.36 \text{ Watt}$$

$$\Rightarrow \quad G_d = \frac{4\pi U(\theta, \phi)}{P_{rad}} = \frac{4\pi(0.5)}{0.36} = \frac{50}{9}\pi = 17.44$$

End of Solution

Q.17 In a semiconductor device, if Fermi level (E_F) is positioned at conduction band (E_C). Determine the approximate probability of finding electrons in states at ($E_C + kT$) (where k is Boltzmann constant and T is device temperature in Kelvin).

(a) 0.18
(b) 0.27
(c) 0.38
(d) 0.52

Ans. (b)

$$f(E) = \frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)}$$

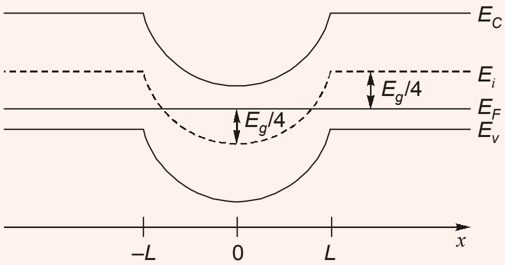
$$E = E_c + kT$$

$$E_F = E_c$$

So,
$$f(E) = \frac{1}{1+\exp(1)} \simeq 0.27$$

End of Solution

Q.18 For the following energy band diagram, determine the approximate resistivity for $x > L$ portion of semiconductor. $E_g = 1.12$ eV, $T = 300$ K, $\mu_n = 600$ cm^2/V-sec, $\mu_p = 400$ cm^2/V-sec, $n_i = 10^{10}$/cm^3.



(a) 11.00 ohm-cm
(b) 15.75 ohm-cm
(c) 23 ohm-cm
(d) 31.25 ohm-cm

Ans. (d)

For $x > 0$, device acts as p-type

$$P_o = n_i \exp\left(\frac{E_i - E_F}{kT}\right)$$

$$E_i - E_F = \frac{E_g}{4} = 0.28$$

$$P_o = (10^{10})\exp\left(\frac{0.28}{0.0259}\right) \simeq 5\times10^{14}\ \text{cm}^{-3}$$

$$P = \frac{1}{P_o q \mu_p} = \frac{1}{(5\times10^{14})(1.6\times10^{-19})(400)}$$

$$= \frac{1000}{32} = 31.25\ \Omega\text{-cm}$$

End of Solution

Q.19 The radiation intensity of a given antenna is $U = 2(\sin\theta \sin\phi)$ in the range $0 \le \theta \le \pi$ and $0 \le \phi \le \pi$ and 0 elsewhere. The direction is

(a) 3 dB
(b) 6 dB
(c) 8 dB
(d) 9 dB

Ans. (b)

$$U(\theta,\phi) = 2\sin\theta\sin\phi \text{ for } \begin{cases} 0 \le \theta \le \pi \\ 0 \le \phi \le \pi \end{cases}$$

Find directivity (D), $$D = \frac{4\pi U_{max}}{P_{rad}} \quad \text{...(i)}$$

Given, $$U_{max} = 2 \quad \text{...(ii)}$$

$$P_{rad} = \iint U(\theta,\phi)\, d\Omega$$

$$= \iint 2\sin\theta\sin\phi(\sin\theta\, d\theta\, d\phi)$$

$$= \int 2\sin^2\theta\, d\theta \int \sin\phi\, d\phi$$

$$= \int_{\theta=0}^{\pi} (1-\cos 2\theta)d\theta \int_{\phi=0}^{\pi} \sin\phi\, d\phi$$

$$= \left(\pi - \left(\frac{\sin 2\theta}{2}\right)_{\theta=0}^{\pi}\right)(-\cos\phi)_{\phi=0}^{\pi}$$

$$= (\pi - 0)2$$

$$P_{rad} = 2\pi \quad \text{...(iii)}$$

Put equation (ii), (iii) in (i)

$$D = \frac{4\pi(2)}{2\pi} = 4$$

$$D(\text{dB}) = 10\log_{10}4 = 6.02 \text{ dB}$$

End of Solution

Q.20 Which of the following is an example of oversampling ADC architecture?

(a) Sigma delta
(b) Successive approximation
(c) Integrator
(d) Flash

Ans. (a)

An analog signal first undergoes the process of sampling before it is applied to ADC for conversion into a digital signal.

Oversampling is a process in which an analog signal is sampled at a sampling frequency that is much greater than the Nyquist rate. A Sigma-Delta ADC is an example of a ADC that employs oversampling.

End of Solution

Q.21 A radar receiver has a detection SNR threshold of 10 dB for a 4 MHz bandwidth signal at 300 MHz frequency. If the transmit EIRP of the radar is 40 dBW and receive G/T is 10 dB/K, what is the maximum Radar cross-section (in dB-meter square) detectable at 10 km range? (Given: $10\log(4\pi) = 11$, $10\log(k) = -228.6$, k is Boltzmann constant).

(a) -15.6 dBm^2
(b) -12.6 dBm^2
(c) -9.6 dBm^2
(d) -5.6 dBm^2

Ans. **(c)**

$$P_r = \frac{P_t G_t^2 \lambda^2 \sigma}{(4\pi)^3 R^4}$$

$$\text{SNR} = \frac{P_r}{N_o B} = \frac{P_r}{kTB}$$

In decilogs,

$$[\text{SNR}] = [\text{EIRP}] + \left[\frac{G}{T}\right] - [K] - [B] + \left[\frac{\lambda^2}{(4\pi)^3 R^4}\right] + [\sigma]$$

$$[\text{SNR}] = 10 \text{ dB}$$

$$[\text{EIRP}] = 40 \text{ dBW}$$

$$[K] = -228.6 \text{ dB-Hz/K}$$

$$\left[\frac{G}{T}\right] = 10 \text{ dB/K}$$

$$[B] = 10\log_{10}(4 \times 10^6) = 66 \text{ dB-Hz}$$

$$\left[\frac{\lambda^2}{(4\pi)^3 R^4}\right] = 10\log_{10}\left[\frac{(1)^2}{(4\pi)^3 (10^4)^4}\right] = -3(11) - 160 = -193 \text{ dB m}^2$$

So,

$$[\sigma] = 10 - 40 - 10 - 228.6 + 66 + 193$$

$$= -9.6 \text{ dB-m}^2$$

End of Solution

Q.22 A source generates four messages m1, m2, m3 and m4 with probabilities 0.5, 0.25, 0.125 and 0.125 respectively. The messages are generated independently of each other. A source coder assigns binary code to each message. Which of the following codes has minimum average length is also uniquely decodable (sequence as per m1, m2, m3, m4)?

(a) 00, 01, 10, 11
(b) 0, 1, 10, 11
(c) 110, 111, 10, 0
(d) 0, 10, 110, 111

Ans. **(d)**

$P_1 = 0.5$, $P_2 = 0.25$, $P_3 = 0.125$, $P_4 = 0.125$

Uniquely decodable code means a code should not be prefix to another code.

Option (b) is not uniquely decodable i.e. 0, 1, 10, 11

'1' is prefix to last code '11'

Option (a) ⇒ 00, 01, 10, 11

$$\text{Average code length} = \Sigma n_i \, P_i$$

$$= 2 \times 0.5 + 2 \times 0.25 + 2 \times 0.125 + 1 \times 0.125$$

$$L = 2$$

Option (c) ⇒ 110, 111, 10, 0

$$L = 3 \times 0.5 + 3 \times 0.25 + 2 \times 0.125 + 1 \times 0.125$$

$$L = 2.625$$

Option (d) ⇒ 0, 10, 110, 111

$$L = 1 \times 0.5 + 2 \times 0.25 + 3 \times 0.125 + 3 \times 0.125$$

$$L = 1.75$$

Option (d) is giving minimum average code length.

End of Solution

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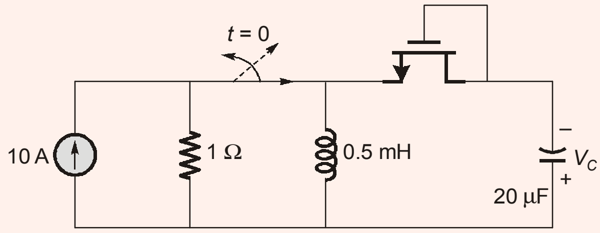
Q.23 For the given circuit, switch remains closed for a long time and opens at $t = 0$ seconds. Assuming ideal model for every device, find steady state magnitude of voltage at capacitor.

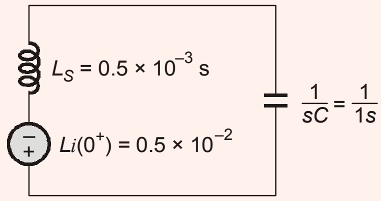


(a) 1
(b) 25
(c) 50
(d) 100

Ans. **(c)**

$$i_L(\delta) = 10 \text{ A}, \quad V_c(0^-) = 0$$

For $t = 0$



$$I(s) = \frac{0.5 \times 10^{-2}}{0.5 \times 10^{3} s + \frac{10^6}{20s}}$$

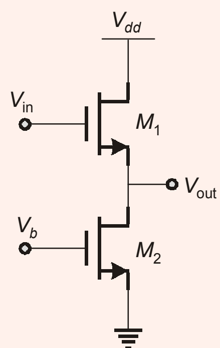
$$V_c(s) = \frac{1}{Cs} I(s) = \frac{10^4(50)}{S^2 + 10^8}$$

$$v_c(t) = L^{-1}\ v_c(s) = 50 \sin 10^4 t$$

Steady state voltage is 50 V.

End of Solution

Q.24 For the given circuit, aspect ratio of M_1 transistor is 20/0.5, I_{D1} = 200 μA, V_{THO} = 0.6 V, $2\phi_F$ = 0.81 V, γ = 0.4 V_2 and $\mu_n C_{ox}$ = 59.5 mA/V^2. If V_{in} = 1.2 V, find the minimum value of aspect ratio of M_2 transistor to remain saturated. $(\sqrt{10} = 3.16)$



(a) 92
(b) 195
(c) 280
(d) 560

Ans. (*)

For M_1, $V_T = V_{T0} + \gamma\left[\sqrt{2\phi_F + V_{SB}} - \sqrt{2\phi_F}\right]$

Since V_{SB} value is not provided, assume $V_{SB} = 0$

$\Rightarrow$ $V_T = V_{T0} = 0.6$ V

For M_1 to remain in conduction,

$$V_{GS1} > V_T$$

$$V_{in} - V_{out} > 0.6 \text{ V}$$

Now, $V_{DS2} = V_{out} \Rightarrow V_{DS2} < 0.6$ V

M_2 will operate in saturation if $V_{DS2} \geq V_{GS2} - V_T$

or $V_{GS2} - V_T \leq V_{DS2}$

$\Rightarrow$ $V_{GS2} - V_T \leq 0.6$ V

$$I_{DS2} = \frac{\mu_n C_{ox}}{2} \times \frac{W}{L}(V_{GS2} - V_T)^2$$

$$200 = \frac{59.5}{2} \times \frac{W}{L}(V_{GS2} - V_T)^2$$

$$\frac{W}{L} = \frac{400}{59.5(V_{GS2} - V_T)^2}$$

$$\frac{W}{L} = \frac{400}{59.5 \times 0.6^2} \Rightarrow \frac{W}{L} \geq 18.67$$

None of the given options match according to this solution.

Alternatively Solution:

But if we consider both transistors to be in saturation region then

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

$$200 \text{ μA} = \frac{1}{2}(59.5 \times 10^{-6}) \times \frac{20}{0.5}(1.2 - V_o - V_T)^2$$

$$1.2 - V_o - V_T = 0.4$$

$$1.2 - 0.6 - 0.4 = V_o$$

$$V_o = 0.2$$

$$V_{DS} = V_{GS} - V_T$$

$$V_{GS} = 0.2 + 0.6 = 0.8 \text{ V}$$

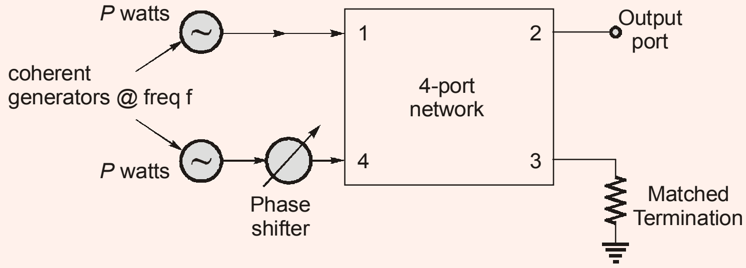
$$200 \times 10^{-6} = \frac{1}{2}(59.5 \times 10^{-6})\left(\frac{W}{L}\right)(0.8 - 0.6)^2$$

$$\frac{W}{L} = 168$$

Approximately option (b) satisfies.

End of Solution

Q.25 Two coherent microwave power sources of same frequency *f*, each generating *P* Watts of average power, are combined using a four port network in the following manner:



If the S-parameter of 4-port network are $\begin{bmatrix} 0 & \frac{j}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \\ \frac{j}{\sqrt{2}} & 0 & 0 & \frac{-1}{\sqrt{2}} \\ \frac{-1}{\sqrt{2}} & 0 & 0 & \frac{j}{\sqrt{2}} \\ 0 & \frac{-1}{\sqrt{2}} & \frac{j}{\sqrt{2}} & 0 \end{bmatrix}$, what should be the phase difference between the inputs to maximize the output at port 2 and what is the maximum power?

(a) 90°, $2P$ (b) $[90°, \sqrt{2}P]$

(c) 45°, $2P$ (d) $[45°, \sqrt{2}P]$

Ans. **(a)**

The signal component at port-2 can be written as,

$$a_2 = s_{21}a_1 + s_{24}a_4$$

Let, $a_1 = |a_p|e^{j\alpha}$

$$a_4 = |a_p|e^{j0°}$$

here, α = Phase difference between the inputs

$|a_p|$ is the signal component that gives *P* watts average power.

So, $a_2 = |a_p|e^{j\alpha}\left(\frac{j}{\sqrt{2}}\right) + |a_p|\left(-\frac{1}{\sqrt{2}}\right)$

$$= |a_p|\left[\frac{j}{\sqrt{2}}e^{j\alpha} + \left(-\frac{1}{\sqrt{2}}\right)\right]$$

To get maximum power at part-2,

$$\frac{j}{\sqrt{2}} e^{j\alpha} = -\frac{1}{\sqrt{2}} \Rightarrow e^{j\alpha} = j$$

So, $\alpha = 90°$

Now with $\alpha = 90°$, $a_2 = 2\left(-\frac{1}{\sqrt{2}}\right)|a_p| = -\sqrt{2}|a_p|$

If the average power of $|a_p| = P$ watts, then the average power of $a_2 = -\sqrt{2}|a_p|$ will be $2P$ watts.

End of Solution

Q.26 Which of the following statement is wrong?

(a) $(1000.64)_8 = (1000000000.1101)_2$
(b) $(512.512) = (4022.224)_5$
(c) $(2202)_6 = (426)_{11}$
(d) $(0.23)_4 = (0.1011)_2$

Ans. **(c)**

$$(0.23)_4 = (0.1011)_2$$
$$2 \times 6^3 + 2 \times 6^2 + 0 + 2 \times 6^0 \neq (426)_{11}$$

End of Solution

Q.27 Which of the following statement is correct?

(a) NAND and NOR functions are Commutative and Associated
(b) Both NAND and NOR functions are neither Commutative nor Associative
(c) NAND and NOR functions are Associative but Commutative
(d) NAND and NOR functions are Commutative but not Associative

Ans. **(d)**

$$\overline{A \cdot B} = \overline{B \cdot A}$$

and $$\overline{A + B} = \overline{B + A}$$

Hence, NAND and NOR functions are commutative.

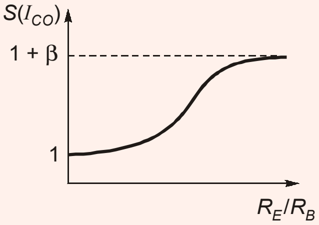
$$\overline{\overline{AB} \cdot C} \neq \overline{A \cdot \overline{B \cdot C}}$$

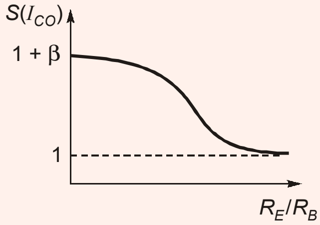
and $$\overline{\overline{A + B} + C} \neq \overline{A + \overline{B + C}}$$

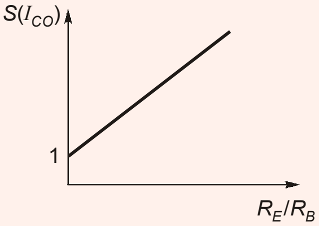
Hence, NAND and NOR function are not associative.

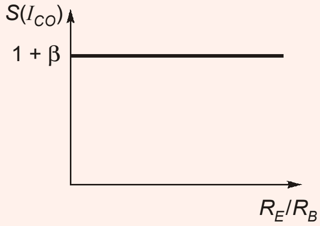
End of Solution

Q.28 Which one plot gives the closed resemblance to the stability $S(I_{CO})$ of emitter bias configuration of BJT with respect to $\frac{R_E}{R_B}$? (R_E is emitter resistance and R_B is base resistance)

(a)


(b)


(c)


(d)


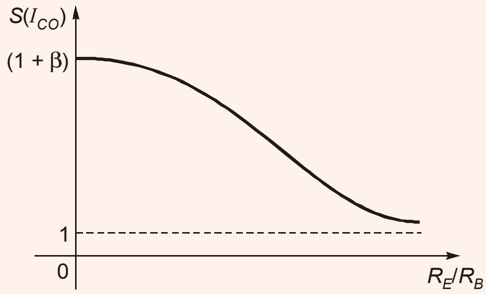
Ans. (b)

$$S = \frac{1+\beta}{1-\beta\frac{\partial I_B}{\partial I_C}}$$

$$\frac{\partial I_B}{\partial I_C} = -\frac{R_E}{R_B+R_E}$$

$$S = \frac{1+\beta}{1+\beta\frac{R_E}{R_B+R_E}}$$

$$S = \frac{(1+\beta)(R_B+R_E)}{R_B+(1+\beta)R_E}$$



If, $R_E = 0$

$$S = \frac{(1+\beta)R_B}{R_B} = (1+\beta)$$

If, $R_E >> R_B$

$$S = \frac{(1+\beta)R_E}{(1+\beta)R_E} = 1$$

Alternatively Solution:

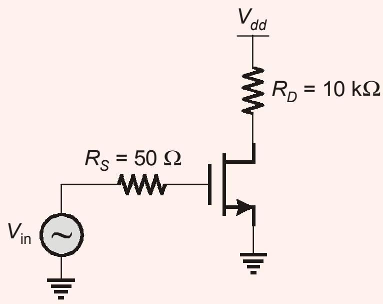
$$S = \frac{1+\beta}{1+\frac{\beta R_E}{R_D+R_E}}$$

If $R_E = 0$ then $\frac{R_E}{R_B} = 0 \Rightarrow S = 1 + \beta$

If $R_E \uparrow$ then S reduces upto 1

End of Solution

Q.29 For the given amplifier circuit, find the input cut-off frequency. FET parameters are g_m = 4 mA/V, C_{gs} = 4 pf, r_{ds} = 40 kΩ, C_{gd} = 2 pF.



(a) 35.5 MHz
(b) 45.5 MHz
(c) 90.5 MHz
(d) 10.5 MHz

Ans. (b)

Given data,

$$g_m = 4 \text{ mA/V}$$
$$C_{gs} = 4 \text{ pF}$$
$$r_{ds} = 40 \text{ k}\Omega$$
$$C_{gd} = 2 \text{ pF}$$

$$f_H = \frac{1}{2\pi\{C_{gs} + (1 + A_v)\,C_{gd}\}\,R_s || \infty}$$

$$= \frac{1}{2\pi\{C_{gs} + (1 + A_v)\,C_{gd}\}\,R_s}$$

$$A_v = -g_m r_d || R_D = \frac{4 \times 40 \times 10}{50}$$

$$= -32$$

$$f_H = \frac{1}{2 \times 3.14\,\{4\text{pf} + (1 + 32)\,2\text{pf}\}\,50\,\Omega}$$

$$= \frac{1}{2 \times 3.14 \times 10^{-12}\{70\} \times 50}$$

$$= \frac{1}{2 \times 3.14 \times 3500 \times 10^{-12}}$$

$$= \frac{1}{219.8 \times 10^{-10}} = 0.0045 \times 10^{10}$$

$$f_{Hi} = 45.49 \text{ MHz}$$

End of Solution

Q.30 Which of the following digital devices requires an external refresh circuit?

(a) FLASH Memory (b) E^2PROM
(c) SRAM (d) DRAM

Ans. (d)

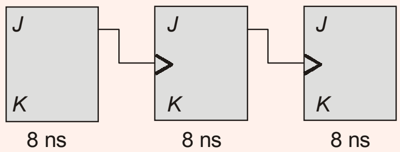
A DRAM stores data in the form of charge on capacitor. Since a capacitor has a natural tendency to discharge, for valid operation it is required to recharge/refresh the charge on capacitor again and again at periodic instants of time to maintain the charge across the capacitor.

End of Solution

Q.31 What would be the maximum operating frequency of Mod-8 counter constructed with JK flip flops, having propagation delay of 8 ns?

(a) 16.525 MHz (b) 15.625 MHz
(c) 25.625 MHz (d) 18.525 MHz

Ans. (b)



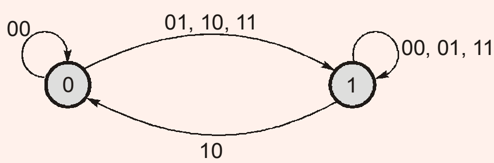
Total delay = 24 ns

$$\text{maximum frequency} = \frac{1}{24\,\text{ns}} \Rightarrow \frac{1000}{24}\,\text{MHz} = 41.667\,\text{MHz}$$

answer not matching
Closest answer is (b).
Might be asking 8 FFs, not MOD-8 then answer is 15.625 MHz.

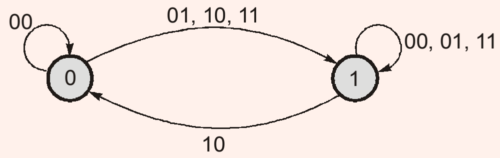
End of Solution

Q.32 The following state diagram represents which of the input equation. (Given $D_A = [A, x, y]$) (Where D_A denotes a DFF with output. The x and y are the inputs to the circuit)

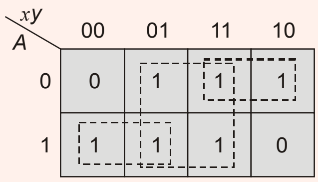


(a) $D_A = A \oplus x \oplus y$
(b) $D_A = A + x \oplus y$
(c) $D_A = A \oplus x + y$
(d) $D_A = A + x + y$

Ans. **(c)**



$A\,x\,y$	A^+
0 0 0	0
0 0 1	1
0 1 0	1
0 1 1	1
1 0 0	1
1 0 1	1
1 1 0	0
1 1 1	1



$$A^+ = y + \bar{A}x + A\cdot\bar{x}$$

$$D_A = A^+ = y + A\oplus x = A\oplus x + y$$

End of Solution

Q.33 Which of the following logic circuits do not have no-change condition?

(a) D-FF (b) T-FF

(c) JK-FF (d) SR-latch

Ans. **(a)**

"No change condition" refers to "Hold State" of the circuit.

A T–FF, JK–FF and SR–Latch have input conditions that drive them in Hold State. However, a D–FF does not have such an input condition. In a D–FF, the output follows the data input.

D	$Q_n + 1$	
0	0	⇒ Reset State
1	1	⇒ Set State

End of Solution

Q.34 In VHDL, following statement is written a process, where Clock frequency is 24 MHz.

```
If (clock' event and clock = '1') then
   counter_4bit <= counter_4bit + x "1";
End if;
```

The frequency of counter_4bit (2) will be:

(a) 12 MHz (b) 4 MHz

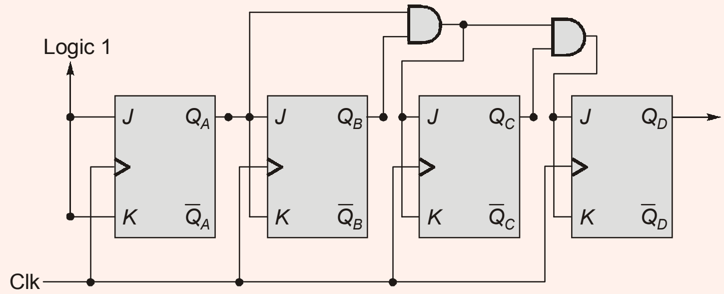
(c) 6 MHz (d) 3 MHz

Ans. (d)

f_{clk} = 24 MHz

If (clock'event and clock = '1') then

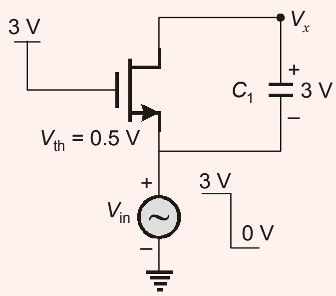
counter_4bit <= counter_4bit + x "1";

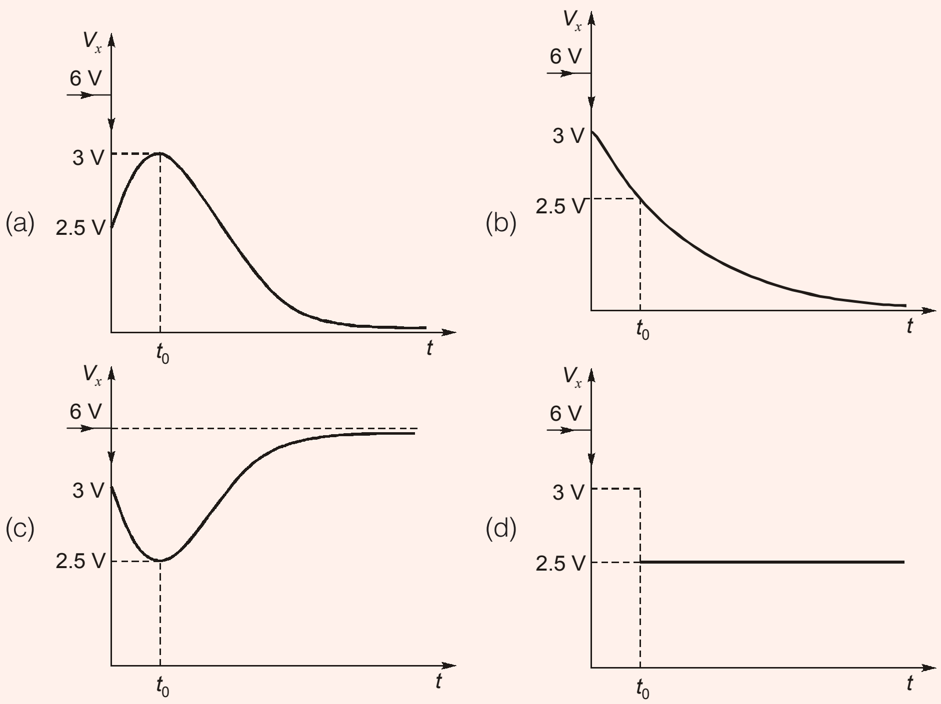


frequency at counter_4 bit(2) = 3 MHz

End of Solution

Q.35 Initial voltage of C_1 capacitance is 3 V in the given circuit. Correct sketch of V_x as a function of time is. (Threshold voltage (V_{th}) = 0.5 V)





Ans. (b)

For $t < 0$: $V_{GS} = 3 - 3 = 0$

MOSFET is OFF

$V_x = 3 + 3 = 6$ V

At t = 0: $V_x = 3$ V

For $t > 0$: $V_{GS} = 3 - 0 = 3$ V

MOSFET becomes ON so capacitor discharges through MOSFET upto 0.

End of Solution

Q.36 An SRAM has address lines from A_0 to A_{19} and data width from D_0 to D_{15}. Total capacity of the SRAM will be

(a) 20 MB
(b) 16 MB
(c) 8 MB
(d) 4 MB

Ans. (b)

In SRAM the number of address lines = 20

Number of data lines = 16

Capacity of RAM = $2^{20} \times 16 = 16$ Mbits

Note: Correct answer is 2 MB, but none of the above option is matching.

End of Solution

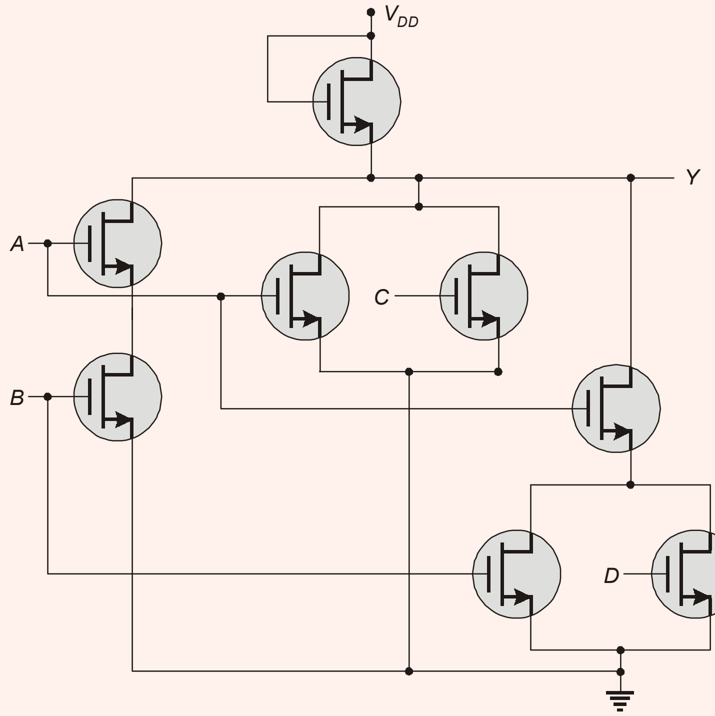
Q.37 Which of the following digital integrated circuit cannot be used as wired logic connections?

(a) Totem-pole TTL gate
(b) Open collector TTL gate
(c) Totem-pole output with 3-state gate
(d) Emitter Coupled Logic

Ans. (a)

End of Solution

Q.38 The logic function implemented by following circuit can be represented as

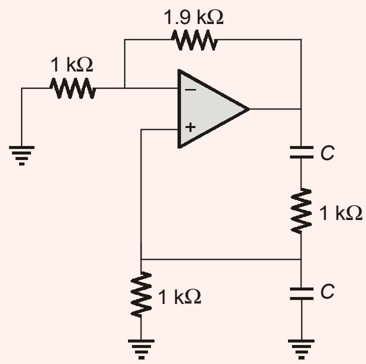


(a) $Y = [(AB) + (B + C) + (B + D)]'$
(b) $Y = [(AB) + (A + C) + (B + D)]'$
(c) $Y = [(AB)' + (A + C)' + (AB + D)]'$
(d) $Y = [(AB) + (A + C) + (AD)]'$

Ans. (d)

End of Solution

Q.39 The value of C required for sinusoidal oscillation of frequency = 2 kHz in the given circuit is



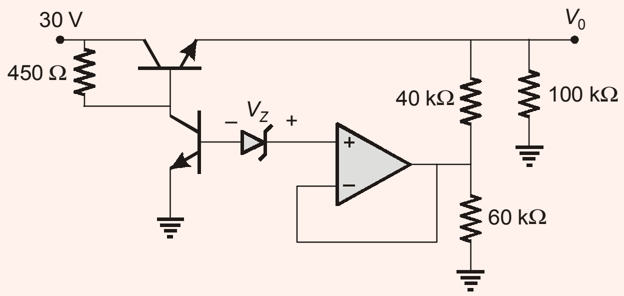
(a) $\frac{1}{(2\pi)}\mu F$
(b) $\frac{1}{(4\pi)}\mu F$
(c) $\frac{1}{\pi}\mu F$
(d) None of these

Ans. (d)

Given circuit is Wien-bridge oscillation. It will act as oscillator if $R_2 \geq 2R_1$. But given circuit does not satisfy above condition,
Hence if cannot act as oscillator.

End of Solution

Q.40 In the given circuit, V_{be} = 0.7 V, V_z = 5.3 V, β = 100. V_0 is



(a) 5 V
(b) 10 V
(c) 15 V
(d) 20 V

Ans. (b)

If output current of op-amp is neglected then 40 kΩ and 60 kΩ from voltage divider

$$V^- = \frac{V_o \times 60}{40 + 60} = 0.6\,V_o$$

$$V^- = V_z + V_{BE} = 6 \text{ V}$$

By using virtual short,

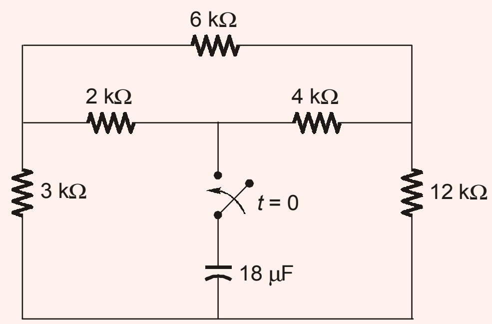
$$V^- = V^+$$

$$0.6V_o = 6$$

$$V_o = 10 \text{ V}$$

End of Solution

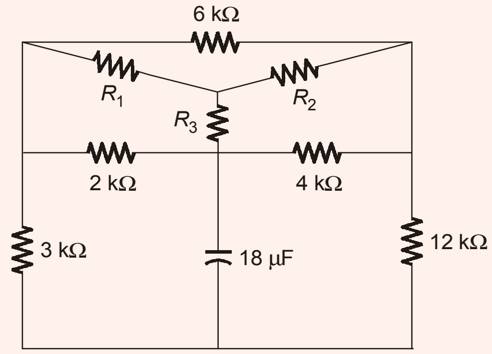
Q.41 A 18 μf capacitor holding charge of Q coulomb is connected to the circuit at time t = 0 sec.



The time at which the capacitor will be discharged to approximately Q/2.72 coulombs.

(a) 68 ms
(b) 34 ms
(c) 17 ms
(d) 2.72 ms

Ans. (a)

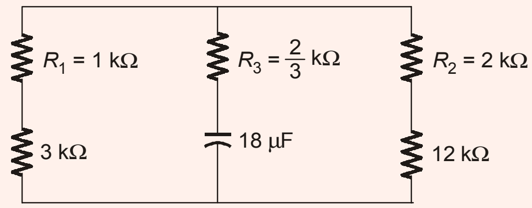


By transforming delta to star

$$R_1 = \frac{2\times 6}{2+6+4} = 1\,k\Omega$$

$$R_2 = \frac{6\times 4}{2+6+4} = 2\,k\Omega$$

$$R_3 = \frac{2\times 4}{2+6+4} = \frac{2}{3}\,k\Omega$$



$$R_{eq} = \frac{2}{3} + \frac{14\times 4}{14+4} = 3.778\,k\Omega$$

For discharging capacitor

$$Q' = Qe^{-t/R_{eq}C}$$

$$\frac{Q}{2.72} = Qe^{-t/R_{eq}C}$$

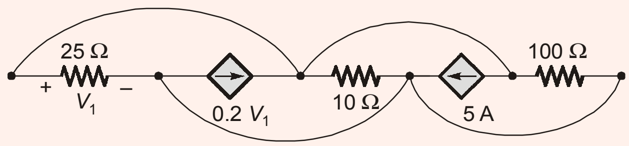
$$\frac{-t}{R_{eq}C} = \ln\left[\frac{1}{2.72}\right]$$

$$t = 1.0023 \times 3.778 \times 10^3 \times 18 \times 10^{-6}$$

$$t = 68\text{ ms}$$

End of Solution

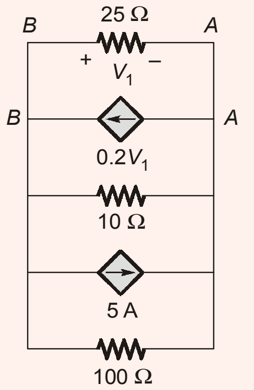
Q.42 Determine the value of voltage V_1 in the figure shown below.



The value of voltage V_1 in volts is

(a) 100 V
(b) 14.28 V
(c) 50 V
(d) 68.25 V

Ans. (a)



By KCL,

$$V_1\left[\frac{1}{25}+\frac{1}{10}+\frac{1}{100}\right]+5 = 0.2V_1$$

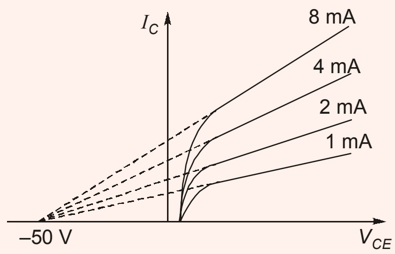
$$V_1[0.15] + 5 = 0.2V_1$$

$$0.05V_1 = 5$$

$$V_1 = 100 \text{ V}$$

End of Solution

Q.43 Output characteristics of a BJT amplifier is given. Find the minimum collector current required for r_0 = 50 kΩ. (r_0 is output resistance)



(a) 1 mA
(b) 5 mA
(c) 10 mA
(d) 100 mA

Ans. (a)

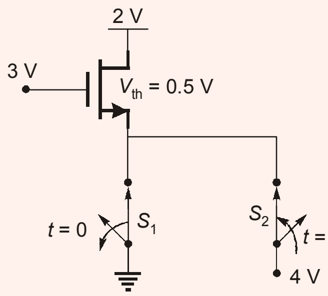
$$r_o \simeq \frac{V_A}{I_C}$$

From given graph, $V_A = 50$ V

$$I_C = \frac{V_A}{r_o} = \frac{50}{50} = 1\text{mA}$$

End of Solution

Q.44 In the given circuits, S_1 switch remains closed and S_2 remains open for the long time. At t = 0, S_1 opens and S_2 closes and remain in this position for the long time. Find drain current for $t < 0$ and $t >> 0$ respectively if, $\mu_n C_{ox}$ = 100 μA/V^2 and Aspect ratio = 2.



(a) 600 μA, 0 μA
(b) 600 μA, 25 μA
(c) 600 μA, –25 μA
(d) 0 μA, 600 μA

Ans. **(a)**

If we consider unidirectional MOS then

For $t < 0$: S_1 – closed

S_2 – open

V_{GS} = 3 V ⇒ MOSFET is in conduction

V_{DS} = 2 V

$V_{GS} - V_T$ = 2.5 V

$V_{DS} < V_{GS} - V_T$ = Linear region

$$I_{DS} = \mu_n C_{ox} \frac{W}{L}\left[(V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2}\right]$$

$$= 100 \times 2\left[2.5 \times 2 - \frac{4}{2}\right] = 600\ \mu\text{A}$$

For $t > 0$: S_1 – open

S_2 – closed

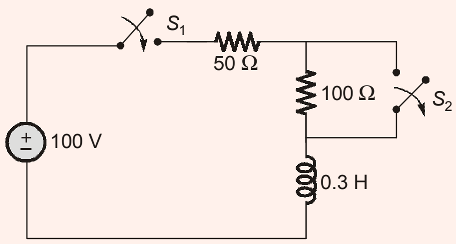
V_{GS} = 3 – 4 = –1 V

$V_{GS} < V_T$ ⇒ MOSFET becomes OFF

and I_{DS} = 0

End of Solution

Q.45 In the circuit shown below, switch S_1 is closed at t = 0 seconds. Switch S_2 is opened at t = 0 seconds.



The current flowing through the inductor of 0.3 H at t = 8 mili seconds is

(a) 0.65 mA
(b) 0.32 mA
(c) 0.26 mA
(d) 0.18 mA

Ans. (a)

$$i(t) = \frac{V}{R}\left[1-e^{-Rt/L}\right] = \frac{100}{150}\left[1-e^{-150t/0.3}\right]$$

$$i = \left[1-e^{-150\times 8\times 10^{-3}/0.3}\right]$$

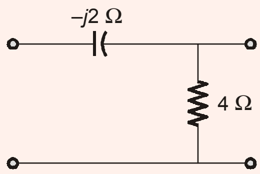
$$i = 0.65 \text{ A}$$

Note: There may be a misprint in the question paper for option 'a' as the correct answer is 0.65 A.

End of Solution

Q.46 The transmission parameters of the network given below is represented in the matrix form as

$$[T] = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

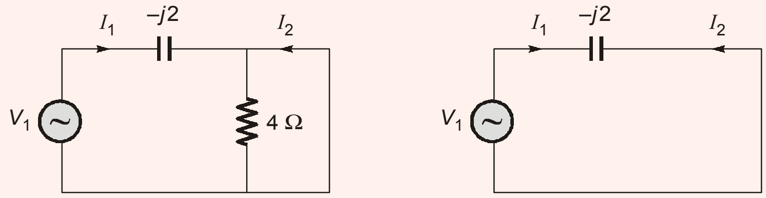


Calculate the Transmission parameter B of $[T]$ matrix.

(a) $j2$ ohms
(b) $-j2$ ohms
(c) $-j2 + 4$ ohms
(d) 4 ohms

Ans. (b)

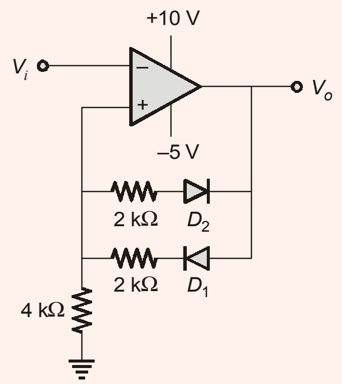
$$B = -\left.\frac{V_1}{I_2}\right|_{V_2=0}$$

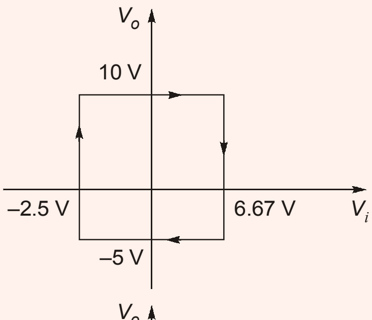


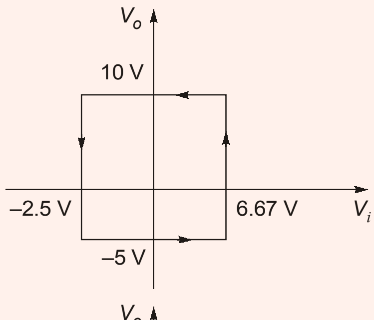
$$B = -\frac{V_1}{I_2} = -j2\ \Omega$$

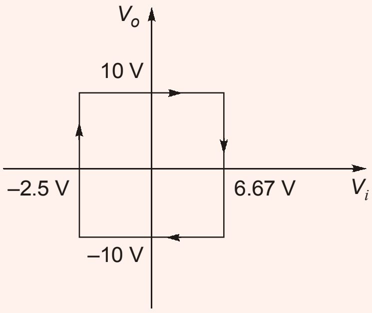
End of Solution

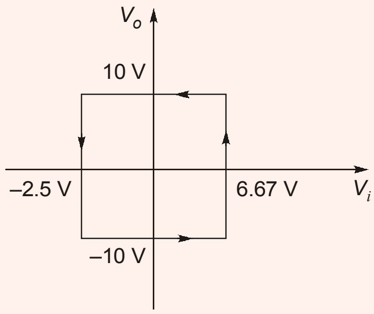
Q.47 In the circuit shown diodes are ideal. Which is the correct representation of transfer characteristics of the circuit?



(a)


(b)


(c)


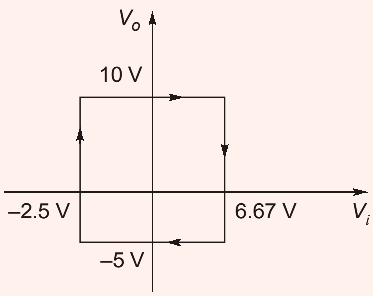
(d)


Ans. (a)

$$V_{UTP} = 10 \times \frac{4\,k\Omega}{4\,k\Omega + 2\,k\Omega} = 10 \times \frac{4\,k\Omega}{6\,k\Omega} = \frac{20}{3} = 6.67\text{ V}$$

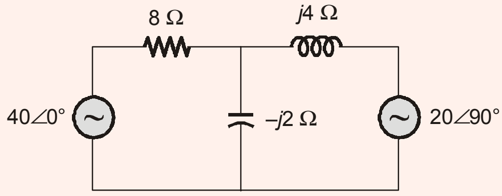
$$V_{LTP} = -5 \times \frac{4\,k\Omega}{4\,k\Omega + 2\,k\Omega} = -5 \times \frac{2}{3} = -3.33\text{ V}$$

But, VLTP should be = –3.33 V



End of Solution

Q.48 Consider the R-L-C network shown below,



The average power absorbed by the inductor in Watts is

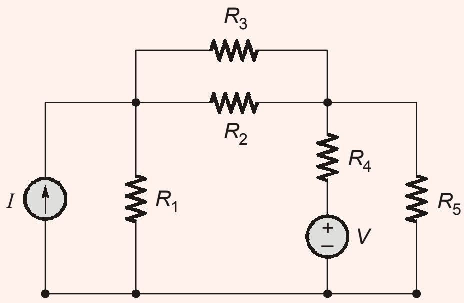
(a) +40 (b) 15
(c) 0 (d) 5

Ans. **(c)**

Power absorbed by inductor is equal to zero.

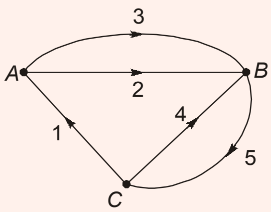
End of Solution

Q.49 The total number of possible trees corresponding to the network shown below is



(a) 9 (b) 5
(c) 8 (d) 7

Ans. **(c)**



$$[A_a] = \begin{array}{c|ccccc} & 1 & 2 & 3 & 4 & 5 \\ A & -1 & 1 & 1 & 0 & 0 \\ B & 0 & -1 & -1 & -1 & 1 \\ C & 1 & 0 & 0 & 1 & -1 \end{array}$$

$$[A_r] = \begin{array}{c|ccccc} & 1 & 2 & 3 & 4 & 5 \\ A & -1 & 1 & 1 & 0 & 0 \\ B & 0 & -1 & -1 & -1 & 1 \end{array}$$

Total no. of possible trees = $\left|[A_r][A_r]^T\right|$

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

$$= \begin{bmatrix} 3 & -2 \\ -2 & 4 \end{bmatrix}$$

$$|A_r A_r^T| = 12 - (4) = 8$$

End of Solution

Q.50 For an n-type Ge specimen, width = 4 mm, length = 1 mm, current (along the length of specimen) = 1 mA, magnetic field (perpendicular to the current flow direction) = 0.1 Wb/m^2 and Hall voltage magnitude = 0.005 V. Calculate the majority carriers density.

(a) 3×10^{19} cm^{-3}
(b) 3×10^{19} m^{-3}
(c) 6×10^{19} cm^{-3}
(d) 6×10^{19} m^{-3}

Ans. (b)

$$V_H = \frac{R_H BI}{W} \Rightarrow R_H = \frac{V_H W}{BI} = 0.2\ \text{m}^3/\text{C}$$

$$R_H = \frac{1}{ne} \Rightarrow n = \frac{1}{eR_H} = \frac{1}{1.6\times10^{-19}\times0.2}$$

$$n = 3.12 \times 10^{19} \text{ per m}^3$$

End of Solution

Q.51 The following table gives the forward characteristics of a Si diode. Estimate the temperature of a diode junction. (Given: ln(0.2) = –1.609)

V_f(V)	I_f (mA)
0.6	1
0.65	5

(a) 240 K
(b) 360 K
(c) 400 K
(d) 470 K

Ans. (b)

$$I = I_o e^{V/\eta V_T}$$

$$V = \eta V_T \ln\frac{I}{I_o}$$

$$V_1 - V_2 = \eta V_T \ln\frac{I_1}{I_2}$$

$$0.6 - 0.65 = \eta V_T \ln\frac{1}{5} = -1.609 \times \eta V_T$$

$$0.05 = 1.609 \times \eta \times \frac{T}{11600}$$

Take $\eta = 1 \Rightarrow T \cong 360$ K

End of Solution

Q.52 An n-channel MOS transistor is made on a p-type substrate with $N_a = 10^{15}$ cm^{-3}. Find approximate depletion charge per unit area (Q_d) at strong inversion.

$$\{\ln(10) = 2.3, \sqrt{0.046} \approx 0.215, n_i = 10^{10}\text{ cm}^{-3}\}$$

(a) -6.9×10^{-8} C/cm^2
(b) 6.9×10^{-8} C/cm^2
(c) -3.4×10^{-8} C/cm^2
(d) 3.4×10^{-8} C/cm^2

Ans. (c)

$$Q_d' = -eN_A \times W_{d\max} = -eN_A \times \sqrt{\frac{2\in_{si} \times 2\phi_F}{eN_A}}$$

$$Q_d' = -\sqrt{4\in_{si} eN_A\phi_F}$$

where, $$\phi_F = V_T \ln\frac{N_A}{n_i} = 0.026 \ln 10^5 = 0.3\text{ V}$$

$$Q_d' = -\sqrt{4 \times 11.7 \times 8.85 \times 10^{-14} \times 1.6 \times 10^{-19} \times 10^{15} \times 0.3}$$
$$= -1.41 \times 10^{-8}\text{ C/cm}^2$$

Approximately option 'c' is nearest answer.

End of Solution

Q.53 For a p-channel Si JFET, $N_a = 3 \times 10^{16}$ cm^{-3}, $N_d = 10^{18}$ cm^{-3}. Channel thickness dimension is $a = 0.33$ μm. Find approximate pinch-off voltage V_p. {$n_i = 10^{10}$ cm^{-3}, $V_T = 26$ mV, ln(3) = 1.098}.

(a) 2.5 V
(b) 1.7 V
(c) 4.2 V
(d) 3.6 V

Ans. (b)

$$V_p = \frac{a^2 eN_A}{2\in} - V_{bi}$$

$$V_{bi} = V_T \ln\frac{N_A N_D}{n_i^2} = 0.866\text{ V}$$

$$V_p = 2.6 - 0.866 \simeq 1.7\text{ V}$$

End of Solution

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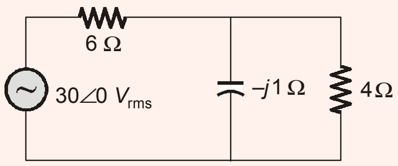
Q.54 Consider the circuit shown below:



The power factor of the above circuit as seen by the source is

(a) 0.988 LAG
(b) 0.988 LEAD
(c) 0.235 LAG
(d) 0.235 LEAD

Ans. (b)

$$Z_{eq} = 6 + \frac{4(-j1)}{4 - j1}$$

$$Z_{eq} = 6 + \left[\frac{j4}{4 - j1} \times \frac{4 + j1}{4 + j1}\right]$$

$$Z_{eq} = 6 + j4\left[\frac{4}{17} + \frac{j1}{17}\right] = \left(6 + \frac{4}{17}\right) - j\frac{16}{17}$$

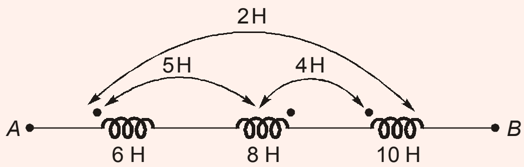
$$= 6.235 - j0.941$$

$$|Z_{eq}| = 6.305$$

$$\text{p.f.} = \cos\theta = \frac{R}{|Z_{eq}|} = 0.988 \text{ LEAD}$$

End of Solution

Q.55 All the three inductors are perfectly coupled as shown below, the value of total inductance (in Henry) across the terminal AB is



(a) 46
(b) 38
(c) 12
(d) 10

Ans. (d)

$$L_{eq} = L_1 + L_2 + L_3 - 2M_1 - 2M_2 + 2M_3$$

$$L_{eq} = 6 + 6 + 8 + 10 - 2[5] - 2[4] + 2[2] = 10 \text{ H}$$

End of Solution

Q.56 For a uniformly doped *npn* transistor, find the approximate emitter injection efficiency. Given that:
$N_E = 2 \times 10^{18}$ cm^{-3}, $N_B = 10^{17}$ cm^{-3}, $N_C = 4 \times 10^{19}$ cm^{-3}, $D_E = 8$ cm^2/s, $D_C = 28$ cm^2/s, $D_B = 20$ cm^2/s, $x_E = 0.5$ μm, $x_B = 0.3$ μm.

(a) 0.95 (b) 0.92
(c) 0.99 (d) 0.94

Ans. (c)

$$\gamma = \frac{1}{1+\frac{D_E}{D_B}\times\frac{W_B}{L_E}\times\frac{N_B}{N_E}} = 0.99$$

End of Solution

Q.57 In a long *p*-type Si-bar with cross-sectional area = 0.5 cm^2 and $N_a = 2 \times 10^{17}$ cm^{-3}, extra holes = 10^{16} cm^{-3} are injected. Assume $\mu_p = 500$ cm^2/Vs, $n_i = 10^{10}$ cm^{-3} and $\tau_p = 10^{-10}$ s, find minority carrier lifetime.

(a) 10 μs (b) 15 μs
(c) 20 μs (d) 25 μs

Ans. (*)
Data insufficient.

End of Solution

Q.58 In a *p*-type Si at 300 K and $N_a = 8 \times 10^{15}$ cm^{-3}, variation of space-charge density in the semiconductor as a function of surface potential is plotted, then select the true statement for weak inversion region. Given that p_s and n_s are hole and electron concentrations at the surface.

(a) $p_s > N_a$ (b) $n_s < N_a$ and $n_s > p_s$
(c) $n_s < N_a$ and $p_s < N_a$ (d) $n_s > N_a$

Ans. (b)

$$n_s < N_A, \quad n_s > p_s$$

End of Solution

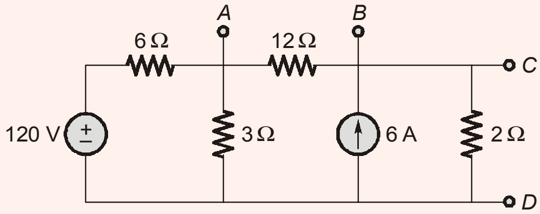
Q.59 In order to ensure that the output voltage of an op-amp is zero, when both its inputs are grounded

(a) internal negative feedback is used
(b) an external offset balancing circuit is used at the input terminals
(c) the currents incident at the output node are carefully designed
(d) the totem-pole output transistors are designed to have exactly equal cut-in voltages

Ans. (b)

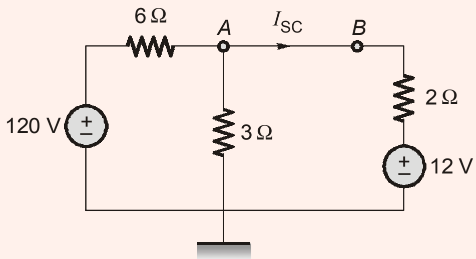
End of Solution

Q.60 Consider the resistive network shown below, the value of Norton current across the terminal AB



(a) –6 A
(b) 2 A
(c) 7A
(d) –4.5 A

Ans. (c)



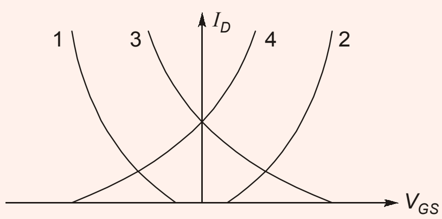
$$\frac{V_A - 120}{6} + \frac{V_A}{3} + \frac{V_A - 12}{2} = 0$$

$$V_A = 26$$

$$I_{SC} = \frac{V_A - 12}{2} = \frac{26 - 12}{2} = \frac{14}{2} = 7 \text{ A}$$

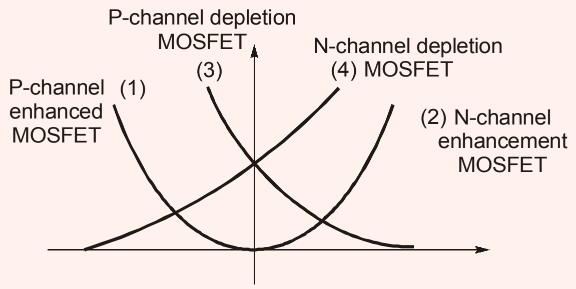
End of Solution

Q.61 The transfer characteristic of the different types of MOSFETs is shown below, where I_D is drain current and V_{GS} is the Gate-Source voltage, the correct combination of MOSFET w.r.t. to transfer characteristics is

Type of MOSFET	Transfer Characteristics
(P) P-Channel Enhancement MOSFET	
(Q) P-Channel Depletion MOSFET	
(R) N-Channel Enhancement MOSFET	
(S) N-Channel Depletion MOSFET	

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

Ans. (c)



End of Solution

Q.62 Acceptor impurity concentration of Si at 300K is 10^{19} cm^{-3}. Calculate the concentration of donor impurity atoms that must be added so that Si is *n*-type and the Fermi Energy is 26 meV below the conduction band edge.
(Given: Effective density state $N_C = 2.7 \times 10^{19}$ cm^{-3} and Thermal Voltage (V_T) at 300K is 26 mV)

(a) 1.5×10^{19} cm^{-3}
(b) 3×10^{19} cm^{-3}
(c) 10^{19} cm^{-3}
(d) 2×10^{19} cm^{-3}

Ans. (d)

$$E_C - E_F = kT \ln\frac{N_C}{N_D - N_A}$$

$$\frac{N_C}{N_D - N_A} = e^{(E_C - E_F)/kT} = e = 2.72$$

$$N_D - N_A = \frac{2.7 \times 10^{19}}{2.7} = 10^{19}$$

$$N_D = 10^{19} + 10^{19} = 2 \times 10^{19} \text{ cm}^{-3}$$

End of Solution

Q.63 The electric field between two parallel plates placed in vacuum is '*E*'. If a slab of dielectric constant $\sqrt{3}$ is inserted in between the plates such that the normal to the boundary makes an angle 45° with the lines of electric force in between the plates. Find the angle (θ) between the electric lines in the medium between the plates (vacuum) and dielectric slab.

(a) 60°
(b) 15°
(c) 30°
(d) 25°

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5	Ayush Chandra Dwivedi	Postal Course
6	Kabil Bhargava	Online T. S.
7	Abhishek Kumar	Classroom Course
8	Yogesh Kumar	Classroom Course
9	Ankit Kumar	Classroom Course
10	Tushar Garg	Classroom Course

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6	Ch. Pushpak Pramod	Classroom Course
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8	Hemant Kumar Singh	Online T. S.
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5	Kumar Mayank	Classroom Course
6	Ritesh Lalwani	Classroom Course
7	Kartikey Singh	Online T. S.
8	Anshuman Mitra	Classroom T. S.
9	Deepita Roy	Classroom Course
10	Ankita Sharma	Classroom Course

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4	Amir Khan	Classroom Course
5	Y. Naga Rahul	Classroom Course
6	Janga Srinivasa Reddy	Classroom Course
7	Rahul Jain	Classroom Course
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9	Shubham Karnani	Classroom Course
10	Gaurav Srivastava	Classroom Course

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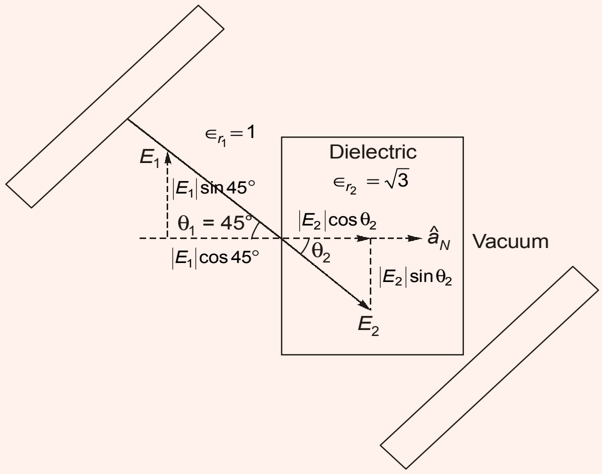
Ans. (b)



Boundary conditions:

$$|\vec{E}_{t_1}| = |\vec{E}_{t_2}|$$

$$|E_{t_1}|\sin 45° = |E_2|\sin\theta_2 \quad \text{...(i)}$$

$$|\vec{D}_{N_1}| = |\vec{D}_{N_2}|$$

$$\epsilon_1|E_{N_1}| = \epsilon_2|E_{N_2}|$$

$$\epsilon_0|E_1|\cos 45° = \epsilon_0\sqrt{3}|E_2|\cos\theta_2 \quad \text{...(ii)}$$

Equation (i) ÷ (ii), $\tan 45° = \dfrac{\tan\theta_2}{\sqrt{3}}$

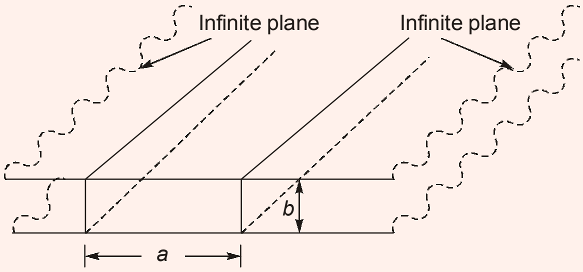
$$\tan\theta_2 = \sqrt{3} \Rightarrow \theta_2 = 60°$$

Angle between E_2 and E_1 is

$$\theta_2 - \theta_1 = 60° - 45° = 15°$$

End of Solution

Q.64 Two parallel perfectly conducting planes of infinite extent are placed 'b' distance apart so that the cut-off frequency of the lowest order TE mode is 15 GHz. If additionally, two perfectly conducting planes are placed 10 mm apart so as to form a rectangular waveguide as shown in figure. Find the cut-off frequency of TE_{11} mode.



(a) 30 GHz
(b) $15/\sqrt{2}$ GHz
(c) $15\sqrt{2}$ GHz
(d) $10\sqrt{2}$ GHz

Ans. (c)

For parallel plate wave guide separation is b and lowest cut off frequency is 15 GHz

$$f_{C_m} = \frac{cm}{2b}$$

$$\Rightarrow \quad f_{C_1} = \frac{c(1)}{2b} (f_{C_1} \text{ lowest mode})$$

$$15 \times 10^9 = \frac{3\times10^8}{2b}$$

$$\Rightarrow \quad b = \frac{3\times10^8}{2(15\times10^9)} = 0.01\text{m} = 1 \text{ cm}$$

given a = 10 mm to form rectangular wave guide

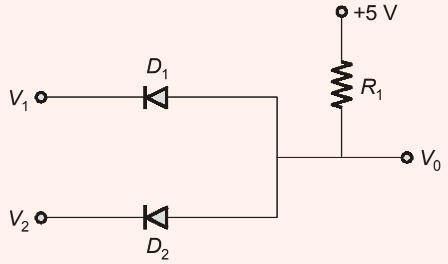
$$f_{C_{mn}} = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$f_{C_{11}} = \frac{3\times10^8}{2}\sqrt{\frac{1}{(10^{-2})^2} + \frac{1}{(10^{-2})^2}}$$

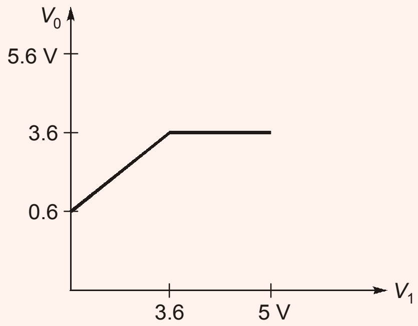
$$= \frac{3\times10^8}{2}\frac{\sqrt{2}}{(10^{-2})} = 15\sqrt{2}\text{ GHz} = 21.21 \text{ GHz}$$

End of Solution

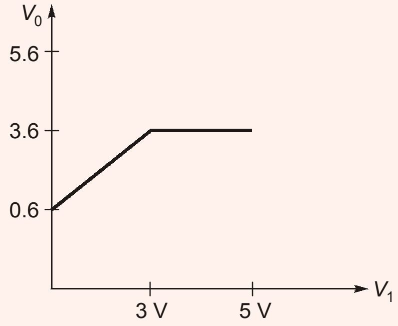
Q.65 Consider the AND logic circuit in which V_2 = 3 V and V_1 lies between 0 to 5 volts. The output voltage is V_0. The cut-in voltage of the diode D_1 and D_2 is 0.6 Volts. The output voltage V_0 versus V_1 corresponding to the below network is



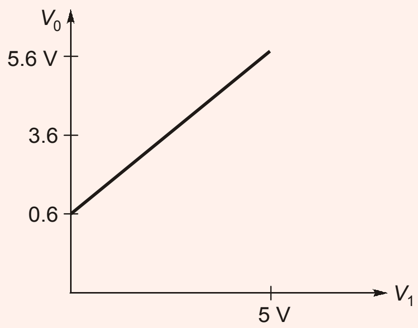
(a)



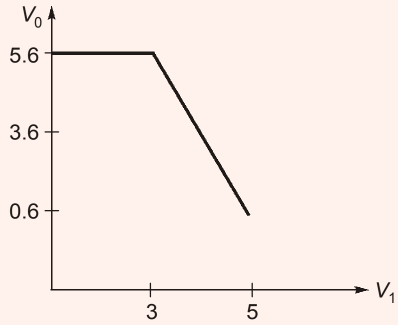
(b)



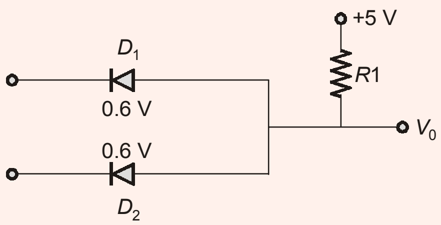
(c)

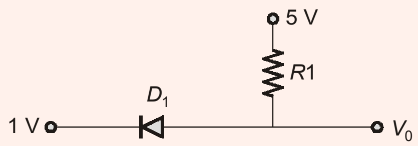


(d)

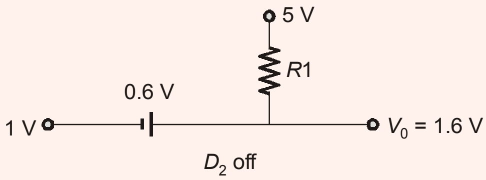


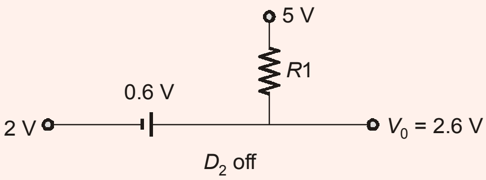
Ans. (b)

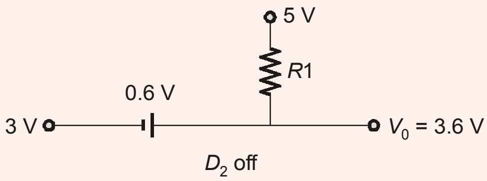


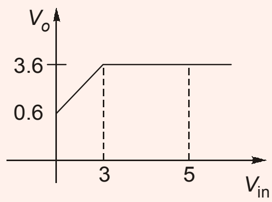


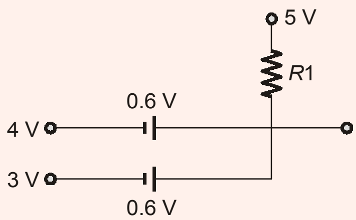
Assume D_2 off











Assuming D_2 OFF and D_1 conducting.

$$V_0 = 1.6 \text{ V}$$

End of Solution

Q.66 Following are the applications of a Buck and Boost Converters respectively

A. Regulated DC power supplies
B. Regenerative braking of DC motors
C. DC motor speed control

(a) A, B
(b) B, C
(c) A, C
(d) B, A

Ans. (a)

End of Solution

Q.67 In a MOSFET, SiO_2 breaks down at electric field of the order of 5×10^6 V/cm. For a gate oxide of thickness 1000 Å and channel thickness of 2 μm, what is the maximum V_{GS} it can withstand?

(a) 5 V
(b) 10 V
(c) 100 V
(d) None of the above

Ans. (d)

Field in SiO_2 is, $E_{ox} = \frac{V_{ox}}{T_{ox}}$

$$V_{ox} = E_{ox} \times T_{ox} = 5 \times 10^6 \times 1000 \times 10^{-8} = 50 \text{ V}$$

$$V_{GS} = V_{ox} + \psi_s$$

ψ_s is surface potential which is unknown.

V_{GS} cannot be calculated.

End of Solution

Q.68 Which of the following is false for a Thyristor?

A. Thyristor is a majority-carrier device.

B. The forward-bias portion of Thyristor's *i-v* characteristics has two stable operating regions.

C. The forward-bias portion of Thyristor's *i-v* characteristic has one stable operating region.

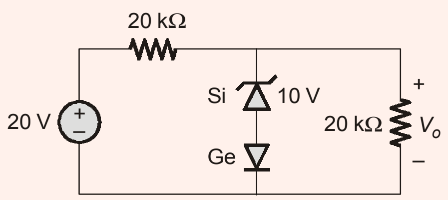
D. The negative gate current turns off the Thyristor.

(a) A, B
(b) B, C, D
(c) A, C, D
(d) B, C

Ans. (c)

End of Solution

Q.69 The Zener regulator circuit shown below consists of Si based Zener diode and Ge diode. The cut-in Voltage of Ge diode is 0.2 Volts, whereas cut-in Voltage of Si-diode is 0.7 Volts.



The output voltage (V_o) of the Zener regulator circuit is

(a) 10.2 V
(b) 10 V
(c) 9.8 V
(d) 0.2 V

Ans. (b)

Let diodes branch be OFF

$$V_o = \frac{20 \times 20}{20 + 20} = 10 \text{ V}$$

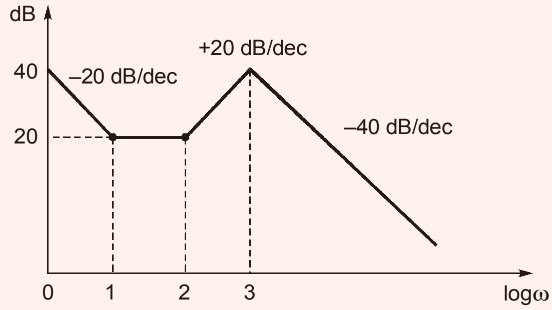
$\because$ $V_o < 10.2$ V

$\Rightarrow$ Diode branch cannot conduct

$\therefore$ $V_o = 10$ V

End of Solution

Q.70 The asymptotic bode plot for the gain magnitude of a minimum phase system G(s) is shown in figure below.



The steady state error for the ramp input is

(a) infinite
(b) 0.1
(c) 0
(d) 0.01

Ans. (b)

Initial slope = –20 dB/dec

Hence type = 1

$$e_{ss} \text{ for ramp input } = \frac{1}{K_v} = \frac{1}{K}$$

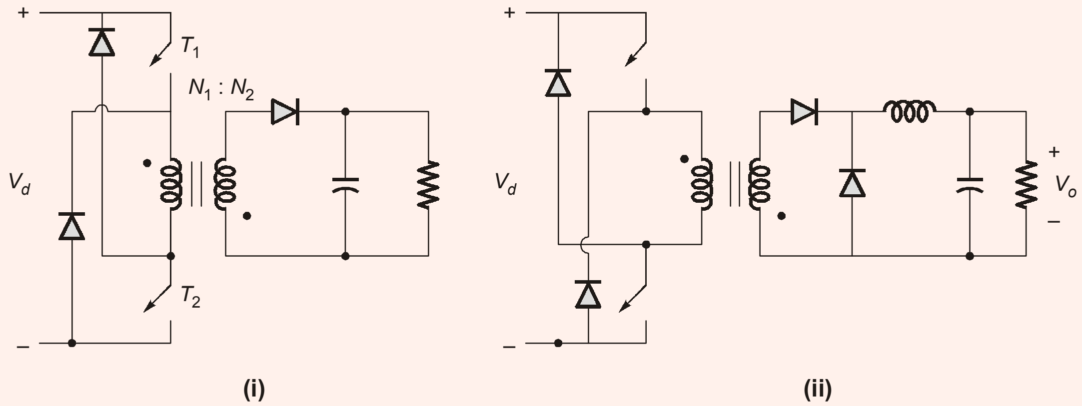
From diagram, $20\log_{10}K = 20$

$\therefore$ $K = 10$

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

End of Solution

Q.71 Identify the convertor topologies from the figures given below:



(a) (i) Flyback Converter (ii) Forward Converter
(b) (i) Forward Converter (ii) Flyback Converter
(c) Both are Forward Converters
(d) Both are Flyback Converters

Ans. (a)

End of Solution

Q.72 Consider two control systems with following transfer function,

System 1 : $G(s) = \dfrac{1}{3s+1}$

System 2 : $G(s) = \dfrac{1}{s+1}$

Which of the following is true?

(a) Bandwidth of System 1 is greater than bandwidth of System 2
(b) Bandwidth of System 2 is greater than bandwidth of System 1
(c) Bandwidth of both the systems is same
(d) Both systems have infinite bandwidth

Ans. (b)

$$S_1 : \frac{1}{3s+1}$$

$$\tau = 3$$

$$\therefore \quad \text{BW} = \frac{1}{\tau} = \frac{1}{3}$$

$$S_2 : \frac{1}{s+1}$$

$$\tau = 1$$

$$\therefore \quad \text{BW} = \frac{1}{\tau} = 1$$

∴ System 2 has more BW than system 1

End of Solution

Q.73 A system's open loop transfer function is given $G(s) = \dfrac{K}{s(s+2)(s+4)}$. If system is having a unity negative feedback, which of the following is true for such system to be stable?

(a) $K > 0$
(b) $0 < K < 24$
(c) $K < 24$
(d) None of the above

Ans. (b)

$$q(s) = 1 + \frac{K}{s(s+2)(s+4)} = 0$$

$$q(s) = s^3 + 6s^2 + 8s + K = 0$$

Given negative FB $\therefore K > 0$

For stability $bc > ad$

$\therefore 48 > K$

$$\therefore \quad 0 < K < 48$$

Exactly no option matching, option (b) can be chosen since if $K < 24$ then $K < 48$ also.

End of Solution

Q.74 The third peak overshoot and second undershoot of the step response of the second order underdamped system is given by

(a) $e^{-\frac{3\epsilon\pi}{\sqrt{1-\epsilon^2}}}$ and $e^{-\frac{2\epsilon\pi}{\sqrt{1-\epsilon^2}}}$ respectively
(b) $e^{-\frac{4\epsilon\pi}{\sqrt{1-\epsilon^2}}}$ and $e^{-\frac{5\epsilon\pi}{\sqrt{1-\epsilon^2}}}$ respectively
(c) $e^{-\frac{6\epsilon\pi}{\sqrt{1-\epsilon^2}}}$ and $e^{-\frac{4\epsilon\pi}{\sqrt{1-\epsilon^2}}}$ respectively
(d) $e^{-\frac{5\epsilon\pi}{\sqrt{1-\epsilon^2}}}$ and $e^{-\frac{4\epsilon\pi}{\sqrt{1-\epsilon^2}}}$ respectively

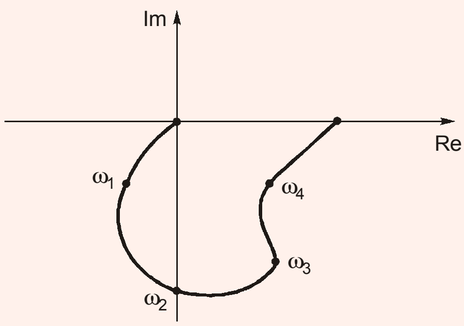
Ans. (d)

$$M_p = e^{-n\pi\epsilon/\sqrt{1-\xi^2}}$$

For 3rd overshoot $n = 5$
For 2nd undershoot $n = 4$
Hence option (d).

End of Solution

Q.75 Consider the Nyquist plot of the second order underdamped system shown in the below figure.



The Resonant Frequency corresponding to the Nyquist plot is
(a) ω_1
(b) ω_2
(c) ω_3
(d) ω_4

Ans. (b)
Resonance frequency is that at which magnitude is maximum.
Magnitude is length of the phasor drawn from origin.

End of Solution

Q.76 The unit step response of a system with the transfer function $G(s) = \frac{1-s}{1+s}$ is given by which of the following? (A unit step function is represented by $u(t)$).
(a) $(1 - 2e^{-t})\ u(t)$
(b) $(1 - e^{-t})\ u(t)$
(c) $e^{-t}\ u(t)$
(d) $2e^{-t}\ u(t)$

Ans. (a)

$$C(s) = \frac{1-s}{1+s} \times \frac{1}{s} = \frac{1}{s} - \frac{2}{s+1}$$

$$c(t) = (1 - 2e^{-t})\ u(t)$$

End of Solution

Q.77 The system $\frac{1600}{s(s+1)(s+16)}$ is to be compensated such that its gain-crossover frequency becomes same as its uncompensated Phase-crossover frequency. Which of the following is the phase crossover frequency of the compensated system?

(a) 4 rad/sec
(b) 8 rad/sec
(c) 16 rad/sec
(d) None of the above

Ans. (d)

Compressed ω_{gc} = uncompensated

$$\omega_{pc} = \frac{1}{\sqrt{T_1 T_2}} = 4 \text{ rad/s}$$

But phase cross-over frequency of compensated system cannot be (provided) solved with given data.

End of Solution

Q.78 A discrete time, linear time invariant system with input sequence x_n and output sequence y_n is characterised by

$$y_n = 0.1x_n + 0.9\ y_{n-1}$$

If two such systems are connected in series, which of the following is the governing difference equation of the overall system?

(a) $y_n - 1.8y_{n-1} + 0.81y_{n-2} = 0.01x_n$
(b) $y_n + 0.81y_{n-1} = 0.01x_n$
(c) $y_n - 0.81y_{n-1} + 1.8y_{n-2} = 0.01x_n$
(d) $y_n - 1.8y_{n-i} = 0.01x_n$

Ans. (a)

$$y(n) = 0.1x(n) + 0.9y(n-1)$$

By taking z-transform,

$$Y(z) = 0.1X(z) + 0.9z^{-1}Y(z)$$

$$\Rightarrow \quad \frac{Y(z)}{X(z)} = H(z) = \frac{0.1}{1-0.9z^{-1}}$$

For cascaded sys, resultant transfer function

$$H'(z) = H(z) \cdot H(z) = \left[\frac{0.1}{(1-0.9z^{-1})}\right]^2$$

$$\Rightarrow \quad \frac{Y'(z)}{X'(z)} = \frac{0.01}{1-1.8z^{-1}+0.81z^{-2}}$$

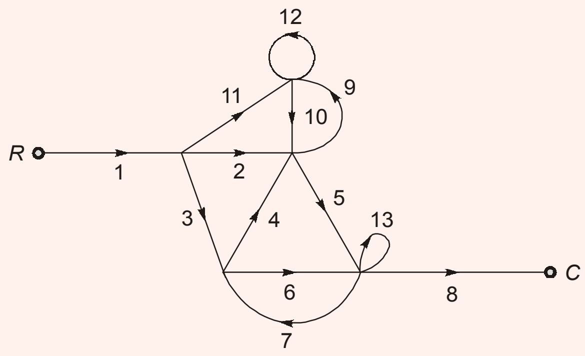
$\Rightarrow \quad Y'(z) - 1.8z^{-1}Y'(z) + 0.81z^{-2}Y'(z) = 0.01X'(z)$

By taking inverse transform

$\Rightarrow \quad y(n) - 1.8y(n-1) + 0.81y(n-2) = 0.01x(n)$

End of Solution

Q.79 The total number of feedback loops of the signal flow graph is, where R is input and C is output



(a) 3
(b) 4
(c) 5
(d) 6

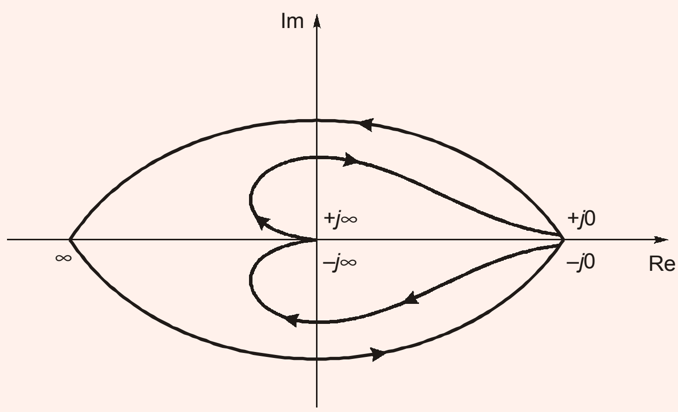
Ans. **(c)**

A loop is a closed path that starts and ends at same node.

∴ Total number of loops = 5

End of Solution

Q.80 From the below given Nyquist plot, calculate the number of open loop poles on the right hand side of s-plane for the closed loop system to be stable



(a) 1
(b) 2
(c) 0
(d) –1

Ans. **(a)**

For closed loop stability

$$N = P$$

From Nyquist plot $N = 1$

∴ $P = 1$

End of Solution

■■■■