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GATE 2021

Instrumentation Engineering

Questions & Answers (Memory Based)

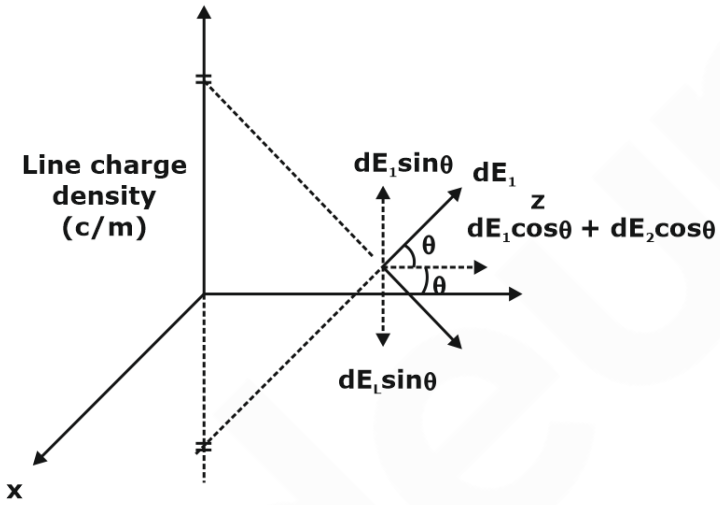
1. A infinitely long line, with uniform positive charge density, lies along the z-axis. In cylindrical coordinates (r, φ, z), at any point $\vec{p}$ not on the z-axis, the direction of the electric field is

A. $\hat{r}$ B. $\frac{\hat{r}+\hat{z}}{\sqrt{2}}$

C. $\hat{\phi}$ D. $\hat{z}$

Ans. A.

Sol.



2. Consider a system with transfer function $G(s)=\frac{2}{s+1}$, A unit step function μ(t) is applied to the system, which results in an output y(t)

If e(t) = y(t) = y(t) – μ(t), then line $\lim_{t\to 10} e(t)$ is _____

Sol. $G(s)=\frac{2}{s+1}$ unit step is applied to this system.

Output

$$y(s)=\frac{2}{s(s+1)}=\frac{K_1}{s}+\frac{K_2}{s+1}=\frac{2}{s}-\frac{2}{s+1}$$

Inverse laplace transform

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

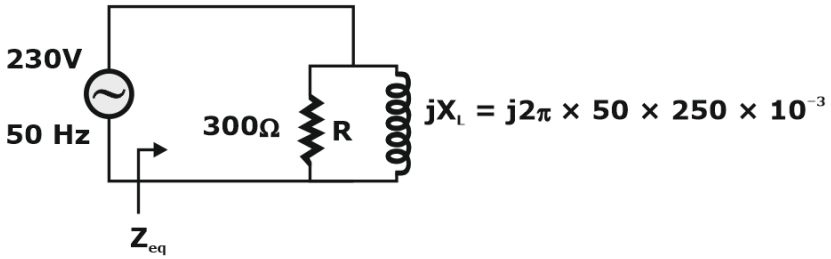
$e(t) = y(t) - u(t) = (2 - 2e^{-t})u(t) - u(t)$

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

$\lim_{t\to\infty} = -1$

3. Single phase transformer has a magnetizing inductance of 250 mH and a core loss resistance of 300 Ω, referred to the primary side. When excited with a 230 V 50 Hz Sinusoidal supply the primary the power factor of the input current drawn, with secondary an open circuited _____ (round off to two decimal places)

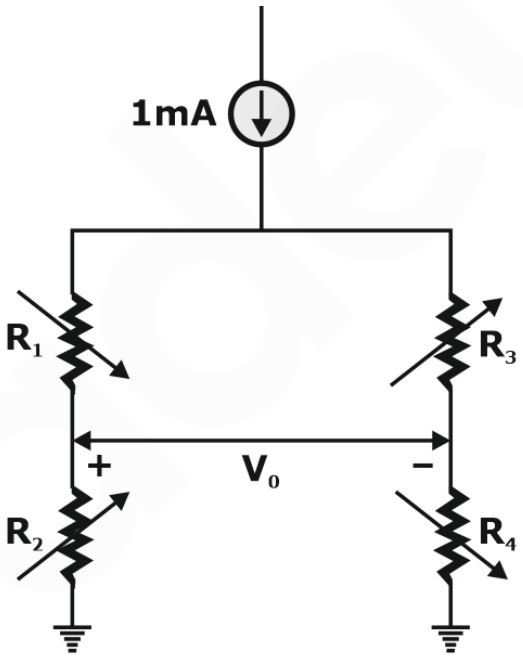
Sol. $Z_{eq} = \frac{R \times jx}{R + jx}$



$75.97 \angle 75.32°$

Cos (75.32°) = 0.253 lagg

4. For the full bridge made of linear strain gauges with gauge factor 2 as shown in the diagram, $R_1 = R_2 = R_3 = R_4 = 100\ \Omega$ at 0°C. All strain gauges are made of same material and exposed to the same temperature. While measuring a strain of 0.01 of a temperature of 50°C, the output V_0 in millivolt is _____ (rounded off to two decimal places)



Sol. −2.5

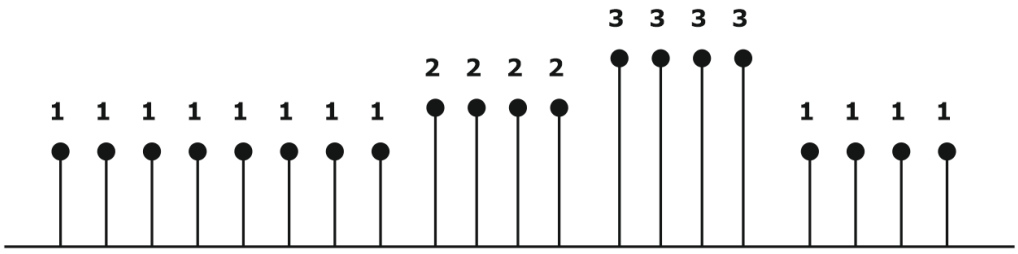
5. A 10 bit ADC has a full scale of 10 point 230 volt, when digital output is $(1111111111)_2$. Quantization error of ADC mini volt is _____.

Sol. $\Delta = \text{Resolution} = \frac{V_{FS}}{2^n - 1} = \frac{10.230}{2^{10} - 1} = \frac{10.230}{1023} = 0.01$

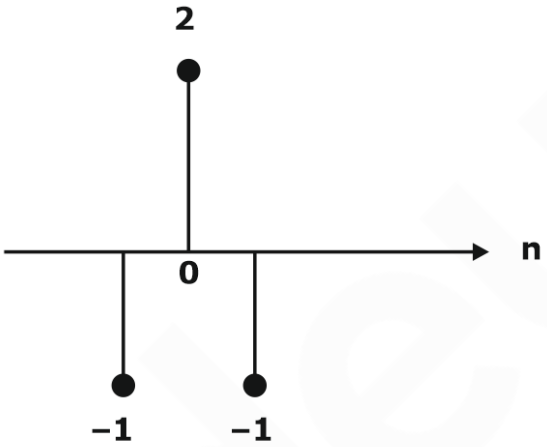
Quantization error $= \frac{\Delta}{2} = \frac{0.01}{2} = 0.005 = 5\ \text{m}$

Answer = 5

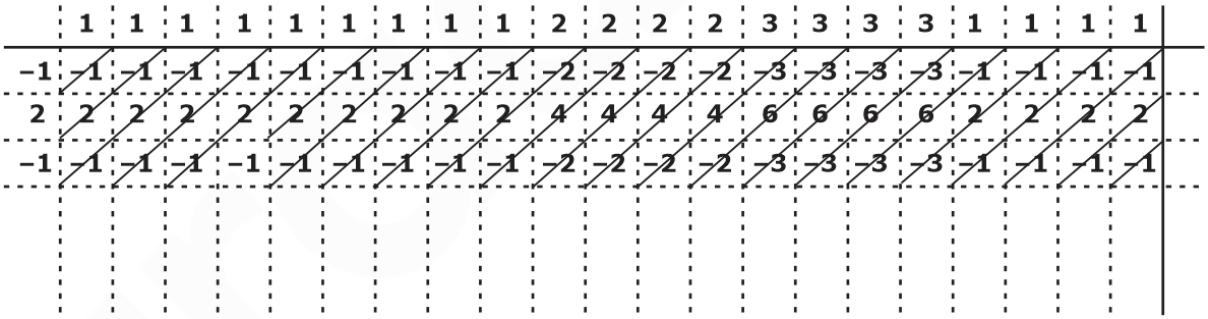
6. The input signal is shown below



Is passed through the filter with the following.



Sol. By tabulation method



y[n] = {−1, 1, 0, 0, 0, 0, 0, 0, 0, −1, 1, 0, −1, 1, 0, 0, 2, 2, 0, 0, 3, −1}

7. $y(t) = e^{-3t}u(t) * u(t+3)$

Where * denotes convolution and u(t) denotes the step function

The value of y(t) as $t \to \infty$ is _____.

Sol. $y(t) = e^{-3t}\, u(y)\, u(t+3)$

$$Y(s) = \frac{1}{s+3} \cdot \frac{e^{3s}}{s}$$

$$\lim_{x\to\infty} y(t) = \lim_{s\to 0} s.Y(s) = \lim_{s\to\infty} \frac{s \cdot e^{3s}}{s(s+3)} = \frac{1}{3} = 0.33$$

8. Let u(t) denotes the unit step function the bilateral Laplace transformer of function $f(t) = e^{t}u(-t)$ is

A. $1/s-1$ with real part of $s > 1$ B. $1/s - 1$ with real part of $s < 1$

C. $-1/s - 1$ with real part of $s > 1$ D. $-1/s - 1$ with real pant of $s < 1$ Ans. ?

Ans. D

Sol. $f(t) = e^{t}u(-t)$

Laplace transform

$$F(s) = \frac{-1}{s-1}, \quad R_e\{s\} < 1$$

9. $\sqrt{2}$ sin t ult, is applied to system with T.F. $a(s) = \frac{1}{s+1}$. Amplitude of S.S. o/p is _____.

Sol. $\sqrt{2}\sin \rightarrow \boxed{\frac{1}{s+1}} \rightarrow$

$$Y(w) = \sqrt{2}\sin t \cdot \frac{1}{j\omega + 1}$$

$w = 1$

$$y(w) = \sqrt{2}\sin t \cdot \frac{1}{j1 + 1}$$

$$y(t) = \frac{\sqrt{2}}{\sqrt{2}}\sin(t - 45°)$$

$y(t) = 1\sin(t - 45°)$

Amplitude = 1

10. Tanking N as positive for cw encirclement the no. of encirclement of [−1, 0] in the Nyquil.

Plot of $G(s) = \frac{3}{s-1}$ is _____.

Ans. -1

Sol.: $G(s) = \frac{3}{s-1} \rightarrow P_{+} = 1 \rightarrow$ No. of RHP Poter of G(s)

CE: $1 + GW = 0$

$$1 + \frac{3}{s-1} = 0$$

$s + 2 = 0$

$s = -2 \rightarrow$ LHP

so, RHP roots of CE = 0

and $Z_+ = 0$

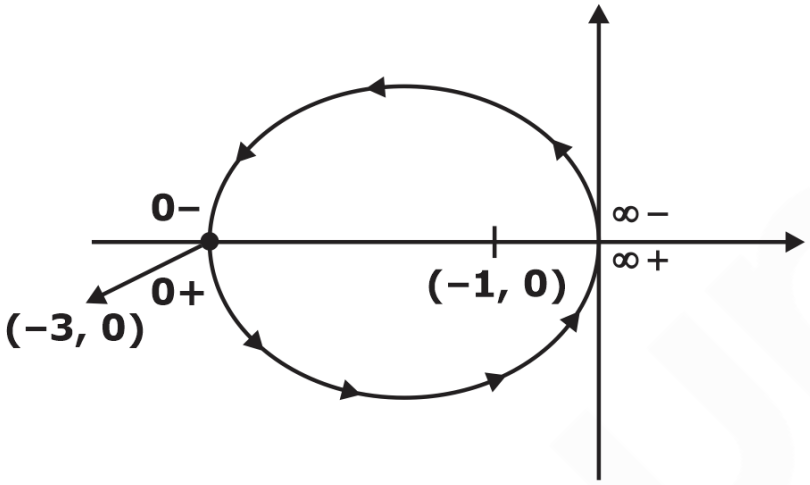
$N = P_+ - Z_+$

N = 1 – 0 = 1

But this "N" is with the ACW positive convenction. Here, we need to take CW as positive.

So, N = –1

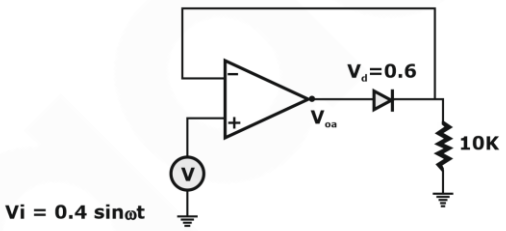
Alternate: Nyquist plot of G(s) will be



Clearly one ACW encirclement

So, N = –1

11.



When V_i is at its peak, the value of V_{oa} =

Sol. For peak value of i/p i.e. V_{imax} = 0.4 V

$V_P = V_n = V_{imax} = 0.4V$

∵ virtual short concept

Diode is FB

∴ $V_{oa} = V_D + V_0 = 0.6 + 0.4 = 1.0V$.

12. A single phase T/F has has a max^m efficiency of 98% Core loss = 80 W, eq winding resistance as seen from the primary side 0.5Ω. I current 25A % of crated current at which η_{max} occurs.

$$x = \sqrt{\frac{\text{iron loss}}{\text{Fl copper}}} \quad x\ W_i = w_{cm}$$

Ans. 50.6

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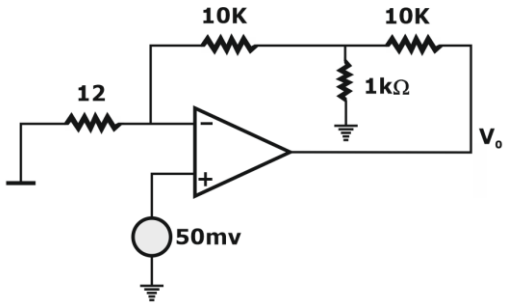
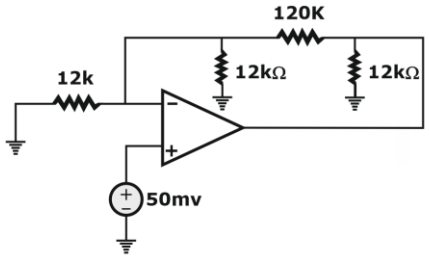
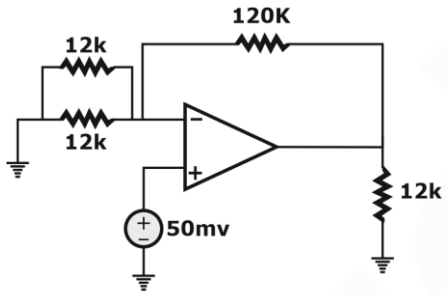
13.



Sol. Using star to Delta.





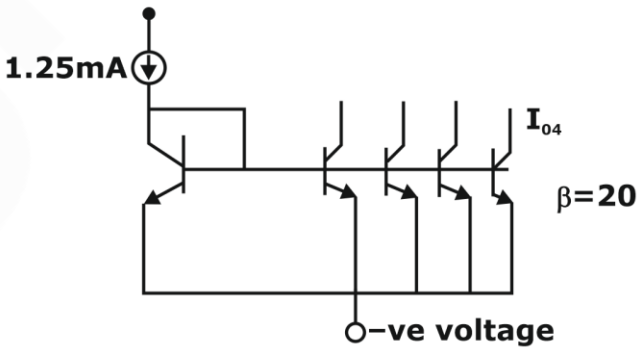
$V_0 = [1 + R_f/R_1]V_i = [1 + 120/(12//12)] \times 50$

$= 1050$ mV

$= 1.05$ V

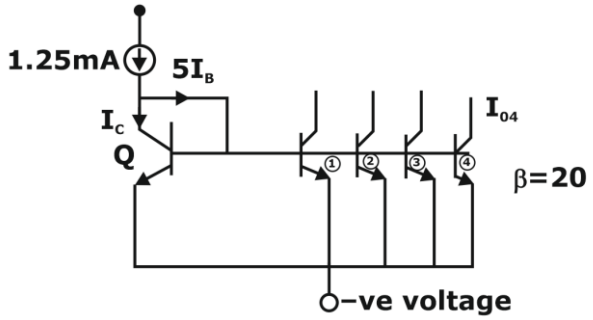
$V_0 \cong 1$ volt

14.



Find value of i_{04} = mA

Sol.



Q 1 2 3 4 are identical transistors.

$\therefore \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_Q = 20$

$I_{B1} = I_{B2} = I_{B3} = I_{B4} = I_{BQ}$

$\therefore I_{04} = I_{03} = I_{02} = I_{01} = I_{BQ}$

$I_{ref.} = I_{CQ} + 5I_B$

$I_{ref.} = \beta I_B + 5I_B = 20\ I_B + 5I_B = 25\ I_B$

$1.25 = 25I_B$

$\Rightarrow I_B = \dfrac{1.25}{25}$

$I_{04} = I_{C1} = \beta I_{B1} = 20 \times \dfrac{1.25}{25} = 1\text{mA}$

15. A house hold fan concours 60w an draws a current of 0.3125A when connected to 230 r.m.s. AC, 50Hz Q = ?

Sol. $P = V.I\cos\phi$

$60 = 230 \times 0.3125 \times \cos\phi$

$\cos\phi = 0.83$

$Q = V.I.\sin(\cos^{-1}0.831)$

$Q = 39.57$ VAR

16. A slep ring Induction machine is started by an extrunal resistance so advantage of external resistance added is

A. Pf at starting is lower
B. Starting torque is high
C. Losses at starting is lower
D. Starting current is higher

Sol. $\downarrow I_{st} = \dfrac{V}{z\uparrow}$

$\uparrow I\cos\phi = \dfrac{R}{z}$

$\uparrow I_{st} \propto (R_2 + R_{ex})\uparrow$

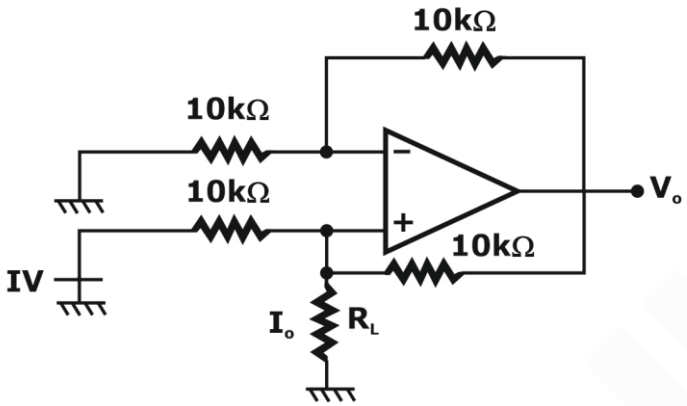
$\downarrow \text{losses} \propto \downarrow I_2^2 R_{02}$

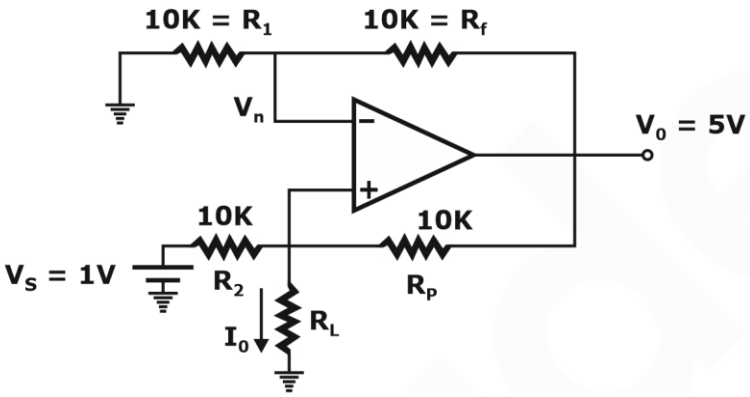
B and C are correc.

17. The output Vo of ideal Op. Amp used in circuit shown below is 5V. The n the value of resistor RL in kΩ is

A. 25 B. 50

C. 5 D. 2.5





Sol. $R_L = \frac{V_P}{I_o}$ ...(i)

Vp = Vn virtual short concept

$\because R_f / R_1 = \frac{R_P}{R_2}$

$\therefore I_0 = \frac{V_S}{R_2} = \frac{1}{10} = 0.1\ mA$ ...(ii)

KCL at V_n

$\frac{V_n - 0}{R_1} + \frac{V_n - V_0}{R_f} = 0$

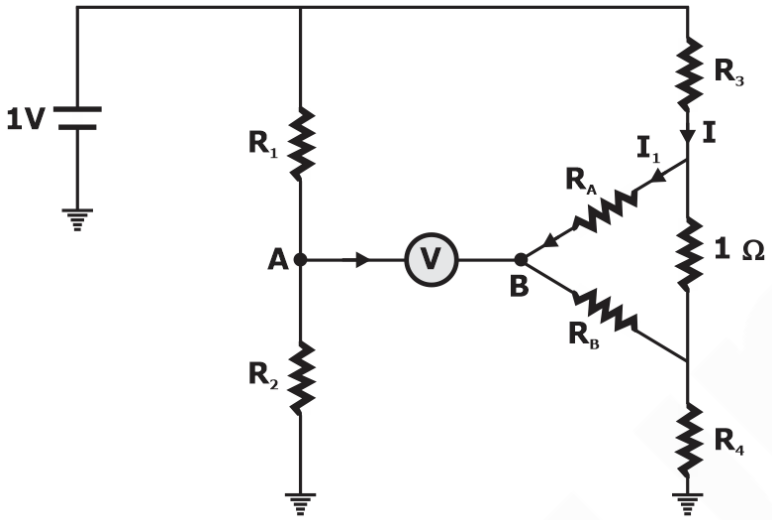
$\frac{V_n}{10} + \frac{V_n - 5}{10} = 0$

$2V_n = 5 \Rightarrow V_n = V_P = 2.5\ V$ ...(iii)

Put (iii) & (ii) in (i)

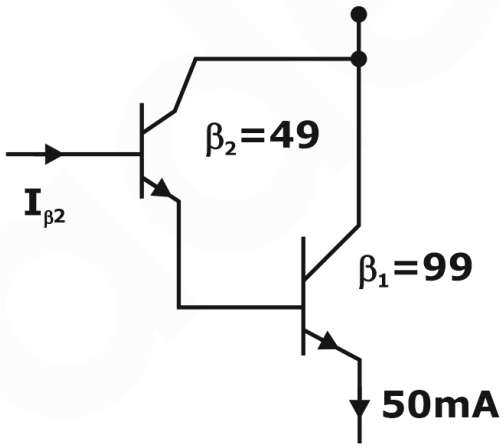
RL = 2.5/0.1 = 225 KΩ

18. In the bridge circuit shown, the voltmeter V showed zero when the value of the resistors are $R_1 = 100\Omega$, $R_2 = 100\Omega$, $R_3 = 90\Omega$, If $\left(R_1 / R_2 = \frac{RA}{RB}\right)$ the value of R_4 in ohms is _____.

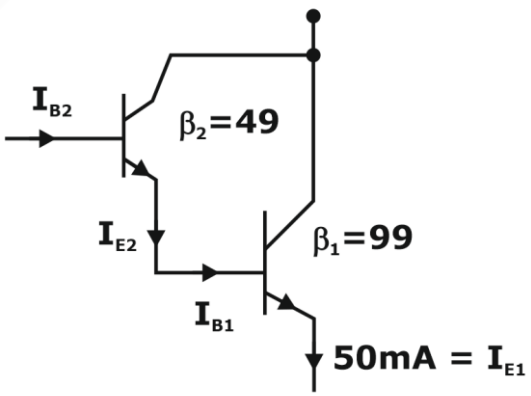


Ans. 99

19. The transistor Q_1 has gain $\beta_1 = 99$ and Q_2 has $\beta_2 = 49$, the current $I\beta_2$ is _____ μA.



Sol. ?



$I_{E1} = (1 + B)\, IB1$

$I_{B1} = I_{E2} = (1 + B_2)\, I_{B2}$

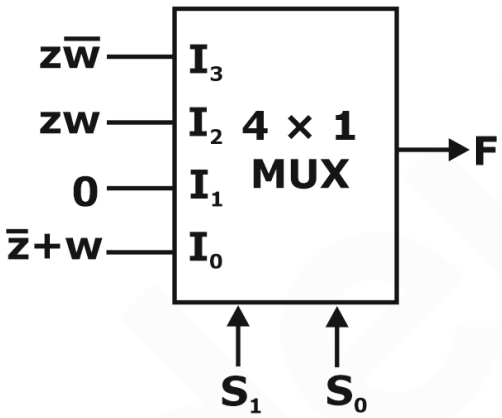
$\therefore I_{E1} = (1 + B_1)(1 + B_2) I_{B2}$

$$I_{B2} = \frac{50}{100 \times 50} = 0.01\text{mA}$$

20. 4 × 1 multiplexer with two selection line is used to realize Boolean function F having four Boolean variable x, y, z, w as shown, S_0, S_1 denotes the LSB and MSB of selection lines of multiplexer. I_0, I_1, I_2, I_3 are input line, The canonical sum of product of F is

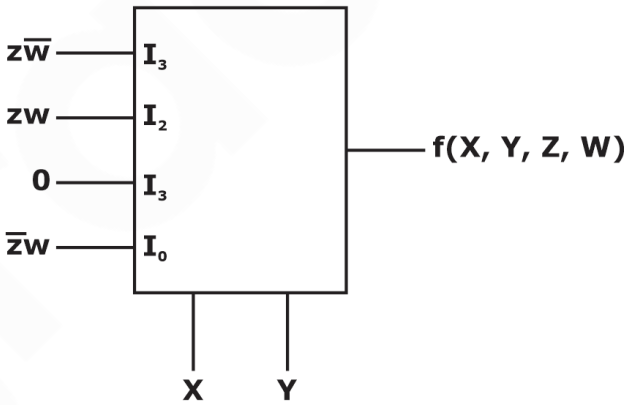
A. $F(x, y, z, w) = \Sigma m(2, 5, 9, 11, 14)$ B. $F(x, y, z, w) = \Sigma m(0, 1, 3, 14, 15)$

C. $F(x, y, z, w) = \Sigma m(0, 1, 3, 11, 14)$ D. ?



Ans. C

Sol.



$f = \bar{x}\bar{y}(\bar{z} + w) + x\bar{y}zw + xyz\bar{w} = \bar{x}\bar{y}\bar{z} + \bar{x}\bar{y}w + x\bar{y}zw + xyz\bar{w}$

$f = \bar{x}\bar{y}\bar{z}(\bar{w} + w) + \bar{x}\bar{y}(\bar{z} + z)w + x\bar{y}zw + xyz\bar{w}$

$f = \bar{x}\bar{y}\bar{z}\bar{w} + \bar{x}\bar{y}\bar{z}w + \bar{x}\bar{y}\bar{z}w + \bar{x}\bar{y}\bar{z}w + \bar{x}\bar{y}zw + x\bar{y}zw + xyz\bar{w}$

$f = \Sigma m(0,1,3,11,14)$

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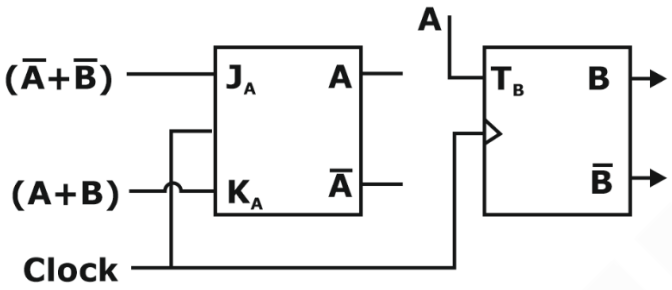
21. Given block diagram of synchronous sequential circuit with one JK-flip flop and one T-flop with their output denoted as A and B respectively with $J_A = (\bar{A} + \bar{B})$, KA = (A + B) and TB = A, starting and initial state AB = 00, the sequence of states AB visited by the circuit.

A. 00 → 10 → 11 → 01 → 00 B. 00 → 01 → 10 → 11 → 00

C. 00 → 10 → 01 → 11 → 00 D. ?



Ans. C

Sol.

Present State A	B	J_A $\overline{AB}$	K_A $A+B$	$T_B = A$	Next State A	B
0	0	1	0	0	1	0
1	0	1	1	1	0	1
0	1	1	1	0	1	1
1	1	0	1	1	0	0

00 → 10 → 01 → 11 → 00

22. For a 4-bit flash type Analog to Digital Converter (ADC) with fall scale input voltage range 'V' which of the following statement is/are correct?

A. The ADC requires one 4 to 2 priority encoder and 4 comparators

B. The ADC requires 15 comparators

C. A change in input voltage by V/16 will always flip MSB of the output

D. A change in the input voltage by V/16 will always flip the LSB of the output

Ans. B & D

Sol. For 'n' bit flash type ADC

Number of comparator $n^n - 1$

Number of Resistance = 2^n

Priority Encoder = $2^n \times n$

23. When the movable arm of a Michalon interferometer in vacuum (n = 1) is moved by 325 μm, the number of fringe crossing is 1000. The covalength of the laser used in nanometer is_____

Ans. 650

24. Let $f(z) = \frac{1}{z^2 + 6z + 9}$ defined in the complex plane. The integral $\oint_c f(z)dz$ over the contour of a circle C with centre at the origin and unit radius is_____.

Sol. Given

Poles of f(z) are given by,

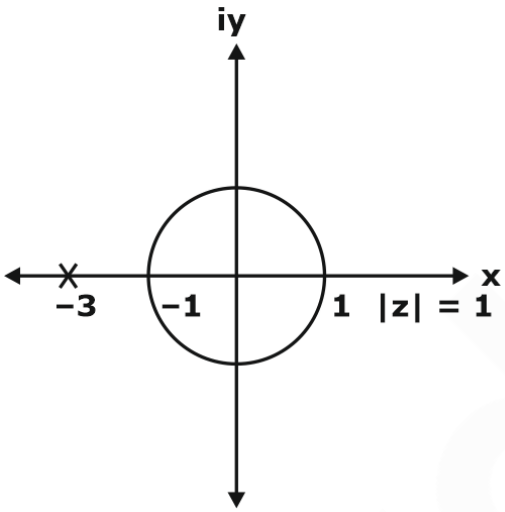
$Z^2 + 6z + 9 = 0$

$(Z + 3)^2 = 0$

$Z_1 = Z_2 = -3$

C : |z| = 1

⇒ unit circle (centre at (0, 0) and radius = 1)



Both the poles are outside 'c': |z| = 1

∴ No – singular points

∴ f(z) is completely analytic function

By Cauchy's integral theorem

$\oint_c f(z)\cdot dz = 0$

25. $f(z) = (z - 1)^{-1} - 1 + (z - 1) - (z - 1)^2 + \ldots\ldots$ is series expansion of

A. $\frac{-1}{z(z-1)}$, for |z − 1| < 1

B. $\frac{1}{z(z-1)}$, |z − 1| < 1

C. $\frac{-1}{z-1}$, for |z − 1| < 1

D. $\frac{1}{(z-1)^2}$, for |z − 1| < 1

Ans. B

Sol $f(z) = (z - 1)^{-1} - 1 + (z - 1)(z - 1)^2 + (z - 1)^3$ _____

$f(z) = (z - 1)^{-1} - [1 - (z - 1) + (z - 1)^2 + (z - 1)^2 - (z - 1)^3 + \ldots\ldots$

$f(z) = (z - 1)^{-1} [1 + (z - 1)]^{-1}$

$f(z) = (z - 1)^{-1} - z^{-1}$

$$f(z) = \frac{1}{z-1} - \frac{1}{z}$$

$$f(z) = \frac{z-(z-1)}{z(z-1)}$$

$$f(z) = \frac{1}{z(z-1)}; \quad |z-1| < 1$$

26. Given $A = \begin{pmatrix} 2 & 5 \\ 0 & 3 \end{pmatrix}$

The value of the determinant of

$|A^4 - 5A^3 + 6A^2 + 2I|$

Sol. Given $A = \begin{bmatrix} 2 & 5 \\ 0 & 3 \end{bmatrix}$

Eigen values of A are 2, 3

Let $f(A) = A^4 - 5A^3 + 6A^2 + 2I$

$f(\lambda) = \lambda^4 - 5\lambda^3 + 6\lambda^2 + 2$

$\therefore$ Eigen values of f(A) are f(2) and f(3)

i.e. 1 and $f(2) = 2^4 - 5 \times 2^3 + 6 \times 2^2 + 2 = 16$

$= 16 - 40 + 24 + 2$

$f(2) = 2$

$f(3) = 3^4 - 5 \times 3^3 + 6 \times 3^2 + 2$

$f(3) = 81 - 135 + 54 + 2$

$f(3) = 2$

Now,

$|A^4 - 5A^3 + 6A^2 + 2I|$

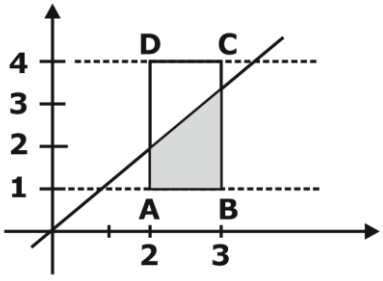
$= |f(A)| = f(2) \cdot f(3)$

$= 4$

27. Consider X and Y are independent continuous valued random variables with uniform PDF given by X ~ U(2, 3) and Y ~ U(1, 4). Then $P(Y \le X)$ is

Sol. X and Y are uniformly distributed

X ~ U(2, 3) and Y ~ U(1, 4)



$$P(Y \le X) = \frac{\text{Shaded Area}}{\text{Total area of rectangle ABCD}}$$

$$= \frac{\frac{1}{2}(1+2)\times 1}{1\times 3}$$

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

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

28. Consider row vectors

U(1, 0), W = (2, 0)

Sol. $2U^T U + 3 W^T W$

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

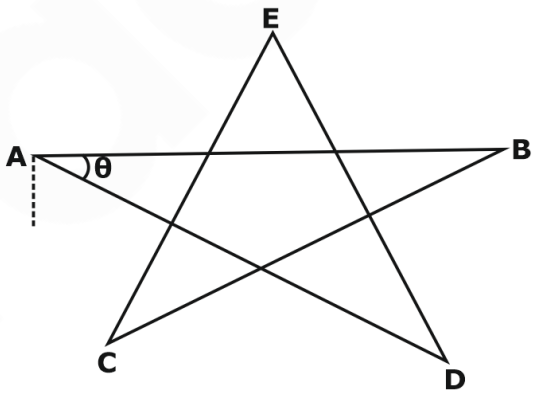
$$= 2\begin{bmatrix}1 & 0\\0 & 0\end{bmatrix} + \begin{bmatrix}4 & 0\\0 & 0\end{bmatrix}$$

$$= \begin{bmatrix}2 & 0\\0 & 0\end{bmatrix} + \begin{bmatrix}12 & 0\\0 & 0\end{bmatrix}$$

$$M = \begin{bmatrix}14 & 0\\0 & 0\end{bmatrix} = \text{Echelon form}$$

29. θ =?

AB = BC = CD = DE = EA



A. 36

B. 45

C. 72

D. 108

Ans. A

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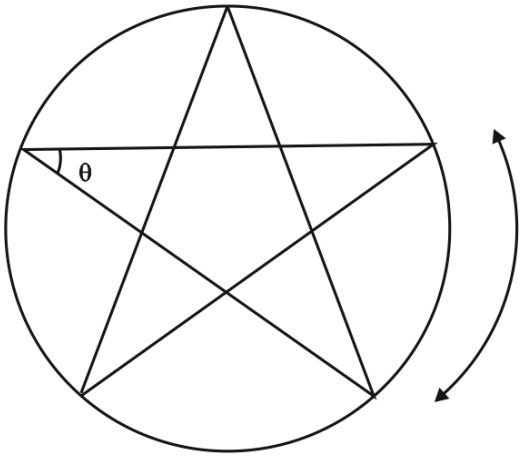
Sol. Given AB = BC = CD = DE = EA

Known as regular star

The vertices of regular star lies on a circle



Angle of this arc at centre = 2θ
So, length = (2θ)r

(2θ × r) × 5 = circumference = 2π r

⇒ θ × 5 = π

$\Rightarrow \theta = \frac{\pi}{5} = 360^\circ$

30. Consider a unity feedback configuration with a plant and a P.D controller shown in figure

$$G(s) = \frac{1}{(s+1)(s+3)} \text{ \& } c(s) = \frac{K(s+3-j)(s+3+j)}{s}$$

With k being scalar. The closed loop is?

A. only stable for K > 0

B. only stable for k between −1 and +1.

C. stable for all value of K

D. only stable for K < 0

Ans. A

Sol. 1 + G(s) C(s) = 0

$$1 + \frac{1}{(s+1)(s+3)} \times \frac{k(a+3-j)(s+3+j)}{s}$$

$s(s^2 + 4s + 3) + k[s^2 + 6s + 9 + 1] = 0$

$s^3 + (4 + k)s^2 + s(6k + 3) + 10k = 0$

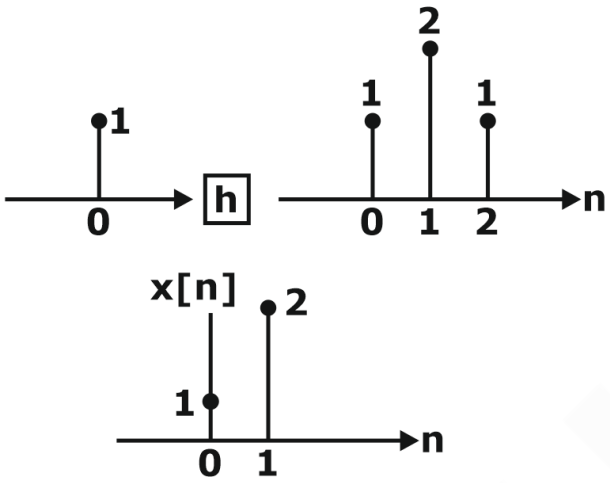
No, need to go for routh area

As according to necessary condition, ak co efficient must be of same sign

So, k > 0 → only options (a) matches.

31. Input-output relationship of LTI system is shown below

The peak value of output when x(n) is passed through it, is



A. 4

B. 5

C. 2

D. 6

Ans. B

Sol. The given output is output for impulse input, i.e. impulse response h(n).

Now, Output for input x(n)

Will be y(n) = x(n) * h(n)

	1	2	1	
1	1	2	1	
2		2	4	2
	1	4	5	2

So peak value = 5

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