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GATE 2017

Instrumentation Engineering

Questions with Detailed Solutions

AFTERNOON SESSION

All Queries related to GATE - 2017 key are to be send to the following email address
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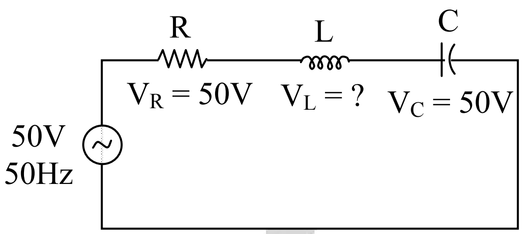
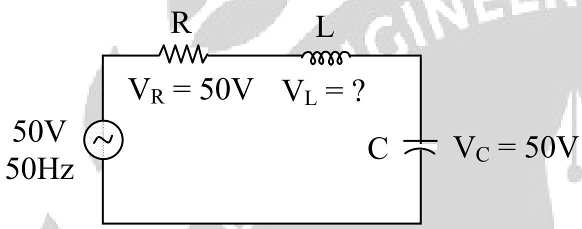
01. A series R-L-C circuit is excited with a 50V, 50Hz sinusoidal source. The voltages across the resistance and the capacitance are shown in the figure. The voltage across the inductor (V_L) is ____________V.



01. Ans: 50

Sol:



$$50 = \sqrt{V_R^2 + (V_L - V_S)^2}$$

$$V_L = 50\ V$$

02. The term hysteresis is associated with

(A) ON-OFF control (B) P-I control

(C) Feed-forward control (D) Ratio control

02. Ans: (A)

Sol: Hysteresis term is associated with ON-OFF controller only.

03. A system is described by the following differential equation: $\frac{dy(t)}{dt} + 2y(t) = \frac{dx(t)}{dt} + x(t)$, $x(0) = y(0) = 0$ Where x(t) and y(t) are the input and output variables respectively. The transfer function of the inverse system is

(A) $\frac{s+1}{s-2}$ (B) $\frac{s+2}{s+1}$

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

03. Ans: (B)

Sol: Given $\frac{dy(t)}{dt}+2y(t)=\frac{dx(t)}{dt}+x(t)$

Apply laplace transform to above equation

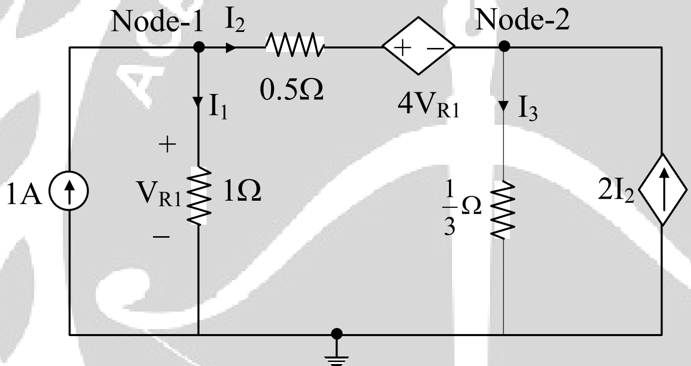
SY(s) + 2Y(s) = SX(s) + X(s)

Y(s) [s+2] = X(s) (s+1)

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

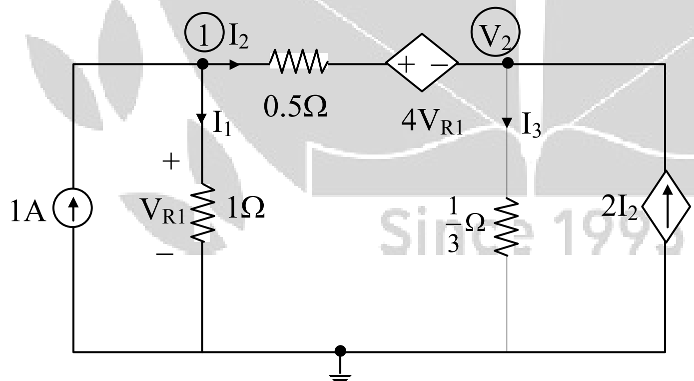
$$H_{inv}(s)=\frac{S+2}{S+1}$$

04. A circuit consisting of dependent and independent sources is shown in the figure. If the voltage at Node-1 is -1V, then the voltage at Node-2 is ____________ V.



04. Ans: 2

Sol:



Given that $V_1 = -1$ Volts then find V_2

By KCL at (1) $V_{R_1} = V_1 = -1$

$$1=\frac{V_{R_1}}{1}+\frac{V_{R_1}-4V_{R_1}-V_2}{0.5}$$

$1 = V_{R_1} - 6V_{R_1} - 2V_2$

$1 = -5V_{R_1} - 2V_2$

$1 = -5\ (-1) - 2\ V_2$

$2V_{R_2} = 4$

$\Rightarrow V_{R_2} = 2\text{Volts}$

05. The most suitable pressure gauge to measure pressure in the range of 10^{-4} to 10^{-3} torr is

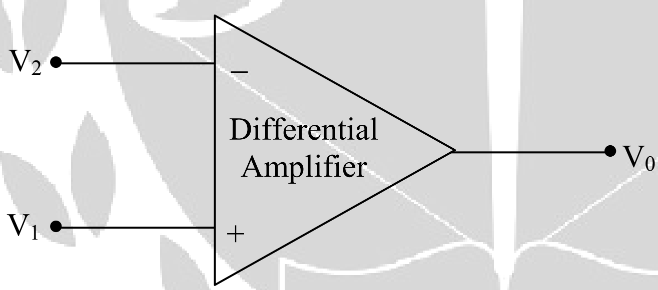
(A) Bellows (B) Barometer

(C) Strain gauge (D) Pirani gauge

05. Ans: (D)

Sol: Gauge is the suitable pressure gauge to measure vacuum pressure up to the range of 10^{-4} torr

06. The differential amplifier, shown in the figure, has a differential gain of A_d = 100 and common mode gain of A_c = 0.1. If V_1 = 5.01 V and V_2 = 5.00 V, the V_0, in Volt (up to one decimal place) is ______________



06. Ans: 1.5005

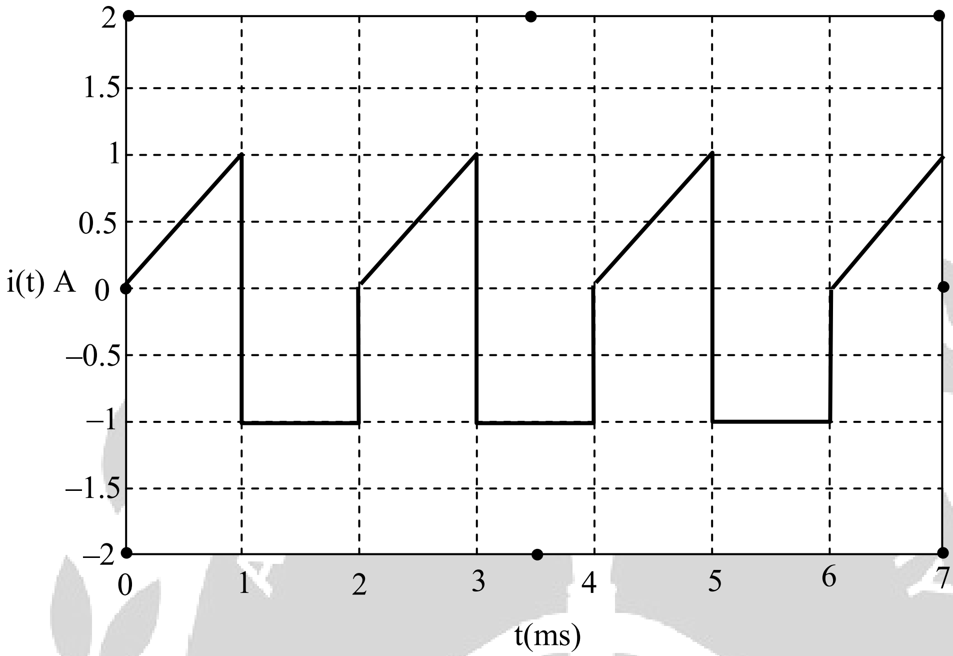
Sol: $V_0 = A_d V_d + A_{cm} V_{cm}$

$= 100(0.01) + 0.1\ (5.005)$

$= 1 + 0.5005$

$= 1.5005$

07. A current waveform, i(t), shown in the figure, is passed through a Permanent Magnet Moving Coil (PMMC) type ammeter. The reading of the ammeter up to two decimal places is



(A) –0.25 A (B) –0.12 A

(C) 0.37 A (D) 0.5 A

07. Ans: (A)

Sol: PMMC always measures average value

$$I_{avg} = \frac{\text{Area}}{T}$$

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

$$= \frac{1}{2}\left[\frac{1}{2} - 1\right]$$

$$= \frac{1}{2}\left[\frac{1}{2}\right]$$

$$= -\frac{1}{4}$$

$$= -0.25(A)$$

08. The Region of Convergence (ROC) of the Z-transform of a causal unit step discrete-time sequence is

(A) $|z| < 1$ (B) $|z| \le 1$

(C) $|z| > 1$ (D) $|z| \ge 1$

08. Ans: (C)

Sol: Given x(n) = u(n)

$$X(z) = \sum_{n=-\infty}^{\infty} x(n) z^{-n} = \sum_{n=0}^{\infty} z^{-n} = \sum_{n=0}^{\infty} \left(z^{-1}\right)^n = \frac{1}{1-2^{-1}} \quad \left|z^{-1}\right| < 1$$

ROC = $|z| > 1$

09. The eigen values of the matrix $A = \begin{bmatrix} 1 & -1 & 5 \\ 0 & 5 & 6 \\ 0 & -6 & 5 \end{bmatrix}$ are

(A) –1, 5, 6 (B) 1, – 5 ±j6

(C) 1, 5 ± j6 (D) 1, 5, 5

09. Ans: (C)

Sol: Given $A = \begin{bmatrix} 1 & -1 & 5 \\ 0 & 5 & 6 \\ 0 & -6 & 5 \end{bmatrix}$

tr(A) = 11

det(A) = (25 + 36) + (0) + 5(0) = 61 = product of eigen values

only option (C) satisfies these conditions

10. For a first order low pass filter with unity d.c. gain and –3 dB corner frequency of 2000π rad/s, the transfer function H(jω) is

(A) $\dfrac{1}{1000 + j\omega}$ (B) $\dfrac{1}{1 + j1000\omega}$

(C) $\dfrac{2000\pi}{2000\pi + j\omega}$ (D) $\dfrac{1000\omega}{1 + j1000\omega}$

10. Ans: (c)

Sol: For –3dB corner frequency

We equate

$$\left.\frac{2000\pi}{\sqrt{(2000\pi)^2+\omega^2}}\right|_{\omega=2000\pi}=\frac{1}{\sqrt{2}} \quad \text{\_\_\_\_\_\_\_\_(1)}$$

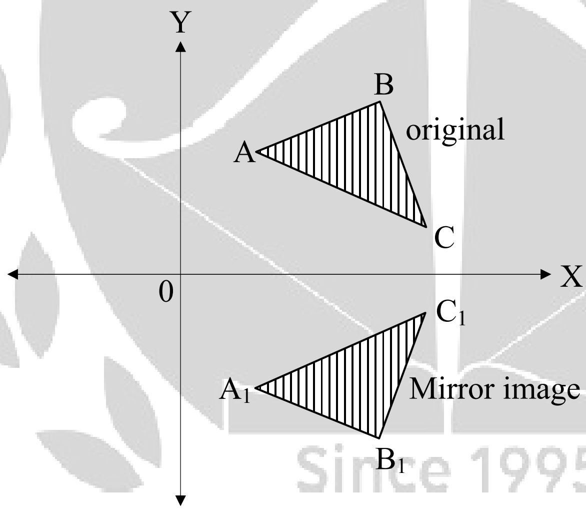
$$\text{LHS}=\frac{2000\pi}{\sqrt{(2000\pi)^2+(2000\pi)^2}}$$

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

RHS = LHS

Hence option (c) is the required LPF

11. The figure shows a shape ABC and its mirror image $A_1B_1C_1$ across the horizontal axis (x-axis). The coordinate transformation matrix that maps ABC to $A_1B_1C_1$ is



(A) $\begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}$ (B) $\begin{bmatrix}0 & 1\\ -1 & 0\end{bmatrix}$

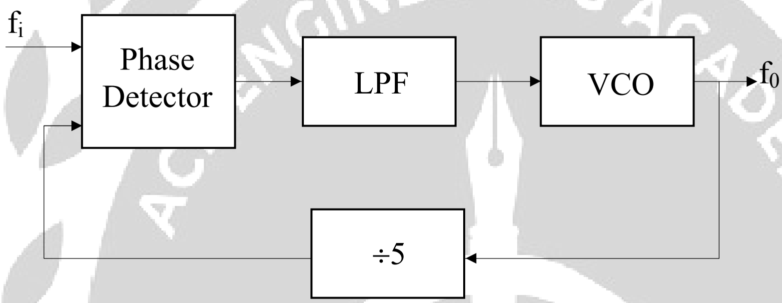
(C) $\begin{bmatrix}-1 & 0\\ 0 & 1\end{bmatrix}$ (D) $\begin{bmatrix}1 & 0\\ 0 & -1\end{bmatrix}$

11. Ans: (D)

Sol: The required transformation matrix for reflection of given original image about X-axis is $\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$

$$[x \quad y]\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} = [x \quad -y]$$

12. The figure shows a phase locked loop. The output frequency is locked at f_0 = 5 kHz. The value of f_i in kHz is _______________

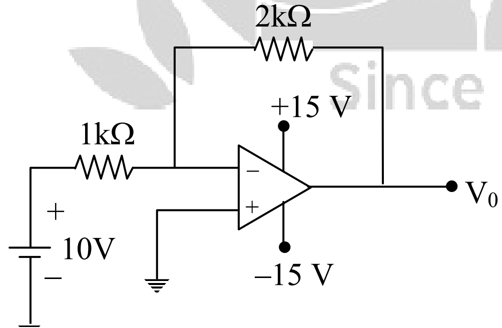


Frequency divider

12. Ans: 1

Sol: $f_i = \frac{f_0}{n} = \frac{5}{5} = 1\,\text{kHz}$

13. The output V_0 shown in the figure, in Volt, is close to



(A) –20 (B) –15

(C) –5 (D) 0

13. Ans: (B)

Sol: $V_0 = \left(\frac{-2k}{1k}\right)10 = -20$

Since op-amp is saturated $V_0 = -15V$

14. If a continuous-time signal x(t) = cos(2πt) is sampled at 4Hz, the value of the discrete time sequence x(n) at n = 5 is

(A) –0.707 (B) –1
(C) 0 (D) 1

14. Ans: (C)

Sol: The distance time signal obtained by sampling continuous time signal x(t) = cos(2πt) is

$x(nT_s) = \cos(2\pi \times n \times T_s)$

Given $f_s = 4Hz$

$T_s = \frac{1}{f_s} = \frac{1}{4}$

$x(n) = \cos\left(2\pi \times n \times \frac{1}{4}\right) = \cos\left(\frac{n\pi}{2}\right)$

$x(5) = \cos\left(\frac{5\pi}{2}\right) = \cos\left(\frac{\pi}{2}\right) = 0$

15. Let z = x + iy where $j = \sqrt{-1}$. Then $\overline{\cos z}$ =

(A) cosz (B) $\cos\bar{z}$
(C) sinz (D) $\sin\bar{z}$

15. Ans: (A)

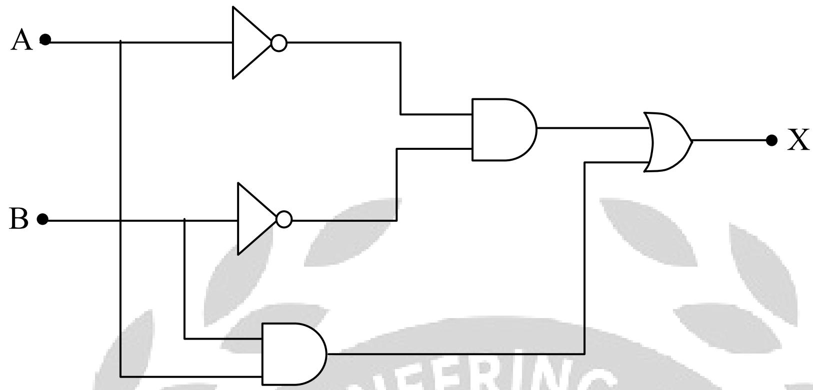
Sol: $\overline{\cos z} = \overline{\cos(x+iy)} = \cos(x-iy) = \cos\bar{z}$

16. The condition for oscillation in a feedback oscillator circuit is that at the frequency of oscillation, initially the loop gain is greater than unity while the total phase shift around the loop in degree is

(A) 0 (B) 90 (C) 180 (D) 270

16. Ans: 0°

17. A and B are the logical inputs and X is the logical output shown in the figure. the output X is related to A and B by



(A) $X = \overline{A}B + \overline{B}A$

(B) $X = AB + \overline{B}A$

(C) $X = AB + \overline{A}\,\overline{B}$

(D) $X = \overline{A}\,\overline{B} + \overline{B}A$

17. Ans: (C)

Sol: $X = \overline{A}\,\overline{B} + A\,B$

18. If V is a non-zero vector of dimension 3×1, then the matrix $A = VV^T$ has a rank = ————

18. Ans: 1

Sol: Let $V = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}_{3\times1}$ be a non-zero vector $\rho(V) = 1$, $\rho(V^T) = 1$

$A = (V\,V^T)_{3\times3}$

$\rho(A) = \rho(V\,V^T) = 1$

19. The standard for long distance analog signal transmission in process control industry is

(A) 4 - 20 mV (B) 0 - 20 mA (C) 4 - 20 mA (D) 0 - 5 V

19. Ans: (C)

Sol: 4–20mA is the standard for long distance analog signal transmission in process control industry.

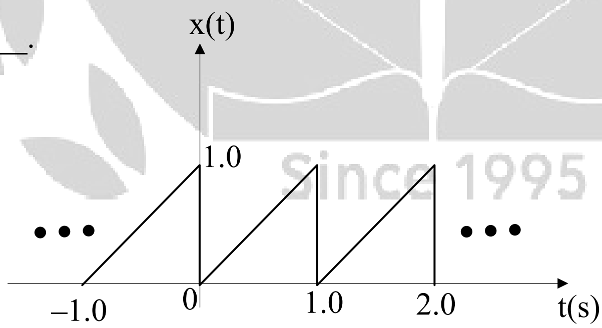
20. An 8-bit microcontroller with 16 address lines has 3 fixed interrupts i.e., Int1, Int2 and Int3 with corresponding interrupt vector addresses as 0008H, 0010H and 0018H. To execute a 32-byte long interrupt service subroutine for Int1 staring at the address ISS1, the location 0008H onwards should ideally contain

(A) a CALL to ISS1 (B) an unconditional JUMO to ISS1

(C) a condition JUMP to ISS1 (D) only ISS1

20. Ans: (B)

21. A periodic signal x(t) is shown in the figure. the fundamental frequency of the signal x(t) in Hz is ______________.



21. Ans: 1

Sol: The fundamental period of given signal is $T_0 = 1$ sec

Fundamental frequency $f_0 = \frac{1}{T_0} = 1\text{Hz}$

22. The pressure drop across an orifice plate for a particular flow rate is 5 kg/m^2. If the flow rate is doubled (within the operating range of the orifice), the corresponding pressure drop in kg/m^{2}is

(A) 2.5 (B) 5.0 (C) 20.0 (D) 25.0

22. Ans: (C)

Sol: We know for orifice plate

$$Q \alpha \sqrt{\Delta P}$$

$$\frac{Q_1}{Q_2} = \sqrt{\frac{\Delta P_1}{\Delta P_2}}$$

$Q_2 = 2Q_1$, $\Delta P_1 = 5$ (kg/m^2)

$$\frac{Q_1}{2Q_1} = \sqrt{\frac{5}{\Delta P_2}}$$

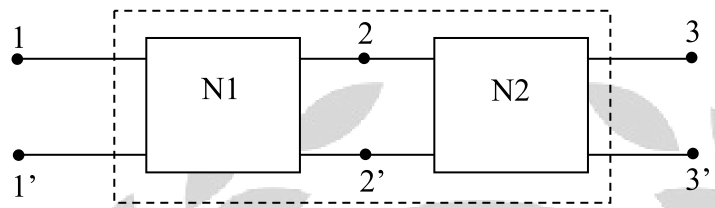
$$\frac{1}{2} = \sqrt{\frac{5}{\Delta P_2}}$$

$$\frac{1}{4} = \frac{5}{\Delta P_2}$$

$\Delta P_2 = 20$ (kg/m^2)

23. The connection of two 2-port networks is shown in the figure. The ABCD parameter of N1 and N2 networks are given as

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{N1} = \begin{bmatrix} 1 & 5 \\ 0 & 1 \end{bmatrix} \text{ and } \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{N2} = \begin{bmatrix} 1 & 0 \\ 0.2 & 1 \end{bmatrix}$$

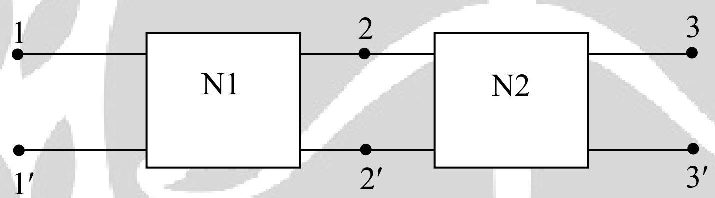


The ABCD parameters of the combined 2-port network are

(A) $\begin{bmatrix} 2 & 5 \\ 0.2 & 1 \end{bmatrix}$ (B) $\begin{bmatrix} 1 & 2 \\ 0.5 & 1 \end{bmatrix}$ (C) $\begin{bmatrix} 5 & 2 \\ 0.5 & 1 \end{bmatrix}$ (D) $\begin{bmatrix} 1 & 2 \\ 0.5 & 5 \end{bmatrix}$

23. Ans: (A)

Sol:



$$[T] = [T_1] \text{ X } [T_2]$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 5 \\ 0 & 1 \end{bmatrix} \text{X} \begin{bmatrix} 1 & 0 \\ 0.2 & 1 \end{bmatrix} = \begin{bmatrix} 2 & 5 \\ 0.2 & 1 \end{bmatrix}$$

24. Identify the instrument that does not exist:

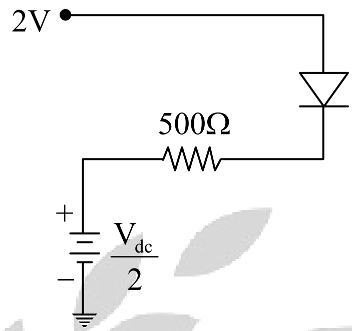
(A) Dynamometer-type ammeter (B) Dynamometer-type wattmeter

(C) Moving-iron voltmeter (D) Moving-iron wattmeter

24. Ans: (D)

Sol: Moving-iron wattmeter does not exist

25. The silicon diode, shown in the figure, has a barrier potential of 0.7 V. There will be no forward current flow through the diode, if V_{dc}, in volt, is greater than



(A) 0.7 (B) 1.3 (C) 1.8 (D) 2.6

25. Ans: (D)

Sol: $2-\frac{V_{dc}}{2}\geq 0.7$

$V_{dc_{min}} = 2.6\ \text{V}$

26. The magnetic flux density of an electromagnetic flowmeter is 100 mWb/m^2. The electrodes are wall-mounted inside the pipe having a diameter of 0.25 m. A voltage of 1V is generated when a conducting fluid is passed through the flowmeter. The volumetric flow rate of the fluid in m^3/s is __________.

26. Ans: 1.9634

Sol: $e = BlV = 100\times10^{-3}\times0.25\times V$

$1 = 0.25\times10^{-1}V$

$V = 40$ (m/sec)

$$Q = AV = \frac{\pi}{4}d^2\times V = \frac{\pi}{4}\times(0.25)^2\times40 = 1.9634\left(m^3/sec\right)$$

27. Quantum efficiency of a photodiode (ratio between the number of liberated electrons and the number of incident photons) is 0.75 at 830 nm. Given Planck's constant $h = 6.625\times10^{-34}$J, the charge of an electron $e = 1.6\times10^{-19}$C and the velocity of light in the photodiode $C_m = 2\times10^8$ m/s. For an incident optical power of 100μW at 830 nm, the photocurrent in μA is __________

27. Ans: 75.18

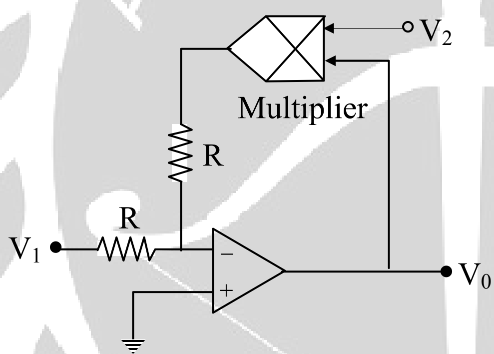
Sol: $\frac{I}{P} = \frac{\eta e \lambda}{hc}$

$$I = \frac{\eta e \lambda}{hc} \times P$$

$$= \frac{0.75 \times 1.6 \times 10^{-19} \times 830 \times 10^{-9} \times 100 \times 10^{-6}}{6.624 \times 10^{-34} \times 2 \times 10^{8}}$$

$I = 75.18\mu A$

28. The two-input voltage multiplier, shown in the figure, has a scaling factor of 1 and produces voltage output. If $V_1 = +15V$ and $V_2 = +3$ V, the value of V_0 in volt is ________



28. Ans: –5

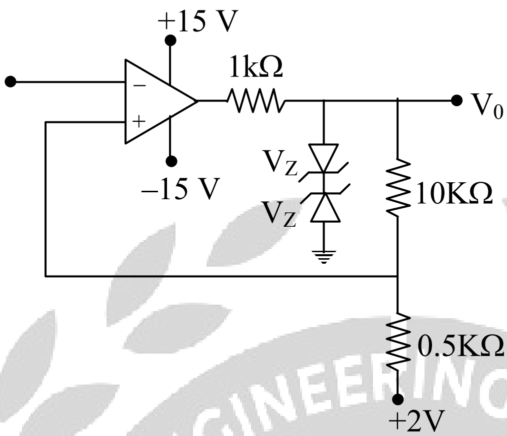
Sol: Given $V_1 = +\,15V$, $V_2 = +\,3V$

KCL at inverting terminal

$$\frac{0 - V_1}{R} + \frac{0 - (1.V_2\,V_0)}{R} = 0$$

$$V_0 = -\frac{V_1}{V_2} = -5\text{ V}$$

29. The circuit of a Schmitt trigger is shown in the figure. The zener-diode combination maintains the output between ±7V. The width of the hysteresis band is ______________ V.



29. Ans: 0.667

Sol: $$\text{UTP} = \frac{7\times0.5+2\times10}{10.5} = \frac{23.5}{10.5} = 2.238$$

$$\text{LTP} = \frac{-7\times0.5+2\times10}{10.5} = 1.57142$$

Hysteresis width = $V_{UTP} - V_{LTP}$

= 0.667V

30. The angle between two vectors $x_1 = [2 \quad 6 \quad 14]^T$ and $x_2 = [-12 \quad 8 \quad 16]^T$ in radian is ____________.

30. Ans: 0.7235

Sol: Given $X_1 = \begin{bmatrix} 2 \\ 6 \\ 14 \end{bmatrix}$ & $X_2 = \begin{bmatrix} -12 \\ 8 \\ 16 \end{bmatrix}$ angle between two vectors is

$$\cos\theta = \frac{X_1 X_2}{|X_1||X_2|} = \frac{-24+48+224}{\sqrt{4+36+196}\sqrt{144+64+256}} = \frac{248}{\sqrt{236}\sqrt{466}} = \frac{248}{\sqrt{109976}}$$

$$= \frac{248}{331.626} = 0.74783$$

$\theta = 41.45^o = 0.7235$ rad

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31. The Laplace transform of a causal signal y(t) is $Y(s) = \frac{s+2}{s+6}$. The value of the signal y(t) at t = 0.1s is ____________ unit.

31. Ans: –2.19

Sol: The laplace transform $Y(s) = \frac{s+2}{s+6}$ then y(t) at t = 0.1 is

$$Y(s) = \frac{s+2}{s+6} = \frac{s+6-4}{s+6}$$

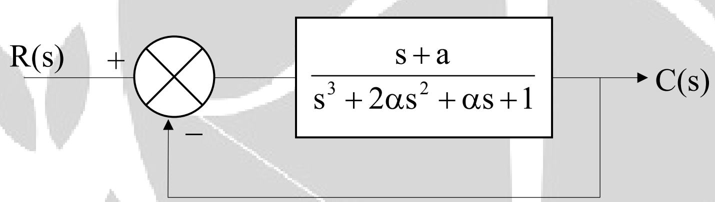
$$y(t) = L^{-1}\left[1 - \frac{4}{s+6}\right]$$

$y(t) = [\delta(t) - 4\,e^{-6t}]$

t = 0.1 $y(0.1) = \delta(0.1) - 4e^{-6(0.1)}$

$y(0.1) = -2.19$

32. A closed-loop system is shown in the figure. The system parameter α is not known. The condition for asymptotic stability of the closed loop system is



(A) $\alpha < -0.5$ (B) $-0.5 < \alpha < 0.5$

(C) $0 < \alpha < 0.5$ (D) $\alpha > 0.5$

32. Ans: (D)

Sol: Characteristics equation

$C.E = s^3 + 2\alpha s^2 + (\alpha+1)s + 1 + \alpha = 0$

Condition for stability

$2\alpha(\alpha+1) > 1 + \alpha$

$2\alpha^2 + 2\alpha - \alpha - 1 > 0$

$2\alpha^2 + \alpha - 1 > 0$

$2\alpha^2 + 2\alpha - \alpha - 1 > 0$

$(2\alpha - 1)(\alpha+1) > 0$

$2\alpha - 1 > 0$

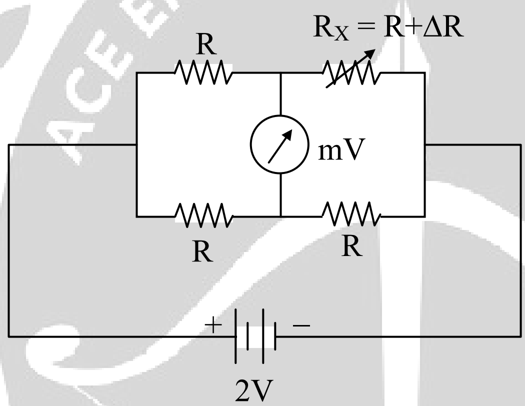
$\alpha + 1 > 0$

$\alpha > ½$

$\alpha > -1$

$\alpha > 0.5$

33. The unbalanced voltage of the Wheatstone bridge, shown in the figure, is measured using a digital voltmeter having infinite input impedance and a resolution of 0.1 mV. If R = 1000 Ω. Then the minimum value of ΔR in Ω to create a detectable unbalanced voltage is ______________



33. Ans: 0.2

Sol: $0.1 \times 10^{-3} = 2 \times \left(\frac{R + \Delta R}{2R + \Delta R} - \frac{R}{2R} \right)$

$$= 2 \times \left(\frac{1}{1 + \frac{R}{R + \Delta R}} - \frac{1}{2} \right)$$

$$= 2 \times \left(\frac{1}{1 + \frac{1000}{1000 + \Delta R}} - \frac{1}{2} \right)$$

Let $\dfrac{1000}{1000+\Delta R} = x$

$$0.5\times10^{-4} = \left(\frac{1}{1+x} - \frac{1}{2}\right)$$

$$0.50005 = \frac{1}{1+x}$$

$1 + x = 1.9998$

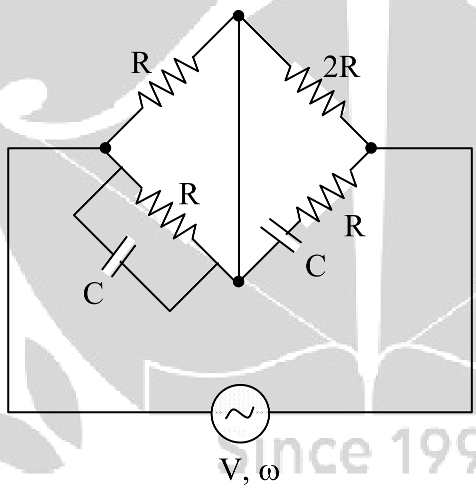
$x = 0.9998$

$$\frac{1000}{1000+\Delta R} = 0.9998$$

$1000 + \Delta R = 1000.2$

$\Delta R = 0.2\Omega$

34. In the a.c. bridge, shown in the figure, $R = 10^3\Omega$ and $C = 10^{-7}$ F. If the bridge is balanced at a frequency ω_0, the value of ω_0 in rad/s is ______________



34. Ans: 10000

Sol: $$\omega_0 = \frac{1}{RC} = \frac{1}{10^3\times10^{-7}}$$

$$= \frac{1}{10^{-4}} = 10000(\text{rad/sec})$$

35. The loop transfer function of a closed-loop system is given by $G(s)H(s)=\frac{k(s+6)}{s(s+2)}$.

The breakaway point of the root-loci will be

35. Ans: – 1.01

Sol: $G(s)=\frac{k(s+6)}{s(s+2)}$

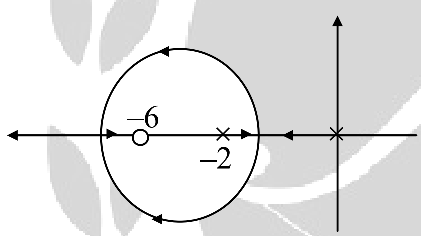
$$\frac{k(s+6)}{s(s+2)}=-1$$

$$k=\frac{-(s^2+2s)}{s+6}$$

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

$2s^2 + 2s + 12s + 12 - s^2 - 2s = 0$

$s^2 + 12s + 12 = 0$



s = – 1.01

s = – 10.8

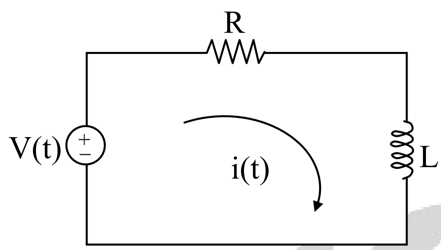
The break away point s = – 1.01

36. The current response of a series R-L circuit to a unit step voltage is given in the table. The value of L is ______________H.

t in s	0	0.25	0.5	0.75	1.0	…	∞
i(t) in A	0	0.197	0.316	0.388	0.432	…	0.5

36. Ans: 1

Sol: The current response of a series R-L to a unit step voltage



$$i(t) = \frac{V}{R}\left(1 - e^{-t/\tau}\right)$$

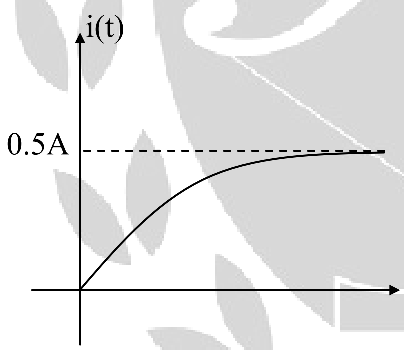
$$\tau = \frac{L}{R}$$

From the table t = ∞

$$i(\infty) = \frac{V}{R} = 0.5$$

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

At t = τ



$$i(t) = \frac{V}{R}\left(1 - e^{-t/\tau}\right)$$

At t = τ ;

$$i(t) = 0.5\left(1 - e^{-1}\right)$$

$$= 0.5\ (0.632)$$

$$= 0.316$$

From the table $\tau = 0.5$

$\Rightarrow i(t) = 0.316$

$$\frac{L}{R} = 0.5$$

$L = 1H$

37. Consider two discrete-time signals

$X_1(n) = \{1,1\}$ and $\{1,2\}$, for n = 0,1

The Z – transform of the convoluted sequence $x(n) = x_1(n) * x_2(n)$ is

(A) $1 + 2z^{-1} + 3z^{-1}$

(B) $z^2 + 3z + 2$

(C) $1 + 3z^{-1} + 2z^{-2}$

(D) $z^{-2} + 3z^{-3} + 2z^{-4}$

37. Ans: (C)

Sol: $x_1(n) = [1, 1]$

$x_2(n) = [1, 2]$

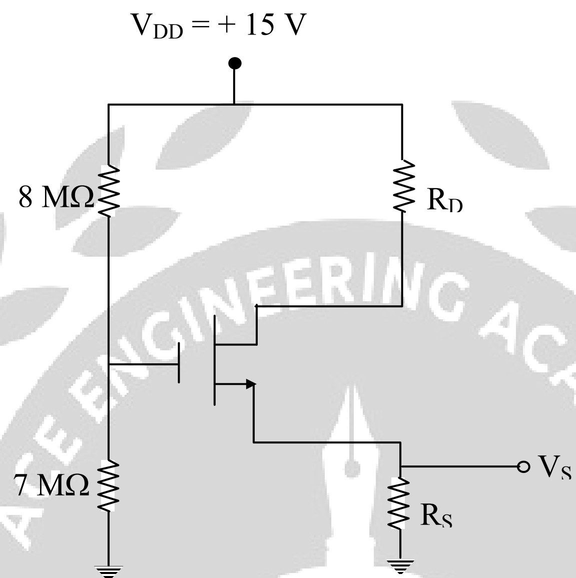
$x(n) = x_1(n) * x_2(n)$

	1	2
1	1	2
1	1	2

$x(n) = [1, 3, 2]$

$$X(z) = \sum_{n=-\infty}^{\infty} = 1 + 3z^{-1} + 2z^{-2}$$

38. In the circuit, shown in the figure, the MOSFET is operating in the saturation zone. The characteristics of the MOSFET is given by $I_D = \frac{1}{2}(V_{GS} - 1)^2$ mA, where V_{GS} is in V. If V_s = + 5V, then the value of R_s in kΩ is ________



38. Ans: 10

Sol: $I_D = \frac{1}{2}(V_{GS} - 1)^2$

$V_G = \frac{15 \times 7}{15} = 7V$

$V_S = +5V$

$V_{GS} = 2V$

$I_D = \frac{1}{2}(1) = 0.5mA$

$V_S = I_D R_S$

$R_S = 10k\Omega$

39. An angle modulated signal with carrier frequency $\omega_c = 2\pi \times 10^6$ rad/s is given by $\varphi_m(t) = \cos(\omega_c t + 5\sin(1000\pi t) + 10\sin(2000\pi t)$. The maximum deviation of the frequency in the angle modulated signal from that of the carriers is _______ kHz

39. Ans: 12.5 kHz

Sol: $\phi(t) = \cos[\omega_c t + 5\sin 1000\pi t + 10\sin 2000\pi t]$

$\phi(t) = \cos[\omega_c t + \beta_1 \sin 2\pi f_1 t + \beta_2 \sin 2\pi f_2 t]$

$\beta_1 = 5,\ f_1 = 500$ Hz

$\beta_2 = 10,\ f_2 = 1000$ Hz

The maximum frequency deviation is

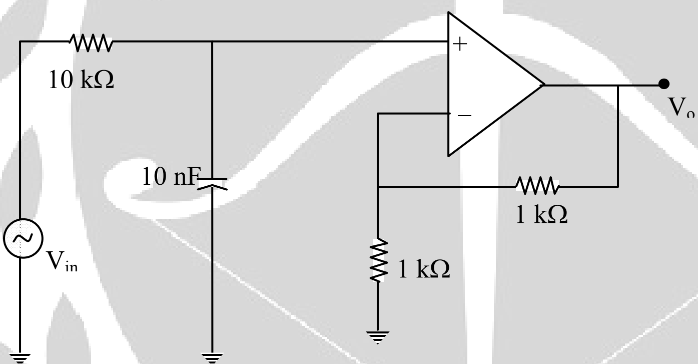
$(\Delta f)_{max} = \beta_1 f_1 + \beta_2 f_2$

$= 5\times500 + 10\times1000$

$= 2500 + 10{,}000$

$= 12.5$ kHz

40. Assuming the op-amp shown in the figure to be ideal , the frequency at which the magnitude of V_0 will be 95% of the magnitude of V_{in} is ________ kHz



40. Ans: 2.9

Sol: $V_0 = 2V_+$

$$= \frac{2V_{in}}{1+SCR}$$

$$\frac{V_0}{V_{in}} = \frac{2}{1+j\omega 10^4 10^{-8}} = 0.95$$

$$0.95V_i = 2V_i \frac{1}{\sqrt{1+(2\pi fRC)^2}}$$

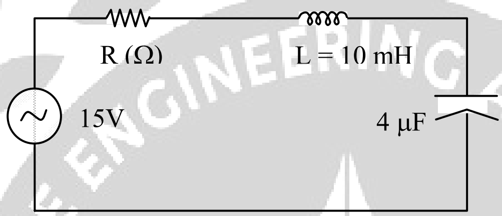
$$\sqrt{1+(2\pi fRC)^2} = \frac{2}{0.95} = 2.10526$$

$1 + (2\pi fRC)^2 = 4.432$

$(2\pi fRC)^2 = 3.432$

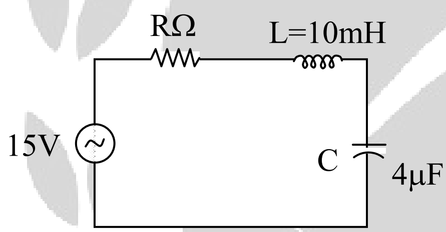
$f = 2.9485\text{kHz}$

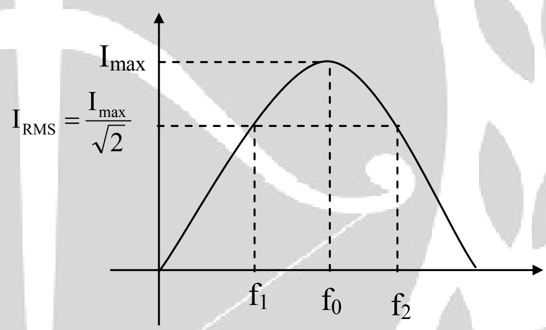
41. A series R-L-C circuit is excited with an a. c. voltage source . The quality factor (Q) of the circuit is given as Q = 30. The amplitude of current in ampere at upper half-power frequency will be____



41. Ans: 6.365

Sol:





$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$30 = \frac{1}{R}\sqrt{\frac{10\times10^{-3}}{4\times10^{-6}}}$$

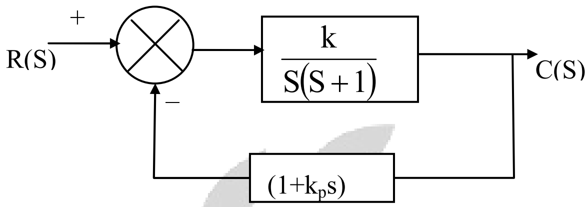
$$30 = \frac{1}{R}\sqrt{\frac{10000}{4}} = \frac{50}{R} \Rightarrow R = \frac{5}{3}\Omega$$

$$f_2 \ \& \ f_1 \rightarrow I = I_{RMS} = \frac{I_{max}}{\sqrt{2}}$$

$$I = \frac{V}{\sqrt{2}R} = \frac{15}{\sqrt{2}\times\frac{5}{3}} = \frac{9}{\sqrt{2}}$$

$I = 6.365$ A

42. The block diagram of a closed-loop control system is shown in the figure. The values of k and k_p are such that the system has a damping ration of 0.8 and an undamped natural frequency ω_n of 4 rad/s respectively . The value of k_p will be _______



42. Ans: 0.3375

Sol: $$\frac{C(s)}{R(s)} = \frac{\dfrac{k}{s(s+1)}}{\dfrac{1+k(1+k_p s)}{s(s+1)}}$$

$$\frac{C(s)}{R(s)} = \frac{k}{s^2 + s + kk_p s + k}$$

By comparing with standard second order system

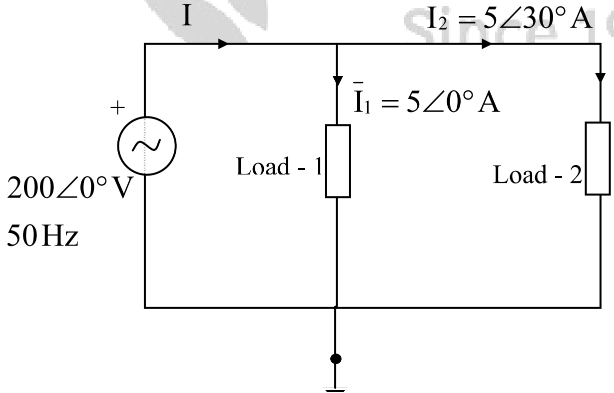
$k = \omega_n^2 = 16$

$(1 + kk_p) = 2\,\xi\,\omega_n$

$1 + 16\,(k_p) = 2\,(0.8)\,4$

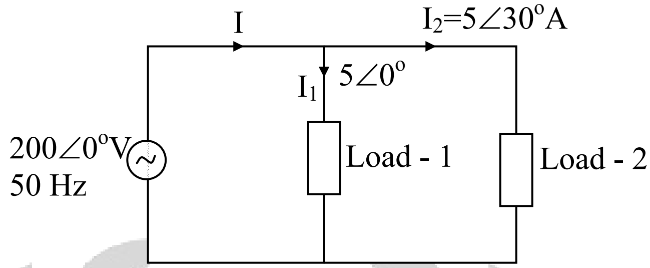
$k_p = 0.3375$

43. For the circuit, shown in the figure, the total real power delivered by the source to the loads is ____ kW



43. Ans: 1.866

Sol: $I = I_1 + I_2$



$= 5\angle 0^o + 5\angle 30^o$

$= 5 + 5\frac{\sqrt{3}}{2} + j\frac{5}{2}$

$I = 5\left(1 + \frac{\sqrt{3}}{2}\right) + j\frac{5}{2}$

$= 5(1.866) + j\frac{5}{2}$

So, $S = VI^*$

$= (200\angle 0^o)(9.33 - j2.5)$

$P + jQ = 1866 - j5000$

Real power P = 1866 W = 1.866 kW

44. The following table lists an n^{th} order polynomial $f(x) = a_n x^n + a_{n-1} + \ldots\ldots + a_1 x + a_0$ and the forward differences evaluated at equally spaced values of x. The order of the polynomial is

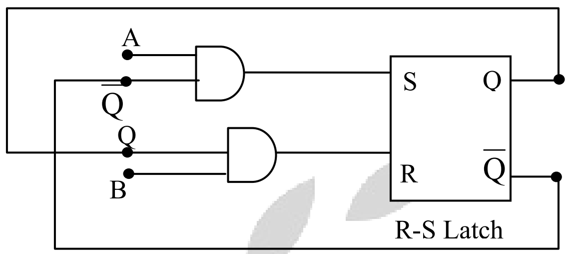
x	f(x)	Δf	$\Delta^2 f$	$\Delta^3 f$
-0.4	1.7648	-0.2965	0.089	-0.03
-0.3	1.4683	-0.2075	0.059	-0.0228
-0.2	1.2608	-0.1485	0.0362	-0.0156
-0.1	1.1123	-0.1123	0.0206	-0.0084
0	1	-0.0917	0.0122	-0.0012
0.1	0.9083	-0.0795	0.011	0.006
0.2	0.8288	-0.0685	0.017	0.0132

(A) 1 (B) 2 (C) 3 (D) 4

44. Ans: (B)

Sol: All the third order differences are approximately zero hence the given function can be approximated as 2^{nd} order polynomial.

45. The two inputs A and B connected to an R-S latch via two AND gates as shown in the figure. If A = 1 and B = 0, the output $Q\overline{Q}$ is



(A) 00
(B) 10
(C) 01
(D) 11

45. Ans: (B)

Sol: It is similar to JKFF where A = J, B = K

46. Three DFT coefficients, out of five DFT coefficients of a five-point real sequence are given as: X (0) = 4 , X (1) = 1– j1 and X (3) = 2 + j2. The zero-th value of the sequence x (n) x(0) is.

(A) 1
(B) 2
(C) 3
(D) 4

46. Ans: (B)

Sol: Given N = 5

X(n) is real, so X(k) = X(N–k)

Given that X(0) = 4, X(1) = 1–j1, X(3) = 2 + j2

X(4) = X(5–4) = X(1) = 1+j1

X(2) = X(5–2) = X(3) = 2 – j2

$$x(0)\frac{1}{N}\sum_{k=0}^{4}X(k)=\frac{1}{5}[4+1-j1+2-j2+2+j2+1+j1]$$

$$x(0)=\frac{1}{5}[10]=2$$

47. In a sinusoidal amplitude modulation scheme (with carrier) the modulated signal is given by A_m (t) = 100 cos (ω_ct) + 50 cos (ω_mt) cos (ω_ct) , where ω_c is the carrier frequency an ω_m is the modulation frequency . The power carried by the sidebands in % of total power is ______ %

47. Ans: 11.1

Sol: $S(t) = 100 \cos \omega_c t + 50 \cos \omega_m t \cos \omega_c t$

$= 100 [1+ 0.5 \cos \omega_m t] \cos \omega_c t$

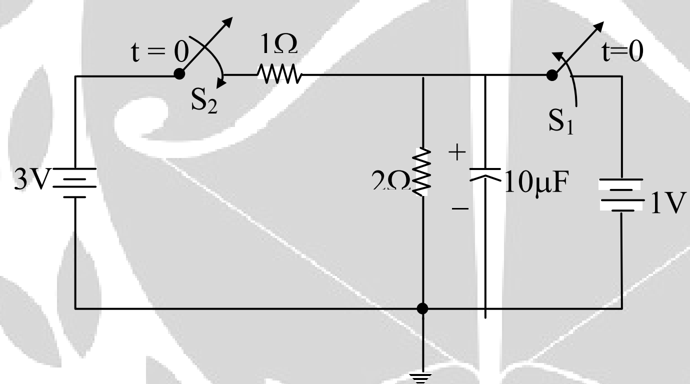
$A_C = 100$ $\mu= 0.5$

$$\eta = \frac{P_{SB}}{P_t} = \frac{\mu^2}{2+\mu^2} = \frac{0.25}{2.25}$$

$$\frac{P_{SB}}{P_t} = 11.1\%$$

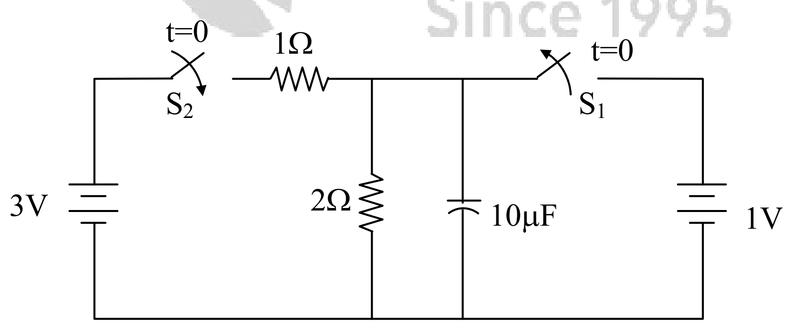
$P_{SB} = 11.1\%\ P_t$

48. In the circuit diagram, shown in the figure, S_1 was closed and S_2 was open for a very long time . At t = 0, S_1 is opened and S_2 is closed . The voltage across the capacitor, in voltage , at t = 5 μs is ____



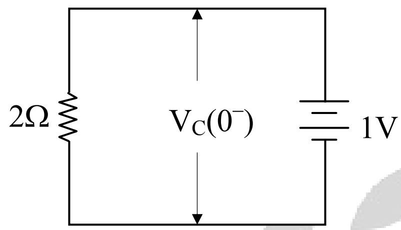
48. Ans: 1.5276

Sol:



For t < 0, S_1 is closed & S_2 is opened

C → 1V source at t = 0, (steady state) C → O. C

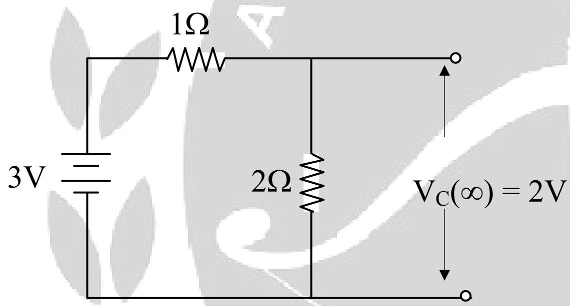


$V = V_C(0^-) = V_C(0^+) = V_0$ (Initial value)

For t > 0, S_1 is opened & S_2 is closed

C → 3V source t = ∞, (steady state) C → O.C

For final value



$$\tau = R_{eq}C = \frac{2\times1}{2+1}\times10\mu F = \frac{20}{3}\mu sec$$

$$V_C(t) = V_C(\infty) + \left(V_C(0) - V_C(\infty)\right)e^{-t/\tau}$$

$$= 2 + (1-2)e^{-3t/20\times10^{-6}}$$

$$V_C(t) = \left(2 - e^{-3t/20\times10^{-6}}\right)$$

t = 5μsec,

$$V_C(t) = 2 - e^{-\frac{3(5\times10^{-6})}{20\times10^{-6}}} = 2 - e^{-3/4}$$

$V_C(t)$ = 1.5276 Volts

49. When the voltage across a battery is measured using a d .c . potentiometer , the reading shows 1.08 V. But when the same voltage is measured using a Permanent Magnet Moving Coil (PMMC) voltmeter, the voltmeter reading shows 0.99 V. If the resistance of the voltmeter is 1100 Ω is ————

49. Ans: 100

Sol: $0.99 = 1.08 \dfrac{R_V}{R_V + R_m}$

R_V = voltmeter resistance

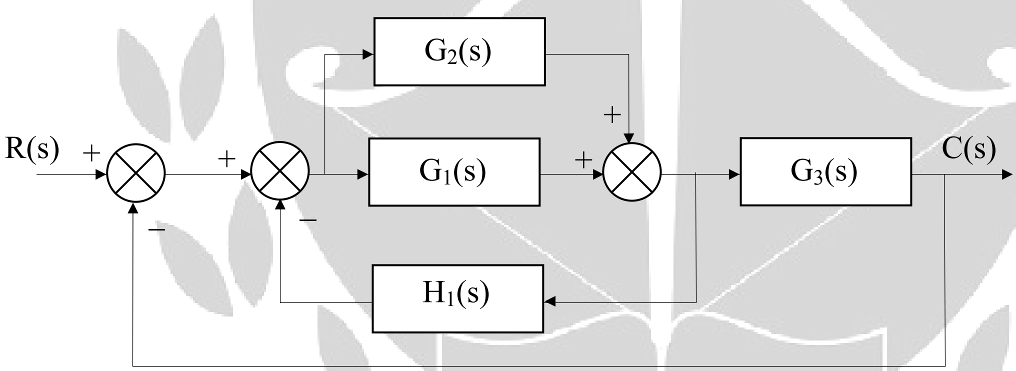
R_m = battery internal resistance

$0.99 = 1.08 \times \dfrac{1100}{1100 + R_m}$

$1100 + R_m = 1200$

$R_m = 100\Omega$

50. The overall closed loop transfer function $\dfrac{C(s)}{R(s)}$, represented in the figure, will be



(A) $\dfrac{(G_1(s)+G_2(s))G_3(s)}{1+(G_1(s)+G_2(s))(H_1(s)+G_3(s))}$

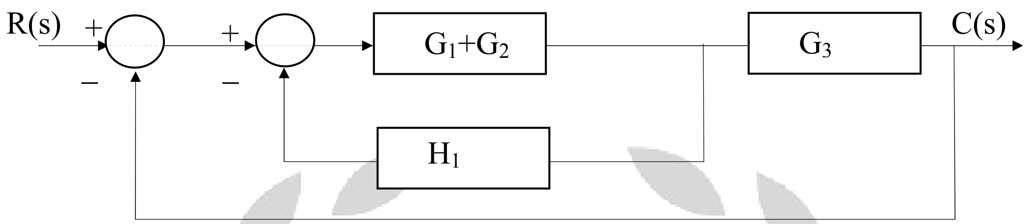
(B) $\dfrac{(G_1(s)+G_3(s))}{1+G_1(s)H_1(s)+G_2(s)G_3(s)}$

(C) $\dfrac{(G_1(s)-G_2(s))H_1(s)}{1+(G_1(s)+G_3(s))(H_1(s)+G_1(s))}$

(D) $\dfrac{G_1(s)G_2(s)H_1(s)}{1+G_1(s)H_1(s)+G_1(s)G_3(s)}$

50. Ans: (A)

Sol: $\frac{C(s)}{R(s)}$



$$\frac{C(s)}{R(s)} = \frac{G_3(G_1+G_2)}{[1-(-H_1(G_1+G_2)-G_3(G_1+G_2))]}$$

$$= \frac{G_3(G_1+G_2)}{1+H_1(G_1+G_2)+G_3(G_1+G_2)}$$

$$= \frac{G_3(G_1+G_2)}{1+(G_1+G_2)(1+1+G_3)}$$

51. The hot junction of a bare thermocouple, initially at room temperature (30°C), is suddenly dipped in molten metal at t = 0 s. The cold junction is kept at room temperature. The thermocouple can be modeled as first-order instrument with a time constant of 1.0 s and a static sensitivity of 10 μV/°C . If the voltage across the thermocouple indicates 10.0 mV at t= 1.0s, then the temperature of the molten metal in °C is _______________

51. Ans: 1564.52

Sol: For first order system

$\theta(t) = \theta_{final} + (\theta_{initial} - \theta_{final})\, e^{-t/\tau}$

$\frac{10\times10^{-3}}{10\times10^{-6}} = T_{molten\,metal} + (30 - T_{molten\,metal})e^{-t/\tau}$

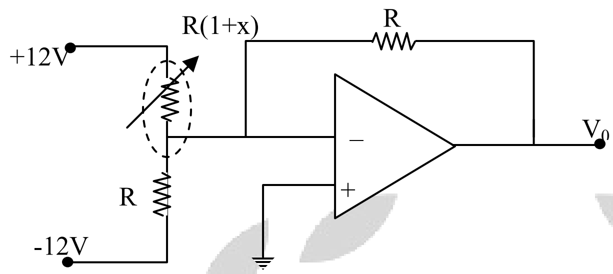
t = 1sec, T =1sec

$10^3 = T_{moltenmetal} + (30 - T_{moltenmetal})\, e^{-1}$

$1000 = T_{moltenmetal}\,(1 - e^{-1}) + 30e^{-1}$

$T_{moltenmeal} = 1564.52°C$

52. A resistance temperature detector (RTD) is connected to a circuit, as shown in the figure. Assume the op-amp to be ideal. If V_0 = + 2.0 V, then the value of x is ___



52. Ans: 0.2

Sol: KCL at inverting terminal:-

$$\frac{0-12}{R(1+x)}+\frac{0+12}{R}+\frac{0-V_0}{R}=0 \quad \{\text{Given } V_0 = +2\}$$

x = 0.2

53. The probability that a communication system will have high fidelity is 0.81 . The probability that the system will have both high fidelity and high selectivity is 0.18. The probability that a given system with high fidelity will have selectivity is

(A) 0.181 (B) 0.191 (C) 0.222 (D) 0.826

53. Ans: 0.222

Sol: P(HF) = 0.81, P(HF $\cap$ HS) = 0.18

$$P(HS|HF)=\frac{P(HS\cap HF)}{P(HF)}$$

$$=\frac{2}{9}$$

$$= 0.222$$

54. The power delivered to a single phase inductive load is measured with a dynamometer type wattmeter using a potential transformer (PT) of turns ratio 200: 1 and the current transformer (CT) of turns ration 1:5. Assume both transformers to be ideal . The power factor of the load is 0.8. If the wattmeter reading is 200 W, then the apparent power of the load in kVA is ____

54. Ans: 250

Sol: Given,

Turns ratio of potential transformer $(PT)\left(\frac{N_1}{N_2}\right)_{PT} = 200:1$

Turns ratio of current transformer $(CT)\left(\frac{N_1}{N_2}\right)_{CT} = 1:5$

Let 'V' be the voltage across the given load.

'I' be the current through the given load.

Similarly let V_d be the voltage across the wattmeter and I_d be the current through the wattmeter

Given power factor = 0.8 lag [$\because$ inductive load]

Given wattmeter reading = W_1 = 200W

But,

$W_1 = V_d\, I_d \times$ power factor

$200 = V_d\, I_d \times 0.8$

$\Rightarrow V_d\, I_d = 250\ V_A \to (1)$

From the turns ratio of PT,

$$\frac{V}{V_d} = \left(\frac{N_1}{N_2}\right)_{PT} = \frac{200}{1}$$

$$\Rightarrow V_d = \frac{V}{200} \to (2)$$

From the turns ratio of CT_1

$$\frac{I}{I_d} = \left(\frac{N_2}{N_1}\right)_{CT} = \frac{5}{1}$$

$$\Rightarrow I_d = \frac{I}{5} \to (3)$$

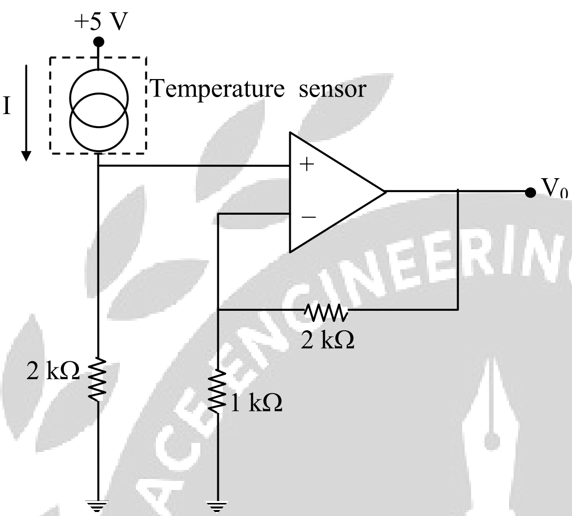
Substituting (2) and (3) in (1) we get,

$$\left(\frac{V}{200}\right)\left(\frac{I}{5}\right) = 250VA$$

$VI = 250 \times 10^3$ VA

$\therefore$ apparent power of load = 250KVA

55. The junction semiconductor temperature sensor shown in the figure is used to measure the temperature of hot air . The output voltage V_0 is 2.1 V. The current output of the sensor is given by I = T μA where T is the temperature in K. Assuming the op-amp to be ideal, the temperature of the hot air in °C is approximately _____



55. Ans: 77

Sol: $V_0\left(\frac{1k}{2k+1k}\right) = \frac{V_0}{3} = \frac{2.1}{3} = 0.7 = V_+$ (virtual and concept)

$$I = \frac{V_+}{2k} = 0.35mA = T\mu A$$

T = 350 K

T = 77°C

General Aptitude

01. Two dice are thrown simultaneously. The probability that the product o the numbers appearing on the top faces of the dice is a perfect square is

(A) 1/9 (B) 2/9

(C) 1/3 (D) 4/9

01. Ans: (B)

Sol: Total chances = 6×6 = 36 events

Product of numbers on 2 dice have to perfect square = Favourable chances

= (1,1), (2,2), (1,4), (3,3), (4,1), (5,5), (4,4), (6,6) = 8

$$\text{Probability} = \frac{\text{Favourable chances}}{\text{Total chances}} = \frac{8}{36} = \frac{2}{9}$$

∴ Option (B) is correct

02. Four cards lie on a table. Each card has a number printed on one side and a colour on the other. The faces visible on the cards are 2,3, red, and blue.

Proposition: If a card has an even value on one side, then its opposite face is red.

The cards which MUST be turned over to verify the above proposition are

(A) 2, red (B) 2, 3, red

(C) 2, blue (D) 2 red, blue

02. Ans: (C)

Sol: Total number of cards = 4

Visible numbers on the cards = 2 and 3

Visible colours on the cards = red and blue

If numbers on the cards = 1,2,3 and 4 then possible colours are blue, red, blue and red respectively.

In order to verify the proposition, we have to turn to card 2 then opposite must be red. In all options except ‘C’ 2 and red are present

∴ Option ‘C’ is correct.

03. What is the value of x when $81\times\left(\frac{16}{25}\right)^{x+2}+\left(\frac{3}{5}\right)^{2x+4}=144$?

(A) 1 (B) –1 (C) –2 (D) Cannot be determined

03. Ans: (B)

Sol: $81\times\left(\frac{16}{25}\right)^{x+2}\div\left(\frac{3}{5}\right)^{2x+4}=144$

$$\frac{\left(\frac{16}{25}\right)^{x+2}}{\left(\frac{3}{5}\right)^{2x+4}}=\frac{144}{81}=\frac{(12)^2}{(9)^2}=\left(\frac{12}{9}\right)^2$$

$$\frac{\left(\frac{4}{5}\right)^{2x+4}}{\left(\frac{3}{5}\right)^{2x+4}}=\left(\frac{12}{9}\right)^2$$

$$\frac{(4)^{2x+4}}{(5)^{2x+4}}\times\frac{(5)^{2x+4}}{(3)^{2x+4}}=\left(\frac{12}{9}\right)^2$$

$$\frac{(4)^{2x+4}}{(3)^{2x+4}}=\left(\frac{12}{9}\right)^2=\left(\frac{4}{3}\right)^2$$

$$\left(\frac{4}{3}\right)^{2x+4}=\left(\frac{4}{3}\right)^2$$

$2x + 4 = 2$

$2x = -2$

$x = -1$

04. The event would have been successful if you ____ able to come.

(A) are (B) had been

(C) have been (D) Would have been

04. Ans: (B)

Sol: Conditional tense type (3 had+V3 +would have +V3)

05. There was no doubt that their work was <u>thorough</u>

Which of the words below is closet in meaning to the underlined word above?

(A) pretty (B) complete (C) sloppy (D) haphazard

05. Ans: (B)

Sol: Through means including every possible detail, parts or complete or absolute.

06. P, Q, R, S, T and U are seated around a circular table , R is seated two places to the right of Q, P is seated three places to the left of R.S is seated opposite U. If P and U now switch seats, which of the following must necessarily be true?

(A) P is immediately to the right of R

(B) T is immediately to the left of P

(C) T is immediately to the left of P or P is immediately to the right of Q

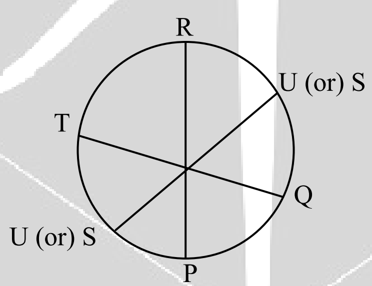
(D) U is immediately to the right of R or P is immediately to the left of T

06. Ans: (C)

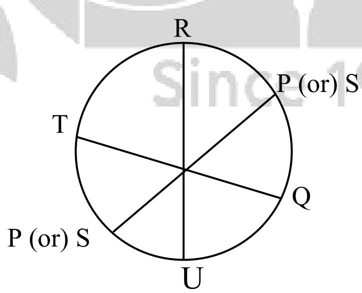
Sol: From the given data, all are seated around a circular table as follows

P Q – R

S is opposite to U



P and U are switch seated means, they are interchange their places



In option (C), before interchange T is immediately to the left of P and After interchange P is immediately to the right of Q

∴ Option 'C' is correct

07. Budhan covers a distance of 19 km in 2 hours by cycling one fourth of the time and walking the rest. The next day he cycles (at the same speed as before) for half the time and walks the rest (at the same speed as before) and covers 26 km in 2 hours. The speed in km/h at which Budhan walks is

(A) 1 (B) 4 (C) 5 (D) 6

07. Ans: (D)

Sol:

19 km → 2 hrs

Cycling ⇒ $\frac{1}{4}$th $= 2\times\frac{1}{4} = \frac{1}{2}$

Walking ⇒ $\frac{3}{4}$th $= 2\times\frac{3}{4} = \frac{3}{2}$

Let cycling speed = C

Walking speed = W

$\frac{C}{2}+\frac{3W}{2}=19$ …………(i)

26 km → 2 hrs

Cycling ⇒ $\frac{1}{2}$th $= 2\times\frac{1}{2} = 1$

Walking ⇒ $\frac{1}{2}$th $= 2\times\frac{1}{2} = 1$

C +W = 26………..(ii)

By solving equation no (i) and (ii)

W = 6 km/hr

∴ The speed at which Budhan walks = 6 kmph

08. A map shows the elevation of Darjeeling, Gangtok, Kalimpong, Pelling, and Siliguri, Kalimpong is at a lower elevation than Gangtok. Pelling is at a lower elevation than Gangtok. Pelling is at a higher elevation than siliguri. Darjeeling is at a higher elevation than Gangtok.

Which of the following statements can be inferred from the paragraph above?

i. Pelling is at a higher elevation than Kalimpong

ii. Kalimpong is at a lower elevation than Darjeeling

iii. Kalimpong is at a higher elevation than Siliguri

iv. Siliguri is at lower elevation than Gangtok

(A) Only ii (B) Only ii and iii (C) Only ii and iv (D) Only iii and iv

08. Ans: (C)

09. Bhaichung was observing the pattern of people entering and leaving a car service centre. There was a single window where customers were being served. He saw that people inevitably came out of the centre in the order that they went in. However, the time they spent inside seemed to vary a lot:

Some people came out in a matter of minutes while for others it took much longer.

From this, what can one conclude?

(A) The centre operates on a first-come –first-served basis, but with variable service times, depending on specific customer needs.

(B) Customers were served in an arbitarary order, since they took varying amounts of time for service completion in the centre.

(C) Since some people came out within a few minutes of entering the centre, the system is likely to operate on a last-come-first-served basis.

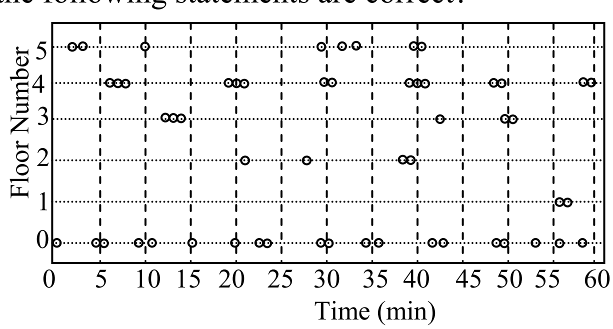
(D) Entering the centre early ensured that one would have shorter service times and most people attempted to do this.

09. Ans: (A)

Sol: The key sentence is "the order that they went in"

10. The points in the graph below represent the halts of a lift for durations of 1 minute, over a period of 1 hour.

Which of the following statements are correct?



i. The elevator never moves directly from any non-ground floor to another non-ground floor over the one hour period

ii. The elevator stays on the fourth floor for the longest duration over the one hour period

(A) Only I (B) Only ii (C) Both i and ii (D) Neither i nor ii

10. Ans: (D)

Sol: (i) is in correct as it has move directly

(ii) is incorrect as it stayed for maximum duration on the ground floor