Instrumentation Engineering

Q. No. 1 to 25 Carry One Mark Each

1. 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) $\frac{s-1}{s-2}$

Key: (B)

Exp: We know for inverse system

$$h(t)*h_I(t)=\delta(t)$$

$$\Rightarrow H(S)H_I(t)=1\Rightarrow H_I(S)=\frac{1}{H(S)}=\frac{1}{Y(S)/X(S)}=\frac{X(S)}{Y(S)}$$

So the transfer function of inverse system is $H_I(S)=\frac{X(S)}{Y(S)}$

It is given that

$$\frac{dy(t)}{dt}+zy(t)=\frac{dx(t)}{dt}+x(t)$$

$$\Rightarrow SY(S)+2Y(S)=SX(S)+X(S)$$

$$\Rightarrow Y(S+2)=X(S)(S+1)$$

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

2. If v is a non-zero vector of dimension 3×1, then the matrix $A=vv^T$ has a rank = _______

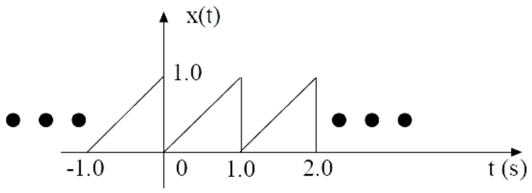
Key: 1 to 1

Exp: $\begin{pmatrix} \because V \text{ is non}-\text{zero} \\ \therefore \rho(V.V^T)\geq 1 \text{ and } \rho(V.V^T)\leq\rho(V)=1 \end{pmatrix}$

Rank of the matrix

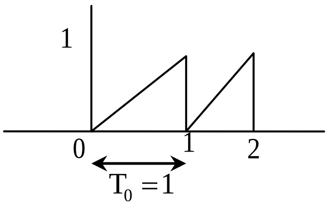
$A=V.V^T$ is 1

3. A periodic signal x(t) is shown in the figure. The fundamental frequency of the signal x (t) in Hz is________



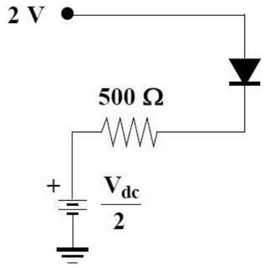
Key: **1 to 1**

Exp:



Fince fundamental time period T_0=1 so the fundamental frequency $f_0=1/T_0$=1Hz

4. 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

Key: **(D)**

Exp: $2 = 0.7 + 500\, I_D + \frac{V_{dc}}{2}$

$V_{dc} = 2\left[2 - 0.7 - 500 I_D\right]$

$\text{when } I_D = 0$

$V_{d.c} > 2.6\text{V}$

5. For a first order low pass filter with unity d.c. gain and -3 dB corner frequency of 2000π rad/s, the transfer function $H(j\omega)$ is

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

Key: **(C)**

Exp: A first order LPF that satisfy unity D.C. Gain should of forms

$$H(S) = \frac{a}{s+a} = \frac{1}{1 + s/a}$$

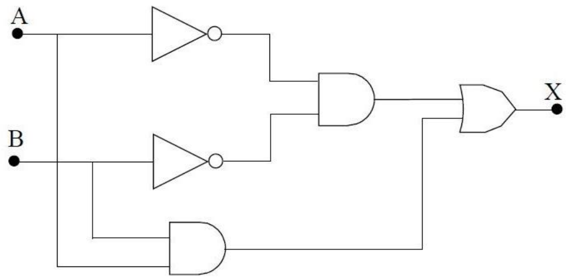
And the – 3 db cut off frequency should be 'a' so that

$$H(\omega) = \frac{i}{1 + j\left(\omega/a\right)} = \frac{1}{1+j} = \frac{1}{\sqrt{1^2 + 1^2}} = \frac{1}{\sqrt{2}}(\text{D.C.gain}) = \frac{1}{\sqrt{2}}$$

$$H(0) = \frac{1}{1 + j0} = 1$$

Only option (C) is of form $\frac{a}{s+a} = \frac{2000\pi}{2000 + s}$

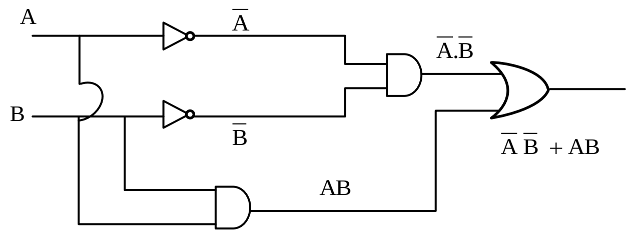
6. A and B are the logical inputs and X is the logical output shown in the figure. The output X is related to A and B by



(A) $X=\bar{A}B+\bar{B}A$ (B) $X=AB+\bar{B}A$ (C) $X=AB+\bar{A}\bar{B}$ (D) $X=\bar{A}\bar{B}+\bar{B}A$

Key: (C)

Exp:



7. 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

Key: (D)

Exp: Pirani Gauge is best suitable for the above range 10^{-4} to 10^{-3} torr Application is to measure "Vacuum Pressure

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

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

Key: (C)

Exp: In process industries, the control signal used is

Current $\rightarrow$ 4-20 mA

Pressure$\rightarrow$ 3-15 psi

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

(A) -0.707 (B) -1 (C) 0 (D) 1

Key: (C)

Exp: $x(t)=\cos(2\pi t)$

If the sampling interval is T_s then the sampled signal

$$x(nT_s)=\cos(2\pi nT_s)=\cos\left[\left(\frac{2\pi}{f_s}\right)n\right]; \quad \text{since } f_s=4\text{Hz}$$

$$x(nT_s)=x(n)\cos\left[\frac{2\pi}{4}n\right]=\cos\left(\frac{n\pi}{2}\right)\Rightarrow x(5)=\cos\left(\frac{5\pi}{2}\right)=0$$

10. The term hysteresis is associated with

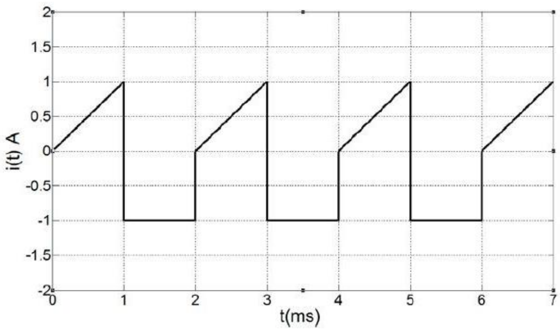
(A) ON-OFF control (B) P-I control

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

Key: (A)

Exp: Hyeres's is need to be introduce in on off control to reduce the oscillation.

11. 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) -0.12A (C) 0.37 A (D) 0.5 A

Key: (A)

Exp: Consider the PMMC as zero centered meter

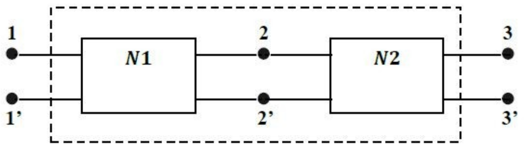
Average value of the above signal is

$$\frac{1}{T}\left[\int_0^1 t\,dt+\int_1^2 -1\,dt\right]$$

$$\frac{1}{2}\left[\frac{t^2}{2}\Big|_0^1 - t\Big|_1^2\right]=\frac{1}{2}\left[\frac{1}{2}-1\right]=-0.25\text{ Amps.}$$

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

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



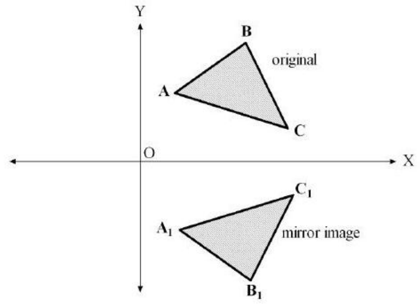
The ABCD parameters of the combined 2-port network are

(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) $\begin{bmatrix} 1 & 2 \\ 0.5 & 5 \end{bmatrix}$

Key: A

Exp: $$[T]=[T_1][T_2]=\begin{bmatrix} 1 & 5 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ 0.2 & 1 \end{bmatrix}=\begin{bmatrix} 1+1 & 0+5 \\ 0+0.2 & 0+1 \end{bmatrix}=\begin{bmatrix} 2 & 5 \\ 0.2 & 1 \end{bmatrix}$$

13. The figure shows a shape ABC and its mirror image $A_1B_1C_1$ across the horizontal axis $(X-\text{axis})$. 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) $\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$

Key: **(D)**

Exp: $\begin{bmatrix} & \\ & \end{bmatrix}$ Mirror image across

$A(1, 2)$

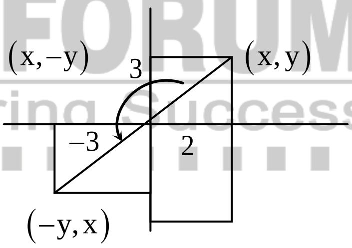
$$\begin{bmatrix} 1 & 2 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} = \begin{bmatrix} 1 & -2 \end{bmatrix}$$

$$A(x_1\ y_1) \rightarrow A_1(x_1\ -y_1) \Rightarrow (x_1\ y_1)\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

$$B(x_2\ y_2) \rightarrow (x_2\ -y_2)$$

$$C(x_3\ y_3) \rightarrow (x_{3_1}\ -y_3)$$

$$\begin{bmatrix} x & y \end{bmatrix}\begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} = (-y\ \ x)$$

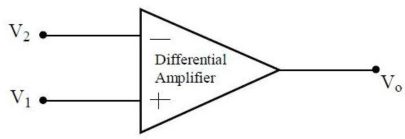


$x = -y$

$y = x$

$x + y = 0$

14. 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 $V_2 = 5.00V$, then V_0, in volt (up to one decimal place) is ___________.



Key: **1.4 to 1.6**

Exp: Given

$$A_c = 0.1;\ V_1 = 5.01V;\ V_2 = 5.00V;\ A_d = 100$$

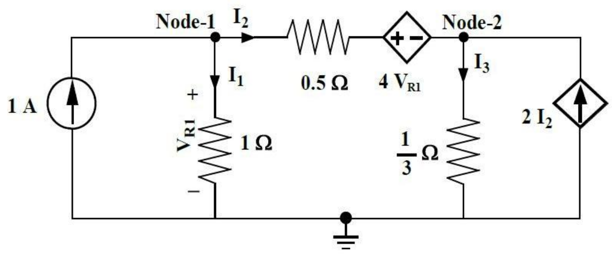
$$V_o = A_d V_d + A_c V_c$$

$$V_d = V_1 - V_2 = 5.01 - 5.00 = 0.01V$$

$$V_c = \frac{V_1 + V_2}{2} = \frac{5.01 + 5.00}{2} = \frac{10.01}{2} = 5.005V$$

$$V_0 = 100 \times 0.01 + 0.1 \times 5.005 = 1 + 0.5005 = 1.5005V \simeq 1.5V$$

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



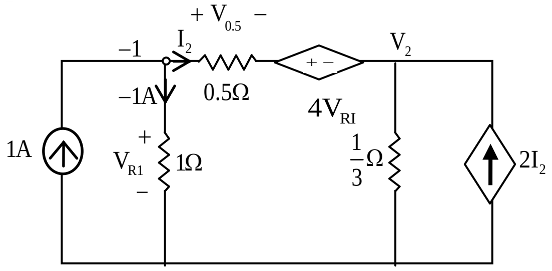
Key: 2 to 2

Exp: $I_2 = 1-(-1) = 2A$

$V_{0.5} = 2\times 0.5 = 1V$

$V_{R1} = 1\times 1 = -V$

$V_2 = -4V_{R1} - V_{0.5} - 1 = 4-1-1 = 2V$



16. 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) $1, -5 \pm j6$ (C) $1, 5 \pm j6$ (D) $1, 5, 5$

Key: (C)

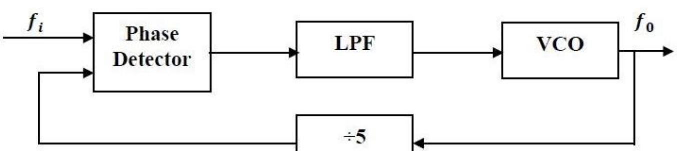
Exp: Characteristic equation is $\begin{vmatrix} 1-\lambda & -1 & 5 \\ 0 & 5-\lambda & 6 \\ 0 & -6 & 5-\lambda \end{vmatrix} = 0$

$\Rightarrow (1-\lambda)\left[(5-\lambda)^2 + 36\right] = 0$

$\lambda = 1;\ \lambda^2 - 10\lambda + 61 = 0$

$\Rightarrow \lambda = \dfrac{10 \pm \sqrt{100-224}}{2} = \dfrac{10 \pm 12j}{2} = 5 \pm j6$

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



Frequency divider

Key: 1 to 1

Exp: $f_0 = nf_i$

$f_i = \dfrac{5}{5} = 1kHz$

18. Identify the instrument that does not exist:

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

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

Key: (D)

Exp: To Measure power we require to coils (C.C & P.C)

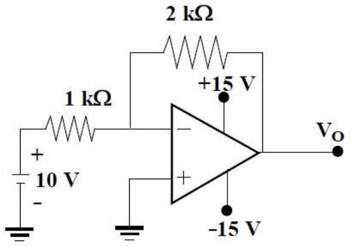
→ Dynamo meter will consist two coils. So it can measure power.

→ Dynamo meter can also measure current and voltage, if we connect C.C & P.C in series.

→ Moving Iron meter will have only one coil, so it can measure current and voltage But not power.

Note: Moving Iron wattmeter doesn't exist.

19. The output V_o shown in the figure, in volt, is close to



(A) −20 (B) −15 (C) −5 (D) 0

Key: (B)

Exp: $V_0 = -\frac{R_2}{R_1} \times V_i = \frac{-2}{1} \times 10 = -10V$

$V_0 < -V_{sat}$

so $V_0 = -V_{sat} = -15V$

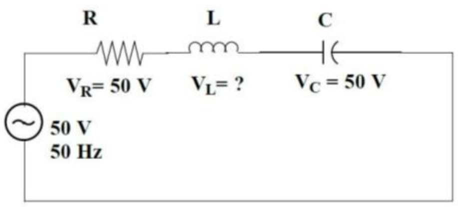
20. An 8-bit microcontroller with 16 address lines has 3 fixed interrupts i.e., Int1, Int2 and Int3 with corresponding interrupt vector addresses as 0008H. 0010H and 0018H. To execute a 32-byte long Interrupt Service Subroutine for Int1 starting at the address ISSI, The location 0008H onwards should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

(A) a CALL to ISSI (B) an unconditional JUMP to ISSI

(C) a conditional JUMP to ISSI (D) only ISSI

Key: (A) or (B)

21. A series R-L-C circuit is excited with a 50V, 50 Hz sinusoidal source. The voltage across the resistance and the capacitance are shown in the figure. The voltage across the inductor (V_L) is __________V



Key: 50 to 50

Exp: bc3 $V_R = V = 50V \Rightarrow$ The circuit is at resonance

at resonance $V_L = V_C \Rightarrow V_{L:} = 50V$

22. 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

Key: **A**

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

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

Key: **(B)**

Exp: $\overline{\cos z} = \cos\bar{z}$

24. 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) $|z| \ge 1$

Key: **(C)**

Exp: The Z-transform of unit step sequence is

$$x(z) = \sum_{n=-\infty}^{\infty} u(n)z^{-1} = \sum_{0}^{\infty} z^{-1} = \frac{1}{1-z^{-1}}; |z^{-1}| < 1 \Rightarrow |z^{-1}| < 1$$

$$\Rightarrow |z^{-1}| < 1 \qquad \left[\because \sum_{0}^{\infty} a^n = \frac{1}{1-a} \text{only when } |a| < 1\right]$$

$$\Rightarrow \left|\frac{1}{z}\right| < 1 \Rightarrow |z| > 1$$

25. 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^3 is

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

Key: **(C)**

Exp: In case of an orifice plate

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

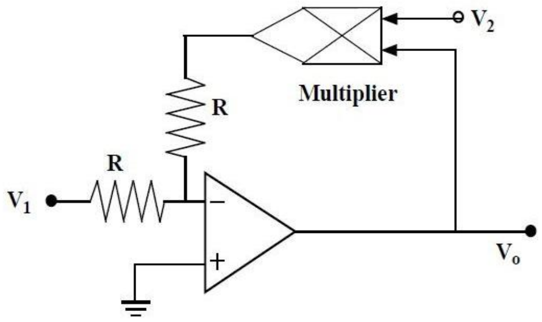
$$\therefore \frac{Q}{2Q} = \sqrt{\frac{5}{\Delta P}}$$

$$\text{or } \frac{1}{2} = \sqrt{\frac{5}{\Delta P}}$$

$$\Delta P = 5 \times 4 = 20 kg/m^2$$

Q. No. 26 to 55 Carry Two Marks Each

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



Key: **-5 to -5**

Exp: Given $V_1 = 15V; \quad V_2 = 3V$

Using nodal analysis

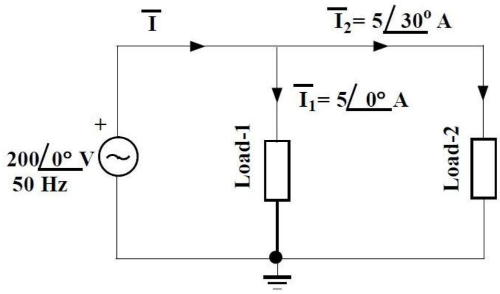
$$\frac{0 - V_1}{R} + \frac{0 - (1 \times V_0 V_2)}{R} = 0$$

$$-V_1 = V_0 V_2;$$

$$V_0 = -\frac{V_1}{V_2}$$

$$V_0 = -\frac{15}{3} = -5V$$

27. For the circuit, shown in the figure, the total real power delivered by the source to the loads is _________kW



Key: **1.75 to 1.96**

Exp: $I = \bar{I}_1 + \bar{I}_2 \;= 5\angle 0° + 5\angle 30°$

$$= 9.66\angle 15°$$

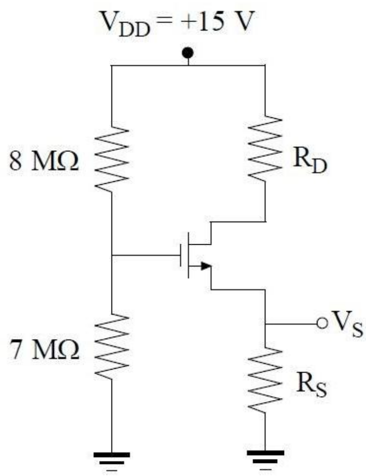
$$\text{Real power} = VI\cos\theta = 200 \times 9.66 \times \cos 15°$$

$$= 1.86kW$$

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

Key: **1.9 to 2**

29. 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 $k\Omega$ is ________.



Key: **9.9 to 10.1**

Exp: Given

$$V_s = 5V;\ I_D = \frac{1}{2}[V_{GS}-1]^2 \text{ mA}$$

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

$$V_{GS} = V_G - V_S = 7-5 = 2V$$

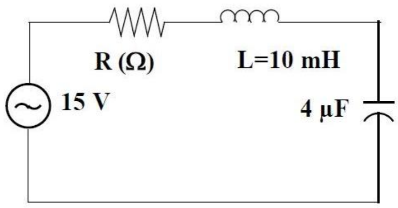
$$I_D = \frac{1}{2}[2-1]^2 = 0.5\text{mA}$$

$$R_S = \frac{V_S}{I_D} = \frac{5}{0.5\times 10^{-2}} = 10k\Omega$$

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

Key: **1605 to 1618**

31. 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 __________.



Key: **6 to 7**

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

$$\Rightarrow R = \frac{1}{Q}\sqrt{\frac{L}{C}} = \frac{1}{30}\sqrt{\frac{10\times 10^{-3}}{4\times 10^{-6}}} = \frac{5}{3}\Omega$$

$$\text{at upper half power frequency } |z| = \sqrt{2}R = \frac{5\sqrt{2}\Omega}{3}$$

$$\Rightarrow |I| = \frac{|V|}{|Z|} = \frac{15}{5\sqrt{2}}\times 3 = 6.36A$$

32. An angle modulated signal with carrier frequency $\omega_c = 2\pi\times10^6\text{ rad/s}$ 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 carrier is _________ kHz.

Key: 12 to 13

Exp: $\phi_m(t)=\cos(\omega_c t+5\sin(1000\pi t)+10\sin(2000\pi t))$

Instantaneous phase

$\phi_i(t)=\omega_c t+5\sin(1000\pi t)+10\sin(2000\pi t)$

$$\frac{d\phi_i(t)}{a^t}=\omega_i(t)=\omega_c+5\times1000\pi\cos(1000\pi t)$$
$$+10\times2000\pi\cos(2000\pi t)$$

Instantaneous frequency

$\Rightarrow f_i(t)=f_c+2500\cos(1000\pi t)+10000\cos(2000\pi t)$

$\Rightarrow$ Maximum deviation in maximum value is

$2500\cos(1000\pi t)+10000\cos(2000\pi t)=2500+10000=12.5\text{kHz}$

33. Three DFT coefficients, out of five DFT coefficients of a five-point real sequence are given as 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

Key: (B)

Exp: We know for N point DFT (for real sequence)

$x(K)=x^*(N-K)$, here $N=5$ so $x(K)=x^*(5-K)$....(1)

The standard IDFT

$$x(n)=\frac{1}{N}\sum_{K=0}^{N-1}x(K)e^{j\frac{2\pi}{N}Kn}, \text{Substituting } n=0$$

$$x(0)=\frac{1}{N}\sum_{K=0}^{N-1}x(K) \text{ if } N=5 \text{ then}$$

$$x(0)=\frac{1}{5}\sum_{K=0}^{4}x(K)=\frac{x(0)+x(1)+x(2)+x(3)+x(4)}{5}...(2)$$

It is given that

$x(0)=4$

$x(1)=1-j1$

$x(3)=2+j2$

using equation (1)

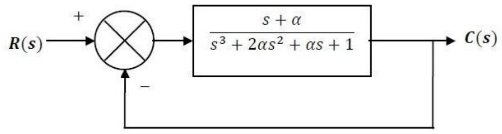
$x(2)=x^*(5-2)=x^*(3)=(2+j2)^*=2-j2$

$x(4)=x^*(5-4)=x^*(1)=(1-j1)^*=1+j1$

using equation (2)

$$x(0)=\frac{4+(1-j1)+(2-j2)+(2+j2)+(1+j1)}{5}=10/5=2$$

34. 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) $\alpha > 0.5$

Key: (D)

Exp: The characteristic equation of the unity feedback system is 1 + G(S)=0

$$\Rightarrow 1 + \frac{S+\alpha}{S^3+2\alpha S^2+\alpha S+1} = 0 \Rightarrow S^3+2\alpha S^2+\alpha S+1+S+\alpha = 0$$

$$\Rightarrow S^3+2\alpha S^2+(\alpha+1)S+(\alpha+1)=0$$

By R-H criterian if the equation is of form $as^3+bs^2+cs+d=0$ then the condition for stability is bc > ad,

Using this

$$(2\alpha)(\alpha+1) > (\alpha+1).1 \Rightarrow 2\alpha > 1 \Rightarrow \alpha > 0.5$$

35. 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 ratio 1:5. Assume both the transformers to be ideal. The power factor of the load is 0.8. If the wattmeter reading is 200W, then the apparent power of the load in kVA is _________.

Key: 250 to 250

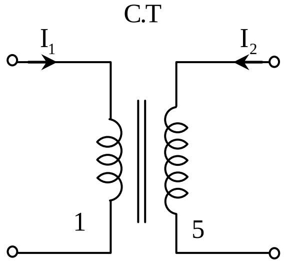
Exp:

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

$$I_2 = \frac{N_1}{N_2} I_1$$

$$I_2 = \frac{I_1}{5}$$

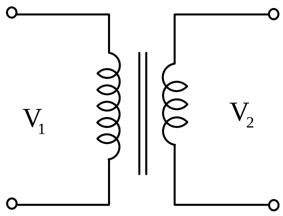
C.T



$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$$V_2 = \frac{V_1}{200}$$

P.T



200 : 1

I through C.C $\rightarrow I_2$

V / g cross P.C $\rightarrow V_2$

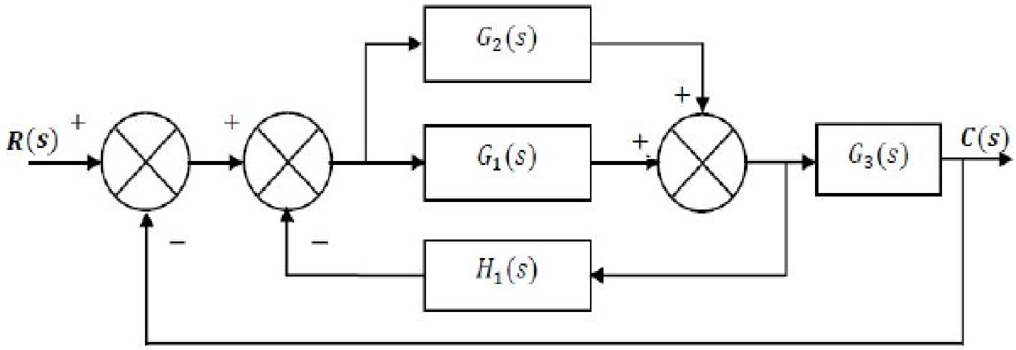
Power measured by w/m will be

$$200 = V_2.I_2 \cos\phi$$

$$200 = \frac{V_1}{200} \times \frac{I_1}{5} \times 0.8$$

$$V_1 I_1 = \frac{200}{0.8} \times 10^3 = 250\text{kVA}$$

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



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

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

Key: (A)

Exp: The Parallel connection of G_1,G_2 can be replaced by G_1+ G_2.

(G_1+G_2) forms a feedback loop with H_1, it can be replaced by $\frac{G_1+G_2}{1+(G_1+G_2)H_1}$

Final considering G_3 and the unity feedback

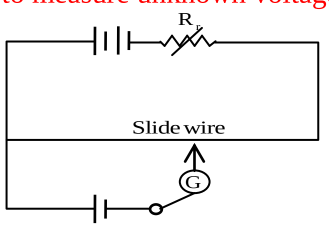
$$\frac{C(S)}{R(S)}=\frac{G}{1+G}=\frac{\frac{(G_1+G_2)G_3}{1+(G_1+G_2)H_1}}{1+\frac{(G_1+G_2)H_1}{1+(G_1+G_2)H_1}}$$

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

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

Key: 100 to 100

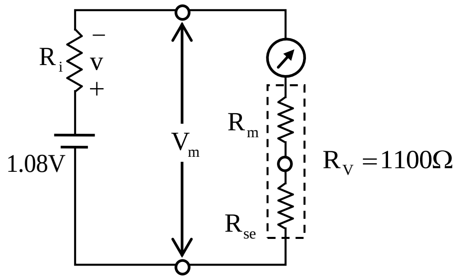
Exp: We use potentiometer to measure unknown voltages (very low) it is a Null type instrument



→ The Galvanometer reads zero when the voltage drop across slide wire and unknown Battery voltages are equal.

→ Given that potentiometer reading as 1.08V

i.e., The Battery voltage will be 1.08 volts.



PMMC reads,

$v_m = 0.99V.$

By KVL

$V = 1.08 - 0.99$

$V = 0.09$ Volts.

$$\rightarrow I_m = \frac{V_m}{R_V} = \frac{0.99}{1100} = 9\times10^{-4}\text{ AMPS.}$$

$$\rightarrow R_i = \frac{V}{I_m} = \frac{0.09}{9\times10^{-4}} = 100\Omega.$$

38. 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 high selectivity is

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

Key: (C)

Exp: Let A, B be the events respectively that the communication system will have high fidelity, high selectivity then

$$P(A) = 0.81 \text{ and } P(A\cap B) = 0.18$$

$$\text{required probability is } P(B/A) = \frac{P(A\cap B)}{P(A)} = \frac{0.18}{0.18} \approx 0.222$$

39. 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	…	∞
t(t) in A	0	0.197	0.316	0.388	0.432	…	0.5

Key: 1 to 1

Exp: We know $i(t) = 0.5 - 0.5e^{-\frac{R}{L}t}$

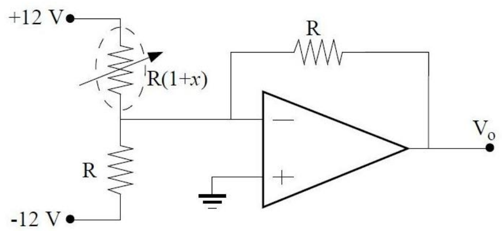
$$\text{at } t=\infty,\ i(t)=\frac{V(t)}{R}=0.5$$

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

$$\text{at } t=0.25$$

$$0.197=0.5-0.5e^{-\frac{R}{L}\times 0.25}\Rightarrow\frac{R}{L}=2\Rightarrow L=\frac{R}{2}=\frac{2}{2}=1H$$

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



Key: 0.19 to 0.21

Exp: At the inverting terminal of the op-amp

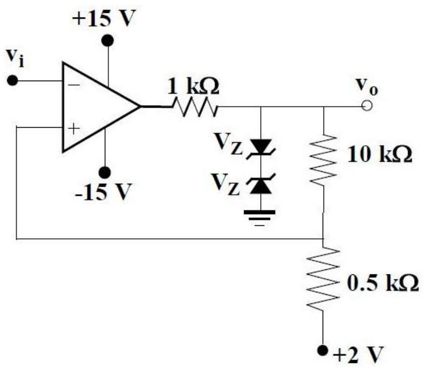
i.e., at $V_{(-)}$

By virtual ground $V_{(t)}=V_{(-)}=0$

$$\therefore\frac{(12-0)}{R(1+x)}+\frac{(V_o-0)}{R}+\frac{(-12-0)}{R}=0$$

$$\frac{12}{R(1+x)}+\frac{2}{R}=\frac{12}{R}\Rightarrow\frac{12}{(1+x)}=10\Rightarrow 12=10(1+x)\Rightarrow x=1.2-1=0.2$$

41. The circuit of a Schmitt trigger is shown in the figure. The zener-diode combination maintains the output between $\pm 7V$. The width of the hysteresis band is _________V.



Key: 0.6 to 0.7

Exp: When zener diode combination maintains output of $\pm 7V$

$$V_{UTP}=\frac{7\times 0.5}{10.5}=0.333V$$

$$V_{LTP}=\frac{-7\times 0.5}{10.5}=-0.333V$$

$$\text{Width of hysteresis band}=V_{UTP}-V_{LTP}=0.333-(-0.333)=0.666V$$

42. 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 ____________.

Key: –1.2 to -1.0

Exp: To obtain the Break point first of all we have to arrange K intevms of GH, then the roots of $\frac{dk}{ds}=0$ gives break point

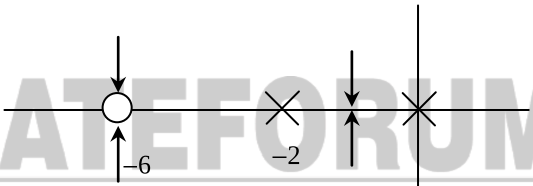
$$GH=\frac{K(S+6)}{S(S+2)}\Rightarrow\frac{-1(S(S+2))}{S+6}=K$$

$$\Rightarrow K=-\left[\frac{S^2+25}{S+6}\right]\Rightarrow\frac{dk}{ds}=\frac{(S+6)\frac{d}{dS}(S^2+25)-(S^2+25)\frac{d}{dS}(S+6)}{(S+6)^2}$$

$$\Rightarrow 0=(S+6)(2S+2)-(S^2+25)\Rightarrow 2S^2+2S+12S+12-S^2-25=0$$

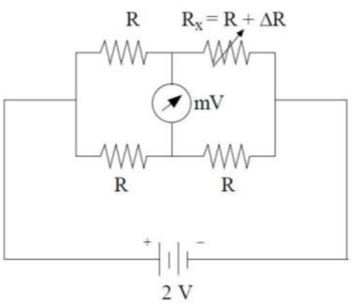
$$\Rightarrow S^2+12S+12=0\Rightarrow S=-1.1,-10.83$$

To decide which among the two root is Breakaway draw the pole zero plot & mark real axis branch.



So break away point be in 0 to -2 so break away point is -1.1.

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



Key: 0.17 to 0.23

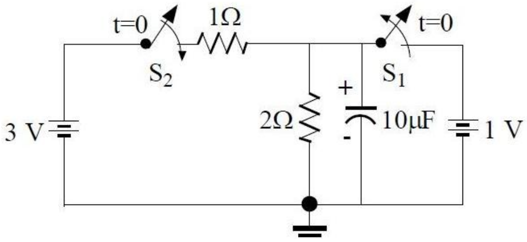
Exp: $V_x=2\times\left[\frac{1k+\Delta R}{2k+\Delta R}\right]-(1)$ By Voltage division Rule.

$V_x=1.0001\text{volts}-(2)$ By KVL

$$\frac{1.0001}{2}=\frac{1k+\Delta R}{2k+\Delta R.}$$

By solving above equation, we get $\Delta_R=0.2\Omega$

44. 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 volt, at t = 5 μs is ___________.



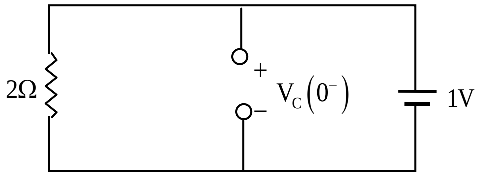
Key: 1.43 to 1.63

Exp: at $t=0^-$

$V_c(0^-)=1V$

at $t\to\infty$

$V_C(\infty)=\frac{2}{3}\times 3=2V$

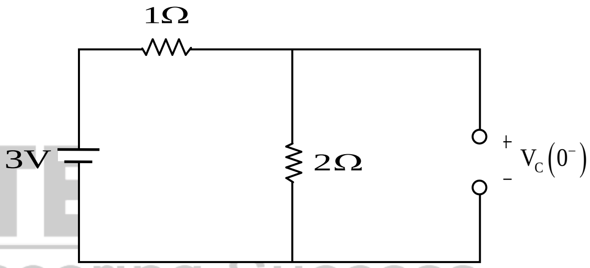


$\tau=R_{eq}\,C_{eq}=\frac{2}{3}\times 10\times 10^{-6}=\frac{20}{3}\mu s$

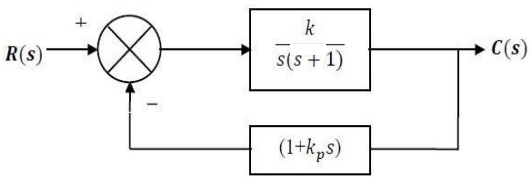
$V_C(t)=V_C(\infty)+\left(V_C(0)-V_C(\infty)\right)e^{-t/\tau}$

$=2-e^{\frac{t}{20\times 10^{-6}}\times 3}$

$V_C(5\mu s)=2-e^{\frac{5\times 10^{-6}}{20\times 10^{-6}}\times 3}=1.527V$



45. 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 ratio of 0.8 and an undamped natural frequency ω_n of 4 rad/s respectively. The value of k_p will be ___________.



Key: 0.32 to 0.4

Exp: 1+GH=0 represent the characteristic equation of the close loop –ve feed back system

$\Rightarrow 1+\frac{K(1+K_pS)}{S(S+1)}=0\Rightarrow S(S+1)+K(1+K_pS)-0$

$\Rightarrow S^2+S+K+KK_pS=0\Rightarrow S^2+(1+KK_p)S+K=0$

Comparing with standard 2nd order equation

$\Rightarrow S^2+2\xi\omega_nS+\omega_n^2=0\Rightarrow \omega_n^2=K\Rightarrow 4^2=K\Rightarrow K=16$

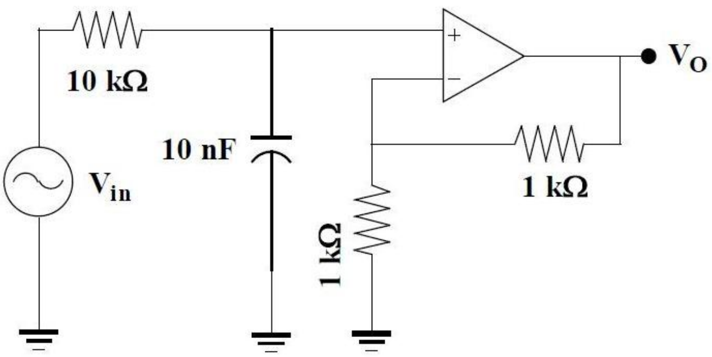
Using K=16, the characteristic equation becomes

$$S^2 + (1+16K_P)S + 16 = 0 \Rightarrow 2\xi\omega_n = 1+16K_P$$

$$\Rightarrow K_P = \frac{2\xi\omega_n - 1}{16} = \frac{(2\times0.8\times4)-1}{16}$$

$$= \frac{27}{80} = 0.3375$$

46. Assuming the op-amp shown in the figure to be ideal, the frequency at which the magnitude of V_o will be 95% of the magnitude of V_{in} is ____________kHz.



Key: 2.9 to 3

Exp:

$$V_x = \frac{V_i}{1+RCS} = \frac{V_i}{1+10\times10^3\times10\times10^{-9}S}$$

$$V_x = \frac{V_i}{1+j10^{-4}2\pi f} = \frac{V_i}{1+j6.28\times10^{-4}f}$$

$$V_0 = \left(1+\frac{R_2}{R_1}\right)V_x = (1+1)\times\frac{V_i}{1+j6.28\times10^{-4}f} = \frac{2V_i}{1+j6.28\times10^{-4}f}$$

when $V_0 = 0.95V_i$

$$0.95V_i = \frac{2V_i}{\sqrt{1+(6.28\times10^{-4}f)^2}}$$

$$\sqrt{1+(6.28\times10^{-4}f)^2} = \frac{2}{0.95} = 2.105$$

$$1+(6.28\times10^{-4}f)^2 = 4.431$$

$$6.28\times10^{-4}f = \sqrt{3.431}$$

$$f = \frac{\sqrt{3.431}}{6.28\times10^{-4}}$$

$$= 2.949\text{kHz}$$

47. The following table lists an n^{th} order polynomial $f(x) = a_n x^n + a_{n-1}x^{n-1} + \cdots + a_1 x + a_0$ 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

Key: (D)

Exp: Clearly the entries in the fourth forward difference $\left(\text{i.e.} \Delta^4 f\right)$ are all same which is 0.0072

$\therefore$ The order of the polynomial is 4.

48. Consider two discrete-time signals:

$x_1(n) = \{1,1\}$ and $x_2(n) = \{1,2\}$, for $n = 0.1$.

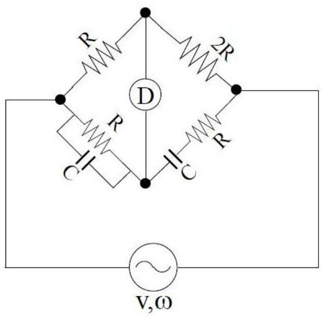
The Z-transform of the convoluted sequence $x(n) = x_1(n) * x_2(n)$ is

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

(C) $1 + 3z^{-1} + 2z^{-2}$ (D) $z^{-2} + 3z^{-3} + 2z^{-4}$

Key: (C)

49. 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 ___________.



Key: 10000 to 10000

Exp: According to bridge balancing condition

$$R\times\left(R+\frac{1}{j\omega C}\right)=2R\left[\frac{R\times\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}}\right]$$

$$R^2+\frac{R}{j\omega C}=2R\frac{R}{j\omega CR+1}$$

$$\frac{R^2 j\omega C+R}{j\omega C}=\frac{2R^2}{j\omega CR+1}$$

$$\left(R^2 j\omega C+R\right)\left(j\omega CR+1\right)=2R^2 j\omega C$$

$$\left(j\omega C\right)^2R^3+R^2 j\omega C+j\omega CR^2+R=2R^2 j\omega C$$

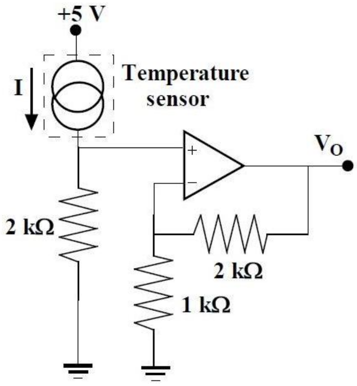
$$j\omega C\left[j\omega CR^3+R^2+R^2-2R^2\right]=-R$$

$$-\omega^2C^2R^3=-R$$

$$\omega^2C^2=\frac{1}{R^2}\Rightarrow\omega=\frac{1}{\sqrt{R^2C^2}}$$

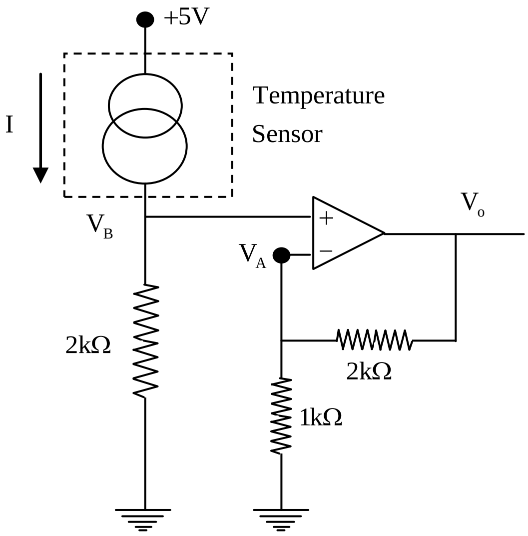
$$\omega=\frac{1}{RC}=\frac{1}{10^3\times10^{-7}}=\frac{1}{10^{-4}}=10^4$$

50. The junction semiconductor temperature sensor shown in the figure is used to measure the temperature of hot air. The output voltage V_o is 2.1V. The current output of the sensor is given by $I=T\mu A$ where T is the temperature in K. Assuming the op-amp to be ideal, the temperature of the hot air in ^oC is approximately ___________.



Key: 76 to 78

Exp: Voltage at point $V_{A,}$ is



$$V_A=\frac{1}{1+2}\times V_o=\frac{1}{3}\times2.1=0.7V$$

By virtual ground

$$V_+=V_-=0.7V$$

$$\therefore V_B=0.7V$$

$$I=\frac{V_B-0}{2k\Omega}=\frac{0.7}{2000}=350\mu A$$

As given $I=I\mu A$

$$\therefore T=350K=(350-273)^oC=77^oC$$

51. In a sinusoidal amplitude modulation scheme (with carrier) the modulated signal is given by $A_m(t) = 100\cos(\omega_c t) + 50\cos(\omega_m t)\cos(\omega_c t)$, where ω_c is the carrier frequency and ω_m is the modulation frequency. The power carried by the sidebands in % of total power is __________%

Key: 11 to 11.2

Exp: Given amplitude modulated signal

$$A_m(t) = 100\cos(\omega_c t) + 50\cos(\omega_m t)\cos(\omega_c t)$$
$$= \underbrace{100\cos(\omega_c t)}_{\text{Carrier}} + \underbrace{25\cos(\omega_c + \omega_m)t + 25\cos(\omega_c - \omega_m)}_{\text{Side Branch}}$$

$$P_C = \frac{100^2}{2} = 5000 \qquad P_{SB} = \frac{(25)^2}{2} + \frac{(25)^2}{2} = 625$$

Total power = 5625

$$\text{Power carried by the side bands in \% of total power} = \frac{625}{5625} = 11.11\%$$

52. 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 __________.

Key: 0.65 to 0.8

Exp: $$\cos\theta = \frac{(2)(-12)+(6)(8)+(14)(16)}{\sqrt{4+36+196}\sqrt{144+64+256}} = \frac{248}{\sqrt{236}\sqrt{464}} = \frac{62}{\sqrt{59}\sqrt{116}} = \approx 0.75$$

$\therefore \theta = 0.72$ radians

53 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 Plank's constant $h = 6.624\times10^{-34}$ 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 100 μW at 830 nm, the photocurrent in μA is ___________.

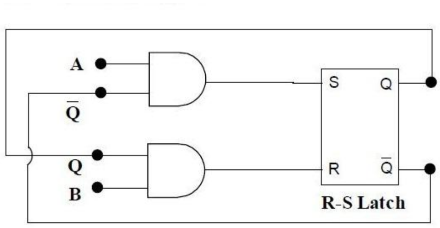
Key: 74.5 to 75.5

Exp: Responsivity $$R = \eta e = \frac{0.75\times1.6\times10^{-9}}{6.624\times10^{-34}\times2\times10^{8}} \times 830\times10^{-9} = 7518.11\times10^{-4}$$

Now $R = \dfrac{I_P}{P_o}$

$$I_P = R\times P_o = 7518.11\times10^{-4}\times100\times10^{-6} = 7518.11\times10^{-8} = 75.18\times10^{-6}\,A = 75.18\mu A$$

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



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

Key: (B)

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

J	K	Q_{n+1}
0	0	Q_n
0	1	0
1	0	1
1	1	$\bar{Q}_n$

A	B	Previous State $[Q_n]$	J $A.\bar{Q}$	K $B.Q$	Next State Q_{n+1}	Next State $\overline{Q}_{n+1}$
1	0	0	1	0	1	0
1	0	1	0	0	1(Previous output)	0

55. 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 = 0.1 s is __________ unit.

Key: -2.4 to -2.0

Exp: $Y(S)=\frac{S+2}{S+6}=\frac{S+6-4}{S+6}=\frac{S+6}{S+6}-\frac{4}{S+6}=1-\frac{4}{S+6}$

Taking inverse Laplace

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

$y(0.1)=\delta(0.1)-4e^{-6\times0.1}u(0.1)=0-4\left(e^{-0.6}\right)(1)=-4e^{-0.6}=-2.19$

General Aptitude

Q. No. 1 - 5 Carry One Mark Each

1. The event would have been successful if you ______ able to come.

   (A) are (B) had been (C) have been (D) would have been

Key: B

2. 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

Key: C

Exp: To check even $\Rightarrow$ red, we must confirm that back of 2 is red and back of blue is an odd number.

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

   (A) 1 (B) -1 (C) -2 (D) cannot be determined

Key: B

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

$$\Rightarrow\left(\frac{4}{3}\right)^{2x+4}\times 81=144\Rightarrow\left(\frac{4}{3}\right)^{2x}.\frac{4^4}{3^4}\times 81=144\Rightarrow\left(4/3\right)^{2x}=\frac{9}{16}\Rightarrow x=-1$$

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

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

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

Key: B

5. Two dice are thrown simultaneously. The probability that the product of 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

Key: B

Exp: Required probability= $\frac{\cancel{8}}{\cancel{36}}=\frac{2}{9}$

Q. No. 6- 10 Carry Two Marks Each

6. 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 arbitrary order, since they took varying amounts of time of 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.

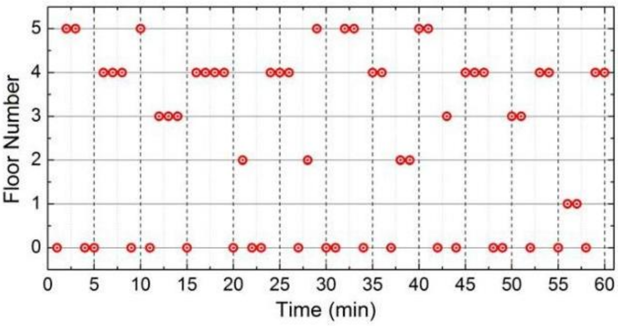
(D) Entering the centre early ensured that one would have shorter service times and most people attempted to do this.

Key: **(A)**

Exp: People coming out in the same order in which they enter indicates that the centre operates on a first-come-first-serve basis.

7. 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

Key: **(D)**

Exp: (i) is incorrect as it moves directly

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

8. A map show the elevations of Darjeeling, Gangtok, Kalimpong, Pelling, and Siliguri, Kalimpong is at a lowest 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 a lower elevation than Gangtok

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

Key: (C)

Exp: The given information is $K<G$, $P<G$, $S<P$ and $G<D$

From these it can be inferred

$S<P<G<D$ and also $K<G$

So $K<D$ as well but no comparison between K and S (or) K and P is given.

9. 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

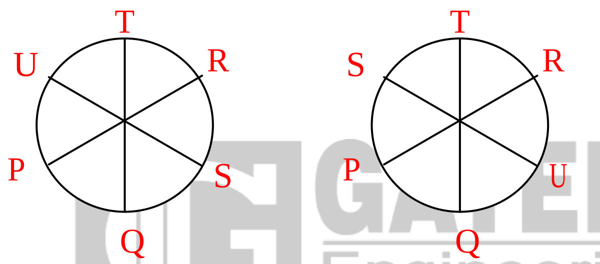
(B) T is immediately to the left of P

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

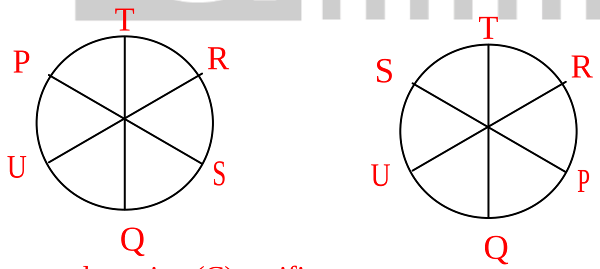
(D) U is immediately to the right of R or P is immediately to the left of T

Key: (C)

Exp: Following two possibilities can be drawn



Given in question P and U interchange then new diagram can be drawn.



now only option (C) verifies.

10. 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

Key: (D)

Exp: Let cycling speed = c and walking speed = w

Given $c\left(\frac{1}{2}\right)+w\left(\frac{3}{2}\right)=19 \quad \text{(i)}$

$c+w=26 \quad \text{(ii)}$

On solving eq(i) and (ii), we get

$w = 6\text{km/hr}$