GENERAL APTITUDE

Q. No. 1 - 5 Carry One Mark Each

1. Until Iran come along, India had never been ______ in kabaddi.

(A) defeated (B) defeating
(C) defeat (D) defeatist

Key: (A)

2. The fishermen ,_______the flood victims owed their lives, were rewarded by the government

(A) whom (B) to which (C) to whom (D) that

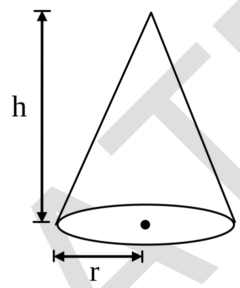
Key: (C)

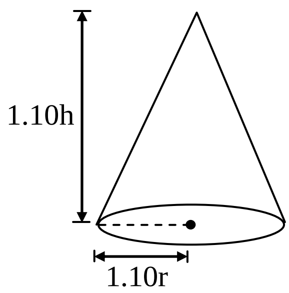
3. The radius as well as the height of a circular cone is increases by 10%. The percentage increase in its volume is ____________.

(A) 17.1 (B) 21.0 (C) 33.1 (D) 72.8

Key: (C)

Sol: Initial Stage | After increasing 10% for radius & height





Volume of circular cone,

$$V_i = \frac{1}{3}\pi . r^2 h$$

Volume, $V_f = \frac{1}{3}\pi(1.1r)^2(1.1h)$

$$= \frac{1.331}{3}\pi r^2 h$$

$$\text{Percentage increase} = \frac{V_f - V_i}{V_i} \times 100 = \frac{\frac{1.331}{3}\pi r^2 h - \frac{1}{3}\pi r^2 h}{\frac{1}{3}\pi r^2 h} \times 100 = \frac{1.331 - 1}{1} \times 100 = 33.1\%$$

4. Five numbers 10, 7, 5, 4, 2 are arranged in a sequence from left to right following the directions given below:

(1) No two odd or even numbers are next to each other.

(2) The second number from left is exactly half of the left -most number.

(3) The middle number is exactly twice the right most number.

Which is the second number from the right ?

(A) 2 (B) 4 (C) 7 (D) 10

Key: **(C)**

Sol: Numbers are 2, 4, 5, 7, and 10

The correct order of arrangement 10, 5, 4, 7, and 2

Thus an arrangement follows given three conditions

Second number from right = 7

5. “Some students were not involved in the strike”. If the above statement is true, which of the following conclusions is/are logically necessary ?

1. Some who were involved in strike were students.

2. No student was involved in the strike.

3. At least one student was involved in the strike.

4. Some who were not involved in the strike were students.

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

Key: **(C)**

Q. No. 6 - 10 Carry Two Marks Each

6. "I read somewhere that in ancient times the prestige of a kingdom depended upon the number of taxes that it was able to levy on its people. It was very much like the prestige of a head -hunter in his own community".

Based on the paragraph above, the prestige of a head- hunter depended upon ____

(A) the prestige of the kingdom

(B) the prestige of the heads

(C) the number of taxes he could levy

(D) the number of head she could gather

Key: **(D)**

7. Two trains started at 7 AM from the same point. The first train travelled towards north at a speed of 80 km/h and the second train travelled south at a speed of 100 km/h. The time at which they were 540 km apart is _______ AM.

(A) 9 (B) 10 (C) 11 (D) 11:30

Key: **(B)**

Sol: For X

Time taken = t

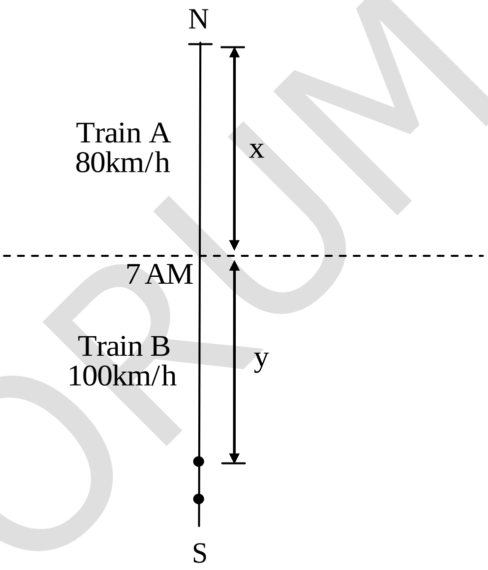
Distance $x = \text{velocity} \times \text{time}$

$$x = 80t \Rightarrow t = \frac{x}{80} \qquad ...(1)$$

For y time taken = t

$$\text{Distance } y = 100t \Rightarrow t = \frac{y}{100} \qquad ..(2)$$

$$x + y = 540\text{km} \qquad ...(3)$$



From (1) and (2)

$$t = \frac{x}{80} = \frac{y}{100} \Rightarrow x = 0.8y$$

$$x + y = 540 \Rightarrow 0.8y + y = 540$$

$$1.8y = 540 \Rightarrow y = 300\text{km}$$

$$\text{Time taken} = \frac{y}{100} = \frac{300}{100} = 3\text{hrs}$$

Time at which these trains $= 7.00\text{AM} + 3\text{hrs} = 10.00\text{AM}$

8. In a country of 1400 million population, 70% own mobile phones. Among the mobile phone owners only 294 million access the internet. Among these Internet users, only half buy goods from e-commerce portals. What is the percentage of these buyers in the country ?

(A) 10.50 (B) 14.70 (C) 15.00 (D) 50.00

Key: **(A)**

Sol: Total population = 1400 million

Number of people whose having own mobile phones

$= 70\%$ of $1400 = 0.7 \times 1400 = 980$ million

Number of people whose accesses the internet = 294 million

Number of people who buy goods from e-commercial portals = Half of internet users

$$= \frac{294}{2} = 147\text{million}$$

$$\text{Percentage buyers} = \frac{147\text{ million}}{1400\text{ million}} \times 100 = 10.5\%$$

9. The nomenclature of Hindustani music has changed over centuries. Since the medieval period *dhrupad* styles were identified as *baanis*. Terms like *gayaki* and *baaj* were used to refer to vocal and instrumental styles, respectively. With institutionalization of music education the term *gharana* became acceptable. *Gharana* originally referred to hereditary musicians from a particular lineage, including disciples and ground disciples. Which one of the following pairings is NOT Correct ?

(A) Dhrupad, baani
(B) Gayaki, Vocal
(C) Baaj, institution
(D) Gharana, lineage

Key: (C)

10. Since the last one year, after a 125 basis point reduction in repo rate by the Reserve Bank of India, banking institutions have been making a demand to reduce interest rates on small savings schemes. Finally, the government announced yesterday a reduction in interest rates on small saving schemes to bring them on par with fixed deposit interest rates.

Which one of the following statements can be inferred from the given passage ?

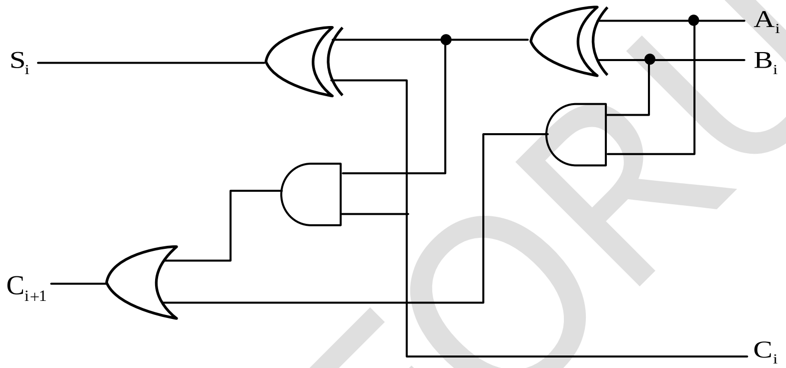
(A) Whenever the Reserve Bank of India reduces the repo rate, the interest rates on small saving schemes are also reduced.
(B) Interest rates on small saving schemes are always maintained on par with fixed deposit interest rates.
(C) The government sometimes takes into consideration the demands of banking institutions before reducing the interest rates on small saving schemes.
(D) A reduction in interest rates on small saving schemes follow only after a reduction in repo rate by the Reserve Bank of India.

Key: (D)

INSTRUMENTATION ENGINEERING

Q. No. 1 to 25 Carry One Mark Each

1. The figure below shows the i^{th} full-adder block of a binary adder circuit. C_i is the input carry and C_{i+1} is the output carry of the circuit. Assume that each logic gate has a delay of 2 nanosecond, with no additional time delay due to the interconnecting wires. If the inputs A_i, B_i are available and stable throughout the carry propagation, the maximum time taken for an input C_i to produce a steady-state output C_{i+1} is ________nanosecond.



Key: **(6)**

Sol: To get circuit output bit, the input signals has to propagate through 3 stages and each stage having delay 2n sec so the total delay is

$2\times3=6\text{n sec.}$

2. The resistance of a resistor is measured using a voltmeter and an ammeter. The voltage measurements have a mean value of 1V and standard deviation of 0.12V while current measurements have a mean value of 1 mA with standard deviation of 0.05mA. Assuming that the errors in voltage and current measurements are independent, the standard deviation of the calculated resistance value is ________________Ω.

Key: **(130)**

Sol: Given $V_{mean}=1V, \sigma_V=0.12V$

$I_{mean}=1mA, \sigma_I=0.05mA$

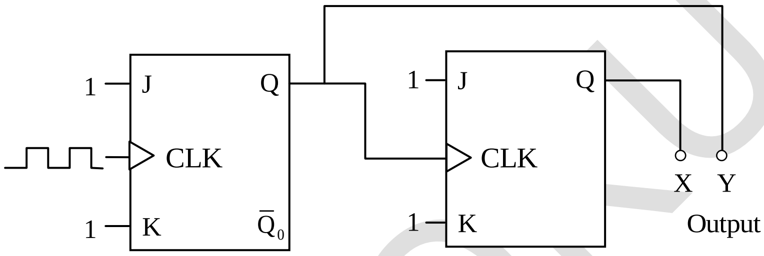
$R=\frac{V}{I}(\text{from basic})$

$$\sigma_R = \sqrt{\left(\frac{\partial R}{\partial I}\right)^2 (\sigma_I)^2 + \left(\frac{\partial R}{\partial I}\right)^2 \sigma_V^2} = \sqrt{\left(\frac{-V}{I^2}\right)^2 \sigma_I^2 + \left(\frac{1}{I}\right)^2 \sigma_V^2}$$

$$= \sqrt{\left(\frac{-1}{10^{-3}}\right)^4 \left(0.05\times10^{-3}\right)^2 + \left(\frac{1}{10^{-3}}\right)^2 \times 0.12^2} = \sqrt{2500+14400}$$

$\sigma_R = 130\Omega \rightarrow$ It is standard deviation in calculated resistance.

3. The circuit shown in the figure below uses ideal positive edge-triggered synchronous J-K flip flops with outputs X and Y. If the initial state of the output is X = 0 and Y = 0 just before the arrival of the first clock pulse, the state of the output just before the arrival of the second pulse is



(A) $X=0, Y=0$ (B) $X=0, Y=1$ (C) $X=1, Y=0$ (D) $X=1, Y=1$

Key: (D)

Sol: Just before 2nd clock means, after the 1st clock, since the given circuit is a standard 2 bit ripple down counter, the counting sequence is

00-11-10-01-00-11…..

So if the initial state is $X=0, Y=0,$ then after 1st clock $X=1, Y=1$

4. The input x[n] and output y[n] of discrete-time system are related as $y[n]=\alpha y[n-1]+x[n]$. The condition of a for which the system is Bounded-Input Bounded-Output (BIBO) stable is

(A) $|\alpha|<1$ (B) $|\alpha|=1$ (C) $|\alpha|>1$ (D) $|\alpha|<3/2$

Key: (A)

Sol: $y(n)=\alpha y(n-1)+x(n)$

$\Rightarrow y(z)\left(1-\alpha z^{-1}\right)=x(z)$

$\Rightarrow \dfrac{y(z)}{x(z)}=\dfrac{1}{1-\alpha z^{-1}} \Rightarrow H(z)=\dfrac{1}{1-\alpha z^{-1}}$

$\Rightarrow h(n)=\alpha^n u(n)$

→The system can be stable if $\sum_{K=\infty}^{\infty}|h(K)|<\infty$ to satisfy this condition $|\alpha|<1$ i.e

$\sum_{K=0}^{\infty}\alpha^k=\frac{1}{1-\alpha}$, Provided $|a|<1$.

5. A box has 8 red balls and 8 green balls. Two balls are drawn randomly in succession from the box without replacement. The probability that the first ball drawn is red and the second ball drawn is green is

(A) 4/15 (B) 7/16 (C) 1/2 (D) 8/15

Key: (A)

Sol: Total balls = 8(red) + 8 (green) =16

Let A, B be events respectively that drawing a red ball in 1^{st} draw & a green ball in 2^{nd} draw and balls drawn without replacement.

$\therefore$ Required probability is $P(A\cap B)=P(A).P(B/A)$

$$=\frac{8C_1}{16C_1}\times\frac{8C_1}{15C_1}=\frac{1}{2}\times\frac{8}{15}=\frac{4}{15}$$

6. Consider a circuit comprising only resistors with constant resistance and ideal independent DC voltage sources. If all the resistances are scaled down by a factor 10, and all source voltages are scaled up by a factor 10, the power dissipated in the circuit scales up by a factor of ________.

Key: (1000)

Sol: $P=\frac{V^2}{R}$

$$P'=\frac{V^2}{R'}=\frac{(10V)^2}{(R/10)}=1000\frac{V^2}{R}$$

$$\frac{P'}{P}=1000$$

$\Rightarrow P'=1000\,P\Rightarrow P_{old}=1000\,P_{new}$

So Power increased by 1000 times.

7. If each of the values of inductance, capacitance and resistance of a series LCR circuit are doubled, the Q-factor of the circuit would

(A) reduce by a factor $\sqrt{2}$ (B) reduce by a factor 2

(C) increase by a factor $\sqrt{2}$ (D) increase by a factor 2

Key: (B)

Sol: $\rightarrow$For a series RLC circuit

$$Q=\frac{1}{R}\sqrt{\frac{L}{C}} \qquad ...(1)$$

$\rightarrow$ If all components values becomes doubles

$$Q'=\frac{1}{2R}\sqrt{\frac{2L}{2C}}=\frac{1}{2}\left[\frac{1}{R}\sqrt{\frac{L}{C}}\right] \qquad ...(2)$$

$\rightarrow$By Comparing equation (1) and equation (2) we can say the new value of quality factor becomes half of old quality factor.

8. A signal $\cos(2\pi f_m t)$ modulates a carrier $\cos(2\pi f_c t)$ using the double-sideband-with-carrier (DSBWC) scheme to yield a modulated signal $\cos(2\pi f_c t)+0.3\cos(2\pi f_m t)\cos(2\pi f_c t)$. The modulation index is ________. (Rounded off to one decimal place).

Key: (0.3)

Sol: $\rightarrow$ Standard form of DSB with carrier modulation is given by

$$A_c[1+\mu Am\cos 2\pi fmt]\cos 2\pi fet$$

$\rightarrow$ In the given problem $A_c = A_m = 1$, So the equation becomes

$$[1+\mu\cos 2\pi fmt]\cos 2\pi fet$$

$\rightarrow$ Then given modulated signal is

$$S(t)=\cos 2\pi fet+0.3\cos 2\pi fet\cos 2\pi fmt$$

$$S(t)=[1+0.3\cos 2\pi fmt]\cos 2\pi fet$$

By comparing with standard equation

$$[1+\mu\cos 2\pi fmt]\cos 2\pi fet$$

$$\mu=0.3$$

9. In a single-mode optical fiber, the zero-dispersion wavelength refers to the wavelength at which the

(A) material dispersion is zero

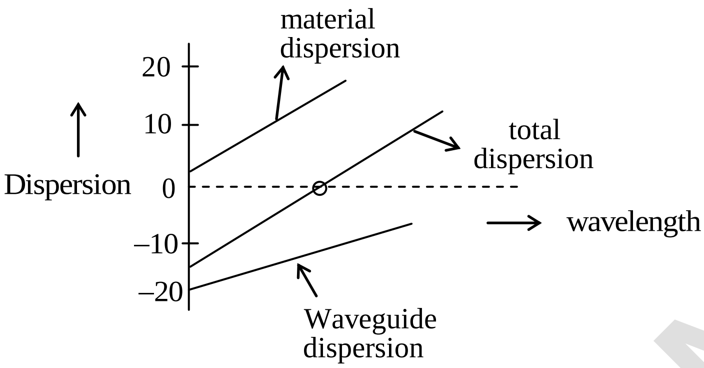
(B) waveguide dispersion is zero

(C) sum of material dispersion and waveguide dispersion is zero

(D) material dispersion and waveguide dispersion are simultaneously zero.

Key: **(C)**

Sol: For a single mode optical fibre, the wavelength V_s Dispersion curve is given by



So, total dispersion is sum of waveguide and material dispersion.

10. The total number of Boolean functions with distinct truth-tables that can be defined over 3 Boolean variables is _________.

Key: **(256)**

Sol: Using 'n' number of Boolean variable we can have 2^{2^n} number of Boolean function so when n=3 if becomes $2^{2^3} = 2^8 = 256$

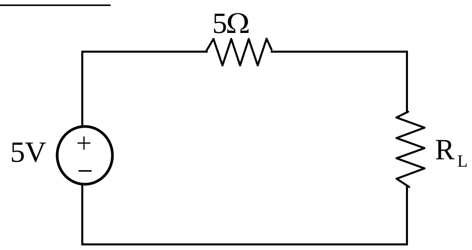
11. A 3×3 matrix has eigen values 1, 2 and 5. The determinant of the matrix is ________.

Key: **(10)**

Sol: Determinant of a matrix is given by product of its Eigen values.

$|A| = \lambda_1.\lambda_2.\lambda_3 = 1\times 2\times 5 = 10$

12. In the circuit shown below, maximum power is transferred to the load resistance R_L, when $R_L =$ ________________ Ω.



Key: **(5)**

Sol: By maximum power transfer theorem, if a variable resistor is connected across a practical voltage sources then the load R_L receives maximum power from source when

$R_L = R_S \Rightarrow R_L = 5\Omega.$

13. An 8-bit weighted resistor digital-to-analog converter (DAC) has the smallest resistance of 500 Ω. The largest resistance has a value of __________ kΩ .

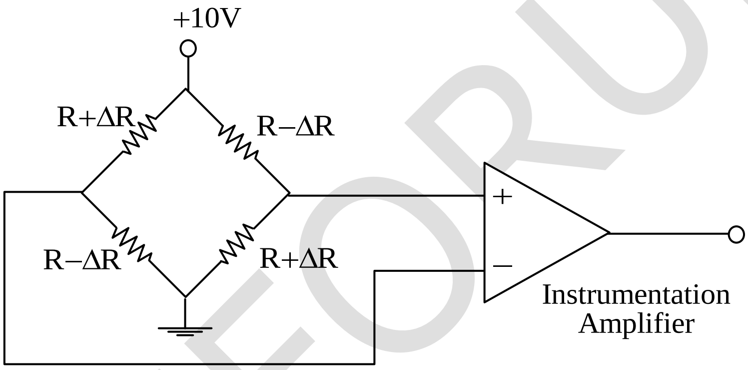
Key: (64)

Sol: → In a n bit binary weighted resistor type DAC, the minimum values of resistance is $2^0 R = R = 500$ maximum value of resistance is $2^{n-1} R$

→ So if n=8 then maximum value of resistance is

$2^{8-1} R = 2^7 R = 128R = 128 \times 500 = 64000\Omega = 64k\Omega$

14. Four strain gauges in a Wheatstone bridge configuration are connected to an instrumentation amplifier as shown in the figure. From the choices given below, the preferred value for the common mode rejection ratio (CMRR) of the amplifier, in dB, would be



(A) –20 (B) 0 (C) 3 (D) 100

Key: (D)

15. The correct biasing conditions for typical operation of light emitting diodes, photodiodes, Zener diodes are respetively,

(A) forward bias, reverse bias, reverse bias
(B) reverse bias, reverse bias, forward bias
(C) forward bias, forward bias, reverse bias
(D) reverse bias, forward bias, reverse bias

Key: (A)

Sol:

	Type of Diode		Biasing
i.	Light Emitting diodes (LEDs)	→	Forward bias
ii.	Photo diodes	→	Reverse bias
iii.	Zener diodes	→	Reverse bias

16. The output $y(t)$ of a system is related to its input x(t) as

$y(t)=\int_0^t x(\tau-2)d\tau.$ where, x(t) = 0 and y(t) = 0 for $t\le 0$. The transfer function of the system is

(A) $\frac{1}{s}$ (B) $\frac{(1-e^{-2s})}{s}$ (C) $\frac{e^{-2s}}{s}$ (D) $\frac{1}{s}-e^{-2s}$

Key: **(C)**

Sol: $y(t)=\int_0^t x(\tau-1)dz$

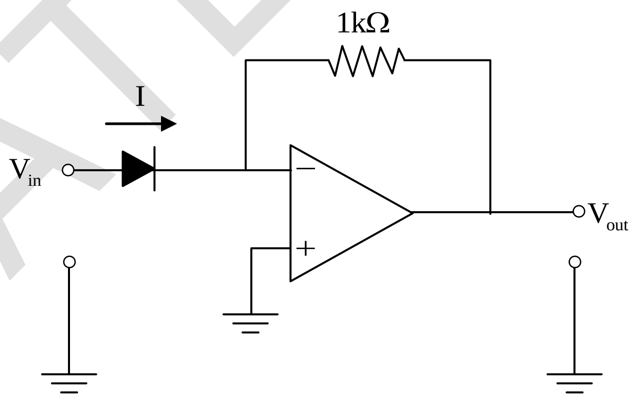
$\rightarrow x(\tau)\leftrightarrow x(s)$

$x(\tau-2)\leftrightarrow x(s)e^{-2s}$ ($\because$ time shift properly)

$\int_0^t x(\tau-2)dz \leftrightarrow \frac{x(s)e^{-2s}}{s}$

$\Rightarrow Y(s)=\frac{x(s)e^{-2s}}{s}\Rightarrow \frac{Y(s)}{X(s)}=1+(s)=\frac{e^{-2s}}{s}$

17. In the circuit shown below, the input voltage V_{in} is positive. The current (I) – Voltage (V) characteristics of the diode can be assumed to be $I=I_0e^{V/V_T}$ under the forward bias condition, where V_T is the thermal voltage and I_0 is the reverse saturation current. Assuming an ideal op-amp, the output voltage V_{out} of the circuit is proportional to



(A) $\log_e(V_{in}/V_T)$ (B) $2V_{in}$

(C) e^{V_{in}/V_T} (D) V_{in}^2

Key: **(C)**

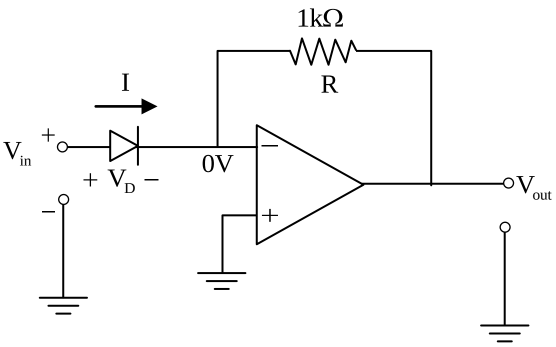
Sol: $V_{out}=0-IR$

$=-IR$ ...(1)

$+V_{in}-V_D=0\Rightarrow V_D=V_{in}$

Diode current equation is given by

$$I = I_0 \exp\frac{V_D}{V_T} = I_0 e^{\frac{V_{in}}{V_T}} \quad (\because V_D = V_{in})$$



Substitute the value of I in equation (1),

then we get

$$V_{out} = -I_0 e^{\frac{V_{in}}{V_T}} \times 1\times 10^3 \text{Volt}$$

From above equation it is obvious that $V_{out} \propto e^{\frac{V_{in}}{V_T}}$

Given circuit is a prototype of exponential (Antilogarithmic) amplifier.

18. $\vec{a}, \vec{b}, \vec{c}$ are three orthogonal vectors. Given that $\vec{a} = \hat{i}+2\hat{j}+5\hat{k}$ and $\vec{b} = \hat{i}+2\hat{j}-\hat{k}$, the vector $\vec{c}$ is parallel to

(A) $\hat{i}+2\hat{j}+3\hat{k}$ (B) $2\hat{i}+\hat{j}$ (C) $2\hat{i}-\hat{j}$ (D) $4\hat{k}$

Key: **(C)**

Sol: Let $\vec{c}$ be parallel to a vector $\vec{d}$ $\Rightarrow \vec{a}, \vec{b}, \vec{d}$ are also mutually perpendicular

$\Rightarrow$ Dot product of every two vectors as 0.

By option method, the vector say $\vec{d}$ in option (C) only satisfies $\vec{a}\,.\,\vec{d} = 0$ and $\vec{b}\,.\vec{d} = 0$

Hence answer is option (C)

19. The vector function $\vec{A}$ is given by $\vec{A} = \vec{\nabla}u$, where $u(x,y)$ is a scalar function. Then $|\vec{\nabla}\times\vec{A}|$ is

(A) –1 (B) 0 (C) 1 (D) ∞

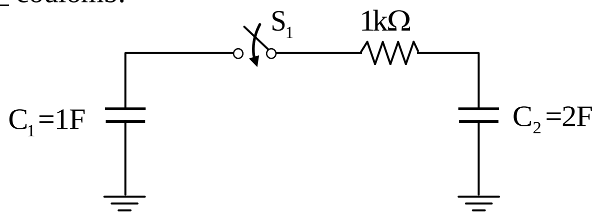
Key: **(B)**

Sol: $\nabla \times \vec{A} = \nabla \times (\nabla u) = \vec{0}$ ie., Zero vector

$\therefore |\nabla \times \vec{A}| = 0 \Rightarrow \text{option}(B)$

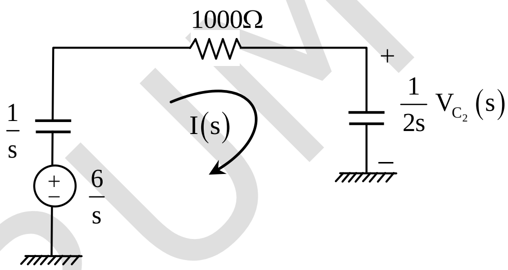
(From Vector Identities $\text{curl}(\text{grad}\,\phi) = \vec{0}$, where ϕ is scalar function).

20. In the circuit shown below, initially the switch S_1 is open, the capacitor C1 has a charge of 6 coulomb, and the capacitor C2 has 0 coulomb. After S_1 is closed, the charge on C2 in steady state is ___________ coulomb.



Key: **(4)**

Sol: **Method-I:** For $t>0$, the circuit is,



$$I(s)=\frac{6/s}{\frac{(3+2000s)}{2s}}=\frac{6\times 2}{(3+2000s)}$$

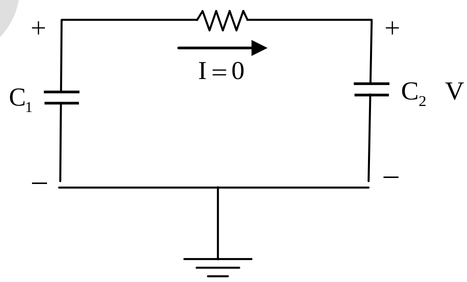
$$V_{C2}(s)=\frac{12}{(3+2000s)}\times\frac{1}{2s}$$

From final value theorem,

$$V_{C_2}(t=\infty)=V_{C_2}(0)=\lim_{s\to 0}\frac{12s}{(3+2000\times D)}\times\frac{1}{2s}=\frac{12}{3\times 2}=2V$$

$$q_2=C_2V_2=2\times 2=4C$$

Method-2: (Charge conservation) at $t=\infty$



$$C_1V_1(\text{initial charge})=(C_1+C_2)V_{net}$$

$$\Rightarrow 6=3V\Rightarrow V=2=V_2=V_1$$

Hence $q_2=2\times 2=4C$

21. A pitot-static tube is used to estimate the velocity of an incompressible fluid of density $1kg/m^3$. If the pressure difference measured by the tube is $200\,N/m^2$, the velocity of the fluid, assuming the pitot-tube coefficient to be 1.0, is ___________m/s.

Key: **(20)**

Sol: For a Pitot-static tube it is given that

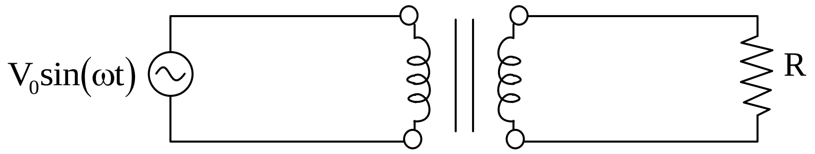
density$(\rho)=1kg/m^3$

Pressure difference$(\Delta P)=200N/m^2$

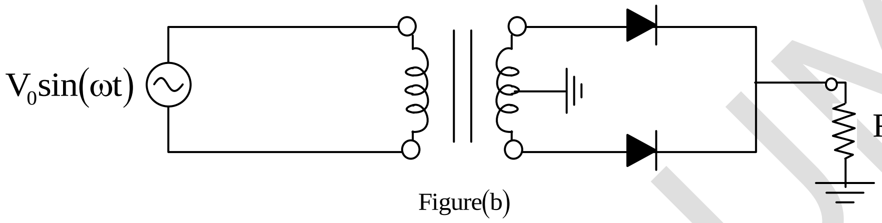
Pitot tube co-efficient $=1$

$$\text{Velocity}, V=\sqrt{\frac{2\Delta P}{\rho}}=\sqrt{\frac{2\times 200}{1}}=\sqrt{400}=20\text{m/sec}$$

22. In the figures (a) and (b) shown below, the transformers are identical and ideal, except that the transformer in figure (b) is centre-tapped. Assuming ideal diodes, the ratio of the root-mean-square (RMS) voltage across the resistor R in figure (a) to that in figure (b) is



Figure(a)



Figure(b)

(A) $\sqrt{2}:1$ (B) $2:1$ (C) $2\sqrt{2}:1$ (D) $4:1$

Key: (*)

23. In a cascade control system, the closed loop transfer function of the inner loop may be assumed to has a single time-constant τ_1. Similarly, the closed loop transfer function of the outer loop may be assumed to have a single time-constant τ_2. The desired relationship between τ_1 and τ_2 in a well-designed control system is

(A) τ_1 is much less than τ_2

(B) τ_1 is equal to τ_2

(C) τ_1 is much greater than τ_2

(D) τ_1 is independent less than τ_2

Key: (A)

Sol: For the given cascade control system

τ_1 : Represent time constant of inner loop

τ_2 : Represent time constant of outer loop

We know in a cascade control system $\tau_1 \ll \tau_2$

24. The loop-gain function $L(s)$ of a control system with unity feedback is given to be $L(s)=\frac{k}{(s+1)(s+2)(s+3)}$, where $k>0$. If the gain cross-over frequency of the loop-gain function is less than its phase cross-over frequency, the closed-loop system is

(A) unstable (B) marginally stable

(C) conditionally stable (D) stable

Key: (D)

Sol: We know in general when $\omega_{pc} > \omega_{gc}$ the control system is stable.

25. Thermocouples measure temperature based on

(A) Photoelectric effect (B) Seebeck effect

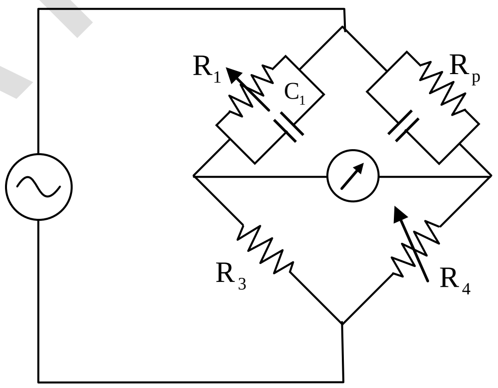
(C) Hall effect (D) Thermal expansion

Key: (B)

Sol: Thermocouple operating principle is a temperature difference across a metal produces emf which is known as Seebeck effect.

Q. No. 26 to 55 Carry Two Marks Each

26. The parallel resistance-capacitance bridge shown below has a standard capacitance value of $C_1 = 0.1\mu F$ and a resistance value of $R_3 = 10k\Omega$. The bridge is balanced at a supply frequency of 100Hz for $R_1 = 375k\Omega, R_3 = 10k\Omega$ and $R_4 = 14.7\ k\Omega$.



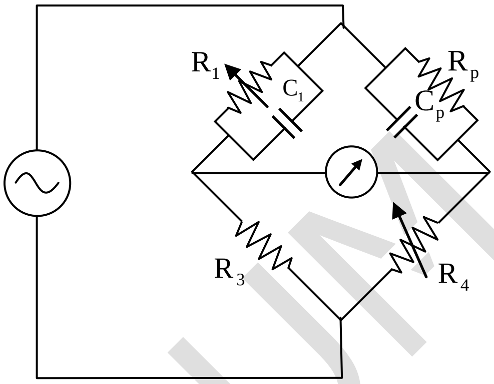
The value of the dissipation factor $D = 1/(\omega R_p C_p)$ of the parallel combination of C_p and R_p is _________. (Rounded off to three decimal places).

Key: **(0.042)**

Sol: Given that $C_1 = 0.1\mu f$, $R_3 = 10k\Omega$ $R_1 = 375k\Omega$, $R_3 = 10k\Omega$

$$R_4 = 14.7k\Omega, \quad D = \frac{1}{\omega R_p C_p}, \; f_s = 100Hz.$$

At balance condition



$$\bar{z}_1\bar{z}_4 = \bar{z}_3\bar{z}_p$$

$$\Rightarrow \frac{R_1R_4\left(\frac{-j}{\omega C_1}\right)}{R_1 - \frac{j}{\omega C_1}} = \frac{R_3\left\{R_p\left(\frac{-j}{\omega C_p}\right)\right\}}{R_p - \frac{j}{\omega C_p}}$$

$$\Rightarrow \frac{-jR_1R_4}{R_1\omega C_1 - j} = \frac{-jR_3R_p}{R_p\omega C_p - j}$$

$$\Rightarrow R_1R_4\left(R_p\omega C_p - j\right) = R_3R_p\left(R_1\omega C_1 - j\right)$$

$$\Rightarrow R_1R_4R_p\omega C_p - jR_1R_4 = R_3R_pR_1\omega C_1 - jR_3R_p$$

(Imaginary part and real part will be same at both sides from balance condition).

$$R_1R_4 = R_3R_4 \qquad ...(1)$$

$$R_p = \frac{R_1R_4}{R_3} = \frac{375\times 14.7}{10} = 551.25k\Omega$$

$$R_1R_4R_p\omega C_p = R_3R_pR_1\omega C_1$$

$$C_p = \frac{R_3C_1}{R_4} = \frac{10\times 10^3\times 0.1\times 10^{-6}}{14.7\times 10^3} = 0.068\mu F$$

Dissipation factor, $D = \frac{1}{\left(2\pi f_s R_p C_p\right)} = \frac{1}{2\pi\times 100\times 551.25\times 10^3\times 0.068\times 10^{-6}} = 0.042$

27. The curve $y = f(x)$ is such that the tangent to the curve at every point (x, y) has a Y-axis intercept c, given by $c = -y$. Then, f(x) is proportional to

(A) x^{-1} (B) x^2 (C) x^3 (D) x^4

Key: **(B)**

Sol: Equation of the tangent to the curve $y = f(x)$ at a point $P(x_1, y_1)$ is $y - y_1 = m(x - x_1)$,

where $m = \left(\frac{dy}{dx}\right)_p$ or $f'(x)$

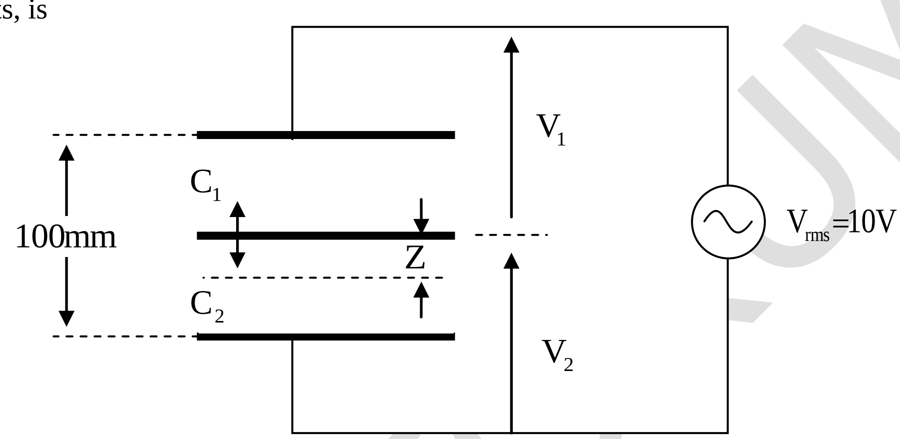
Using y- intercept, we get $y_1 - mx_1 = -y_1$

$$\Rightarrow m = \frac{2y_1}{x_1} \Rightarrow m = \frac{2y}{x}\left(\text{dropping suffix}\right)$$

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

Integrating, we get $y = k.x^2 \Rightarrow f(x)$ is proportional to x^2

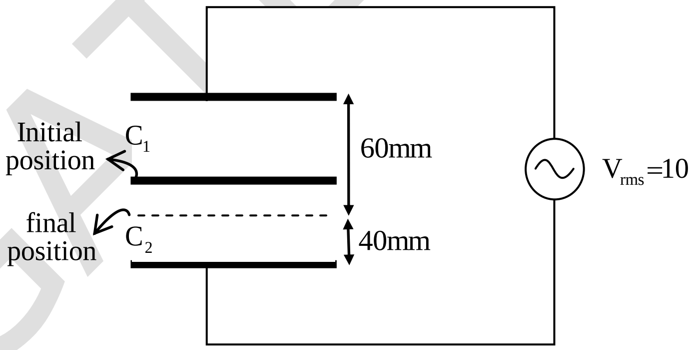
28. A differential capacitive sensor with a distance between the extreme plates 100mm is shown in figure below. The difference voltage $\Delta V = V_1 - V_2$, where V_1 and V_2 are the rms values, for a downward displacement of 10mm of the intermediate plate from the central position, in volts, is



(A) 0.9 (B) 1.0 (C) 1.1 (D) 2

Key: **(D)**

Sol: From the given figure



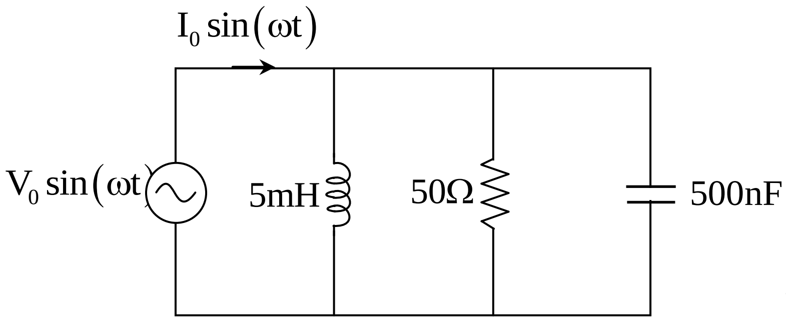
$$C_1 = \frac{\in A}{60mm}; \quad C_2 = \frac{\in A}{40mm}$$

$$\Rightarrow V_1 = \frac{V_{rms} C_2}{C_1 + C_2} = \frac{10 \times \frac{\in A}{40mm}}{\frac{\in A}{60mm} + \frac{\in A}{40mm}} = \frac{10 \times \frac{1}{40}}{\frac{1}{60} + \frac{1}{40}} = 6V$$

$$\Rightarrow V_2 = V_s - V_1 = 10 - 6 = 4$$

$$\Rightarrow \Delta V = V_1 - V_2 = 6 - 4 = 2V.$$

29. In the circuit shown below, the angular frequency ω at which the current is in phase with the voltage is ________ rad/s.

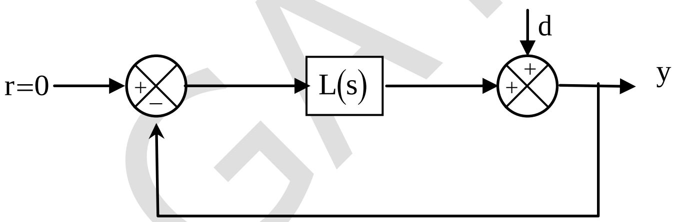


Key: (20,000)

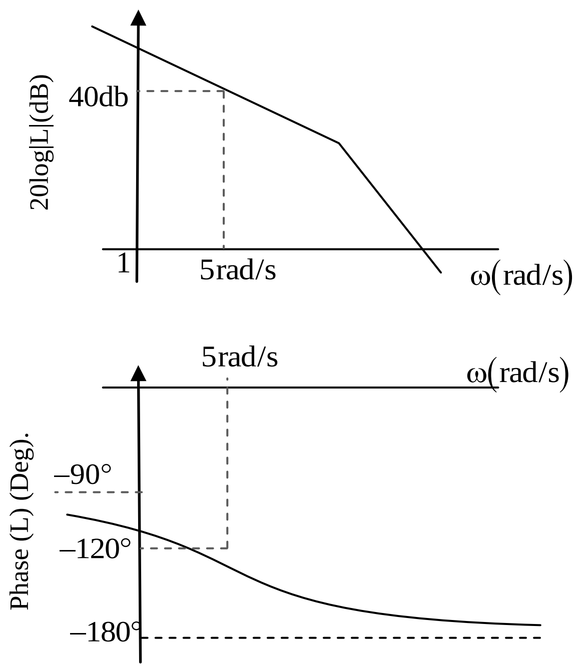
Sol: → For a parallel RLC circuit, the resonant frequency is $\omega_0 = \dfrac{1}{\sqrt{LC}}$

$$= \frac{1}{\sqrt{5\times10^{-3}\times500\times10^{-9}}} = 20{,}000 \text{ rad/sec.}$$

30. The forward path transfer function L(s) of the control system shown in figure (a) has the asymptotic Bode plot shown in Figure (b). If the disturbance d(t) is given by $d(t) = 0.1\sin(\omega t)$ where $\omega = 5\text{rad/s}$, the steady-state amplitude of the output y(t) is



Figure(a)



Figure(b)

(A) 1.00×10^{-3} (B) 2.50×10^{-3} (C) 5.00×10^{-3} (D) 10.00×10^{-3}

Key: (A)

Sol: At $w = 5$, gain $= 40db$

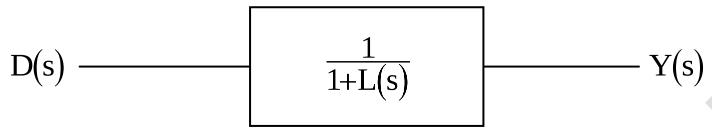
$20\log m = 40$

$\log m = 2$

$m = 10^2 = 100$

$\rightarrow \frac{Y(s)}{D(s)} = \frac{1}{1+L(s)}$ (By using SFG on the block diagram)

By considering y(t) as output and d(t) as input we can redraw the block diagram as



$\rightarrow |L(s)|_{w=5} = 40db = 100$

$\rightarrow$ if $d(t) = 0.1\sin 5t$

then $y(t) = \left[\frac{1}{1+L(s)}\Big|_{w=5}\right](0.1\sin 5t)$

$= \frac{1}{1+100}(0.1)\sin 5t = (1\times10^{-3})\sin 5t$

So the steady state amplifier is 1×10^{-3}.

31. The function p(x) is given by $p(x) = A/x^{\mu}$ where A and μ are constants with $\mu > 1$ and $1 \le x < \infty$ and $p(x) = 0$ for $-\infty < x < 1$. For p(x) to be probability density function, the value of A should be equal to

(A) $\mu - 1$ (B) $\mu + 1$ (C) $1/(\mu-1)$ (D) $1/(\mu+1)$

Key: (A)

Sol: Since P(x) is p.d.f $\Rightarrow \int_{-\infty}^{\infty} p(x)dx = 1$

$\Rightarrow \int_{-\infty}^{1}(0)dx + \int_{1}^{\infty}\frac{A}{x^{\mu}}dx = 1$

$\Rightarrow A\int_{1}^{\infty} x^{-\mu}dx = 1 \Rightarrow A\left[\frac{1}{(1-\mu).x^{\mu-1}}\right]_1^{\infty} = 1$

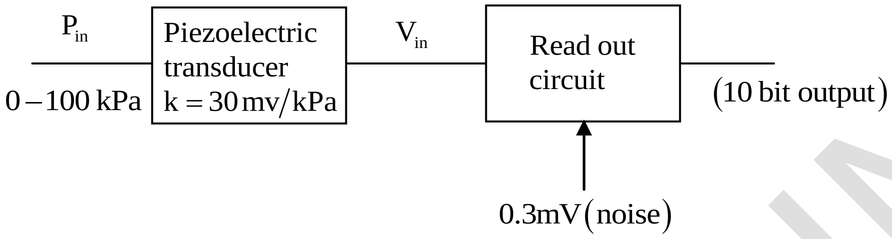
$\Rightarrow \frac{A}{1-\mu}[0 \quad -1] = 1 \Rightarrow A = \mu - 1 \quad \left(\because \mu - 1 > 0 \Rightarrow \frac{1}{x^{\mu-1}} \rightarrow 0 \text{ when } x \rightarrow \infty\right)$

32. A piezoelectric transducer with sensitivity of 30mV/kPa is intended to be used in the range of 0 kPa to 100 kPa. The readout circuit has a peak noise amplitude of 0.3mV and measured signals over the full pressure range are encoded with 10 bits. The smallest pressure that produces a non-zero output, in units of Pa, is approximately

(A) 10 (B) 100 (C) 240 (D) 300

Key: (B)

Sol:



The read out circuit shown in the above figure is nothing but an ADC. Since we are expecting the a non zero output, then it input should must be at least

$V_{in} \geq [\text{Resolution of read out}] + [\text{noise}]$

$$\text{Resolution of read out} = \frac{[V_{in}]_{max}}{2^{10}} = \frac{100\text{kPa} \times 30\frac{\text{mv}}{\text{kPa}}}{2^{10}} = \frac{300}{1024} = 2.92\text{mV}$$

$\Rightarrow V_{in} \geq 2.92 + 0.3$

$\Rightarrow V_{in} \geq 3.22\text{mV}$

$V_{in} = k \times P_{in}$

$$P_{in} = \frac{V_{in}}{k} = \frac{3.22\text{mV}}{30\text{ mV/kPa}} = 0.1076\text{ kPa} = 107\text{ Pa} \simeq 100\text{Pa}$$

33. A 100W light source emits uniformly in all directions. A photo detector having a circular active area whose diameter is 2cm is placed 1m away from the source, normal to the incident light. If the responsivity of the photo detector is 0.4A/W, the photo-current generated in the detector, in units of mA, is ___

(A) 1 (B) 4 (C) 100 (D) 400

Key: (Insufficient information)

34. $X = X_1X_0$ and $Y = Y_1Y_0$ are 2- bit binary numbers. The Boolean function S that satisfies the condition "If $X > Y$, then S=1", in its minimized form, is

(A) $X_1Y_1 + X_0Y_0$

(B) $X_1\bar{Y}_1 + X_0\bar{Y}_0\bar{Y}_1 + X_o\bar{Y}_0X_1$

(C) $X_1\bar{Y}_1\ X_0\bar{Y}_0$

(D) $X_1Y_1 + X_0\bar{Y}_0Y_1 + X_o\bar{Y}_0\bar{X}_1$

Key: (B)

Sol: $\left.\begin{matrix} X_1 & X_0 \\ Y_1 & Y_0 \end{matrix}\right\}$ when we compare X and Y, then X > Y can happen in 2 possible waves

$$(i)\ X_1 = 1, Y_1 = 0 \Rightarrow X_1\overline{Y_1}$$

$$(ii)\ (X_1 = Y_1)\text{and}(X_0 = 1, Y_0 = 0) \Rightarrow (X_1 \odot Y_1)\left(X_0\overline{Y_0}\right)$$

So the expression for X > Y will be

$$S = X_1\overline{Y_1} + \left[(X_1 \odot Y_1).\left(X_0\overline{Y_0}\right)\right]$$

$$= X_1\overline{Y_1} + \left[\left(X_1Y_1 + \overline{X_1}\,\overline{Y_1}\right)\left(X_0\overline{Y_0}\right)\right]$$

$$= \left(X_1\overline{Y_1} + X_1Y_1X_0\overline{Y_0}\right) + \overline{X_1}\,\overline{Y_1}X_0\overline{Y_0}$$

$$= \left[X_1\left(\overline{Y_1} + Y_1X_1X_0\overline{Y_0}\right)\right] + \overline{X_1}\,\overline{Y_1}X_0\overline{Y_0}$$

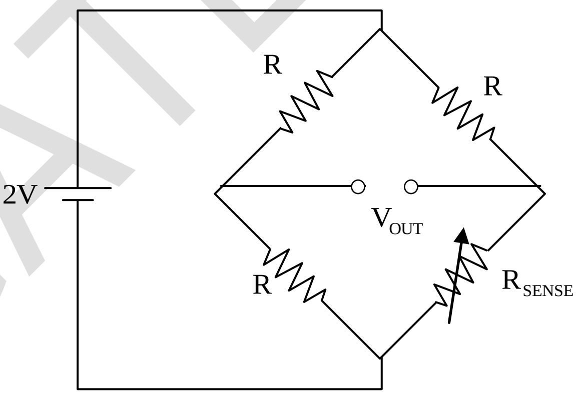
$$= \left[X_1\left(\overline{Y_1} + X_1X_0\overline{Y_0}\right)\right] + \overline{X_1}\,\overline{Y_1}X_0\overline{Y_0}\left(\because \overline{A} + AB = \overline{A} + B\right)$$

$$= \underbrace{X_1\overline{Y_1} + X_1X_0\overline{Y_0} + \overline{X_1}\,\overline{Y_1}X_0\overline{Y_0}}$$

$$= \left[\overline{Y_1}\left(X_1 + \overline{X_1}X_0\overline{Y_0}\right)\right] + X_1X_0\overline{Y_0} = \overline{Y_1}\left(X_1 + X_0\overline{Y_0}\right) + X_1X_0\overline{Y_0}$$

$$= X_1\overline{Y_1} + X_0\overline{Y_0}\,\overline{Y_1} + X_0\overline{Y_0}X_1$$

35. Four identical resistive strain gauges with gauge factor of 2.0 are used in a Wheatstone bridge as shown in the figure below.



Only one of the strain gauges R_{SENSE} changes its resistance due to strain. If the output voltage V_{OUT} is measure to be 1 mV, the magnitude of strain, in units of micro strain, is

(A) 1 (B) 10 (C) 100 (D) 1000

Key: **(D)**

Sol: The given circuits is Standard Quarter Bridge, whose output voltage is given by

$$V_0 = \frac{V_S}{4}(G.F).\varepsilon$$

Where,

V_0 – Output voltage = 1 mV(given)

V_S – Supply voltage = 2V (given)

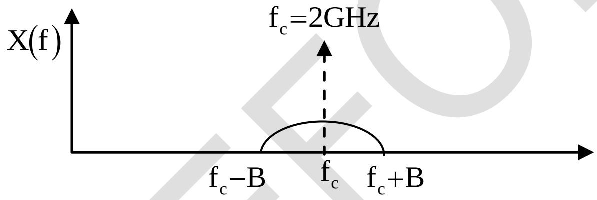
G.F– Gauge Factor = 2 (given)

ε – Strain

$$\Rightarrow \varepsilon = \frac{4V_0}{V_S.(G.F)} = \frac{(4)\times(1\times10^{-3})}{(2)\times(2)} = 1\times10^{-3} = 10^3\times10^{-3}\times10^{-3}$$

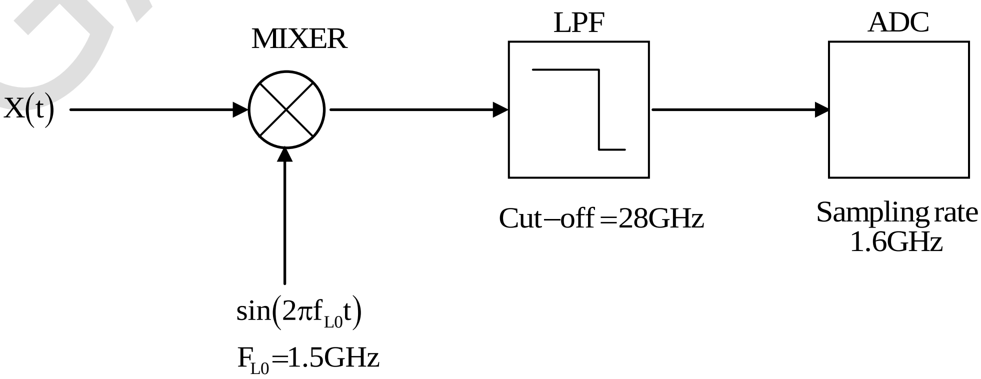
$$= 1000\times10^{-6} = 1000 \text{ unit of micro strain}$$

36. A signal x(t) has a bandwidth 2B about a carrier frequency of $f_c = 2\text{GHz}$ as shown in figure (a) below.



Figure(a)

In order to demodulate this signal, it is first mixed (multiplied) with a local oscillator of frequency $f_{LO} = 1.5\text{GHz}$, and then passed through an ideal low-pass filter (LPF) with a cut-off frequency of 2.8GHz. The output of the LPF is sent to a digitizer ADC with a sampling rate of 1.6 GHz as shown in figure (b) below.

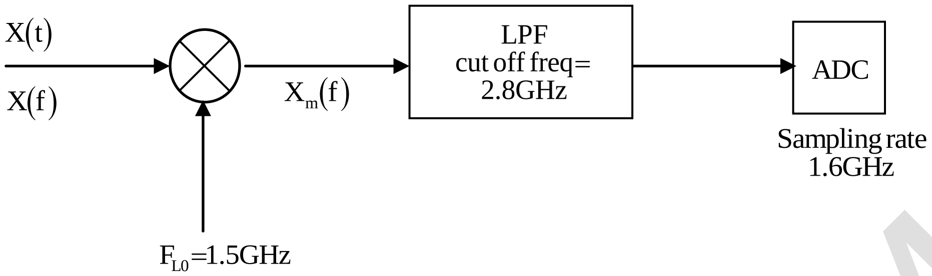


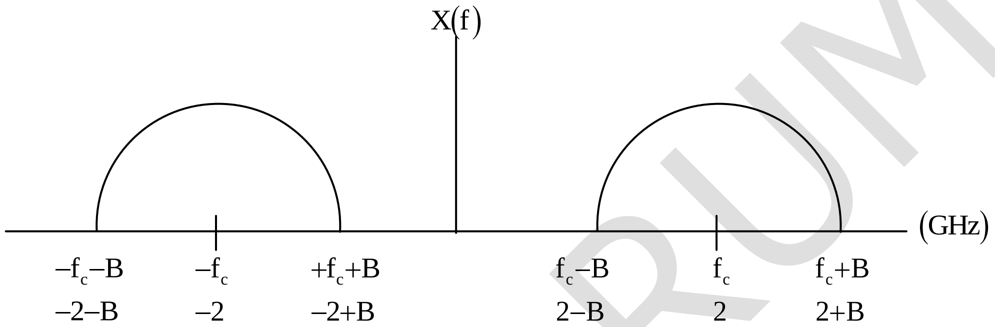
Figure(b)

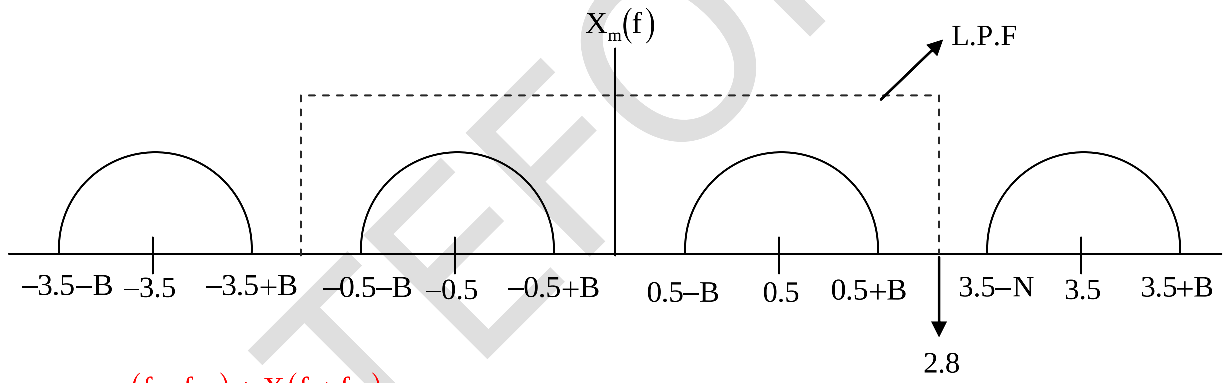
The maximum value of B so that the signal x(t) can be reconstructed from its sample according to the Nyquist sampling theorem is __________ MHz.

Key: (300)

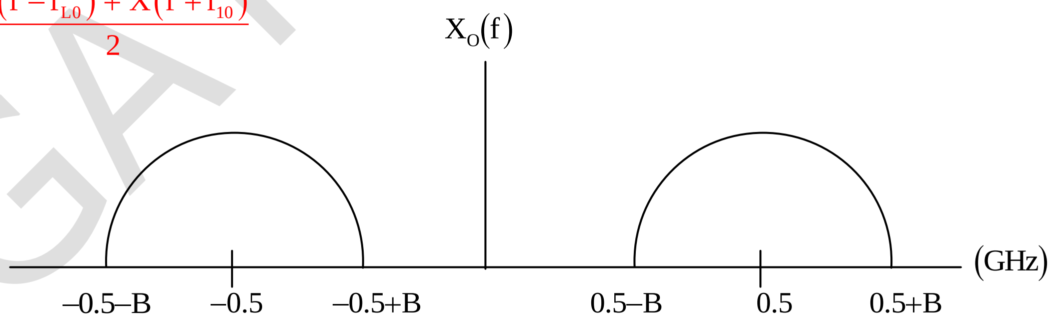
Sol:







$$X_m(f) = \frac{x(f - f_{L0}) + X(f + f_{10})}{2}$$



Nyquist rate of $X_O(f) = 2(0.5 + B) = 1 + 2B$

The sampling frequency of $X_O(f)$ should be 1.6 GHz

$\Rightarrow 1 + 2B = 1.6$

$\Rightarrow 2B = 0.6$

$\Rightarrow B = 0.3\text{GHz} = 300\text{MHz}$

37. A resistance-meter has five measurement range-settings between 200Ω and 2 MΩ in multiplies of 10. The meter measures resistance of a device by measuring a full-range voltage of 2V across the device by passing an appropriate constant current for each range-setting. If a device having a resistance value in the range 8kΩ to 12kΩ and a maximum power rating of 100μW is to be measured safely with this meter, the choice for range-setting on the meter for best resolution in measurement, in kΩ is

(A) 2 (B) 20 (C) 200 (D) 2000

Key: (C)

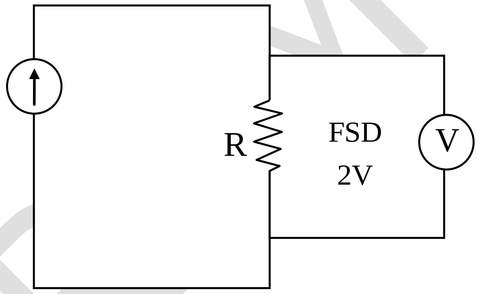
Sol: $8k\Omega < R < 12k\Omega$

→ When the resistance is 20kΩ

$$I = \frac{2V}{20k\Omega} = \frac{1}{10}mA$$

$$P_{max} = I^2R_{max} = \left(\frac{1}{10}\times10^{-3}\right)^2\left(12\times10^3\right)$$

$$=120\mu w > 100\mu w \text{ (so not suitable)}$$

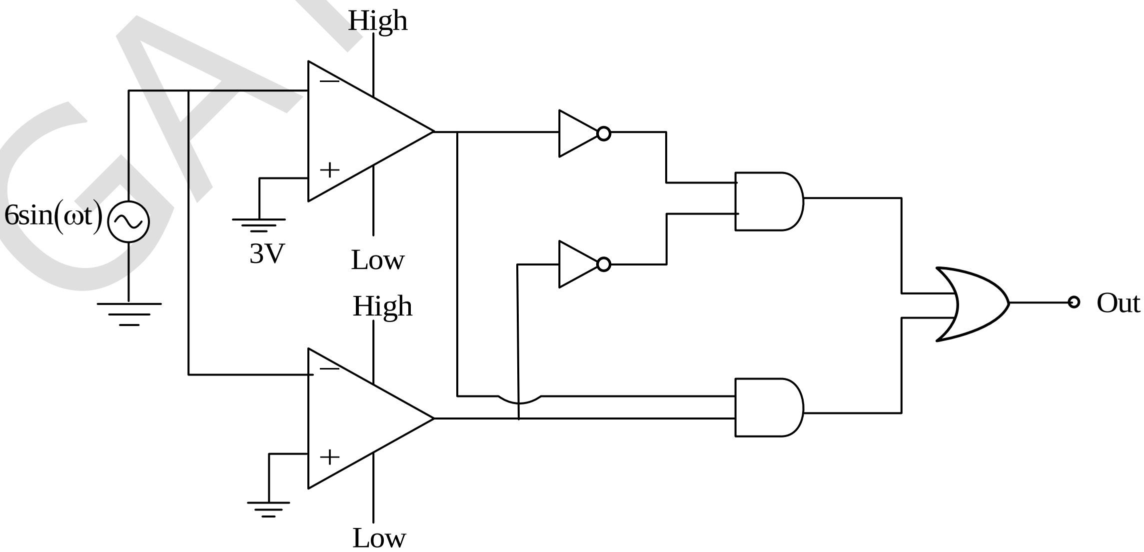


→ When the resistance is 200kΩ

$$I = \frac{2V}{200k\Omega} = \frac{1}{100}mA$$

$$P_{max} = I^2R_{max} = \left(\frac{1}{100}\times10^{-3}\right)^2\times\left(12\times10^3\right)=1.2\mu w$$

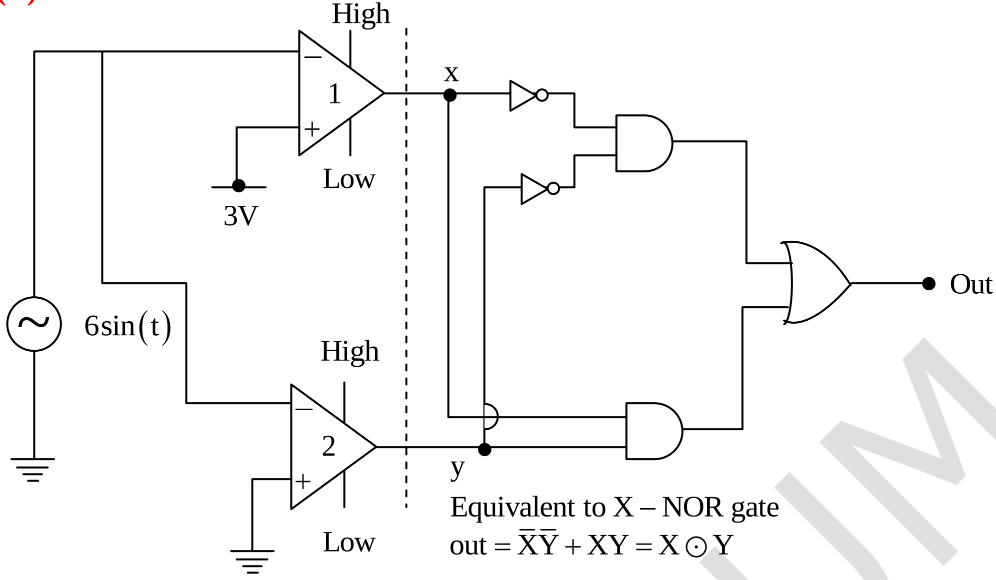
38. In the circuit shown below, assume that the comparators are ideal and all components have zero propagation delay. In one period of the input signal $V_{in} = 6\sin(\omega t)$, the fraction of the time for which the output OUT is in logic state HIGH is

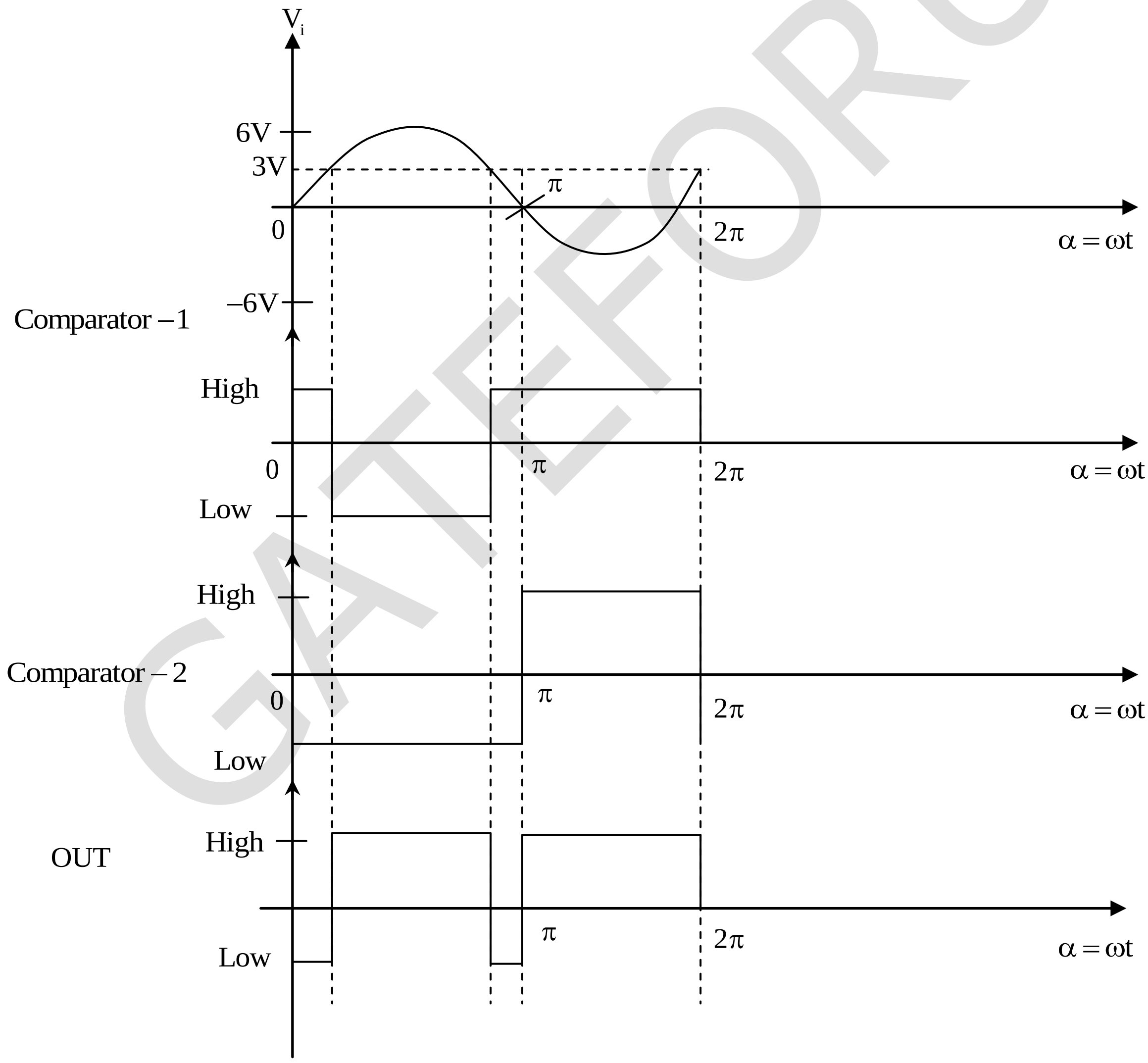


(A) 1/12 (B) 1/2 (C) 2/3 (D) 5/6

Key: **(D)**

Sol:


High
1
3V
Low
x
Out
6sin(t)
High
2
Low
y
Equivalent to X – NOR gate
out = $\bar{X}\bar{Y} + XY = X \odot Y$


V_i
6V
3V
0
π
2π
α = ωt
–6V
Comparator – 1
High
0
Low
π
2π
α = ωt
High
Comparator – 2
0
Low
π
2π
α = ωt
OUT
High
Low
π
2π
α = ωt

Operator of comparator:

$V_+ > V_- \rightarrow \text{output is logic } 1$

$V_+ < V_- \rightarrow \text{output is logic} < 0$

For comparator 1:

$0 < \alpha < 2\pi$

When input is less than 3V,

$V_+ - V_- > 0 \text{ so output } x \rightarrow \text{High}$

When input is more than 3V

$V_+ - V_- < 0 \text{ So output } x \rightarrow \text{low}$

For comparator 2:

When: $0 < \alpha < \pi$

$V_+ - V_- < 0 \text{ so output } Y \rightarrow \text{low}$

When: $n < \alpha < 2\pi$

$V_+ - V_- > 0, \text{ so outpu } Y = \text{High}$

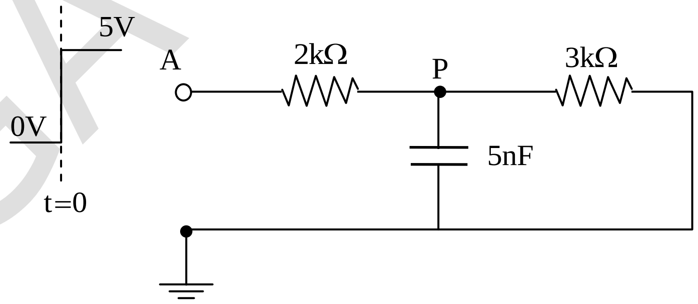
Now, $3 = 6\sin(\omega t) \Rightarrow \theta = (\omega t) = \sin^{-1}\left(\frac{3}{6}\right) = \frac{\pi}{6}$

$$T = \frac{T_{ON}}{T} = \frac{\pi - 2\theta + \pi}{2\pi} = \frac{2\pi - \frac{\pi}{3}}{2\pi} = \frac{5}{6}$$

Therefore, friction of time of which XNOR (out) is high:

$$T = \frac{5}{6}$$

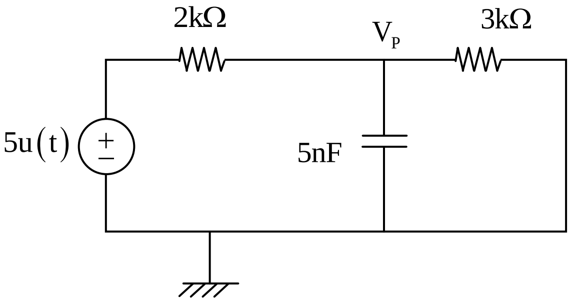
39. In the circuit shown below, a step input voltage of magnitude 5V is applied at node A at time t=0.



If the capacitor has no charge for $t \leq 0$, the voltage at node P at t=6μs is ________V. (Rounded off to two decimal places)

Key: (1.89)

Sol: The given circuit is

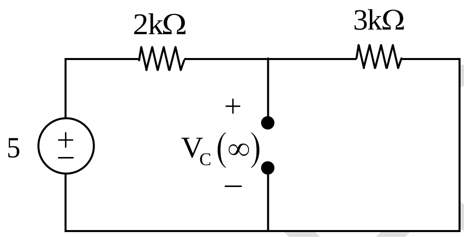


Voltage at node P = Voltage of capacitor

For 1st order RC N/W, the voltage across capacitor is given by

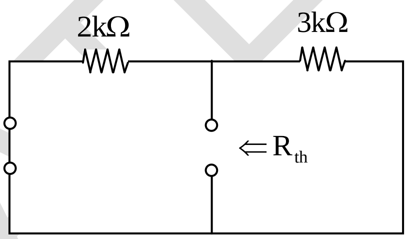
$V_c(t) = V_c(\infty)\left[1 - e^{-t/\tau}\right]\left[\because V_c(0^-) = 0 \text{ given}\right]$ Vlc

At $t = \infty$, N/W is in steady state and the capacitor is open circuit.



$V_C(\infty) = V_{3k\Omega} = \frac{3}{2+3}5 = 3V$

To calculate $\tau = R_{th}C$, the independent voltage source is short circuited, & Rth is obtained from capacitor terminal.



$R_{th} = (2 \| 3) = 1.2k\Omega$
$C = 5nF$
$\tau = R_{th}C = 1.2\times10^3 \times 5\times10^{-9} = 6\times10^{-6}$ sec

$R_{th} = (2/3) = 1.2k\Omega$

$C = 5nF$

$\tau = R_{th}C = 1.2\times10^3 \times 5\times10^{-9} = 6\times10^{-6}$ sec

$V_C(t) = V_P = V_C(\infty)\left(1 - e^{-t/z}\right) = 3\left(1 - e^{-t/6\times10^{-6}}\right)$

$V_C(6\mu\text{sec}) = 3\left(1 - e^{-\frac{6\times10^{-6}}{6\times10^{-6}}}\right) = 3\left(1 - e^{-1}\right) = 1.89V$

40. The frequency response of a digital filter $H(\omega)$ has the following characteristics

Passband: $0.95 \le |H(\omega)| \le 1.05$ for $0 \le \omega \le 0.3\pi$ and

Stopband: $0 \le |H(\omega)| \le 0.005$ for $0.4\pi \le \omega \le \pi$,

Where ω is the normalized angular frequency in rad/sample. If the analog upper cut off frequency for the passband of the above digital filter is to be 1.2 kHz, then the sampling frequency should be __________kHz.

Key: (8)

Sol: For the given digital filter $H(\omega)$, having

Passband: $0.95 \le |H(\omega)| \le 1.05; 0 \le \omega \le 0.3\pi$

Stop band: $0 \le |H(\omega)| \le 0.005; 0.4\pi \le \omega \le \pi$

ω: Represent normalized angular frequency (rad/sample) which is nothing but the digital frequency.

It is clear that is a low pass filter (practical), with digital cut-off frequency $(\omega_d) = 0.3\pi$ and its corresponding analog cut-off frequency $(f_a) = 1.2\,\text{kHz}$

The relation between analog frequency (ω_a) and the digital frequency (ω_d) is given by

Let $x(a) = \cos\omega_a t$

$$x(nT_s) = \cos\omega_a T_s = \cos n\frac{\omega_a}{f_s} = \cos n\omega_d$$

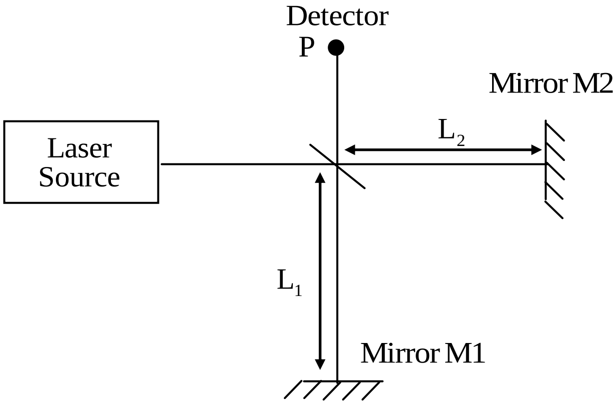
$$\omega_d = \frac{\omega_a}{f_s}$$

ω_d : digital frequency
ω_a : Ana log frequency
f_s : sampling frequency

$$\omega_d = \frac{\omega_a}{f_s}$$

$$f_s = \frac{\omega_a}{\omega_d} = \frac{2\pi f_a}{\omega_d} = \frac{2\pi \times 1.2 \times 10^3}{0.3\pi} = 8 \times 10^3 = 8\text{kHz}$$

41. Consider a Michelson interferometer as shown in the figure below. When the wavelength of the laser light source is switched from 400 nanometer to 500 nanometer, it is observed that the intensity measured at the output P goes from a minimum to a maximum.



This observation is possible when the smallest path difference between the two arms of the interferometer is _______ nanometer.

Key: (250)

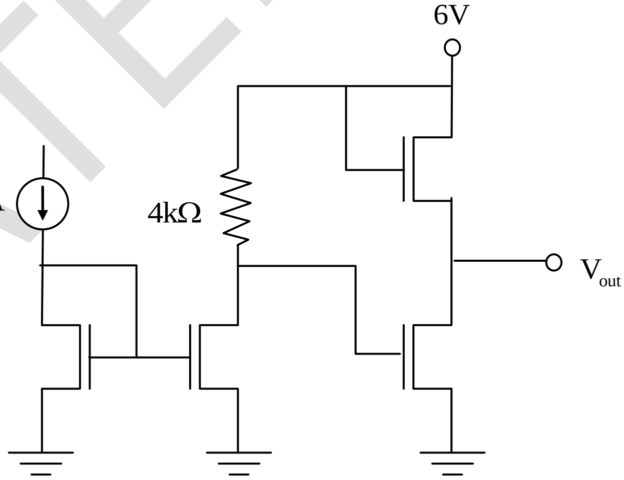
Sol: In Michelson Interferometer

$$n\lambda = 2d \left(\text{where d is path difference}\right)$$

→ When the wavelength of light source is adjusted to 500nm then

$$d = \frac{\lambda}{2} = \frac{500}{2} = 250\text{nm}$$

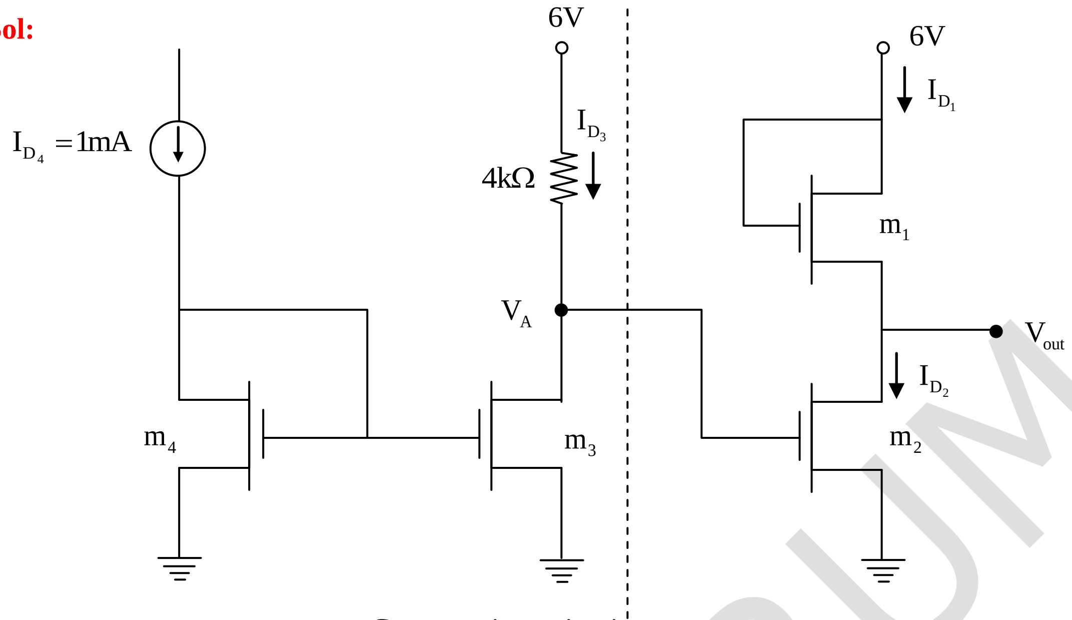
42. In the circuit shown below, all transistors are n-channel enhancement mode MOSFETs. They are identical and are biased to operate in saturation mode.



Ignoring channel length modulation, the output voltage V_{out} is ___________V.

Key: (4)

Sol:



First stage of the circuit is current mirror circuit:

$$V_{GS3} = V_{GS4} \text{ so that } I_{D3} = I_{D4} = 1\,mA$$

$$V_A = 6V - 4k \times 1m = 2V$$

For 2[nd] stage of the circuit as per the question all the transistor working into saturation

So, $I_{D1} = I_{D2}$

$$\left(V_{GS1} - V_t\right)^2 = \left(V_{GS2} - V_t\right)^2$$

$$V_{Gs1} - V_t = \pm\left(V_{Gs2} - V_t\right)$$

As threshold voltage (v_t) unit mentioned in the question, so take only +ve sign.

$$V_{Gs1} - V_t = V_{Gs2} - V_t$$

$$V_{G1} - V_{s1} = V_{G2} - V_{s2}$$

$$6V - V_{S1} = 2V - 0$$

$$\therefore V_{S1} = 4V$$

$$V_{s1} = V_{D2} = V_{out} = 4V$$

43. In a control system with unity gain feedback, the transfer function of the loop-gain function is $L(s) = 9e^{-0.1s}/s$. The phase margin of the loop-gain function L(S) is _____ degree.

Key: **(38.44)**

Sol: Given,

The transfer function of the loop-given function is $L(s) = 9e\frac{-0.1s}{S}, H(s) = 1$

To calculate the phase margin, we need to calculate find ω_{ge}.

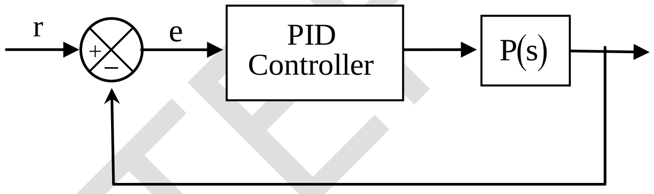
$$|L(j\omega)| = 1 \Rightarrow \left|\frac{9}{\omega}\right| = 1$$

$$\omega_{gc} = 9 \text{ rad/sec}$$

$$\Rightarrow \phi \text{ at } \omega_{ge} = -90° + \angle -0.1 \times 9 \times \frac{180}{\pi} = -90° - 51.56 = -141.56°$$

$$\text{Phase margin } = 180 + \phi_{at\omega_{ge}} = 180 - 141.56 = 38.44°$$

44. In the control system shown in the figure below, a reference signal $r(t) = t^2$ is applied at time t = 0. The control system employs a PID controller $C(s) = K_p + K_1/s + K_D s$ and the plant has a transfer function $P(s) = 3/s$. If $K_p = 10$, $K_1 = 1$ and $K_D = 2$, the steady state value of e is



(A) 0 (B) 2/3 (C) 1 (D) ∞

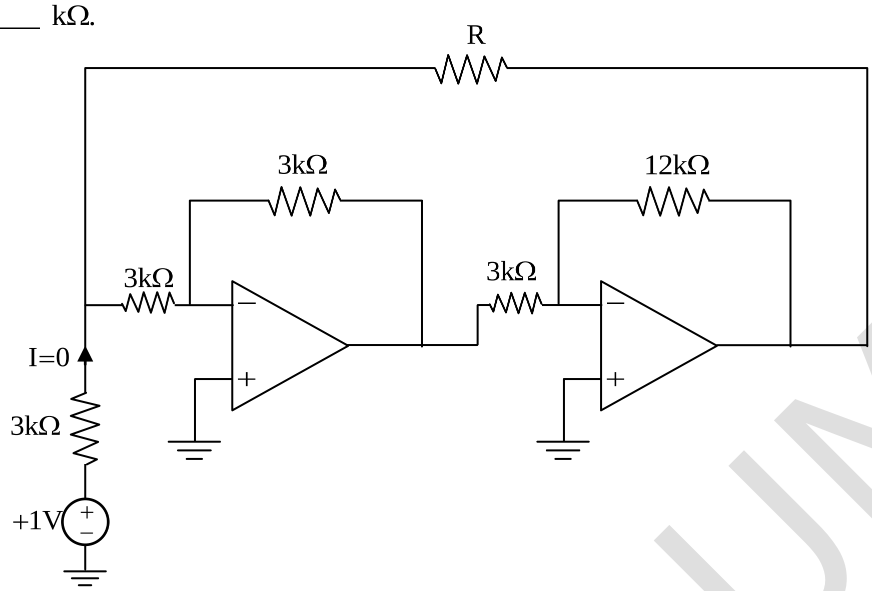
Key: **(B)**

Sol: The steady state value e $= \lim_{s \to 0} \frac{sR(s)}{1 + G(s)H(s)}$ (Valid for unity feedback)

$$G(s)H(s) = C(s)P(s) = \frac{3}{s}\left\{10 + \frac{1}{s} + 2s\right\} = \frac{3}{s}\left\{\frac{10s + 1 + 2s^2}{s}\right\} = \frac{3}{s^2}\left(10s + 1 + 2s^2\right)$$

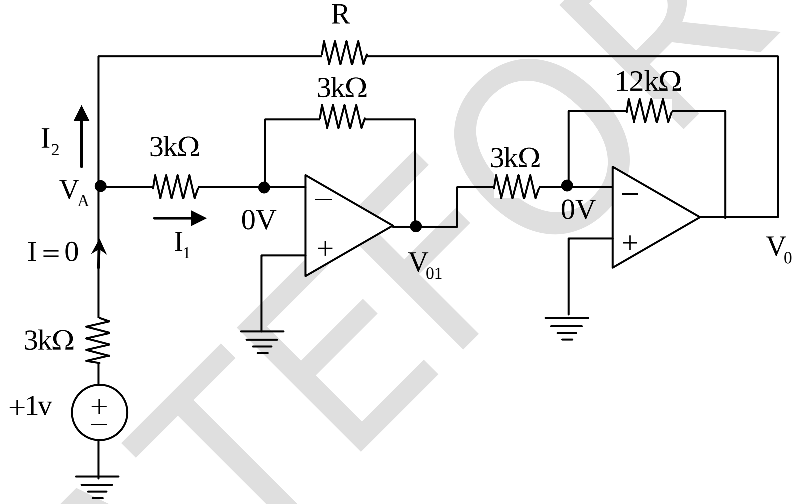
$$\therefore ess = \lim_{s \to 0} \frac{s \times \frac{2}{s^3}}{1 + \frac{3}{s^2}\left(10s + 1 + 2s^2\right)} = \frac{2}{3}$$

45. In the circuit shown below, all OPAMPS are ideal. The current I = 0A when the resistance R = ____ kΩ.



Key: (9)

Sol:



Apply KCL at node V_A

$$I = I_1 + I_2$$

$$I = \frac{V_A - 0}{3k} + \frac{V_A - V_0}{R} \qquad \ldots (1)$$

From the circuit $V_{01} = \frac{-3k}{3k} \times V_A = -V_A$

And $V_0 = \frac{-12k}{3k} \times V_{01} = -4 \times (-V_A) = +4V_A$

Substitute the value of V_0 in equation (1) and make I = 0, then

$$I = \frac{V_A}{3k} + \frac{V_A - 4V_a}{R} \Rightarrow 0 = \frac{V_A}{3k} - \frac{3V_A}{R}$$

$$\frac{3V_A}{R} = \frac{V_A}{3k} \Rightarrow \therefore R = 9\,k\Omega$$

46. In a microprocessor with a 16bit address bus, the most significant address line A15 to A12 are used to select a 4096 word memory unit, while line A0 to A11 are used to address a particular word in the memory unit. If the 3 least significant lines of the address bus A0 to A2 are short-circuited to ground, the addressable number of words in the memory unit is ______.

Key: **(512)**

Sol: → From the given information it is clear that $A_{15}A_{14}A_{13}A_{12}$ are used for chip selection purpose

→ $A_2A_1A_0$ are shorted means logic 0.

→Out of 16 address line 7 address line have fixed value so effective's 9 address line whose values can be varied, so total number of words that can be accessed is $2^9 = 512$.

47. A discrete-time signal $x[n] = e^{j\left(\frac{5\pi}{3}\right)n} + e^{j\left(\frac{\pi}{4}\right)n}$ is down-sampled to the signal $x_d[n]$ such that $x_d[n] = x[4n]$. The fundamental period of the down-sampled signal $x_d[n]$ is _________.

Key: **(6)**

Sol: It is given that $x(n) = e^{j\left(\frac{5x}{3}\right)n} + e^{j\left(\frac{\pi}{4}\right)n}$

We need to find fundamental period of $x_d(n) = x(4n)$

$$\Rightarrow x(n) = e^{j\left(\frac{5x}{3}\right)n} + e^{j\left(\frac{x}{4}\right)n}$$

$$\Rightarrow x(4n) = e^{j\left(\frac{5x}{3}\right)(4n)} + e^{j\left(\frac{x}{4}\right)(4n)} = e^{j\left(\frac{20x}{3}\right)n} + e^{(jx)n}$$

For $e^{j\left(\frac{20x}{3}\right)n}$, the fundamental period is

$$N_1 = \frac{2x}{\omega_0}k \qquad \left(\because \frac{2x}{\omega_0} \text{ is integer in this case}\right)$$

$$= 2x \times \frac{3}{20\pi} \times k = \frac{3}{10}k = 3 \qquad (\text{if } k = 10)$$

For $e^{j(x)n}$

$$N_2 = \frac{2x}{\omega_0}k \qquad \left(\because \frac{2x}{\omega_0} \text{ is integer in this case}\right)$$

$$= \frac{2x}{x}k = 2k = 2 \ (\text{if } k = 1)$$

Since both of individual signals are periodic with period N_1 and N_2, then their combination is also periodic and is given by

$$N = LCM(N_1, N_2) = LCM(3,2) = 6$$

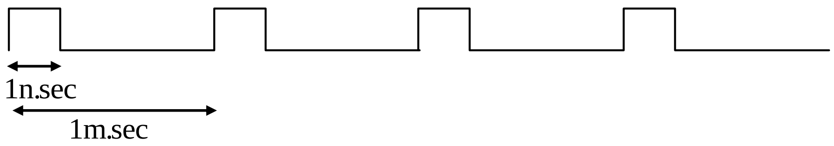
So the fundamental period of $x_d(n) = 6$

48. A pulsed laser emits rectangular pulses of width 1 nanosecond at a repetition rate of 1 kHz. If the average power output is 1mW, the average power over a single pulse duration, in watts, is

(A) 1 (B) 10 (C) 100 (D) 1000

Key: (D)

Sol: The nature of waveform will be



→ It is given that frequency = 1 kHz, so its period is 1 m.sec.

→ Energy of each pulse, $E = \dfrac{P_{av}}{\text{frequency}} = \dfrac{1\times10^{-3}}{1\times10^{3}} = 1\times10^{-6}$ joules

→ Power of each pulse, $P_{pulse} = \dfrac{E}{\text{Duration of pulse}} = \dfrac{1\times10^{-6}}{1\times10^{-9}} = 1000$

49. The dynamics of the state $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$ of a system is governed by the differential equation

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ -3 & -4 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 20 \\ 10 \end{bmatrix}$$

Given that the initial state is $\begin{bmatrix} 0 \\ 0 \end{bmatrix}$, the steady state value of $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$ is

(A) $\begin{bmatrix} -30 \\ -40 \end{bmatrix}$ (B) $\begin{bmatrix} -20 \\ -10 \end{bmatrix}$ (C) $\begin{bmatrix} 5 \\ -15 \end{bmatrix}$ (D) $\begin{bmatrix} 50 \\ -35 \end{bmatrix}$

Key: (D)

Sol: $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ -3 & -4 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 20 \\ 10 \end{bmatrix}$ and initial state is $\begin{bmatrix} 0 \\ 0 \end{bmatrix}$

$$x(t) = L^{-1}\{[sI - AJ^{-1}X(0)]\} + L^{-1}\{[SI-A]^{-1}B(s)V(s)\}$$

As initial state is zero, x(t) reduced to $x(t) = L^{-1}\{[SI-A]^{-1}B(s)V(s)\}$

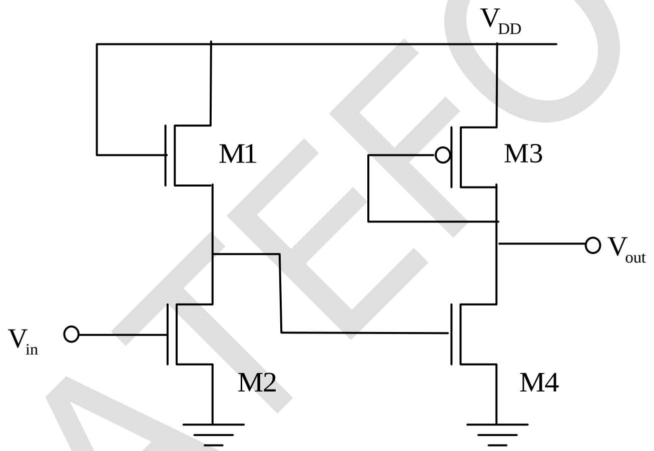
$$(SI-A)^{-1} = \begin{bmatrix} s-1 & 2 \\ -3 & s+4 \end{bmatrix}^{-1} \Rightarrow \frac{1}{(s+4)(s-1)+6}\begin{bmatrix} s+4 & +2 \\ -3 & (s-1) \end{bmatrix}$$

$$sx(s)=\frac{1}{(s+4)(s-1)+6}\begin{bmatrix} s+4 & 2 \\ -3 & s+1\end{bmatrix}\begin{bmatrix}20\\10\end{bmatrix}$$

$$\lim_{s\to 0} x(s)=\frac{1}{2}\begin{bmatrix}4 & 2\\ -3 & -1\end{bmatrix}\begin{bmatrix}20\\10\end{bmatrix}=\frac{1}{2}\begin{bmatrix}80+20\\-60-10\end{bmatrix}=\frac{1}{2}\begin{bmatrix}100\\-70\end{bmatrix}=\begin{bmatrix}50\\-35\end{bmatrix}$$

Hence, the steady state value of $\begin{bmatrix}x_1\\x_2\end{bmatrix}$ is $\begin{bmatrix}50\\-35\end{bmatrix}$

50. A Voltage amplifier is constructed using enhancement mode MOSFETs labeled M1, M2, M3 an M4 in the figure below. M1, M2 and M4 are n-channel MOSFETs and M3 s a p-channel MOSFET. All MOSFETs operate in saturation mode and channel length modulation can be ignored. The low frequency, small signal input and output voltages are V_{in} and V_{out} respectively and the dc power supply voltage is V_{DD}. All n-channel MOSFETs have identical transconductance g_{mn} while the p-channel MOSFET has transconductance g_{mp}. The expressions for the low frequency small signal voltage gain V_{out}/V_{in} is



(A) $-g_{mn}/g_{mp}$

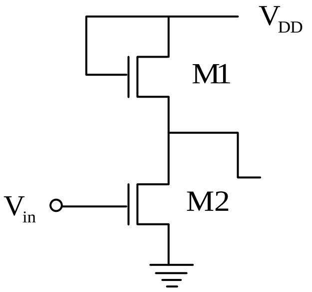
(B) $-g_{mn}\left(g_{mn}+g_{mp}\right)^{-1}$

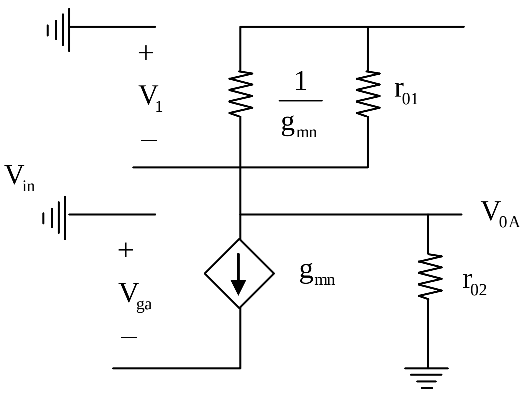
(C) $+g_{mn}/g_{mp}$

(D) $g_{mn}\left(g_{mn}+g_{mp}\right)^{-1}$

Key: (C)

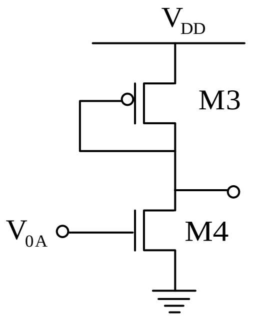
Sol:

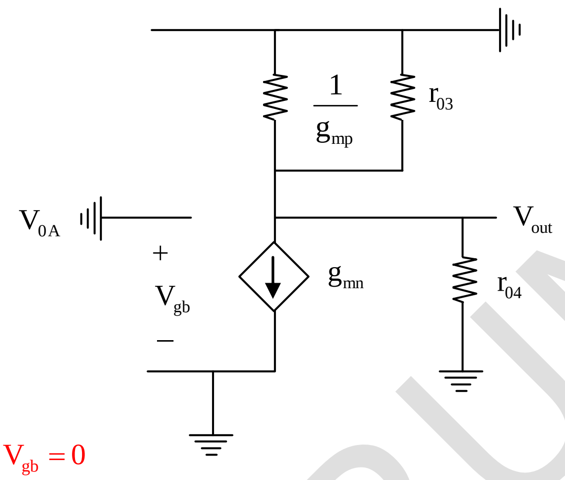




$$V_0 + g_{mn}\left[\gamma_{01} \| \gamma_{02} \| \frac{1}{g_{mn}}\right]V_{ga} = 0 \qquad \because \gamma_{01} = \gamma_{02} = \infty$$

$$\frac{V_{0A}}{V_{in}} = -\frac{g_{mn}}{g_{mn}} = -1 \qquad \ldots (1)$$





$$V_{out} + g_{mn}\left[\gamma_{03} \| \gamma_{04} \| \frac{1}{g_{mp}}\right]V_{gb} = 0$$

$$\because V_{gb} = V_{0A} \text{ and } \gamma_{03} = \gamma_{04} = \infty$$

$$\frac{V_{out}}{V_{0A}} = -\frac{g_{mn}}{g_{mp}} \qquad \ldots(2)$$

$$\frac{V_{out}}{V_{in}} = \frac{V_{oA}}{V_{in}} \times \frac{V_{out}}{V_{oA}} = (-1)\left[\frac{-g_{mn}}{g_{mp}}\right]$$

$$\frac{V_{out}}{V_{in}} = \frac{g_{mn}}{g_{mp}}$$

51. The transfer function relating the input x(t) to the output y(t) of a system is given by $G(s) = 1/(s+3)$. A unit-step input is applied to the system at time t=0. Assuming that $y(0) = 3$, the value of y(t) at time t = 1 is ________. (Rounded off to two decimal places).

Key: (0.46)

Sol: It is given that

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

$$\Rightarrow \frac{Y(s)}{X(s)} = \frac{1}{s+3} \Rightarrow SY(s) + 3Y(s) = X(s)$$

$$\Rightarrow \frac{dy(t)}{dt} + 3y(t) = x(t)$$

[Since initial condition is specified, to incorporate it we need to derive its corresponding differential equation]

Taking Laplace on both sides

$$SY(s)-y(0)+3Y(s)=X(s)$$

$$\Rightarrow Y(s)=\frac{x(s)}{s+3}+\frac{y(0)}{s+3}$$

$$=\frac{1}{s(s+3)}+\frac{3}{s+3} \qquad \left[\because \text{given not } x(t)=u(t)\Rightarrow x(s)=\frac{1}{s} \text{ and } y(0)=1\right]$$

$$=\frac{1/3}{s}+\frac{-1/3}{s+3}+\frac{3}{s+3}=\frac{1/3}{s}+\frac{8/3}{s+3}=\frac{1}{3}\left[\frac{1}{s}+\frac{8}{s+3}\right]$$

$$\Rightarrow y(t)=\frac{1}{3}\left[1+8e^{-3t}\right]u(t)$$

$$\Rightarrow y(t)=\frac{1}{3}\left[1+8e^{-3.1t}\right]u(1)$$

$$=\frac{1}{3}\left[1+8e^{-3}\right]=0.466 \qquad [\because u(t)=1]$$

52. In a control system with unit gain feedback, the plant has the transfer function $P(s)=3/s$. Assuming that a controller of the form $C(s)=K/(s+9)$ is used, where K is a positive constant, the value of p for which the root-locus of the closed-loop system passes through the points $-3\pm j3\sqrt{3}$ where $j=\sqrt{-1}$, is

(A) 3 (B) $3\sqrt{3}$ (C) 6 (D) 9

Key: **(C)**

Sol: Given, plant transfer function $=\frac{3}{s}$

Controller $(s)=\frac{k}{(s+p)}$

$$G(s)H(s)=C(s)P(s)H(s)=\frac{3k}{s(s+p)} \qquad (\because H(s)=1)$$

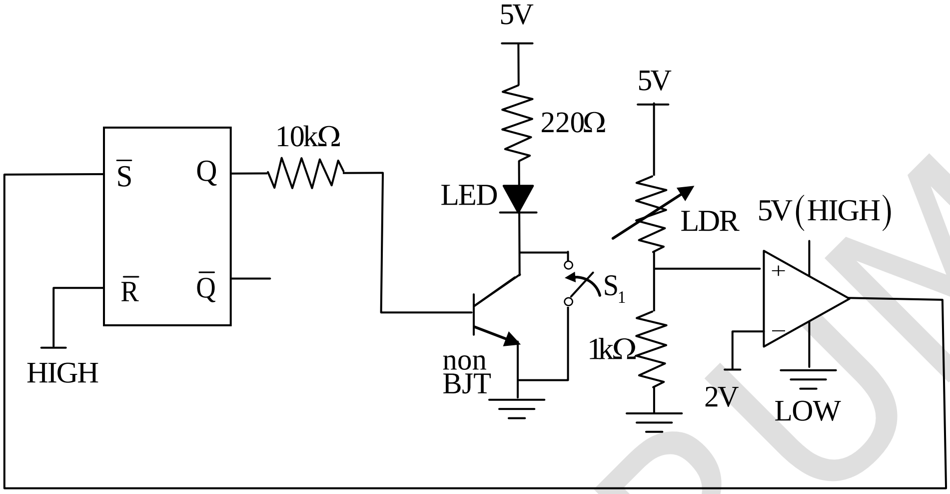
As the root locus of the closed-loop system passes through the point $-3\pm j3\sqrt{3}$. Angle condition should following. Angle condition stated as for a point to lie on root locus, the angle evaluated at the point must be an odd multiple of $\pm180°$.

$$\angle G(s)H(s)=-90°-\tan^{-1}\left\{\frac{3\sqrt{3}}{P-3}\right\}$$

$$=-90°-\tan^{-1}\left\{\frac{3\sqrt{3}}{P-3}\right\}=-180=\tan^{-1}\left(\frac{3\sqrt{3}}{P-3}\right)=90°$$

$$P-6=0\Rightarrow P=6$$

53. In the circuit below, the light dependent resistor (LDR) receives light from the LED. The LDR has resistances of $5k\Omega$ and 500Ω under dark and illuminated conditions, respectively. The LED is OFF at time $t<0$. At time t=0s, the switch S_1 is closed for 1ms and then kept open thereafter. Assuming zero propagation delay in the devices, the LED



(A) turns ON when S_1 is closed and remains ON after S_1 is opened.

(B) turns ON when S_1 is closed and turns OFF after S_1 is opened.

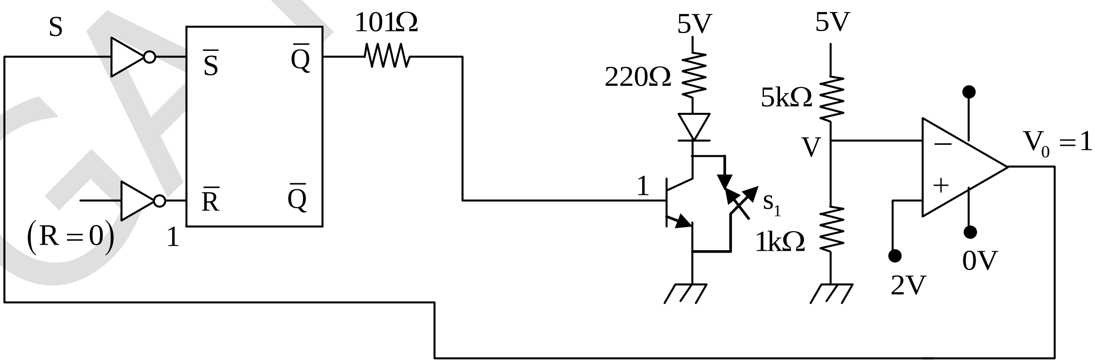
(C) turns ON when S_1 is closed and toggles periodically from ON to OFF after S_1 is opened.

(D) remains OFF when S_1 is closed and continues to remain OFF after S_1 is opened.

Key: **(A)**

Sol: It is given that, for t < 0

Switch S1, is open and LED is off



Since LED is off for t < 0, the resistance of LDR under dark condition is $5000\Omega = 5k\Omega$

So $V^- = \left[\frac{1000}{5000+1000}\right]5 = \frac{5}{6} = 0.533$

$V^+ = 2V \quad \because V^+ > V^- \Rightarrow V_0 = 1 = S$

Now to the SRFF, S = 1, R = 0

So $Q^+ = 1$

For 0 < t < 1 m-sec, Switch S, is closed,

So LED will be F. B and it will glow, now the resistance of LDR will be 500Ω

$$V^- = \frac{1000}{500+1000} \times 5 = \frac{5000}{1500} = 3.33V$$

Now $V^- > V^+ \Rightarrow V_0 = 0 = S$

Now $S = 0, R = 0, \text{So } Q^+ = Q(t<0) = 1$

When Q^+ = 1, the base of npn transistor is 1. So the transistor will behave as a on switch.

So LED will glow.

So during 0 < t < 1 m sec, S_1 is closed

$Q = 1 \Rightarrow$ Transistor, ON

And $V_0 = 1$

For t > 1 m-sec, S_1 open, even the switch S_1 is open, still Q = 1, Transistor is ON, LED will glow for ever.

So the LED, turns ON when S_1 is closed and remain ON after S_1 is opened.

54. A complex function $f(z) = u(x,y) + iv(x,y)$ and its complex conjugate $f'(z) = u(x,y) - i\,v(x,y)$ are both analytic in the entire complex plane, where $z = x + iy$ and $i = \sqrt{-1}$. The function f is then given by

(A) $f(z) = x + iy$ (B) $f(z) = x^2 - y^2 + i\,2xy$

(C) $f(z) = \text{constant}$ (D) $f(z) = x^2 + y^2$

Key: (C)

Sol: We know that, every constant function is always analytic.

[i.e; $f(z) = K_1 + i\,K_2$; where K_1 & K_2 are real constants

$u(x,y) = K_1$ & $v(x,y) = K_2$

$u_x = 0 \mid v_x = 0$

$u_y = \mid v_y = 0$

$\therefore$ L − R Equations are satisfied $\forall Z$.

$\therefore f(z) = K_1 + i\,K_2$ is analytic]

Similarly, conjugate of f(z), i.e, $f'(z) = K_1 - i\,K_2$ also analytic.

Option (A) is false, since f(z) is analytic but f'(z) is not analytic.

Option (B) is false, since f(z) is analytic, but f'(z) is not analytic

Option (D) is false, since f(z) is not analytic.

55. The output of a continuous-time system y (t) is related to its input x(t) as

$y(t) = x(t) + \frac{1}{2}x(t-1)$. If the Fourier transforms of x(t) and y(t) are $X(\omega)$ and $Y(\omega)$

respectively, and $|X(0)|^2 = 4$. The value of $|Y(0)|^2$ is ________,

Key: **(9)**

Sol: It is given that

$$y(t) = x(t) + \frac{1}{2}x(t-1) \text{ and } |x(0)|^2 = 4$$

We need to obtain $|Y(0)|^2$

$$y(t) = x(t) + \frac{1}{2}x(t-1)$$

$$Y(\omega) = X(\omega) + \frac{1}{2}X(\omega)e^{-j\omega} = \left(1 + \frac{1}{2}e^{-j\omega}\right)X(\omega)$$

$$Y(0) = \left(1 + \frac{1}{2}e^{-j0}\right)X(0) = \frac{3}{2}X(0)$$

$$|Y(0)| = \frac{3}{2}|X(0)|$$

$$|Y(0)|^2 = \left(\frac{3}{2}\right)^2 |X(0)|^2 = \frac{9}{4} \times 4 = 9$$