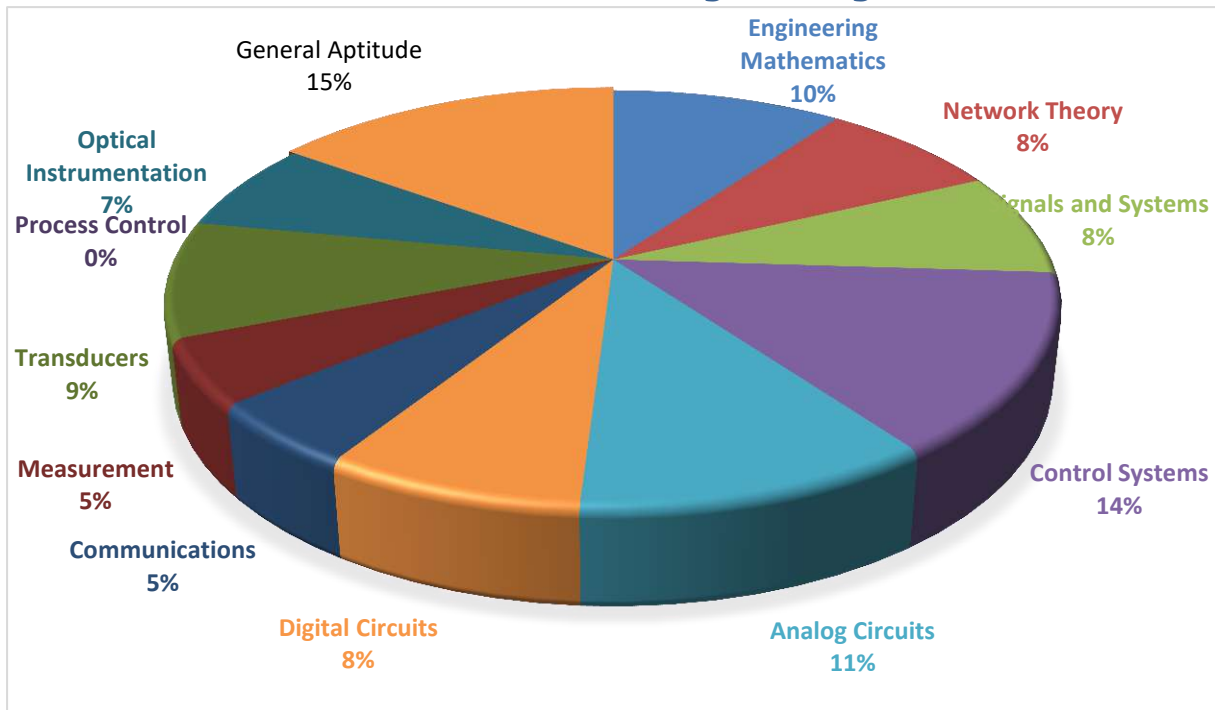


**ANALYSIS OF GATE 2019**

**Instrumentation Engineering**



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**IN ANALYSIS-2019\_Feb-3\_Afternoon**

SUBJECT	No. of Ques.	Topics Asked in Paper(Memory Based)	Level of Ques.	Total Marks
Engineering Mathematics	1 Marks: 4 2 Marks: 3	Matrix, Vector Calculus, Probability, Complex, Tangent of Curve	Easy	10
Network Theory	1 Marks: 4 2 Marks: 2	MPTT, KVL, Transient Analysis, Parallel RLC, Steady state analysis	Easy	8
Signals and Systems	1 Marks: 2 2 Marks: 3	BIBO Criteria, LT, FT, Fourier Representation of Signals	Tough	8
Control Systems	1 Marks: 2 2 Marks: 6	Bode Plot, Root Locus, State space, Free response	Medium	14
Analog Circuits	1 Marks: 3 2 Marks: 4	Rectifier, Diode, OP-Amp, MOSFET, Current mirror	Medium	11
Digital Circuits	1 Marks: 4 2 Marks: 2	Boolean Algebra, Logic CKT, ADC, Combinational circuits, Sequential Circuits	Medium	8
Communications	1 Marks: 1 2 Marks: 2	Receiver, Analog Communication(DSB-SC)	Tough	5
Measurement	1 Marks: 1 2 Marks: 2	Error Analysis, Standard Deviation, AC Bridge	Medium	5
Transducers	1 Marks: 3 2 Marks: 3	Thermocouple, Instrumental Amplifier	Medium	9
Process Control	1 Marks: - 2 Marks: -			0
Optical Instrumentation	1 Marks: 1 2 Marks: 3	Michelson Interferometer, Optical detector	Tough	7
General Aptitude	1 Marks: 5 2 Marks: 5	Data Interpretation, Grammar, Percentage, Time, speed and distance, Seating arrangement	Easy	15
<b>Total</b>	<b>65</b>			<b>100</b>
Faculty Feedback	Overall medium level paper. Compare to last year this year question paper was easy.			



## GATE 2019 Examination

## Instrumentation Engineering

Test Date: 3-FEB-2019

Test Time: 2.30 PM to 5:30 PM

Subject Name: Instrumentation Engineering

## General Aptitude

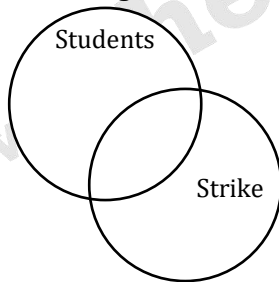
Q.1 - Q.5 Carry One Mark each.

1. 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 the 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

**[Ans. C]**

Given statements: Some students were not involved in the strike.

Venn diagram:



Only conclusion 4 is logically necessary.

2. The fishermen, \_\_\_\_\_ the flood victims owed their lives, were rewarded by the government.
- (A) Whom  
(B) To which  
(C) To whom  
(D) That

**[Ans. C]**

3. The radius as well as the height of a circular cone increases by 10%. The percentage increase in its volume is \_\_\_\_\_.
- (A) 17.1  
 (B) 21.0  
 (C) 33.1  
 (D) 72.8

**[Ans. C]**

We know formula for volume of a (right circular) cone is  $\frac{1}{3}\pi r^2 h$

Original volume ( $V_0$ )

$$V_0 = \frac{1}{3}\pi r_1^2 h_1$$

Now we know radius and height both are increased by 10%. So after increase the new volume will be

$$V_n = \frac{1}{3}\pi(1.1r_1)^2(1.1)h_1$$

$$= 1.331\left(\frac{1}{3}\pi r_1^2 h_1\right)$$

$$= 1.331(V_0)$$

$$\% \text{ change in volume} = \frac{V_n - V_0}{V_0} \times 100 = \frac{1.331V_0 - V_0}{V_0} \times 100$$

$$= 33.1\%$$

4. Until Iran came along, India had never been \_\_\_\_\_ in kabaddi.
- (A) Defeated  
 (B) Defeating  
 (C) Defeat  
 (D) Defeatist

**[Ans. A]**

Until Iran came along, India had never been defeated in Kabaddi.

If two events occur in past one after another, the event completing first takes past perfect tense. And another event is expressed in Simple past tense.

5. Five numbers 10, 7, 5, 4 and 2 are to be 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 the 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

**[Ans. C]**

Required number is: **10, 5, 4, 7, 2** which satisfy all the three conditions given in question.



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**Q.6 - Q.10 Carry Two Mark each.**

6. The nomenclature of Hindustani music has changed over the 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 the institutionalization of music education the term gharana became acceptable. Gharana originally referred to hereditary musicians from a particular lineage, including disciples and grand disciples.

Which one of the following pairings is NOT correct?

- (A) Dhrupad, baanis  
 (B) Gayaki, vocal  
 (C) Baaj, institution  
 (D) Gharana, lineage

**[Ans. C]**

Baaj, institution

Following are the correct pairings:

- Dghruspad style - baani
- Gayaki - vocal style
- Baaj - insturmental style
- Gharana - musicians from a particular line age

7. In a country of 1400 million populations, 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

**[Ans. A]**



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Total population of the country = 1400 million.

Number of mobile phone users = 70% of total population = 980 million.

Number of internet users = 294 million

Number of e-commerce users =  $1/2 (294) = 147$  million.

Percentage of e-commerce users =  $\frac{147}{1400} \times 100 = 10.5 \%$

8. Since the last one year, after a 125 basis point reduction in repo rate by Reserve Bank of India, banking institutions have been making a demand to reduce interest rates on small saving 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 reducing in interest rates on small saving schemes follow only after a reduction in repo rate by the Reserve Bank of India

**[Ans. C]**

The argument says that banking institutions had been demanding for a reduction in interest rates for the last one year. Finally the government decided to reduce the interest rates of small saving schemes thus implying that the govt. does consider the demands of banking institutions before making any such policy decision.

9. "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 heads he could gather

**[Ans. D]**

The way prestige of a kingdom depended upon the number of taxes, the prestige of a head-hunter depended upon the number of heads he could collect.

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

- (A) 9  
(B) 10  
(C) 11  
(D) 11.30

[Ans. B]

Since, both the trains are moving in **opposite** directions.

So, Speed of second train with respect to the first one =  $(100+80)$  km/hr = 180 km/hr

Time taken to be a gap of 540 km =  $\frac{540}{180} = 3$  hours

Since, 3 hours after 7 AM is 10 AM. So, at 10 AM, both the trains will be 540 kms apart.



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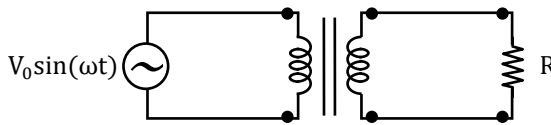
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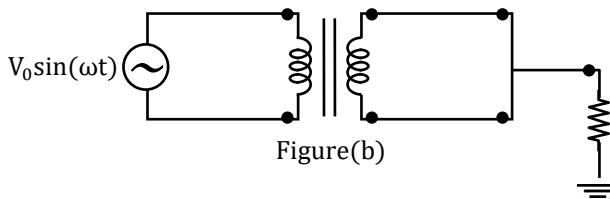
**Technical**

Q.1 - Q.25 Carry One Mark each.

1. 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 ration 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)  $4:1$

**[Ans. B]**

Fig (a)

The resultant output  $V_{01}$  is

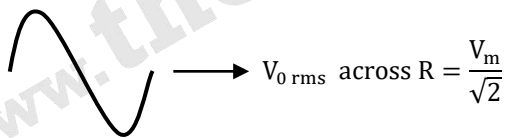
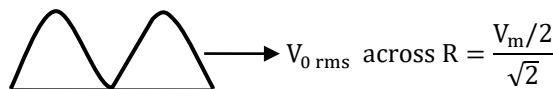


Fig (b)

The resultant output  $V_{02}$  is



$\frac{V_m}{2}$  due to centertap

The ratio  $\frac{V_{01}}{V_{02}}$  is

$$\frac{V_m/\sqrt{2}}{V_m/2\sqrt{2}} = 2 : 1$$



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

**[Ans. \*]Range 256 to 256**

The total number of Boolean function with distinct truth table will be for n Boolean variables

$$(2^{2^n}) \text{ so for 3 Boolean variables} = (2^{2^3}) = 256$$

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

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

**[Ans. A]**

Here,  $H(z) = \frac{1}{1 - \alpha z^{-1}}; |z| > |\alpha|$

For system to be stable,  $|\alpha| < 1$

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

- (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

**[Ans. A]**

LED  $\rightarrow$  FB

Photodiode  $\rightarrow$  RB

Zener diode  $\rightarrow$  RB

5. A  $3 \times 3$  matrix has eigenvalues 1, 2 and 5. The determinant of the matrix is \_\_\_\_\_.

**[Ans. \*]Range 10 to 10**

Product of eigen values =  $|A|$

$$= (1)(2)(5) = 10$$

6. An 8-bit weighted resistor digital-to-analog converter (DAC) has the smallest resistance of  $500\Omega$ . The largest resistance has a value \_\_\_\_\_  $k\Omega$ .

**[Ans. \*]Range 64 to 64**

In general, in a binary weighted resistor DAC, the relationship between LSB and MSB resistance is given as:

LSB Resistance =  $(2^{n-1})$  MSB resistance where, n is the number of bits in the DAC.

Given,  $n = 8$

Smallest resistance =  $500 \Omega$

MSB resistance =  $500 \Omega$

$\therefore$  LSB resistance =  $(28 - 1) \times 500 \Omega$

=  $128 \times 500 \Omega$

=  $64000 \Omega$

=  $64 \text{ k}\Omega$

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

**[Ans. \*]Range 20 to 20**

Given that,

Density of the fluid,  $\rho = 1 \text{ kg/m}^3$

If the pressure difference measured,  $\Delta p = 200 \text{ N/m}^2$

The velocity of the fluid measured by pitot static tube is

$$v = \sqrt{\frac{2\Delta p}{\rho}} = \sqrt{\frac{2 \times 200}{1}} = 20 \text{ m/s}$$

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

$$y(t) = \int_0^t x(t-2) dt,$$

where,  $x(t) = 0$  and  $y(t) = 0$  for  $t \leq 0$ . The transfer function of the system is

(A)  $\frac{1}{s}$

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

(C)  $\frac{e^{-2s}}{s}$

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

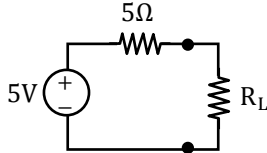
**[Ans. C]**

Put  $x(t) = \delta(t)$

$$y(t) = h(t) = \int_0^t \delta(\tau - 2) dz = u(t - 2)$$

$$H(s) = \frac{e^{-2s}}{s}$$

9. In the circuit shown below, maximum power is transferred to the load resistance  $R_L$ , when  $R_L = \underline{\hspace{2cm}} \Omega$ .



**[Ans. \*]Range 5 to 5**

According to maximum power transfer theorem, the maximum power will be transferred to the load when,

$$R_L = R_S$$

$$\therefore R_L = 5 \Omega$$

10. 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 0.05 mA. Assuming that the errors in voltage and current measurements are independent, the standard deviation of the calculated resistance value is  $\underline{\hspace{2cm}} \Omega$ .

**[Ans. \*]Range 130 to 130**

$$\text{Given, } R = \frac{V}{I}$$

$$\text{Where } V = 1 \pm 0.12 \text{ V, } I = 1 \pm 0.05 \text{ mA}$$

Here the standard deviation in  $R(\sigma_R)$  will be

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

$$\frac{\partial R}{\partial V} = \frac{\partial}{\partial V} \left(\frac{V}{I}\right) = \frac{1}{I} = \frac{1}{10^{-3}} = 10^3$$

$$\frac{\partial R}{\partial I} = \frac{\partial}{\partial I} \left(\frac{V}{I}\right) = -\frac{V}{I^2} = \frac{-1}{10^{-6}} = -10^6$$

$$\sigma_V = 0.12 \text{ V and } \sigma_I = 0.05 \text{ mA}$$

Substituting, we have

$$\sigma_R = \sqrt{(10^3)^2 (0.12)^2 + (-10^6)^2 (0.05 \times 10^{-3})^2}$$

$$= \sqrt{10^6 \times 0.0144 + 10612 \times 2.5 \times 10^{-9}}$$

$$= \sqrt{14400 + 2500} = \pm 130 \Omega$$



11. 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)  $8/15$

**[Ans. A]**

First is red and second is green  $\frac{8}{16} \times \frac{8}{15} = \frac{4}{15}$

12. 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 \_\_\_\_\_. (Answer should be rounded off to one decimal place)

**[Ans. \*]Range 0.3 to 0.3**

Double sideband with carrier signal is given by

$$s(t) = \cos(2\pi f_c t) + 0.3 \cos(2\pi f_m t) \cos(2\pi f_c t)$$

$$= [1 + 0.3 \cos(2\pi f_m t)] \cos 2\pi f_c t$$

Comparing with standard amplitude modulated signal

$$s(t) = A_c [1 + \mu \cos 2\pi f_m t] \cos 2\pi f_c t$$

$$\mu = 0.3$$

13. 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

**[Ans. D]**

$$\text{OLTF} = \frac{k}{(s+1)(s+2)(s+3)}$$

If the  $\omega_{gc} < \omega_{pc}$  then that minimum phase system is stable.

14. Thermocouples measure temperature based on
- (A) Photoelectric effect  
 (B) Seebeck effect  
 (C) Hall effect  
 (D) Thermal expansion

**[Ans. B]**

15.  $\vec{a}, \vec{b}, \vec{c}$ , are three orthogonal vectors. Given that  $\vec{a} = \hat{i} + 2\hat{j} + 5\hat{k}$  and  $\vec{b} = 2\hat{j} - \hat{k}$ , 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)  $4\hat{k}$

**[Ans. C]**

$\vec{a}, \vec{b}, \vec{c}$  are mutually perpendicular

$\therefore \vec{c}$  is perpendicular is  $\vec{a} \times \vec{b}$

$$\vec{a} \times \vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 2 & 5 \\ 0 & 2 & -1 \end{vmatrix}$$

$$= \hat{i}(-12) - \hat{j}(-6) + 0\hat{k}$$

$$= -6(-2\hat{i} - \hat{j})$$

16. 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

**[Ans. B]**

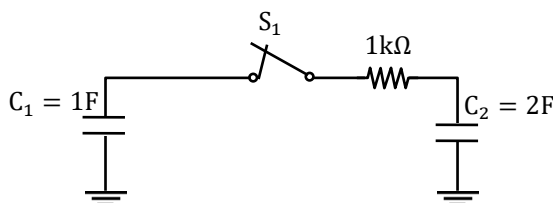
$$Q = \frac{1}{R} \sqrt{\frac{L}{C}}$$

And as R, L and C are doubled

$$\therefore Q' = \frac{1}{2R} \sqrt{\frac{2L}{2C}} = \frac{1}{2} \left[ \frac{1}{R} \sqrt{\frac{L}{C}} \right]$$

$$Q' = \frac{1}{2} Q$$

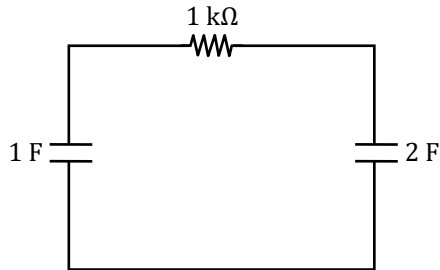
17. In the circuit shown below, initially the switch  $S_1$  is open, the capacitor  $C_1$  has a charge of 6 coulomb, and the capacitor  $C_2$  has 0 coulomb. After  $S_1$  is closed, the charge on  $C_2$  in steady state is \_\_\_\_\_ coulomb.



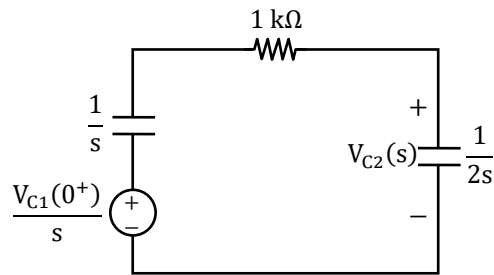
**[Ans. \*]Range 4 to 4**

$$V_{C_1}(0^-) = \frac{6}{1} = 6 \text{ V and } V_{C_2}(0^-) = 0 \text{ V}$$

For  $t > 0$



Transforming the circuit to the Laplace domain,



$$V_{C_2}(s) = \frac{\frac{6}{s}}{\frac{1}{s} + 1k + \frac{1}{2s}} \times \frac{1}{2s} = \frac{6}{s[2 + 2sk + 1]}$$

Voltage across the capacitor  $C_2$  in steady state,

$$V_{C_2}(\infty) = \lim_{s \rightarrow 0} sV_{C_2}(s) = \lim_{s \rightarrow 0} \frac{6}{[2 + 2sk + 1]} = \frac{6}{3}$$

$$V_{C_2}(\infty) = 2 \text{ V}$$

∴ The charge on  $C_2$  in steady state,  $Q = C_2 V_{C_2}(\infty)$

$$Q = (2)(2) = 4 \text{ C}$$

**Alternate method:**

$$Q_1(0^-) = 6 \text{ C}$$

$$V_{C_1}(0^-) = \frac{Q_1(0^-)}{C} = \frac{6}{1} = 6 \text{ V}$$

The initial voltage across the capacitor  $C_1$  is 6V and capacitor  $C_2(0^-)$  is 0V

i.e.  $V_{C_2}(0^-) = 0 \text{ V}$

In steady state the voltage across two capacitors are equal i.e.

$$V_{C_1}(\infty) = V_{C_2}(\infty) = \frac{V_{C_1}(0^-)C_1 + V_{C_2}(0^-)C_2}{C_1 + C_2}$$

$$V_{C_1}(\infty) = V_{C_2}(\infty)$$

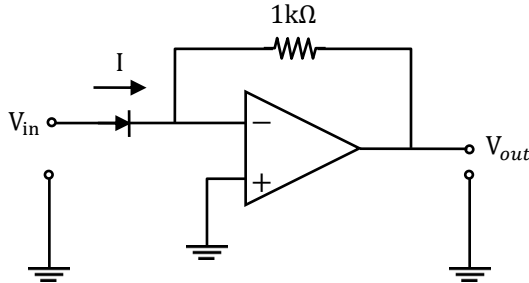
$$\Rightarrow \frac{(6 \times 1) + 0}{1 + 2} = 2 \text{ V}$$

The steady state voltage across capacitor  $C_2$  is 2V

And change  $Q_2 = C_2 V_2 = 2 \times 2 = 4 \text{ C}$

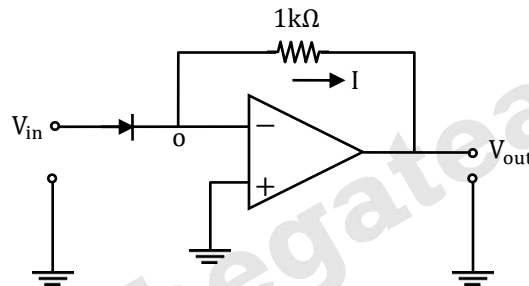


18. In the circuit shown below, the input voltage  $V_{in}$  is positive. The current (I)-voltage (V) characteristics of the diode can be assumed to be  $I = I_0 e^{V/V_T}$  under the forward bias condition, where  $V_T$  is the thermal voltage and  $I_0$  is the reverse saturation current. Assuming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



- (A)  $\log_0(V_{in}/V_T)$
- (B)  $2V_{in}$
- (C)  $e^{V_{in}/V_T}$
- (D)  $V_{in}^2$

[Ans. C]



$V^+ = V^- = 0$  (Virtual ground)

$i = I_0 e^{\frac{V_D}{V_T}} = I_0 e^{\frac{V_{in}}{V_T}}$

$0 - V_{out} = I \times 1 \text{ k}\Omega$

$V_{out} = -I \times 1 \text{ k}\Omega$

$V_{out} \propto e^{V_{in}/V_T}$

This circuit is an exponential amplifier.

19. 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.

[Ans. C]

In single mode optical fiber 'zero-dispersion' wave length means, sum of material dispersion and waveguide dispersion is zero.

20. In a cascade control system, the closed loop transfer function of the inner loop may be assumed to have a single time-constant  $T_1$ . Similarly, the closed loop transfer function of the outer loop may be assumed to have a single time-constant  $T_2$ . The desired relationship between  $T_1$  and  $T_2$  in a well-designed control system is
- (A)  $T_1$  is much less than  $T_2$   
 (B)  $T_1$  is equal to  $T_2$   
 (C)  $T_1$  is much greater than  $T_2$   
 (D)  $T_1$  is independent of  $T_2$

**[Ans. A]**

In a Cascade control system, inner loop should function fast compared to the outer loop. Infact it is the basic characteristic of cascade control strategy. Generally speed of response of loop is inversely proportional to time constant of the transfer function. So, time constant of inner loop  $\tau_1$  should be less compared to the time constant of outer loop  $\tau_2$ .

21. 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)  $\infty$

**[Ans. B]**

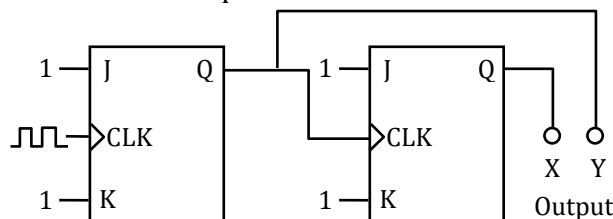
Given that  $u(x, y)$  is a scalar point function, and

$$\vec{A} = \nabla u$$

$$\nabla \times \vec{A} = \nabla \times (\nabla u) = 0$$

Vector identity Curl (grad $\phi$ ) = 0

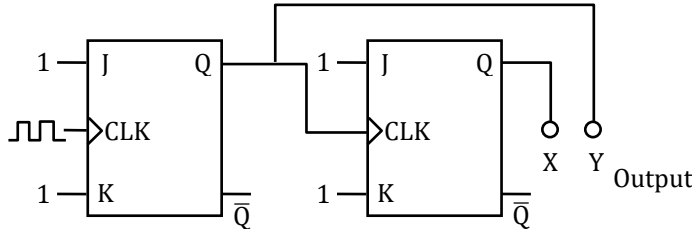
22. The circuit shown in the figure below uses ideal positive edge-triggered synchronous J-K flip flops with outputs X and Y. If the initial state of the output is  $X = 0$  and  $Y = 0$  just before the arrival of the first clock pulse, the state of the output just before the arrival of the second clock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



- (A)  $X = 0, Y = 0$   
 (B)  $X = 0, Y = 1$

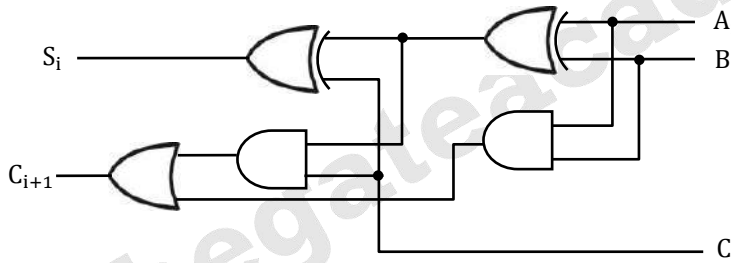
- (C)  $X = 1, Y = 0$
- (D)  $X = 1, Y = 1$

[Ans. D]



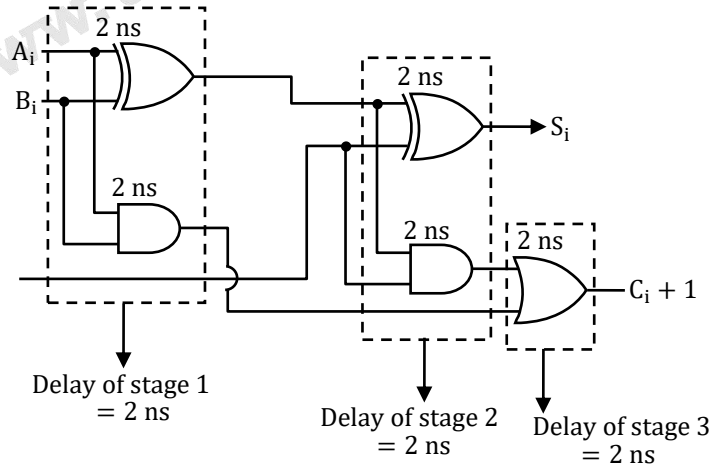
Initial state of output is  $X = 0$  and  $Y = 0$   
 After 1 Clock pulse,  $Y = 1$   
 $\Rightarrow X = 1$

23. The figure below shows the  $i^{\text{th}}$  full-adder block of a binary adder circuit.  $C_1$  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 input  $A_i, B_i$  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.



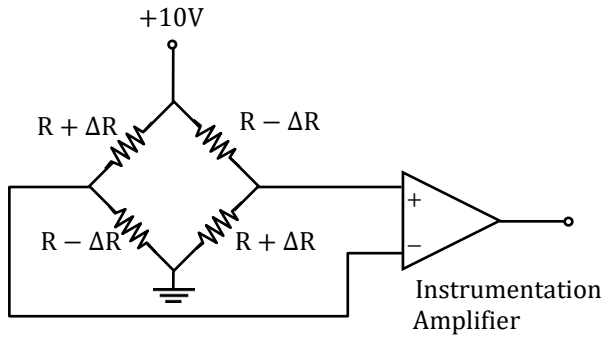
[Ans. \*] Range 4 to 4

Given that each logic gate has a delay of 2 ns



$\therefore$  total delay for an input  $C_i$  to procedure  $C_{i+1} = 2 + 2 = 4$  ns.

24. 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

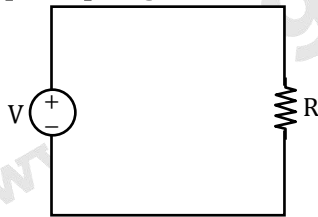


- (A) -20  
(B) 0  
(C) 3  
(D) 100

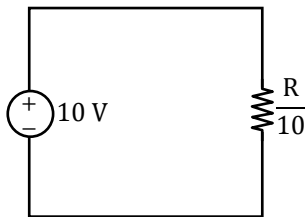
[Ans. D]

25. 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 \_\_\_\_\_.

[Ans. \*]Range: 1000 to 1000



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



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

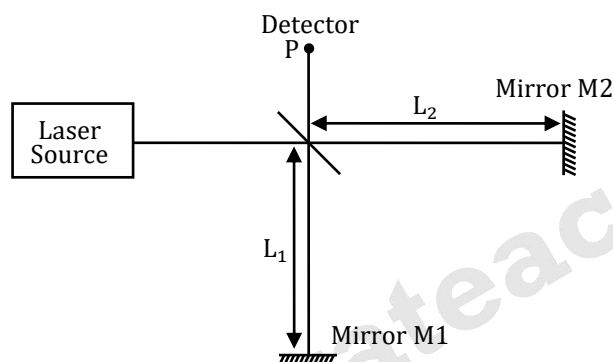
$$\therefore P' = 1000P$$

$\therefore$  Power dissipated scales up by a factor of 1000.



Q.26 - Q.55 Carry Two Mark each.

26. 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 port 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



[Ans. \*]Range 1000 to 1000

As per the question the optical path difference in both the cases (400 nm or 500 nm) should be same but for 400 nm wavelength we should get destructive interference whereas for 500 nm wavelength we should get constructive interference.

∴ for constructive interference optical path difference  $(2x) = n\lambda_c$

For destructive interference optical path difference  $(2x) = \frac{(2m+1)\lambda_D}{2}$

As per equation,

$$h\lambda_c = \frac{(2m+1)\lambda_D}{2}$$

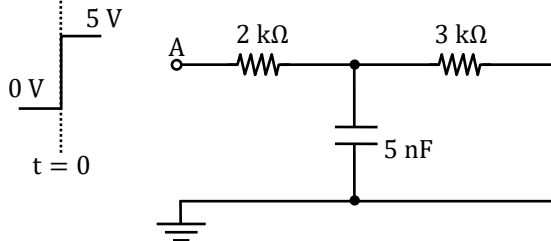
$$n(500) = \frac{(2m+1)400}{2}$$

∴ For  $n = 2$  or  $m = 2$  condition satisfied

∴ Optical path difference

$$\begin{aligned} 2x &= n\lambda \\ &= 2(500 \text{ nm}) \\ &= 1000 \text{ nm} \end{aligned}$$

27. In the circuit shown below, a step input voltage of magnitude 5 V 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  $t = 6 \mu\text{s}$  is \_\_\_\_\_ V. (Answer should be rounded off to two decimal places)

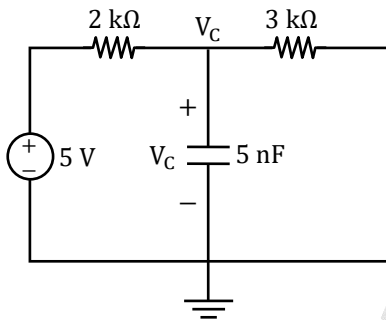


[Ans. \*]Range: 1.87 to 1.91

$$V_C(0^-) = 0 \text{ V}$$

$$\text{As } V_C(0^+) = V_C(0^-)$$

$$\therefore V_C(0^+) = 0 \text{ V}$$



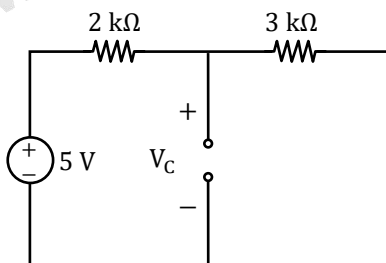
$$V_C(t) = V_C(\infty) + [V_C(0^+) - V_C(\infty)]e^{-\frac{t}{\tau}}$$

$$\tau = R_{eq} \cdot C$$

$$R_{eq} = 2k \parallel 3k = \frac{(2k)(3k)}{5k} = \frac{6}{5} \text{ k}\Omega$$

$$\therefore \tau = \left(\frac{6}{5} \text{ k}\right) (5\text{n}) = 6 \times 10^{-6} \text{ sec}$$

At  $t = \infty$



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

Using equation (i)

$$V_C(t) = 3 + [0 - 3]e^{-\frac{t}{6} \times 10^{-6}}$$

$\therefore$  Voltage at node P at  $t = 6 \mu\text{s}$ ,



$$V_C(6 \mu s) = 3 \left[ 1 - e^{-6 \times \frac{10^{-6}}{6} \times 10^{-6}} \right] = 3[1 - e^{-1}]$$

$$V_C(6 \mu s) = 1.896 \text{ V}$$

28. In a microprocessor with a 16 bit address bus, the most significant address lines A15 to A12 are used to select a 4096 word memory unit, while lines 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 \_\_\_\_\_.

[Ans. \*]Range: 512 to 512

Total address line = 16

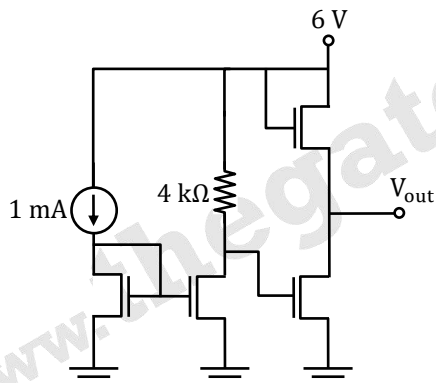
3 lines grounded

4 lines for chip select

Remaining lines 9

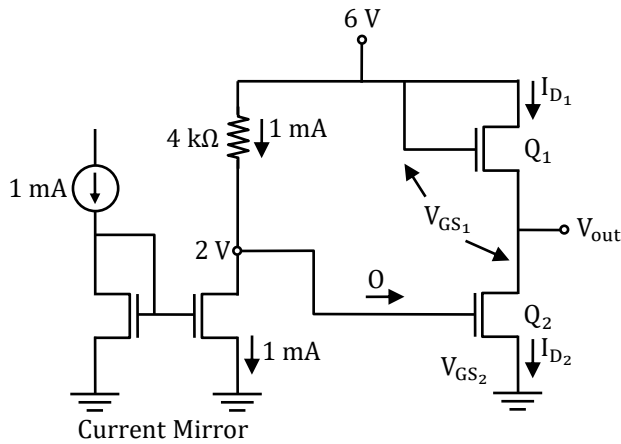
$2^9 = 512$  words.

29. 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.



[Ans. \*]Range: 4 to 4





$Q_1$  and  $Q_2$  are in current saturation mode

$$-6 + (1 \times 10^6 - 3 \times 4 \times 10^3) + V_{GS_2} = 0$$

$$V_{GS_2} = 2V$$

$$I_{D_1} = I_{D_2}$$

$$\frac{1}{2}k_n(V_{GS_1} - V_T)^2 = \frac{1}{2}k_n(V_{GS_2} - V_T)^2$$

$$V_{GS_1} = V_{GS_2} = 2V$$

$$-6 + V_{GS_1} + V_0 = 0$$

$$V_0 = 6 - V_{GS_1}$$

$$V_0 = 6 - 2 = 4V$$

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

(A)  $\mu - 1$

(B)  $\mu + 1$

(C)  $1/(\mu - 1)$

(D)  $1/(\mu + 1)$

[Ans. A]

$$\int_{-\infty}^{\infty} f(x)dx = 1$$

$$\int_{-\infty}^1 f(x)dx + \int_1^{\infty} f(x)dx = 1$$

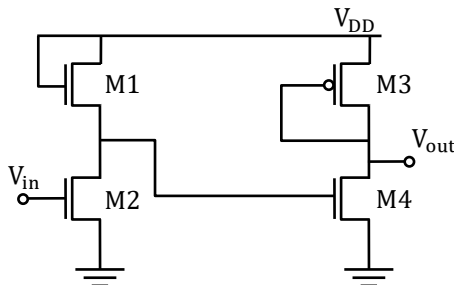
$$0 + \int_1^{\infty} \frac{A}{x^\mu} dx = 1$$

$$A \left( \frac{x^{-\mu+1}}{-\mu+1} \right) \Big|_1^\infty = 1$$

$$\frac{A(0-1)}{1-\mu} = 1$$

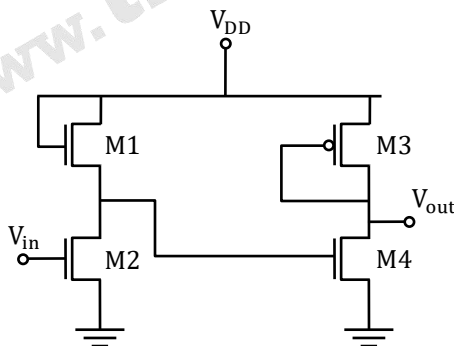
$$A = \mu - 1$$

31. A voltage amplifier is constructed using enhancement mode MOSFETs labeled M1, M2, M3 and M4 in the figure below. M1, M2 and M4 are n-channel MOSFETs and M3 is 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 trans conductance  $g_{mn}$  while the p-channel MOSFET has trans conductance  $g_{mp}$ . The expressions for the low frequency small signal voltage gain  $V_{out}/V_{in}$  is



- (A)  $-g_{mn}/g_{mp}$   
 (B)  $-g_{mn}(g_{mn} + g_{mp})^{-1}$   
 (C)  $+g_{mn}/g_{mp}$   
 (D)  $g_{mn}(g_{mn} + g_{mp})^{-1}$

[Ans. C]



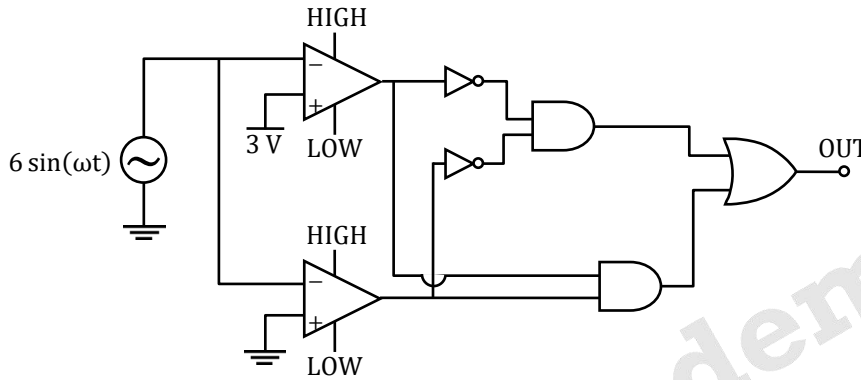
$$V_{01} = A_x V_{in} = -g_{mn} \times \frac{1}{g_{mn}} \times V_{in} = -V_{in}$$

$$V_0 = A_y V_{01} = -g_{mn} \times \frac{1}{g_{mp}} \times V_{01}$$

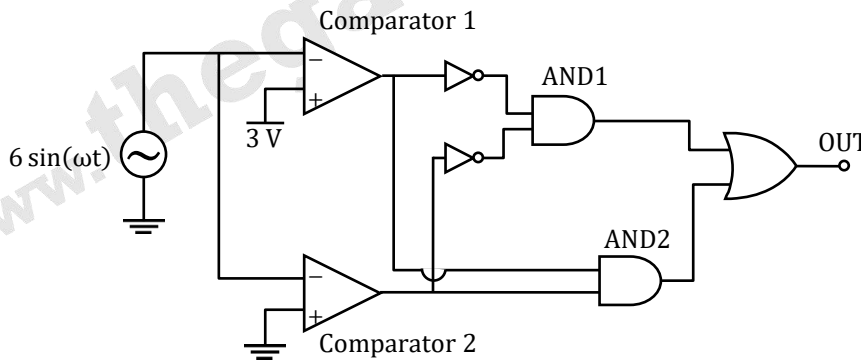
$$= -g_{mn} \times \frac{1}{g_{mp}} \times (-V_{in}) = + \frac{g_{mn}}{g_{mp}} \times V_{in}$$

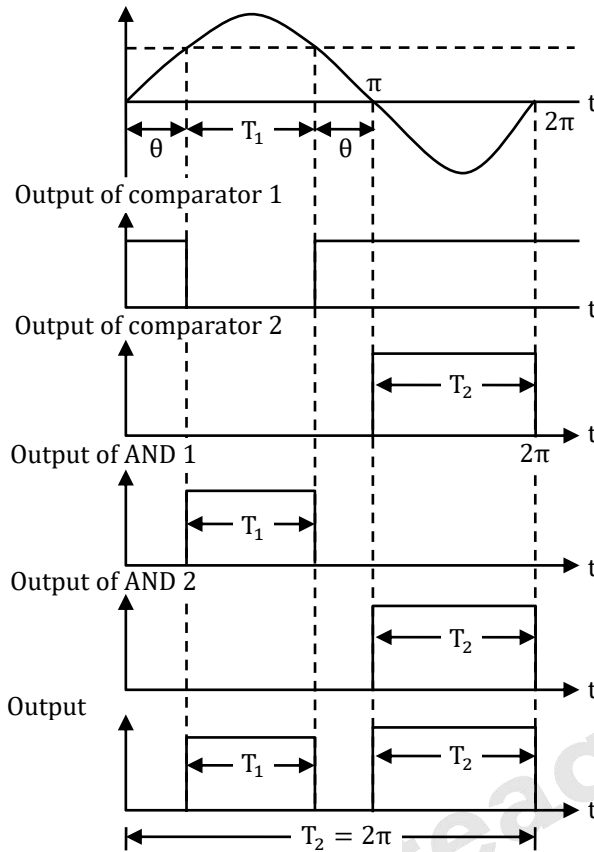
$$\frac{V_o}{V_{in}} = \frac{g_{mn}}{g_{mp}}$$

32. 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  
[Ans. D]





$$6 \sin \theta = 3$$

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

$$T_1 = \pi - 2\theta$$

$$= \pi - \frac{2\pi}{6} = \frac{2\pi}{3}$$

$$T_2 = \pi$$

$$\text{Fraction of time for which output is high} = \frac{T_1 + T_2}{T}$$

$$\frac{\frac{2\pi}{3} + \pi}{2\pi} = \frac{5}{6}$$

33. The output of 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 \_\_\_\_\_

[Ans. \*] Range 9 to 9

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



Apply Fourier transform

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

$$|Y(\omega)| = |X(\omega)| + \frac{1}{2}|X(\omega)|$$

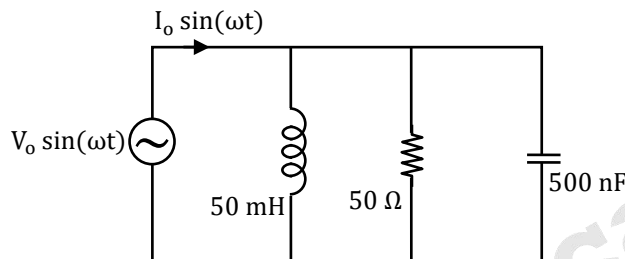
$$|Y(\omega)|^2 = |X(\omega)|^2 + \frac{1}{4}|X(\omega)|^2 + |X(\omega)|^2$$

Put  $\omega = 0$

$$|Y(0)|^2 = |X(0)|^2 + \frac{1}{4}|X(0)|^2 + |X(0)|^2$$

$$|Y(0)|^2 = 9$$

34. In the circuit shown below, the angular frequency  $\omega$  at which the current is in phase with the voltage is \_\_\_\_\_ rad/s.



[Ans. \*]Range 20,000 to 20,000

At resonance the source voltage and source current will be in phase.

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5 \times 10^{-6} - 3 \times 500 \times 10^{-9}}} \text{ rad/sec}$$

$$= \frac{1}{\sqrt{25 \times 10^{-10}}} = \frac{100 \times 10^3}{5} = 20 \text{ k}$$

$$\omega = 20000 \text{ rad/sec}$$

35. 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)  $x^4$

[Ans. B]

$$y = mx + c$$

$$y = \frac{dy}{dx}x + c \quad (\text{given that Y intercept is } -y)$$

$$y = \frac{dy}{dx}x - y$$



$$\begin{aligned} \partial y &= \frac{dy}{dx} x \\ \frac{dy}{\partial y} &= \frac{dx}{x} \\ \Rightarrow \frac{1}{2} \ln y &= \ln x + \ln C \\ \ln y^{\frac{1}{2}} &= \ln(xC) \\ y &= x^2 c^2 \\ \therefore y &\propto x^2 \end{aligned}$$

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

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

[Ans. C]

$$\text{OLTF} = \frac{3k}{s(s + P)}$$

Given root locus passes through the point  $-3 \pm j3\sqrt{3}$

$$\therefore \angle G(s)H(s)_{s=-3 \pm j3\sqrt{3}} = \pm 180^\circ$$

$$\therefore P = 6$$

37. 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)  $\begin{bmatrix} 50 \\ -35 \end{bmatrix}$

[Ans. D]

$$X(s) = \phi(s) \cdot x(0) + \phi \cdot B \cdot U(s)$$

$$\text{where, } \phi(s) = (sI - A)^{-1} \quad \text{Given } x(0) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\begin{aligned} \therefore X(s) &= \phi(s) \cdot b \cdot u(S) \\ &= \frac{1}{(S-1)(S+4)+6} \cdot \begin{bmatrix} 20(s+4)+20 \\ -60+10(s-1) \end{bmatrix} \end{aligned}$$

Steady-state value of X(t) for step input is

$$X(\infty) = \lim_{s \rightarrow 0} sX(s) = \begin{bmatrix} 50 \\ -35 \end{bmatrix}$$

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

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

[Ans. D]

Given that Laser emits rectangular pulse width of 1 nsec.

Repetition rate of 1 kHz.

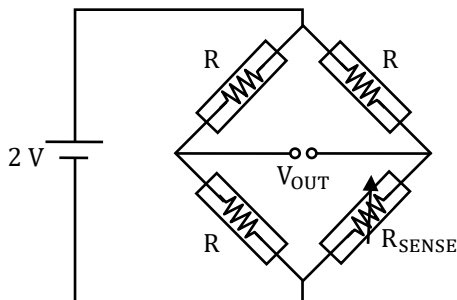
If the average output power is 1 mW.

Energy of each pulse is given by

$$E = \frac{P_{av}}{R_{rate}} = \frac{1 \times 10^{-3}}{1 \times 10^3} = 1 \times 10^{-6} \text{ Joules}$$

$$\begin{aligned} \text{Power of each pulse } P_{pulse} &= \frac{E}{\text{Duration of pulse}} \\ &= \frac{1 \times 10^{-6}}{1 \times 10^{-9}} = 1000 \end{aligned}$$

39. Four identical resistive strain gauges with gauge factor of 2.0 are used in 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 measured to be 1 mV, the magnitude of strain in units of microstrain is



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

**[Ans. D]**

The given resistance bridge is of Quarter bridge. So the output voltage of the bridge is

$$V_{OB} = \frac{V_s}{4} \times \frac{\Delta R}{R_0} \dots (1)$$

In strain gauge,  $G_f = \frac{\left(\frac{\Delta R}{R_0}\right)}{\epsilon} \dots (2)$

Where,  $V_s$  = Supply voltage  $\Delta R$  = change in resistance,

$R_0$  = Initial resistance of the gauge

and  $\epsilon$  = strain,

From eq. (1) and (2),

$$V_{OB} = \frac{V_s}{4} \times G_f \times \epsilon$$

$$1 \times 10^{-3} = \frac{2}{4} \times 2 \times \epsilon$$

$$\epsilon = 1 \times 10^{-3} \text{ units} = 1000 \text{ micro strain}$$

40. A complex function  $f(z) = u(x, y) + i v(x, y)$  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)  $f(z) = x^2 + y^2$

**[Ans. C]**

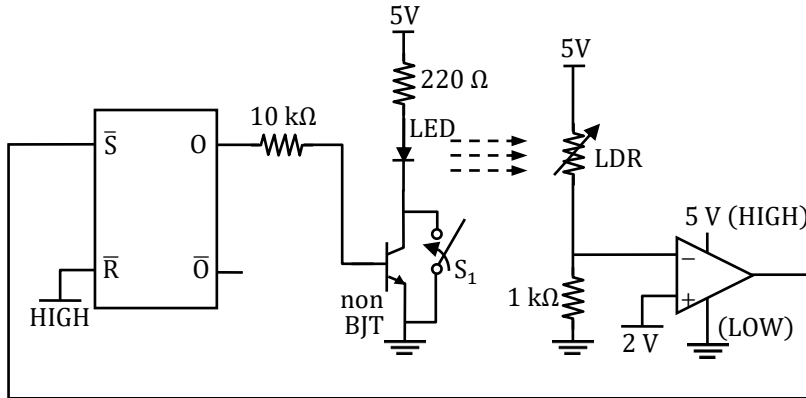
$$f(z) = u + iv$$

$$f^*(z) = u - iv$$

Both are analytic when  $f(z)$  is constant

41. In the circuit below, the light dependent resistor (LDR) receives light from the LED. The LDR has resistances of  $5 \text{ k}\Omega$  and  $500 \Omega$  under dark and illuminated conditions, respectively. The LED is OFF at time  $t < 0$ . At time  $t = 0$ , the switch  $S_1$  is closed for 1 ms 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

[Ans. A]

When switch  $S_1$  is closed, a conducting path will be formed from  $V_{cc}$  to ground irrespective of the operating condition of the BJT. So, LED turns ON.

In this situation, LDR will have a resistance of  $500 \Omega$ . Voltage at the inverting terminal of the op-amp is,

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

$$V^+ = 2V$$

$$V^- > V^+$$

$$\Rightarrow V_{out} = 0V \text{ (logic - LOW)}$$

So,  $\bar{S}$  will be at logic - LOW at  $\bar{R}$  will be at logic -HIGH. It pulses Q to logic-HIGH, which causes to flow some current into the base terminal of the BJT.

When switch  $S_1$  is opened after 1 ms:

Now, let us assume that LED is in OFF state. To check the validity of this assumption, we have to check whether current is flowing into the base terminal of the BJT.

When LED is in OFF state, LDR will have a resistance of  $5 k\Omega$ .

$$V^- = \frac{1}{1 + 5} \times 5V = 0.83V$$

$$V^+ = 2V$$

$$V^- < V^+$$

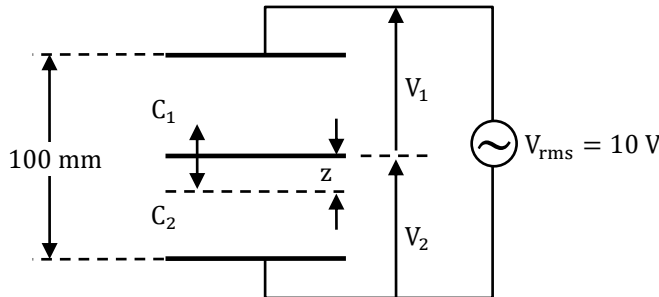
$$\Rightarrow V_{out} = 5V \text{ (logic - High)}$$

So,  $\bar{S}$  will be at logic - HIGH at  $\bar{R}$  will be at logic -HIGH. It pulses Q to be in previous state (i.e., logic-HIGH). This makes the transistor to be in ON state and in turn LED will be in ON state.

So, our assumption is wrong, i.e., the LED will not be in OFF state after  $S_1$  is opened.

Hence, LED will be in ON state both during the switch  $S_1$  is closed and after it is opened.

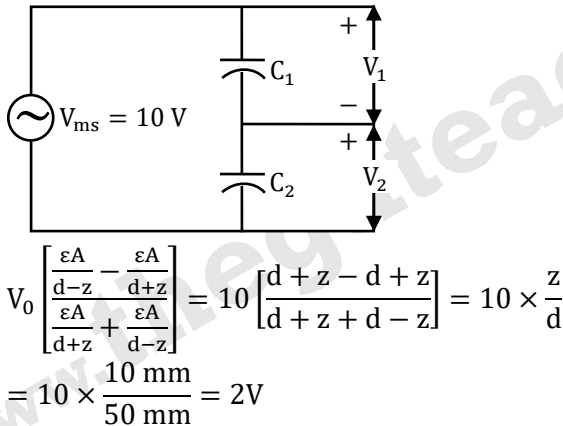
42. A differential capacitive sensor with a distance between the extreme plates 100 mm is shown in figure below. The difference voltage  $\Delta V = V_1 - V_2$ , where  $V_1$  and  $V_2$  are the rms values, for a downward displacement of 10 mm of the intermediate plate from the central position, in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



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

[Ans. D]

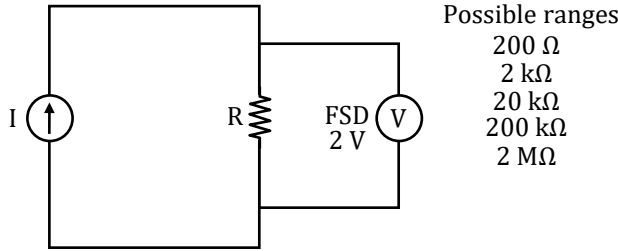
The given figure in the question can be redrawn as



43. A resistance-meter has five measurement range-settings between 200  $\Omega$  and 2 M $\Omega$  in multiples of 10. The meter measures resistance of a device by measuring a full-range voltage of 2 V across the device by passing an appropriate constant current for each range-setting. If a device having a resistance value in the range 8 k $\Omega$  to 12 k $\Omega$  and a maximum power rating of 100  $\mu$ W is to be measured safely with this meter, the choice for range-setting on the meter for best resolution in measurement, in k $\Omega$  is

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

[Ans. C]



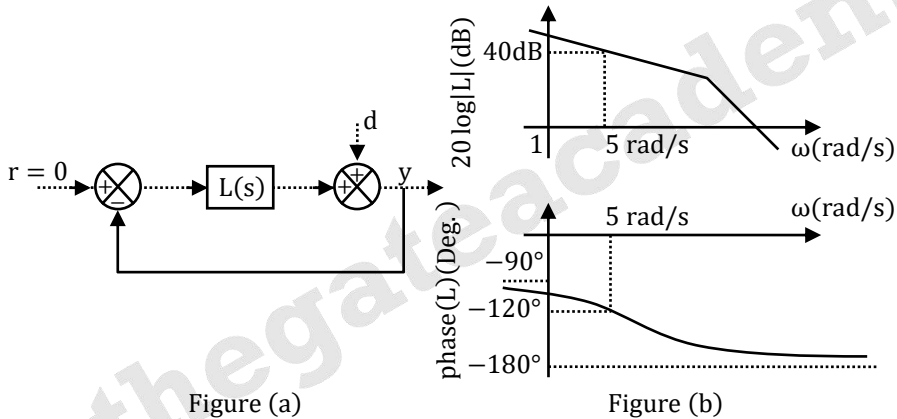
Resistance to be measured  $\Rightarrow 8 \text{ k}\Omega$  to  $12 \text{ k}\Omega$

So, minimum range should be  $20 \text{ k}\Omega$ .

With  $20 \text{ k}\Omega$  range:

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

44. 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



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

[Ans. A]

$$\frac{Y(s)}{D(s)} = \frac{1}{1 + L(s)}$$

$$\left| \frac{Y(j\omega)}{D(j\omega)} \right|_{\omega=5} = \frac{1}{\sqrt{1 + (100)^2}} \approx \frac{1}{100}$$

$$\therefore \text{Steady-state amplitude of output} = 0.1 \times \frac{1}{100} = 1.00 \times 10^{-3}$$





45. A piezoelectric transducer with sensitivity of 30 mV/kPa is intended to be used in the range of 0 kPa to 100 kPa. The readout circuit has a peak noise amplitude of 0.3 mV 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

**[Ans. B]**

Given that,

Piezoelectric transducer sensitivity is 30 mV/kPa

Input measurement range is 0 kPa to 100 kPa.

The readout has peak noise amplitude of 0.3 mV.

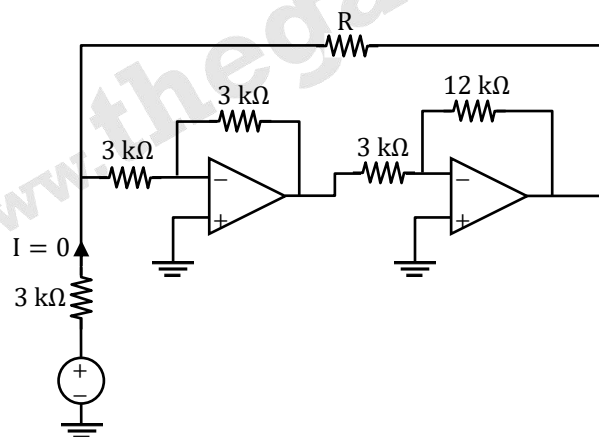
According to the information given in the question, to produce the non-zero output piezoelectric transducer should produce output voltage more than peak noise amplitude of readout.

So, output voltage of piezo-electric transducer,  $V_0 > 0.3 \text{ mV}$

As the sensitivity of transducer is 30 mV/1 kPa, To produce minimum 0.3 mV, the input pressure should be minimum of 10 Pa.

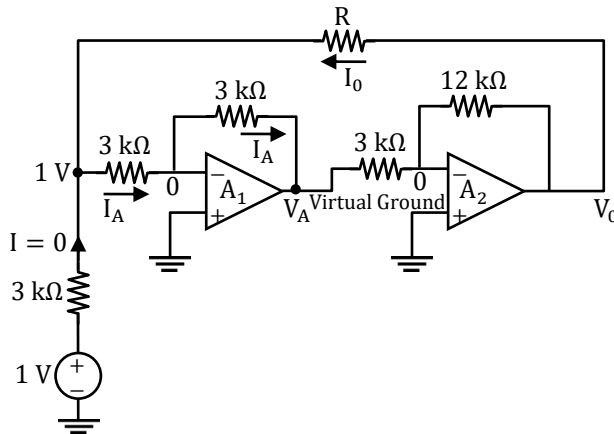
So, the required input pressure should be at least of 10 Pa.

46. In the circuit shown below, all OPAMPS are ideal. The current  $I = 0 \text{ A}$  when resistance  $R = \underline{\hspace{2cm}}$  k $\Omega$



**[Ans. \*]Range 9 to 9**





Opamp  $A_1$

KCL at  $V^-$

$$\frac{1V - 0}{3k} = \frac{0 - V_A}{3k}$$

$$V_A = -1V$$

Opamp  $A_2$

KCL at  $V^-$

$$\frac{V_A - 0}{3k} = \frac{0 - V_0}{12k}$$

$$\frac{1}{3k} = \frac{V_0}{12k}$$

KCL at 1V

$$I_0 + I = I_A$$

$$I_0 = I_A = \frac{1V - 0}{3k} = \frac{1}{3} \text{ mA}$$

$$R = \frac{V_0 - 1V}{I_0} = \frac{4V - 1V}{\frac{1}{3} \text{ mA}} = \frac{3}{\frac{1}{3}} = 9 \text{ k}\Omega$$

$$R = 9 \text{ k}\Omega$$

47. The frequency response of a digital filter  $H(\omega)$  has the following characteristics  
 passband:  $0.95 \leq |H(\omega)| \leq 1.05$  for  $0 \leq \omega < 0.3\pi$  and  
 Stopband:  $0 \leq |H(\omega)| \leq 0.005$  for  $0.4\pi \leq \omega \leq \pi$   
 Where  $\omega$  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

[Ans. \*]Range 8.0 to 8.0

$$\omega_p = 0.3 \pi$$

$$\omega_s = 0.5 \pi$$

$$F_p = 1.2 \text{ kHz}$$

Since,  $\omega_p = \frac{2\pi F_p}{F_r}$

So, sampling frequency,

$$F_r = \frac{2\pi F_p}{\omega_p}$$

$$= \frac{2\pi \times 1.2 \text{ kHz}}{0.3\pi} = 8 \text{ kHz}$$

48. A discrete-time signal  $x[n] = e^{j(\frac{5\pi}{2})n} + e^{j(\frac{\pi}{4})n}$  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 \_\_\_\_\_.

[Ans. \*] Range 6 to 6

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

$$\omega_1 = \frac{5\pi}{3}$$

$$\omega_2 = \frac{\pi}{4}$$

$$\text{GCD}(\omega_1, \omega_2) \quad \omega_0 = \frac{\pi}{12}$$

$$x_d(n) = x(4n)$$

Apply time scaling so,

$$\omega_d = 4\omega_0 = \frac{4\pi}{12} = \frac{\pi}{3}$$

$$\frac{\omega_d}{2\pi} = \frac{m}{n}$$

$$\Rightarrow \frac{\frac{\pi}{3}}{2\pi} = \frac{m}{n}$$

$$N = 6$$

49.  $X = X_1 X_0$  and  $Y = Y_1 Y_0$  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)  $X_1 Y_1 + X_0 Y_0$

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

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

(D)  $X_1 Y_1 + X_0 \bar{Y}_0 Y_1 + X_0 \bar{Y}_0 X_1$

[Ans. B]

Given  $X = X_1 X_0$

and  $Y = Y_1 Y_0$

If  $X > Y$

Then,  $S = 1$

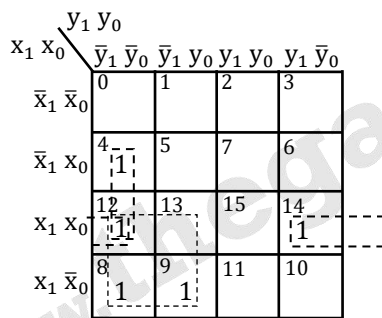
The truth table for  $S$  can be drawn as follows,

	x		y		s
	x <sub>1</sub>	x <sub>0</sub>	y <sub>1</sub>	y <sub>0</sub>	
0	0	0	0	0	0
1	0	0	0	1	0
2	0	0	1	0	0
3	0	0	1	1	0
4	0	1	0	0	1
5	0	1	0	1	0
6	0	1	1	0	0
7	0	1	1	1	0
8	1	0	0	0	1
9	1	0	0	1	1
10	1	0	1	0	0
11	1	0	1	1	0
12	1	1	0	0	1
13	1	1	0	1	1
14	1	1	1	0	1
15	1	1	1	1	0

The Boolean function S can be represented in the sum of min terms form as

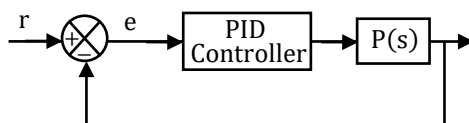
$$S(X_1, X_0, Y_1, Y_0) = \Sigma(4, 8, 9, 12, 13, 14)$$

The above function can be simplified asking k-Map as follows:



$$S = X_1 \bar{Y}_1 + X_0 \bar{Y}_1 \bar{Y}_0 + X_1 X_0 \bar{Y}_0$$

50. 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)  $\infty$

[Ans. B]

$$\frac{E(s)}{R(s)} = \frac{1}{1 + [(PID)(P)]}$$

$$= \frac{1}{s^2}$$

$$= \frac{1}{3[s^2 + k_p s + k_i + k_D s^2]}$$

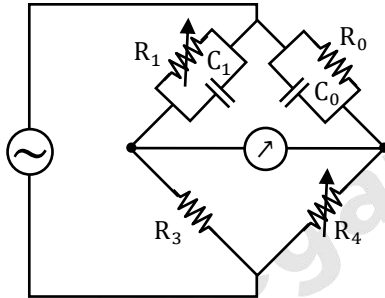
∴ Steady-state value of E is

$$E(\infty) = \lim_{s \rightarrow 0} sE(s)$$

$$\lim_{s \rightarrow 0} s \cdot \frac{s^2}{3[s^2 + k_p s + k_i + k_D s^2]} \times \frac{2}{s^3}$$

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

51. The parallel resistance-capacitance bridge shown below has a standard capacitance value of  $C_1 = 0.1 \mu\text{F}$  and a resistance value of  $R_3 = 10 \text{ k}\Omega$ . The bridge is balanced at a supply frequency of 100 Hz for  $R_1 = 375 \text{ k}\Omega$ ,  $R_3 = 10 \text{ k}\Omega$  and  $R_4 = 14.7 \text{ k}\Omega$ . The value of the dissipation factor  $D = 1/(\omega R_p C_p)$  of the parallel combination of  $C_p$  and  $R_p$  is \_\_\_\_\_ (Answer should be round off to THREE decimal places)



[Ans. \*] Range 0.035 to 0.045

$$Z_1 = \frac{R_1}{1 + j\omega C_1 R_1}$$

$$Z_2 = \frac{R_p}{1 + j\omega C_p R_p}$$

$$Z_3 = R_3$$

$$Z_4 = R_4$$

At balance condition,

$$Z_1 Z_4 = Z_2 Z_3$$

$$\frac{R_1 R_4}{1 + j\omega C_1 R_1} = \frac{R_p R_3}{1 + j\omega C_p R_p}$$

$$R_1 R_4 + j\omega C_p R_p R_1 R_4 = R_p R_3 + j\omega C_1 R_1 R_p R_3$$

Separately the real and imaging components

$$R_1 R_4 = R_p R_3 \text{ or } R_p = \frac{R_1 R_4}{R_3}$$

$$C_p R_4 = C_1 R_3$$



$$D = \frac{1}{\omega C_P R_P} = \frac{1}{\omega} \times \frac{R_4}{C_1 R_3} \times \frac{R_3}{R_1 R_4} = \frac{1}{\omega C_1 R_1}$$

$$C_1 = 0.1 \times 10^{-6} \text{ F}; R_1 = 375 \times 10^3 \Omega$$

$$\omega = 2 \times \pi \times 100 = 628.318$$

$$D = \frac{1}{628.318 \times 0.1 \times 10^{-6} \times 375 \times 10^3} = 0.0424$$

52. 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 \_\_\_\_\_ (Answer should be rounded off to two decimal places)

**[Ans. \*]Range 0.46 to 0.48**

The solution can be split into two portions

$$y(t) = y_s(t) + y_n(t)$$

Where,  $y_s(t)$  = steady response,  $y_n(t)$  = normal response

∴ To calculate the steady-state response, we will assume initial input to be zero.

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

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

$$(s + 3)Y(s) = X(s)$$

$$sY(s) + 3Y(s) = X(s)$$

Now, given input is a step response

$$\therefore sY(s) + 3Y(s) = \frac{1}{s}$$

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

$$Y(s) = \frac{A}{s} + \frac{B}{s + 3} = \frac{\sqrt{3}}{s} + \frac{-\frac{1}{3}}{s + 3}$$

Applying, inverse Laplace transform, we get

$$y_s(t) = \frac{1}{3}u(t) - \frac{1}{3}e^{-3t}u(t)$$

Now, to calculate the natural response, we assume that the input  $x(t) = 0$

$$sy(s) - y(0) + 3y(s) = 0$$

$$(s + 3)Y(s) = y(0)$$

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

Given  $y(0) = 3$

$$\therefore Y(s) = \frac{3}{s + 3}$$

Taking the inverse Laplace transform, we get

$$y_n(t) = 3e^{-3t}u(t)$$



$$\begin{aligned} \therefore \text{Total response, } y(t) &= y_s(t) + y_n(t) \\ \therefore y(t) &= 3e^{-3t}u(t) + \frac{1}{3}u(t) - \frac{1}{3}e^{-3t}u(t) \\ \therefore y(t) &= 0.4659 \end{aligned}$$

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

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

[Ans. A]

$$\text{Intensity of light at photo detector} = \left( \frac{\text{Power}}{4\pi d^2} \right) \text{W/m}^2$$

$$\text{Where } d \text{ is distance in meters} = \frac{100}{4\pi(1)^2} = \frac{100}{4\pi} \text{W/m}^2$$

Power received by photodetector = Intensity of light  $\times$  Active area of photo detector

$$= \frac{100}{4\pi} \times \pi \times (0.01)^2 = \frac{1}{400} \text{W}$$

$$\text{Responsibility} = \frac{\text{Output current}}{\text{Power}}$$

Output current = Responsibility  $\times$  Power

$$= \frac{1}{400} \times 0.4 = \frac{1}{1000} \text{A} = 1 \text{ mA}$$

54. A signal  $x(t)$  has a bandwidth  $2B$  about a carrier frequency of  $f_c = 2$  GHz as shown in figure (a) below. In order to demodulate this signal, it is first mixed (multiplied) with a local oscillator of frequency  $f_{LO} = 1.5$  GHz, and then passed through an ideal low-pass filter (LPF) with a cut-off frequency of 2.8 GHz. The output of the LPF is sent to a digitizer ADC with a sampling  $x(t)$  can be reconstructed from its samples according to the Nyquist sampling theorem is \_\_\_ MHz.



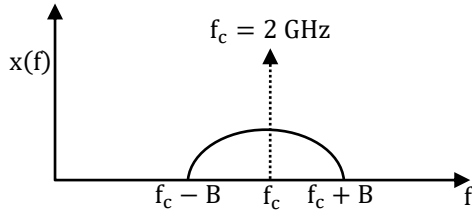


Figure (a)

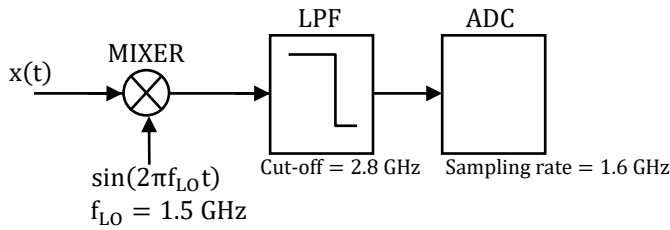
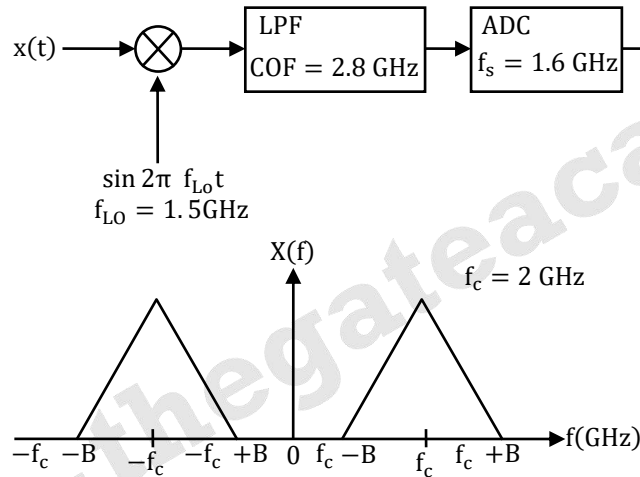
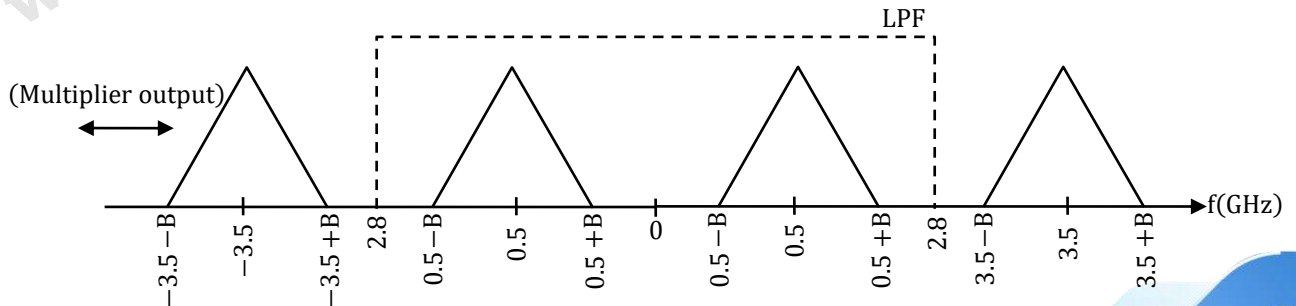


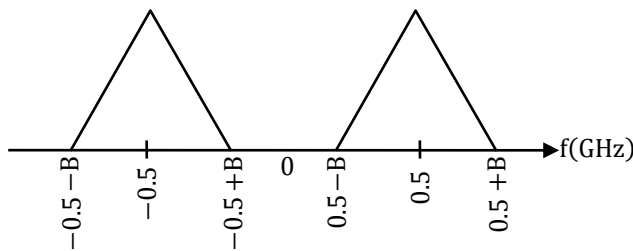
Figure (b)

[Ans. \*]Range 300 to 300



By multiplying with sinusoidal signal,  
 $X(f)$  shifted to right by  $f_{L0}$  and left by  $f_{L0}$





$$\text{Nyquist rate} = 2 \times f_{\text{max}}$$

$$= 2[0.5 + B] = 1 + 2B$$

Given sampling rate,  $f_s = 16 \text{ GHz}$

To recover original signal,  $f_s \geq \text{Nyquist rate}$

$$1.6 \text{ GHz} \geq 1 \text{ GHz} + 2B$$

$$2B \leq 0.6 \text{ GHz}$$

$$B = 0.3 \text{ GHz}$$

$$B_{\text{max}} = 0.3 \text{ GHz}$$

$$= 300 \text{ MHz}$$

55. 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

[Ans. \*] Range 37 to 39

$$G(s) = \frac{9e^{-0.1s}}{s}$$

$$\text{PM} = 180^\circ + \left[ -90^\circ - 0.1\omega \times \frac{180^\circ}{\pi} \right]_{\omega=\omega_{gc}}$$

$$\omega_{gc} = 9 \frac{r}{s}$$

$$\therefore \text{Phase margin} = 38.43^\circ$$



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