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GATE 2022

INSTRUMENTATION ENGINEERING

Exam held on 06/02/2022

Questions & Solutions

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SECTION - A GENERAL APTITUDE

Q.1 Inhaling the smoke from a burning ________ could ________ you quickly.

(a) tire / tier
(b) tire / tyre
(c) tyre / tire
(d) tyre / tier

Ans. (c)

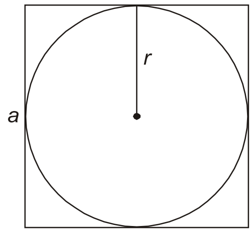
End of Solution

Q.2 A sphere of radius r cm is packed in a box of cubical shape.

What should be the minimum volume (in cm^3) of the box that can enclose the sphere?

(a) $\frac{r^3}{8}$
(b) r^3
(c) $2r^3$
(d) $8r^3$

Ans. (d)



$$\text{Diameter of sphere} = \text{Side of cube}$$
$$a = 2r$$
$$\text{Volume of cube} = (2r)^3$$
$$= 8r^3$$

End of Solution

Q.3 Pipes P and Q can fill a storage tank in full with water in 10 and 6 minutes, respectively. Pipe R draws the water out from the storage tank at a rate of 34 litres per minute. P, Q and R operate at a constant rate.
If it takes one hour to completely empty a full storage tank with all the pipes operating simultaneously, what is the capacity of the storage tank (in litres)?

(a) 26.8
(b) 60.0
(c) 120.0
(d) 127.5

Ans. (c)
Let the capacity of storage tank is x liters. Amount of water drawn only by pipe R is in one minute.

$$\frac{x}{60} + \left(\frac{x}{6} + \frac{x}{10}\right) = \frac{17x}{60}$$

Total time taken R to draw a storage tank

$$= \frac{x}{\frac{17x}{60}} = \frac{60}{17}\text{min}$$

$$\text{Capacity of tank} = \frac{60}{17} \times 34 = 120 \text{ liters}$$

End of Solution

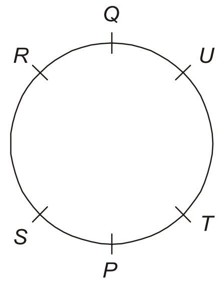
Q.4 Six persons P, Q, R, S, T and U are sitting around a circular table facing the center not necessarily in the same order. Consider the following statements:

- P sits next to S and T.
- Q sits diametrically opposite to P.
- The shortest distance between S and R is equal to the shortest distance between T and U.

Based on the above statements, Q is a neighbor of

(a) U and S
(b) R and T
(c) R and U
(d) P and S

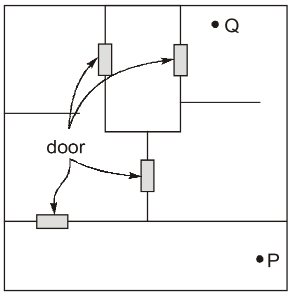
Ans. (c)



End of Solution

Q.5 A building has several rooms and doors as shown in the top view of the building given below. The doors are closed initially.

What is the minimum number of doors that need to be opened in order to go from the point P to the point Q?



(a) 4
(b) 3
(c) 2
(d) 1

Ans. (c)

End of Solution

Q.6 Rice, a versatile and inexpensive source of carbohydrate, is a critical component of diet worldwide. Climate change, causing extreme weather, poses a threat to sustained availability of rice. Scientists are working on developing Green Super Rice (GSR), which is resilient under extreme weather conditions yet gives higher yields sustainably.

Which one of the following is the CORRECT logical inference based on the information given in the above passage?

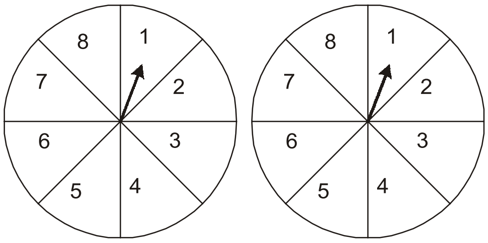
(a) GSR is an alternative to regular rice, but it grows only in an extreme weather.
(b) GSR may be used in future in response to adverse effects of climate change.
(c) GSR grows in an extreme weather, but the quantity of produce is lesser than regular rice.
(d) Regular rice will continue to provide good yields even in extreme weather.

Ans. (b)

End of Solution

Q.7 A game consists of spinning an arrow around a stationary disk as shown below. When the arrow comes to rest, there are eight equally likely outcomes. It could come to rest in any one of the sectors numbered 1, 2, 3, 4, 5, 6, 7 or 8 as shown. Two such disks are used in a game where their arrows are independently spun.

What is the probability that the sum of the numbers on the resulting sectors upon spinning the two disks is equal to 8 after the arrows come to rest?



(a) $\frac{1}{16}$
(b) $\frac{5}{64}$
(c) $\frac{3}{32}$
(d) $\frac{7}{64}$

Ans. (d)

Probability of getting only one number $= \frac{1}{8}$

As they are independent spins probability of getting one number for each disc is

$$P = \frac{1}{8} \times \frac{1}{8}$$

Possible outcomes to the sum of 8

$$= (1, 7), (2, 6), (3, 5), (4, 4), (5, 3), (6, 2), (7, 1)$$

$$\text{Required probability} = \frac{7}{64}$$

End of Solution

Q.8 Consider the following inequalities.

(i) $3p - q < 4$

(ii) $3q - p < 12$

Which one of the following expressions below satisfies the above two inequalities?

(a) $p + q < 8$ (b) $p + q = 8$

(c) $8 \le p + q < 16$ (d) $p + q \ge 16$

Ans. (a)

Adding both equation

$$2p + 2q < 16$$

$$p + q < 8$$

End of Solution

Q.9 Given below are three statements and four conclusions drawn based on the statements.

Statement 1: Some engineers are writers.

Statement 2: No writer is an actor.

Statement 3: All actors are engineers.

Conclusion I: Some writers are engineers.

Conclusion II: All engineers are actors.

Conclusion III: No actor is a writer.

Conclusion IV: Some actors are writers.

Which one of the following options can be logically inferred?

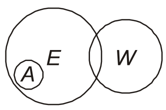
(a) Only conclusion I is correct

(b) Only conclusion II and conclusion III are correct

(c) Only conclusion I and conclusion III are correct

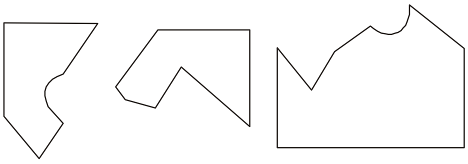
(d) Either conclusion III or conclusion IV is correct

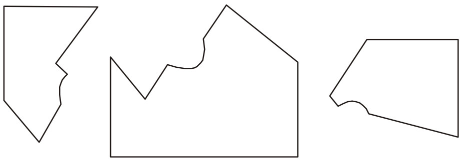
Ans. (c)

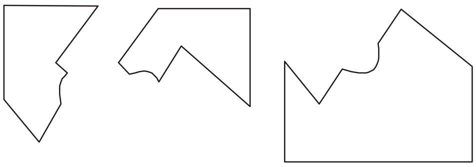


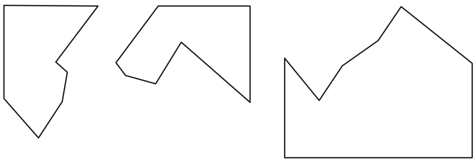
End of Solution

Q.10 Which one of the following sets of pieces can be assembled to form a square with a single round hole near the center? Pieces cannot overlap.

(a)


(b)


(c)


(d)


Ans. (c)

End of Solution

■■■■

SECTION - B TECHNICAL

Q.11 The input $x(t)$ to a system is related to its output $y(t)$ as

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

Here $u(t)$ represents a unit-step function.
The transfer function of this system is ________.

(a) $\dfrac{e^{-3s}}{s+3}$

(b) $\dfrac{3e^{-3s}}{s+1}$

(c) $\dfrac{3e^{-(s/3)}}{s+1}$

(d) $\dfrac{e^{-(s/3)}}{s+3}$

Ans. (b)

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

Taking laplace both sides,

$$sY(s) + Y(s) = 3X(s)e^{-3s}$$

$$H(s) = \frac{Y(s)}{X(s)} = \frac{3e^{-3s}}{(s+1)}$$

End of Solution

Q.12 A pneumatic nozzle-flapper system is conventionally used to convert ________

(a) Small changes in flapper's velocity to large changes in output temperature.
(b) Small changes in flapper's displacement to large changes in output temperature.
(c) Small changes in flapper's velocity to large changes in output pressure.
(d) Small changes in flapper's displacement to large changes in output pressure.

Ans. (d)

The nozzle and flapper mechanism is a displacement type detector which converts mechanical movement into pressure signal.

End of Solution

Q.13 A periodic function $f(x)$, with period 2, is defined as

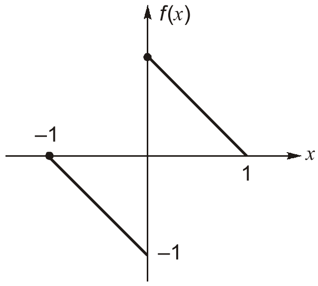
$$f(x) = \begin{cases} -1-x & -1 \le x < 0 \\ 1-x & 0 < x \le 1 \end{cases}$$

The Fourier series of this function contains ________.

(a) Both cos $(n\pi x)$ and sin $(n\pi x)$ where n = 1, 2, 3, ...
(b) Only sin $(n\pi x)$ where n = 1, 2, 3, ...
(c) Only cos $(n\pi x)$ where n = 1, 2, 3, ...
(d) Only cos $(2n\pi x)$ where n = 1, 2, 3, ...

Ans. (b)

$$f(x) = \begin{cases} -1-x\,; & -1 \le x < 0 \\ +1-x\,; & 0 < x \le 1 \end{cases}$$



This function is odd function and $f(x)$ don't have halfwave symmetry.
So only sine terms will be present in expansion $f(x)$

$$f(x) = \sin(n\pi x)\,; \qquad n = 1, 2, 3, \ldots\infty$$

End of Solution

Q.14 The output of a system $y(t)$ is related to its input $x(t)$ according to the relation $y(t) = x(t)\sin(2\pi t)$. This system is ________

(a) Linear and time-variant
(b) Non-linear and time-invariant
(c) Linear and time-invariant
(d) Non-linear and time-variant

Ans. (a)

$$y(t) = x(t)\sin(2\pi t)$$

for $x(t) = x_1(t)$,

$$y_1(t) = x_1(t)\sin(2\pi t)$$

for $x(t) = x_2(t)$,

$$y_2(t) = x_2(t)\sin(2\pi t)$$

for input $x(t) = x_1(t) + x_2(t)$

$$y_3(t) = [x_1(t) + x_2(t)]\sin(2xt)$$

$$y_3(t) = y_1(t) + y_2(t)$$

So, it is a linear system.
$\sin(2\pi t)$ has time varying. So, $y(t)$ is time variant. So, system is linear and time variant.

End of Solution

Q.15 A unity-gain negative-feedback control system has a loop-gain $L(s)$ given by

$$L(s) = \frac{6}{s(s-5)}$$

The closed-loop system is ________.

(a) Causal and stable
(b) Causal and unstable
(c) Non-causal and stable
(d) Non-causal and unstable

Ans. (b)

$$G(s) = \frac{6}{s(s-5)}$$

The characteristic equation

$$s^2 - 5s + 6 = 0$$

Poles lies in right side of s-plane. So, it is unstable system and system is causal. So, causal and unstable.

End of Solution

Q.16 A sinusoidal carrier wave with amplitude A_c and frequency f_c is amplitude modulated with a message signal $m(t)$ having frequency $0 < f_m << f_c$ to generate the modulated wave $s(t)$ given by

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

The message signal that can be retrieved completely using envelope detection is ________.

(a) $m(t) = 0.5\cos(2\pi f_m t)$

(b) $m(t) = 1.5\sin(2\pi f_m t)$

(c) $m(t) = 2\sin(4\pi f_m t)$

(d) $m(t) = 2\cos(4\pi f_m t)$

Ans. (a)

For envelope detection modulation index must be less than 1.

End of Solution

Q.17 A Hall sensor is based on the principle of ________.

(a) Photoelectric effect

(b) Seebeck effect

(c) Piezoelectric effect

(d) Lorentz force

Ans. (d)

Hall effect works on the principle of Lorentz force.

End of Solution

Q.18 A signal $x(t)$ is band-limited between 100 Hz and 200 Hz. A signal $y(t)$ is related to $x(t)$ as follows:

$$y(t) = x(2t - 5)$$

The statement that is always true is ________.

(a) $y(t)$ is band-limited between 50 Hz and 100 Hz

(b) $y(t)$ is band-limited between 100 Hz and 200 Hz

(c) $y(t)$ is band-limited between 200 Hz and 400 Hz

(d) $y(t)$ is not band-limited

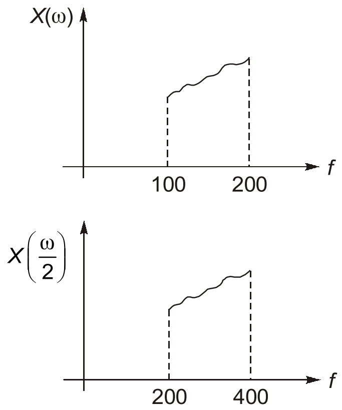
Ans. (c)

$x(t)$ is band limited to 100 Hz to 200 Hz

$$y(t) = x(2t - 5)$$

$$x(t) \rightleftharpoons X(\omega)$$

$$x(2t) \rightleftharpoons \frac{1}{2} \cdot X\left(\frac{\omega}{2}\right)$$

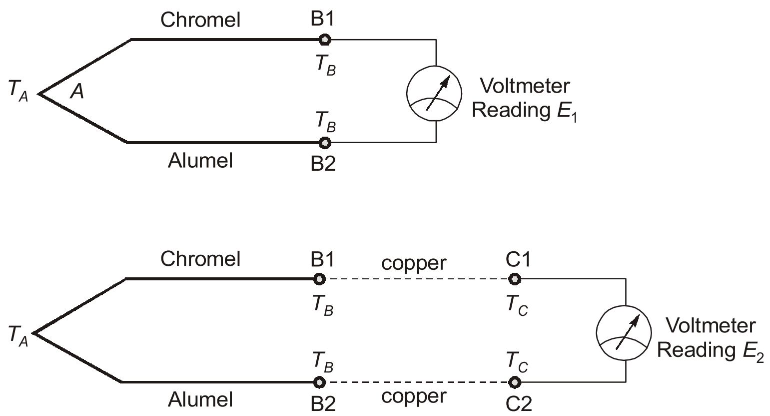


Time shifting will not change bandwidth,

So $x(2t - 5)$ will be band limited to 200 to 400.

End of Solution

Q.19 The figure shows a Chromel-Alumel thermocouple, where the junction A is held at temperature T_A, and a thermal emf E_1 is measured using an ideal voltmeter between the open ends B1 and B2, both held at temperature T_B. Two identical copper wires are introduced between B1-C1 and B2-C2 as shown in the figure. When C1 and C2 are held at temperature T_C, the voltmeter reads a thermal emf E_2. Then, ________



(a) $E_1 < E_2$ (b) $E_1 > E_2$

(c) $E_1 = 2E_2$ (d) $E_1 = E_2$

Ans. (d)

End of Solution

Q.20 The resistance of a pure copper wire of length 10 cm and diameter 1 mm is to be measured. The most suitable method from amongst the choices given below is ________

(a) Two wire method
(b) Three wire method
(c) Four wire method
(d) Ellipsometry

Ans. **(c)**

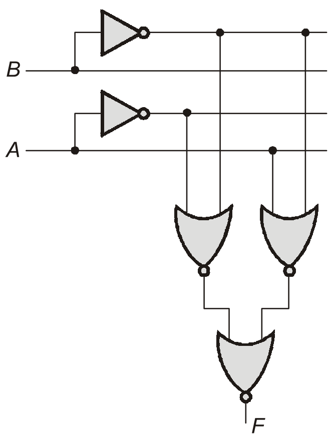
For very low (in mΩ) resistance 4-wire method is used.

In this case, $R = \frac{PL}{A} = \frac{1.6\times10^{-8}\times10\times10^{-2}\times4}{3.14\times(1\times10^{-3})^2}$

$= 8.03 \text{ m}\Omega$

End of Solution

Q.21 The logic block shown has an output F given by ________



(a) $A + B$
(b) $A\cdot\bar{B}$
(c) $A+\bar{B}$
(d) $\bar{B}$

Ans. **(d)**

$$F = \left(\overline{\overline{A+\bar{B}}+\overline{\bar{A}+\bar{B}}}\right)$$

$$F = \left(\overline{\overline{A+\bar{B}}}\right)\cdot\left(\overline{\overline{\bar{A}+\bar{B}}}\right)$$

$$F = (A+\bar{B})\cdot(\bar{A}+\bar{B})$$

$$F = A\bar{A}+A\bar{B}+\bar{B}\bar{A}+\bar{B}\bar{B}$$

$$F = \bar{B}(A+\bar{A})+\bar{B}$$

$$F = \bar{B}+\bar{B}=\bar{B}$$

End of Solution

Q.22 In which of the following bridge(s) is the balancing condition frequency-independent?

(a) Maxwell bridge (b) Wien bridge
(c) Schering bridge (d) Wheatstone bridge

Ans. (a,c,d)

Bridge in balanced conditions :

- Maxwell bridge at balance :

$$R_1 = \frac{R_2 R_3}{R_4}$$

$$L_1 = R_2 R_3 C_4$$

- Schering bridge at balance :

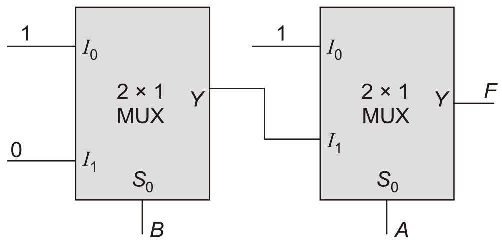
$$r_1 = \frac{R_3 C_4}{C_2}$$

$$C_1 = C_2\left(\frac{R_4}{R_3}\right)$$

- Wheat stone bridge is DC bridge used for measurement of resistance.
- Wein bridge at balance, for a given frequency has fixed values of circuit parameters which vary with change in frequency (dependent on frequency).

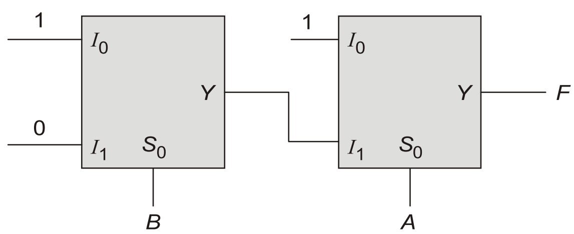
End of Solution

Q.23 The output F of the digital circuit shown can be written in the form(s) ________



(a) $\overline{A \cdot B}$ (b) $\bar{A} + \bar{B}$
(c) $\overline{A + B}$ (d) $\bar{A} \cdot \bar{B}$

Ans. (a, b)



$$F_1 = I_0\bar{B} + I_1 B$$

$$F_1 = (1)\bar{B} + (0)B = \bar{B}$$

So, $F = I_0\bar{A} + I_1A$

Here, $I_0 = 1,\ I_1 = \bar{B}$

So, $F = (1)\bar{A} + \bar{B}A$

$F = \bar{A} + A\bar{B} = \bar{A} + \bar{B}$

$F = \overline{A \cdot B}$

End of Solution

Q.24 Given $M = \begin{bmatrix} 2 & 3 & 7 \\ 6 & 4 & 7 \\ 4 & 6 & 14 \end{bmatrix}$, which of the following statement(s) is/are correct?

(a) The rank of M is 2
(b) The rank of M is 3
(c) The rows of M are linearly independent
(d) The determinant of M is 0

Ans. (a, d)

Given matrix, $M = \begin{bmatrix} 2 & 3 & 7 \\ 6 & 4 & 7 \\ 4 & 6 & 14 \end{bmatrix}$

Applying $R_3 \to R_3 - 2R_1$

$M = \begin{bmatrix} 2 & 3 & 7 \\ 6 & 4 & 7 \\ 0 & 0 & 0 \end{bmatrix}$

Rank of matrix is 2.
Rank of matrix is less than 3.
Hence, determinant is zero.

End of Solution

Q.25 An analog-to-digital converter with resolution 0.01 V converts analog signals between 0 V to +10 V to an unsigned binary output. The minimum number of bits (in integer) in the output is ________

Ans. (10)
Given resolution, $R = 0.01$ V

$$\text{Resolution} = \frac{V_{in}}{2^n - 1} = 0.01$$

$$\frac{10}{2^n - 1} = 0.01$$

$$2^n = 1001$$
$$n = \log_2 1001 \cong 9.96$$
$$n = 10 \text{ number of bits}$$

End of Solution

Q.26 Consider 24 voice signals being transmitted without latency using time-division multiplexing. If each signal is sampled at 12 kHz and represented by an 8-bit word, the bit-duration (in microseconds) is ________ (round off to two decimal places).

Ans. (0.434)

$$\text{Bit rate } R_b = Nnf_s$$

[$\because$ N = No. of signals; n = No. of bits; f_s = sampling frequency]

$$\text{Bit interval} = \frac{1}{R_b} = \frac{1}{Nnf_s}$$

$$T_b = \frac{1}{24 \times 12 \times 8 \times 10^{-3}} = 0.434\ \mu\text{sec}$$

End of Solution

Q.27 A photodiode is made of a semiconductor with a bandgap of 1.42 eV. Given that Planck's constant is 6.626×10^{-34} Js, the speed of light in vacuum is 3×10^8 m/s, and 1 eV = 1.6×10^{-19} J, the cut-off wavelength (in nanometers) of the photodiode is ________ (round off to one decimal place)

Ans. (874.91)

As we know $$E_g = h\nu = \frac{hC}{\lambda}$$

Cut-off wavelength, $$\lambda = \frac{hC}{E_g}$$

$$\lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{1.42 \times 1.6 \times 10^{-19}}$$

$$\lambda = 874.91 \text{ nm}$$

End of Solution

Q.28 The global minimum of $x3e^{-|x|}$ for $x \in (-\infty, \infty)$ occurs at x = ________ (round off to one decimal place)

Ans. (–3)

$x^3e^{-|x|}$

For $x < 0$, $$y = x^3e^x$$

$$\frac{dy}{dx} = 3x^2e^x + x^3e^x = 0$$

$$3x^2e^x = -x^3e^x$$
$$x = -3$$
$$\frac{d^2y}{dx^2} = 3x^2e^x + x^3e^x + 6xe^x + 3x^2e^x$$
$$= e^x(x^3 + 6x^2 + 6x)$$
$$= e^{-3}(-27 + 54 - 18)$$
$$= 9e^{-3} > 0$$

Hence, at $x = -3$ global minimum occurs.

End of Solution

Q.29 A 440 V, 8 kW, 4-pole, 50 Hz, star-connected induction motor has a full load slip of 0.04. The rotor speed (in rpm) at full load is ________
(round off to one decimal place)

Ans. (1440)

The slip of motor, $s = 0.04$

The synchronous speed, $N_s = 120 \times \frac{f}{P}$

$$N_s = 120 \times \frac{50}{4} = 1500 \text{ rpm}$$

So, $N_r = N_s(1 - s)$
$$= 1500(1 - 0.04)$$
$$N_r = 1440 \text{ rpm}$$

End of Solution

Q.30 The transfer function of a system is:

$$\frac{(s+1)(s+3)}{(s+5)(s+7)(s+9)}$$

In the state-space representation of the system, the minimum number of state variables (in integer) necessary is ________.

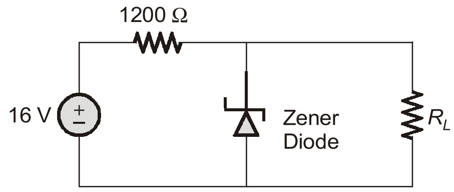
Ans. (3)

The transfer function, $G(s) = \frac{(s+1)(s+3)}{(s+5)(s+7)(s+9)}$

The transfer function is of order = 3.
So, minimum number of state variable = 3.

End of Solution

Q.31 A Zener diode is used as a 4 V voltage regulator in the circuit shown. Given that the diode requires a minimum current of 4 mA for voltage regulation, the maximum current (in milliamperes) permitted to flow through the load R_L is ________ (round off to one decimal place)



Ans. (6)

$$I_z = I - I_L$$
$$I_{z,\min} = I - I_{L,\max}$$
$$I_{L,\max} = \frac{16-4}{1.2} - 4 = 6 \text{ mA}$$

End of Solution

Q.32 A bag contains six red balls and four blue balls. If three balls are drawn in succession without replacement, the probability that the second and third balls drawn are red is ________ (round off to two decimal places).

Ans. (0.333)

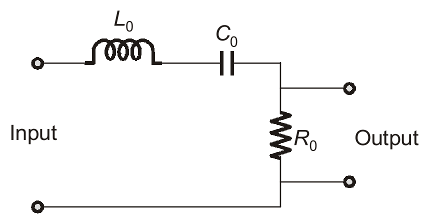
Number of red balls = 6
Number of blue balls = 4

Balls are drawn three times. So, probability of getting red color balls during 2nd and 3rd time

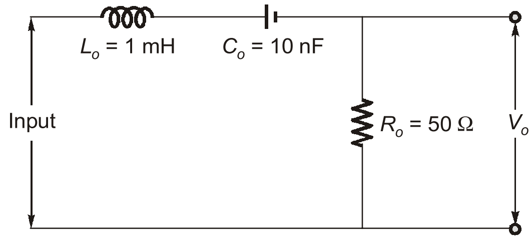
$$P(R) = \frac{6\times5\times4+4\times6\times5}{10\times9\times8}$$
$$P(R) = \frac{240}{720} = \frac{1}{3} = 0.333$$

End of Solution

Q.33 In the bandpass filter circuit shown, R_0 = 50 Ω, L_0 = 1 mH, C_0 = 10 nF. The Q factor of the filter is ________ (round off to two decimal places)



Ans. (6.32)



The quality factor,
$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$
$$Q = \frac{1}{50}\sqrt{\frac{1}{10 \times 10^{-6}}}$$
$$Q = 6.32$$

End of Solution

Q.34 The Newton-Raphson method is applied to determine the solution of $f(x) = 0$ where $f(x) = x - \cos(x)$. If the initial guess of the solution is $x_0 = 0$, the value of the next approximation x_1 is ________
(round off to two decimal places)

Ans. (1)

According to Newton-Raphson method,
$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$
$$= 0 - \left[\frac{0-1}{1}\right] = 1$$

End of Solution

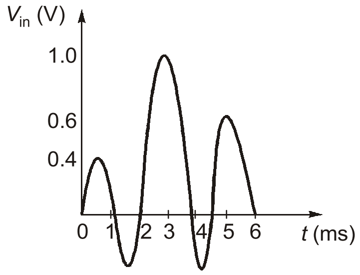
Q.35 An OPAMP has a gain of 10^4, an input impedance of 10 MΩ and an output impedance of 100 Ω. The OPAMP is used in unity-gain feedback configuration in a voltage buffer circuit. The closed-loop output impedance of the OPAMP (in milliohms) in the circuit is ________ (round off to one decimal place)

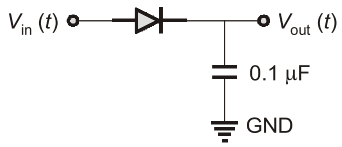
Ans. (10)

Output impedance of unity-gain feedback
$$R_{of} = \frac{R_0}{1 + A_{OL}\beta} = \frac{100}{1 + 10^4 \times 1} = \frac{100}{10^4} = 10\ \text{m}\Omega$$

End of Solution

Q.36 A signal $V_{in}(t)$ shown is applied from t = 0 ms to t = 6 ms to the circuit shown. Given the initial voltage across the capacitor is 0.3 V, and that the diode is ideal, the open circuit voltage $V_{out}(t)$ at t = 5 ms is ________.

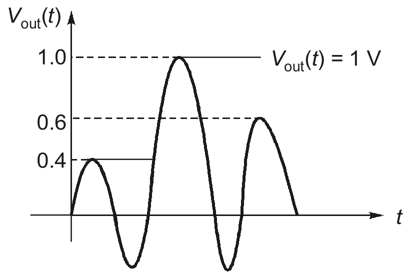




(a) 0.3 V
(b) 0.6 V
(c) 0.7 V
(d) 1.0 V

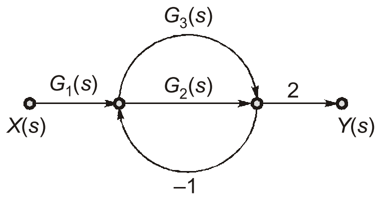
Ans. (d)

Given circuit is positive peak detector, so capacitor will detect the peak of input and capacitor voltage will remains at peak value of input voltage.



End of Solution

Q.37 The signal flow graph of a system is shown.
The expression for $Y(s)/X(s)$ is ________.



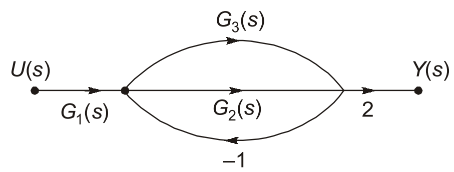
(a) $\dfrac{2G_1(s)G_2(s)+2G_1(s)G_3(s)}{1+G_2(s)+G_3(s)}$

(b) $2+G_1(s)+G_3(s)+\dfrac{G_2(s)}{1+G_2(s)}$

(c) $G_1(s)+G_3(s)-\dfrac{G_2(s)}{2+G_2(s)}$

(d) $\dfrac{2G_1(s)G_2(s)+2G_1(s)G_3(s)-G_1(s)}{1+G_2(s)+G_3(s)}$

Ans. (a)



By Mason's gain formula

$$\frac{Y(s)}{U(s)} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

$$\frac{Y(s)}{U(s)} = \frac{2G_1G_3 + 2G_2G_1}{1 + G_2 + G_3}$$

$$\frac{Y(s)}{U(s)} = \frac{2(G_2 + G_3)G_1}{1 + G_2 + G_3}$$

End of Solution

Q.38 Consider the transfer function

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

Bilinear transformation with a sampling period of 0.1 s is employed to obtain the discrete-time transfer function $H_d(z)$. Then $H_d(z)$ is ________.

(a) $\dfrac{(1+z^{-1})^2}{(19-21z^{-1})(23-17z^{-1})}$

(b) $\dfrac{(1-z^{-1})^2}{(21-19z^{-1})(17-23z^{-1})}$

(c) $\dfrac{(1+z^{-1})^2}{(21-19z^{-1})(23-17z^{-1})}$

(d) $\dfrac{(1+z^{-1})^2}{(21-19z^{-1})(17-23z^{-1})}$

Ans. (c)

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

$$T_s = 0.1 \text{ sec}$$

Bilinear transfer - transformation

$$s = \frac{2}{T}\left(\frac{1-z^{-1}}{1+z^{-1}}\right) = \frac{2}{0.1}\left(\frac{1-z^{-1}}{1+z^{-1}}\right)$$

$$s = 20\left(\frac{1-z^{-1}}{1+z^{-1}}\right)$$

So z-transform of given transfer function becomes

$$H_d(z) = \left.\frac{1}{(s+1)(s+3)}\right|_{s=20\left(\frac{1-z^{-1}}{1+z^{-1}}\right)}$$

$$H_d(z) = \frac{1}{\left[1+\frac{20(1-z^{-1})}{1+z^{-1}}\right]\left[3+\frac{20(1-z^{-1})}{1+z^{-1}}\right]}$$

$$H_d(z) = \frac{(1+z^{-1})^2}{(1+z^{-1}+20-20z^{-1})(3+3z^{-1}+20-20z^{-1})}$$

$$H_d(z) = \frac{(1+z^{-1})^2}{(21-19z^{-1})(23-17z^{-1})}$$

End of Solution

Q.39 A car is moving collinearly with a laser beam emitted by a transceiver. A laser pulse emitted at $t = 0$ s is received back by the transceiver 100 ns (nanoseconds) later after reflection from the car. A second pulse emitted at $t = 0.1$ s is received back 90 ns later. Given the speed of light is 3×10^8 m/s, the average speed of the car in this interval is ________.

(a) 54 kmph, moving towards the transceiver
(b) 108 kmph, moving towards the transceiver
(c) 54 kmph, moving away from the transceiver
(d) 108 kmph, moving away from the transceiver

Ans. (a)

End of Solution

Q.40 The signal $x(t) = (t-1)^2 u(t-1)$, where $u(t)$ is the unit-step function, has the Laplace transform $X(s)$. The value of $X(1)$ is ________.

(a) $\frac{1}{e}$
(b) $\frac{2}{e}$
(c) $2e$
(d) e^2

Ans. (b)

$$x(t) = (t-1)^2\, u(t-1)$$

$$x_1(t) = t^2\, u(t)$$

$$\uparrow\downarrow$$

$$X_1(s) = \frac{2}{s^2}$$

$$x_2(t) = x(t-1) \rightleftharpoons X_2(s) = \frac{2e^{-s}}{s^2}$$

So,

$$X(1) = \frac{2e^{-1}}{1} = \frac{2}{e}$$

Answer is (b)

End of Solution

Q.41 A proportional-integral-derivative (PID) controller is employed to stably control a plant with transfer function

$$P(s) = \frac{1}{(s+1)(s+2)}$$

Now, the proportional gain is increased by a factor of 2, the integral gain is increased by a factor of 3, and the derivative gain is left unchanged. Given that the closed-loop system continues to remain stable with the new gains, the steady-state error in tracking a ramp reference signal ________.

(a) Remains unchanged
(b) Decreases by a factor of 2
(c) Decreases by a factor of 3
(d) Decreases by a factor of 5

Ans. (c)

Transfer function of PID controller,

$$G_c(s) = K_p + \frac{K_I}{s} + sK_D$$

$$= \left(\frac{s^2K_D + sK_P + K_I}{s}\right)$$

Overall loop-transfer function,

$$L(s) = G_c(s) \cdot P(s)$$

$$L(s) = \frac{(s^2K_D + sK_P + K_I)}{s(s+1)(s+2)} \quad ...(1)$$

Steady state error due to ramp signal,

$$K_V = \lim_{s\to 0} sL(s)$$

$$K_V = \frac{K_I}{2} \Rightarrow e_{ss} = \frac{1}{K_V} = \frac{2}{K_I}$$

Now, $K_P' = 2K_P,\ K_I' = 3K_I$ and $K_D' = K_D$

Then $K_V' = \lim_{s\to 0} sL'(s)$

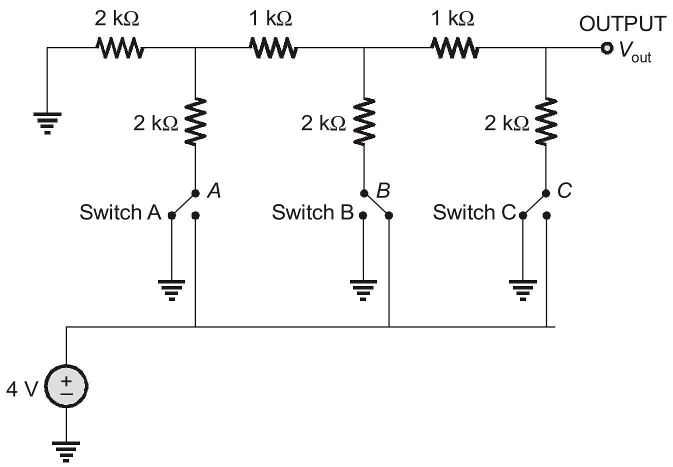
$$K_V' = \frac{3K_I}{2}$$

$$e_{ss}' = \frac{1}{K_V'} = \frac{2}{3K_I}$$

So, steady state error decreased by factor 3.

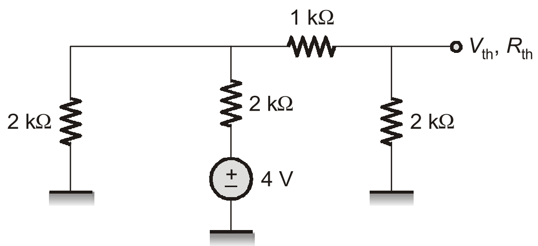
End of Solution

Q.42 A resistor ladder digital-to-analog converter (DAC) receives a digital input that results in the circuit having the state as shown in the figure. For this digital input, the Thevenin voltage, V_{th}, and Thevenin resistance, R_{th}, as seen at the output node are ________.



(a) V_{th} = 0.5 V, R_{th} = 1 kΩ
(b) V_{th} = 0.5 V, R_{th} = 2 kΩ
(c) V_{th} = 1 V, R_{th} = 1 kΩ
(d) V_{th} = 1 V, R_{th} = 2 kΩ

Ans. (c)



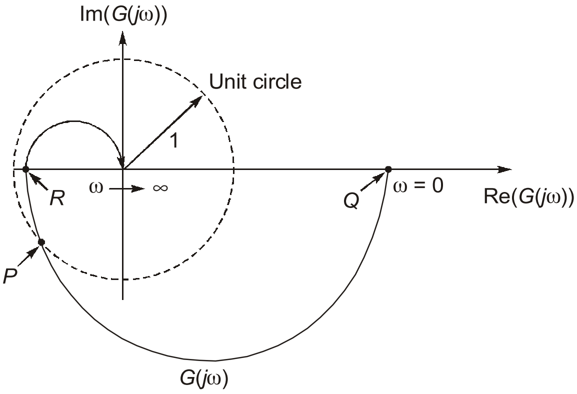
$$R_{th} = \{[(2 \parallel 2) + 1] \parallel 2\} \text{ k}\Omega$$
$$= 1 \text{ k}\Omega$$

By KCL at Node V,

$$\frac{V-4}{2} + \frac{V}{2} + \frac{V}{3} = 0$$
$$3V - 12 + 3V + 2V = 0$$
$$8V = 12$$
$$V = \frac{12}{8} \text{ Volt}$$
$$V_{th} = \frac{12}{8} \times \frac{2}{1+2} = \frac{12}{8} \times \frac{2}{3} = 1 \text{ Volt}$$

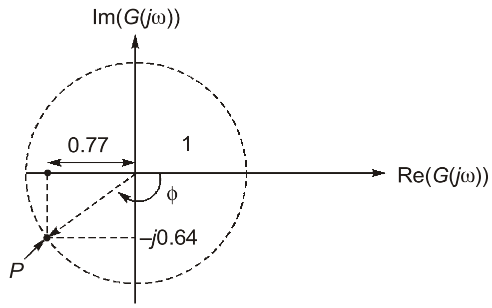
End of Solution

Q.43 The Nyquist plot of a stable open-loop system $G(j\omega)$ is plotted in the frequency range $0 \le \omega < \infty$ as shown. It is found to intersect a unit circle with center at the origin at the point $P = -0.77 - 0.64j$. The points Q and R lie on $G(j\omega)$ and assume values $Q = 14.40 + 0.00j$ and $R = -0.21 + 0.00j$. The phase margin (PM) and the gain margin (GM) of the system are ________.



(a) PM = 39.7° and GM = 4.76
(b) PM = 39.7° and GM = 0.07
(c) PM = –39.7° and GM = 4.76
(d) PM = –39.7° and GM = 0.07

Ans. (a)



$$\phi = \left[90° + \tan^{-1}\left(\frac{0.77}{0.64}\right)\right]$$

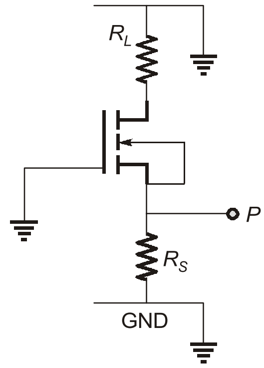
$$\phi = -140.26°$$

$$\text{P.M} = 180° + \phi = 39.73°$$

$$\text{G.M} = \left|\frac{1}{R}\right| = \frac{1}{0.21} = 4.76$$

End of Solution

Q.44 In the small signal circuit shown, the enhancement mode n-channel MOSFET is biased in saturation with transconductance g_m. If channel length modulation is ignored, the small signal impedance looking into the node P is given by ________.



(a) $R_S \,||\, R_L \,||\, g_m^{-1}$

(b) $R_s \,||\, g_m^{-1}$

(c) $(R_S + R_L) \,||\, g_m^{-1}$

(d) $\dfrac{R_L g_m}{1 + R_S g_m}(R_L \,||\, g_m^{-1})$

Ans. **(b)**

Resistance seen at point P in small signal analysis is

$$R_P = (g_m^{-1} \,||\, R_s)$$

End of Solution

Q.45 Consider the differential equation

$$\frac{dy}{dx} + y\ln(y) = 0$$

If $y(0) = e$, then $y(1)$ is ________.

(a) e^e

(b) e^{-e}

(c) $e^{(1/e)}$

(d) $e^{(-1/e)}$

Ans. **(c)**

Given differential equation :

$$\frac{dy}{dx} + y\ln y = 0$$

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

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

Integrating both sides

$$\int \frac{dy}{y\ln y} = -\int dx$$

$$\ln|\ln y| = -x + C$$

$$\ln y = Ke^{-x} \qquad [\text{Let } K = e^C]$$

Given : $y(0) = e^1$

So, $\ln(e^1) = Ke^{-0}$

$K = 1$

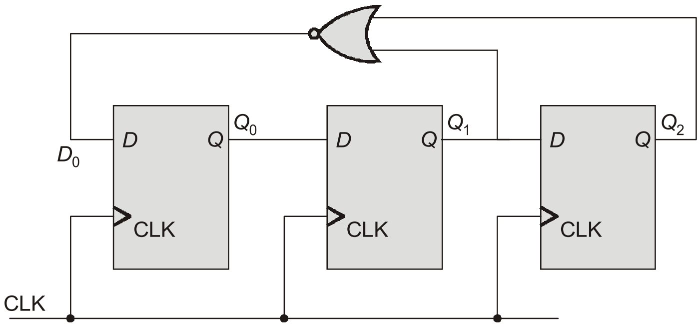
So, $\ln y = e^{-x}$

For $x = 1$, $\ln y(1) = e^{-1} = \frac{1}{e}$

$y(1) = e^{1/e}$

End of Solution

Q.46 The digital circuit shown _______.



(a) is a divide-by-5 counter

(b) is a divide-by-7 counter

(c) is a divide-by-8 counter

(d) does not function as a counter due to disjoint cycles of states

Ans. (a)

Next state, $Q_0^+ = \bar{Q}_1 \cdot \bar{Q}_2$

$Q_1^+ = Q_0$

$Q_2^+ = Q_1$

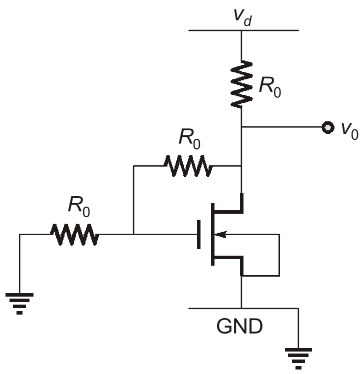
Present State			Next State		
Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+
0	0	0	0	0	1
0	0	1	0	1	1
0	1	1	1	1	0
1	1	0	1	0	0
1	0	0	0	0	0

0 – 4 – 6 – 4 – 0

So, total states are 5. So, frequency divides by 5.

End of Solution

Q.47 In the small signal circuit shown, the enhancement mode n-channel MOSFET is biased in saturation with a transconductance g_m. A small signal low-frequency voltage v_d injected at the supply terminal results in a small signal voltage fluctuation v_0 at the output. If the channel length modulation of the MOSFET is ignored, the small signal gain v_0/v_d is given by ________



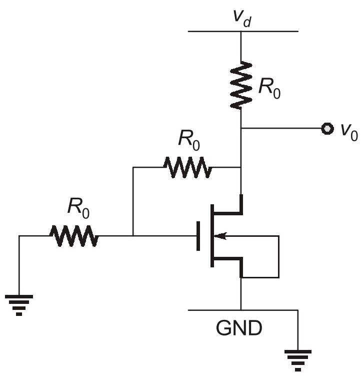
(a) $\dfrac{-g_m R_0}{1+g_m R_0}$

(b) $(g_m R_0 + 1)^{-1}$

(c) $\dfrac{-g_m R_0}{1+2g_m R_0}$

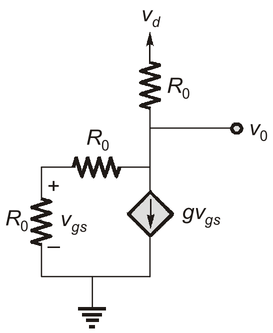
(d) $\left(\dfrac{g_m R_0}{2}+\dfrac{3}{2}\right)^{-1}$

Ans. **(d)**



$$\left(\frac{gR_0}{2}+\frac{3}{2}\right)^{-1}$$

AC model:



$$v_{gs} = \frac{R_0}{R_0 + R_0} \times v_0 = \frac{v_0}{2}$$

KCL @ V_0

$$\frac{v_d - v_0}{R_0} = \frac{v_0}{2R_0} + g v_{gs}$$

$$= \frac{v_0}{2R_0} + g\frac{v_0}{2}$$

$$\frac{v_d}{R_0} = v_0\left(\frac{3}{2R_0} + \frac{g}{2}\right)$$

$$\Rightarrow \quad v_d = v_0\left(\frac{3}{2} + \frac{1}{2}g_m R_0\right)$$

$$\Rightarrow \quad \frac{v_0}{v_d} = \left(\frac{3}{2} + \frac{1}{2}g_m R_0\right)^{-1}$$

End of Solution

Q.48 $A = a_1a_0$ and $B = b_1b_0$ are two 2-bit unsigned binary numbers. If $F(a_1, a_0, b_1, b_0)$ is a Boolean function such that $F = 1$ only when $A > B$, and $F = 0$ otherwise, then F can be minimized to the form ________.

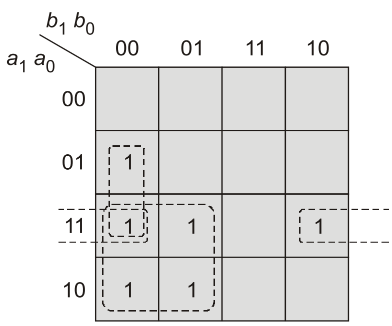
(a) $a_1\bar{b}_1 + a_1a_0\bar{b}_0$

(b) $a_1\bar{b}_1 + a_1a_0\bar{b}_0 + a_0\bar{b}_0\bar{b}_1$

(c) $a_1a_0\bar{b}_0 + a_0\bar{b}_0\bar{b}_1$

(d) $a_1\bar{b}_1 + a_1a_0\bar{b}_0 + a_0\bar{b}_0b_1$

Ans. (b)



$$F = a_1 a_0 \bar{b}_0 + a_1 \bar{b}_1 + a_0 \bar{b}_1 \bar{b}_0$$

End of Solution

Q.49 The matrix $A = \begin{bmatrix} 4 & 3 \\ 9 & -2 \end{bmatrix}$ has eigenvalues – 5 and 7. The eigenvector(s) is/are ________.

(a) $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$

(b) $\begin{bmatrix} 3 \\ 4 \end{bmatrix}$

(c) $\begin{bmatrix} 2 \\ -6 \end{bmatrix}$

(d) $\begin{bmatrix} 2 \\ 8 \end{bmatrix}$

Ans. (a, c)

Eigen values given, $\lambda = -5, 7$

Now for eigen values, $\lambda_1 = -5$

$$[A - \lambda_1 I][x] = 0$$

$$\begin{bmatrix} 4-(-5) & 3 \\ 9 & -2-(-5) \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 9 & 3 \\ 9 & 3 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$9x_1 + 3x_2 = 0$$

$$x_2 = -3x_1$$

Let $x_1 = K$, then $x_2 = -3K$

So, eigen vector for $\lambda_1 = 5$,

$$= K\begin{bmatrix} 1 \\ -3 \end{bmatrix}$$

For eigen value $\lambda_2 = 7$

$$\begin{bmatrix} 4-7 & 3 \\ 9 & -2-7 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} -3 & 3 \\ 9 & -9 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$-3x_1 + 3x_2 = 0$$

$$x_1 = x_2$$

So, eigen vector is $K\begin{bmatrix} 1 \\ 1 \end{bmatrix}$.

End of Solution

Q.50 For the complex number $Z = \frac{a+jb}{a-jb}$, where $a > 0$ and $b > 0$. Which of the following statement(s) is/are true?

(a) The phase is $2\tan^{-1}\frac{b}{a}$

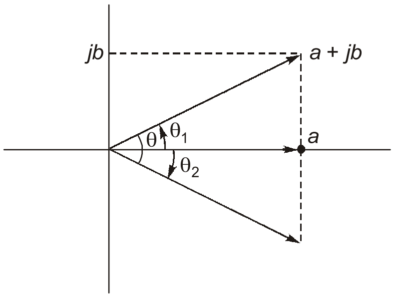
(b) The phase is $\tan^{-1}\frac{2b}{a}$

(c) The magnitude is 1

(d) The magnitude is $\sqrt{\frac{a^2+b^2}{a^2-b^2}}$

Ans. (a, c)

$$Z = \frac{a+jb}{a-jb},\ a > 0,\ b > 0$$



Magnitude, $$|z| = \frac{\sqrt{a^2+b^2}}{\sqrt{a^2+b^2}} = 1$$

Phase angle, $$\theta = \theta_1 - (\theta_2)$$

$$\theta = \tan^{-1}\left(\frac{b}{a}\right) - \left(-\tan^{-1}\left(\frac{b}{a}\right)\right)$$

$$\theta = 2\tan^{-1}\left(\frac{b}{a}\right)$$

End of Solution

Q.51 Monochromatic light of wavelength 532 nm is used to measure the absorption coefficient of a material in a UV-Visible Spectrophotometer. The measured light intensity after transmission through a 1 cm thick sample of the material is 0.414 mW/cm^2. For a sample of thickness 2 cm, the measured light intensity is 0.186 mW/cm^2. The absorption coefficient (in cm^{-1}) of the material is ________ (round off to two decimal places)

Ans. (0.80)

$$I_t = I_i\, e^{-\mu x}$$

$$0.414\ \text{mW/cm}^2 = I_i\, e^{-\mu(1\times 10^{-2}\ \text{m})} \quad ...(i)$$

$$0.186\ \text{mW/cm}^2 = I_i\, e^{-\mu(2\times 10^{-2}\ \text{m})} \quad ...(ii)$$

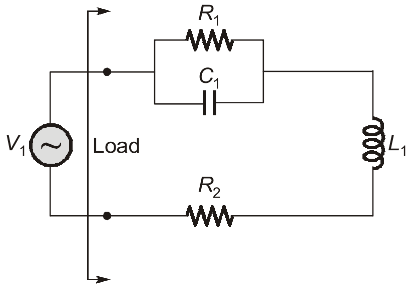
On dividing equation (i) by equation (ii),

$$\frac{0.414}{0.186} = e^{-\mu + 2\mu}$$
$$e^{\mu} = 2.225$$
$$\mu = \ln(2.225)$$

Absorption coefficient, $\mu = 0.80\ \text{cm}^{-1}$

End of Solution

Q.52 In the circuit shown, the load is driven by a sinusoidal ac voltage source $V_1 = 100\angle 0^0$ V at 50 Hz. Given $R_1 = 20\ \Omega$, $C_1 = \left(\frac{1000}{\pi}\right)\mu F$, $L_1 = \left(\frac{20}{\pi}\right)$mH and $R_2 = 4\ \Omega$, the power factor is ________ (round off to one decimal place)



Ans. (0.80)

$$\vec{Z}_{in} = R_2 + j\omega L_1 + \frac{R_1}{1 + j\omega R_1 C_1}$$
$$\vec{Z}_{in} = 4 + j100\pi \times \frac{20}{\pi} \times 10^{-3} + \frac{20}{1 + j100\pi \times 20 \times \frac{10^{-3}}{\pi}}$$
$$= 4 + j2 + \frac{20}{1 + j2} = 4 + j2 + \frac{20(1 - j2)}{5} = 4 + j2 + 4 - j8$$
$$\vec{Z}_{in} = (8 - j6)\ \Omega$$
$$\cos\phi = \frac{8}{\sqrt{8^2 + 6^2}} = 0.80 \text{ leading}$$

End of Solution

Q.53 In a unity-gain feedback control system, the plant

$$P(s) = \frac{0.001}{s(2s + 1)(0.01s + 1)}$$

is controlled by a lag compensator

$$C(s) = \frac{s + 10}{s + 0.1}$$

The slope (in dB/decade) of the *asymptotic* Bode magnitude plot of the loop gain at $\omega = 3$ rad/s is ________ (in integer)

Ans. (–60)

$$P(s) = \frac{0.001}{s(2s+1)(0.01s+1)}$$

$$C(s) = \frac{s+10}{(s+0.1)}$$

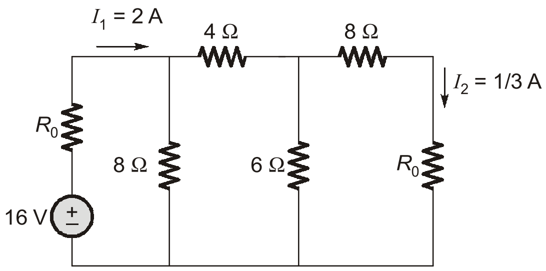
$$P(s)C(s) = \frac{0.001(s+10)}{s(2s+1)(0.01s+1)(s+0.1)}$$

Slope for ω = 3 rad/sec

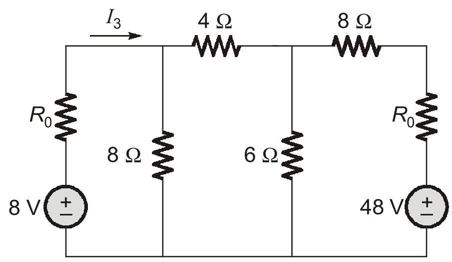
Slope = –20 – 20 – 20 = –60 dB/dec

End of Solution

Q.54 Given Circuit A with currents I_1 and I_2 as shown, the current I_3 in Circuit B (in amperes), is ________(round off to one decimal place)



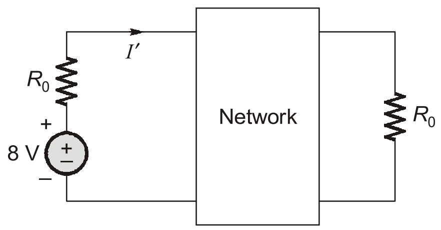
Circuit A



Circuit B

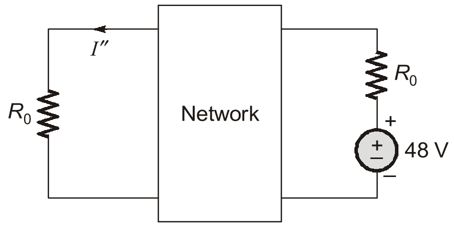
Ans. (0)

First taking 8 V only



$$I' = 2\left(\frac{8}{16}\right) = 1 \text{ Amp}$$

Taking 48 V only



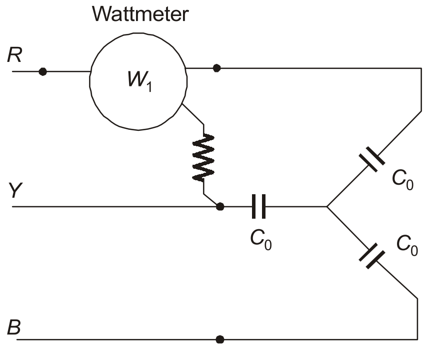
$$I'' = \left(\frac{1}{3}\right)\left(\frac{48}{16}\right) = 1 \text{ Amp}$$

So, $I = I' - I'' = 1 - 1 = 0$ Amp

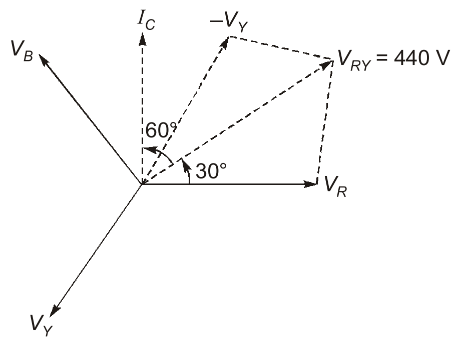
So current-I is zero (0).

End of Solution

Q.55 In the balanced three-phase circuit shown, C_0 = 8.2 μF and the line-to-line r.m.s. voltage is 440 V at 50 Hz. The reading on the wattmeter (in watts) is _______ (round off to two decimal places)



Ans. (143.97)



Reading of wattmeter :

$$W = V_{RY} I_C \cos\angle V_{RY} I_C$$

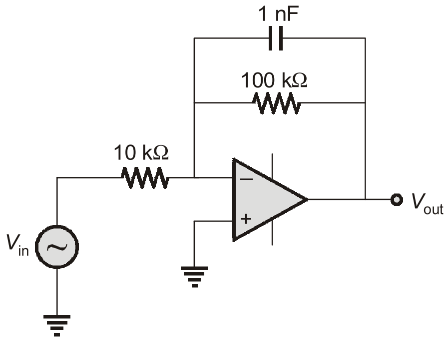
$$= 440 \times \frac{440}{\sqrt{3}} \times 100\pi \times 8.2 \times 10^{-6} \times \cos(60°)$$

$$= \frac{(440)^2 \times 100\pi \times 8.2 \times 10^{-6}}{2\sqrt{3}}$$

$$W = 143.97 \text{ Watt}$$

End of Solution

Q.56 The circuit shown is driven by a sinusoidal input voltage, V_{in}, resulting in the output voltage, V_{out}. The frequency (in kilohertz) at which the voltage gain is 0 dB is ________ (round off to two decimal places)



Ans. (15.83) (15.60 to 16.00)

$$\frac{V_o}{V_i} = -\frac{Z_2}{Z_1}$$

$$Z_1 = 10\ \text{k}\Omega$$

$$Z_2 = R \| \frac{1}{j\omega C} = \frac{R}{1 + j\omega CR}, \quad \text{where, } R = 100\ \text{k}\Omega, \ C = 1\text{nF}$$

$$\left|\frac{V_o}{V_i}\right| = 0\ \text{dB}$$

$$\Rightarrow \left|\frac{V_o}{V_i}\right| = 1$$

$$\Rightarrow \left|\frac{Z_2}{Z_1}\right| = 1$$

$$\Rightarrow \left|\frac{R}{(1 + j\omega CR) \times 10}\right| = 1$$

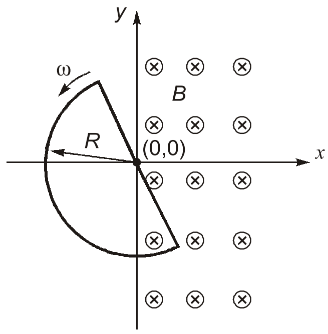
$$\Rightarrow 10 = \sqrt{1 + \omega^2 C^2 K^2}$$

$$\Rightarrow \omega CR = \sqrt{99}$$

$$\Rightarrow f = \frac{\sqrt{99}}{2\pi CR} = \frac{\sqrt{99}}{2\pi \times 100\ \text{k}\Omega \times 1\text{n}} = 15.83\ \text{kHz}$$

End of Solution

Q.57 A conducting semi-circular loop of radius R = 0.1 m, with its diameter centered at the origin, rotates in the x-y plane about the origin with a constant angular velocity, ω = 20 rad/s, as shown. A magnetic field of magnitude B = 2 T and normal to x-y plane exists in the region $x \geq 0$ as shown. If the loop has a resistance of 2 Ω, and negligible inductance, the peak-to-peak current (in milliamperes) in the loop is ________ (round off to one decimal place)



Ans. (200)

Induced emf in semi-circular loop is given as

$$E_{ind} = \frac{1}{2}B\omega R^2$$

$$= \frac{1}{2} \times 2 \times 20 \times (0.1)^2 = 0.2 \text{ V}$$

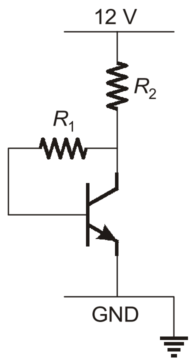
$$\text{Peak current in loop} = \frac{E_{ind}}{R} = \frac{0.2}{2} = 0.1 \text{ A}$$

Peak to peak current in loop,

$$I_{p-p} = 2 \times 0.1$$
$$= 0.24$$
$$= 200 \text{ mA}$$

End of Solution

Q.58 In the circuit shown, R_1 =100 kΩ and R_2 =1 kΩ. If the base-to-emitter voltage of the npn BJT is 0.7 V and the collector-to-emitter voltage is 5.2 V, the β (current gain) of the BJT is _______ (round off to two decimal places)



Ans. **(150.11)**

Apply KVL in base emitter loop

$$-5.2 + I_\beta R_1 + 0.7 = 0$$

$$I_B = \frac{4.5}{100} = 0.045 \text{ mA}$$

$$I_C + I_B = (1 + \beta)I_B = \frac{12-5.2}{1}$$

$$(1 + \beta) = 151.11$$

$$\beta = 150.11$$

End of Solution

Q.59 A capacitor is constructed using two concentric spheres and air as the dielectric medium (permittivity of air = 8.854×10^{-12} F/m). The radii of the inner and outer spheres are a = 10 cm and b = 15 cm, respectively. The capacitance (in picofarads) is ________ (round off to 2 decimal places)

Ans. **(33.36)**

$$C = \frac{4\pi\varepsilon}{\frac{1}{a}-\frac{1}{b}} = \frac{4\pi \times 8.85 \times 10^{-12}}{\frac{100}{10}-\frac{100}{15}} = 33.36 \text{ pF}$$

End of Solution

Q.60 A 1 kHz sine-wave generator having an internal resistance of 50 Ω generates an open-circuit voltage of 10 $V_{p\text{-}p}$. When a capacitor is connected across the output terminals, the voltage drops to 8 $V_{p\text{-}p}$. The capacitance of the capacitor (in microfarads) is _______ (round off to two decimal places)

Ans. **(2.387)**

Given data :

$$V_{in} = 10V_{P\text{-}P}$$

$$V_o = 8V_{P\text{-}P}$$

The frequency, $f = 1$ kHz

We know, $$V_o = \frac{X_C}{\sqrt{X_C^2 + R^2}} V_{in}$$

$$8 = \frac{X_C}{\sqrt{X_C^2 + 50^2}} \times 10$$

$$0.8 = \frac{X_C}{\sqrt{X_C^2 + 50^2}}$$

$$X_C^2 + 50^2 - 1.5625X_C^2 = 0$$

$$X_C^2 - 1.5625X_C^2 + 2500 = 0$$

$$X_C = \frac{200}{3}\Omega$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \times 10^3 \times \frac{200}{3}} = 2.387\ \mu\text{F}$$

So, value of capacitance, $C = 2.387\ \mu$F.

End of Solution

Q.61 Consider thefunction $f(z) = \frac{1}{(z+1)(z+2)(z+3)}$. The residue of $f(z)$ at $z = -1$, is _______

Ans. (0.5)

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

Residue at $z = -1$

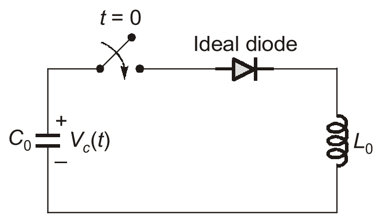
$$\text{Res }(z = -1) = \lim_{z \to -1}(z+1)f(z)$$

$$= \lim_{z \to -1}\frac{1}{(z+2)(z+3)} = \frac{1}{(-1+2)(-1+3)}$$

$$\text{Res }(z = -1) = 0.5$$

End of Solution

Q.62 In the circuit shown, the capacitance C_0 = 10 μF and inductance L_0 = 1 mH and the diode is ideal. The capacitor is initially charged to 10 V and the current in the inductor is initially zero. If the switch is closed at t = 0 s, the voltage $V_c(t)$ (in volts) across the capacitor at t = 0.5s is ______ (round off to one decimal place)



Ans. (–10)

$$V_c(0) = V_o = V_o$$

$$V_c(t) = V_o \cos \omega_o t$$

$$i_c(t) = i_L(t) = -c\frac{dV_c}{dt}$$

$$= -cV_o(-\sin \omega_{ot}) \times \omega_o$$

$$i_L(t) = V_o\sqrt{\frac{C}{L}}\sin\omega_o t$$

at $\omega_o t = \pi$, $\quad i_L(\pi) = 0$

$$V_c(\pi) = V_o \cos(\pi) = -V_o = -10 \text{ V}$$

So, this time capacitor plates are charged opposite to its initial.

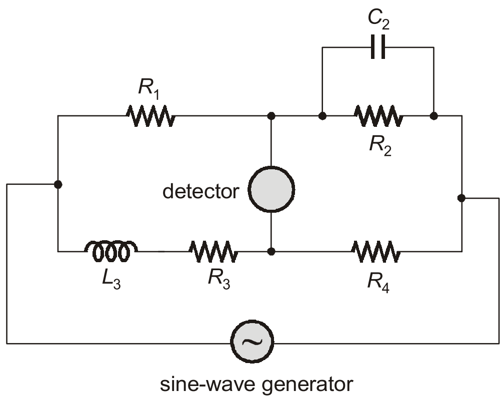
So, after $\omega_o t = \pi$, $\quad t = \dfrac{\pi}{\omega_o} = \pi\sqrt{Lc}$

$$t = 10^{-4}\pi \text{ sec capacitor}$$

Voltage is always –10 V.

End of Solution

Q.63 The bridge shown is balanced when $R_1 = 100\ \Omega$, $R_2 = 210\ \Omega$, $C_2 = 2.9\ \mu\text{F}$, and $R_4 = 50\ \Omega$. The 2 kHz sine-wave generator supplies a voltage of 10 $V_{p\text{-}p}$. The value of L_3 (in millihenry) is _______ (round off to two decimal places)



Ans. (14.50)

At balance condition,

$$R_1 R_4 = (R_2 + j\omega L_3) \times \left[R_2 \,||\, \frac{1}{jg\omega C_2}\right]$$

$$R_2 + j\omega L_3 = [R_1 R_4] \times \left[\frac{1}{R_2} + j\omega C_2\right]$$

$$R_2 + j\omega L_3 = \frac{R_1 R_4}{R_2} + j\omega C_2 R_1 R_4$$

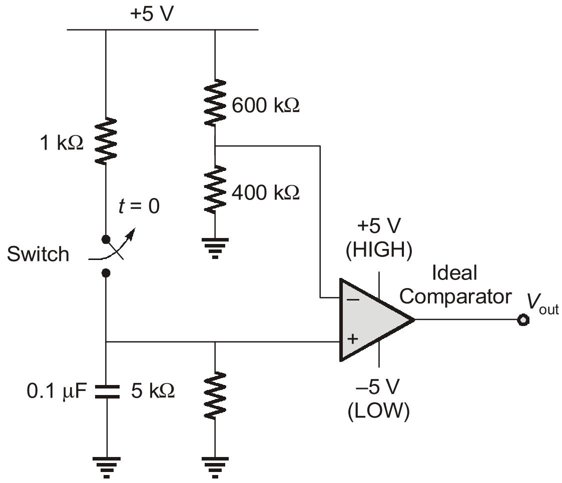
$$L_3 = R_1 R_4 C_2$$

$$= 100 \times 50 \times 2.9 \times 10^{-6}$$

$$L_3 = 14.50 \text{ mH}$$

End of Solution

Q.64 In the circuit shown, the switch is initially closed. It is opened at t = 0s and remains open thereafter. The time (in milliseconds) at which the output voltage V_{out} becomes LOW is ________ (round off to three decimal places)



Ans. **(0.367)**

For $t < 0$, capacitor open circuited :

$$V_c(0) = \frac{5}{5+1}\times 5 = \frac{25}{6}\text{V}$$

At t = 0; switch opened.

Capacitor starts discharging through 5 kΩ resistor.

$$V_c(t) = V_c(0)e^{-t/\tau}\ \text{V} \qquad (t > 0)$$

$$V_c(t) = \frac{25}{6}e^{-t/\tau}$$

Let at $t = t_1$; comparator switches to $-V_{sat}$ (–5 V) and at that instant,

$$V_c(t) = 2\ \text{V}$$

$$2 = \frac{25}{6}e^{-t/\tau}$$

On solving,

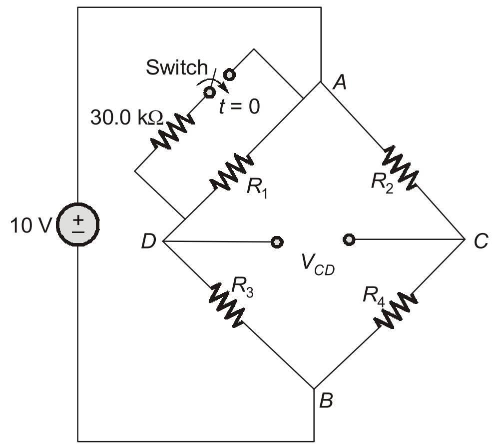
$$t = \tau \ln\left[\frac{25}{12}\right]$$

$$t = 0.1\times 5\ln\left[\frac{25}{12}\right]\ \text{msec}$$

$$t = 0.367\ \text{msec}$$

End of Solution

Q.65 In the Wheatstone bridge circuit shown, R_1 = 1.5 kΩ and $R_2 = R_3 = R_4$ = 1 kΩ. The switch is initially open and the voltage between the points C and D is V_{CD}. Upon closing the switch at t = 0, the resistance in the arm AD changes by an amount δR_1, and the voltage between C and D changes by δV_{CD}. The sensitivity of the bridge (in volt/kiloohm), defined as $\left|\frac{\delta V_{CD}}{\delta R_1}\right|$, is ________ (round off to two decimal places)

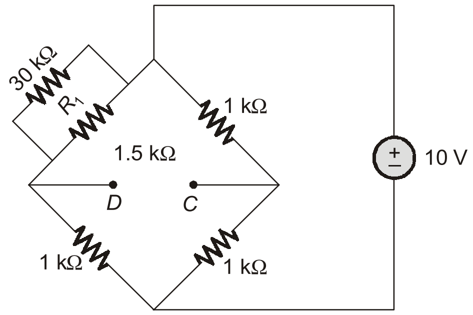


Ans. **(1.645)**

Switch open,

$$V_{CD} = V_C - V_D$$
$$= 10\left[\frac{1}{2} - \frac{1}{2.5}\right]$$
$$= 10[0.5 - 0.4] = 1 \text{ V}$$

When switch closed



$$V_{CD} = 10\left[\frac{1}{2} - \frac{1}{1+1.4285}\right]$$
$$= 0.882$$
$$\text{Sensitivity} = \frac{\Delta V_{CD}}{\Delta R} = \frac{0.882 - 1}{1.4285 - 1.5} \text{ V/k}\Omega$$
$$= 1.645 \text{ V/k}\Omega$$

End of Solution

■■■■