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GATE 2020

Electrical Engineering

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Questions and Solutions

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SECTION A : GENERAL APTITUDE

Q.1 Select the next element of the series: Z, WV, RQP, _______ .

(a) JIHG (b) KJIH
(c) NMLK (d) LKJI

Ans. (b)

Z,	M V,	R Q P	K J I H
26,	23,22	18,17,16	11,10,9,8

End of Solution

Q.2 If *P*, *Q*, *R*, *S* are four individuals. How many teams of size exceeding one can be formed, with *Q* as a member?

(a) 8 (b) 6
(c) 5 (d) 7

Ans. (d)

$^3C_1 + {^3C_2} + {^3C_3}$

$3 + 3 + 1 = 7$

Possible combinations,

PQ, RQ, SQ, PRQ, PSQ, RSQ, PQRS

End of Solution

Q.3 In four-digit integer numbers from 1001 to 9999, the digit group "37" (in the same sequence) appears _____ times.

(a) 299 (b) 270
(c) 280 (d) 279

Ans. (c)

$10 \times 10 + 9 \times 10 + 9 \times 10 = 280$

Question is asking 37 appears how many times and not how many numbers.

End of Solution

Q.4 Non-performing Assets (MPAs) of a bank in India is defined as an asset, which remains unpaid by a borrower for a certain period of time in terms of interest, principal, or both. Reserve Bank of India (RBI) has changed the definition of NPA thrice during 1993-2004. in terms of the holding period of loans. The holding period was reduced by one quarter each time. In 1993, the holding period was four quarters (360 days). Based on the above paragraph, the holding period of loans in 2004 after the third revision was ______ days.

(a) 45 (b) 135
(c) 90 (d) 180

Ans. (c)

As given in question holding period was reduced by one quarter each time. Therefore, after third division holding period remains 90 days.

End of Solution

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Q.5 Stock markets ________ at the news of the coup.
(a) plunged (b) plugged
(c) poised (d) probed

Ans. (a)

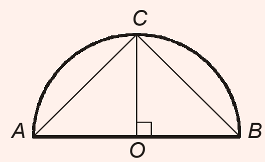
End of Solution

Q.6 People were prohibited ________ their vehicles near the entrance of the main administrative building.
(a) to park (b) to have parked
(c) from parking (d) parking

Ans. (c)

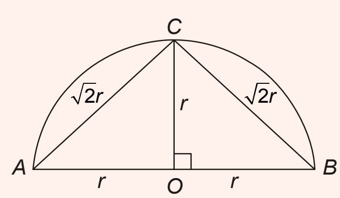
End of Solution

Q.7 Given a semicircle with O as the centre; as shown in the figure, the ratio $\frac{\overline{AC}+\overline{CB}}{\overline{AB}}$ is ________ . Where $\overline{AC}$, $\overline{CB}$ and $\overline{AB}$ are chords.



(a) $\sqrt{2}$ (b) $\sqrt{3}$
(c) 2 (d) 3

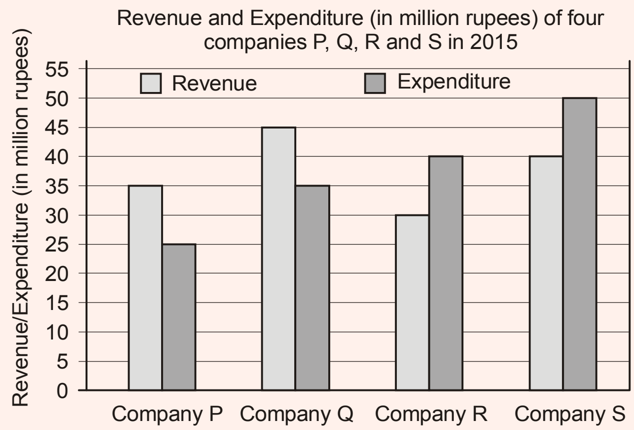
Ans. (a)



The ratio, $\frac{\overline{AC}+\overline{CB}}{\overline{AB}} = \frac{\sqrt{2}r+\sqrt{2}r}{2r} = \frac{2\sqrt{2}}{2} = \sqrt{2}$

End of Solution

Q.8 The revenue and expenditure of four different companies P, Q, R and S in 2015 are shown in the figure. If the revenue of company Q in 2015 was 20% more than that in 2014, and company Q had earned a profit of 10% on expenditure in 2014, then its expenditure (in million rupees) in 2014 was ______.



(a) 34.1
(b) 32.7
(c) 33.7
(d) 35.1

Ans. (a)

Let the revenue of company *Q* in 2010 = x in million rupees.

Then the revenue of company *Q* in 2015 = 1.2 x in million rupees.

Given in graph, $1.2x = 45$

$x = 37.5$ in million rupees

As given in question *Q* had earned a profit of 10%.

$\because$ Expenditure of company *Q* in 2014

$$= \frac{37.5}{1.1} = 34.09 \approx 34.1$$

End of Solution

Q.9 Select the word that fits the analogy:

Do : Undo : Trust : ______

(a) Untrust
(b) Intrust
(c) Distrust
(d) Entrust

Ans. (c)

Do : Undo : Trust : Distrust

End of Solution

Q.10 This book, including all its chapters ______ interesting. The students as well as the instructor ______ in agreement about it.

(a) are, are
(b) is, was
(c) is, are
(d) were, was

Ans. (c)

End of Solution

SECTION B : TECHNICAL

Q.1 x_R and x_A are, respectively, the rms and average values of $x(t) = x(t - T)$, and similarly, y_R and y_A are, respectively, the rms and average values of $y(t) = kx(t) \cdot k$, T are independent of t. Which of the following is true?

(a) $y_A = kx_A$; $y_R = kx_R$
(b) $y_A = kx_A$; $y_R \neq kx_R$
(c) $y_A \neq kx_A$; $y_R \neq kx_R$
(d) $y_A \neq kx_A$; $y_R = kx_R$

Ans. **(a, b)**

Given, $y(t) = Kx(t)$ ...(1)

then, Average of $y(t) = K \times$ Average of $x(t)$

$\Rightarrow$ $Y_A = KX_A$

From equation (1),

$$\text{Power of } y(t) = |K|^2 \cdot \text{power of } x(t)$$

$$\Rightarrow \quad Y_R^2 = |K|^2 \cdot X_R^2 \qquad [\because \text{Power} = \text{Rms}^2]$$

$$\Rightarrow \quad Y_R = |K| \cdot X_R$$

Case (i): When K is real and positive then,

$$|K| = K$$

and $Y_R = KX_R$

Thus option (a) is satisfied.

Case (ii): When K is imaginary or complex or real and negative then,

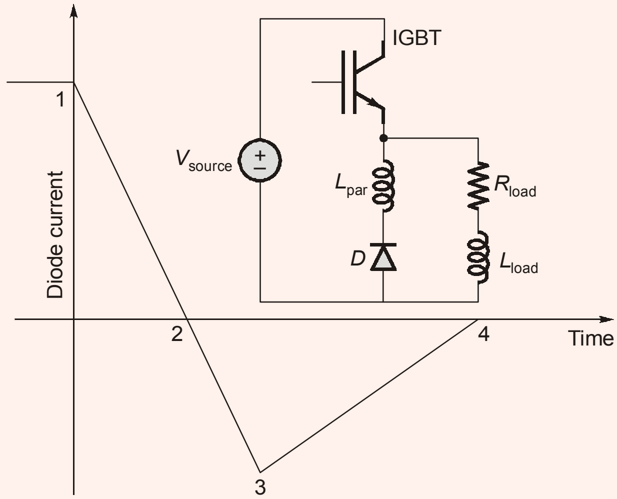
$$|K| \neq K$$

and $Y_R \neq KX_R$

Thus option (b) is satisfied, option (a) and (b) both satisfies the given condition.

End of Solution

Q.2 A double pulse measurement for an inductively loaded circuit controlled by the IGBT switch is carried out to evaluate the reverse recovery characteristics of the diode. D, represented approximately as a piecewise linear plot of current vs time at diode turn-off. L_{par} is a parasitic inductance due to the wiring of the circuit, and is in series with the diode. The point on the plot (indicate your choice by entering 1. 2, 3 or 4) at which the IGBT experiences the highest current stress is ______.



Ans. (3)

End of Solution

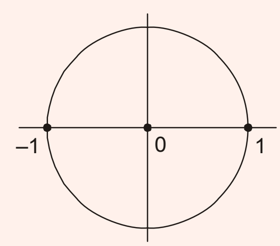
Q.3 The value of the following complex integral, with C representing the unit circle centered at origin in the counterclockwise sense, is:

$$\int_C \frac{z^2+1}{z^2-2z}dz$$

(a) $-\pi i$
(b) πi
(c) $8\pi i$
(d) $-8\pi i$

Ans. (a)

$\int \frac{z^2+1}{z^2-2z}dz$ where C is $|z| = 1$



$$= \int \frac{z^2+1}{z(z-2)}dz$$

$$= \int \frac{\frac{z^2+1}{z-2}}{z}dz$$

By integral formula,

$2\pi i\ f(0)$ where, $\quad f(z) = \frac{z^2+1}{z-2} = 2\pi i\left(\frac{1}{-2}\right) = -\pi i$

End of Solution

Q.4 Which of the following is true for all possible non-zero choices of integers m, n; $m \neq n$. or all possible non-zero choices of real numbers p, q ; $p \neq q$, as applicable?

(a) $\frac{1}{\pi}\int_0^{\pi} \sin m\theta \sin n\theta\, d\theta = 0$
(b) $\frac{1}{2\pi}\int_{-\pi}^{\pi} \sin p\theta \cos q\theta\, d\theta = 0$
(c) $\frac{1}{2\pi}\int_{-\pi/2}^{\pi/2} \sin p\theta \sin q\theta\, d\theta = 0$
(d) $\lim_{\alpha\to\infty} \frac{1}{2a}\int_{-\alpha}^{\alpha} \sin p\theta \sin q\theta\, d\theta = 0$

Ans. (a, b, d)

1. $\int_{-l}^{l} \cos\left(\frac{n\pi x}{l}\right)\cos\left(\frac{m\pi x}{l}\right)dx = \begin{cases} 2l & \text{if } n = m = 0 \\ l & \text{if } n = m \neq 0 \\ 0 & \text{if } m \neq n \end{cases}$

2. $\int_{0}^{l} \cos\left(\frac{n\pi x}{l}\right)\cos\left(\frac{m\pi x}{l}\right)dx = \begin{cases} l & \text{if } n = m = 0 \\ l/2 & \text{if } n = m \neq 0 \\ 0 & \text{if } m \neq n \end{cases}$

3. $\int_{-l}^{l} \sin\left(\frac{n\pi x}{l}\right)\sin\left(\frac{m\pi x}{l}\right)dx = \begin{cases} l & \text{if } m = n \\ 0 & \text{if } m \neq n \end{cases}$

4. $\int_{0}^{l} \sin\left(\frac{n\pi x}{l}\right)\sin\left(\frac{m\pi x}{l}\right)dx = \begin{cases} l/2 & \text{if } n = m \\ 0 & \text{if } n \neq m \end{cases}$

5. $\int_{-l}^{l} \sin\left(\frac{n\pi x}{l}\right)\cos\left(\frac{m\pi x}{l}\right)dx = 0$

(A): $\frac{1}{\pi}\int_{0}^{\pi} \sin m\theta \cos n\theta = 0$

Put $l = \pi$ in rule 4

$$\int_{0}^{\pi} \sin\left(\frac{n\pi x}{\pi}\right)\sin\left(\frac{m\pi x}{\pi}\right)dx$$

Given that, $m \neq n$

$$\frac{1}{\pi}\int_{0}^{\pi} \sin nx \sin mx \, dx = 0$$

(B): $\frac{1}{2\pi}\int_{-\pi}^{\pi} \sin p\theta \cos q\theta \, d\theta = 0$

Put $l = \pi$ in rule 5

$$\int_{-\pi}^{\pi} \sin\left(\frac{n\pi x}{\pi}\right)\cos\left(\frac{m\pi x}{\pi}\right)dx$$

Given that, $m \neq n$

$$\int_{-\pi}^{\pi} \sin nx \cos mx \, dx = 0$$

(C): $\underset{\alpha\to\infty}{Lt} \frac{1}{2\alpha}\int_{-\alpha}^{\alpha} \sin p\theta \sin q\theta \, d\theta = 0$

When, $\alpha \to \infty$,

$$\frac{1}{2\infty}\int_{-\infty}^{\infty} \sin p\theta \sin q\theta \, d\theta = \frac{1}{\infty}(\text{finite}) = 0$$

End of Solution

Q.5 A common-source amplifier with a drain resistance, R_D = 4.7 kΩ, is powered using a 10 V power supply. Assuming that the transconductance, g_m, is 520 μA/V, the voltage gain of the amplifier is closest to:

(a) 1.22 (b) –1.22
(c) 2.44 (d) –2.44

Ans. **(d)**

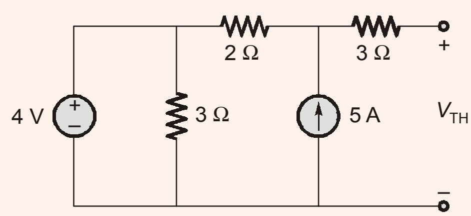
Given data: R_D = 4.7 kΩ, g_m = 520 μA/V

Voltage gain of CS amplifier

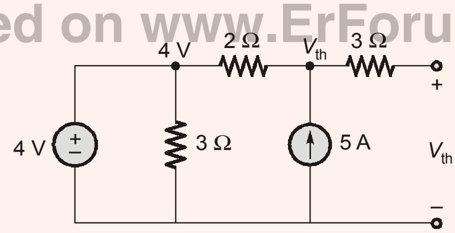
$$= -g_m R_D$$
$$= -520\ \mu AV \times 4.7\ k\Omega = -2.44$$

End of Solution

Q.6 The Thevenin equivalent voltage, V_{TH}, in V (rounded off to 2 decimal places) of the network shown below, is _______ .



Ans. **(14.00)**



$$\frac{V_{th} - 4}{2} = 5$$
$$V_{th} = 14\ V$$

End of Solution

Q.7 Consider a signal $x[n] = \left(\frac{1}{2}\right)^n 1[n]$, where 1[$n$] = 0 if n < 0, and 1[n] = 1 if $n \geq 0$. The z-transform of $x[n-k]$, k > 0 is $\frac{z^{-k}}{1-\frac{1}{2}z^{-1}}$ with region of convergence being

(a) $|z| < \frac{1}{2}$ (b) $|z| > \frac{1}{2}$

(c) $|z| < 2$ (d) $|z| > 2$

Ans. (b)

$$x(n) = \left(\frac{1}{2}\right)^n u(n), \quad \text{ROC of } x(n) : |z| > \frac{1}{2}$$

$$x(n-k) \Longleftrightarrow X(z) = \frac{z^{-k}}{1-\frac{1}{2}z^{-1}}, \quad \text{ROC of } x(n-k) : |z| > \frac{1}{2}$$

For $x(n-k)$ ROC will be $|z| > \frac{1}{2}$.

End of Solution

Q.8 A single-phase, full-bridge diode rectifier fed from a 230 V, 50 Hz sinusoidal source supplies a series combination of finite resistance. R, and a very large inductance, L, The two most dominant frequency components in the source current are:

(a) 150 Hz, 250 Hz
(b) 50 Hz, 150 Hz
(c) 50 Hz, 100 Hz
(d) 50 Hz, 0 Hz

Ans. (b)

End of Solution

Q.9 Consider the initial value problem below. The value of y at $x = ln\ 2$. (rounded off to 3 decimal places) is ______ .

$$\frac{dy}{dx} = 2x - y, \; y(0) = 1$$

Ans. (0.886)

$$\frac{dy}{dx} = 2x - y; \qquad y(0) = 1, \; y \text{ at } x = \ln 2$$

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

$$P = 1, \qquad Q = 2x$$

$$I.F. = e^{\int P dx} = e^{\int 1 dx} = e^x$$

Solution,

$$y(I.F) = \int Q(I.F.)dx$$

$$ye^x = \int 2x \cdot e^x dx = 2(xe^x - e^x) + C$$

$$y = 2x - 2 + ce^{-x}$$

$$y(0) = 1$$

$$1 = 0 - 2 + C$$

$$C = 3$$

$\therefore$

$$y = 2x - 2 + 3e^{-x}$$

At $x = \ln 2$

$$y = 2(\ln 2) - 2 + 3e^{-\ln 2}$$

$$= 1.386 - 2 + \frac{3}{2} = 0.886$$

End of Solution

Q.10 A single-phase, 4 kVA, 200 V/100 V, 50 Hz transformer with laminated CRGO steel core has rated no-load loss of 450 W. When the high-voltage winding is excited with 160 V, 40 Hz sinusoidal ac supply, the no-load losses are found to be 320 W. When the high-voltage winding of the same transformer is supplied from a 100 V, 25 Hz sinusoidal ac source, the no-load losses will be ________W (rounded off to 2 decimal places).

Ans. (162.50)

200 V, 50 Hz, $P_c = 450$ Watt

160 V, 40 Hz, $P_c = 320$ Watt

100 V, 25 Hz, $P_c = ?$ Watt

$$\frac{V}{f} = \text{constant} = \frac{200}{50} = \frac{160}{40} = \frac{100}{25}$$

So,
$$P_c = Af + Bf^2$$
$$450 = A \times (50) + B \times (50)^2 \quad \text{...(i)}$$
$$320 = A \times (40) + B \times (40)^2 \quad \text{...(ii)}$$

From (i) and (ii),
$$\frac{450}{50} = A + B(50) \quad \text{...(iii)}$$
$$\frac{320}{40} = A + B(40) \quad \text{...(iv)}$$

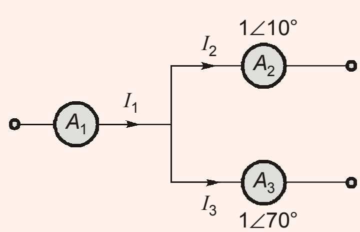
Equation (iii) – (iv),
$$(9 - 8) = B(10)$$
$$B = \frac{1}{10}$$

and
$$A = 9 - \frac{1}{10} \times 50 = 4$$

Now at 100 V, 25 Hz,
$$P_c = 4 \times 25 + \frac{1}{10} \times (25)^2$$
$$= 100 + 62.5 = 162.50 \text{ Watt}$$

End of Solution

Q.11 Currents through ammeters A_2 and A_3 in the figure are $1\angle 10°$ and $1\angle 70°$ respectively. The reading of the ammeter A_1 (rounded off to 3 decimal places) is ________ A.



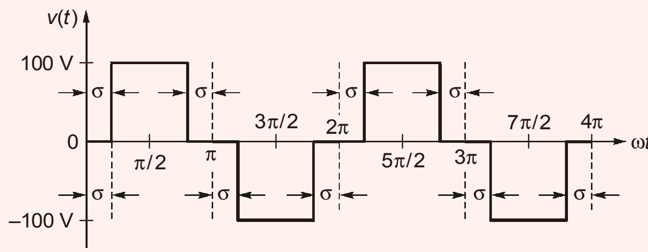
Ans. (1.732)

$$I = 1\angle 10° + 1\angle 70°$$
$$I = 1.732\angle 40°$$

The ready of ammeter is 1.732 A.

End of Solution

Q.12 A single-phase inverter is fed from a 100 V dc source and is controlled using a quasi-square wave modulation scheme to produce an output waveform, $v(t)$. as shown. The angle σ is adjusted to entirely eliminate the 3rd harmonic component from the output voltage. Under this condition, for $v(t)$, the magnitude of the 5th harmonic component as a percentage of the magnitude of the fundamental component is _______(rounded off to 2 decimal places).



Ans. (20)

Using result, $V_n = \frac{4V_s}{n\pi}\cos n\sigma$

For $V_3 = 0$

$\cos 3\sigma = 0$

or $3\sigma = \frac{\pi}{2}$

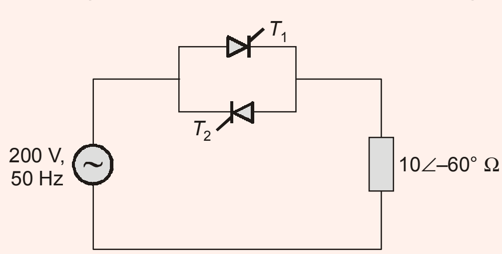
$\sigma = \frac{\pi}{6}$

Now, $\frac{V_5}{V_1} = \frac{\cos 5\sigma}{5\cos\sigma} = \frac{\cos 5\pi/6}{5\cos\pi/6} = -\frac{1}{5}$

$\%\left|\frac{V_5}{V_1}\right| = \frac{1}{5}\times 100 = 20\%$

End of Solution

Q.13 Thyristor T_1 is triggered at an angle α (in degree), and T_2 at angle 180° + α, in each cycle of the sinusoidal input voltage. Assume both thyristors to be ideal. To control the load power over the range 0 to 2 kW, the minimum range of variation in α is:



(a) 0° to 60°
(b) 60° to 180°
(c) 0° to 120°
(d) 60° to 120°

Ans. (b)

End of Solution

Q.14 A sequence detector is designed to detect precisely 3 digital inputs, with overlapping sequences detectable. For the sequence (1, 0, 1) and input data (1,1, 0,1,0,0,1,1,0,1,0,1,1,0): what is the output of this detector?

(a) 0,1,0,0,0,0,0,1,0,1,0,0 (b) 0,1,0,0,0,0,0,0,1,0,0,0

(c) 1,1,0,0,0,0,1,1,0,1,0,0 (d) 0,1,0,0,0,0,0,1,0,1,1,0

Ans. **(a)**

Sequence detector problem:

- If consider the case of non-overlapping sequence detector, then the pattern 101 is appearing 2 times in the given bit sequence.
- If we consider the case of overlapping sequence detector, then the pattern 101 is appearing 3 times in the given bit sequence.

The question says that the detector is overlapping, hence answer is (a).

End of Solution

Q.15 A three-phase. 50 Hz. 4-pole induction motor runs at no-load with a slip of 1%. With full load, the slip increases to 5 %. The % speed regulation of the motor (rounded off to 2 decimal places) is ________ .

Ans. **(4.21)**

4 pole, 50 Hz I.M has no load slip 1%

4 pole, 50 Hz I.M has full load slip 5%

$$N_S = 1500 \text{ rpm}$$

$$N_0 = N_s(1 - s) = 1500(1 - 0.01) = 1485$$

$$N = N_s(1 - s) = 1500(1 - 0.01) = 1425$$

Speed regulation is

$$\%\text{S.R.} = \frac{N_0 - N}{N} \times 100 = \frac{1485 - 1425}{1425} \times 100 = 4.21\%$$

End of Solution

Q.16 A lossless transmission line with 0.2 pu reactance per phase uniformly distributed along the length of the line, connecting a generator bus to a load bus, is protected up to 80% of its length by a distance relay placed at the generator bus. The generator terminal voltage is 1 pu. There is no generation at the load bus. The threshold pu current for operation of the distance relay for a solid three phase-to-ground fault on the transmission line is closest to:

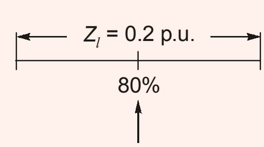
(a) 1.00 (b) 5.00

(c) 3.61 (d) 6.25

Ans. **(d)**

$$I_f = \frac{1}{Z_{Th}} = \frac{1}{0.2}$$

$= 5$ pu for 100% of line



Relay is operated for 80%

$$Z_f = 0.8\ Z_l \Rightarrow 0.8 \times 0.2 = 0.16 \text{ p.u.}$$

For 80% of line, $I_f = \frac{1}{0.16} = 6.25$ p.u.

End of Solution

Q.17 $ax^3 + bx^2 + cx + d$ is a polynomial on real x over real coefficients a, b, c, d wherein $a \neq 0$. Which of the following statements is true?

(a) No choice of coefficients can make all roots identical.
(b) a, b, c, d can be chosen to ensure that all roots are complex.
(c) d can be chosen to ensure that $x = 0$ is a root for any given set a, b, c.
(d) c alone cannot ensure that all roots are real.

Ans. (c)

$$ax^3 + bx^2 + cx + d = 0\ ; \quad a \neq 0$$

$x = 0$ is the root for any values of a, b, c only when $d = 0$.

End of Solution

Q.18 Consider a linear time-invariant system whose input $r(t)$ and output $y(t)$ are related by the following differential equation.

$$\frac{d^2y(t)}{dt^2} + 4y(t) = 6\ r(t)$$

The poles of this system are at

(a) $+4j, -4j$
(b) $+4, -4$
(c) $+2, -2$
(d) $+2j, -2j$

Ans. (d)

$$\frac{dy(t)}{dt^2} + 4y(t) = 6\ r(t)$$

$$[s^2 + 4]\ Y(s) = 6\ R(s)$$

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

Poles: $s^2 + 4 = 0$

$$s = \pm j2$$

End of Solution

Q.19 A three-phase cylindrical rotor synchronous generator has a synchronous reactance X_s and a negligible armature resistance. The magnitude of per phase terminal voltage is V_A and the magnitude of per phase induced emf is E_A. Considering the following two statements, P and Q.

P : For any three-phase balanced leading load connected across the terminals of this synchronous generator, V_A is always more than E_A.

Q : For any three-phase balanced lagging load connected across the terminals of this synchronous generator, V_A is always less than E_A.

Which of the following options is correct?

(a) P is true and Q is true. (b) P is true and Q is false.

(c) P is false and Q is false. (d) P is false and Q is true.

Ans. (d)

End of Solution

Q.20 Which of the following statements is true about the two sided Laplace transform?

(a) It has no poles for any bounded signal that is non-zero only inside a finite time interval.

(b) If a signal can be expressed as a weighted sum of shifted one sided exponentials, then its Laplace Transform will have no poles.

(c) It exists for every signal that may or may not have a Fourier transform.

(d) The number of finite poles and finite zeroes must be equal.

Ans. (a)

End of Solution

Q.21 A single 50 Hz synchronous generator on droop control was delivering 100 MW power to a system. Due to increase in load, generator power had to be increased by 10 MW. as a result of which, system frequency dropped to 49.75 Hz. Further increase in load in the system resulted in a frequency of 49.25 Hz. At this condition, the power in MW supplied by the generator is ________ (rounded off to 2 decimal places).

Ans. (130)

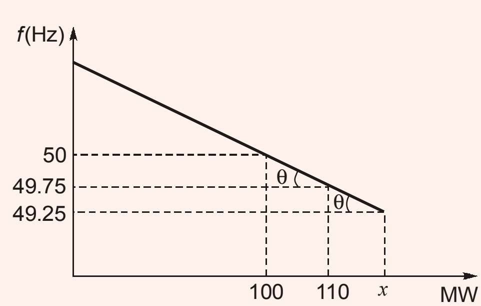
Assumed full load frequency is 50 Hz

$$\tan\theta = \frac{50-49.75}{110-100} = \frac{49.75-49.25}{(x-(110))}$$

$$\frac{0.25}{10} = \frac{0.5}{(x-150)}$$

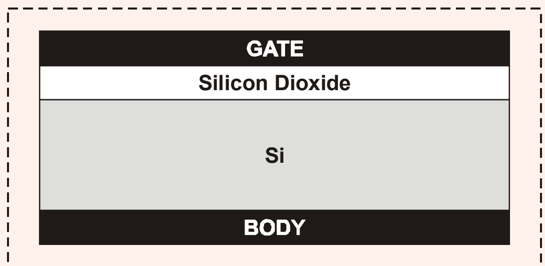
$$x - 110 = \frac{0.5\times 10}{0.25}$$

$$x = 110 + 20 = 130 \text{ MW}$$



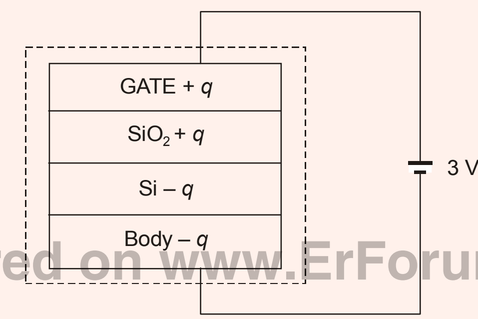
End of Solution

Q.22 The cross-section of a metal-oxide-semiconductor structure is shown schematically. Starting from an uncharged condition, a bias of +3 V is applied to the gate contact with respect to the body contact. The charge inside the silicon dioxide layer is then measured to be $+Q$. The total charge contained within the dashed box shown, upon application of bias, expressed as a multiple of Q (absolute value in Coulombs, rounded off to the nearest integer) is ________ .



DASHED BOX

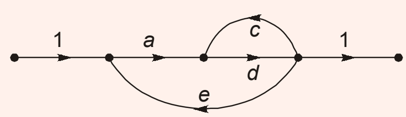
Ans. (0)

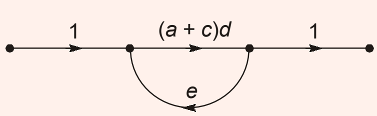


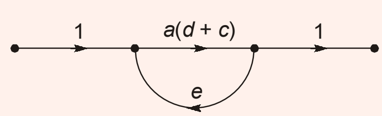
Overall charge in side the box $q + q - q - q = 0$ charge

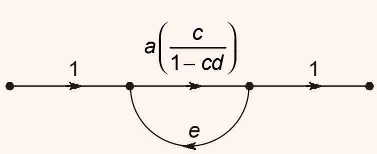
End of Solution

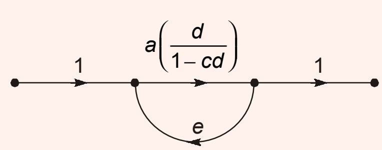
Q.23 Which of the options is an equivalent representation of the signal flow graph shown here?



(a)


(b)


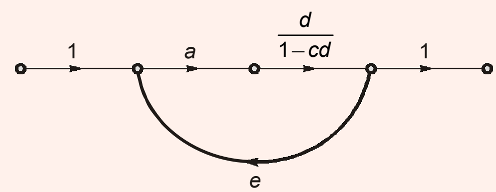
(c)


(d)


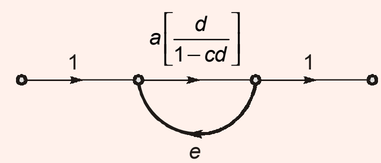
Ans. (d)

Simplifying given signal flow graph

Step-1:



Step-2:



End of Solution

Q.24 Consider a negative unity feedback system with forward path transfer function $G(s) = \frac{K}{(s+a)(s-b)(s+c)}$, where K, a, b, c are positive real numbers. For a Nyquist path enclosing the entire imaginary axis and right half of the s-plane in the clockwise direction, the Nyquist plot of $(1 + G(s))$, encircles the origin of $(1 + G(s))$ plane once in the clockwise direction and never passes through this origin for a certain value of K. Then, the number of poles of $\frac{G(s)}{1+G(s)}$ lying in the open right half of the s-plane is ________ .

Ans. (2)

$$\text{O.L.T.F} = G(s) = \frac{K}{(s+a)(s-b)(s+c)}$$

$$N = P - Z\ ; \qquad P = 1$$

$$-1 = 1 - Z\ ; \qquad N = -1$$

$$Z = 2$$

End of Solution

Q.25 Out of the following options, the most relevant information needed to specify the real power (P) at the PV buses in a load flow analysis is

(a) solution of economic load dispatch
(b) base power of the generator
(c) rated power output of the generator
(d) rated voltage of the generator

Ans. (a)

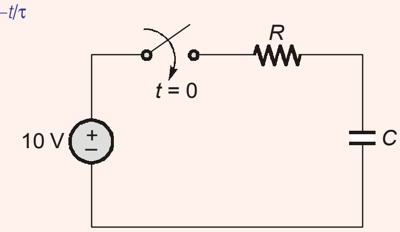
End of Solution

Q.26 A resistor and a capacitor are connected in series to a 10 V dc supply through a switch. The switch is closed at $t = 0$, and the capacitor voltage is found to cross 0 V at $t = 0.4\tau$, where τ is the circuit time constant. The absolute value of percentage change required in the initial capacitor voltage if the zero crossing has to happen at $t = 0.2\tau$ is ______ (rounded off to 2 decimal places).

Ans. **(54.99)**

If initial charge polarities on the capacitor is opposite to the supply voltage then only the capacitor voltage crosses the zero line.

$V_c(t) \Rightarrow$ Final value + (Initial value – Final value) $e^{-t/\tau}$



$$0 = 10 + (-V_0 - 10)\, e^{-0.4}$$

$$10 = (V_0 + 10)\, e^{-0.4}$$

$$V_0 = 4.918 \text{ V}$$

Now, $t = 0.2\tau$

$$0 = 10 + (-V_0' - 10)e^{-0.2}$$

$$V_0' = 2.214$$

$$\%\text{change in voltage} = \frac{4.918 - 2.214}{4.918} \times 100\% = 54.99\%$$

End of Solution

Q.27 A single-phase, full-bridge, fully controlled thyristor rectifier feeds a load comprising a 10 Ω resistance in series with a very large inductance. The rectifier is fed from an ideal 230 V, 50 Hz sinusoidal source through cables which have negligible internal resistance and a total inductance of 2.28 mH. If the thyristors are triggered at an angle $\alpha = 45°$, the commutation overlap angle in degree (rounded off to 2 decimal places) is_____.

Ans. **(4.80)**

1-ϕ, SCR bridge rectifier

$$\alpha = 45°, \; R = 10 \; \Omega$$

supply 230 V, 50 Hz

$$L_s = 2.28 \text{ mH}$$

$$\mu = ?$$

$$\Delta V_d = \frac{V_m}{\pi}[\cos\alpha - \cos(\alpha + \mu)] = 4f\, L_s I_0$$

$$V_0 = \frac{2V_m}{\pi}\cos\alpha - 4f\, L_s I_0$$

$$I_0 R = \frac{2V_m}{\pi}\cos\alpha - 4f\, L_s I_0$$

Find I_0

$$I_0 \times 10 = \frac{2 \times 230\sqrt{2}}{\pi} \cdot \cos 45 - 4 \times 50 \times 2.28 \times 10^{-3} I_0$$

$$I_0(10 + 0.456) = 146.42$$

$$I_0 = \frac{146.49}{10.456} = 14.0036 \text{ A}$$

$$\Delta V_{d0} = \frac{230\sqrt{2}}{\pi}[\cos 45 - \cos(45 + \mu)]$$

$$= 4 \times 50 \times 2.28 \times 10^{-3} \times 14 = 6.384$$

$$\cos 45° - \cos(45° + \mu) = 0.061659$$

$$45 + \mu = 49.80$$

$$\therefore \quad \mu = 4.80°$$

End of Solution

Q.28 An 8085 microprocessor accesses two memory locations (2001 H) and (2002H), that contain 8-bit numbers 98H and B1H respectively. The following program is executed:

```
LXI H,   2001 H
MVIA,    21H
INX H
ADD M
INX H
MOV M,  A
HLT
```


At the end of this program, the memory location 2003H contains the number in decimal (base 10) form ________.

Ans. **(210)**

LXI H, 2001 H → [H: 20 | L: 01]

MVI A, 21 H → [A: 21H]

INX H → HL + 1 [H: 20 | L: 02]

ADD M → [A] + data @ reference of HL pair

21 H + B1H = D2H → [A]

INX H → [HL] + 1 → 2002H + 1H → 2003H

MOV M, A → [A] to Memory, i.e., @ reference of HL pair

2003H [D2] ← [A: D2]

HLT → Stop

$\therefore$ content in the 2003 H is D2H

Converting in decimal

$D \times 16^1 + 2 \times 16^0 \Rightarrow 13 \times 16 + 2 = (210)_{10}$

End of Solution

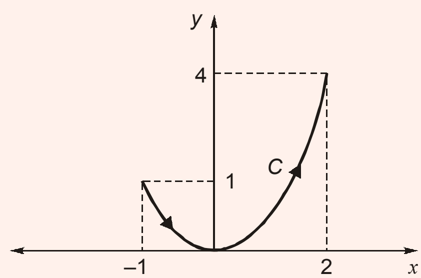
Q.29 Let a_x and a_y be unit vectors along x and y directions, respectively. A vector function is given by

$$F = \mathbf{a}_x y - \mathbf{a}_y x$$

The line integral of the above function

$$\int_c F \cdot dl$$

along the curve C, which follows the parabola $y = x^2$. as shown below is _______ (rounded off to 2 decimal places).



Ans. (–3)

$$\vec{F} = y\hat{a}_x - x\hat{a}_y$$

$$\vec{r} = x\hat{i} + y\hat{j}$$

$$\vec{F} = y\hat{i} - x\hat{j}$$

$$d\vec{r} = dx\hat{i} + dy\hat{j}$$

$$= \int_c F \cdot d\vec{r} = \int_c F_1 dx + F_2 dy = \int_c y dx - x dy$$

where C is, $y = x^2$

$dy = 2x\ dx$

x varies from –1 to 2,

$$\int_c \vec{F} dl = \int_{-1}^{2} x^2 dx - x \cdot 2x dx = \int_{-1}^{2} (x^2 - 2x)\, dx$$

$$= \int_{-1}^{2} -x^2 dx = -\frac{x^3}{3}\Big|_{-1}^{2} = -\frac{8}{3} - \frac{1}{3} = -\frac{9}{3}$$

$$= -3$$

End of Solution

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Q.30 Let a_r, a_ϕ and a_z be unit vectors along r, ϕ and z directions, respectively in the cylindrical coordinate system. For the electric flux density given by $D = (a_r 15 + a_\phi 2r - a_z 3rz)$ Coulomb/m^2, the total electric flux, in Coulomb, emanating from the volume enclosed by a solid cylinder of radius 3 m and height 5 m oriented along the z-axis with its base at the origin is:

(a) $108\,\pi$ (b) $54\,\pi$
(c) $90\,\pi$ (d) $180\,\pi$

Ans. **(180π)**

ψ/Crossing closed surface $= \oint\!\!\oint \vec{D}\cdot\vec{ds} = \iiint(\vec{\nabla}\cdot\vec{D})\,dv$ ...(i)

$$\vec{\nabla}\cdot\vec{D} = \frac{1}{\rho}\frac{\partial}{\partial\rho}(\rho D_\rho) + \frac{1}{\rho}\frac{\partial D_\phi}{\partial\phi} + \frac{\partial D_z}{\partial z}$$

$$= \frac{1}{\rho}\frac{\partial}{\partial\rho}(\rho 15) + \frac{1}{\rho}\frac{\partial}{\partial\phi}(2\rho) + \frac{\partial}{\partial z}(-3\rho z) = \frac{1}{\rho}15 - 3\rho$$

$$\iiint(\vec{\nabla}\cdot\vec{D})\,dv = \iiint\left(\frac{15}{\rho} - 3\rho\right)\rho\,d\rho\,d\phi\,dz$$

$$= \iiint 15\,d\rho\,d\phi\,dz - 3\iiint \rho^2\,d\rho\,d\phi\,dz$$

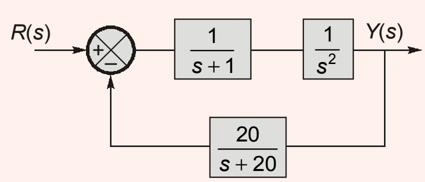
$$= 15\int_{\rho=0}^{3} d\rho \int_{\phi=0}^{2\pi} d\phi \int_{z=0}^{5} - 3\int_{\rho=0}^{3}\rho^2 d\rho \int_{\phi=0}^{2\pi} d\phi \int_{z=0}^{5} dz$$

$$= 15(3-0)(2\pi)(5) - 3\left(\frac{3^3}{3}\right)\times(2\pi)(5)$$

$$= 45(10\pi) - 27\,(10\pi) = 180\pi C$$

End of Solution

Q.31 Which of the following option is correct for the system shown below?



(a) 3rd order and stable (b) 4th order and unstable
(c) 4th order and stable (d) 3rd order and unstable

Ans. **(b)**

$$1 + \frac{20}{s^2(s+1)(s+20)} = 0$$

$$(s^3 + s^2)(s + 20) + 20 = 0$$

$$s^4 + 20s^3 + s^3 + 20s^2 + 20 = 0$$

$$s^4 + 21s^3 + 20s^2 + 20 = 0$$

s^1 coefficient $= 0$

Given system is fourth order sytem and unstable.

End of Solution

Q.32 A 250 V dc shunt motor has an armature resistance of 0.2 Ω and a field resistance of 100 Ω. When the motor is operated on no-load at rated voltage. It draws an armature current of 5 A and runs at 1200 rpm. When a load is coupled to the motor, it draws total line current of 50 A at rated voltage, with a 5 % reduction in the air-gap flux due to armature reaction. Voltage drop across the brushes can be taken as 1 V per brush under all operating conditions. The speed of the motor, in rpm, under this loaded condition, is closest to:

(a) 900
(b) 1200
(c) 1000
(d) 1220

Ans. (d)

No load current 5 A

$$\text{B.R.D} = 1 \text{ V per brush}$$

$$\text{loaded, } I_L = 50 \text{ A}$$

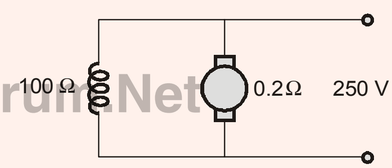
$$R_{sh} = 100\ \Omega$$

$$I_{sh} = \frac{250}{100} = 2.5 \text{ A}$$

$$I_{a0} = 2.5 \text{ A}$$

$$I_{aL} = 47.5 \text{ A}$$

$$V = E_b + I_a R_a + \text{B.R.D}$$



$$E_{b\text{ no load}} = V - I_{a0}R_a - \text{B.R.D}$$

$$= 250 - 2.5(0.2) - 1 \times 2$$

$$= 247.5 \text{ Volts}$$

$$E_{b\text{ load}} = 250 - 47.5(0.2) - 1 \times 2$$

$$= 238.5 \text{ volts}$$

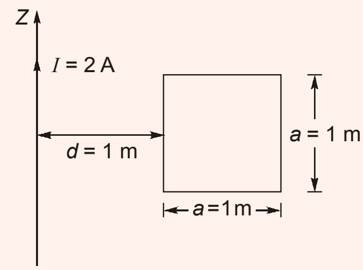
$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2}$$

$$\frac{N_2}{1200} = \frac{238.5}{247.5} \times \frac{\phi_1}{0.95\phi_1}$$

$$N_2 = 1217.22 \text{ rpm}$$

End of Solution

Q.33 A conducting square loop of side length 1 m is placed at a distance of 1 m from a long straight wire carrying a current $I = 2$ A as shown below. The mutual inductance, in nH (rounded off to 2 decimal places), between the conducting loop and the long wire is __________.



Ans. (138.63)

$$\phi \propto I$$
$$\phi = MI$$
$$\vec{B} = \frac{\mu_o I}{2\pi\rho}\hat{a}_\phi \quad (\vec{B} \text{ due to infinite long line})$$

Magnetic flux crossing square loop is

$$\phi = \iint \vec{B}\cdot\vec{ds}$$
$$= \iint \frac{\mu_o I}{2\pi\rho}\hat{a}_\phi \cdot (d\rho\, dz)\,\hat{a}_\phi = \frac{\mu_o I}{2\pi}\int_{\rho=1}^{2}\frac{d\rho}{\rho}\int_{z=0}^{1} dz$$

$$\phi = \frac{\mu_o I}{2\pi}(\ln\rho)_{\rho=1}^{2}(z)_{z=0}^{1}$$
$$\phi = \frac{\mu_o I}{2\pi}(\ln 2)$$
$$M = \frac{\phi}{I}$$
$$M = \frac{\mu_o(\ln 2)}{2\pi} = \frac{4\pi\times 10^{-7}(\ln_2)}{2\pi}$$
$$M = 1.386 \times 10^{-7} \text{ Henry} \simeq 138.63 \text{ nH}$$

End of Solution

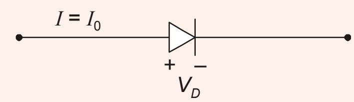
Q.34 A non-ideal Si-based pi: junction diode is tested by sweeping the bias applied across its terminals from —5 V to +5 V. The effective thermal voltage, V_T, for the diode is measured to be (29 ± 2) mV. The resolution of the voltage source in the measurement range is 1 mV. The percentage uncertainty (rounded off to 2 decimal plates) in the measured current at a bias voltage of 0.02 V is _______.

Ans. (5.87)

$$V_T = (29 \pm 2) \text{ mV}$$

$$= \left(\underset{V_T}{\underset{\downarrow}{0.029}} \pm \underset{W_{V_T}}{\underset{\downarrow}{(0.002)}}\right) \text{V} \Bigg| \begin{aligned} V_D &= 0.02 \text{ V} \\ W_{V_D} &= 1 \text{ mV} = 0.001 \text{ V} \end{aligned}$$

$$I_D = I = I_0 \cdot e^{\frac{V_D}{\eta V_T}}$$



Applying log on both sides,

$$\ln (I) = \ln(I_0) + \frac{V_D}{\eta V_T}$$

Differentiating w.r.t. 'V_T',

$$\frac{\partial I}{I} = 0 + \left(\frac{V_D}{\eta}\right)\left(1 - \frac{1}{V_T^2} \times \partial V_T\right) \Rightarrow \frac{\partial I}{\partial V_T} = -\frac{V_D I}{\eta V_T^2}$$

For $\eta = 1 \Rightarrow \frac{\partial I}{\partial V_T} = -\frac{V_D I}{V_T^2}$

Differentiating w.r.t. 'V_D',

$$\frac{\partial I}{I} = 0 + \frac{1}{\eta V_T} \cdot \partial V_D \Rightarrow \frac{\partial I}{\partial V_D} = -\frac{I}{\eta V_T}$$

$$\Rightarrow \frac{\partial I}{\partial V_D} = \frac{I}{V_T}; \quad \text{for } \eta = 1$$

$$W_{\text{res}} = \sqrt{\left(\frac{\partial I}{\partial V_T}\right)^2 W_{V_T}^2 + \left(\frac{\partial I}{\partial V_D}\right)^2 W_{V_D}^2}$$

$$= \sqrt{\left(-\frac{V_D I}{V_T^2}\right)^2 W_{V_T}^2 + \left(\frac{I}{V_T}\right)^2 W_{V_D}^2}$$

$$= \sqrt{\frac{V_D^2 \cdot I^2}{V_T^4} \times W_{V_T}^2 + \left(\frac{I}{V_T}\right)^2 \times W_{V_D}^2}$$

$$W_{\text{res}} = \sqrt{\frac{I^2 \times (0.02)^2}{(0.029)^4} \times (0.002)^2 + \frac{I^2}{(0.029)^2} \times (0.001)^2}$$

$$= I \times \sqrt{2.262 \times 10^{-3} + 1.189 \times 10^{-3}}$$

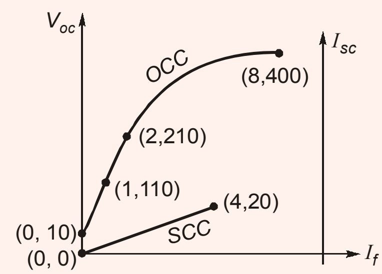
$$= 0.0587 \times I$$

$$\% \frac{W_{\text{res}}}{I} = \pm 0.0587 \times 100$$

$$\Rightarrow \% \frac{W_I}{I} = \pm 5.87\%$$

End of Solution

Q.35 The figure below shows the per-phase Open Circuit Characteristics (measured in V) and Short Circuit Characteristics (measured in A) of a 14 kVA, 400 V, 50 Hz, 4-pole, 3-phase, delta connected alternator, driven at 1500 rpm. The field current, If is measured in A. Readings taken are marked as respective (x, y) coordinates in the figure. Ratio of the unsaturated and saturated synchronous impedances $(Z_{s(unsat)}/Z_{s(sat)})$ of the alternator is closest to



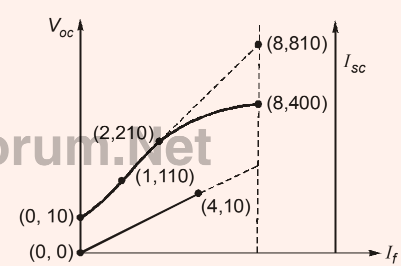
(a) 1.000
(b) 2.100
(c) 2.000
(d) 2.025

Ans. (d)

At 400 V,

$$I_f = 8 \text{ A}$$

So, air gap line equation will be like,



$$y = mx + C$$

$$y = 100x + 10 \quad \text{...(i)}$$

at I_f = 8 A,

Unsaturated voltage = 100 × 8 + 10 = 810

$$Z_{s\,unsat} = \frac{810}{20} = \frac{81}{2} \quad \text{...(ii)}$$

and

$$Z_{saturated} = \frac{400}{20} = \frac{40}{2} \quad \text{...(iii)}$$

From equation (ii) and (iii),

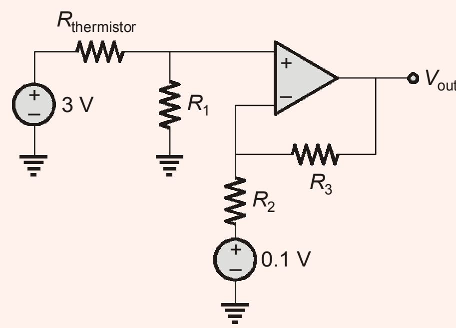
$$\frac{Z_{unsaturated}}{Z_{saturated}} = \frac{81/2}{40/2} = 2.025$$

Note: As, (0,10), (1, 110) and (2, 210) are colinear so, air gap line is an shown in figure.

∗ Data given is not realistic because at $V_{(residual)}$, $I_{(SC)}$ should have some non-zero value.

End of Solution

Q.36 The temperature of the coolant oil bath for a transformer is monitored using the circuit shown. It contains a thermistor with a temperature-dependent resistance, $R_{thermistor} = 2(1 + \alpha T)$ kΩ. Where T is the temperature in °C. The temperature coefficient α, is –(4 ± 0.25) %/°C. Circuit parameters: R_1 = 1 kΩ, R_2 = 1.3 kΩ, R_3 = 2.6 kΩ. The error in the output signal (in V. rounded off lo 2 decimal places) at 150° C is ________.



Ans. (0.04)

Given data, $R_{thermistor} = R_{th} = 2(1 + \alpha T)$ kΩ

$\alpha = -(4 + 0.25)\%$ /°C = –(0.04 ± 0.0025) °C

$\alpha_{max} = -0.0425$ /°C, $\alpha_{min} = -0.375$/°C

Temeprature, T = 150°C

R_1 = 1 kΩ, R_2 = 1.3 kΩ, R_3 = 2.6 kΩ

Considering, $\alpha = -0.04$

⇒ $R_{th} = 2[1 - 0.04 \times 150] = -10$ kΩ

$$V_0 = V_1 \times \frac{R_1}{R_1 + R_{th}}\left[1 + \frac{R_2}{R_3}\right] = 3 \times \frac{1k}{1k + 10k}\left[1 + \frac{1.3k}{2.6k}\right] = 0.5 \text{ V}$$

Case-1:

Considering, $\alpha_{max} = -0.0425$/°C

$R_{thmax} = 2[1 + (-0.0425) \times 150]$ kΩ = –10.75 kΩ

$$V_0 = V_1 \times \frac{R_1}{R_1 + R_{th}}\left[1 + \frac{R_2}{R_3}\right] = 3 \times \frac{1k}{1k - 10.75k}\left[1 + \frac{1.3k}{2.6k}\right]$$

= –0.46 Volt ⇒ For $R_{Th\ max}$

Case-2:

Considering, $\alpha_{min} = -0.0375$/°C

$R_{Th\ min} = 2[1 + (-0.0375) \times 150]$ kΩ = –9.25 kΩ

$$V_0 = 3 \times \frac{1k}{1k + (-9.25k)}\left[1 + \frac{1.3k}{2.6k}\right] = -0.54 \text{ Volt} = \text{For } R_{Th\ min}$$

Output voltage, V_0 = 0.5 ± 0.04 ⇒ (Error)

Error = 0.04

End of Solution

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For ESE & GATE 2021

Date of Test : 1st Mar, 2020

Scholarship applicable on Long Term Classroom Courses for ESE & GATE

Valid on batches commencing from **Apr-June, 2020**

Students may opt any one of the following paper:

- **Technical Paper :** CE, ME, EE, EC, CS, IN
- **Aptitude Based Paper :** Maths + Reasoning + English

- 50 Questions;
- 100 Marks;
- 1 Hour duration

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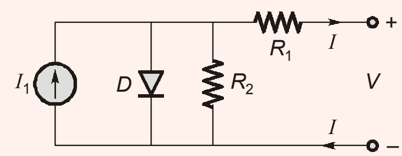
Q.37 Consider the diode circuit shown below. The diode, D, obeys the current-voltage characteristic $I_D = I_S\left(\exp\left(\frac{V_D}{nV_T}\right)-1\right)$, where $n > 1$, $V_T > 0$, V_D is the voltage across the diode and I_D is the current through it. The circuit is biased so that voltage, $V > 0$ and current, $I < 0$. If you had to design this circuit to transfer maximum power from the current source (I_1) to a resistive load (not shown) at the output, what values R_1 and R_2 would you choose?



(a) Small R_1 and small R_2.
(b) Large R_1 and large R_2.
(c) Small R_1 and large R_2.
(d) Large R_1 and small R_2.

Ans. (c)

R_1, low, R_2 high

$$V_D = V \times \frac{R_2}{R_1 + R_2}$$

If R_2 is large V_d (high)

R_1 is less $V_D = V$

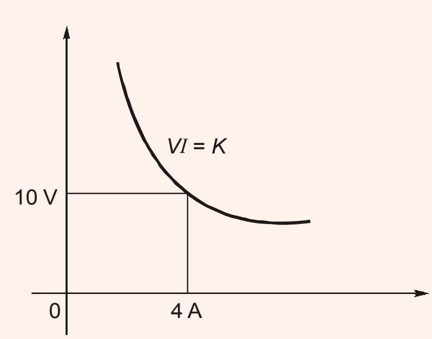
So for maximum power to deliver to load R_1 is small and R_2 is large.

End of Solution

Q.38 A benchtop dc power supply acts as an ideal 4 A current source as long as its terminal voltage is below 10 V. Beyond this point, it begins to behave as an ideal 10 V voltage source for all load currents going down to 0 A. When connected to an ideal rheostat, find the load resistance value at which maximum power is transferred, and the corresponding load voltage and current.

(a) 2.5 Ω, 4 A, 10 V
(b) 2.5 Ω, 4 A, 5 V
(c) Open, 4 A, 0 V
(d) Short, ∞ A, 10 V

Ans. (a)



Maximum power transistor of *VI* product is maximum. If draw the the curve, it intersect (10, 4) that will give maximum power.
The terminal voltage is 10 V (Load voltage) and current is 4 A (Load current).

Load resistance is $\frac{10}{4} = 2.5\ \Omega$.

End of Solution

Q.39 The causal realization of a system transfer function *H*(*s*) having poles at (2, –1), (–2, 1) and zeroes at (2, 1), (–2, –1) will be

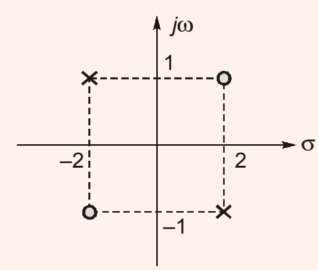
(a) unstable, complex, allpass
(b) unstable, real, highpass
(c) stable, complex, lowpass
(d) stable, real, allpass

Ans. **(a)**

Pole locations: (2, –1) and (–2, 1)

Zero locations: (2, 1) and (–2, 1)

Filter is all pass since for each pole, there is a mirror image zero.



System is unstable because for stability of causal system all poles should lie in the L.H.S. of s-plane and here one pole is lying in the R.H.S.

$$H(s) = \frac{[s-(2+j)[s-(-2-j)]}{[s-(2+j)[s-(-2+j)]}$$

$$= \frac{[s-(2+j)[s+(2+j)]}{[s-(2-j)[s+(-2-j)]}$$

$$= \frac{s^2-(2+j)^2}{s^2-(2-j)^2} = \frac{s^2-(4-1+4j)}{s^2-(4-1-4j)} = \frac{s^2-3-4j}{s^2-3+4j}$$

i.e. transfer function is complex.

End of Solution

Q.40 The static electric field inside a dielectric medium with relative permittivity. $\varepsilon_r = 2.25$, expressed in cylindrical coordinate system is given by the following expression

$$E = \hat{a}_r 2r + a_\varphi\left(\frac{3}{T}\right) + \hat{a}_z 6$$

where $\hat{a}_r, a_\varphi, \hat{a}_z$ are unit vectors along *r*, φ and *z* directions, respectively. If the above expression represents a valid electrostatic field inside the medium, then the volume charge density associated with this field in terms of free space permittivity, ε_0, in SI units is given by:

(a) $4\ \varepsilon_0$
(b) $5\ \varepsilon_0$
(c) $3\ \varepsilon_0$
(d) $9\ \varepsilon_0$

Ans. (d)

$$\vec{D} = \epsilon \vec{E} = \epsilon_o \epsilon_r \vec{E}$$

$$\vec{D} = \epsilon_o 2.25\left(2r\hat{a}_r + \frac{3}{r}\hat{a}_\phi + 6\hat{a}_z\right)$$

$$\vec{D} = 4.5\epsilon_o r\hat{a}_r + \frac{6.75\epsilon_o}{r}\hat{a}_\phi + 13.5\epsilon_o \hat{a}_z$$

Volume charge density

$$\rho_v = \vec{\nabla}\cdot\vec{D}$$

$$\rho_v = \frac{1}{r}\frac{\partial}{\partial r}(rD_r) + \frac{1}{r}\frac{\partial D_\phi}{\partial \phi} + \frac{\partial D_z}{\partial z}$$

$$\rho_v = \frac{1}{r}\frac{\partial}{\partial r}(r4.5\epsilon_o r) + \frac{1}{r}\frac{\partial}{\partial \phi}\left(\frac{6.75\epsilon_o}{r}\right) + \frac{\partial}{\partial z}(13.5\epsilon_o)$$

$$= \frac{1}{r}\frac{\partial}{\partial r}(4.5\epsilon_o r^2) + 0 + 0$$

$$= \frac{1}{r}(4.5\epsilon_o)(2r) = 9\epsilon_o$$

End of Solution

Q.41 Consider a negative unity feedback system with the forward path transfer function $\frac{s^2+s+1}{s^3+2s^2+2s+K}$, where K is a positive real number. The value of K for which the system will have some of its poles on the imaginary axis is ________ .

(a) 8
(b) 9
(c) 6
(d) 7

Ans. (a)

CE is $1 + G(s)H(s) = 0$

$$\Rightarrow \quad 1 + \frac{s^2+s+1}{s^3+2s^2+2s+K} = 0$$

$$\Rightarrow \quad s^3 + 3s^2 + 3s + (1+K) = 0$$

R.H. criteria:

s^3	1	3
s^2	3	$(1+K)$
s^1	$9-(1+K)$	0

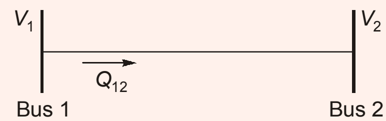
For marginal stability

$$9 - (1+K) = 0$$

$$\Rightarrow \quad K = 8$$

End of Solution

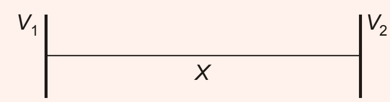
Q.42 Bus 1 with voltage magnitude $V_1 = 1.1$ p.u. is sending reactive power Q_{12} towards bus 2 with voltage magnitude $V_2 = 1$ p.u. through a lossless transmission line of reactance X. Keeping the voltage at bus 2 fixed at 1 p.u., magnitude of voltage at bus 1 is changed, so that the reactive power Q_{12} sent from bus 1 is increased by 20%. Real power flow through the line under both the conditions is zero. The new value of the voltage magnitude, V_1, in p.u. (rounded off to 2 decimal places) at bus 1 is _______ .



Ans. **(1.12)**

With real power zero, load angle $\delta = 0$

With initial values, $V_1 = 1.1,\quad V_2 = 1$



$$Q_{12} = \frac{V_1^2}{X} - \frac{V_1 V_2}{X}\sin\delta$$

$$= \frac{(1.1)^2}{X} - \frac{1.1\times 1}{X}\sin 0 = \frac{0.11}{X}$$

With increased value of voltage,

new value of $Q_{12} = 1.2Q_{12},\quad V_2 = 1$

$$1.2\,Q_{12} = \frac{V_1^2}{X} - \frac{V_1\times 1}{X} = 1.2\times\frac{0.11}{X}$$

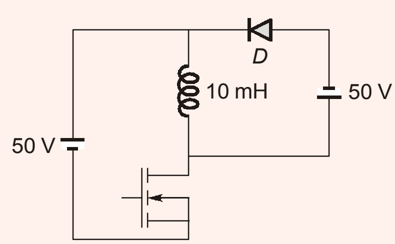
$$V_1^2 - V_1 - 0.132 = 0$$

$$V_1 = 1.12,\quad -0.118$$

Hence the practical value in per unit, $V_1 = 1.12$ p.u.

End of Solution

Q.43 In the dc-dc converter circuit shown, switch Q is switched at a frequency of 10 kHz with a duty ratio of 0.6. All components of the circuit are ideal, and the initial current in the inductor is zero. Energy stored in the inductor in mJ (rounded off to 2 decimal places) at the end of 10 complete switching cycles is _______.



Ans. (5)

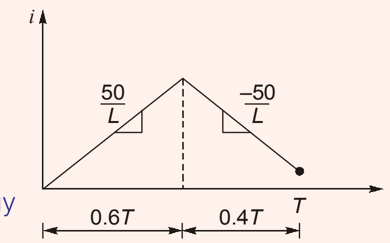
Buck boost converter,

$$D = 0.6 \rightarrow \text{stores energy}$$

$$D = \frac{T_{ON}}{T} = 0.6$$

$$T_{ON} = 0.6T \rightarrow \text{store energy}$$

$$T_{OFF} = 0.4\text{ T} \rightarrow \text{releasing energy}$$



For one cycle: Rise in current for 0.2T

For 10 cycles: Find rise in current $(0.2T) \times 10 = 2T$

$$i = \frac{50}{L}t$$

$$i = \frac{50}{L}(2T) = \frac{50 \times 2}{LP} = \frac{100}{10 \cdot 10^{-3} \times 10 \cdot 10^{3}} = 1\text{ A}$$

$$\therefore \quad \text{Energy stored} = \frac{1}{2}Li^2 = \frac{1}{2} \times (10 \cdot 10^{-3}) \cdot (1)^2 = 5 \text{ mJ}$$

End of Solution

Q.44 Which of the following options is true for a linear time-invariant discrete time system that obeys the difference equation:

$$y[n] - ay[n-1] = b_0x[n] - b_1x[n-1]$$

(a) When $x[n] = 0$, $n < 0$, the function $y[n]$; $n > 0$ is solely determined by the function $x[n]$.

(b) The system is necessarily causal.

(c) $y[n]$ is unaffected by the values of $x[n-k]$; $k > 2$.

(d) The system impulse response is non-zero at infinitely many instants.

Ans. (d)

$$y(n) - ay(n-1) = b_0\,x(n) - b_1\,x(n-2)$$

By applying ZT,

$$Y(z) - az^{-1}\,Y(z) = b_0X(z) - b_1z^{-1}\,X(z)$$

$$\Rightarrow \quad H(z) = \frac{Y(z)}{X(z)} = \frac{b_0 - b_1z^{-1}}{1 - az^{-1}}$$

By taking right-sided inverse ZT,

$$h(n) = b_0a^n\,u(n) - b_1a^{n-1}u(n-1)$$

By taking left-sided inverse ZT,

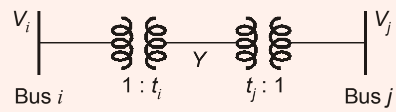
$$h(n) = -b_0a^n\,u(-n-1) + b_1a^{n-1}u(-n)$$

Thus system is not necessarily causal.

The impulse response is non-zero at infinitely many instants.

End of Solution

Q.45 Two buses, i and j, are connected with a transmission line of admittance Y, at the two ends of which there are ideal transformers with turns ratios as shown. Bus admittance matrix for the system is:



(a) $\begin{bmatrix} -t_i t_j Y & t_j^2 Y \\ t_i^2 Y & -t_i t_j Y \end{bmatrix}$

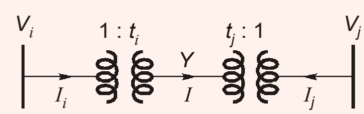
(b) $\begin{bmatrix} t_i t_j Y & -t_j^2 Y \\ -t_i^2 Y & t_i t_j Y \end{bmatrix}$

(c) $\begin{bmatrix} t_i t_j Y & -(t_i - t_j)^2 Y \\ -(t_i - t_j)^2 Y & t_i t_j Y \end{bmatrix}$

(d) $\begin{bmatrix} t_i^2 Y & -t_i t_j Y \\ -t_i t_j Y & t_j^2 Y \end{bmatrix}$

Ans. (d)

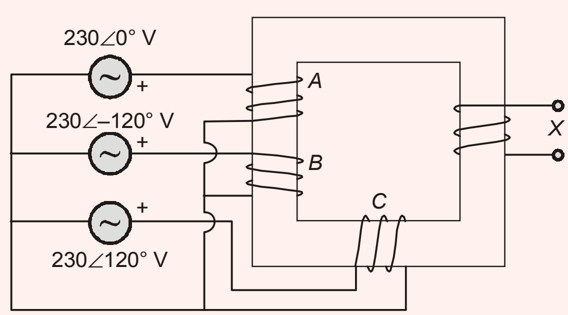
$$I = Y(t_i V_i - V_j t_j)$$
$$I_i = t_i I$$
$$= t_i^2 Y V_i - t_i t_j Y V_j$$
$$I_j = -t_j I$$
$$= -I_i t_j Y V_i + t_j^2 Y V_j$$



$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} t_i^2 Y & -t_i t_j Y \\ -t_i t_j Y & t_j^2 Y \end{bmatrix} \begin{bmatrix} V_i \\ V_j \end{bmatrix}$$

End of Solution

Q.46 Windings 'A', 'B' and 'C' have 20 turns each and are wound on the same iron core as shown, along with winding 'X' which has 2 turns. The figure shows the sense (clockwise/anti-clockwise) of each of the windings only and does not reflect the exact number of turns, If windings 'A', 'B' and 'C' are supplied with balanced 3-phase voltages at 50 Hz and there is no core saturation, the no-load RMS voltage (in V, rounded off to 2 decimal places) across winding 'X' is ________ .



Ans. (46)

$$V_X = \frac{2}{20}(230\angle 0° - 230\angle 120° - 230\angle -120°) = 46\angle 0° \text{ V}$$

End of Solution

Q.47 The vector function expressed by $F = \mathbf{a}_x(5y - k_1z) + \mathbf{a}_y(3z + k_2x) + \mathbf{a}_z(k_3y - 4x)$ represents a conservative field, where $\mathbf{a}_x$, $\mathbf{a}_y$, $\mathbf{a}_z$ are unit vectors along x, y and z directions, respectively. The values of constants k_1, k_2, k_3 are given by:

(a) $k_1 = 3, k_2 = 3, k_3 = 7$
(b) $k_1 = 4, k_2 = 5, k_3 = 3$
(c) $k_1 = 3, k_2 = 8, k_3 = 5$
(d) $k_1 = 0, k_2 = 0, k_3 = 0$

Ans. (b)

$$\bar{F} = (5y - k_1z)\hat{i} + (3z + k_2x)\hat{j} + (k_3y - 4x)\hat{k}$$

is conservative field

$\bar{F}$ is irrotational, $\nabla \times \bar{F} = 0$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 5y - k_1z & 3z + k_2x & k_3y - 4x \end{vmatrix} = 0$$

$$\hat{i}(k_3 - 3) - \hat{j}(-4 + k_1) + \hat{k}(k_2 - 5) = 0$$

$k_3 - 3 = 0$ $\quad$ $4 - k_1 = 0$ $\quad$ $k_2 - 5 = 0$

$k_3 = 3$ $\quad$ $k_1 = 4$ $\quad$ $k_2 = 5$

$k_1 = 4$ $\quad$ $k_2 = 5$ $\quad$ $k_3 = 3$

End of Solution

Q.48 A cylindrical rotor synchronous generator has steady state synchronous reactance of 0.7 pu and subtransient reactance of 0.2 pu. It is operating at $(1 + j0)$ pu terminal voltage with an internal emf of $(1 + j0.7)$ pu. Following a three-phase solid short circuit fault at the terminal of the generator, the magnitude of the subtransient internal emf (rounded off to 2 decimal places) is ________ pu.

Ans. (1.02)

$$\text{Prefault current, } I_0 = \frac{E_f - V_t}{jX_d} = \frac{1 + j0.7 - 1}{j0.7} = 1$$

Subtransient induced emf,

$$E_f'' = V_0 + jX_d'' I_0$$
$$= 1 + j0.2 \times 1 = 1 + j0.2$$
$$|E_f''| = \sqrt{1^2 + 0.2^2} = 1.02$$

End of Solution

Q.49 A cylindrical rotor synchronous generator with constant real power output and constant terminal voltage is supplying 100 A current to a 0.9 lagging power factor load. An ideal reactor is now connected in parallel with the load, as a result of which the total lagging reactive power requirement of the load is twice the previous value while the real power remains unchanged. The armature current is now _______ A (rounded off to 2 decimal places).

Ans. (125.29)

At $P_{constant}$, $I_{a1} \cos \phi_1 = I_{a2} \cos \phi_2$

$$\cos \phi_1 = 0.9$$

$$\tan \phi_1 = 0.484 = \frac{Q}{P}$$

$$\Rightarrow \quad \frac{2Q}{P} = 0.9686 = \tan \phi_2$$

$$\cos \phi_2 = 0.7182$$

$$\therefore \quad 100 \times 0.9 = I_{a2} \times 0.7182$$

$$\Rightarrow \quad I_{a2} = 125.29 \text{ A}$$

End of Solution

Q.50 A non-ideal diode is biased with a voltage of –0.03 V, and a diode current of I_1 is measured. The thermal voltage is 26 mV and the ideality factor for the diode is 15/13. The voltage, in V, at which the measured current increases to $1.5I_1$ is closest to:

(a) –4.50
(b) –0.09
(c) –0.02
(d) –1.50

Ans. (b)

$$I_1 = I_0\left[e^{-\frac{0.03}{15/13 \times 26 \text{ mV}}} - 1\right]$$

As, $V_D = -\text{ve}$ '1' can not be neglected in diode current equation

$$I_1 = I_0[e^{-30 \text{ mV}/30 \text{ mV}} - 1]$$

$$= I_0[e^{-1} - 1]$$

$$= -0.64\, I_0 \quad \text{...(i)}$$

$$1.5I_1 = I_0\left[e^{V_D/30 \text{ mV}} - 1\right]$$

$$-1.5 \times 0.64I_0 = I_0\left[e^{V_D/30 \text{ mV}} - 1\right]$$

$$-0.96 = e^{V_{D2}/30 \text{ mV}} - 1$$

$$1 - 0.96 = e^{V_D/30 \text{ mV}}$$

$$0.04 = e^{V_D/30 \text{ mV}}$$

$$30 \text{ mV} \ln(0.04) = V_D$$

$$V_D = -0.09 \text{ V}$$

End of Solution

Q.51 A stable real linear time-invariant system with single pole at p, has a transfer function $H(s) = \frac{s^2+100}{s-p}$ with a dc gain of 5. The smallest positive frequency, in rad/s at unity gain is closed to:

(a) 11.08
(b) 78.13
(c) 8.84
(d) 122.87

Ans. **(c)**

$$H(s) = \text{T.F.} = \frac{s^2+100}{s-p}$$

$$\text{D.C. gain} = 5$$

$$\Rightarrow \quad \frac{100}{-p} = 5 = p = -20$$

$$H(j\omega) = \frac{-\omega^2+100}{j\omega+20}$$

$$|H(j\omega)| = \frac{-\omega^2+100}{\sqrt{\omega^2+400}}$$

$$\frac{-\omega^2+100}{\sqrt{\omega^2+400}} = 1$$

$$\Rightarrow \quad \omega = 8.84 \text{ rad/sec.}$$

End of Solution

Q.52 Consider a permanent magnet dc (PMDC) motor which is initially at rest. At t = 0. a dc voltage of 5 V is applied to the motor. Its speed monotonically increases from 0 rad/s to 6.32 rad/s in 0.5 s and finally settles to 10 rad/s. Assuming that the armature inductance of the motor is negligible, the transfer function for the motor is

(a) $\frac{2}{0.5s+1}$
(b) $\frac{10}{0.5s+1}$
(c) $\frac{2}{s+0.5}$
(d) $\frac{10}{s+0.5}$

Ans. **(a)**

$$\text{Input} = 5 \text{ V}$$

$$\Rightarrow \quad R(s) = \frac{5}{s}$$

$$\frac{C(s)}{R(s)} = \text{T.F.} = \frac{K}{1+Ts}$$

$$C(s) = \frac{5K}{s(1+Ts)}$$

$$\underset{s\to 0}{Lt}\, sC(s) = 5\,K = 10 \Rightarrow K = 2$$

Steady state speed = 10 rad/sec. (Given)

$$C(s) = \frac{2}{1+0.5s} \times \frac{5}{s}$$

$$\Rightarrow \quad \underset{s \to 0}{Lt}\, sC(s) = 10$$

End of Solution

Q.53 Suppose for input $x(t)$ a linear time-invariant system with impulse response $h(t)$ produces output $y(t)$, so that $x(t) * h(t) = y(t)$. Further, if $|x(t)| * |h(t)| = z(t)$, which of the following statements is true?

(a) For some but not all $t \in (-\infty, \infty)$, $z(t) \le y(t)$

(b) For all $t \in (-\infty, \infty)$, $z(t) \ge y(t)$

(c) For all $t \in (-\infty, \infty)$, $z(t) \le y(t)$

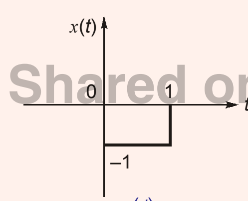
(d) For some but not all $t \in (-\infty, \infty)$, $z(t) \ge y(t)$

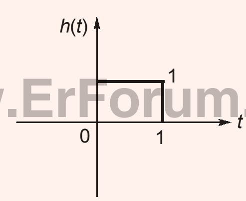
Ans. (b)

Since, $y(t) = x(t) + h(t)$

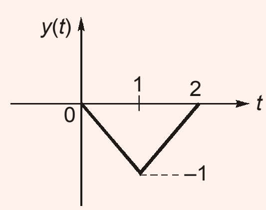
and $z(t) = |x(t)| \times |h(t)|$

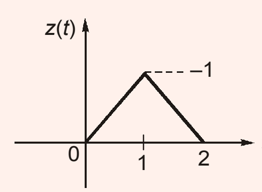
Case-1:



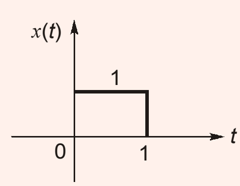


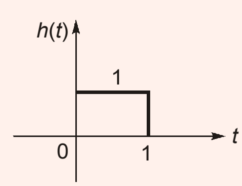
then, $y(t)$ and $z(t)$



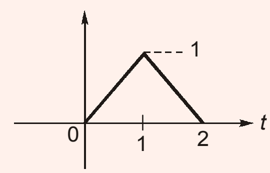


Case-2:





then, $y(t) = z(t)$



Thus, $z(t) \geq y(t)$, for all 't'

End of Solution

Q.54 The real numbers, x and y with $y = 3x^2 + 3x + 1$, the maximum and minimum value of y for $x \in [-2, 0]$ are respectively ________ .

(a) 7 and $\frac{1}{4}$

(b) 7 and 1

(c) −2 and $\frac{-1}{2}$

(d) 1 and $\frac{1}{4}$

Ans. (a)

$$y = 3x^2 + 3x + 1 \quad \text{in } [-2, 0]$$

$$\frac{\partial y}{\partial x} = 6x + 3, \qquad \frac{\partial^2 y}{\partial x^2} = 6$$

$$\frac{dy}{dx} = 0$$

$$6x + 3 = 0$$

$$x = \frac{-1}{2}$$

$$\frac{d^2y}{dx^2} = 6 > 0 \text{ minimum}$$

Maximum value of y in [−2, 0] is maximum $\{f(-2), f(0)\}$

$$\max\{7, 1\} = 7$$

Minimum value of y in [−2, 0]

$$\min\left\{\begin{matrix} f(-2) \\ \downarrow \\ 7 \end{matrix}, \begin{matrix} f(0) \\ \downarrow \\ 1 \end{matrix}, \begin{matrix} f\left(-\frac{1}{2}\right) \\ \downarrow \\ \frac{1}{4} \end{matrix}\right\} + = \frac{1}{4}$$

Maximum value 7, minimum value $\frac{1}{4}$.

End of Solution

Q.55 The number of purely real elements in a lower triangular representation of the given 3×3 matrix, obtained through the given decomposition is

$$\begin{bmatrix} 2 & 3 & 3 \\ 3 & 2 & 1 \\ 3 & 1 & 7 \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{12} & a_{22} & 0 \\ a_{13} & a_{23} & a_{33} \end{bmatrix} \begin{bmatrix} a_{11} & 0 & 0 \\ a_{12} & a_{22} & 0 \\ a_{13} & a_{23} & a_{33} \end{bmatrix}^T$$

(a) 6
(b) 5
(c) 8
(d) 9

Ans. (d)

$$\begin{bmatrix} 2 & 3 & 3 \\ 3 & 2 & 1 \\ 3 & 1 & 7 \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} u_{11} & u_{12} & u_{13} \\ 0 & u_{22} & u_{23} \\ 0 & 0 & u_{33} \end{bmatrix}$$

Consider $u_{11} = u_{22} = u_{33} = 1$

$$\begin{bmatrix} 2 & 3 & 3 \\ 3 & 2 & 1 \\ 3 & 1 & 7 \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} 1 & u_{12} & u_{13} \\ 0 & 1 & u_{23} \\ 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 3 & 3 \\ 3 & 2 & 1 \\ 3 & 1 & 7 \end{bmatrix} = \begin{bmatrix} l_{11} & l_{11}u_{12} & l_{11}u_{13} \\ l_{21} & l_{21}u_{12}+l_{22} & l_{21}u_{13}+l_{22}u_{23} \\ l_{31} & l_{31}u_{12}+l_{32} & l_{31}u_{13}+l_{32}u_{23}+l_{33} \end{bmatrix}$$

$l_{11} = 2$ $\quad l_{11}u_{12} = 3$ $\quad l_{11}u_{13} = 3$

$l_{21} = 3$ $\quad 2u_{12} = 3$ $\quad 2u_{13} = 3$

$l_{31} = 3$ $\quad u_{12} = \frac{3}{2}$ $\quad u_{13} = \frac{3}{2}$

$l_{21}u_{12} + l_{22} = 2$ $\quad l_{21}u_{13} + l_{22}u_{23} = 1$

$(3)\left(\frac{3}{2}\right) + l_{22} = 2$ $\quad (3)\left(\frac{3}{2}\right) + \left(-\frac{5}{2}\right)u_{23} = 1$

$l_{22} = -\frac{5}{2}$ $\quad u_{23} = \frac{7}{5}$

$l_{31}u_{12} + l_{32} = 1$ $\quad l_{31}u_{13} + l_{32}u_{23} + l_{33} = 7$

$(3)\left(\frac{3}{2}\right) + l_{32} = 1$ $\quad (3)\left(\frac{3}{2}\right) + \left(-\frac{7}{2}\right)\left(\frac{7}{5}\right) + l_{33} = 7$

$l_{32} = -\frac{7}{2}$ $\quad l_{33} = \frac{74}{10}$

$$L = \begin{bmatrix} 2 & 0 & 0 \\ 3 & -5/2 & 0 \\ 3 & -7/2 & 74/10 \end{bmatrix}$$

The number of purely real elements of lower triangular matrix are 9.

End of Solution

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