Electrical Engineering
(Afternoon Session)
Exam Date- 02-02-2025

SECTION - A GENERAL APTITUDE

Q.1 Kavya _____ go to work yesterday as she _____ feeling well. Select the most approrpriate option to complete the above sentence.

(a) didn't; isn't
(b) wouldn't; wasn't
(c) wasn't; wasn't
(d) couldn't; wasn't

Ans. (d)

End of Solution

Q.2 Good : Evil : : Genuine : ?

Select the most appropriate option to complete the analogy.

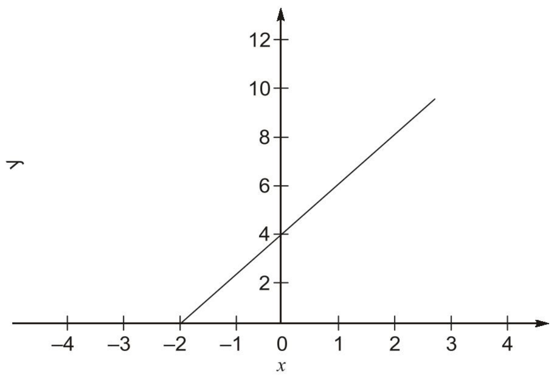
(a) Counterfeit
(b) contraband
(c) Counterfoil
(d) counterpart

Ans. (a)

End of Solution

Q.3 The relationship between two variables x and y is given by $x + py + q = 0$ and is shown in the figure. Find the values of p and q.

Note : The figure shown is representative.



(a) $p = -\frac{1}{2}; q = 2$
(b) $p = 2 ; q = -2$
(c) $p = \frac{1}{2}; q = 4$
(d) $p = 2 ; q = 4$

Ans. (a)

$$x + py + q = 0$$

$$x - \frac{1}{2}y + 2 = 0$$

$$2x - y + 4 = 0$$

$\therefore$ Slope = 2

From diagram also,

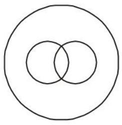
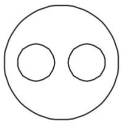
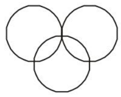
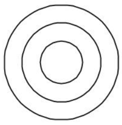
Slope = 2

End of Solution

Q.4 Each row of Column-I has three items and each item is represented by a circle in Column-II. The arrangement of circles in Column-II represents the relationship among the items in Column-I.

Identify the option that has the most appropriate match between Column-I and Column-II.

Note: The figure shown are representative.

Column-I	Column-II
(1) Animal, Zebra, Giraffe	**(P)** 
(2) Director, Producer, Actor	**(Q)** 
(3) Word, Sentence, Novel	**(R)** 
(4) Pianist, Guitarist, Instrumentalist	**(S)** 

(a) (1) – (Q); (2) – (P); (3) – (S); (4) – (R)
(b) (1) – (Q); (2) – (R); (3) – (S); (4) – (P)
(c) (1) – (S); (2) – (P); (3) – (R); (4) – (Q)
(d) (1) – (R); (2) – (S); (3) – (Q); (4) – (P)

Ans. (b)

(1) – (Q); (2) – (R); (3) – (S); (4) – (P)

End of Solution

Q.5 What is the value of $\left(\dfrac{3^{81}}{27^{4}}\right)^{1/3}$?

(a) 3^{13}
(b) 3^{96}
(c) 3^{23}
(d) 3^{69}

Ans. (c)

$$\left(\frac{3^{81}}{27^{4}}\right)^{1/3} = \left(\frac{3^{81}}{(3^{3})^{4}}\right)^{1/3} = \left(\frac{3^{81}}{3^{12}}\right)^{1/3}$$

$$= (3^{81-12})^{1/3} = (3^{69})^{1/3} = 3^{23}$$

End of Solution

Q.6 Identify the option that has the most appropriate sequence such that a coherent paragraph is formed :

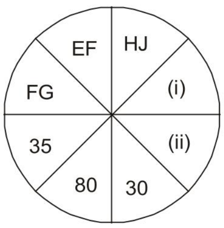
(P) It is because deer, like most of the animals that tigers normally prey on, run much faster! It simply means, another day of empty stomach for the big cats.
(Q) Tigers spend most of their life searching for food.
(R) If they trace the scent of deer, tigers follow the trail, chase the deer for a mile or two in the dark, and yet may not catch them.
(S) For several nights, they relentlessely prowl through the forest, hunting for a trail that may lead to their prey.

(a) S → P → R → Q
(b) R → P → S → Q
(c) Q → S → R → P
(d) P → Q → S → R

Ans. (c)

End of Solution

Q7 In the given figure, EF and HJ are coded as 30 and 80, respectively. Which one among the given options is most appropriate for the entires marked (i) and (ii)?



(a) (i) EH; (ii) 40
(b) (i) JK: (ii) 36
(c) (i) EG; (ii) 42
(d) (i) PS; (ii) 14

Ans. (c)

$$\overset{5}{E}\ \overset{7}{G} \rightarrow 5\times 7 = 35$$

$$\overset{6}{F}\ \overset{7}{G} \rightarrow 6\times 7 = 42$$

End of Solution

Q8 Scores obtained by two students P and Q in seven courses are given in the table below. Based on the information given in the table, which one of the following statements is INCORRECT?

P	22	89	50	45	78	60	39
Q	35	65	60	56	81	45	50

(a) Average score of P is less than the average score of Q.
(b) Median score of P is same as the median score of Q.
(c) Difference between the maximum and minimum scores of P is greater than the difference between the maximum and minimum scores of Q.
(d) Median score and the average score of Q are same.

Ans. **(b)**

Median of $P = 50$
Median of $Q = 56$

$\therefore$ Median of score of P is same as the median score of Q is incorrect.

End of Solution

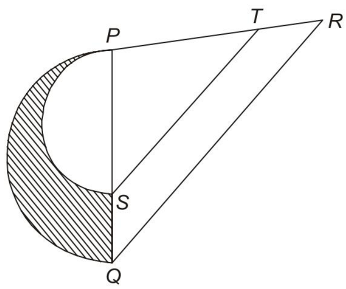
Q9 Spheres of unit diameter are centered at (l, m, n) where l, m and n take every possible integer values.
The distance between two spheres is computed from the center of one sphere to the center of the other sphere. For a given sphere, x is the distance to its nearest sphere and y is the distance to its next nearest sphere. The value of $\frac{y}{x}$ is :

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

Ans. **(c)**

End of Solution

Q10 In the triangle PQR, the lengths of PT and TR are in the ratio of 3 : 2.
ST is parallel to QR. Two semi-circles are drawn with PS and PQ as diameters, as shown in the figure.
Which one of the following statements is true about the shaded area PQS?
Note : The figure shown is representative.



(a) The shaded area is $\frac{16}{9}$ times the area of the semi-circle with the diameter PS.

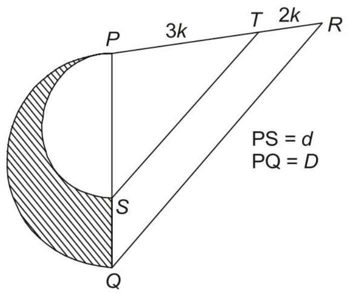
(b) The shaded area is equal to the area of the semi-circle with the diameter PS.

(c) The shaded area is $\frac{14}{9}$ times the area of the semi-circle with the diameter PS.

(d) The shaded area is $\frac{14}{25}$ times the area of the semi-circle with the diameter PQ.

Ans. (a)

PT : TR = 3 : 2



$$\Delta PST \sim \Delta PQR$$

$$\frac{PT}{PR} = \frac{PS}{PQ}$$

$$\frac{3k}{5k} = \frac{PS}{PQ}$$

$$\frac{PS}{PQ} = \frac{3k}{5k} = \frac{3}{5}$$

$$PQ = \frac{5}{3}PS$$

Area of shaded = Area of big semi-circle – Area of small semi-circle

$$= \frac{1}{2}\pi\left(\frac{D}{2}\right)^2 - \frac{1}{2}\pi\left(\frac{d}{2}\right)^2$$

$$= \frac{\pi}{8}\left(D^2 - d^2\right) = \frac{16}{9}\frac{\pi}{8}PS^2$$

End of Solution

SECTION - B TECHNICAL

Q.11 Consider the set S of points $(x, y) \in R^2$ which minimize the real valued function

$$f(x, y) = (x + y - 1)^2 + (x + y)^2$$

Which of the following statements is true about the set S?

(a) The number of elements in the set S is finite and more than one.

(b) The numebr of elements in the set S is infinite.

(c) The set S is empty.

(d) The number of elements in the set S is exactly one.

Ans. (b)

$$f(x, y) = (x + y - 1)^2 + (x + y)^2$$
$$= x^2 + (y - 1)^2 + 2(x)(y - 1) + x^2 + y^2 + 2xy$$
$$= 2x^2 + 2y^2 + 4xy - 2x - 2y + 1$$

Finding stationary points :

$$\frac{\partial f}{\partial x} = 4x + 4y - 2 = 0$$

$$\frac{\partial f}{\partial y} = 4y + 4x - 2 = 0$$

$\Rightarrow$ $x + y = 2$

$$r = f_{xx} = 4 > 0$$
$$S = f_{xy} = 0, \ t = f_{yy} = 4$$
$$rt - S^2 = (4)(4) - 0^2 = 16 > 0$$

$\because$ $rt - S^2 > 0, \ r > 0$ at all

The infinite stationary points.

$\therefore$ It is minimum at infinite points.

Solving we get infinite points $P(x, y)$

End of Solution

Q.12 Let v_1 and v_2 be the two eigen vectors corresponding to distinct eigen values of a 3×3 real symmetric matrix. Which one of the following statements is true?

(a) $v_1^T v_2 \neq 0$

(b) $v_1^T v_2 = 0$

(c) $v_1 + v_2 = 0$

(d) $v_1 - v_2 = 0$

Ans. (b)

Eigen vectors of symmetric matrix of 3×3.

Corresponding to distinct λ are orthogonal to each other.

$\therefore$ $V_1^T V_2 = 0$

End of Solution

Q.13 Let $A=\begin{bmatrix}1 & 1 & 1\\ -1 & -1 & -1\\ 0 & 1 & -1\end{bmatrix}$ and $b=\begin{bmatrix}1/3\\ -1/3\\ 0\end{bmatrix}$, then the system of linear equations $Ax = b$ has

(a) a unique solution
(b) infinitely many solutions
(c) a finite number of solutions
(d) no solution

Ans. **(b)**

$$AX = B$$

$$\begin{bmatrix}1 & 1 & 1\\ -1 & -1 & -1\\ 0 & 1 & -1\end{bmatrix}\begin{bmatrix}x\\ y\\ z\end{bmatrix} = \begin{bmatrix}\frac{1}{3}\\ -\frac{1}{3}\\ 0\end{bmatrix}$$

$$C = [A : B] = \begin{bmatrix}1 & 1 & 1 & \vdots & \frac{1}{3}\\ -1 & -1 & -1 & \vdots & -\frac{1}{3}\\ 0 & 1 & -1 & \vdots & 0\end{bmatrix}$$

$R_2 \to R_2 + R_1$
$$\begin{bmatrix}1 & 1 & 1 & \vdots & \frac{1}{3}\\ 0 & 0 & 0 & \vdots & 0\\ 0 & 1 & -1 & \vdots & 0\end{bmatrix}$$

$R_2 \leftrightarrow R_3$
$$\begin{bmatrix}1 & 1 & 1 & \vdots & \frac{1}{3}\\ 0 & 1 & -1 & \vdots & 0\\ 0 & 0 & 0 & \vdots & 0\end{bmatrix}$$

$\Rightarrow$ $\rho(A) = 2 = \rho(A \mid B) < n = 3$

System has infinite solutions.

End of Solution

Q.14 Let $P = \begin{bmatrix} 2 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ and let I be the identity matrix. Then P^2 is equal to

(a) $2P - I$
(b) P
(c) I
(d) $P + I$

Ans. (a)

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

$$|P - \lambda I| = \begin{vmatrix} 2-\lambda & 1 & 0 \\ -1 & 0-\lambda & 0 \\ 0 & 0 & 1-\lambda \end{vmatrix} = 0$$

$$|P - \lambda I| = (1 - \lambda)\,[-2\lambda + \lambda^2 + 1] = 0$$

By C-H Theorem : Replace λ by P

$$= (I - P)\,(-2P + P^2 + I) = 0$$

$\Rightarrow P = I, \quad P^2 - 2P + I = 0$

$\Rightarrow \qquad P^2 = 2P - I$

End of Solution

Q.15 Consider discrete random variable X and Y with probabilities as follows:

$$P(X = 0 \text{ and } Y = 0) = \frac{1}{4}$$

$$P(X = 1 \text{ and } Y = 1) = \frac{1}{8}$$

$$P(X = 0 \text{ and } Y = 1) = \frac{1}{2}$$

$$P(X = 1 \text{ and } Y = 1) = \frac{1}{8}$$

Given X = 1, the expected value of Y is

(a) $\frac{1}{4}$
(b) $\frac{1}{2}$
(c) $\frac{1}{8}$
(d) $\frac{1}{3}$

Ans. **(b)**

$$E\left[\frac{Y}{K=1}\right] = \sum_j Y_j P\left(\frac{Y/y_j}{X=1}\right)$$

$$= 0\times P\left(\frac{Y=0}{X=1}\right)+1\times P\left(\frac{Y=1}{X=1}\right)$$

$$= 0\times\frac{P(X=1,Y=0)}{P(X=1)}+1\times\frac{P(X=1,Y=1)}{P(X=1)}$$

$$= 0\times\frac{\frac{1}{8}}{\frac{1}{4}}+1\times\frac{\frac{1}{8}}{\frac{1}{4}}$$

$$= 0+\frac{1}{2}=\frac{1}{2}$$

End of Solution

Q.16 Which one of the following statements is true about the small signal voltage gain of a MOSFET based single stage amplifier?

(a) Common source and common gate amplifiers are both inverting amplifiers

(b) Common source and common gate amplifiers are both non-inverting amplifiers

(c) Common source amplifier is inverting and common gate amplifier is non-inverting amplifier

(d) Common source amplifiers is non-inverting and common gate amplifier is inverting amplifier

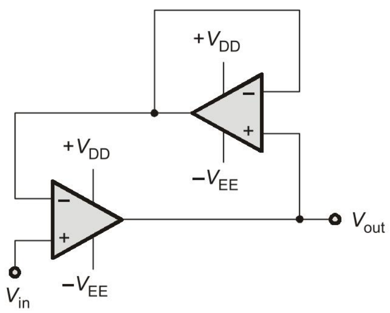
Ans. **(c)**

MOSFET CS amplifier is inverting.

CG amplifier is non-inverting.

End of Solution

Q.17 Assuming ideal op-smps, the circuit represents is



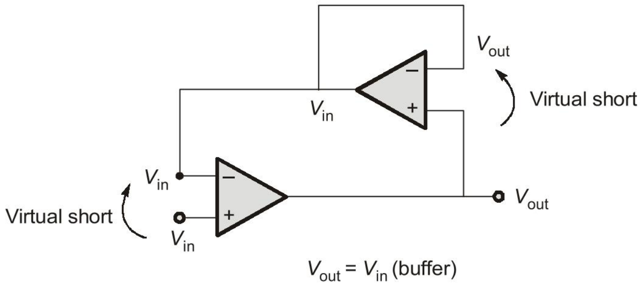
(a) summing amplifier

(b) difference amplifier

(c) logarithmic amplifier

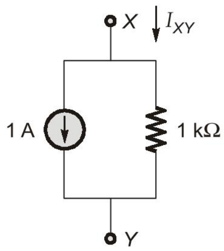
(d) buffer

Ans. (d)

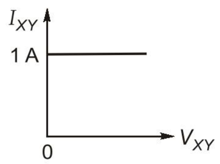


End of Solution

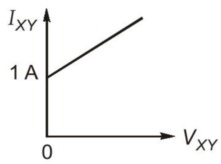
Q.18 The I-V characteristics of the elements between the nodes X and Y is best depicted



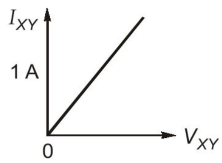
(a)



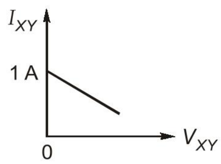
(b)



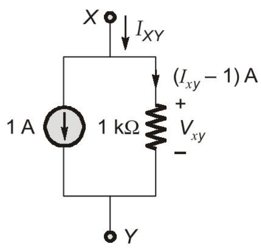
(c)



(d)



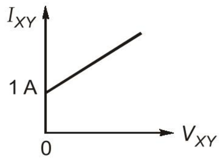
Ans. (b)



$$V_{xy} = (I_{xy} - 1)1k$$

$V_{xy} = 0$ $\qquad 0 = (I_{xy} - 1)1k \Rightarrow I_{xy} = 1$

$V_{xy} = 1$ kV $\qquad 1k = (I_{xy} - 1)1k \Rightarrow I_{xy} = 2$



V_{xy} = 5 kV

$$5k = (I_{xy} - 1)1k \quad \Rightarrow \quad I_{xy} = 6$$

End of Solution

Q.19 A nullator is defined as a circuit element where the voltage across the device and the current through the device are both zero. A series combination of a nullator and a resistor of value, R, will behave as a

(a) resistor of value R
(b) nullator
(c) open circuit
(d) short circuit

Ans. (b)

In a series combination of nullator and a resistor, the current through the entire series circuit must be zero.

If no current flows through R, then the voltage across R is simply $V = I.R = 0$ V. Since, both voltages across the resistance is zero and current through it is zero, the entire combination behaves like a Nullator itself.

End of Solution

Q.20 Consider a discrete-time linear time-invariant (LTI) system, $\boldsymbol{S}$, where

$$y[n] = \boldsymbol{S}\{x(\mathrm{n})\}.$$

Let
$$S\{\delta[n]\} = \begin{cases} 1, & n \in \{0, 1, 2\} \\ 0, & \text{otherwise} \end{cases}$$

where $\delta[n]$ is the discrete-time unit impulse function. For an input signal $x[n]$, the output $y[n]$ is

(a) $x[n] + x[n-1] + x[n-2]$
(b) $x[n-1] + x[n] + x[n+1]$
(c) $x[n] + x[n+1] + x[n+2]$
(d) $x[n+1] + x[n+2] + x[n+3]$

Ans. (a)

Given that the system is LTI and for i/p $\delta(n) \xrightarrow{\text{system}}$ O/P = {1, 1, 1}

i.e.,
$$h(n) = \text{impulse response of system}$$
$$= \delta(n) + \delta(n-1) + \delta(n-2)$$

As we know,
$$y(n) = x(n) * h(n)$$
$$= x(n) * [\delta(n) + \delta(n-1) + \delta(n-2)]$$
$$= x(n) + x(n-1) + x(n-2)$$

End of Solution

Q.21 Consider a continuous-time signal

$$x(t) = -t^2 \{u(t+4) - u(t-4)\}$$

where $u(t)$ is the continuous-time unit step function. Let $\delta(t)$ be the continuous-time unit impulse function. The value of

$$\int_{-\infty}^{\infty} x(t)\, \delta(t+3) dt$$

is

(a) –9 (b) 9

(c) 3 (d) –3

Ans. **(a)**

$$I = \int_{-\infty}^{\infty} x(t)\delta(t+3)dt = x(-3)$$

$$= \{-t^2[u(t+4) - u(t-4)]\}_{t=-3}$$

$$= -(-3)2[u(1) - u(-7)]\}$$

$$= -9[1 - 0] = -9$$

End of Solution

Q.22 Selected data points of the step response of a stable first-order linear time-invariant (LTI) system are given below. The closest value of the time-constant, in sec, of the system is

Time (sec)	0.6	1.6	2.6	10	∞
Output	0.78	1.65	2.18	2.98	3

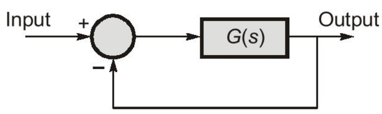
(a) 1 (b) 2

(c) 3 (d) 4

Ans. **(b)**

End of Solution

Q.23 The Nyquist plot of a strictly stable $G(s)$ having the numerator polynomial as $(s - 3)$ encircles the critical point –1 once in the anti-clockwise direction. Which one of the following statements on the closed-loop system shown in figure, is correct?



(a) The system stability cannot be ascertained.
(b) The system is marginally stable.
(c) The system is stable
(d) The system is unstable.

Ans. **(d)**

$$P = 0, \quad N = +1$$
$$N \neq P$$

$\therefore$ Closed loop system is unstable.

End of Solution

Q.24 During a power failure, a domestic household uninterruptible power supply (UPS) supplies AC power to a limited number of lights and fans in various rooms. As per a Newton-Raphson load-flow formulation, the UPS would be represented as a

(a) Slack bus
(b) PV bus
(c) PQ bus
(d) PQV bus

Ans. **(a)**

End of Solution

Q.25 Which one of the following figures represents the radial electric field distribution E_R caused by a spherical cloud of electrons with a volume charge density. $\rho = -3\rho_0$ for $0 \leq R \leq a$ (both ρ_0, a are positive and R is the radial distance) and $\rho = 0$ for $R > a$?

(a) Fig. (i)
(b) Fig. (ii)
(c) Fig. (iii)
(d) Fig. (iv)

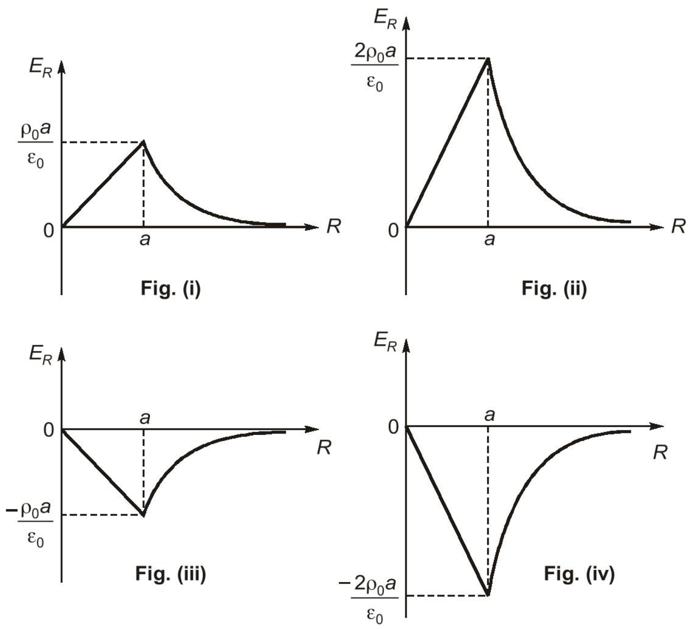
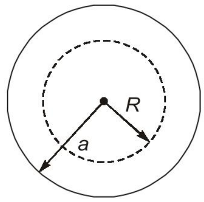


Fig. (i) Fig. (ii) Fig. (iii) Fig. (iv)

Ans. (c)

Given : $\rho_V = \begin{cases} -3\rho_0 \text{ c/m}^3 & 0 \le R \le a \\ 0 & R > a \end{cases}$

Case (i) : $R \le a$:



$$\oint \bar{D}\cdot d\bar{S} = Q_{enc} = \int \rho_V dv$$

$$Q_{enc} = \int \rho_V dv = -\int 3\rho_0 R^2 \sin\theta\, d\theta\, d\phi\, dR$$

$\Rightarrow$ $$Q_{enc} = -3\rho_0 \int_{R=0}^{R} R^2 dR \int_{\theta=0}^{\pi} \sin\theta d\theta \int_{\phi=0}^{2\pi} d\phi$$

$\Rightarrow$ $$Q_{enc} = -3\rho_0 \cdot \frac{R^3}{3}\bigg|_0^R - \cos\theta\big|_0^{\pi} \cdot \phi\big|_0^{2\pi}$$

$\Rightarrow$ $$Q_{enc} = -\rho_0.a^3.2.2\pi = -(4\pi R^3)\rho_0$$

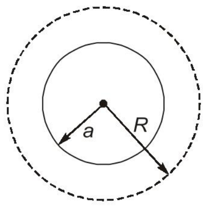
$$\oint \bar{D}\cdot d\bar{S} = D \times 4\pi R^2$$

= $$D.4\pi R^2 = -4\pi R^3 \rho_0$$

$\Rightarrow$ $$D = -\rho_0 R$$

$\Rightarrow$ $$E = -\frac{\rho_0 R}{\epsilon_0}$$

$\Rightarrow$ $$\bar{E} = -\frac{\rho_0 R}{\epsilon_0}\hat{a}_r$$



Case (ii) : $R > a$

$$\oint \bar{D}\cdot d\bar{S} = Q_{enc} = \int \rho_V dv$$

$$Q_{enc} = \int -3\rho_0.R^2 \sin\theta\, d\theta\, d\phi\, dR$$

$\Rightarrow$ $$Q_{enc} = -3\rho_0 \int_{R=0}^{a} R^2 dR \int_{\theta=0}^{\pi} \sin\theta d\theta \int_{\phi=0}^{2\pi} d\phi$$

$\Rightarrow$ $$Q_{enc} = -3\rho_0 \cdot \frac{R^3}{3}\bigg|_0^a - \cos\theta\big|_0^{\pi} \cdot \phi\big|_0^{2\pi} = -\rho_0 a^3 \pi.2\pi = -4\pi a^3 \rho_0$$

$$\oint \bar{D}\cdot d\bar{S} = D \times 4\pi R^2$$

$\therefore$ $$D.4\pi R^2 = -4\pi a^3 \rho_0$$

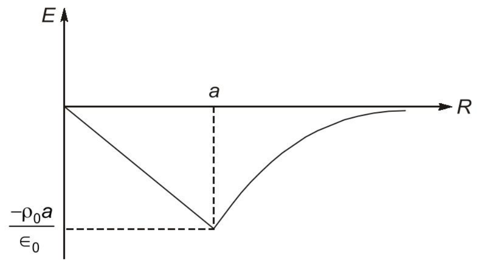
$\Rightarrow$ $$D = -\frac{\rho_0 a^3}{R^2}$$

$\Rightarrow$ $$E = -\frac{\rho_0 a^3}{\in R^2}$$

$\Rightarrow$ $$\bar{E} = \frac{-\rho_0 a^3}{\epsilon_0 R^2}\hat{a}_R$$

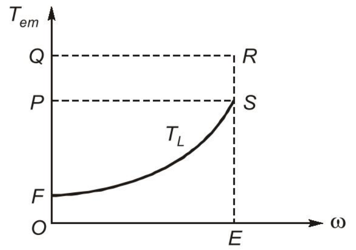
Hence, $\bar{E} = \begin{cases} \dfrac{-\rho_0 R}{\epsilon_0}\hat{a}_r, & 0 \le R \le a \\ \dfrac{-\rho_0 a^3}{\epsilon_0 R^2}\hat{a}_r, & R > a \end{cases}$

Graph :



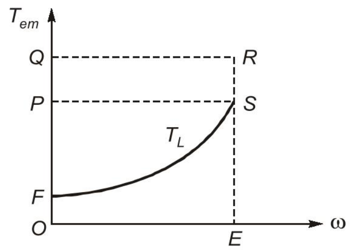
End of Solution

Q.26 The operating region of the developed torque (T_{em}) and speed (ω) of an induction motor drive is given by the shaded region OQRE in the figure. The load torque (T_L) characteristic is also shown. The motor drive moves from the initial operating point O to the final operating point S. Which one of the following trajectories will take the shortes time?



(a) O – Q – R – S
(b) O – P – S
(c) O – E – S
(d) O – F – S

Ans. **(a)**



The shortest time will be taken if motor follows the path that maximize the net accelerating torque (Tem-T_L) at all points.
Trajectories which takes shortest time.

End of Solution

Q.27 The input voltage $v(t)$ and current $i(t)$ of a converter are given by,

$v(t) = 300 \sin(\omega t)$ V

$$i(t) = 10\sin\left(\omega t - \frac{\pi}{6}\right) + 2\sin\left(3\omega t + \frac{\pi}{6}\right) + \sin\left(5\omega t + \frac{\pi}{2}\right) A$$

where, $\omega = 2\pi \times 50$ rad/s. The input power factor of the converter is closest to

(a) 0.845
(b) 0.867
(c) 0.887
(d) 1.0

Ans. (a)

$$v = 300 \sin(\omega t)$$

$$i = 10\sin\left(\omega t - \frac{\pi}{6}\right) + 2\sin\left(3\omega t + \frac{\pi}{6}\right) + \sin\left(5\omega t + \frac{\pi}{2}\right) \text{A}$$

$$P_1 = \frac{300}{\sqrt{2}} \times \frac{10}{\sqrt{2}} \times \cos\left(\frac{\pi}{6}\right) = 1299 \text{ W}$$

$$I_{RMS} = \sqrt{\frac{1}{2}(10^2 + 2^2 + 1^2)} = 7.245$$

$$S = V_{RMS} \cdot I_{RMS} = \frac{300}{\sqrt{2}} \times 7.245 = 1537.27 \text{ V}$$

$$\text{PF} = \frac{P}{S} = \frac{P_1}{S} = \frac{1299}{1537.27} = 0.845$$

End of Solution

Q.28 Instruments required to synchronize an alternator to the grid is/are

(a) Voltmeter
(b) Wattmeter
(c) Synchroscope
(d) Stroboscope

Ans. (a, c)

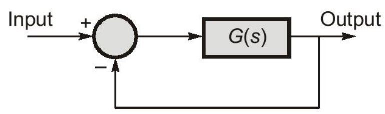
To synchronise alternator to grid, synchroscope and voltmeter are used.

End of Solution

Q.29 The open-loop transfer function of the system shown in the figure, is

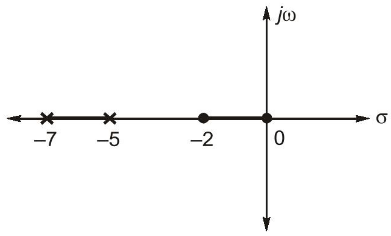
$$G(s) = \frac{Ks(s+2)}{(s+5)(s+7)}$$

For $K \geq 0$, which of the following real axis point(s) is/are on the rool locus?



(a) –1
(b) –4
(c) –6
(d) –10

Ans. **(a, c)**



Root locus exist between –7 to –5 and –2 to 0.

End of Solution

Q.30 A continuous time periodic signal $x(t)$ is

$$x(t) = 1 + 2\cos 2\pi t + 2\cos 4\pi t + 2\cos 6\pi t$$

If T is the period of $x(t)$, then $\frac{1}{T}\int_0^T |x(t)|^2\, dt$ = _____ (round off to the nearest integer).

Ans. **(7)**

$$\frac{1}{T}\int_0^T |x(t)|^2\, dt = \text{Power of } x(t)$$

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

$$= 1 + 2 + 2 + 2 = 7$$

End of Solution

Q.31 The maximum percentage error in the equivalent resistance of two parallel connected resistors of 100 Ω and 900 Ω with each having a maximum 5% error is ________ %. (Round off to nearest integer value)

Ans. **(5)**

Given resistors :

$$R_1 = 100 \pm 5\% = (100 \pm 5)\ \Omega$$

$$R_2 = 900 \pm 5\% = (900 \pm 45)\ \Omega$$

$$R_{eq} = R_1 \parallel R_2 = 100 \parallel 900 = 90\ \Omega$$

For parallel combination,

$$\frac{\delta R_{eq}}{R_{eq}} = \pm\left[\frac{R_{eq}}{R_1} \times \frac{\delta R_1}{R_1} \times \frac{R_{eq}}{R_2} \times \frac{\delta R_2}{R_2}\right]$$

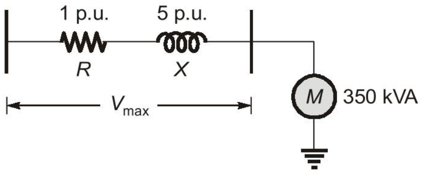
$$= \pm\left[\frac{90}{100} \times 5\% + \frac{90}{900} \times 5\%\right]$$

$$= \pm 5\%$$

End of Solution

Q.32 Consider a distribution feeder, with R/X ratio of 5. At the receiving end, a 350 kVA load is connected. The maximum voltage drop will occur from the sending end to the receiving end, when the power factor of the load is ________ (round off to three decimal places).

Ans. (0.980)(0.975 to 0.985)



$$R\cos\phi + \sin\phi = -R\sin\phi + \cos\phi = 0$$

$$\tan\phi = \frac{X}{R}$$

$$\phi = \tan^{-1}\left(\frac{X}{R}\right) = \tan^{-1}\left[\frac{1}{5}\right] = 11.31°$$

$$\cos\phi = \cos\left[\tan^{-1}\left(\frac{X}{R}\right)\right] = 0.9805$$

End of Solution

Q.33 The bus impedance matrix of a 3-bus system (in pu) is

$$Z_{bus} = \begin{bmatrix} j0.059 & j0.061 & j0.038 \\ j0.061 & j0.093 & j0.066 \\ j0.038 & j0.066 & j0.110 \end{bmatrix}$$

A symmetrical fault (through a fault impedance of $j0.007$ p.u.) occurs at bus 2. Neglecting pre-fault loading conditions, the voltage at bus 1, during the fault is ________ p.u. (round off to three decimal places).

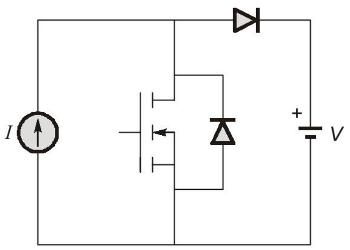
Ans. (0.39)(0.38 to 0.40)

$$V_2 = V_1 - I_f Z_{12} = V_1 - \frac{1}{(Z_{22}+Z_f)} \times Z_{12}$$

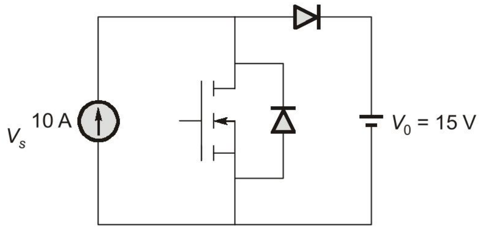
$$= 1\angle 0° - \frac{1}{j(0.007+0.93)} \times j0.061 = 0.39$$

End of Solution

Q.34 In the circuit with ideal devices, the power MOSFET is operated with a duty cycle of 0.4 in a switching cycle with I = 10 A and V = 15 V. The power delivered by the current source, in W, is ______________. (round off to the nearest integer)



Ans. (90)



Boost Converter: Continuous condition.

$$V_0 = \frac{V_s}{1-\alpha}$$

$$\frac{V_0}{V_s} = \frac{I_s}{I_0} = \frac{1}{1-\alpha}$$

$$I_0 = (1 - \alpha)I_s = (1 - 0.4)10 = 6 \text{ A}$$
$$P_0 = V_0 I_0 = 15 \times 6 = 90 \text{ W}$$

End of Solution

Q.35 The induced emf in a 3.3 kV, 4-pole, 3-phase, star-connected synchronous motor is considered to be equal and in phase with the terminal voltage under no load condition. On application of a mechanical load, the induced emf phasor is deflected by an angle of 2° mechanical with respect to the terminal voltage phasor. If the synchronous reactance is 2 Ω, and stator resistance is negligible, then the motor armature current magnitude, in ampere, during loaded condition, is closest to _______. (round off to two decimal places)

Ans. **(66.49) (66.25 to 66.75)**

$$(E_f)_{NL} = |V| = \frac{3.3\times10^3}{\sqrt{3}},\ X_S = 2\ \Omega$$

$$\delta = 2^\circ \text{ mechanical} = 2^\circ \times \frac{4}{2} = 4^\circ \text{ electrical}$$

$$\frac{3.3\times10^3}{\sqrt{3}}\angle -4^\circ = \frac{3.3\times10^3}{\sqrt{3}}\angle 0^\circ - j\vec{I}_a(2)$$

$$\vec{I}_a = \frac{\frac{3.3\times10^3}{\sqrt{3}}\angle 0^\circ - \frac{3.3\times10^3}{\sqrt{3}}\angle -4^\circ}{j2}$$

$$= 66.49\angle -2^\circ$$

End of Solution

Q.36 Let X and Y be continuous random variables with probability density functions $P_X(x)$ and $P_Y(y)$, respectively. Further, let $Y = X^2$ and $P_X(x) = \begin{cases} 1, & x \in (0,1] \\ 0, & \text{otherwise} \end{cases}$.

Which one of the following options is correct?

(a) $P_Y(y) = \begin{cases} \dfrac{1}{2\sqrt{y}}, & y \in (0,1] \\ 0, & \text{otherwise} \end{cases}$

(b) $P_Y(y) = \begin{cases} 1, & y \in (0,1] \\ 0, & \text{otherwise} \end{cases}$

(c) $P_Y(y) = \begin{cases} 1.5\sqrt{y}, & y \in (0,1] \\ 0, & \text{otherwise} \end{cases}$

(d) $P_Y(y) = \begin{cases} 2y, & y \in (0,1] \\ 0, & \text{otherwise} \end{cases}$

Ans. **(a)**

$$Y = X^2$$

$$dy = 2Xdx \Rightarrow \frac{dx}{dy} = \frac{1}{2x}$$

$$P_Y(Y) = 1 \cdot \frac{1}{2x} = \frac{1}{2\sqrt{y}}$$

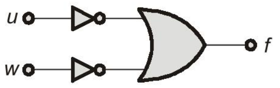
$$P_Y(Y) = \begin{cases} \dfrac{1}{2\sqrt{y}}, & y \in (0,1) \\ 0, & \text{otherwise} \end{cases}$$

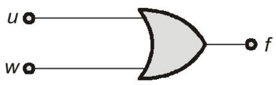
End of Solution

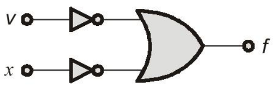
Q.37 A Boolean function is given as

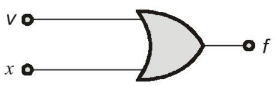
$f = (\bar{u} + \bar{v} + \bar{w} + \bar{x}) \cdot (\bar{u} + \bar{v} + \bar{w} + x) \cdot (\bar{u} + v + \bar{w} + \bar{x}) \cdot (\bar{u} + v + \bar{w} + x)$

The simplified form of this function is represented by

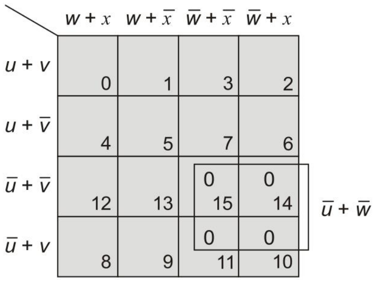
(a) 

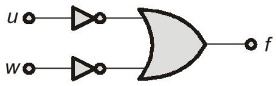
(b) 

(c) 

(d) 

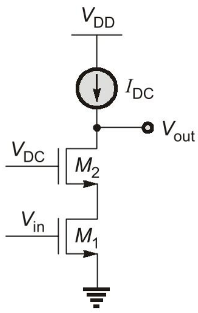
Ans. **(a)**





End of Solution

Q.38 In the circuit, I_{DC} is an ideal current source. The transistors M_1 and M_2 are assumed to be biased in saturation, wherein V_{in} is the input signal and V_{DC} is fixed DC voltage. Both transistors have a small signal resistance of r_{ds} and trans-conductance of g_m. The small signal output impedance of this circuit is



(a) $2r_{ds}$

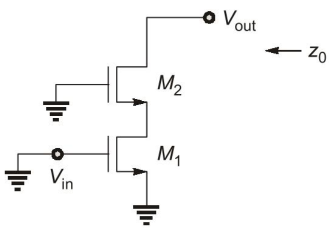
(b) $\frac{1}{g_m} + r_{ds}$

(c) $g_m r_{ds}^2 + 2r_{ds}$

(d) inifinity

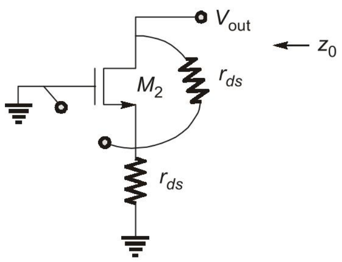
Ans. **(c)**

AC Analysis :



To calculate Z_0 $V_{in} = 0$

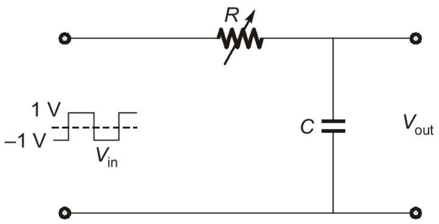
Replace M_1 transistor as active load

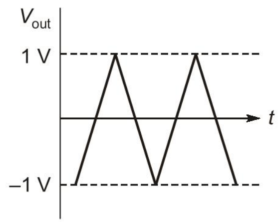


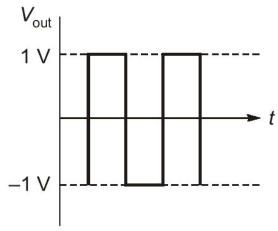
$$Z_0 = r_{ds} + r_{ds} + g_m r_{ds} r_{ds}$$
$$= 2r_{ds} + g_m r^2_{ds}$$

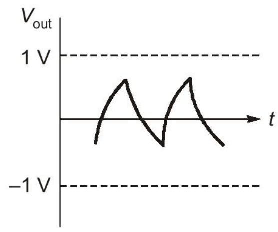
End of Solution

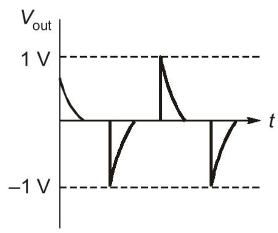
Q.39 In the circuit, shown below, if the values of *R* and *C* are very large, the form of the output voltage for a very high frequency square wave input, is best represented by



(a)


(b)


(c)


(d)


Ans. (c)

$$V_0 = \frac{1}{RC}\int_0^{T/2} V_i dt = \frac{1}{RC}\int_0^{T/2} 1.\, dt = \frac{1}{RC}(t)\Big|_0^{T/2} = \frac{T}{2RC}$$

$\because$ RC >>> T

So, $V_0 < 1$ Volt

End of Solution

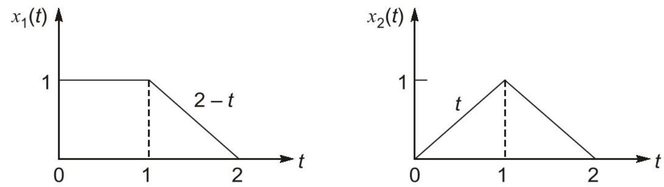
Q.40 Let continuous-time signals $x_1(t)$ and $x_2(t)$ be

$$x_1(t) = \begin{cases} 1, & t \in [0,1] \\ 2-t, & t \in [1,2] \\ 0, & \text{otherwise} \end{cases} \quad \text{and} \quad x_2(t) = \begin{cases} t, & t \in [0,1] \\ 2-t, & t \in [1,2] \\ 0, & \text{otherwise} \end{cases}.$$

Consider the convolution $y(t) = x_1(t) * x_2(t)$. Then $\int_{-\infty}^{\infty} y(t)\,dt$ is

(a) 1.5
(b) 2.5
(c) 3.5
(d) 4

Ans. **(a)**



$y(t) = x_1(t) * x_2(t)$

Area property :

$$Ay = Ax_1 Ax_2$$

$$Ax_1 = 1\times 1 + \frac{1}{2}\times 1\times 1$$

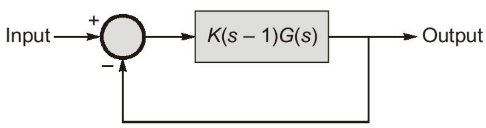
$$= 1 + \frac{1}{2} = \frac{3}{2}$$

$$Ax_2 = \frac{1}{2}\times 2\times 1 = 1$$

$$Ay = \frac{3}{2}\times 1 = 1.5$$

End of Solution

Q.41 Let $G(s) = \dfrac{1}{(s+1)(s+2)}$. Then the closed-loop system shown in the figure below, is



(a) stable for all $K > 2$.
(b) unstable for all $K > 2$.
(c) unstable for all $K > 1$.
(d) stable for all $K > 1$.

Ans. **(b)**

$$G(s)H(s) = \frac{K(s-1)}{s^2 + 3s + 2}$$

Characteristics equation of the system is

$$q(s) = s^2 + s(K + 3) + (2 - K) = 0$$

The system to be stable

$$-3 < K < 2$$

End of Solution

Q.42 The continuous-time unit impulse signal is applied as an input to a continuous-time linear time-invariant system S. The output is observed to be the continuous-time unit step signal $u(t)$. Which one of the following statements is true?

(a) Every bounded input signal applied to S results in a bounded output signal.

(b) It is possible to find a bounded input signal which when applied to S results in an unbounded output signal.

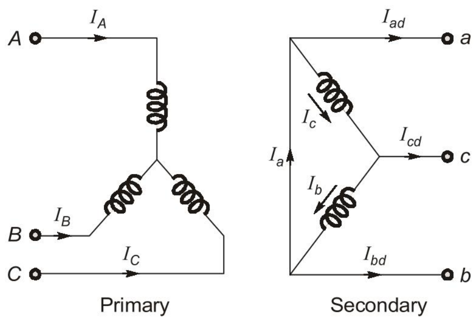
(c) On applying any input signal to S, the output signal is always bounded.

(d) On applying any input signal to S the output signal is always unbounded.

Ans. (b)

End of Solution

Q.43 The transformer connection given in the figure is part of a balanced 3-phase circuit where the phase sequence is "*abc*". The primary to secondary turns ratio is 2 : 1. If $(I_a + I_b + I_c = 0)$, then the relationship between I_A and I_{ad} will be



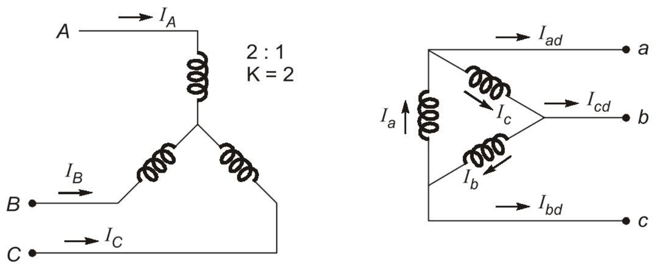
(a) $\dfrac{|I_A|}{|I_{ad}|} = \dfrac{1}{2\sqrt{3}}$ and I_{ad} lags I_A by 30°

(b) $\dfrac{|I_A|}{|I_{ad}|} = \dfrac{1}{2\sqrt{3}}$ and I_{ad} leads I_A by 30°

(c) $\dfrac{|I_A|}{|I_{ad}|} = 2\sqrt{3}$ and I_{ad} lags I_A by 30°

(d) $\dfrac{|I_A|}{|I_{ad}|} = 2\sqrt{3}$ and I_{ad} leads I_A by 30°

Ans. (a)



$$I_a = 2I_A$$

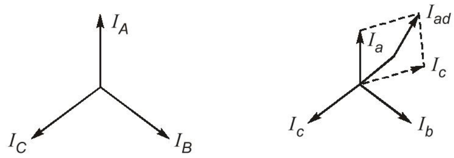
$$I_{ad} = \sqrt{3}I_a = 2\sqrt{3}I_A$$

$$\frac{I_A}{I_{ad}} = \frac{1}{2\sqrt{3}}$$

Applying KCL, $\overline{I}_a = \overline{I}_c + \overline{I}_{ad}$

$$\overline{I}_{ad} = \overline{I}_a - \overline{I}_c$$

$$\overline{I}_{ad} = \overline{I}_a - (-\overline{I}_c)$$



I_{ad} lags I_a by 30°.

$\therefore$ I_{ad} lags I_A by 30°.

$\because$ I_A and I_a in phase.

End of Solution

Q.44 A DC series motor with negligible series resistance is running at a certain speed driving a load, where the load torque varies as cube of the speed. The motor is fed from a 400 V DC source and draws 40 A armature current. Assume linear magnetic circuit. The external resistance, in Ω, that must be connected in series with the armature to reduce the speed of the motor by half, is closest to

(a) 23.28 (b) 4.82

(c) 46.7 (d) 0

Ans. (a)

$T \propto N^3$ (given)

I_a = 40 A, 400 V

R_{ext} = ?, if speed has to reduce half

$400 \propto 40\ N$ ...(1)

$$400 - I_a R_{ext} \propto I_a\left(\frac{N}{2}\right) \quad ...(2)$$

as $T \propto N^3$ (given)

and $T \propto I_a^2$ (series motor)

So, $I_a^2 \propto N^3$

$$\frac{40^2}{I_a^2} = \frac{N^3}{\left(\frac{N}{2}\right)^3}$$

$$\frac{40^2}{I_a^2} = 8 \Rightarrow I_a = 10\sqrt{2}\ \text{A}$$

From (1) and (2)

$$\frac{400}{400 - 10\sqrt{2}(R_{ext})} \propto \frac{40N}{10\sqrt{2}\left(\frac{N}{2}\right)}$$

$$R_{ext} = 23.28\ \Omega$$

End of Solution

Q.45 A 3-phase, 400 V, 4 pole, 50 Hz star connected induction motor has the following parameters referred to the stator :

$$R'_r = 1\ \Omega,\ X_S = X'_r = 2\ \Omega$$

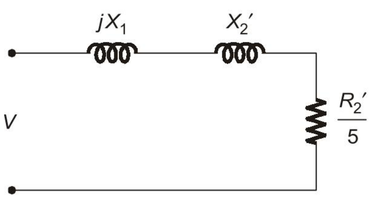
Stator resistance, magnetizing reactance and core loss of the motor are neglected. The motor is run with constant V/f control from a drive. For maximum starting torque, the voltage and frequency output, respectively, from the drive, is closest to,

(a) 400 V and 50 Hz
(b) 200 V and 25 Hz
(c) 100 V and 12.5 Hz
(d) 300 V and 37.5 Hz

Ans. **(c)**

Given : $X_S = X'_r = 2\ \Omega$

$X_1 = X'_2 = 2\ \Omega$



Condition for maximum starting torque :

$$R'_2 = X_1 + X^1_2$$

Let a frequency F_m be the frequency.

Corresponding to maximum T_{st}.

$$2\pi f_m L_1 + 2\pi f_m L'_2 = 1$$

$$2\pi f_m (L_1 + L'_2) = 1$$

$$f_m = \frac{1}{2\pi(L_1 + L'_2)}$$

From given data : $X_1 = 2\pi f L_1 = 2\ \Omega$

$X_2 = 2\pi f L'_2 = 2\ \Omega$

$$L_1 = L'_2 = \frac{2}{2\pi(50)} = 6.369 \times 10^{-3}\ \text{H}$$

$$\therefore \quad f_m = \frac{1}{2\pi(2 \times 6.369 \times 10^{-3})} = 12.5\ \text{Hz}$$

V/F Control : V/F Ratio must remain same.

$$\therefore \quad \frac{V_2}{f_2} = \frac{V_1}{f_1} \Rightarrow V_2 = \frac{400}{50} \times 12.5 = 100 \text{ V}$$

End of Solution

Q.46 The 3-phase modulating waveforms ($v_a(t)$, $v_b(t)$, $v_c(t)$), used in sinusoidal PWM in a voltage source inverter (VSI) are

$$v_a(t) = 0.8\sin(\omega t) \text{ V}$$

$$v_b(t) = 0.8\sin\left(\omega t - \frac{2\pi}{3}\right)\text{V}$$

$$v_c(t) = 0.8\sin\left(\omega t + \frac{2\pi}{3}\right)\text{V}$$

where $\omega = 2\pi \times 40$ rad/s is the fundamental frequency. The modulating waveforms are compared with a 10 kHz triangular carrier whose magnitude varies between +1 and –1. The VSI has a DC link voltage of 600 V and feeds a star connected motor. The per phase fundamental RMS motor voltage in volts is closest to

(a) 169.71
(b) 300.00
(c) 424.26
(d) 212.13

Ans. **(a)**

3ϕ VSI – Sin PWM:

$$A_M = 0.8 \text{ V} \qquad V_S = 600 \text{ V}$$

$$A_C = 1 \text{ V}$$

$$M_A = \frac{A_M}{A_C} = 0.8$$

$$\hat{V}_{L1} = \sqrt{3}M_A \cdot \frac{V_S}{2}$$

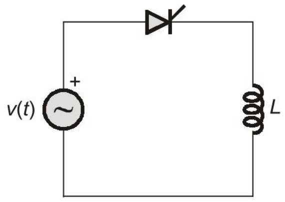
$$V_{L1\,\text{RMS}} = \frac{\sqrt{3}}{2\sqrt{2}} \cdot M_A \cdot V_S$$

$$= 0.612 \times 0.8 \times 600 = 293.938 \text{ V}$$

$$V_{Ph1\,\text{RMS}} = \frac{V_{L1}}{\sqrt{3}} = \frac{293.938}{\sqrt{3}} = 169.7 \text{ V}$$

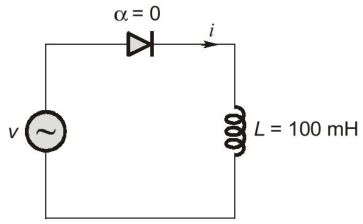
End of Solution

Q.47 An ideal sinusoidal voltage source $v(t) = 230\sqrt{2}\sin(2\pi \times 50t)$ V feeds an ideal inductor L through an ideal SCR with firing angle α = 0°. If L = 100 mH, then the peak of the inductor current, in ampere, is closest to



(a) 20.71
(b) 0
(c) 10.35
(d) 7.32

Ans. **(a)**



$$v = 230\sqrt{2}\sin(2\pi \cdot 50)$$

$$i = \frac{V_M}{\omega_L}[1 - \cos\omega t]$$

$$i_{peak} = \frac{2V_m}{\omega L} = \frac{2 \times 230\sqrt{2}}{2\pi \times 50 \times 100 \times 10^{-3}} = 20.7\text{A}$$

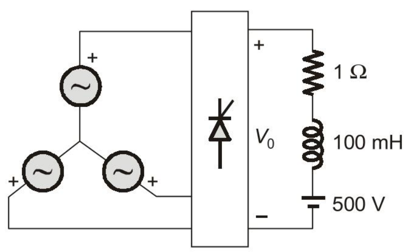
at $\omega t = \pi$

End of Solution

Q.48 In the following circuit, the average voltage

$$V_0 = 400\left(1 + \frac{\cos\alpha}{3}\right) \text{V}$$

where α is the firing angle. If the power dissipated in the resistor is 64 W, then the closest value of α in degrees is



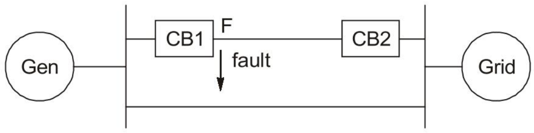
(a) 35.9
(b) 46.4
(c) 41.4
(d) 0

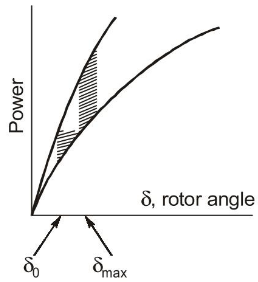
Ans. **(a)**

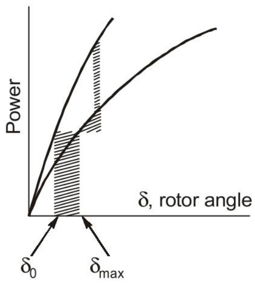
$$P_R = I^2_{or} R = 64 \text{ W}$$
$$I^2_{or} \times 1 = 64$$
$$I_{or} = 8A = I_0 \qquad (\because \text{ Current is ripple free})$$
$$V_0 = E + I_0 R$$
$$400\left[1+\frac{\cos\alpha}{3}\right] = 500 + 8 \times 1 = 508$$
$$\alpha = 35.9°$$

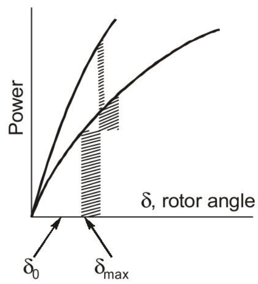
End of Solution

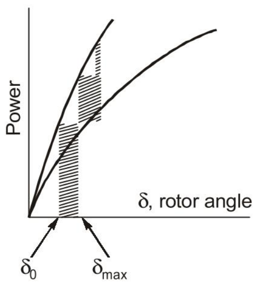
Q.49 In the system shown below, the generator was initially supplying power to the grid. A temporary LLLG bolted fault occurs at F very close to circuit breaker-1. The circuit breakers open to isolate the line. The fault self-clears. The circuit breakers reclose and restore the line. Which one of the following diagrams best indicates the rotor accelerating and decelerating areas?



(i)


(ii)


(iii)


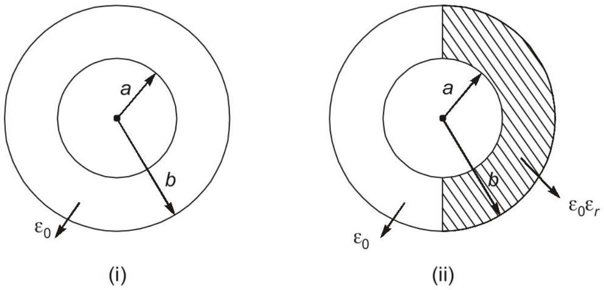
(iv)


(a) Fig. (i)
(b) Fig. (ii)
(c) Fig. (iii)
(d) Fig. (iv)

Ans. **(b)**

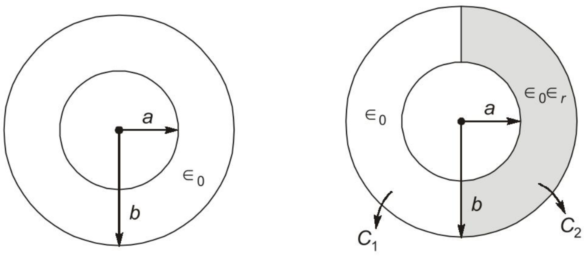
End of Solution

Q.50 An air filled cylindrical capacitor (capacitance C_0) of length L, with a and b as its inner and outer radii, respectively, consists of two coaxial conducting surfaces. Its cross-sectional view is shown in Figure (i). In order to increase the capacitance, a dielectric material of relative permittivity ε_r is inserted inside 50% of the annular region as shown in figure (ii). The value of ε_r for which the capacitance of the capacitor in figure (ii), becomes $5C_0$ is



(a) 4
(b) 5
(c) 9
(d) 10

Ans. **(c)**



Capacitance, $$C_0 = \frac{2\pi\varepsilon_0 l}{\ln\left(\frac{b}{a}\right)}$$

Now, capacitance, $$C_{eq} = C_1 + C_2$$

$$C_1 = \frac{2\pi\varepsilon_0 l}{\ln\left(\frac{b}{a}\right)} \times \frac{1}{2} = \frac{\pi\varepsilon_0 l}{\ln\left(\frac{b}{a}\right)}$$

$$C_2 = \frac{2\pi\varepsilon_0\varepsilon_r l}{\ln\left(\frac{b}{a}\right)} \times \frac{1}{2} = \frac{\pi\varepsilon_0\varepsilon_r l}{\ln\left(\frac{b}{a}\right)}$$

∴ $$C_{eq} = \frac{\pi\varepsilon_0 l}{\ln\left(\frac{b}{a}\right)}[1+\varepsilon_r]$$

According to question,

$$C_{eq} = 5C_0$$

$$\Rightarrow \quad \frac{\pi\varepsilon_0 l}{\ln\left(\frac{b}{a}\right)}[1+\varepsilon_r] = 5\times\frac{2\pi\varepsilon_0 l}{\ln\left(\frac{b}{a}\right)}$$

$$1 + \varepsilon_r = 10$$

$$\Rightarrow \quad \varepsilon_r = 9$$

End of Solution

Q.51 Let a_R be the unit radial vector in the spherical co-ordinate system. For which of the following value(s) of n, the divergence of the radial vector field $f(R) = a_R \frac{1}{R^n}$ is independent of R?

(a) –2
(b) –1
(c) 1
(d) 2

Ans. (b, d)

Given :

$$\bar{f}(R) = \frac{1}{R^n}\hat{a}_R$$

$$\nabla.\bar{f} = \frac{1}{R^2\sin\theta}\left[\frac{\partial}{\partial R}\left(R^2\sin\theta\cdot\frac{1}{R^n}\right)\right]$$

$$= \frac{1}{R^2}\left[\frac{\partial}{\partial R}(R^{2-n})\right]$$

$$= \frac{(2-n)R^{-n+1}}{R^2} = (2-n)R^{-n-1}$$

For $\nabla.\bar{f}$ to be independent of R,

Case (i) :

$$-n - 1 = 0$$

$$\Rightarrow \quad -n = 1 \quad \Rightarrow \quad n = -1$$

Case (ii) :

$$2 - n = 0 \quad \Rightarrow \quad n = 2$$

End of Solution

Q.52 Consider two coupled circuits having self inductances L_1 and L_2 that carry non-zero currents I_1 and I_2 respectively. The mutual inductance between the circuit is M with unity coupling coefficient. The stored magnetic energy of the coupled circuit is minimum at which of the following value(s) of I_1/I_2?

(a) $-\frac{M}{L_1}$
(b) $-\frac{M}{L_2}$
(c) $-\frac{L_1}{M}$
(d) $-\frac{L_2}{M}$

Ans. (a, d)

$$\omega = \frac{1}{2}L_1 I_1^2 + \frac{1}{2}L_2 I_2^2 + M I_1 I_2$$

$$\frac{d\omega}{dI_1} = 0$$

$$\frac{d\omega}{dI_1} = 2I_1\left(\frac{1}{2}L_1\right) + 0 + MI_2$$

$$0 = L_1 I_1 + MI_2$$

$$\frac{I_1}{I_2} = -\frac{M}{L_1}$$

$$\frac{d\omega}{dI_2} = 0$$

$$\frac{d\omega}{dI_2} = 0 + \frac{1}{2}L_2(2I_2) + MI_1$$

$$0 = L_2 I_2 + MI_1$$

$$\frac{I_1}{I_2} = -\frac{L_2}{M}$$

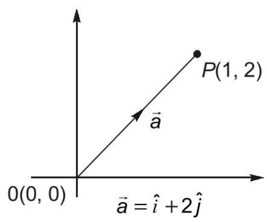
End of Solution

Q.53 Let $(x, y) \in \Re^2$. The rate of change of the real valued function,

$V(x, y) = x^2 + x + y^2 + 1$

at the origin in the direction of the point (1, 2) is ________ (round off to the nearest integer)

Ans. (0)



$$DD = \vec{\nabla V} \cdot \frac{\vec{a}}{|\vec{a}|}$$

$$\vec{\nabla V} = \langle V_x,\ V_y \rangle$$

$$= \langle 2x + 1,\ 2y \rangle$$

$$\left(\vec{\nabla V}\right)_{(D,0)} = \langle 1,\ 0 \rangle$$

$\therefore$

$$D.D = (\hat{i} + 0\hat{j}) \cdot \frac{(\hat{i} + 2\hat{j})}{\sqrt{1^2 + 2^2}}$$

$$= \frac{1}{\sqrt{5}} = 0.447$$

Nearest integer = 0

End of Solution

Q.54 Consider ordinary differential equations given by $\dot{x}_1(t) = 2x_2(t)$, $\dot{x}_2(t) = r(t)$ with initial conditions $x_1(0) = 1$ and $x_2(0) = 0$. If $r(t) = \begin{cases} 1, & t \geq 0 \\ 0, & t < 0 \end{cases}$, then $t = 1$, $x_1(t) =$ _______ . (Round off to the nearest integer).

Ans. **(2)**

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} 0 & 2 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} r(t)$$

From question, $r(t) = u(t)$ $\qquad \left.\begin{matrix} x_1(0) = 1 \\ x_2(0) = 0 \end{matrix}\right\}$ Given

$$A = \begin{bmatrix} 0 & 2 \\ 0 & 0 \end{bmatrix}$$

$$[sI - A] = \begin{bmatrix} s & -2 \\ 0 & s \end{bmatrix}$$

$$[sI - A]^{-1} = \frac{1}{s^2} \begin{bmatrix} s & 2 \\ 0 & s \end{bmatrix} = \begin{bmatrix} \frac{1}{s} & \frac{2}{s^2} \\ 0 & \frac{1}{s} \end{bmatrix}$$

∴ State transition matrix,

$$\phi(t) = L^{-1}\left\{[sI - A]^{-1}\right\} = L^{-1}\left\{\begin{bmatrix} \frac{1}{s} & \frac{2}{s^2} \\ 0 & \frac{1}{s} \end{bmatrix}\right\}$$

$$\phi(t) = \begin{bmatrix} u(t) & 2t\,u(t) \\ 0 & u(t) \end{bmatrix}$$

∴ $$x(t) = \phi(t) \cdot x(0) + L^{-1}\left\{[sI - A]^{-1} B \cdot U(s)\right\} \quad \text{...(i)}$$

Here, $$[sI - A]^{-1} B \cdot U(s) = \begin{bmatrix} \frac{1}{s} & \frac{2}{s^2} \\ 0 & \frac{1}{s} \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} \frac{1}{s} = \begin{bmatrix} \frac{2}{s^2} \\ \frac{1}{s} \end{bmatrix} \frac{1}{s} = \begin{bmatrix} \frac{2}{s^3} \\ \frac{1}{s^2} \end{bmatrix}$$

∴ $$L^{-1}\left\{[sI - A]^{-1} BU(s)\right\} = L^{-1}\left\{\begin{bmatrix} \frac{2}{s^3} \\ \frac{1}{s^2} \end{bmatrix}\right\} = \begin{bmatrix} t^2 u(t) \\ t\,u(t) \end{bmatrix} = \begin{bmatrix} t^2 \\ t \end{bmatrix} u(t)$$

∴ $$x(t) = \begin{bmatrix} 1 & 2t \\ 0 & 1 \end{bmatrix} u(t) \cdot \begin{bmatrix} x_1(0) \\ x_2(0) \end{bmatrix} + \begin{bmatrix} t^2 \\ t \end{bmatrix} u(t)$$

$$= \begin{bmatrix} 1 & 2t \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} u(t) + \begin{bmatrix} t^2 \\ t \end{bmatrix} u(t)$$

$$x(t) = \begin{bmatrix} t^2 + 1 \\ t \end{bmatrix} u(t) = \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$$

$$x_1(t) = (t^2 + 1)u(t)$$

At $t = 1$,

$$x_1(t) = (1^2 + 1)u(1) = 2$$

End of Solution

Q.55 Let C be a clockwise oriented closed curve in the complex plane defined by $|z| = 1$. Further, let $f(x) = jz$ be a complex function, where $j = \sqrt{-1}$. Then, $\oint_C f(z)dz$ = ____.

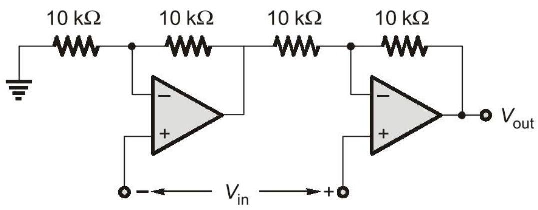
Ans. (0)

$$f(z) = iz \text{ is analytic in } C : |z| = 1$$

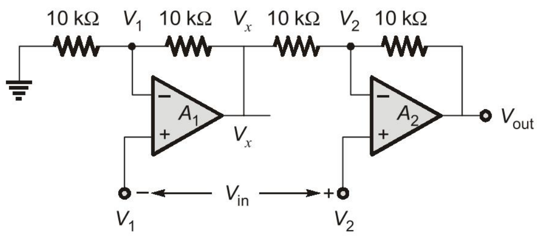
$$\oint_C iz dz = 0 \text{ by C.I.T.}$$

End of Solution

Q.56 The op-amps in the following circuit are ideal. The voltage gain of the circuit is ________. (Round off to the nearest integer)



Ans. (2)



Assume $V_{in} = V_2 - V_1$

Op-amp A_1 :

$$V_X = \left(1 + \frac{10k}{10k}\right) V_1 = 2V_1$$

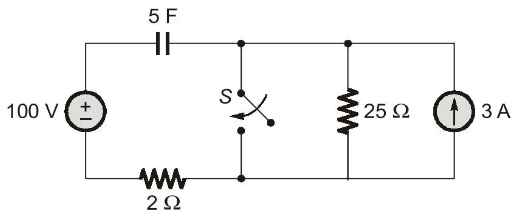
Op-amp A_2 :

KCL at A_2 $$\frac{V_X - V_2}{10k} = \frac{V_2 - V_0}{10k}$$

$$V_X = 2V_2 - V_0$$
$$V_0 = 2V_2 - V_X = 2V_2 - 2V_1 = 2(V_2 - V_1)$$
$$\frac{V_0}{V_2 - V_1} = 2$$

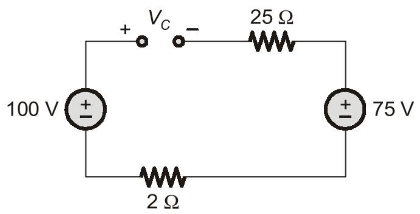
End of Solution

Q.57 The switch (S) closes at $t = 0$ sec. The time, in sec the capacitor takes to charge to 50 V is ________ . (Round off to one decimal places)



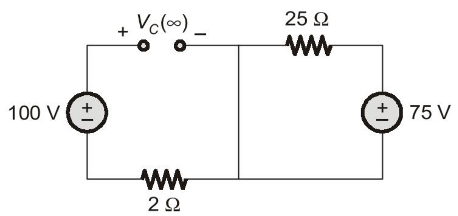
Ans. **(4.05) (4.0 to 4.2)**

$t = 0^-$



$$V_C(0^-) = 100 - 75$$
$$V_C(0^-) = 25 \text{ V}$$
$$V_C(0^+) = 25 \text{ V}$$

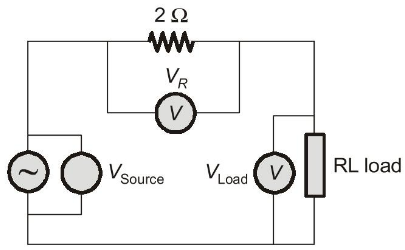
$t \to \infty$



$$V_C(\infty) = 100 \text{ V}$$
$$T = 2 \times 5 = 10 \text{ sec}$$
$$V_C(t) = V_C(\infty) + (V_C(0^+) - V_C(\infty))e^{-t/T}$$
$$V_C(t) = 100 + (25 - 100)e^{-t/10}$$
$$50 = 100 - 75e^{-t/10}$$
$$+50 = +75e^{-t/10}$$
$$e^{-t/10} = \frac{50}{75}$$
$$t = 4.05 \text{ sec}$$

End of Solution

Q.58 In an experiment to measure the active power drawn by a single-phase RL Load connected to an AC source through a 2 Ω resistor, three voltmeters are connected as shown in the figure below. The voltmeter readings are as follows : V_{source} = 200 V, V_R = 9 V, V_{Load} = 199 V. Assuming perfect resistors and ideal voltmeters, the Load-active power measured in this experiment, in *W*, is _____.



Ans. (79.43) (77.0 to 80.0)

$$I_L = \frac{V_R}{2} = \frac{9}{2} = 4.5 \text{ A}$$

$$\cos\phi = \frac{V_S^2 - V_R^2 - V_L^2}{2V_RV_L}$$

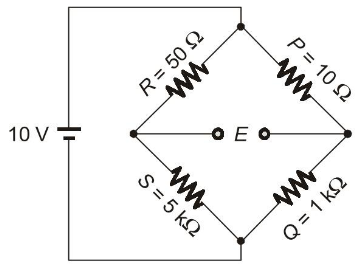
Substitution all the values, we get

$$\cos\phi = 0.0887$$

$$\therefore \quad P_L = 199 \times 4.5 \times 0.0887 = 79.43 \text{ W}$$

End of Solution

Q.59 In the Wheatstone bridge shown below, the sensitivity of the bridge in terms of change in balancing voltage *E* for unit change in the resistance *R*, in mV/Ω, is _______ . (round off to two decimal places)



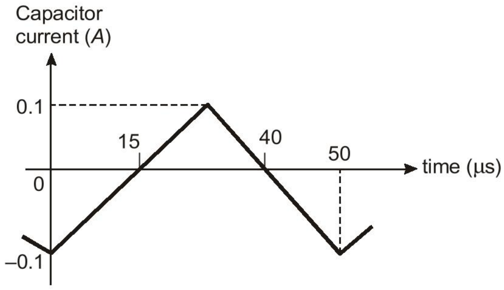
Ans. (1.96) (1.96 to 2.00)

$$E = 10\left[\frac{1000}{1000+10} - \frac{5000}{5000+51}\right] = 1.96 \text{ mV}$$

$$\therefore \quad S = 1.96 \text{ mV/}\Omega$$

End of Solution

Q.60 The steady state capacitor current of a conventional DC-DC buck converter, working in CCM, is shown in one switching cycle. If the input voltage is 30 V, the value of the inductor sued, in mH, is ____ (round off to one decimal place).



Ans. **(1.8) (1.7 to 1.9)**

DC-DC Buck Converter:

$$\Delta I_L = \Delta I_C = 0.2 \text{ A}$$

$$f = \frac{1}{T} = \frac{1}{50.10^{-6}}$$

$$f = 20 \text{ kHz}$$

$$\alpha = \frac{T_{ON}}{T} = \frac{30}{50} = 0.6$$

$$\Delta I_L = \frac{\alpha(1-\alpha)V_s}{fL}$$

$$L = \frac{\alpha(1-\alpha)V_s}{\Delta I_L \times f} = \frac{0.6(1-0.6)\times 30}{0.2\times 20.10^3}$$

$$L = 1.8 \text{ mH}$$

End of Solution

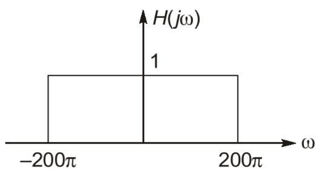
Q.61 An ideal low pass filter has frequency response given by

$$H(j\omega) = \begin{cases} 1, & |\omega| \le 200\pi \\ 0, & \text{otherwise} \end{cases}$$

Let $h(t)$ be its time domain representation. Then $h(0)$ = ________ (round off to the nearest integer)

Ans. **(200)**

1st Method :



$$H(j\omega) = rec\left(\frac{\omega}{400\pi}\right)$$

$$h(t) = \frac{\sin(200\pi t)}{\pi t} = \frac{200\sin(200\pi t)}{200\pi t}$$

$$h(t)|_{t=0} = 200$$

2nd Method :

$$h(0) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} H(j\omega)d\omega$$

$$h(0) = \frac{1}{2\pi}\int_{-200\pi}^{200\pi} 1d\omega = \frac{1}{2\pi}[400\pi] = 200$$

End of Solution

Q.62 Consider the state-space model

$$\dot{x}(t) = Ax(t) + Bu(t)$$
$$y(t) = Cx(t)$$

where $x(t)$, $r(t)$, $y(t)$ are the state, input and output, respectively. The matrices A, B, C are given below

$$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix},\ B = \begin{bmatrix} 0 \\ 1 \end{bmatrix},\ C = [1 \quad 0]$$

The sum of the magnitudes of the poles is _____. (Round off to nearest integer)

Ans. (3)

Characteristics equation of the system is

$$q(s) = |sI - A| = 0$$

$$\begin{vmatrix} s & -1 \\ 2 & s+3 \end{vmatrix} = 0$$

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

Roots of the equation is –1, –2

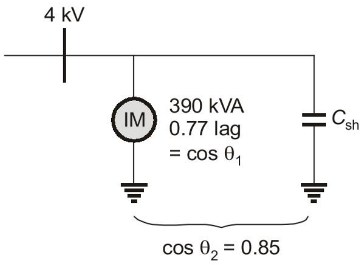
Sum of the magnitudes of the poles

$$= |-1| + |-2| = 1 + 2 = 3$$

End of Solution

Q.63 Using shunt capacitors, the power factor of a 3-phase, 4 kV induction motor (drawing 390 kVA at 0.77 pf lag) is to be improved to 0.85 pf lag. The line current of the capacitor bank, in A, is _______ . (Round off to one decimal places)

Ans. (9.054) (8.5 to 10.0)



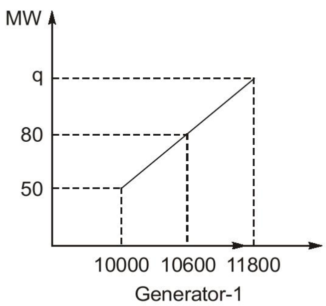
$$\cos\theta_1 = 0.77,\ \theta_1 = 39.64°$$
$$\cos\theta = 0.85,\ \theta_2 = 31.79°$$
$$Q_c = P_1\,[\tan\theta_1 - \tan\theta_2]$$
$$= 390 \times 10^3 \times 0.77\ [\tan \cos^{-1} 0.77 - \tan \cos^{-1} 0.85]$$
$$= 62.73 \text{ KVAR} = 3\ V_{ph}\ I_{ph} \sin\theta_2$$

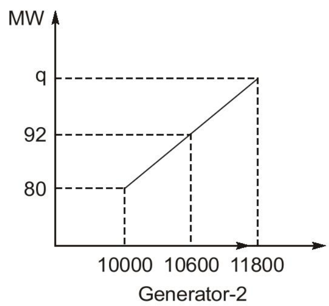
$$I_{ph} = \frac{62.73\times10^3}{3\times\dfrac{4\times10^3}{\sqrt{3}}\times} = 9.054 \text{ A}$$

End of Solution

Q.64 Two units, rated at 100 MW and 150 MW, are enabled for economic load dispatch. When the overall incremental cost is 10,000 Rs./MWh, the units are dispatched to 50 MW and 80 MW respectively. At an overall incremental cost of 10,600 Rs./MWh, the power output of the units are 80 MW and 92 MW, respectively. The total plant MW-output (without overloading any unit) at an overall incremental cost of 11,800 Rs./MWh is ________ (round off to the nearest integer)

Ans. (216)





For unit-1:

$$\text{Slope} = \frac{80-50}{10600-10000} = \frac{30}{600} = 0.05 \text{ MW/Rs}$$

For unit-2:

$$\text{Slope} = \frac{92-80}{10600-10000} = \frac{12}{600} = 0.02 \text{ MW/Rs}$$

For unit-1:

$$P_1 = 80 + 0.05 \times (11800 - 10600)$$
$$= 80 + 0.05 \times 1200 = 80 + 60 = 140 \text{ MW}$$

For unit-2:

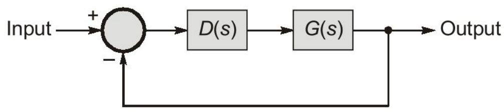
$$P_2 = 92 + 0.02 \times (11800 - 10600)$$
$$= 92 + 0.02 \times 1200 = 92 + 24 = 116 \text{ MW}$$

- Unit 1 capacity: 100 MW (but calculated 140 MW, so it is limited to 100 MW.
- Unit 2 capacity: 150 MW (calculated 116 MW, within limits)

$$P_{total} = P_1 + P_2 = 100 + 116 = 216 \text{ MW}$$

End of Solution

Q.65 A controller $D(s)$ of the form $(1 + K_D s)$ is to be designed for the plant $G(s) = \dfrac{1000\sqrt{2}}{s(s+10)^2}$ as shown in the figure. The value of K_D that yields a phase margin of 45° at the gain cross-over frequency of 10 rad/sec is ________ (round off to one decimal place).



Ans. **(0.1)**

Given compensated system has

$$\text{PM} = 180° + \left[-90° - 2\tan^{-1}\left(\frac{10}{10}\right)\right] = 0°$$

But required 45° phase margin has to be provided by compensator

$$\tan^{-1}[K_d\omega]\Big|_{\text{at } \omega = 10 \text{rad/sec}} = 45°$$

$\therefore$ $$K_D = 0.1$$

End of Solution

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