



GATE 2026

Electrical Engineering

Forenoon Session

Detailed Solutions

Exam held on 14-02-2026

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SECTION - A

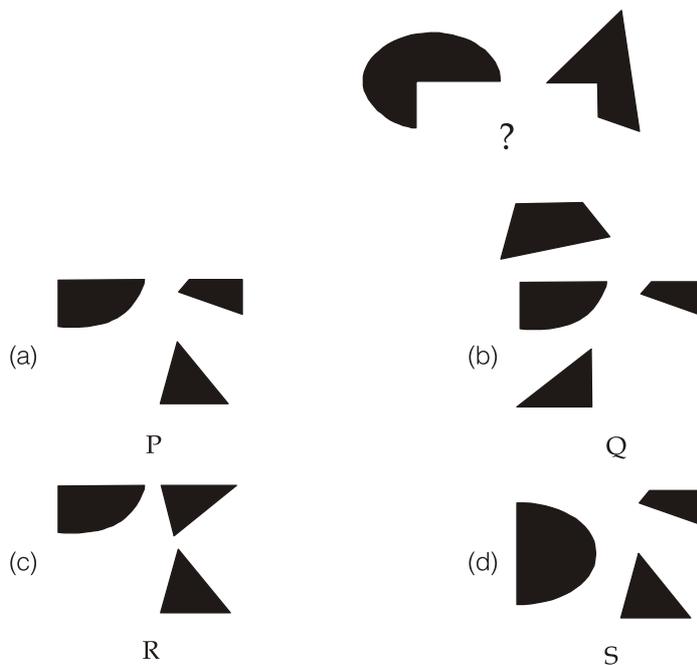
GENERAL APTITUDE

- Q.1** 'The shopkeeper sells lemons.'
 In this sentence, the word 'lemons' is the
- | | |
|---------------|-------------|
| (a) object | (b) subject |
| (c) predicate | (d) verb |

Ans. (a)
 A shopkeeper sells lemons
 Subject Verb Object

End of Solution

- Q.2** The figure below is supposed to show three non-overlapping shapes - one oval and two triangles. Which one of the following figures P, Q, R, or S fits the missing portion indicated by '?' and completes the oval and the two triangles?



Ans. (a)

End of Solution

- Q.3** At how many points will the curves $y = x^2$ and $y = -x^2 - 2x - 1$ intersect in the real (x, y) plane?
- | | |
|-------|-------|
| (a) 0 | (b) 1 |
| (c) 2 | (d) 3 |



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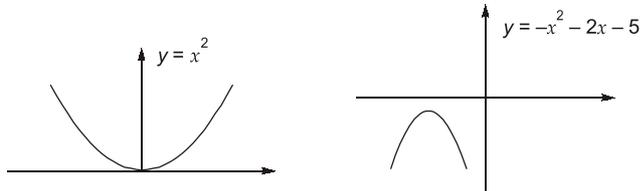
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Ans. (a)



No intersection points,

$y = x^2$	Always positive
$y = -x^2 - 2x - 5$	Always negative

End of Solution

Q.4 'If Anish had scored hundred runs in today's match, he would have been made the captain of his team. He would have then become the youngest captain in his team's history. Unfortunately, he got out without scoring any runs. Hence, there won't be any change in the captaincy for now.'

Based on the paragraph above, which one of the following statements is true?

- (a) Anish made hundred runs but was denied captaincy.
- (b) Anish was the captain of his team before the game today.
- (c) The current captain is older than Anish.
- (d) Anish is the youngest player in his team.

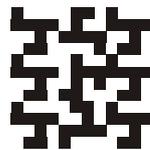
Ans. (c)

As in question it is mentioned.

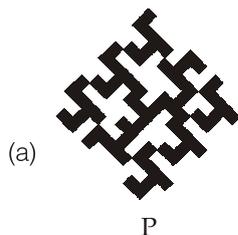
He would have become the youngest captain, so the current captain is older than Anish.

End of Solution

Q.5 Which one of the following figures P, Q, R, or S, correctly shows the 45° clockwise-rotated version of figure (I)?

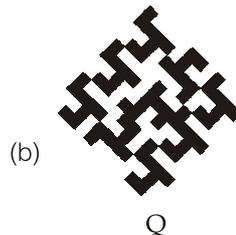


(I)



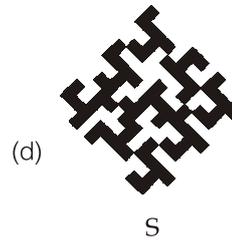
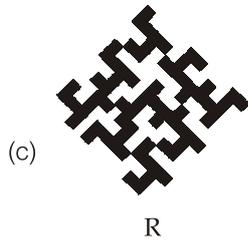
(a)

P



(b)

Q



Ans. (b)

End of Solution

Q.6 Match the words in **Column I** with their synonyms in **Column II**.

Column I

- (i) Lonely
- (ii) Literal
- (iii) Lousy
- (iv) Lethal

Column II

- (p) Verbatim
- (q) Solitary
- (r) Deadly
- (s) Terrible

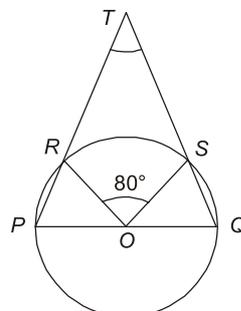
- (a) (i)-(q); (ii)-(p); (iii)-(s); (iv)-(r)
- (b) (i)-(q); (ii)-(s); (iii)-(r); (iv)-(p)
- (c) (i)-(s); (ii)-(p); (iii)-(q); (iv)-(r)
- (d) (i)-(r); (ii)-(s); (iii)-(p); (iv)-(q)

Ans. (a)

- Lonely → Solitary
- Literal → Verbatim
- Lousy → Terrible
- Lethal → Deadly

End of Solution

Q.7 In the given figure, \overline{PQ} is the diameter of a circle with center O . Two points R and S are chosen on the circle such that $\angle ROS = 80^\circ$. When \overline{PR} and \overline{QS} are extended, they meet at T . The value of $\angle RTS$ is _____.



- (a) 40°
- (b) 50°
- (c) 60°
- (d) 80°

Ans. (b)

$$\frac{1}{2}(180^\circ - 80^\circ) = 50^\circ$$

End of Solution

Q.8 Based on the relationship between each polygon and the number inside it, the value of 'X' is _____



- (a) 720 (b) 596
 (c) 24 (d) 240

Ans. (a)

No. of sides = 3
 $3! = 6$
 No. of sides = 4
 $4! = 24$
 No. of sides = 5! = 120
 No. of sides = 6! = 720

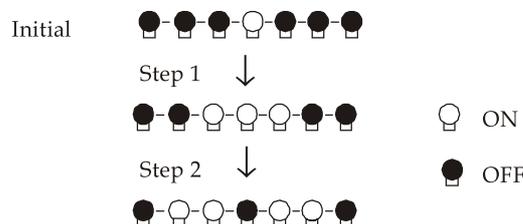
End of Solution

Q.9 Consider a linear arrangement of seven bulbs, each of which can be in the ON or OFF states. The initial configuration of the bulbs is shown in the figure. In every Step, the states of the bulbs are changed based on the following rules:

- Any OFF bulb with exactly one ON neighbor at the end of the previous Step is turned ON.
- Any ON bulb with both neighbors ON at the end of the previous Step is turned OFF.
- The state of any bulb not meeting the conditions above is left unchanged.

The state of bulbs at the end of Step 1 and Step 2 are also shown in the figure.

The number of bulbs which are ON at the end of Step 8 is _____



- (a) 5 (b) 4
 (c) 3 (d) 0

Ans. (b)

Step (1) OFF, OFF, ON, ON, ON, OFF, OFF
 Step (2) OFF, ON, ON, OFF, ON, ON, OFF

Step (3) ON, ON, ON, OFF, ON, ON, ON
Step (4) ON, OFF, ON, OFF, ON, OFF, OFF
No change possible.

End of Solution

Q.10 P and Q are two positive integers such that $P^2 = Q^2 + 13$.

The product of the numbers P and Q is _____

- (a) 13 (b) 26
(c) 39 (d) 42

Ans. (d)

$$\begin{aligned} [P^2 - Q^2] &= 13 \\ (P - Q)(P + Q) &= 13 = 1 \times 13 \\ P - Q &= 1 \\ P + Q &= 13 \\ P &= 7 \\ \text{and } Q &= 6 \\ P \times Q &= 42 \end{aligned}$$

End of Solution

■■■■

SECTION - B

TECHNICAL

Q.11 Consider the infinite-length, discrete-time sequence $x[n] = 0.9^{|n|}$, where n is an integer. The region of convergence of its Z-transform $X(z)$ is given by:

(Note: z is a complex variable)

(a) $|z| > 0.9$

(b) $|z| < 0.9$

(c) $0.9 < |z| < \frac{1}{0.9}$

(d) $\{z \text{ such that } |z| < 0.9\} \cup \{z \text{ such that } |z| > \frac{1}{0.9}\}$

Ans. (c)

$$\begin{aligned} x(n) &= (0.9)^{|n|} \\ &= \begin{cases} (0.9)^{-n}, & n \leq -1 \\ (0.9)^n, & n \geq 0 \end{cases} \\ &= \underbrace{\left(\frac{1}{0.9}\right)^n u(-n-1)}_{|z| < \frac{1}{0.9}} + \underbrace{(0.9)^n u(n)}_{|z| > 0.9} \end{aligned}$$

ROC: $0.9 < |z| < \frac{1}{0.9}$

End of Solution

Q.12 Let $x_c(t)$ be any continuous-time periodic signal with period T . It is sampled uniformly with a sampling period T_s where $T_s \neq T$, resulting in the discrete sequence

$x[n] = x_c(nT_s)$, where n is an integer. Which one of the following statements is correct about $x[n]$?

(a) $x[n]$ will always be periodic with period $\frac{T}{T_s}$ for all values of $\frac{T}{T_s}$

(b) $x[n]$ will always be periodic with period 1 for all values of $\frac{T}{T_s}$

(c) $x[n]$ will always be periodic

(d) $x[n]$ will be periodic if and only if $\frac{T}{T_s}$ is a rational number

Ans. (d)

$$x_c(t) = \sin \omega_0 t, \quad \text{FTP: } T$$

Sampling $t = nT_s$

$$x(n) = \sin \omega_0 n T_s = \sin(\omega_0 T_s) n = \sin \omega'_0 n$$

For periodicity of $x(n)$,

$$\frac{2\pi}{\omega'_0} = \text{rational number}$$

$$\Rightarrow \frac{2\pi}{\omega_0 T_s} = \text{rational number}$$

$$\Rightarrow \frac{2\pi}{\frac{2\pi}{T} \cdot T_s} = \text{rational number}$$

$$\Rightarrow \frac{T}{T_s} = \text{rational number.}$$

End of Solution

Q.13 The Laplace transform of the step response of a system is given by

$$Y(s) = \frac{100}{s(s+100)}$$

The rise time is defined as the time taken for the response to go from 0.1 to 0.9 of its final value. The settling time is defined as the time taken for the response to reach 0.98 of its final value.

For this system, the rise time (T_r), settling time (T_s), and time constant (T_c), all expressed in seconds, are

(a) $T_r = 0.022$, $T_s = 0.04$, $T_c = 0.01$ (b) $T_r = 0.22$, $T_s = 0.404$, $T_c = 0.01$

(c) $T_r = 2.2$, $T_s = 4.04$, $T_c = 1.01$ (d) $T_r = 22$, $T_s = 40.4$, $T_c = 10.1$

Ans. (a)

$$Y(s) = \frac{100}{s(s+100)} = \frac{1}{s} - \frac{1}{s+100}$$

$$y(t) = 1 - e^{-100t}$$

Time constant:

$$T_c = \frac{1}{100} = 0.01 \text{ sec}$$

Rise time (0.1 to 0.9)

$$T_r = \frac{\ln(9)}{100} = \frac{2.197}{100} \approx 0.022 \text{ sec}$$

Settling time (98%),

$$T_s = \frac{\ln(50)}{100} = \frac{3.912}{100} \approx 0.04 \text{ sec}$$

End of Solution

Q.14 Consider the following differential equation:

$$t^2 \frac{d^2y}{dt^2} + 7t \frac{dy}{dt} + 8ty = 10\sin(t)$$

Which one of the following options is correct?

- (a) It is a linear differential equation
- (b) It is a nonlinear differential equation
- (c) It is a time-invariant differential equation
- (d) It is a second-order partial differential equation

Ans. (a)

$$t^2 y''(t) + 7t \cdot y'(t) + y(t) = \sin t$$

→ System is linear because it is following superposition law.

→ System is time-variant because coefficient is function of time.

End of Solution

Q.15 A uniform ring charge of radius R carries a total charge Q . Which one of the following options correctly quantifies the magnitude of the force on a point charge of strength kept at the center of the ring? (ϵ is the permittivity of the medium))

(a) $\frac{Qq}{4\pi \epsilon R}$

(b) $\frac{Qq}{4\pi \epsilon R^2}$

(c) 0

(d) $\frac{q}{4\pi \epsilon R} \times \frac{Q}{2\pi R}$

Ans. (c)

End of Solution

Q.16 A positive point charge with velocity $\vec{v} = 5\hat{x}$ enters a region having electric field $\vec{E} = 4\hat{y}$ and magnetic field $\vec{B} = -6\hat{z}$. Which one of the following statements is correct for the force on the charge as it enters the region?

- (a) The force will be along the magnetic field but perpendicular to the electric field
- (b) The force will be along the electric field but perpendicular to the magnetic field
- (c) The force will be perpendicular to both electric and magnetic field
- (d) The magnetic field does not exert any force on the charge

Ans. (b)

End of Solution

Q.17 A 15 kVA, 1100 V/220 V, single-phase two-winding transformer is configured as a 1.32 kV/1.1 kV autotransformer. What will be the rating of the autotransformer?

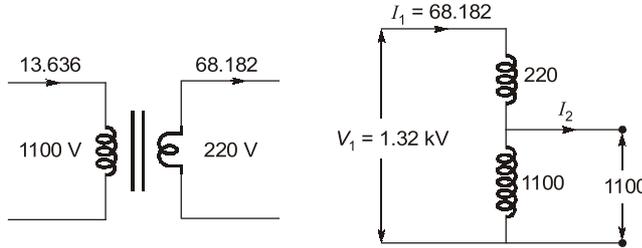
(a) 60 kVA

(b) 75 kVA

(c) 90 kVA

(d) 100 kVA

Ans. (c)



KVA Rating: $V_1 I_1$
 $1320 \times 68.182 = 90 \text{ KVA}$

End of Solution

Q.18 Consider a power system with N buses, of which P are generator buses and the remaining Q are load buses (where there is no generation).

Assume that there are no reactive power-limit violations at the generator buses.

What is the size of the Jacobian matrix in the Newton-Raphson load flow method?

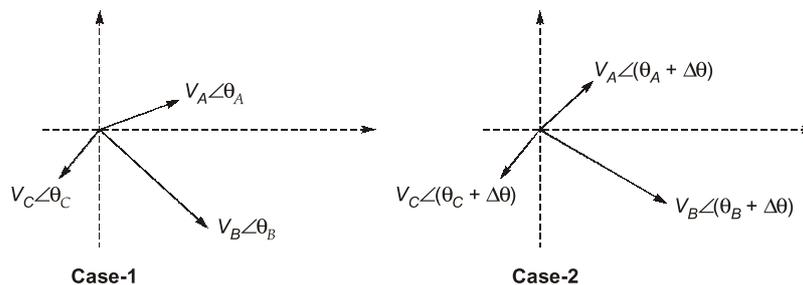
- (a) $2N \times 2N$ (b) $(2N - 1 - P) \times (2N - 1 - P)$
 (c) $(2N - Q) \times (2N - Q)$ (d) $(P + Q) \times (P + Q)$

Ans. (b)

Size of Jacobian = $(2n - m - 1) \times (2n - m - 1)$
 Here m is voltage specified buses
 $= (2n - p - 1) \times (2n - p - 1)$

End of Solution

Q.19 The initial three-phase voltage phasors ($\vec{V}_A, \vec{V}_B,$ and \vec{V}_C) at a bus of a power network are as shown in Case-1. Due to a disturbance, the bus voltage phasors changed in phase by a small angle $\Delta\theta$, and the magnitudes remained the same as depicted in Case-2.



Which one of the following statements is correct about the zero sequence components?

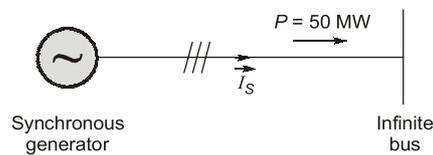
- (a) The zero sequence components in Case-1 and Case-2 have the same phase angle and magnitude
 (b) The magnitude of the zero sequence component in Case-1 is greater than that in Case-2

- Q.21** Which one of the following options is correct regarding the typical double-squirrel-cage structure used in induction motors?
- At starting, a larger portion of the rotor current flows in the outer cage
 - At starting, a larger portion of the rotor current flows in the inner cage
 - At rated speed, most of the rotor current flows in the outer cage
 - The purpose of the double-squirrel-cage structure is to lower the effective rotor resistance at starting

Ans. (a)

End of Solution

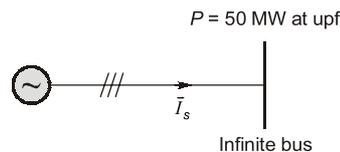
- Q.22** The figure shows the single-line diagram of a synchronous generator delivering $P = 50$ MW of power at unity power factor to an infinite bus.



I_s denotes the stator current phasor. If the field excitation is increased, which one of the following options correctly describes its effect on the stator current, power factor, and load angle of the machine?

- Stator current increases, power factor becomes lagging, load angle remains the same
- Stator current decreases, power factor becomes leading, load angle remains the same
- Stator current increases, power factor becomes lagging, load angle decreases
- Stator current increases, power factor becomes leading, load angle increases

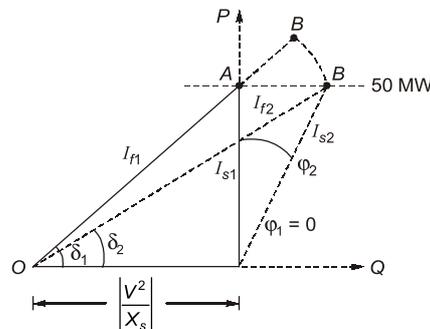
Ans. (c)



I_s = Stator phase current,

Suppose initially at A i.e.

$$\phi_1 = 0$$



If I_f increases, $I_f =$ imitation current

$\delta =$ load angle

$\phi =$ p.f. angle

Then new position is B .

So, to get or keep, $P = 50$ MW

B point rotate in such a manner that it will be again on 50 MW line

So, from OBO's triangle

if, $I_{f2} > I_{f1}$

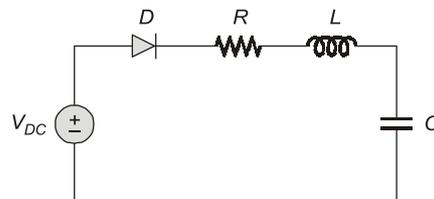
than, $I_{s2} > I_{s1} \Rightarrow$ Stator current increase

$\delta_2 < \delta_1 \Rightarrow$ Load angle decrease

$\Phi_2 > \Phi_1 \Rightarrow \cos \Phi_2 < \cos \Phi_1$ means power factor become more lagging.

End of Solution

Q.23 A circuit with ideal elements is shown.



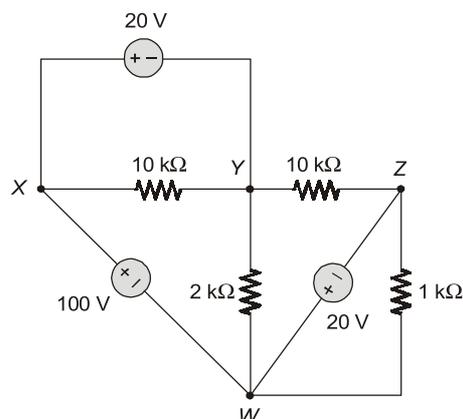
Which one of the following options correctly identifies all the linear elements in the circuit?

- (a) R only
 (b) R, L, and C only
 (c) D only
 (d) L, C and D only

Ans. (b)

End of Solution

Q.24 For the circuit shown, which one of the following options correctly identifies the Thevenin's equivalent parameters between nodes Y and Z?



- (a) $V_{TH} = 100V, R_{TH} = 10 k\Omega$
 (b) $V_{TH} = 140V, R_{TH} = 0 k\Omega$
 (c) $V_{TH} = 100V, R_{TH} = 0 k\Omega$
 (d) $V_{TH} = 140V, R_{TH} = 10 k\Omega$



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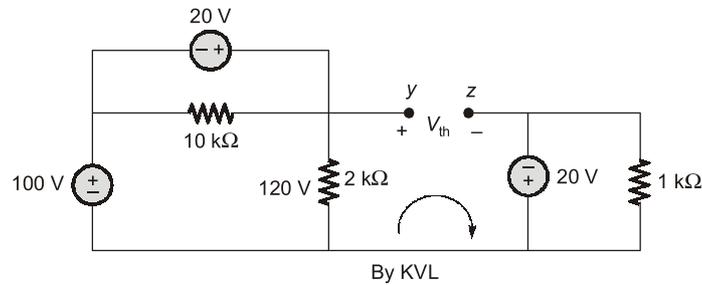
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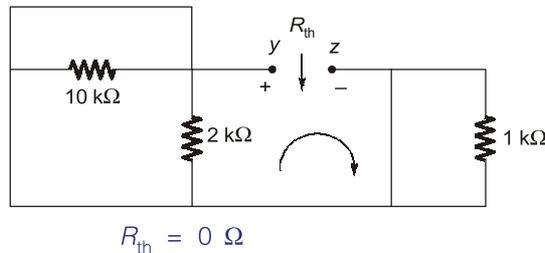
Ans. (b)
 Case-1 (V_{th}):



$$-120 + V_{th} - 20 = 0$$

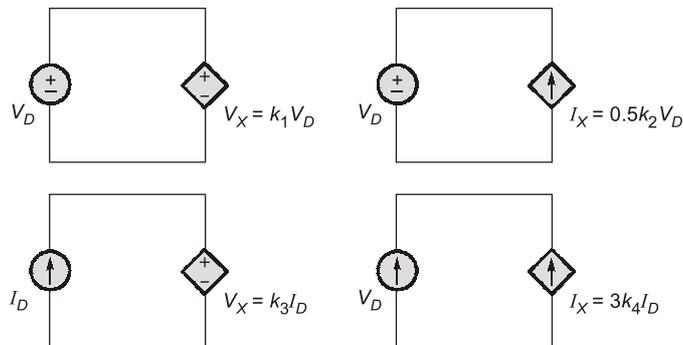
$$V_{th} = 140 \text{ V}$$

Case-2 (R_{th}):



End of Solution

Q.25 Refer to the four circuits shown.



Which one of the following options for k_1 , k_2 , k_3 , and k_4 makes all of them realizable?

- (a) $k_1 = 1$, $k_4 = -\frac{1}{3}$, for all values of k_2 and k_3
- (b) $k_2 = -2$, $k_3 = +\frac{1}{3}$, for all values of k_1 and k_4
- (c) $k_1 = 2$, $k_2 = 0.5$, $k_3 = -\frac{2}{3}$, $k_4 = -3$
- (d) $k_1 = 2$, $k_2 = -0.5$, $k_3 = -\frac{2}{3}$, $k_4 = +3$

Ans. (a)

Applying KVL:

$$V_D = V_X = K_1 V_D$$

$$(1 - K_1)V_D = 0$$

For any V_D :

$$K_1 = 1$$

Applying KCL:

$$I_D + I_X = 0$$

$$I_D + 3K_4 I_D = 0$$

$$1 + 3K_4 = 0$$

$$K_4 = -\frac{1}{3}$$

On K_2 and K_3 no any restriction.

End of Solution

Q.26 A single-phase voltage source $v_s = 325 \sin(2\pi 50t)$ V delivers a current, $i = 12 \sin(2\pi 50t) + 9 \sin(2\pi 150t)$ A to a load.

The load power factor, correct up to two decimal places, is

- (a) 1.00 (b) 0.80
 (c) 0.65 (d) 0.57

Ans. (b)

$$V_s = 325 \sin(100\pi t)$$

$$i = 12 \sin(100\pi t) + 9 \sin(300\pi t)$$

$$S = V_{\text{RMS}} I_{\text{RMS}} = \frac{325}{\sqrt{2}} \frac{15}{\sqrt{2}} = \frac{325 \times 15}{2}$$

$$I_{\text{RMS}} = \sqrt{\frac{12^2}{2} + \frac{9^2}{2}}$$

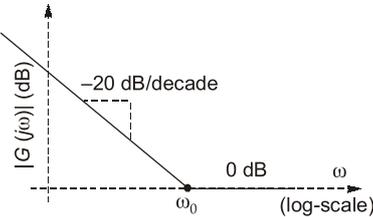
$$= \sqrt{\frac{144 + 81}{2}} = \frac{15}{\sqrt{2}}$$

$$P = VI \cos \phi = \frac{325 \times 12}{2} \times 1$$

$$\cos \theta = \frac{P}{S} = \frac{\frac{325 \times 12}{2}}{\frac{325 \times 15}{2}} = \frac{12}{15} = 0.8$$

End of Solution

Q.29 The asymptotic Bode magnitude plot of a system is shown.



Which one of the following options best represents the transfer function of the system?

(a) $G(s) = \frac{1 + \frac{s}{\omega_0}}{\frac{s}{\omega_0}}$

(b) $G(s) = \frac{\frac{s}{\omega_0}}{1 + \frac{s}{\omega_0}}$

(c) $G(s) = \frac{1 + \frac{s}{\omega_0}}{1 - \frac{s}{\omega_0}}$

(d) $G(s) = \frac{1 - \frac{s}{\omega_0}}{1 + \frac{s}{\omega_0}}$

Ans. (a)

End of Solution

Q.30 Two $n \times n$ matrices A and B have a common eigenvalue 2, and the same corresponding nonzero eigenvector. Which of the following options is/are correct?

(Note: I is the $n \times n$ identity matrix.)

(a) Determinant $(A - 2I) = 0$

(b) Determinant $(B - 2I) = 0$

(c) Determinant $(A + B - 2I) = 0$

(d) Determinant $(A + B - 4I) = 0$

Ans. (a, b, d)

Given, $\lambda_A = 2, \lambda_B = 2$

Then $|A - 2I| = 0$ by characteristic equation

and $|B - 2I| = 0$ by characteristic equation

$$\begin{aligned} \lambda \text{ of } A + B - 4I &= \lambda_A + \lambda_B - 4 \\ &= 2 + 2 - 4 = 0 \end{aligned}$$

$$\Rightarrow |A + B - 4I| = 0$$

End of Solution

Q.31 A 220V/12V single-phase transformer is designed for use in India and rated 100 VA at 50 Hz. Later, this unit is shipped to the USA where it is used as a 110V/6V transformer at 60 Hz. Which of the following statements is/are correct?

(a) No-load current drawn would be smaller for operation in the USA compared to that in India

(b) For the same load current, the losses would be higher in the USA compared to that in India

- (c) The peak magnetic flux density in the core would be higher while operating in the USA compared to that in India
 (d) The eddy current losses in the core would be approximately 44% higher while operating in the USA compared to that in India

Ans. (a)

$$I_0 = I_c + I_m$$

$$I_c \propto \text{Iron loss}$$

$$I_m \propto B_m \propto \frac{V \downarrow}{f \uparrow} \Rightarrow B_m \downarrow$$

As iron loss reduce $I_c \downarrow$

End of Solution

- Q.32 Given that $\vec{F}(x,y,z) = \sin(y)\hat{x} + \cos(x)\hat{y} + 5\hat{z}$, the integral $\iint_S \vec{F}(x,y,z) \cdot \vec{dS}$ over the unit sphere S centered at the origin evaluates to _____. (Round off to one decimal place)

Ans. (0)

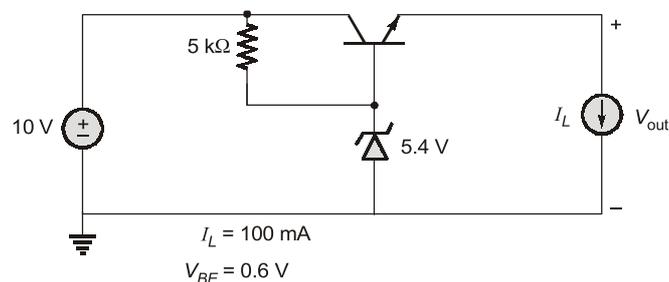
$$\oiint_{S: x^2+y^2+z^2=1} \vec{F} \cdot \vec{dA} = \iiint_V (\nabla \cdot \vec{F}) dV \text{ by div theorem}$$

$$= \iiint_V \left(y \frac{\partial}{\partial x}(\sin y) + \frac{\partial}{\partial y}(\cos x) + \frac{\partial}{\partial z}(5) \right) dv$$

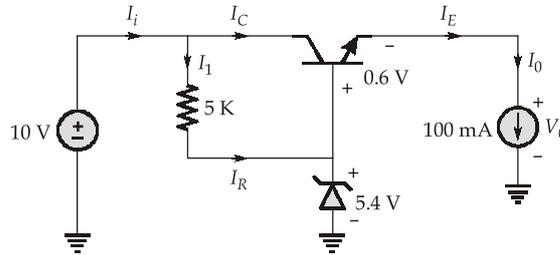
$$= 0.0$$

End of Solution

- Q.33 In the linear regulator circuit shown, the base to emitter voltage V_{BE} of the BJT is 0.6 V. The Zener diode clamps the base voltage to 5.4 V. Ignore the biasing current of the Zener diode and BJT. The maximum possible efficiency of the regulator circuit is _____ % (Round off to one decimal place)



Ans. (47.5) (47.5 to 48.0)



$$\eta = \frac{P_{out}}{P_{in}}$$

$$P_{out} = V_0 \times I_0$$

$$= (V_Z - V_{BE}) \times I_0$$

$$= (5.4 - 0.6) \times 100 \text{ mA}$$

$$= 4.8 \times 100 \text{ mA} = 480 \text{ mW}$$

$$I_1 = \frac{10 - 5.4}{5k} = 0.92 \text{ mA}$$

$$I_i = I_C + I_1 = 100 \text{ mA} + 0.92 \text{ mA}$$

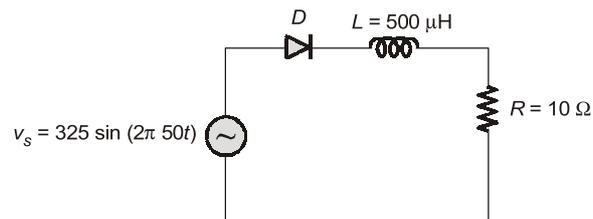
$$= 100.92 \text{ mA}$$

$$P_{in} = V_{in} \times I_i = 10 \times 100.92 \text{ mA} = 1009.2 \text{ mW}$$

$$\eta = \frac{480}{1009.2} \times 100\% = 47.5\%$$

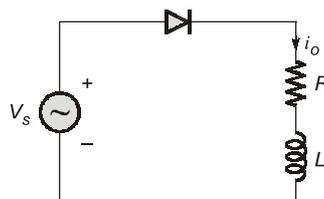
End of Solution

Q.34 Consider the circuit shown. Assume that the diode D is ideal. The supply voltage $v_s = 325 \sin(2\pi 50) \text{ V}$, $L = 500 \mu\text{H}$, and $R = 10 \Omega$. The peak diode current (in amperes) is _____. (Round off to one decimal place)



Ans. (32.49) (32.30 to 32.50)

$$v_s = 325 \cdot \sin(2\pi \cdot 50t)$$



$$R = 10 \Omega, \quad L = 500 \mu\text{H}$$

$$X_L = \omega L = 2\pi \cdot 50 \cdot 500 \cdot 10^{-6}$$



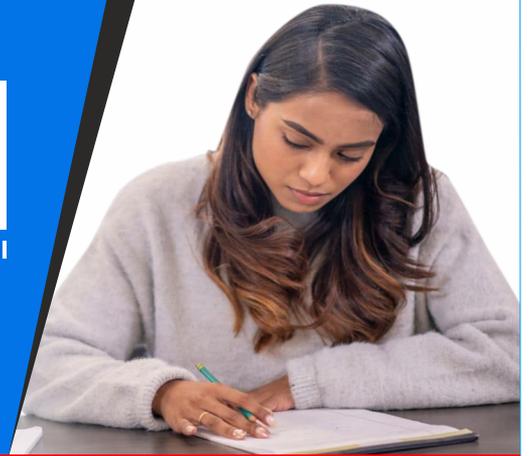
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$$X_L = 0.157 \Omega$$

Here, $|Z| = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + (0.157)^2} = 10.001 \Omega \simeq R$

Here, since inductor value is very small,

$$|Z| \simeq R$$

∴ We can treat as only load resistance.

$$\therefore i_{\text{peak}} = \frac{V_M}{R} = \frac{325}{10} = 32.5 \text{ A}$$

End of Solution

Q.35 A is an $m \times m$ skew-symmetric matrix with real-valued entries, and x is an m -dimensional column vector with real-valued entries such that $x^T x = 1$. The quantity $x^T A x$ evaluates to _____. (Answer in integer)

Ans. (0)

$$A^T = -A$$

$$\varepsilon_f = A = \begin{bmatrix} 0 & -a & -b \\ a & 0 & -c \\ b & c & 0 \end{bmatrix}$$

$$\begin{aligned} X^T A X &= [x_1 \quad x_2 \quad x_3] \begin{bmatrix} 0 & -a & -b \\ a & 0 & -c \\ b & c & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \\ &= 0 \end{aligned}$$

End of Solution

Q.36 A time-limited waveform $g(x)$ is specified as follows:

$$g(x) = \begin{cases} -k, & -\pi < x \leq 0 \\ +k, & 0 < x \leq \pi \\ 0, & \text{otherwise} \end{cases}$$

A new waveform $f(x)$ is constructed from $g(x)$ as follows:

$$f(x) = \sum_{m=-\infty}^{\infty} g(x + 2\pi n), \text{ for all } x \in R$$

The sum of the coefficients of the third harmonics of the sine and cosine terms in the trigonometric Fourier series expansion of $f(x)$ is $\frac{2}{3\pi}$. What is the value of k ?

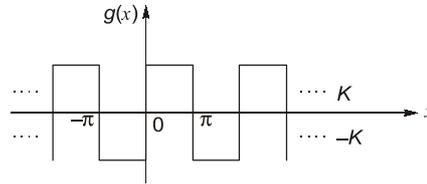
(a) 1

(b) $\frac{1}{2}$

(c) $\frac{1}{3}$

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

Ans. (b)



Since, $g(x)$ is odd signal,
 So, it will contain only
 sine - term

i.e. $a_n = 0$ $\left[\omega_0 = \frac{2\pi}{T_0} = \frac{2\pi}{2\pi} = 1 \right]$

$\therefore a_3 = 0$ where a_3 is coefficient of 3rd harmonic cosine-term

Now,
$$b_n = \frac{2}{T_0} \int_{-T_0/2}^{T_0/2} g(x) \cdot \sin n\omega_0 x dx$$

$$= \frac{2}{2\pi} \int_{-\pi}^{\pi} g(x) \cdot \sin nx dx = \frac{1}{\pi} \times 2 \int_0^{\pi} g(x) \cdot \sin nx dx$$

$\therefore b_3 = \frac{2}{\pi} \int_0^{\pi} K \cdot \sin 3x dx = \frac{2K}{\pi} \cdot \left(\frac{-\cos 3x}{3} \right)_0^{\pi}$

$$= \frac{2K}{3\pi} [-(-1) + 1] = \frac{4K}{3\pi}$$

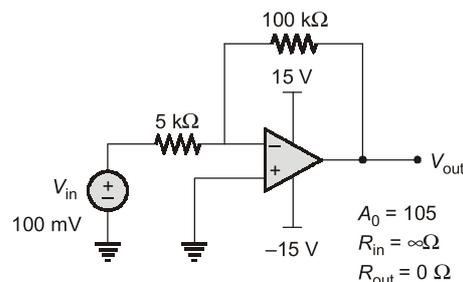
Given that, $a_3 + b_3 = \frac{2}{3\pi}$

$\Rightarrow 0 + \frac{4K}{3\pi} = \frac{2}{3\pi}$

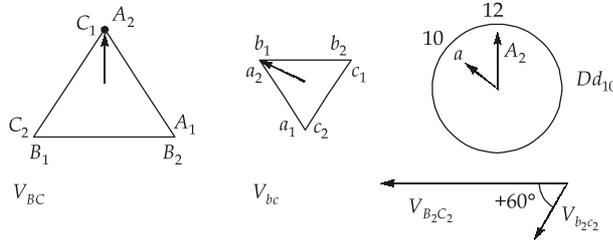
$\Rightarrow K = \frac{2}{4} = \frac{1}{2} = 0.5$

End of Solution

Q.37 In the circuit shown, the open loop gain of the operational amplifier is $A_0 = 105$.



Ans. (d)



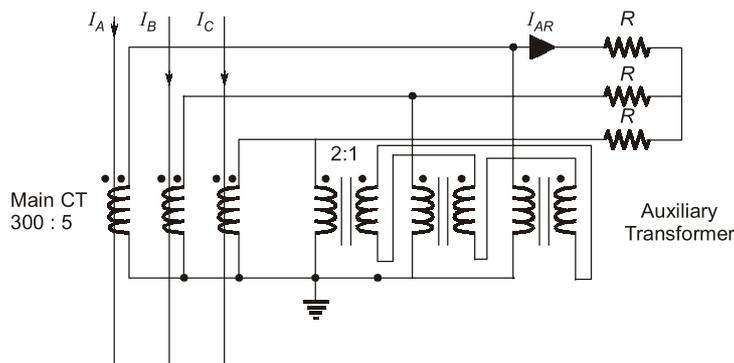
End of Solution

Q.39 In the circuit shown, the phase currents are

$$I_A = 572.812 + j 50.115A$$

$$I_B = -254.525 - j 459.175A$$

$$I_C = -207.083 + j 444.091A$$



Given that the CTs are ideal with no saturation, and the turns ratio of the Main CT is 300 : 5 and that of the Auxiliary Transformer ($Yn\Delta$) is 2 : 1 on every phase, the value of I_{AR} , rounded off to three decimal places, is

- (a) 0A (b) $0.653 \angle 17.556^\circ$ A
 (c) $537.24 \angle 4.105^\circ$ A (d) $8.954 \angle 4.105^\circ$ A

Ans. (d)

$$I_a = \frac{(572.812 + j50.115)}{60} = 9.583 \angle 5^\circ$$

$$I_b = \frac{(-254.525 - j459.175)}{60} = 8.75 \angle -119^\circ$$

$$I_c = \frac{(-207.083 + j444.091)}{60} = 8.166 \angle 115^\circ$$

$$I_{a0} = \frac{I_a + I_b + I_c}{3} = \frac{1.943 \angle 16.01^\circ}{3} = 0.65 \angle 16^\circ$$

As the secondary is not having the neutral grounding,

$$I_{AR} = I_{a1} + I_{a2} = I_a - I_{a0}$$

$$= 8.94 \angle 4.2^\circ$$

End of Solution

Q.40 The operating characteristic of a reactance relay is given by $X \leq 1 \Omega$, where X is the reactance calculated by the relay. Its operating characteristic in the admittance plane (G-B plane, where G and B denote conductance and susceptance, respectively, expressed in Ω) is given by:

- (a) $G^2 + (B + 0.5)^2 \geq \frac{1}{4}$ (b) $B \geq 1$
 (c) $(G - 1)^2 + (B)^2 \leq \frac{1}{2}$ (d) $(G)^2 + (B - 1)^2 \geq \frac{1}{2}$

Ans. (a)

$$Z = \frac{1}{Y} = \frac{1}{G + jB}$$

$$R + jX = \frac{G - jB}{G^2 + B^2}$$

$$X \leq 1$$

$$\frac{-B}{G^2 + B^2} \leq 1$$

$$G^2 + B^2 + B \geq 0$$

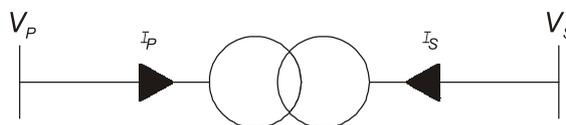
$$G^2 + B^2 + 2 \times B \times \frac{1}{2} + \left(\frac{1}{2}\right)^2 - \left(\frac{1}{2}\right)^2 \geq 0$$

$$G^2 + \left(B + \frac{1}{2}\right)^2 \geq \frac{1}{4}$$

End of Solution

Q.41 A three-phase two-winding transformer has a voltage transformation ratio $\frac{V_P}{V_S} = 0.866 + j0.5$,

where V_P is the primary side voltage in p.u., and V_S is the secondary side voltage in p.u. I_P and I_S represent the currents injected into the primary and secondary sides of the transformer, respectively. The admittance corresponding to the leakage impedance of the transformer referred to the secondary is y_t , p.u. Neglect the magnetizing branch.



The Y bus representation of this transformation is

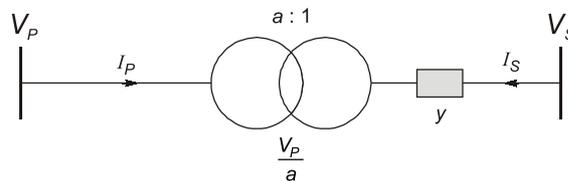
(a)
$$\begin{bmatrix} I_P \\ I_S \end{bmatrix} = \begin{bmatrix} \frac{y_t}{0.866 + j0.5} & \frac{y_t}{0.866 + j0.5} \\ -\frac{y_t}{0.866 + j0.5} & \frac{y_t}{0.866 + j0.5} \end{bmatrix} \begin{bmatrix} V_P \\ V_S \end{bmatrix}$$

$$(b) \begin{bmatrix} I_P \\ I_S \end{bmatrix} = \begin{bmatrix} y_t & -y_t \\ -y_t & y_t \end{bmatrix} \begin{bmatrix} V_P \\ V_S \end{bmatrix}$$

$$(c) \begin{bmatrix} I_P \\ I_S \end{bmatrix} = \begin{bmatrix} y_t & -\frac{y_t}{0.866 + j0.5} \\ -\frac{y_t}{0.866 + j0.5} & y_t \end{bmatrix} \begin{bmatrix} V_P \\ V_S \end{bmatrix}$$

$$(d) \begin{bmatrix} I_P \\ I_S \end{bmatrix} = \begin{bmatrix} y_t & -\frac{y_t}{0.866 - j0.5} \\ -\frac{y_t}{0.866 + j0.5} & y_t \end{bmatrix} \begin{bmatrix} V_P \\ V_S \end{bmatrix}$$

Ans. (d)



$$I_S = \left(V_S - \frac{V_P}{a} \right) y$$

$$= -\frac{y}{a} V_P + y V_S$$

$$\frac{V_P}{V_S} = \left(\frac{-I_S}{I_P} \right)^t = a$$

$$\Rightarrow \frac{-I_S}{I_P} = a^t$$

$$I_P = \frac{-I_S}{a^t} = \frac{-1}{a^t} \left(V_S - \frac{V_P}{a} \right) y$$

$$I_P = y V_P - \frac{y}{a^t} V_S$$

$$\begin{bmatrix} I_P \\ I_S \end{bmatrix} = \begin{bmatrix} y & -\frac{y}{a^t} \\ -\frac{y}{a} & y \end{bmatrix} \begin{bmatrix} V_P \\ V_S \end{bmatrix}$$

End of Solution

Q.42 An electrical component has voltage drop $v = V_m \sin(\omega t)$, when the current through it is $i = I_m \sin(\omega t - \theta)$. What is the average power dissipated over a half cycle corresponding to ω ?

(a) 0 (b) $V_m I_m \cos \theta$

(c) $\frac{V_m I_m}{2} \cos \theta$ (d) $\frac{V_m I_m}{4} \cos \theta$



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Ans. (c)

Given, $V = V_m \sin(\omega t), \quad i = I_m \sin(\omega t - \theta)$

Instantaneous power:

$$P = VI = V_m I_m \sin(\omega t) \sin(\omega t - \theta)$$

Using identity:

$$\sin A \sin B = \frac{1}{2} [\cos(A - B) - \cos(A + B)]$$

$$P = \frac{V_m I_m}{2} [\cos \theta - \cos(2\omega t - \theta)]$$

Now average over half cycle ($0 \rightarrow \pi$)

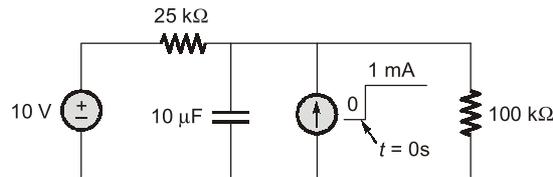
Average of $\cos(2\omega t - \theta)$ over half cycle = 0

So only constant term remains

$$P_{\text{avg}} = \frac{V_m I_m}{2} \cos \theta$$

End of Solution

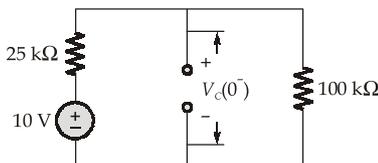
Q.43 The electrical network shown has an independent voltage source (10 V) and a current source (1 u(t) mA).



The voltage across the capacitor at time instants (in seconds) $t = 0^+, t = 0.50,$ and $t = \infty,$ respectively, is:

- (a) 8.00 V, 28.00 V, 26.36 V (b) 8.00 V, 26.36 V, 28.00 V
 (c) 10.00 V, 26.36 V, 28.00 V (d) 10.00 V, 26.36 V, 28.00 V

Ans. (b)

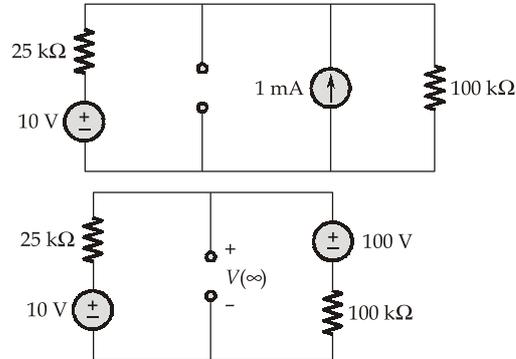


$$V_C(0^-) = 10 \times \frac{100}{100 + 25} = 10 \times \frac{4}{5} = 8 \text{ V}$$

$t = 0^+$

$$V_C(0^+) = 8 \text{ V}$$

$t = \infty$

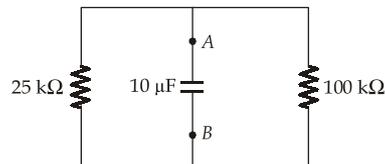


$$\frac{V(\infty) - 10}{25 \times 10^3} + \frac{V_C(\infty) - 100}{100 \times 10^3} = 0$$

$$\frac{4V(\infty) - 40 + V_C(\infty) - 100}{100 \times 10^3} = 0$$

$$\Rightarrow V(\infty) = \frac{140}{5} = 28$$

Time constant



$$R = \frac{100 \times 25}{125} = 20 \text{ k}\Omega$$

$$\tau = RC = 20 \times 10^3 \times 10 \times 10^{-6} = 200 \text{ ms}$$

$$V_C(t) = \left[(V_C(0^+) - V_C(\infty))e^{-t/RC} + V_C(\infty) \right]$$

$$= [8 - 28]e^{-5t} + 28$$

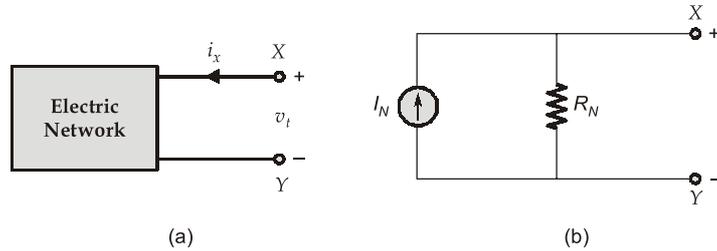
$t = 0.5$

$$V_C(0.5) = (8 - 28)e^{-5(0.5)} + 28 = 26.36 \text{ V}$$

End of Solution

Q.44 The terminal voltage and current of a linear electrical network shown in Figure (a) are given in the table.

Terminal voltage (v_t)	Terminal current (i_t)
18V	-0.5A
30V	0.5A
36V	1.0A



The correct choice for the parameters (I_N , R_N) of the Norton equivalent circuit shown in Figure (b) is:

- (a) $I_N = 3.0\text{A}$, $R_N = 24.0\ \Omega$ (b) $I_N = 12.0\text{A}$, $R_N = 2.0\ \Omega$
 (c) $I_N = 2.0\text{A}$, $R_N = 12.0\ \Omega$ (d) $I_N = 2.0\text{A}$, $R_N = 24.0\ \Omega$

Ans. (c)

$$0.5 = \frac{30 - V_{th}}{R_{th}}$$

$$0.5R_{th} = 30 - V_{th}$$

$$0.5(36 - V_{th}) = 30 - V_{th}$$

$$18 - 0.5V_{th} = 30 - 18$$

$$V_{th} = \frac{12}{0.5} = 24$$

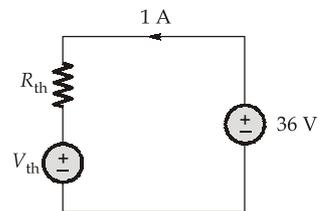
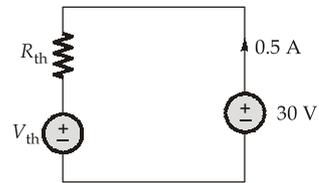
$$\frac{36 - V_{th}}{R_{th}} = 1$$

$$36 - V_{th} = R_{th}$$

$$36 - 24 = R_{th}$$

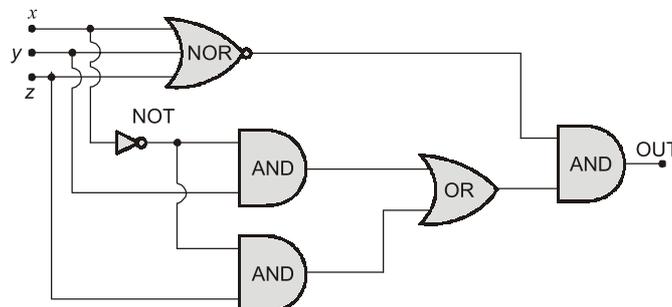
$$R_{th} = 12\ \Omega$$

$$I_N = \frac{24}{12} = 2\text{A}$$



End of Solution

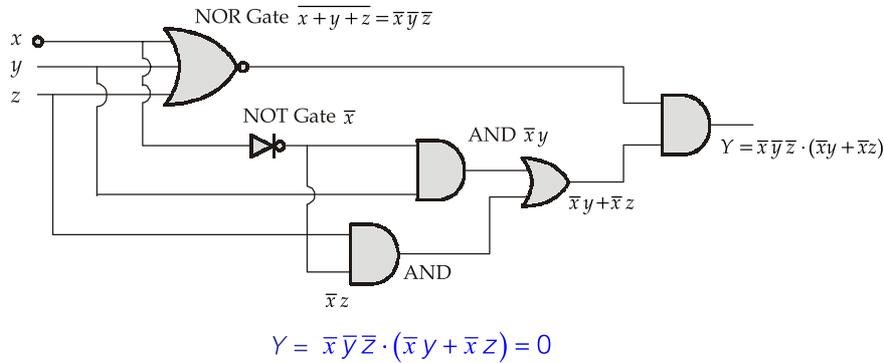
Q.45 The digital circuit shown has 3 inputs (x , y , and z).



The simplified logical expression for the output (OUT) is:

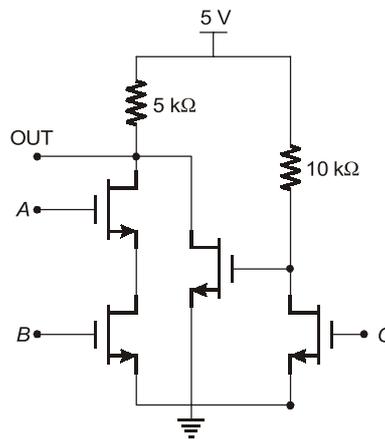
- (a) $\bar{x}\bar{y}\bar{z}$ (b) 0
 (c) $\bar{x}(y+z)$ (d) 1

Ans. (b)



End of Solution

Q.46 The MOSFET switches shown in the circuit are ideal.



Which of the following is the correct option for Boolean logical expression of the output (OUT), and the maximum possible power (P) consumed by the circuit?

- (a) $OUT = \overline{AB + \overline{C}}$, $P = 5 \text{ mW}$ (b) $OUT = \overline{(A + B)\overline{C}}$, $P = 5 \text{ mW}$
 (c) $OUT = \overline{ABC}$, $P = 7.5 \text{ mW}$ (d) $OUT = \overline{ABC}$, $P = 7.5 \text{ mW}$

Ans. (d)

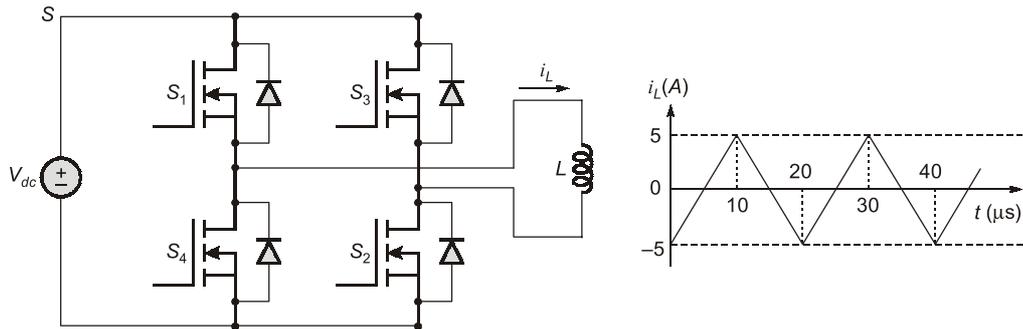
For output,

$$\overline{AB + \overline{C}} = \overline{AB} \cdot C$$

$$P = \frac{5^2}{10k} + \frac{5^2}{5k} = 7.5 \text{ mW}$$

End of Solution

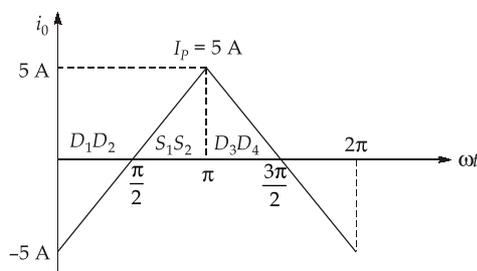
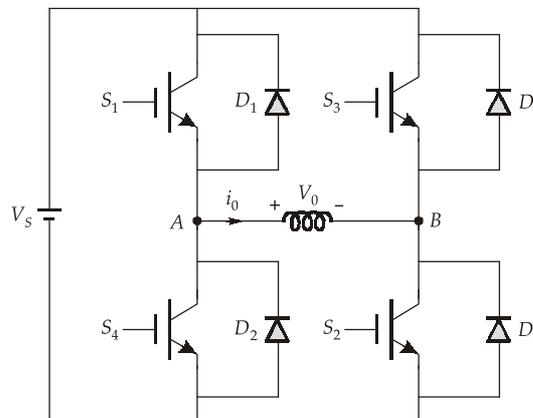
Q.47 Consider the single-phase voltage source inverter circuit feeding an inductive load (L). Assume that the power MOSFET switches are ideal. S_1 and S_2 are switched on during the first $10 \mu\text{s}$, and S_3 and S_4 are switched on during the next $10 \mu\text{s}$ in a switching cycle. The switches in the same leg are thus switched in a complementary fashion. Neglect the dead time. The waveform of the inductor current (i_L) in the steady state is triangular with a peak value of 5A as shown.



The rms value of the current through the switch S_1 is

- (a) 2.88 A
- (b) 2.04 A
- (c) 3.54 A
- (d) 2.50 A

Ans. (b)



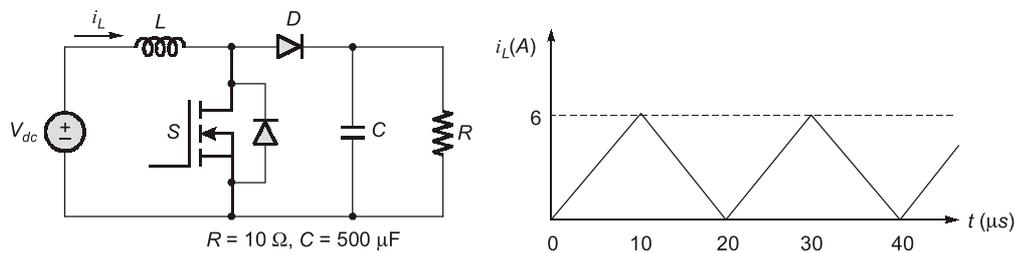
$$I_{0 \text{ rms}} = \frac{I_p}{\sqrt{3}} = \frac{5}{\sqrt{3}}$$

I_{rms} (module) switch, diode

$$= I_{Orms} \left(\frac{\pi}{2\pi} \right)^{1/2} = \frac{5}{\sqrt{3}} \cdot \frac{1}{\sqrt{2}} = \frac{5}{\sqrt{6}} = 2.04 \text{ A}$$

End of Solution

- Q.48** Consider the boost converter circuit shown. Assume that the semiconductor devices are ideal. In steady state, the inductor current rises linearly from 0 A to 6 A in the first 10 μs and then falls linearly from 6 A to 0 A in the next 10 μs of every switching cycle as shown. The load resistance R is 10 Ω and the capacitance C is 500 μF .



Neglect the ripple in the output voltage. What is the input voltage V_{dc} ?

Ans. (c)

Inductor rises for 10 μsec and falls 10 μs
 So, $D = 0.5$

$$V_{out} = \frac{V_{in}}{(1-D)} = \frac{V_{in}}{0.5} = 2V_{in}$$

$$\text{Average inductor current} = \frac{0.6}{2} = 3 \text{ A}$$

$$\text{Output current} = \frac{V_{out}}{10}$$

Power balance:

$$V_{in} \times 3 = \frac{V_{out}^2}{10}, \quad \text{Put } V_{out} = 2V_{in}$$

$$3V_{in} = \frac{4V_{in}^2}{10}$$

$$V_{in} = 7.5 \text{ V}$$

End of Solution

- Q.49** Which one of the following statements is ALWAYS correct about a collection of p column vectors, each having n real-valued entries?

- (a) if $p > n$, then the column vectors must be linearly dependent
- (b) If $p > n$, then the column vectors must be linearly independent
- (c) If $p = n$, then the column vectors must be orthogonal
- (d) If $p < n$, then the column vectors must be linearly independent

Ans. (a)

$$A = [a_{ij}]_{n \times p}$$

If $p > n$, then the no of column more than direction

∴ Some column vectors must be dependent linearly.

End of Solution

Q.50 Consider the second-order differential equation

$$\frac{d^2y}{dx^2} + \frac{dy}{dx} + y = 0$$

with initial conditions

$$y(0) = 1, \left. \frac{dy}{dx} \right|_{x=0} = 1$$

The solution is given by

(a) $y(x) = \exp\left(-\frac{x}{2}\right) \left(\cos\left(\frac{\sqrt{3}x}{2}\right) + \sqrt{3} \sin\left(\frac{\sqrt{3}x}{2}\right) \right)$

(b) $y(x) = \exp\left(-\frac{x}{2}\right) \left(\cos\left(\frac{\sqrt{3}x}{2}\right) + \frac{1}{\sqrt{3}} \sin\left(\frac{\sqrt{3}x}{2}\right) \right)$

(c) $y(x) = \exp\left(-\frac{x}{2}\right) \left(\cos\left(\frac{\sqrt{3}x}{2}\right) - \frac{1}{\sqrt{3}} \sin\left(\frac{\sqrt{3}x}{2}\right) \right)$

(d) $y(x) = \exp\left(-\frac{x}{2}\right) \left(\cos\left(\frac{\sqrt{3}x}{2}\right) - \sqrt{3} \sin\left(\frac{\sqrt{3}x}{2}\right) \right)$

Ans. (a)

$$y'' + y' + y = 0$$

$$y(0) = 1$$

$$y'(0) = 1$$

$$\Rightarrow y = Y_{CF}$$

Y_{CF} : Given by,

$$f(m) = m^2 + m + 1 = 0$$

$$\Rightarrow m = \frac{-1 \pm \sqrt{1-4}}{2} = \frac{-1 \pm i\sqrt{3}}{2}$$

$$\therefore y = y_{CF} = e^{-x/2} \left[C_1 \cos \frac{\sqrt{3}}{2} x + C_2 \sin \frac{\sqrt{3}}{2} x \right]$$

Put $x = 0$, $y = 1$
 $1 = C_1$

$$y' = e^{-x/2} \left[\frac{-\sqrt{3}}{2} C_1 \sin \frac{\sqrt{3}}{2} x + \frac{\sqrt{3}}{2} C_2 \cos \frac{\sqrt{3}}{2} x \right] - \frac{e^{-x/2}}{2} \left[C_1 \cos \frac{\sqrt{3}}{2} x + C_2 \sin \frac{\sqrt{3}}{2} x \right]$$

Put $x = 0, y' = 1,$

$$1 = \frac{\sqrt{3}}{2} C_2 - \frac{C_1}{2}$$

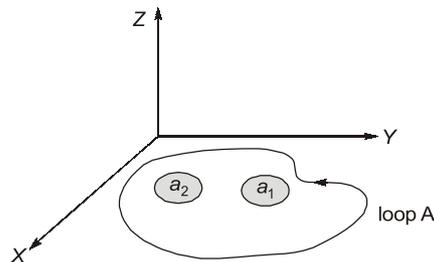
$$C_2 = \frac{3}{2} \times \frac{2}{3} \times \sqrt{3}$$

$$\therefore y = e^{-x/2} \left[\cos \frac{\sqrt{3}}{2} x + \sqrt{3} \sin \frac{\sqrt{3}}{2} x \right]$$

End of Solution

Q.51 The figure shows an arbitrarily shaped planar conducting loop A in the XY plane. Two nonintersecting regions with areas a_1 and a_2 within the loop are subjected to magnetic fields

$$\vec{B}_1 = \frac{m}{\sqrt{2}} \sin(\omega t) (1\hat{x} + 0\hat{y} + 1\hat{z}), \text{ and } \vec{B}_2 = -\frac{n}{\sqrt{2}} \cos\left(2\omega t + \frac{\pi}{4}\right) (0\hat{x} + 1\hat{y} + 1\hat{z}), \text{ respectively.}$$



What is the expression for the induced rms voltage in loop A?

(a) $\sqrt{\frac{a_1^2 \omega^2 m^2 + 4a_2^2 \omega^2 n^2}{4}}$ (b) $\sqrt{\frac{a_1^2 \omega^2 m^2 + 4a_2^2 \omega^2 n^2}{2}}$

(c) $\sqrt{\frac{a_1^2 \omega^2 m^2 - 2a_2^2 \omega^2 n^2}{2}}$ (d) $\sqrt{a_1^2 \omega^2 m^2 + 2a_2^2 \omega^2 n^2}$

Ans. (a)

From Faraday's law,

$$V_{\text{emf}} = \frac{-d\phi}{dt}$$

• For loop a_1 :

$$\phi_1 = \int \vec{B}_1 \cdot \vec{ds} = \int \frac{m}{\sqrt{2}} \sin(\omega t) (\hat{a}_x + \hat{a}_z) \cdot ds_1 \hat{a}_z$$

$$\Rightarrow \phi_1 = \frac{m}{\sqrt{2}} \sin \omega t \int ds_1 = \frac{m}{\sqrt{2}} \sin \omega t \hat{a}_1$$

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$$q(s) = s^2 - as + ab = 0$$

$$q(s) = s^2 + 4s + 13 = 0$$

$$a = -4,$$

$$b = \frac{-13}{4} = -3.25$$

End of Solution

Q.53 A system is represented in state-space form as follows:

(u : input, x : state vector, y : output)

$$\dot{x} = \begin{bmatrix} 1 & 2 \\ -3 & 0 \end{bmatrix}x + \begin{bmatrix} 1 \\ 2 \end{bmatrix}u$$

$$y = [1 \quad 2]x$$

Consider the new state vector $z = \begin{bmatrix} 2 & 1 \\ -1 & 0 \end{bmatrix}x$

What is the state-space representation of the system in terms of the new state vector z ?

(a) $\dot{z} = \begin{bmatrix} -1 & 4 \\ -1 & -2 \end{bmatrix}z + \begin{bmatrix} 4 \\ -1 \end{bmatrix}u$

$$y = [2 \quad 3]z$$

(b) $\dot{z} = \begin{bmatrix} 2 & 3 \\ 0 & 3 \end{bmatrix}z + \begin{bmatrix} 3 \\ 5 \end{bmatrix}u$

$$y = [2 \quad 3]z$$

(c) $\dot{z} = \begin{bmatrix} 4 & 9 \\ -2 & -3 \end{bmatrix}z + \begin{bmatrix} 4 \\ -1 \end{bmatrix}u$

$$y = [2 \quad 3]z$$

(d) $\dot{z} = \begin{bmatrix} 2 & 1 \\ -4 & 1 \end{bmatrix}z + \begin{bmatrix} 4 \\ -1 \end{bmatrix}u$

$$y = [4 \quad -1]z$$

Ans. (c)

Given system:

$$\dot{x} = \begin{bmatrix} 1 & 2 \\ -3 & 0 \end{bmatrix}x + \begin{bmatrix} 1 \\ 2 \end{bmatrix}u$$

$$y = [1 \quad 2]x$$

New state:

$$Z = Tx = \begin{bmatrix} 2 & 1 \\ -1 & 0 \end{bmatrix}x$$

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

$$A' = TAT^{-1}$$

$$= \begin{bmatrix} 2 & 1 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} 2 & 3 \\ 0 & 3 \end{bmatrix} = \begin{bmatrix} 4 & 9 \\ -2 & -3 \end{bmatrix}$$

$$B' = TB = \begin{bmatrix} 2 & 1 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 2 \end{bmatrix} = \begin{bmatrix} 4 \\ -1 \end{bmatrix}$$

$$C^T = CT^{-1} = [1 \ 2] \begin{bmatrix} 0 & -1 \\ 1 & 2 \end{bmatrix} = [2 \ 3]$$

$$Z = \begin{bmatrix} 4 & 9 \\ -2 & -3 \end{bmatrix} z + \begin{bmatrix} 4 \\ -1 \end{bmatrix} u$$

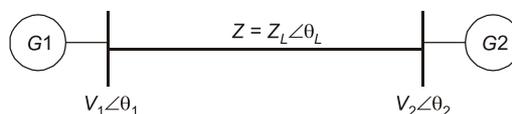
$$y = [2 \ 3]z$$

End of Solution

Q.54 For the balanced 3-phase transmission line shown, consider the following cases:

Case-1 : $|V_1| = 1.1$ p.u., $|V_2| = 0.9$ p.u., $Z = 0.75 \angle 0^\circ$ p.u. and $\theta_{12} = \theta_1 - \theta_2 = 0^\circ$

Case-2 : $|V_1| = 1.1$ p.u., $|V_2| = 0.9$ p.u., $Z = 0.75 \angle 90^\circ$ p.u. and $\theta_{12} = \theta_1 - \theta_2 = 90^\circ$



Which of the following statements is/are correct about real power loss and reactive power loss in the line?

- (a) Real power loss in Case-1 is more than that in Case-2
- (b) Real power loss in Case-2 is more than that in Case-1
- (c) Reactive power loss in Case-1 is more than that in Case-2
- (d) Reactive power loss in Case-2 is more than that in Case-1

Ans. (a, d)

In case-I:

$$z = 0.75 \angle 0^\circ \text{ resistive nature}$$

So only real power loss,

In case-II:

$$z = 0.75 \angle 90^\circ \text{ reactance}$$

So only reactive power loss.

End of Solution

Q.55 Consider an $n \times n$ orthogonal matrix A with real entries and each column having unit Euclidean norm. Which of the following statements is/are correct?

- (a) The value of the determinant of A is either +1 or -1.
- (b) The eigenvalues of A have modulus 1.
- (c) $\|Ax\| = \|x\|$, for all $x \in R^n$, where $\|x\|$ denotes the Euclidean norm of x , and $(Ax)^T(Ay) \neq x^T y$, for all distinct $x, y \in R^n$.
- (d) $\|Ax\| = \|x\|$, for all $x \in R^n$, where $\|x\|$ denotes the Euclidean norm of x , and $(Ax)^T(Ay) = x^T y$, for all distinct $x, y \in R^n$.

Ans. (a, b, d)

$A_{n \times n}$ is orthogonal matrix

$$\Rightarrow |A| = \pm 1 \Rightarrow a \text{ is true}$$

$$\Rightarrow A^{-1} \text{ exists}$$

and $A^{-1} = A^T$
 (b) $A^{-1} = A^T$
 $\frac{1}{\lambda} = \lambda$
 $\Rightarrow \lambda^2 = 1$
 $\Rightarrow |\lambda| = 1$
 (b) is true.
 (d) $(AX)^T (AY) = X^T (A^T A) Y$
 $= X^T I Y \quad (\because AA^T = I)$
 $= X^T Y$
 and also, $|\lambda| = 1$
 $\Rightarrow \|A \times 1\| = \|\lambda \times 1\| = \|X\|$
 \therefore (d) is true.

End of Solution

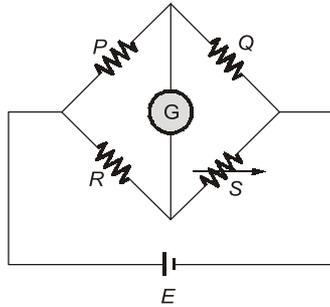
- Q.56** Consider the system of linear equations: $Ax = b$, where A is an $n \times n$ matrix, and x and b are n -dimensional column vectors. Suppose this system of equations has a unique solution. Which of the following statements is/are correct?
- (a) A^{-1} exists
 - (b) The system of equations $A^m x = b$ also has a unique solution for $m = 1, 2, 3, \dots$
 - (c) $\text{rank}(A) = \text{rank}(A^m)$, for $m = 1, 2, 3, \dots$
 - (d) $\text{rank}(A) < \text{rank}([A \mid b])$, where $[A \mid b]$ denotes the augmented matrix.

Ans. (a, b, c)

Given, $AX = b$ has unique solution
 $\Rightarrow |A| \neq 0$
 $\Rightarrow A^{-1}$ exist
 option (a) is true.
 WKT : $\rho(A) = \rho(A^m) \quad (\because |A| \neq 0)$
 $\Rightarrow A^m X = b$ will also holds same condition of rank as $AX = b$
 $\therefore A^m X = b$ has unique solution
 \therefore Option (b) and (c) are also true.
 $\rho(A) < \rho(C)$
 Then system cannot have unique solution.

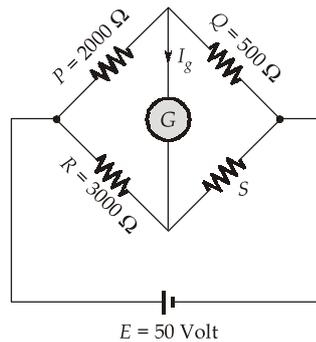
End of Solution

Q.57 The resistance values of the Wheatstone bridge shown are:
 $P = 2000 \Omega$, $q = 500 \Omega$, $R = 3000 \Omega$. The battery voltage $E = 50V$. The battery has an internal resistance of 1Ω and the Galvanometer (G) has a resistance of 50Ω .



The value of the resistance S for balanced condition is _____ Ω . [Answer in integer]

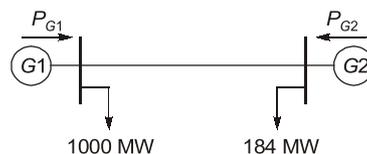
Ans. 750 (750 to 750)
 Balanced condition



$$\begin{aligned} \Rightarrow \quad \frac{P}{Q} &= \frac{R}{S} \\ P \cdot S &= R \cdot Q \\ S &= \frac{3000 \times 500}{2000} \\ S &= 750 \Omega \end{aligned}$$

End of Solution

Q.58 A system with two generators G1 and G2 (without generator limits) is shown.



The total load on the system is 1184 MW. The expression for the cost of generation (C_1 and C_2) and real power loss (P_{loss}) are as follows:

$$\begin{aligned} C_1(P_{G1}) &= 1000 + 50P_{G1} + 0.01(P_{G1})^2 \text{ Rs/MWh} \\ C_2(P_{G2}) &= 2000 + 50P_{G2} + 0.001(P_{G1})^2 \text{ Rs/MWh} \end{aligned}$$

$$P_{\text{Loss}} = 0.001(P_{G2} - 50)^2 \text{ MW}$$

When the generators are operating at their optimal generation, meeting the total load requirement, the real power loss in the system is _____ MW (Round off to one decimal place)

Consider the Lagrange multiplier $\lambda = 70.25$ for optimal generation.

Ans. 19.9 (19.75 to 20.25)

$$I_{C1} = 50 + 0.02P_{G1}$$

$$I_{C2} = 50 + 0.02P_{G2}$$

$$\frac{dP_L}{dP_{G2}} = 0.002(P_{G2} - 50)$$

$$L_1 = \frac{1}{1-0} = 1$$

$$L_2 = \frac{1}{1 - \frac{dP_L}{dG_2}} = \frac{1}{1.1 - 0.002P_{G2}}$$

$$(50 + 0.02P_{G1}) = 70.25$$

$$P_{G1} = 1012.5$$

$$\frac{50 + 0.002P_{G2}}{1.1 - 0.002P_{G2}} = 70.25$$

$$P_{G2} = 191.40 \text{ MW}$$

$$\begin{aligned} \text{Loss} &= P_{G1} + P_{G2} - P_D \\ &= 1012.5 + 191.40 - 1184 \\ &= 19.9 \text{ MW} \end{aligned}$$

End of Solution

Q.59 A balanced three-phase supply is given to a 30 kW, 4-pole, 400 V, 50 Hz, wound rotor induction motor with Y-connected stator and rotor windings. The motor is driving a constant torque load. With shorted slip rings, the machine runs at 1476 rpm.

When an external non-inductive resistance of 0.27Ω per phase is connected in series in the rotor circuit, the steady-state speed drops to 1404 rpm.

Neglecting rotational losses, the actual per phase rotor winding resistance is _____ Ω . (Round off to two decimal places)

Ans. (0.09)

$$P = 30 \text{ kW}; f = 50; N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

$$N_1 = 1476; \quad N_2 = 1404$$

$$N_s = 1500; \quad N_s = 1500$$

$$S_1 = \frac{N_s - N_1}{N_s} = \frac{1500 - 1476}{1500} = 0.016$$

$$S_2 = \frac{N_s - N_2}{N_s} = \frac{1500 - 1404}{1500} = 0.064$$

$$T \propto \frac{S}{R_2}$$

Given constant torque

$$\therefore S \propto R_2$$

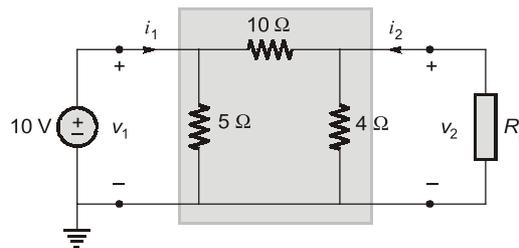
$$\frac{S_2}{S_1} = \frac{R_2 + R_{ext}}{R_2}$$

$$= \frac{0.064}{0.016} = \frac{R_2 + 0.27}{R_2}$$

$$\therefore R_2 = 0.09 \text{ } \Omega/\text{ph}$$

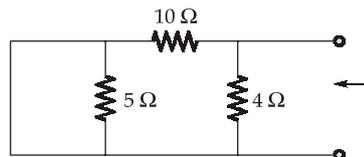
End of Solution

Q.60 Consider the two-port network shown. For maximum power transfer to the resistive load (R_L), the value of R_L should be _____ Ω . (Round off to two decimal places)



Ans. (2.85) (2.81 to 2.91)

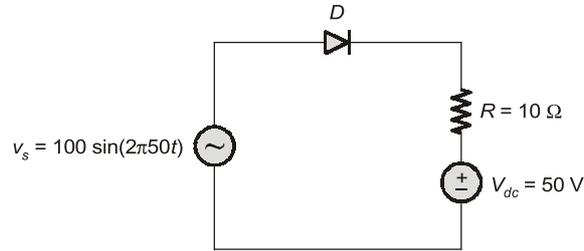
R_{th} :



$$R_{th} = \frac{10 \times 4}{10 + 4} = \frac{40}{14} = 2.857 \Omega$$

End of Solution

Q.61 Consider the circuit shown. Assume that the diode (D) is ideal.



Given $v_s = 100 \sin(2\pi 50t)$, $V_{dc} = 50$ V, and $R = 10 \Omega$, the average value of the current through the diode is _____ A. (Round off to two decimal places)

Ans. (1.08) (1.04 to 1.14)

$$V_s > 50: \quad i = \frac{V_s - 50}{10} = 10 \sin \alpha - 5$$

$$I_{\text{avg}} = \frac{1}{2\pi} \int_{\pi/6}^{5\pi/6} i \cdot d\alpha$$

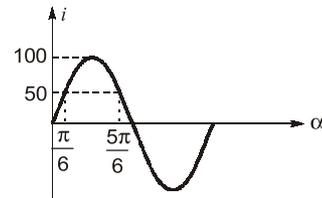
$$= \frac{1}{2\pi} \int_{\pi/6}^{5\pi/6} (10 \sin \alpha - 5) d\alpha$$

$$= \frac{1}{2\pi} [-10 \cos \alpha - 5\alpha]_{\pi/6}^{5\pi/6}$$

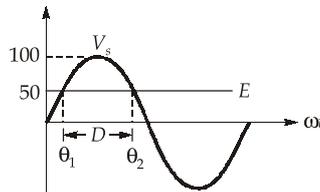
$$= \frac{-1}{2\pi} \left\{ \left[10 \cos \frac{5\pi}{6} - 10 \cos \frac{\pi}{6} \right] + \left[\frac{20\pi}{6} \right] \right\}$$

$$= \frac{-1}{2\pi} \left\{ -10\sqrt{3} + \frac{10\pi}{3} \right\}$$

$$= \frac{1}{2\pi} [10\sqrt{3} - 10.47] = 1.08 \text{ A}$$



Alternate Solution:



$$\theta_1 = \sin^{-1} \frac{E}{V_m} = \sin^{-1} \frac{50}{100} = \frac{\pi}{6}$$

$$\theta_2 = \pi - \frac{\pi}{6} = \frac{5\pi}{6}$$

$$I_D = I_0 = \frac{1}{2\pi} \int_{\theta_1}^{\theta_2} \left(\frac{V_m \sin \omega t - E}{R} \right) d(\omega t)$$

$$\begin{aligned}
 &= \frac{1}{2\pi R} \cdot [V_m(\cos\theta_1 - \cos\theta_2) - E(\theta_2 - \theta_1)] \\
 &= \frac{1}{2\pi \cdot 10} \cdot \left[100(\cos 30^\circ - \cos 150^\circ) - 50 \left(\frac{5\pi}{6} - \frac{\pi}{6} \right) \right] = 1.08 \text{ A}
 \end{aligned}$$

End of Solution

Q.62 The magnitude of the contour integral

$$\int_c \frac{(z+1)^2}{(z-i)(z-2)} dz$$

over the contour $C : |z - 2 - i| = \frac{3}{2}$ is _____. [Round off to two decimal places]

Note : z is a complex variable and $i = \sqrt{-1}$.

Ans. 25.3 (25.00 to 25.60)

$$\oint_c \frac{(z+1)^2}{(z-i)(z-2)} dz,$$

$$C : |z - 2 - i| = \frac{3}{2}$$

$z = i$ lies outside 'c' but $z = 2$ lies inside 'c'

$$\therefore \text{by CRT : } \oint_c f(z) dz = 2\pi i (\text{Res}_2) = 2\pi i \left(\frac{(2+1)^2}{2-i} \right)$$

$$\text{Magnitude} = \frac{2\pi \times 9}{\sqrt{2^2 + 1^2}} = 25.3$$

End of Solution

Q.63 A uniform spherical volume charge distribution of radius 2 m, centered at the origin, has a strength of $\frac{3}{\pi} \times 10^{-6} \text{ C/m}^3$. A point charge of strength $\pi \times 8.854 \times 10^{-12} \text{ C}$ is moved from $(-3, 0, -4)$ to $(0, 0, 4)$ in Cartesian coordinate system. The relative permittivity of the medium is 1 and the coordinate values are in meters. The work done during the process is _____ μJ . (Round off to two decimal places)

Ans. 0.4 (0.38 to 0.42)

$$\text{Given, } \rho_v = \frac{3}{\pi} \times 10^{-6} \text{ C/m}^3$$

$$\Rightarrow Q_{\text{enc}} = \int \rho_v dV = \rho_v \int dV = \rho_v \times V_{r=2\text{m}}$$

$$\Rightarrow Q_{\text{enc}} = \frac{3}{\pi} \times 10^{-6} \times \frac{4\pi}{3} (2)^3 = 32 \times 10^{-6} \text{ C}$$

$$\begin{aligned} \therefore W &= -q \int_i^t \vec{E} \cdot d\vec{l} \\ \vec{E} &= \frac{Q_{\text{enc}}}{4\pi\epsilon r^2} \hat{a}_r \\ d\vec{l} &= dr \hat{a}_r \\ \therefore W &= -q \int_{r_i}^{r_f} \frac{Q_{\text{enc}}}{4\pi\epsilon r^2} dr = \frac{-Q_{\text{enc}} \cdot q}{4\pi\epsilon} \int_{r_i}^{r_f} \frac{dr}{r^2} \\ \Rightarrow W &= \frac{Q_{\text{enc}} \cdot q}{4\pi\epsilon} \left. \frac{1}{r} \right|_{r_i=5}^{r_f=4} \\ \Rightarrow W &= 32 \times 10^{-6} \times \pi \times 8.854 \times 10^{-12} \times 9 \times 10^9 \left[\frac{1}{4} - \frac{1}{5} \right] \\ \Rightarrow W &= 0.4 \mu\text{J} \end{aligned}$$

End of Solution

Q.64 Let X and Y be two real-valued random variables with $E(X) = 1$, $E(Y) = 2$, $E(X^2) = 4$, $E(Y^2) = 9$, and $E(XY) = 0.9$, where E denotes the expectation operator. The value of α that minimizes $E((X - \alpha Y)^2)$ is _____.
 (Round off to one decimal place)

Ans. (0.1)

$$\begin{aligned} E(x - \alpha y)^2 &= E(x^2 + \alpha^2 y^2 - 2\alpha xy) \\ &= E(x^2) + \alpha^2 E(y^2) - 2\alpha E(xy) \\ &= 4 + \alpha^2 (9) - 2\alpha (0.9) \\ &= 9\alpha^2 - 1.8\alpha + 4 \text{ to be minimize is minimum at its stationary pt} \\ \alpha &= \frac{1.8}{2(9)} = \frac{1}{10} \end{aligned}$$

End of Solution

Q.65 The integral

$$\frac{1}{\pi} \int_0^{\infty} \frac{x^{2026}}{(1+x^{2026})(1+x^2)} dx$$

evaluates to _____

(Round off to two decimal places)

Ans. (0.25)

Put, $x = \frac{1}{x}$

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

$$I = \frac{1}{\pi} \int_0^{\infty} \frac{\frac{1}{x^{2026}}}{\left(1 + \frac{1}{x^{2026}}\right) \left(1 + \frac{1}{x^2}\right)} \cdot \frac{1}{x^2} dx$$

$$= \frac{1}{\pi} \int_0^{\infty} \frac{1}{(1 + x^{2026})(1 + x^2)} dx$$

$$\therefore I + I = \frac{1}{\pi} \int_0^{\infty} \frac{(x^{2026} + 1)}{(1 + x^{2026})(1 + x^2)} dx$$

$$2I = \frac{1}{\pi} \int_0^{\infty} \frac{1}{1 + x^2} dx$$

$$I = \frac{1}{\pi} \frac{1}{2} \left(\frac{\pi}{2} \right) = \frac{\pi}{4} \times \frac{1}{\pi} = \frac{1}{4}$$

End of Solution

