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GATE 2019
Electrical Engineering

Detailed Solutions of Questions

Date of Exam : 9/2/2019

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ME	C	20-Feb-2019	Saket Centre	7:30 AM to 1:30 PM
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CE	B	21-Feb-2019	Kalu Sarai Centre	3:00 PM to 9:00 PM
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SECTION A : GENERAL APTITUDE

Q.1 Newspapers are a constant source of delight and recreation for me. The _______ trouble is that I read _______ many of them.

(a) even, quite
(b) only, too
(c) even, too
(d) only, quite

Ans. (b)

End of Solution

Q.2 The passengers were angry _______ the airline staff about the delay.

(a) towards
(b) on
(c) about
(d) with

Ans. (d)

Angry on ... an issue
angry with ... someone.

End of Solution

Q.3 The missing number in the given sequence 343, 1331, _______, 4913 is

(a) 4096
(b) 2744
(c) 3375
(d) 2197

Ans. (d)

$7^3, 11^3, \_\_\_\_\_, 17^3$

$\because$ 7, 11, 13 and 17 are all prime numbers.
The series is cube of these numbers.

End of Solution

Q.4 I am not sure if the bus that has been booked will be able to _______ all the students.

(a) fill
(b) sit
(c) accommodate
(d) deteriorate

Ans. (c)

End of Solution

Q.5 It takes two hours for a person X to mow the lawn. Y can mow the same lawn in four hours. How long (in minutes) will it take X and Y, if they work together to mow the lawn?

(a) 90
(b) 60
(c) 80
(d) 120

Ans. (c)

Work done by X in 1 hour $= \frac{1}{2}$

Work done by Y in 1 hour $= \frac{1}{4}$

Work done by X and Y together in 1 hour

$$= \frac{1}{2} + \frac{1}{4} = \frac{3}{4}$$

$\therefore$ Total time to complete mowing of lawn

$$= \frac{4}{3}\text{hour} = \frac{4}{3} \times 60 = 80 \text{ min}$$

End of Solution

Q.6 An award-winning study by a group of researchers suggests that men are as prone to buying on impulse as women but women feel more guilty about shopping.

Which of the following statements can be inferred from the given text?

(a) Many men and women indulge in buying on impulse
(b) Few men and women indulge in buying on impulse
(c) All men and women indulge in buying on impulse
(d) Some men and women indulge in buying on impulse

Ans. (d)

End of Solution

Q.7 Given two sets $X = \{1,2,3\}$ and $Y = \{2, 3, 4\}$, we construct a set Z of all possible fractions where the numerators belong to set X and the denominators belong to set Y. The product of elements having minimum and maximum values in the set Z is ______.

(a) $\frac{1}{6}$
(b) $\frac{1}{12}$
(c) $\frac{3}{8}$
(d) $\frac{1}{8}$

Ans. (c)

$$X = \{1, 2, 3\}$$
$$Y = \{2, 3, 4\}$$
$$Z = \left\{\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{2}{3}, \frac{2}{4}, \frac{3}{2}, \frac{3}{4}\right\}$$
$$\text{Minimum value in } \{Z\} = \frac{1}{4}$$
$$\text{Maximum value in } \{Z\} = \frac{3}{2}$$
$$\text{Product} = \frac{1}{4} \times \frac{3}{2} = \frac{3}{8}$$

End of Solution

Q.8 How many integers are there between 100 and 1000 all of whose digits are even?

(a) 90
(b) 60
(c) 100
(d) 80

Ans. (c)

All numbers between 100 and 1000 can be 3 digit numbers only
For units and tens digits = 5 integers can be filled (0, 2, 4, 6, 8)
For hundreds digit = 0 can't be filled only 4 digits can be filled (2, 4, 6, 8)

$\therefore$ Total choices $= 4 \times 5 \times 5$
$= 100$ numbers

End of Solution

Q.9 Consider five people - Mita, Ganga, Rekha, Lakshmi and Sana. Ganga is taller than both Rekha and Lakshmi. Lakshmi is taller than Sana. Mita is taller than Ganga. Which of the following conclusions are true?

1. Lakshmi is taller than Rekha
2. Rekha is shorter than Mita
3. Rekha is taller than Sana
4. Sana is shorter than Ganga

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

Ans. (d)

If '>' Implies taller than

1. Ganga > Rekha, Ganga > Lakshmi
2. Lakshmi > Sana
3. Mita > Ganga

$\Rightarrow$ Mita > Ganga > Lakshmi > Sana

$\Rightarrow$ Mita > Ganga > Rekha

Statement 2 is correct.

Statement 4 is correct.

End of Solution

Q.10 The ratio of the number of boys and girls who participated in an examination is 4 : 3. The total percentage of candidates who passed the examination is 80 and the percentage of girls who passed is 90. The percentage of boys who passed is _______.

(a) 72.50 (b) 90.00

(c) 80.50 (d) 55.50

Ans. (a)

Let, Number of boys = $4x$

and Number of girls = $3x$

$$\text{Total passed candidates} = \frac{80}{100}\times 7x = \frac{28}{5}x$$

Number of girls candidates who passed

$$= \frac{90}{100}\times 3x = \frac{27}{10}x$$

Now total number of candidates passed

= Number of girls who passed

+ Number of boys who passed

$$\Rightarrow \quad \text{Number of boys who passed} = \left(\frac{28}{5}-\frac{27}{10}\right)x = \frac{56-27}{10}x = \frac{29}{10}x$$

$$\%\text{ of boys} = \frac{29}{10\times 4x}x\times 100 = 72.5\%$$

Option (a) is correct.

End of Solution

SECTION B : ELECTRICAL ENGINEERING

Q.1 Which one of the following functions is analytic in the region $|z| \leq 1$?

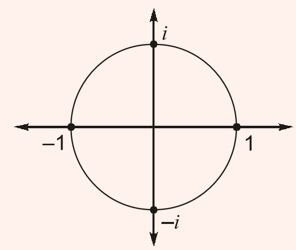
(a) $\dfrac{z^2-1}{z+2}$ (b) $\dfrac{z^2-1}{z+j0.5}$

(c) $\dfrac{z^2-1}{z}$ (d) $\dfrac{z^2-1}{z-0.5}$

Ans. **(a)**

By Cauchy integral theorem,

$$\int \frac{z^2-1}{z+2}\,dz = 0$$



Therefore, $\dfrac{z^2-1}{z+2}$ is analytic in the region $|z| \leq 1$.

End of Solution

Q.2 A co-axial cylindrical capacitor shown in Figure (i) has dielectric with relative permittivity $\varepsilon_{r1} = 2$. When one-fourth portion of the dielectric is replaced with another dielectric of relative permittivity ε_{r2} as shown in Figure (ii); the capacitance is doubled. The value of ε_{r2} is _______.

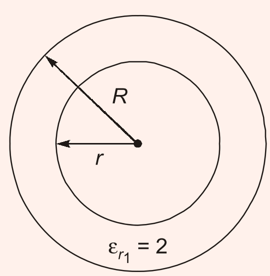


Fig. (i)

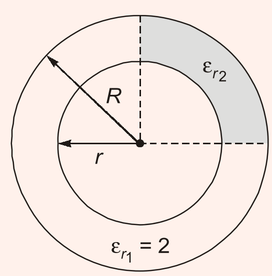
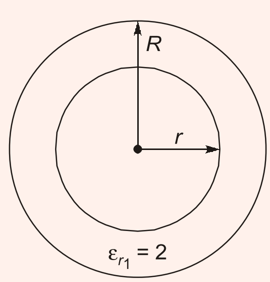


Fig. (ii)

Ans. **(10)**

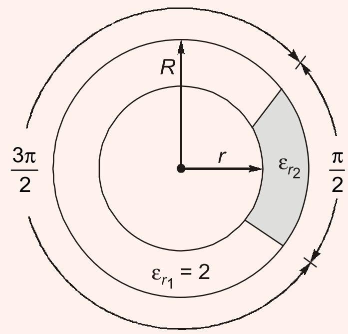
Co-axial cylindrical capacitor-1



$$C_1 = \frac{2\pi \epsilon_h}{\ln\left(\dfrac{b}{a}\right)} = \frac{2\pi \epsilon_0 (2)h}{\ln\left(\dfrac{R}{g}\right)}$$

$$C_1 = \frac{4\pi \epsilon_0 h}{\ln\left(\frac{R}{r}\right)} \quad \text{...(i)}$$

Co-axial cylindrical capacitor-2



$$C_2 = \frac{\left(\frac{3\pi}{2}\right)\epsilon_0 (2)h}{\ln\left(\frac{R}{r}\right)} + \frac{\frac{\pi}{2}\epsilon_0 \epsilon_{r2} h}{\ln\left(\frac{R}{r}\right)}$$

$$C_2 = \frac{\pi \epsilon_0 h}{\ln\left(\frac{R}{r}\right)}\left[3 + \frac{\epsilon_{r_2}}{2}\right] \quad \text{...(ii)}$$

Given, $C_2 = 2C_1$ ...(iii)

Put equation (i), (ii) in equation (iii),

$$\frac{\pi \epsilon_0 h}{\ln\left(\frac{R}{r}\right)}\left[3 + \frac{\epsilon_{r_2}}{2}\right] = 2\left[\frac{4\pi \epsilon_0 h}{\ln\left(\frac{R}{r}\right)}\right]$$

$$3 + \frac{\epsilon_{r_2}}{2} = 8$$

$$\Rightarrow \quad \frac{\epsilon_{r_2}}{2} = 5$$

$$\Rightarrow \quad \epsilon_{r_2} = 10$$

End of Solution

Q.3 A six-pulse thyristor bridge rectifier is connected to a balanced three-phase 50 Hz AC source. Assuming that the DC output current of the rectifier is constant, the lowest harmonic component in the AC input current is

(a) 250 Hz
(b) 100 Hz
(c) 300 Hz
(d) 150 Hz

Ans. (a)

For 6 pulse converter harmonics present in AC current are $6k \pm 1$

Lowest order harmonic = 5

Lowest harmonic frequency = 5 × 50 = 250 Hz

End of Solution

Q.4 M is a 2 × 2 matrix with eigenvalues 4 and 9. The eigenvalues of M^2 are

(a) –2 and –3
(b) 2 and 3
(c) 4 and 9
(d) 16 and 81

Ans. (d)

M is a 2 × 2 matrix with eigen values 4 and 9.

The eigen values of M^2 are 16 and 81.

End of Solution

Q.5 The open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{\pi e^{-0.25s}}{s}$$

In $G(s)$ plane, the Nyquist plot of $G(s)$ passes through the negative real axis at the point.

(a) (–1.25, j0)
(b) (–0.5, j0)
(c) (–1.5, j0)
(d) (–0.75, j0)

Ans. (b)

$$\angle G(j\omega) = -0.25\times\frac{180\omega_{pc}}{\pi} - 90^\circ = -180^\circ$$

$$-0.25\times\frac{180\omega_{pc}}{\pi} = -90^\circ$$

$$\omega_{pc} = \frac{4\pi}{2} = 2\pi$$

$$|G(j\omega)|_{\omega=\omega_{pc}} = \left|\frac{\pi e^{-0.25s}}{s}\right|_{\omega=\omega_{pc}} = \frac{\pi}{2\pi} = 0.5$$

∴ Point is (–0.5, j0).

End of Solution

Q.6 Given, V_{gs} is the gate-source voltage, V_{ds} is the drain source voltage, and V_{th} is the threshold voltage of an enhancement type NMOS transistor, the conditions for transistor to be biased in saturation are

(a) $V_{gs} > V_{th}$; $V_{ds} \leq V_{gs} - V_{th}$
(b) $V_{gs} < V_{th}$; $V_{ds} \geq V_{gs} - V_{th}$
(c) $V_{gs} > V_{th}$; $V_{ds} \geq V_{gs} - V_{th}$
(d) $V_{gs} < V_{th}$; $V_{ds} \leq V_{gs} - V_{th}$

Ans. **(c)**

For NMOS transistor to be in saturation the condition will be

$$V_{gs} > V_{th}$$

and
$$V_{ds} \geq V_{gs} - V_{th}$$

End of Solution

Q.7 The rank of the matrix, $M = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$, is ______ .

Ans. **(d)**

$$M = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

$R_1 \leftrightarrow R_2$

$$\begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

$R_3 \rightarrow R_3 - R_1$

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

$R_3 \rightarrow R_3 - R_2$

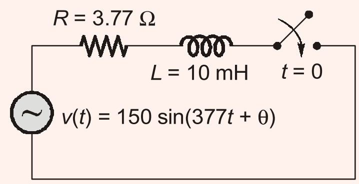
$$\begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & -2 \end{bmatrix}$$

Which is in echelon form

$\therefore$ $\rho(A) = 3$

End of Solution

Q.8 In the circuit shown below, the switch is closed at $t = 0$. The value of θ in degrees which will give the maximum value of DC offset of the current at the time of switching is



(a) –30
(b) 60
(c) –45
(d) 90

Ans. (c)

If the switch is closed at $t = 0$ in series R-L circuit. Then the circuit current $i(t)$ expression is

$$i(t) = \left\{\frac{-V_m}{\sqrt{R^2 + X_L^2}}\sin(\theta - \phi)\right\}e^{-t/\tau} + \frac{V_m}{\sqrt{R^2 + X_L^2}}\sin(\omega t - \phi)$$

The first term of expression indicates DC offset current.
For maximum value of DC offset current, the angle should be 90°

$$-\left(\theta - \tan^{-1}\left(\frac{\omega L}{R}\right)\right) = 90^\circ$$

$$-\left(\theta - \tan^{-1}\left(\frac{377 \times 10 \times 10^{-3}}{3.77}\right)\right) = 90^\circ$$

$$(\theta - 45^\circ) = -90^\circ$$

$$\theta = -45^\circ$$

End of Solution

Q.9 If $f = 2x^3 + 3y^2 + 4z$, the value of line integral $\int_c \text{grad } f.dr$ evaluated over contour C formed by the segments $(-3, -3, 2) \rightarrow (2, -3, 2) \rightarrow (2, 6, 2) \rightarrow (2, 6, -1)$ is _______.

Ans. **(139)**

$$f = 2x^3 + 3y^2 + 4z$$

$$\Delta f = 6x^2\hat{i} + 6y\hat{j} + 4\hat{k}$$

$$\text{curl}(\Delta f) = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ 6x^2 & 6y & 4 \end{vmatrix}$$

$$\therefore \quad \int_c \nabla f \cdot d\bar{x} = \int_c d\left(2x^3 + 3y^2 + 4z\right) = 0$$

$$= \int_{(-3,-3,2)}^{(2,-3,2)} d\left(2x^3 + 3y^2 + 4z\right) + \int_{(2,-3,2)}^{(2,6,2)} d\left(2x^3 + 3y^2 + 4z\right) + \int_{(2,6,2)}^{(2,6,-1)} d\left(2x^3 + 2x^2 + 4z\right)$$

$$= 70 + 81 + (-12)$$

$$= 139$$

End of Solution

Q.10 The mean-square of a zero-mean random process is $\frac{kT}{c}$, where k is Boltzmann's constant, T is the absolute temperature, and C is a capacitance. The standard deviation of the random process is,

(a) $\sqrt{\frac{kT}{c}}$

(b) $\frac{c}{kT}$

(c) $\frac{\sqrt{kT}}{c}$

(d) $\frac{kT}{c}$

Ans. **(a)**

Given that,

$$E(x^2) = \frac{kT}{C}$$

$$E(x) = 0$$

$$= E(x^2) - (E(x))^2$$

$$\text{Var}(x) = \frac{kT}{C} - 0 = \frac{kT}{C}$$

$$\text{Standard deviation} = \sqrt{\frac{kT}{C}}$$

End of Solution

Q.11 A 5 kVA, 50 V/100 V, single-phase transformer has a secondary terminal voltage of 95 V when loaded. The regulation of the transformer is

(a) 5% (b) 1%
(c) 4.5% (d) 9%

Ans. (a)

$$\text{Voltage regulation} = \frac{V_{NL} - V_{FL}}{V_{NL}} \times 100 = \frac{100 - 95}{100} \times 100 = 5\%$$

End of Solution

Q.12 The output response of a system is denoted as $y(t)$, and its Laplace transform is given by

$$Y(s) = \frac{10}{s(s^2 + s + 100\sqrt{2})}$$

The steady state value of $y(t)$ as

(a) $100\sqrt{2}$ (b) $\frac{1}{10\sqrt{2}}$
(c) $10\sqrt{2}$ (d) $\frac{1}{100\sqrt{2}}$

Ans. (b)

$$\text{Steady state value of } y(t) = \underset{s \to 0}{Lt}\, sY(s) = \underset{s \to 0}{Lt} \frac{10s}{s(s^2 + s + 100\sqrt{2})}$$

$$= \frac{10}{100\sqrt{2}} = \frac{1}{10\sqrt{2}}$$

End of Solution

Q.13 A three-phase synchronous motor draws 200 A from the line at unity power factor at rated load. Considering the same line voltage and load, the line current at a power factor of 0.5 leading is

(a) 200 A (b) 100 A
(c) 400 A (d) 300 A

Ans. (c)

$$P = VI \cos \phi$$

For same voltage and load,

$$I \cos \phi = \text{constant}$$

$$I_1 \cos \phi_1 = I_2 \cos \phi_2$$

at unity power factor, $I_1 = 200$ A

$$200 \times 1 = I_2 \times 0.5$$

$$I_2 = 400 \text{ A}$$

End of Solution

Q.14 The characteristic equation of a linear time-invariant (LTI) system is given
$\Delta(s) = s^4 + 3s^3 + 3s^2 + s + k = 0$
The system is BIBO stable if

(a) $0 < k < \frac{12}{9}$
(b) $k > 3$
(c) $0 < k < \frac{8}{9}$
(d) $k > 6$

Ans. (c)

Routh array is

$$\begin{array}{c|ccc} s^4 & 1 & 3 & k \\ s^3 & 3 & 1 & \\ s^2 & \frac{8}{3} & k & \\ s^1 & \frac{\left(\frac{8}{3} - 3k\right)}{8/3} & & \\ s^0 & k & & \end{array}$$

For BIBO stability,

$$\frac{\left(\frac{8}{3} - 3k\right)}{\left(\frac{8}{3}\right)} > 0$$

$\Rightarrow$ $k < \frac{8}{9}$

and $k > 0$

$\therefore$ $0 < k < \frac{8}{9}$

End of Solution

Q.15 The parameter of an equivalent circuit of a three-phase induction motor affected by reducing the rms value of the supply voltage at the rated frequency is

(a) stator resistance
(b) rotor leakage reactance
(c) rotor resistance
(d) magnetizing reactance

Ans. (d)

End of Solution

Q.16 The symbol, a and T, represent positive quantities, and $u(t)$ is the unit step function. Which one of the following impulse responses is NOT the output of a causal linear time-invariant system?

(a) $1 + e^{-at} u(t)$
(b) $e^{+at} u(t)$
(c) $e^{-a(t-T)} u(t)$
(d) $e^{-a(t+T)} u(t)$

Ans. (a)

a and T represents positive quantities.

$u(t)$ is unit step function.

$$h(t) = 1 + e^{-at} u(t), \text{ is non-causal}$$

A '1' is a constant and two sided so the impulse response to be causal only if it satisfies the condition.

$$h(t) = 0, \quad t < 0$$
$$\neq 0, \quad t > 0$$

End of Solution

Q.17 The Y_{bus} matrix of a two-bus power system having two identical parallel lines connected between them in pu is given as,

$$Y_{bus} = \begin{bmatrix} -j8 & j20 \\ j20 & -j8 \end{bmatrix}$$

The magnitude of the series reactance of each line in pu (round off up to one decimal place) is ________ .

Ans. (0.1)

$$Y_{12} = -(y_{12}) = -j20$$

$$\text{Series admittance of each line} = \frac{Y_{12}}{2} = \frac{-j20}{2} = -j10$$

$$\text{Series reactance of each line} = \frac{1}{-j10} = j0.1\text{p.u.}$$

End of Solution

Q.18 The output voltage of a single-phase full bridge voltage source inverter is controlled by unipolar PWM with one pulse per half cycle. For the fundamental rms component of output voltage to be 75% of DC voltage, the required pulse width in degrees (round off up to one decimal place) is ________ .

Ans. (112.9)

$$V_{01,\text{ rms}} = \frac{2\sqrt{2}}{\pi} \sin d\, V_s$$

$$0.9 \sin d\ V_s = 0.75\ V_s$$

$$d = 56.44°$$

$$2d = 112.88°$$

$$\text{Pulse width} = 112.88°$$

End of Solution

Q.19 A current controlled current source (CCCS) has an input impedance of 10 Ω and output impedance of 100 kΩ. When this CCCS is used in a negative feedback closed loop with a loop gain of 9, the closed loop output impedance is

(a) 10 Ω
(b) 100 kΩ
(c) 1000 kΩ
(d) 100 Ω

Ans. (c)

"CCCS" [current controlled current source amplifier]

Given, $Z_0 = 100\ \text{k}\Omega$

loop gain $A\beta = 9$

$$Z_{0F} = Z_0[1 + A\beta] \quad \text{[High impedance CS]}$$
$$= 100\ \text{k}\Omega[1 + 9]$$
$$= 100\ \text{k}\Omega \times 10$$
$$= 1000\ \text{k}\Omega$$

End of Solution

Q.20 A system transfer function is $H(s) = \dfrac{a_1 s^2 + b_1 s + c_1}{a_2 s^2 + b_2 s + c_2}$. If $a_1 = b_1 = 0$, and all other coefficients are positive, the transfer function represents a

(a) high pass filter
(b) low pass filter
(c) notch filter
(d) band pass filter

Ans. (b)

$$H(s) = \frac{c_1}{a_2 s^2 + b_2 s + c_2} \quad \text{as } a_1 = b_1 = 0$$
$$= \frac{c_1}{(1 + s\tau_1)(1 + s\tau_2)}$$

Put $s = 0$, $H(0) = \dfrac{c_1}{c_2}$

Put $s = \infty$, $H(\infty) = 0$

At s = 0	At s = ∞	Type of filter
Constant	0	LPF
0	Constant	HPF
0	0	BPF
1	1	BSF

which represents 2nd order low pass filter.

End of Solution

Q.21 The total impedance of the secondary winding, leads and burden of a 5 A CT is 0.01 Ω. If the fault current is 20 times the rated primary current of the CT. The VA output of the CT is _____.

Ans. (100)

$$I_{sec} = 5 \times 20 = 100 \text{ A}$$
$$V = I_{sec} R = 100 \times 0.01 = 1 \text{ V}$$
$$\text{VA output of the CT} = VI_{sec} = 100 \times 1 = 100 \text{ VA}$$

End of Solution

Q.22 The partial differential equation:

$$\frac{\partial^2 u}{\partial t^2} - C^2\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) = 0; \quad \text{where } C \neq 0$$

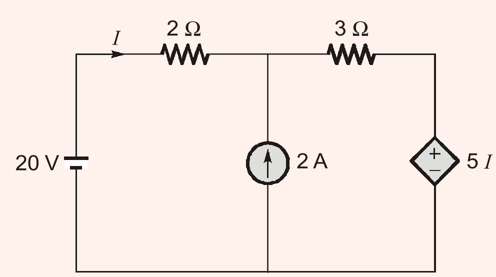
is known as,

(a) Poisson's equation
(b) Wave equation
(c) Heat equation
(d) Laplace equation

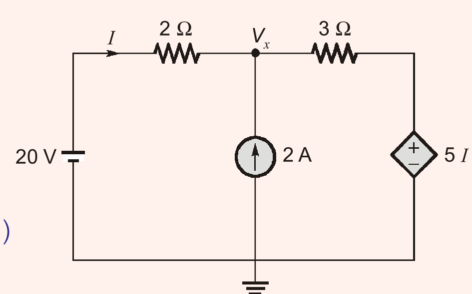
Ans. (b)

End of Solution

Q.23 The current I flowing in the circuit shown below in amperes (round off to one decimal place) is ______.



Ans. (1.4)



Applying nodal at node x,

$$-I - 2 + \frac{V_x - 5I}{3} = 0$$
$$-3I - 6 + V_x - 5I = 0$$
$$\Rightarrow \quad 8I = V_x - 6 \quad \text{...(i)}$$

As,
$$I = \frac{20 - V_x}{2}$$
$$\Rightarrow \quad V_x = 20 - 2I \quad \text{...(ii)}$$

Substituting (ii) in (i),

$$8I = 20 - 2I - 6$$
$$\Rightarrow \quad 10I = 14$$
$$I = 1.4 \text{ A}$$

End of Solution

Q.24 Five alternators each rated 5 MVA, 13.2 kV with 25% of reactance on its own base are connected in parallel to a busbar. The short-circuit level in MVA at the busbar is _____.

Ans. **(100)**

Net reactance of parallel connection,

$$X = \frac{0.25}{5} = 0.05 \text{ p.u.}$$

$$I_{SC} = \frac{1}{X} = \frac{1}{0.05} = 20 \text{ p.u.}$$

$$\text{SC MVA} = 20 \times 5 = 100 \text{ MVA}$$

End of Solution

Q.25 The inverse Laplace transform of $H(s) = \frac{s+3}{s^2+2s+1}$ for $t \geq 0$ is

(a) $2te^{-t} + e^{-t}$
(b) $3e^{-t}$
(c) $3te^{-t} + e^{-t}$
(d) $4te^{-t} + e^{-t}$

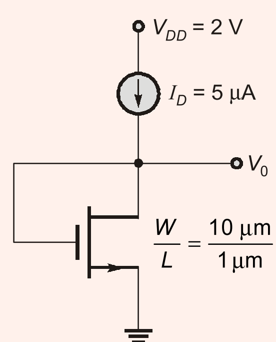
Ans. **(a)**

$$\mathcal{L}^{-1}\left(\frac{s+3}{s^2+2s+1}\right) = \mathcal{L}^{-1}\left(\frac{s+1+2}{(s+1)^2}\right)$$

$$= \mathcal{L}^{-1}\left(\frac{1}{s+1} + \frac{2}{(s+1)^2}\right) = e^{-t} + 2te^{-t}$$

End of Solution

Q.26 The enhancement type MOSFET in the circuit below operates according to the square law. $\mu_n C_{ox}$ = 100 μA/V², the threshold voltage (V_T) is 500 mV. Ignore channel length modulation. The output voltage V_{out} is



(a) 2 V
(b) 500 mV
(c) 100 mV
(d) 600 mV

Ans. (d)

As, $V_{DS} = V_{GS}$

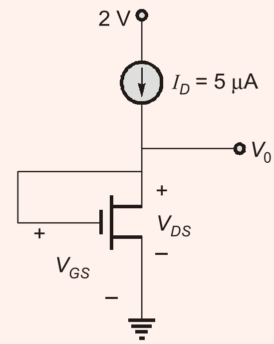
MOSFET is in saturation,

$$I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_T)^2$$

$$5 \times 10^{-6} = \frac{1}{2} \times 100 \times 10^{-6} \times 10\ (V_{GS} - 0.5)^2$$

$\Rightarrow$ $V_{GS} = 0.6$ V

$\Rightarrow$ $V_0 = 600$ mV



End of Solution

Q.27 A single-phase fully controlled thyristor converter is used to obtain an average voltage of 180 V with 10 A constant current to feed a DC load. It is fed from single-phase AC supply of 230 V, 50 Hz. Neglect the source impedance. The power factor (round off to two decimal places) of AC mains is _______.

Ans. (0.78)

$$V_{sr} I_{sr} \cos\phi = V_0\, I_0$$

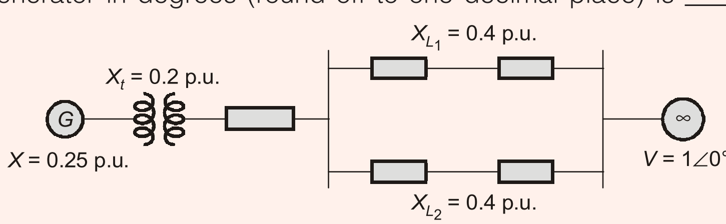
For single-phase fully controlled converter,

$$I_0 = I_{sr} = 10\ \text{A}$$

$$\cos\phi = \frac{V_0}{V_{sr}} = \frac{180}{230} = 0.78$$

End of Solution

Q.28 In the single machine infinite bus system shown below, the generator is delivering the real power of 0.8 pu at 0.8 power factor lagging to the infinite bus. The power angle of the generator in degrees (round off to one decimal place) is ______.



Ans. (20.5)

$$X = 0.25 + 0.2 + 0.4 \,||\, 0.4$$
$$= 0.45 + 0.2 = 0.65 \text{ pu}$$
$$P = V_{pu} \times I_{pu} \cos\phi$$
$$0.8 = 1 \times I_{pu} \times 0.8$$
$$I_{pu} = 1 \text{ pu}$$
$$E = V + jI_a X_s$$
$$= 1 + 1\angle -36.86° \times j0.65 = 1.484\angle 20.51° \text{ pu}$$
$$\delta = 20.51°$$

End of Solution

Q.29 The output expression for the Karnaugh map shown below is

RS \ PQ	00	01	11	10
00	0	1	1	0
01	1	1	1	1
11	1	1	1	1
10	0	0	0	0

(a) $QR + S$

(b) $Q\bar{R} + S$

(c) $Q\bar{R} + \bar{S}$

(d) $QR + \bar{S}$

Ans. (b)

RS \ PQ	00	01	11	10
00	0	1	1	0
01	1	1	1	1
11	1	1	1	1
10	0	0	0	0

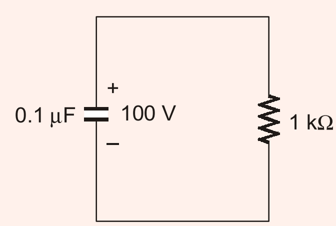
$$\text{Output} = Q\bar{R} + S$$

Option (b) is correct.

End of Solution

Q.30 A 0.1 μF capacitor charged to 100 V is discharged through a 1 kΩ resistor. The time in ms (round off to two decimal) required for the voltage across the capacitor to drop to 1 V is ______.

Ans. (0.46)



$$v_c(t) = V_0\, e^{-t/\tau}$$

$$V_0 = 100 \text{ V}$$

$$\tau = RC = (10^3)(10^{-7}) = 10^{-4} \text{ sec}$$

$$\therefore \quad v_c(t) = 100e^{-10^4 t} \text{ V}$$

Let the time required by the voltage across the capacitor to drop to 1 V is t_1,

$$\therefore \quad v_c(t_1) = 100e^{-10^4 t_1} \qquad v_c(t_1) = 1\text{V}$$

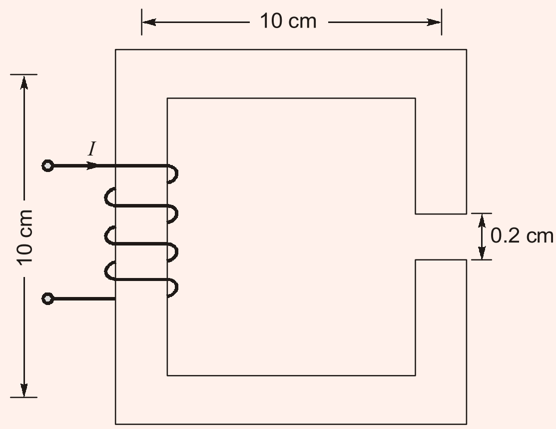
$$\Rightarrow \quad 1 = 100e^{-10^4 t_1}$$

$$e^{-10^4 t_1} = 0.01$$

$$t_1 = 0.46 \text{ msec}$$

End of Solution

Q.31 The magnetic circuit shown below has uniform cross-sectional area and air gap of 0.2 cm. The mean path length of the core is 40 cm. Assume that leakage and fringing fluxes are negligible. When the core relative permeability is assumed to be infinite, the magnetic flux density computed in the air gap is 1 tesla. With same Ampere-turns, if the core relative permeability is assumed to be 1000 (linear), the flux density in tesla (round off to three decimal places) calculated in the air gap is ______.



Ans. (0.833)

Given,
$$l_{ag} = 0.2 \text{ cm}$$
$$l_m = 40 \text{ cm}$$
$$B_0 = 1 \text{ Tesla}$$
$$\phi = \frac{\text{mmf}}{\Re}$$

For same mmf,
$$\phi \propto \frac{1}{\Re}$$

In case-1:
$$\Re_1 = \frac{l_m}{\mu_0 A} = \frac{l_{ag}}{\mu_0 A} + \frac{l_m}{\mu_0 \mu_r A} \qquad \text{As } \mu_r = 0$$

$\therefore$
$$\Re_1 = \frac{0.2 \times 10^{-2}}{\mu_0 A}$$

In case-2:
$$\Re_2 = \frac{l_{ag}}{\mu_0 A} + \frac{l_m}{\mu_0 \mu_r A} = \frac{0.2 \times 10^{-2}}{\mu_0 A} + \frac{40 \times 10^{-2}}{1000 \mu_0 A} = \frac{0.24 \times 10^{-2}}{\mu_0 A}$$

As, flux, $\phi \; \alpha \; B$ for uniform cross section area.

$\therefore$
$$B_2 = \frac{B_1 \times \Re_1}{\Re_2}$$
$$B_2 = \frac{1 \times 0.2 \times 10^{-2} / \mu_0 A}{0.24 \times 10^{-2} / \mu_0 A} = 0.833 \text{ T}$$

End of Solution

Q.32 A 220 V (line), three-phase, Y-connected, synchronous motor has a synchronous impedance of $(0.25 + j2.5)$ Ω/phase. The motor draws the rated current of 10 A at 0.8 pf leading. The rms value of line-to-line internal voltage in volts (round off to two decimal places) is ______.

Ans. (245.36)

For synchronous motor,

$$E_g = V_t - IZ$$

$$V_t = \frac{220}{\sqrt{3}}\ \text{V (phase)}$$

$$Z = (0.25 + j2.5)\ \Omega$$

$$I = 10\angle\cos^{-1} 0.8\ \text{A}$$

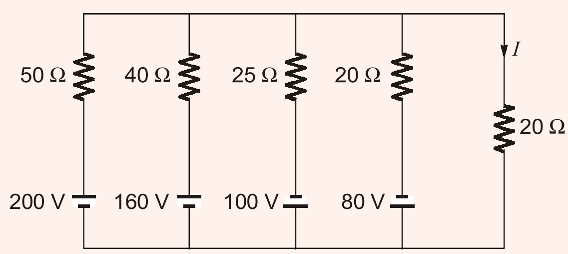
$$E_g = \frac{220}{\sqrt{3}} - (0.25 + j2.5) \times 10\angle\cos^{-1} 0.8$$

$$E_g = 141.658\angle -8.728^\circ\ \text{V (phase)}$$

$$E_g = 245.36\ \text{V (line)}$$

End of Solution

Q.33 The current I flowing in the circuit shown below in ampere is ______.



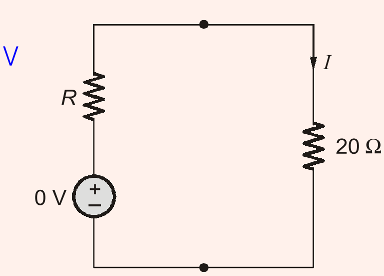
Ans. (0)

By Millman's theorem,

$$E = \frac{\frac{200}{50} + \frac{160}{40} - \frac{100}{25} - \frac{80}{20}}{\frac{1}{50} + \frac{1}{40} + \frac{1}{25} + \frac{1}{20}} = 0\ \text{V}$$

$$\frac{1}{R} = \frac{1}{50} + \frac{1}{40} + \frac{1}{25} + \frac{1}{20}$$

Simplified circuit,



∴ $I = 0$ A

End of Solution

Q.34 In a 132 kV system, the series inductance up to the point of circuit breaker location is 50 mH. The shunt capacitance at the circuit breaker terminal is 0.05 μF. The critical value of resistance in ohms required to be connected across the circuit breaker contacts which will give no transient oscillation is ______.

Ans. **(500)**

$$L = 50 \text{ mH},$$
$$C = 0.05\ \mu\text{F}$$
$$R_{cr} = \frac{1}{2}\sqrt{\frac{L}{C}} = \frac{1}{2}\sqrt{\frac{50\times10^{-3}}{0.05\times10^{-6}}}$$
$$= 500\ \Omega$$

End of Solution

Q.35 A DC-DC buck converter operates in continuous conduction mode. It has 48 V input voltage, and it feeds a resistive load of 24 Ω. The switching frequency of the converter is 250 Hz. If switch-on duration is 1 ms, the load power is

(a) 48 W
(b) 24 W
(c) 6 W
(d) 12 W

Ans. **(c)**

Given that:

Supply voltage, $V_s = 48$ V

Load resistance, $R_L = 24\ \Omega$

Switch frequency, $f_s = 250$ Hz

On time of switch $(T_{ON}) = 1$ ms

Time period, $$T = \frac{1}{f_s} = \frac{1}{250} = 4 \text{ ms}$$

Duty cycle, $$\alpha = \frac{T_{ON}}{T} = \frac{1\text{ ms}}{4\text{ ms}} = 0.25$$

$$\text{Load power} = \frac{(V_0)^2}{R} = \frac{(\alpha V_s)^2}{24}$$
$$= \frac{(0.25\times48)^2}{24} = \frac{12^2}{24} = 6 \text{ Watt}$$

End of Solution

Q.36 The probability of a resistor being defective is 0.02. There are 50 such resistors in a circuit. The probability of two or more defective resistors in the circuit (round off to two decimal places) is _______.

Ans. **(0.26)**

$$p = 0.02$$
$$n = 50$$
$$\lambda = np = 50(0.02) = 1$$
$$p(x \geq 2) = 1 - p(x < 2)$$
$$= 1 - (p(x = 0) + p(x = 1))$$
$$= 1 - \left(\frac{e^{-\lambda}\lambda^0}{0\,!} + \frac{e^{-\lambda}\lambda^1}{1!}\right) = 1 - e^{-\lambda}(1 + \lambda)$$
$$= 1 - e^{-1}(1 + 1) = 0.26$$

End of Solution

Q.37 In a DC-DC boost converter, the duty ratio is controlled to regulate the output voltage at 48 V. The input DC voltage is 24 V. The output power is 120 W. The switching frequency is 50 kHz. Assume ideal components and a very large output filter capacitor. The converter operates at the boundary between continuous and discontinuous conduction modes. The value of the boost inductor (in μH) is ______.

Ans. **(24)**

$$P_0 = 120\text{ W},\quad V_s = 24\text{ V},\quad V_0 = 48\text{ V}$$
$$V_0 = \frac{V_s}{(1-D)}$$
$$1 - D = \frac{24}{48}$$
$$D = 0.5$$
$$P_0 = V_0 I_0 = 120$$
$$I_0 = \frac{120}{48} = 2.54\text{ A}$$
$$V_s I_s = V_0 I_0$$
$$I_s = \frac{120}{24} = 5\text{ A}$$

At boundary of continuous and discontinuous,

$$I_L = I_s = \frac{\Delta I_L}{2}$$
$$\Delta I_L = \frac{DV_s}{fL_c} = 2 \times 5$$
$$L_c = \frac{0.5 \times 24}{50 \times 10^3 \times 10} = 24\ \mu\text{H}$$

End of Solution

Q.38 Consider a 2 × 2 matrix $M = [v_1 \;\; v_2]$, where v_1 and v_2 are the column vectors. Suppose

$M^{-1} = \begin{bmatrix} u_1^T \\ u_2^T \end{bmatrix}$, where u_1^T and u_2^T are the row vectors. Consider the following statements:

Statement-1 : $u_1^T v_1 = 1$ and $u_2^T v_2 = 1$

Statement-2 : $u_1^T v_2 = 0$ and $u_2^T v_1 = 0$

Which of the following options is correct?

(a) Statement 2 is true and statement 1 is false.
(b) Both the statements are false.
(c) Both the statements are true.
(d) Statement 1 is true and statement 2 is false.

Ans. (c)

$$M^{-1} M = I$$

$$\Rightarrow \quad \begin{bmatrix} u_1^T \\ u_2^T \end{bmatrix} [v_1 \;\; v_2] = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} u_1^T v_1 & u_1^T v_2 \\ u_2^T v_1 & u_2^T v_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$u_1^T v_1 = 1 \qquad u_1^T v_2 = 0$$

$$u_2^T v_1 = 0 \qquad u_2^T v_2 = 1$$

Statement (1) and (2) are both correct. Option (c) is correct.

End of Solution

Q.39 If A = $2xi + 3yj + 4zk$ and $u = x^2 + y^2 + z^2$, then div(uA) at (1, 1, 1) is _____.

Ans. (45)

$$\nabla \cdot (uA) = u(\nabla \cdot A) + (\nabla A)\, F$$

$$= (x^2 + y^2 + z^2)\,[2 + 3 + 4] + (2x\hat{i} + 2y\hat{j} + 2z\hat{k}) \cdot (2x\hat{i} + 3y\hat{j} + 4z\hat{k})$$

$$= 9(x^2 + y^2 + z^2) + (4x^2 + 6y^2 + 8z^2)$$

At $(1, 1, 1) = 9(3) + [4 + 6 + 8]$

$$= 27 + 18 = 45$$

End of Solution

Q.40 Consider a state-variable model of a system:

$$\begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\alpha & -2\beta \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ \alpha \end{bmatrix} r$$

$$y = [1 \quad 0]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

where y is the output, and r is the input. The damping ratio ξ and the undamped natural frequency ω_n (rad/sec) of the system are given by

(a) $\xi = \dfrac{\beta}{\sqrt{\alpha}}; \quad \omega_n = \sqrt{\alpha}$

(b) $\xi = \sqrt{\alpha}; \quad \omega_n = \dfrac{\beta}{\sqrt{\alpha}}$

(c) $\xi = \dfrac{\sqrt{\alpha}}{\beta}; \quad \omega_n = \sqrt{\beta}$

(d) $\xi = \sqrt{\beta}; \quad \omega_n = \sqrt{\alpha}$

Ans. (b)

Characteristic equation is,

$$|sI - A| = 0$$

$$|sI - A| = \begin{vmatrix} s & -1 \\ \alpha & s+2\beta \end{vmatrix} = s^2 + 2s\beta + \alpha = 0$$

$$\therefore \quad \omega_n^2 = \alpha$$

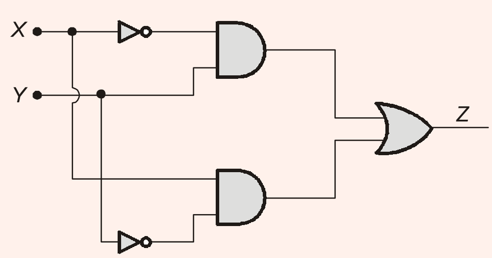
$$\omega_n = \sqrt{\alpha}$$

$$2\xi\omega_n = 2\beta$$

$$\xi = \frac{\beta}{\sqrt{\alpha}}$$

End of Solution

Q.41 In the circuit shown below, X and Y are digital inputs, and Z is a digital output. The equivalent circuit is



(a) XNOR gate

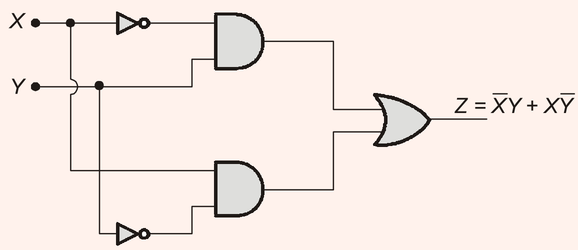
(b) NOR gate

(c) NAND gate

(d) XOR gate

Ans. (d)

The Boolean expression for the output of the digital circuit is shown below.



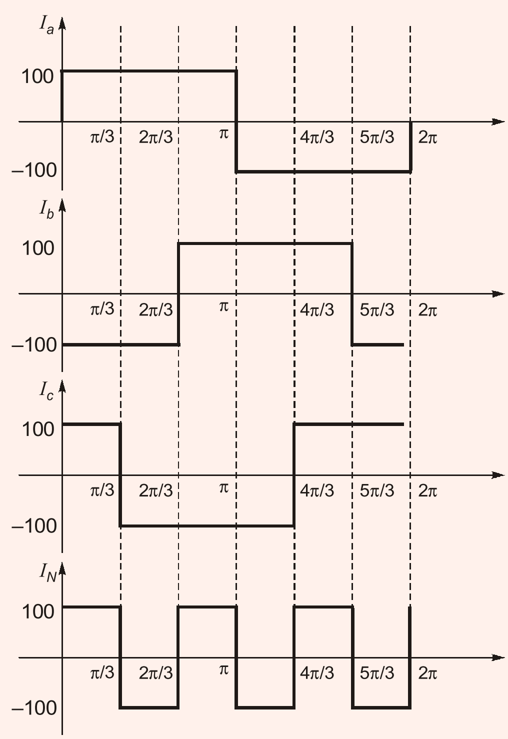
The above expression is of XOR gate.

End of Solution

Q.42 The line currents of a three-phase four wire system are square waves with amplitude of 100 A. The three currents are phase shifted by 120° wish respect to each other. The rms value of neutral current is

(a) 300 A
(b) 0 A
(c) 100 A
(d) $\dfrac{100}{\sqrt{3}}$ A

Ans. (c)

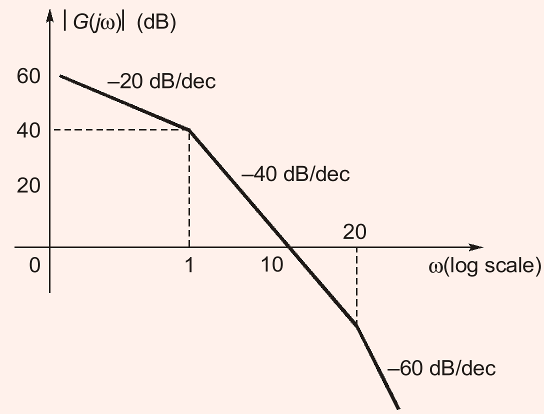


$$I_N = I_a + I_b + I_c$$

$$(I_N)_{rms} = 100\text{ A}$$

End of Solution

Q.43 The asymptotic Bode magnitude plot of minimum phase transfer function $G(s)$ is shown below.



Consider the following statements:

Statement-1: Transfer function $G(s)$ has three plots and one zero.

Statement-2: At very high frequency $(\omega \to \infty)$, the phase angle $\angle G(j\omega) = -\frac{3\pi}{2}$.

Which of the following options is correct?

(a) Statement 2 is true and statement 1 is false.

(b) Both the statements are false.

(c) Both the statements are true.

(d) Statement 1 is true and statement 2 is false.

Ans. (a)

$$G(s) = \frac{k}{s\left(1+\frac{s}{1}\right)\left(1+\frac{s}{20}\right)}$$

Transfer function shows 2 poles and no zeros.
So statement 1 is wrong.

$$\angle G(j\omega) = -90 - \tan^{-1}\omega - \tan^{-1}\frac{\omega}{20}$$

$$\angle G(j\omega)\big|_{\omega\to\infty} = -270° = -\frac{3\pi}{2}\text{ rad}$$

So statement 2 is correct.

End of Solution

Q.44 A periodic function $f(t)$, with a period of 2π, is represented as its Fourier series,

If,
$$f(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos nt + \sum_{n=1}^{\infty} b_n \sin nt$$

$$f(t) = \begin{cases} A\sin t, & 0 \le t \le \pi \\ 0, & \pi < t < 2\pi \end{cases}$$

the Fourier series coefficients a_1 and b_1 of $f(t)$ are:

(a) $a_1 = 0;\ \ b_1 = \frac{A}{\pi}$

(b) $a_1 = \frac{A}{\pi};\ \ b_1 = 0$

(c) $a_1 = 0;\ \ b_1 = \frac{A}{2}$

(d) $a_1 = \frac{A}{2};\ \ b_1 = 0$

Ans. (c)

$$T_0 = 2\pi \Rightarrow \omega_0 = \frac{2\pi}{T_0} = 1$$

Now,
$$b_1 = \frac{2}{T_0}\int_0^{T_0} f(t)\sin\omega_0 t\, dt$$

$$= \frac{2}{2\pi}\int_0^{2\pi} f(t)\sin t\, dt \qquad [\because \omega_0 = 1]$$

$$= \frac{1}{\pi}\int_0^{\pi} A\sin t \cdot \sin t\, dt$$

$$= \frac{A}{2\pi}\int_0^{\pi} 2\sin^2 t\, dt = \frac{A}{2\pi}\int_0^{\pi}[1-\cos 2t]\, dt$$

$$= \frac{A}{2\pi}\left[t - \frac{\sin 2t}{2}\right]_0^{\pi}$$

$$= \frac{A}{2\pi}[(\pi - 0) - (0 - 0)] = \frac{A}{2}$$

$$a_1 = \frac{2}{T_0}\int_0^{T_0} f(t)\cos\omega_0 t\, dt = \frac{2}{2\pi}\int_0^{2\pi} f(t)\cos t\, dt$$

$$= \frac{1}{\pi}\int_0^{\pi} A\sin t \cdot \cos t\, dt = \frac{A}{2\pi}\int_0^{\pi}\sin 2t\, dt = 0$$

End of Solution

Q.45 The transfer function of a phase lead compensator is given by

$$D(s) = \frac{3\left(s + \frac{1}{3T}\right)}{\left(s + \frac{1}{T}\right)}$$

The frequency (in rad/sec), at which $\angle D(j\omega)$ is maximum is

(a) $\sqrt{\frac{3}{T^2}}$

(b) $\sqrt{3T}$

(c) $\sqrt{\frac{1}{3T^2}}$

(d) $\sqrt{3T^2}$

Ans. (c)

$$T(s) = \left(\frac{1+3Ts}{1+Ts}\right)$$

Frequency at which $\angle T(j\omega)$ is maximum,

$$(\omega_m) = \frac{1}{T\sqrt{\alpha}}$$

$$\alpha = \frac{1}{1/3} = 3$$

$$\omega_m = \frac{1}{T\sqrt{3}} = \sqrt{\frac{1}{3T^2}}$$

End of Solution

Q.46 A 220 V DC shunt motor takes 3 A at no-load. It draws 25 A when running at full-load at 1500 rpm. The armature and shunt resistance are 0.5 Ω and 220 Ω, respectively. The no-load speed in rpm (round off to two decimal places) is ______.

Ans. (1579.33)

At full load condition,

$$N_1 = 1500 \text{ rpm}$$

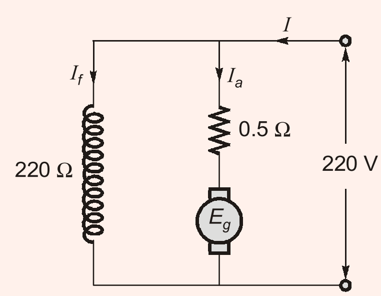
$$I_1 = 25 \text{ A}$$

$$I_f = \frac{220 \text{ V}}{200\ \Omega} = 1 \text{ A}$$

$$I_{a1} = I_1 - I_f = 24 \text{ A}$$

$$E_{g1} = V - I_{a1}R_a$$

$$E_{g1} = 220 - 24 \times 0.5 = 208 \text{ V}$$



At no-load condition,

$$I_2 = 3 \text{ A}$$

$$I_f = 1 \text{ A}$$

$$I_{a2} = I_2 - I_f = 2 \text{ A}$$

$$E_{g2} = 220 - 2 \times 0.5 = 219 \text{ V}$$

$$E_g \propto \phi N$$

Flux is constant, $E_g \propto N$

$$\frac{E_{g2}}{E_{g1}} = \frac{N_2}{N_1}$$

$$\frac{219}{208} = \frac{N_2}{1500}$$

$$N_2 = 1579.33 \text{ rpm}$$

End of Solution

Q.47 The closed-loop line integral $\oint\limits_{|z|=5} \frac{z^3+z^2+8}{z+2}\,dz$ evaluated counter-clockwise, is

(a) $+8j\pi$
(b) $+4j\pi$
(c) $-8j\pi$
(d) $-4j\pi$

Ans. (a)

$$\oint\limits_{|z|=5} \frac{z^3+z^2+8}{2+2}\,dz = 2\pi j \text{ (sum of residues)}$$

$$= 2\pi j \times \left[\lim_{z\to -2} \frac{(z+2)(z^3+z^2+8)}{(z+2)}\right]$$

$$= 2\pi j \times \left[\frac{-8+4+8}{1}\right] = 8\pi j$$

End of Solution

Q.48 The voltage across and the current through a load are expressed as follows:

$$v(t) = -170\sin\left(377t - \frac{\pi}{6}\right) \text{ V}$$

$$i(t) = 8\cos\left(377t + \frac{\pi}{6}\right) \text{ A}$$

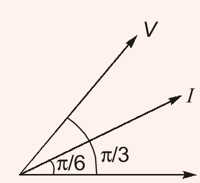
The average power in watts (round off to one decimal place) consumed by the load is _____.

Ans. (588.9)

$$v(t) = -170\sin\left(377t - \frac{\pi}{6}\right)$$

$$i(t) = 8\cos\left(377t + \frac{\pi}{6}\right)$$

$$v(t) = -170\sin\left(377t - \frac{\pi}{6}\right)$$



$$v(t) = 170\cos\left(377 - \frac{\pi}{6} + \frac{\pi}{2}\right)$$

$$v(t) = 170\cos\left(377t + \frac{\pi}{3}\right)$$

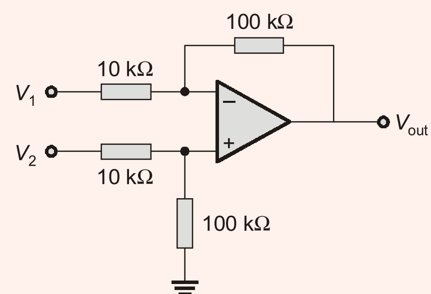
$$P = V_{rms} I_{rms} \cos\phi$$

$$P = \frac{170}{\sqrt{2}} \cdot \frac{8}{\sqrt{2}} \cdot \cos 30$$

$$P = 588.89 \text{ Watts}$$

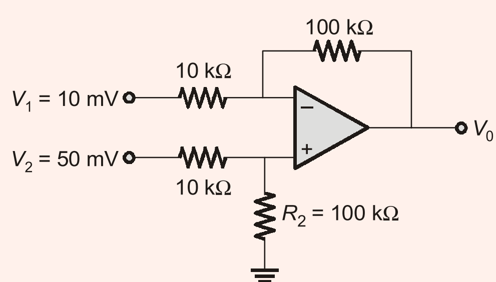
End of Solution

Q.49 In the circuit below, the operational amplifier is ideal. If V_1 = 10 mV and V_2 = 50 mV, the output voltage (V_{out}) is



(a) 400 mV
(b) 500 mV
(c) 600 mV
(d) 100 mV

Ans. (a)



$$V_0 = \frac{R_2}{R_1}(V_2 - V_1)$$

$$= \frac{100k}{10k}(50\text{ mV} - 10\text{ mV})$$

$$= 10\ (40\text{ mV}) = 400\text{ mV}$$

End of Solution

Q.50 A 30 kV, 50 Hz, 50 MVA generator has the positive, negative and zero sequence reactances of 0.25 pu, 0.15 pu, 0.05 pu, respectively. The neutral of the generator is grounded with a reactance so that the fault current for a bolted LG fault and that of a bolted three-phase fault at the generator terminal are equal. The value of grounding reactance in ohms (round off to one decimal place) is ______.

Ans. (1.8)

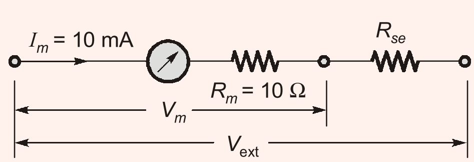
$$X_1 = 0.25 \text{ p.u.}$$
$$X_2 = 0.15 \text{ p.u.}$$
$$X_0 = 0.05 \text{ p.u.}$$
$$I_{f\,(LG)} = I_{f(3\text{-}\phi)}$$
$$\frac{3V_{pu}}{(X_1 + X_2 + X_0 + 3X_n)} = \frac{V_{pu}}{X_1}$$
$$= \frac{3 \times 1}{(0.25 + 0.15 + 0.05 + 3X_n)} = \frac{1}{0.25}$$
$$= \frac{3}{(0.45 + 3X_n)} = \frac{1}{0.25}$$
$$\Rightarrow \quad X_n = 0.1 \text{ p.u.}$$
$$X_n = 0.1 \times Z_B$$
$$= 0.1 \times \frac{30^2}{50} = 1.8\ \Omega$$

End of Solution

Q.51 A moving coil instrument having a resistance of 10 Ω, gives a full-scale deflection when the current is 10 mA. What should be the value of the series resistance, so that it can be used as a voltmeter for measuring potential difference up to 100 V?

(a) 9990 Ω
(b) 990 Ω
(c) 9 Ω
(d) 99 Ω

Ans. (a)



$$V_m = I_m R_m = 10 \text{ mA} \times 10\ \Omega = 100 \text{ mV}$$
$$(0 - 100 \text{ mV}) \Rightarrow (0 - 100 \text{ V})$$
$$m = \frac{V_{ext}}{V_m} = \frac{100 \text{ V}}{100 \text{ mV}} = 1000$$
$$R_{se} = R_m [m - 1]$$
$$R_{se} = 10[1000 - 1] = 9990\ \Omega$$

End of Solution

Q.52 A three-phase 50 Hz, 400 kV transmission line is 300 km long. The line inductance is 1 mH/km per phase, and the capacitance is 0.01 μF/km per phase. The line is under open circuit condition at the receiving end and energized with 400 kV at the sending end, the receiving end line voltage in kV (round off to two decimal places) will be ______.

Ans. (418.85)

$$V_s = 400 \text{ kV}$$
$$l = 300 \text{ km}$$
$$L_1 = 1 \text{ mH/km/phase}$$
$$C_1 = 0.01\ \mu\text{F/km/phase}$$
$$v = \frac{1}{\sqrt{L_1C_1}} = \frac{1}{\sqrt{1\times10^{-3}\times0.01\times10^{-6}}} = 3.16\times10^5 \text{ km/sec}$$
$$\beta' = \frac{2\pi fl}{v} = \frac{2\pi\times50\times300}{3.16\times10^5} = 0.29$$
$$A = 1-\frac{\beta^2}{2} = 1-\frac{(0.29)^2}{2} = 0.955$$
$$V_R = \frac{V_S}{A} = \frac{400}{0.955} = 418.85 \text{ V}$$

End of Solution

Q.53 A single-phase transformer of rating 25 kVA, supplied a 12 kW load at power factor of 0.6 lagging. The additional load at unity power factor in kW (round off to two decimal places) that may be added before this transformer exceeds its rated kVA is _____.

Ans. (7.21)

For a 12 kW, 0.6 pf lagging load,

$$P_L = 12 \text{ kW}$$
$$Q_L = \frac{12}{0.6}\times\sin(\cos^{-1}0.6) = 16 \text{ kVAR}$$

Transformer rating, $S = 25$ kVA

Let us assume load that can be added is P kW then,

$$S^2 = (P+P_L)^2 + Q_L^2$$
$$25^2 = (P+12)^2 + 16^2$$
$$P = 7.21 \text{ kW}$$

End of Solution

Q.54 A fully-controlled three-phase bridge converter is working from a 415 V, 50 Hz AC supply. It is supplying constant current of 100 A at 400 V to a DC load. Assume large inductive smoothing and neglect overlap. The rms value of the AC line current in amperes (round off to two decimal places) is ______.

Ans. **(81.65)**

$$\text{AC line current rms} = (I_s)_{rms} = I_0\sqrt{\frac{2}{3}} = 100 \times \sqrt{\frac{2}{3}} = 81.65 \text{ A}$$

End of Solution

Q.55 A delta-connected, 3.7 kW, 400 V(line), three-phase, 4-pole, 50 Hz squirrel-cage induction motor has the following equivalent circuit parameters per phase referred to the stator. R_1 = 5.39 Ω, R_2 = 5.72 Ω, X_1 = X_2 = 8.22 Ω. Neglect shunt branch in the equivalent circuit. The starting line current in amperes (round off to two decimal places) when it is connected to a 100 V(line), 10 Hz, three-phase AC source is _____.

Ans. **(14.95)**

$$I_L = \sqrt{3}\, I_{ph}$$

At f = 10 Hz,

$$X_1 = X_2 = 8.22 \times \frac{10}{50} = 1.644\ \Omega$$

$$I_{ph} = \frac{V_{ph}}{\sqrt{(R_1+R_2)^2+(X_1+X_2)^2}}$$

$$= \frac{100}{\sqrt{(5.39+5.72)^2+(1.644+1.644)^2}}$$

$$= \frac{100}{11.586} = 8.63 \text{ A}$$

$$I_L = 14.95 \text{ A}$$

End of Solution

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