



GATE 2019

Detailed Solutions

BY

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EE

09th Feb 2019
Afternoon Session

Note:-

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Klassroom 2020 Program for GATE-EE in Kalu Sarai, New Delhi



Aptitude

01. The passengers were angry ____ the airline staff about the delay.

- (a) About (b) Towards
(c) With (d) On

Ans: (c)

Solution:

Passengers were angry with the airline staff

02. The missing number in the given sequence 343, 1331, _____, 4913 is

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

Ans: (c)

Solution:

$$343 = 7^3$$

$$1331 = 11^3$$

$$2197 = 13^3$$

$$4913 = 17^3$$

So, all terms in series are cubes of prime numbers

03. 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) only, quite (d) even too

Ans: (b)

Solution:

News papers are constant source of delight & recreation for one. The only trouble is that I read too many of them

04. I am not sure if the bus that has been booked will be able to ____ all the students

- (a) Deteriorate (b) Fill
(c) Sit (d) Accommodate

Ans: (d)

Solution:

I am not sure if the bus that has been booked will be able to accommodate all the students

05. 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) 120 (b) 60
(c) 90 (d) 80

Ans: (d)

Solution:

$$1 \text{ hour work of X} = \frac{1}{2}$$

$$1 \text{ hour work of Y} = \frac{1}{4}$$

$$1 \text{ hour work if both work together} = \frac{1}{2} + \frac{1}{4} = \frac{3}{4}$$



$$\begin{aligned} \text{Hours required completing work} &= \frac{1}{\frac{3}{4}} = \frac{4}{3} \text{ hours} \\ &= \frac{4}{3} \times 60 \text{ min} = 80 \text{ min} \end{aligned}$$

06. 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) $\frac{3}{8}$

(b) $\frac{1}{12}$

(c) $\frac{1}{8}$

(d) $\frac{1}{6}$

Ans: (a)

Solution:

For minimum element in Z , numerator should be minimum & denominator should be maximum

$$Z = \frac{X}{Y}$$

$$Z_{\min} = \frac{X_{\min}}{Y_{\max}} = \frac{1}{4}$$

For maximum element in Z , numerator should be maximum & denominator should be minimum

$$Z_{\max} = \frac{X_{\max}}{Y_{\min}} = \frac{3}{2}$$

$$Z_{\min} \times Z_{\max} = \frac{1}{4} \times \frac{3}{2} = \frac{3}{8}$$

07. 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) 2 and 4

(d) 1 only

Ans: (c)

Solution:

Based on data given, the heights are as follows,

Mita > Ganga > Rekha, Lakshmi > Sana

Hence, Rekha is shorter than Mita

& Sana is shorter than Ganga

But we cannot compare height of Rekha & Sana

08. 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 one of the following statements can be inferred from the given text?

(a) All men and women buy in impulse

(b) Many men and women buy in impulse

(c) Some men and women buy in impulse

(d) Few men and women buy in impulse

**Ans: (c)****Solution:**

Since men are prone to buy in impulse as women that does not guarantee that all men & women buy in an impulse but since there are chances so there is same part of population that buys in impulse.

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

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

Ans: (c)**Solution:**

We need to fill all 3 places of a 3 digit number by an even numbers

There are 5 even numbers between 0 & 9 but we cannot have 0 as first digit else number will be less than 100

So possible cases = $4 \times 5 \times 5 = 100$

10. The ratio of 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) 90.00 (b) 55.50
(c) 72.50 (d) 80.50

Ans: (c)**Solution:**

Let number of boys = $4x$

Number of girls = $3x$

Total students = $7x$

$$\text{Numbers of students passed} = \frac{80}{100} \times 7x = 5.6x$$

$$\text{Numbers of girls passed} = \frac{90}{100} \times 3x = 2.7x$$

$$\text{Numbers of boys passed} = 5.6x - 2.7x = 2.9x$$

$$\text{Percentage of boys passed} = \frac{2.9x}{4x} \times 100 = 72.50\%$$



Technical

01. A system transfer function is $H(s) = \frac{a_1s^2 + b_1s + c_1}{a_2s^2 + b_2s + c_2}$. If $a_1 = b_1 = 0$, and all other coefficients are positive, the

transfer function represents a

- (a) band pass filter
- (b) High pass filter
- (c) Notch filter
- (d) Low pass filter

Ans: (d)

Solution:

If $a_1 = b_1 = 0$

$$H(s) = \frac{c_1}{a_2s^2 + b_2s + c_2}$$

$$H(j\omega) = \frac{c_1}{-a_2\omega^2 + jb_2\omega + c_2}$$

$$\text{At } \omega = 0, H(j\omega) = \frac{c_1}{c_2}$$

$$\text{At } \omega = \infty, H(j\omega) = 0$$

Hence the filter acts as low pass filter

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

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

Ans: (d)

Solution:

$$H(s) = \frac{s+3}{s^2+2s+1} = \frac{s+1+2}{(s+1)^2} = \frac{1}{(s+1)} + \frac{2}{(s+1)^2} = (e^{-t} + 2te^{-t})u(t)$$

03. 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) $\frac{kT}{C}$
- (c) $\frac{C}{kT}$
- (d) $\frac{\sqrt{kT}}{C}$



$$\begin{aligned}
 &= [2x^3]_{-3}^{-2} + [3y^2]_{-3}^6 + [4z]_2^{-1} \\
 &= 2(8 + 27) + 3(6^2 - 3^2) + 4(-1 - 2) \\
 &= 70 + 81 - 12 = 139
 \end{aligned}$$

07. 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

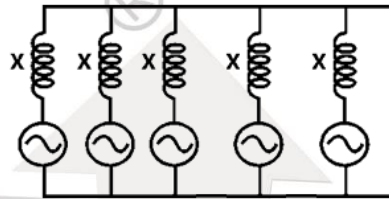
Solution:

$$E_{eq} = 1 \angle 0$$

$$X_{eq} = \frac{X}{5} = \frac{0.25}{5}$$

$$I_{sc} = \frac{E_{eq}}{X_{eq}} = \frac{5}{0.25} = 20 \text{ pu}$$

So level = $20 \times 5 \text{ MVA} = 100 \text{ MVA}$



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

(a) $\frac{z^2 - 1}{z + 2}$

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

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

(d) $\frac{z^2 - 1}{z}$

Ans: (a)

Solution:

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

The pole lies at $z = -2$ which lies outside $|z| \leq 1$ & hence the function is analytic in region $|z| \leq 1$

09. 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) 1 %

(b) 4.5 %

(c) 9 %

(d) 5 %

Ans: (d)

Solution:

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

10. A current controlled current source (CCCS) has an input impedance of 10Ω and output impedance of $100 \text{ k}\Omega$. When this CCCS is used in a negative feedback closed loop with a loop gain of 9, the closed loop output impedance is

(a) $100 \text{ k}\Omega$

(b) 100Ω

(c) 10Ω

(d) $1000 \text{ k}\Omega$

**Ans: (d)****Solution:**

A current controlled current source must have low input impedance & high output impedance

$$R_{if} = \frac{R_i}{1 + A\beta}$$

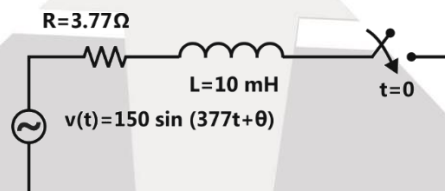
$$R_{of} = R_o(1 + A\beta)$$

Given, $A\beta = 9$

$$R_{if} = \frac{10}{1 + 9} = 1 \Omega$$

$$R_{of} = 100k(1 + 9) = 1000k\Omega$$

11. 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) - 45
(c) 60

- (b) 90
(d) - 30

11. Ans.(a)**Solution:**

$$i(t) = ce^{-\frac{t}{\tau}} + \frac{V_m}{|Z|} \sin(377t + \theta - \phi)$$

at $t = 0$ $i = 0$

$$0 = c + \frac{V_m}{|Z|} \sin(\theta - \phi)$$

$$c = -\frac{V_m}{|Z|} \sin(\theta - \phi)$$

For maximum transient, $\phi - \theta = \pm \frac{\pi}{2}$

$$\theta = \phi \pm \frac{\pi}{2} = \tan^{-1} \frac{\omega L}{R} \pm \frac{\pi}{2} = \tan^{-1} \left(\frac{377 \times 0.01}{3.77} \right) \pm 90 = -45^\circ \text{ or } 135^\circ$$

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

Ans: 3**Solution:**

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



To find rank, we find $|M| = -1(0-1) + 1(1) = 2$

Since, $|M| \neq 0$, rank = 3

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

Ans: (c)

Solution:

For saturation, $V_{GS} > V_{Th}$ & $V_{DS} \geq V_{GS} - V_{Th}$

14. 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. 111 to 114

Solution:

Fundamental rms is given by $\frac{2\sqrt{2}}{\pi} V_{dc} \text{ sind}$

$$\frac{2\sqrt{2}}{\pi} V_{dc} \text{ sind} = \frac{3}{4} V_{dc}$$

$$\text{sind} = \frac{3\pi}{8\sqrt{2}}$$

$$\text{sind} = 0.833, d = 56.4081$$

$$\text{Pulse width} = 2d = 112.80$$

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

$$Y(s) = \frac{10}{s(s^2 + s + 100\sqrt{2})} \text{ the steady state value of } y(t) \text{ is}$$

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

Ans: (b)

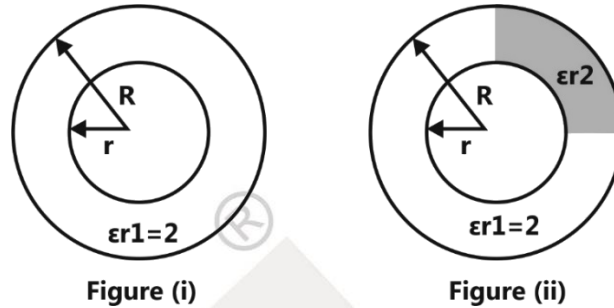
Solution:

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

This system has two poles in left half plane & one pole at origin so we can apply final value theorem

$$y(\infty) = \lim_{s \rightarrow 0} Y(s) = \frac{1}{10\sqrt{2}}$$

19. A co-axial cylindrical capacitor shown in figure (i) has dielectric with relative permittivity $\epsilon_r1 = 2$. 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 _____.



Ans: 10

Solution:

$$\text{Initial capacitance } C_1 = \frac{2\pi\epsilon_0\epsilon_r}{\ln\left(\frac{b}{a}\right)} = \frac{[\phi]_0^{2\pi} \epsilon_0\epsilon_r}{\ln\left(\frac{b}{a}\right)}$$

$$C_1 = \frac{4\pi\epsilon_0}{\ln\left(\frac{b}{a}\right)}$$

When distance is inserted as shown in figure, then electric field is tangential to dielectric interface & hence capacitance are in parallel.

$$C_2 = C_{21} + C_{22} = \frac{\{\phi\}_0^{\pi} \times \epsilon_0\epsilon_{r2}}{\ln\left(\frac{b}{a}\right)} + \frac{\{\phi\}_{\pi/2}^{2\pi} \times \epsilon_0 \times 2}{\ln\left(\frac{b}{a}\right)}$$

$$C_2 = \frac{\pi\epsilon_0}{\ln\left(\frac{b}{a}\right)} \left(\frac{\epsilon_{r2}}{2} + 3 \right)$$

$$\frac{\pi\epsilon_0}{\ln\left(\frac{b}{a}\right)} \left(\frac{\epsilon_{r2}}{2} + 3 \right) = 2 \times C_1$$

$$\epsilon_{r2} + 6 = 16$$

$$\epsilon_{r2} = 10$$

20. 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) 300 A (b) 400 A
(c) 100 A (d) 200 A

Ans: (b)

Solution:

Since load is fixed, $P = \text{constant}$

$$P = \sqrt{3}V_L I_a \cos\phi$$



$$\sqrt{3}V_L \times 200 \times 1 = \sqrt{3}V_L \times I_a \times 0.5$$

$$I_a = 400A$$

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

Ans: 100

Solution:

$$\text{VA output} = I^2 R = (20 \times 5)^2 \times 0.01$$

$$= (100)^2 \times 0.01 = 100VA$$

22. The Characteristic equation of a linear time-invariant (LTI) system is given by

$$\Delta(s) = s^4 + 3s^3 + 3s^2 + s + k = 0$$

The system is BIBO stable if

(a) $0 < k < \frac{12}{9}$

(b) $0 < k < \frac{8}{9}$

(c) $k > 3$

(d) $k > 6$

Ans: (b)

Solution:

Applying Routh Criteria

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

s^4	1	3	K
s^3	3	1	
s^2	$\frac{8}{3}$	K	
s^1	$\frac{\frac{8}{3} - 3k}{\frac{8}{3}}$		
s^0	K		

For stable system, all elements in first column must be greater than 0

$$\text{Hence, } k > 0 \text{ \& } \frac{8}{3} - 3k > 0$$

$$\text{Or, } k < \frac{8}{9}$$

23. 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) Rotor leakage reactance

(b) Magnetizing reactance

(c) Rotor resistance

(d) Stator resistance

**Ans: (c)****Solution:**

By reducing voltage, the slip changes & hence the effective rotor resistance changes

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

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

Ans: (b)**Solution:**

If a matrix M has Eigen value λ then the matrix M^n has Eigen value λ^n

So, M^2 has Eigen value λ^2 & hence Eigen values are 16 & 81

25. 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) (-0.75, j0)
(c) (-1.5, j0) (d) (-0.5, j0)

Ans: (d)**Solution:**

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

$$GH(j\omega) = \frac{\pi e^{-0.25j\omega}}{j\omega}$$

$$\angle GH(j\omega) = -90 - \frac{\omega}{4}$$

For intersecting negative real axis either $\angle GH(j\omega) = -180^\circ$ or 180°

For $\angle GH(j\omega) = -180^\circ$

$$-\pi = -\frac{\pi}{2} - \frac{\omega}{4}$$

$$\frac{\omega}{4} = \frac{\pi}{2}; \omega = 2\pi = 6.28 \text{ rad/sec}$$

$$|GH(j\omega)| = \frac{\pi}{\omega}$$

At $\omega = 2\pi$ rad/sec

$$|GH(j\omega)| = \frac{\pi}{2\pi} = 0.5$$

Since it intersects negative real axis, it intersects at -0.5

26. The output expression for the Karnaugh map shown below is

- (a) $Q\bar{R} + S$
(b) $QR + S$
(c) $QR + \bar{S}$
(d) $Q\bar{R} + \bar{S}$

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



Ans: (a)

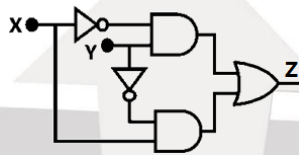
Solution:

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

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

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

- (a) XNOR
- (b) NOR gate
- (c) XOR gate
- (d) NAND gate



Ans: (c)

Solution:

$$\text{Output of first AND gate} = \bar{X}Y$$

$$\text{Output of second AND gate} = X\bar{Y}$$

$$Z = \bar{X}Y + X\bar{Y} = X \oplus Y$$

28. If $A = 2x\hat{i} + 3y\hat{j} + 4z\hat{k}$ and $u = x^2 + y^2 + z^2$, then $\text{div}(uA)$ at $(1, 1, 1)$ is _____.

Ans: 45

Solution:

$$\nabla \cdot (uA) = u(\nabla \cdot \vec{A}) + \vec{A} \cdot (\nabla u)$$

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

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

$$= 13x^2 + 15y^2 + 17z^2$$

$$\text{At } (1, 1, 1), \nabla \cdot (uA) = 13 + 15 + 17 = 45$$

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

Ans: 417 to 420

Solution:

$$\beta = \omega\sqrt{\ell C} = 100\pi\sqrt{10^{-3} \times 10^{-8}} = 9.9345 \times 10^{-4}$$

$$A = \cos\beta\ell = \cos(9.9345 \times 10^{-4} \times 300) = \cos(0.2980\text{rad}) = 0.9559$$

$$V_{RO} = \frac{V_s}{A} = \frac{400}{0.9559} = 418.44\text{kV}$$



30. 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 $0.05 \mu\text{F}$. 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

Solution:

$$\text{Critical resistance, } r = \frac{1}{2} \sqrt{\frac{L}{C}} = \frac{1}{2} \sqrt{\frac{50 \times 10^{-3}}{0.05 \times 10^{-6}}} = 500 \Omega$$

31. A $0.1 \mu\text{F}$ capacitor charged to 100 V is discharged through a $1 \text{ k}\Omega$ resistor. The time in ms (round off to two decimal places) required for the voltage across the capacitor to drop to 1 V is _____.

Ans: 0.45 to 0.47

Solution:

$$\text{Initial capacitor voltage, } V(0) = 100\text{V}$$

$$\text{Due to discharge capacitor } V(\infty) = 0\text{V}$$

$$V(t) = 100e^{-t/\tau}$$

$$\tau = RC = 10^3 \times 10^{-7} \text{F} = 0.1 \text{msec}$$

$$1\text{V} = (100\text{V})e^{-t/0.1}$$

$$t = -0.1 \ln \frac{1}{100} = 0.46 \text{msec}$$

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

(a) $\frac{100}{\sqrt{3}}$ A

(b) 0 A

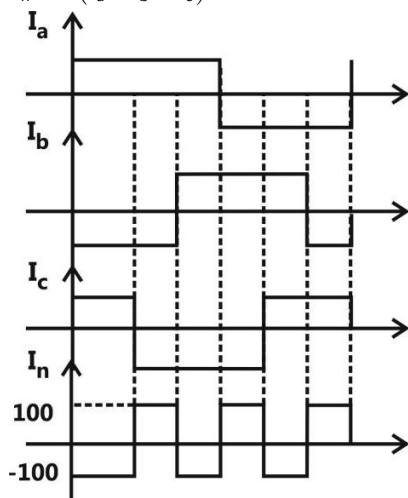
(c) 300 A

(d) 100 A

Ans: (d)

Solution:

$$I_n = -(I_a + I_b + I_c)$$



rms value of $I_n = 100\text{A}$



33. A delta connected 3.7kW, 400V (line), three phase, 4-pole, 50-Hz squirrel-cage induction motor has following equivalent circuit parameters per phase referred to the stator:

$$R_1 = 5.39\Omega, R_2 = 5.72\Omega, X_1 = X_2 = 8.22\Omega$$

Neglect shunt branch in the equivalent circuit. The starting line current in amperes (round off to two decimal places) when it is connected to 100V (line), 10Hz, three-phase AC source is _____.

Ans: 14 to 16

Solution:

$$\text{At starting } s = 1, \frac{R_2}{s} = R_2$$

At 10Hz

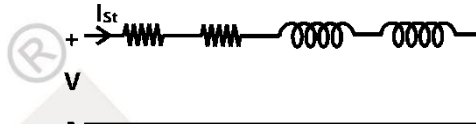
$$X' = X \frac{10}{50} = \frac{X}{5}$$

Since motor is delta connected $V = 100V$

$$I_{st} = \frac{100}{(5.39 + 5.72) + j\left(\frac{16.44}{5}\right)}$$

$$|I_{st}| = \frac{100}{\sqrt{123.43 + \frac{270.2736}{25}}} = \frac{100}{11.586} \text{ A}$$

$$\text{Line current} = \sqrt{3} \times \frac{100}{11.586} = 14.95 \text{ A}$$



34. A DC-DC buck converter operator 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) 12 W
(c) 24 W (d) 6 W

Ans: (d)

Solution:

$$V_0 = DV_s = \frac{T_{ON}}{T} V_s$$

$$V_0 = T_{ON} f V_s = (1\text{msec}) \times 250 \times 48 = 12V$$

Since V_0 is ripple free $V_0 = 12V$

$$P = \frac{V_0^2}{R} = \frac{12^2}{24} = 6W$$

35. A single-phase transformer of rating 25 kVA, supplies 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: 7.17 to 7.25

Solution:

Load = 12kW at 0.6lag

$$\text{Load reactive power } Q_L = P_L \tan \phi_L$$

$$= 12 \times \tan(\cos^{-1} 0.6) = 16 \text{ KVAR}$$

For transformer rating, $S = 25 \text{ KVA}$



$$S^2 = P^2 + Q^2$$

Since additional load has unity pf, so it consumes only P

$$(P+12)^2 + 16^2 = 25^2$$

$$P = 7.21 \text{ kW}$$

36. 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 larger 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

Solution:

By power conservation, $V_s I_s = P_o$

$$24 \times I_s = 120$$

$$I_s = 5 \text{ A}$$

$$I_s = I_L = 5 \text{ A}$$

For boundary condition $I_L = \frac{\Delta I_L}{2}$

From o to DT

$$V_L = V_s$$

$$L \times \frac{\Delta I_L}{2} = V_s$$

$$\Delta I_L = \frac{DV_s}{fL}$$

$$5 = \frac{DV_s}{2fL}$$

Since $V_o = \frac{V_s}{1-D}$

$$48 = \frac{24}{1-D}; D = 0.5$$

$$5 = \frac{0.5 \times 24}{2 \times 50 \times 10^3 \times L}$$

$$L = \frac{2.4}{10^5} = 24 \mu\text{H}$$

37. 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 $u_1^T v_2 = 1$

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

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

**Ans: (c)****Solution:**Since $M^{-1}M = I$

$$\begin{bmatrix} u_1^T \\ u_2^T \end{bmatrix} \begin{bmatrix} V_1 & V_2 \end{bmatrix} = \begin{bmatrix} u_1^T V_1 & u_1^T V_2 \\ u_2^T V_1 & u_2^T V_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$u_1^T V_1 = 1 \quad u_1^T V_2 = 0 \quad u_2^T V_1 = 0 \quad u_2^T V_2 = 1$$

Hence both statements are true

38. 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: 0.77 to 0.79**Solution:**

$$V_0 = \frac{2V_m}{\pi} \cos \alpha$$

$$180 = \frac{2 \times 230\sqrt{2}}{\pi} \cos \alpha$$

$$\cos \alpha = 0.869$$

$$\text{Input pf} = \frac{2\sqrt{2}}{\pi} \cos \alpha = 0.78$$

39. A moving coil instrument having a resistance of 10Ω , 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) 990Ω (b) 9990Ω (c) 9Ω (d) 99Ω **Ans: (b)****Solution:**

$$\text{Original range of instrument} = I_{fs} \times R_m \\ = 10\text{mA} \times 10\Omega = 100\text{mV}$$

$$\text{Multiplication factor} = \frac{100\text{V}}{100\text{mV}} = 1000$$

$$R_{se} = R_m (m - 1)$$

$$= 10(1000 - 1) = 9.99\text{k}\Omega = 9990\Omega$$

40. A 30 kV, 50 Hz, 50 MVA generator has the positive, negative, and zero sequence reactances of 0.25 pu, 0.15 pu, and 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 two decimal place) is _____.

Ans: 1.7 to 1.9**Solution:**

For same fault current

$$I_f = \frac{3}{X_1 + X_2 + X_0 + 3X_n} = \frac{1}{X_1}$$



$$\frac{3}{0.25 + 0.15 + 0.05 + 3X_n} = \frac{1}{0.25}$$

$$0.75 = 0.45 + 3X_n$$

$$X_n = 0.1 \text{ Pu}$$

$$X_n = 0.1 \times \frac{30^2}{50} = 1.8 \Omega$$

41. 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 larger inductive smoothing and neglect overlap. The rms value of the AC line current in amperes (round off to two decimal places) is _____.

Ans: 81 to 82.5

Solution:

$$\text{RMS supply current} = I_o \sqrt{\frac{2}{3}} = 100 \sqrt{\frac{2}{3}} = 81.65 \text{ A}$$

42. 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: 587 to 590

Solution:

For finding power, constant current to sin

$$i(t) = 8 \cos\left(3\pi t + \frac{\pi}{6}\right) = 8 \sin\left(3\pi t + \frac{\pi}{2} + \frac{\pi}{6}\right)$$

$$= 8 \sin\left(8\pi t + \frac{2\pi}{3}\right)$$

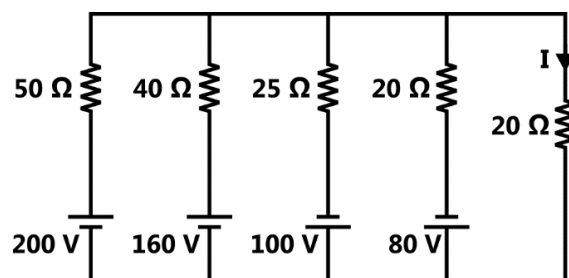
$$v(t) = 170 \sin\left(3\pi t + \frac{5\pi}{6}\right)$$

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

$$= \frac{170}{\sqrt{2}} \times \frac{8}{\sqrt{2}} \times \cos(150 - 120)$$

$$= 170 \times 4 \times \frac{\sqrt{3}}{2} = 340\sqrt{3} = 588.9 \text{ W}$$

43. The current I flowing in the circuit shown below in amperes is _____.



**Ans: 0****Solution:**

By norton's equivalent,

$$I_{sc} = \frac{200}{50} + \frac{160}{40} - \frac{100}{25} - \frac{80}{20} = 0A$$

Since $I_{sc} = 0$, $I = 0A$ **44.** Consider a state-variable model of a system

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

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

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

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

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

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

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

Ans: (b)**Solution:**Characteristic equation is $|sI - A| = 0$

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

$$s^2 + 2\beta s + \alpha = 0$$

Compare to standard equation, $s^2 + 2\xi\omega_n s + \omega_n^2 = 0$

$$\omega_n^2 = \alpha \text{ or } \omega_n = \sqrt{\alpha}$$

$$2\xi\omega_n = 2\beta \text{ or } \xi = \frac{\beta}{\sqrt{\alpha}}$$

45. 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 resistances are 0.5Ω and 220Ω respectively. The no-load speed in rpm (round off to two decimal places) is _____.

Ans: 1577 to 1583**Solution:**

$$\text{Field current } I_f = \frac{220}{220} = 1A$$



At full load,

Line current, $I_L = 25\text{A}$

Armature current, $I_a = I_L - I_f = 24\text{A}$

Induced emf $= V_t - I_a r_a = 220 - 24 \times 0.5 = 208\text{V}$

At no load,

Line current, $I_L = 3\text{A}$

Armature current $I_a = I_L - I_f = 2\text{A}$

Induced emf $= V_t - I_a r_a = 220 - 2 \times 0.5 = 219\text{V}$

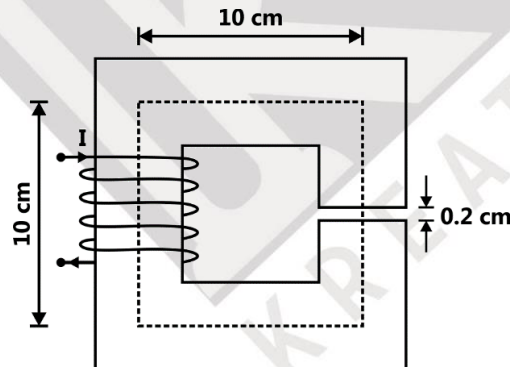
Since $I_f = \text{constant}$, $\phi = \text{constant}$

$E \propto \text{speed}$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

$$N_2 = \frac{219}{208} \times 1500 = 1579.32 \text{ rpm}$$

46. 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: 0.83 to 0.84

Solution:

Initial resistance,

$$R_{\text{core}} = \frac{\ell}{\mu_0 \mu_r A} = 0 \quad (\mu_r = \infty)$$

$$R_{\text{gap}} = \frac{0.2 \times 10^{-2}}{\mu_0 \times A} = \frac{2 \times 10^{-3}}{\mu_0 A}$$

$$R_1 = R_{\text{core}} + R_{\text{gap}} = \frac{2 \times 10^{-3}}{\mu_0 A}$$



$$= 1 - {}^{50}C_0 (0.02)^0 (0.98)^{50} - {}^{50}C_1 (0.02)^1 (0.98)^{49}$$

$$= 1 - 0.36417 - 0.3716 = 0.26$$

49. The closed loop line integral

$$\oint_{|z|=5} \frac{z^3 + z^2 + 8}{z + 2} dz$$

evaluated counter-clockwise, is

(a) $-4j\pi$

(b) $+4j\pi$

(c) $+8j\pi$

(d) $-8j\pi$

Ans: (c)

Solution:

$$\oint_{|z|=5} \frac{z^3 + z^2 + 8}{z + 2} dz$$

$$= 2\pi i \operatorname{Res}[(z + 2)f(z)]_{z=-2}$$

$$= 2\pi i \lim_{z \rightarrow -2} (z^3 + z^2 + 8) = 8\pi i$$

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

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

If

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

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

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

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

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

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

Ans: (a)

Solution:

$$a_1 = \frac{2}{T} \int_{\langle T \rangle} f(t) \cos \omega_0 t dt$$

$$\omega_0 = \frac{2\pi}{T} = 1$$

$$= \frac{2}{2\pi} \left[\int_0^{\pi} A \sin t \cos t dt + \int_{\pi}^{2\pi} 0 dt \right]$$

$$= \frac{2}{2\pi} \int_0^{\pi} \frac{A}{2} \sin 2t dt = 0$$

$$b_1 = \frac{2}{2\pi} \left[\int_0^{\pi} A \sin t \sin t dt + \int_{\pi}^{2\pi} 0 dt \right]$$

$$= \frac{A}{2\pi} \left[\int_0^{\pi} \left(\frac{1 - \cos 2t}{2} \right) dt \right] = \frac{A}{2}$$



51. A 220 V (line), three-phase, Y-connected, synchronous motor has a synchronous impedance of $(0.25 + j2.5) \Omega/\text{phase}$. 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 to 246

Solution:

$$E = \left[(V \cos \phi - I_a r_a)^2 + (V \sin \phi + I_a X_s)^2 \right]^{1/2}$$

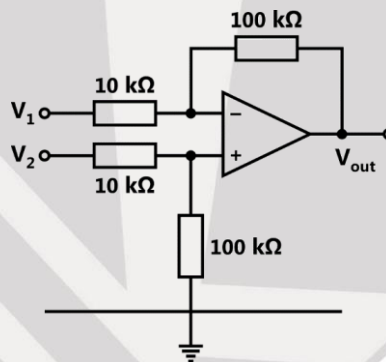
$$= \left[\left(\frac{220}{\sqrt{3}} \times 0.8 - 2.5 \right)^2 + \left(\frac{220}{\sqrt{3}} \times 0.6 + 25 \right)^2 \right]^{1/2}$$

$$= \left[(101.6166 - 2.5)^2 + (76.2124 + 25)^2 \right]^{1/2}$$

$$= \left[(99.1166)^2 + (101.2124)^2 \right]^{1/2} = 141.6617V$$

Line to line voltage = 245.38V

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



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

Ans: (d)

Solution:

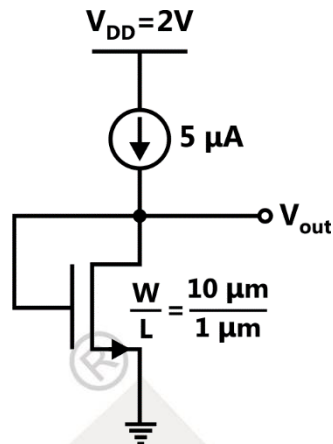
By voltage division

$$V_+ = V_2 \times \frac{100}{110} = \frac{10}{11} V_2$$

By using superposition,

$$V_0 = V_+ \left(1 + \frac{100}{10} \right) + V_1 \left(-\frac{100}{10} \right) = \frac{10}{11} V_2 (11) - 10 V_1 = 10 (V_2 - V_1) = 400 \text{ mV}$$

53. The enhancement type MOSFET in the circuit below operates according to the square law. $\mu_n C_{ox} = 100 \mu\text{A}/\text{V}^2$, the threshold voltage (V_T) is 500 mV. Ignore channel length modulation. The output voltage V_{out} is



- (a) 500 mV
(c) 2 V

- (b) 600 mV
(d) 100 mV

Ans: (b)

Solution:

Since, MOSFET is in saturation region,

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

$$5\mu A = \frac{10\mu A}{2} \times \frac{100\mu m}{10\mu m} (V_{GS} - 0.5)^2$$

$$(V_{GS} - 0.5)^2 = \frac{5 \times 2}{100} = \frac{1}{100} = 0.01$$

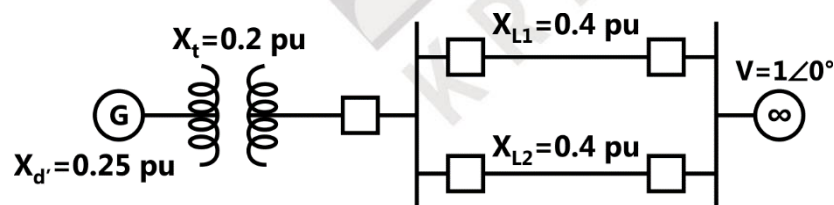
$$V_{GS} - 0.5 = 0.1$$

$$V_{GS} = 0.6$$

$$V_G - V_{GS} = 0.6 \text{ or } V_0 - 0 = 0.6$$

$$V_0 = 0.6V = 600 \text{ mV}$$

54. 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 to 21

Solution:

$$X_{eq} = 0.25 + 0.2 + (0.4 \parallel 0.4) = 0.65 \text{ pu}$$

$$I = \frac{P}{V \cos \phi} = \frac{0.8}{1 \times 0.8} = 1 \text{ pu}$$

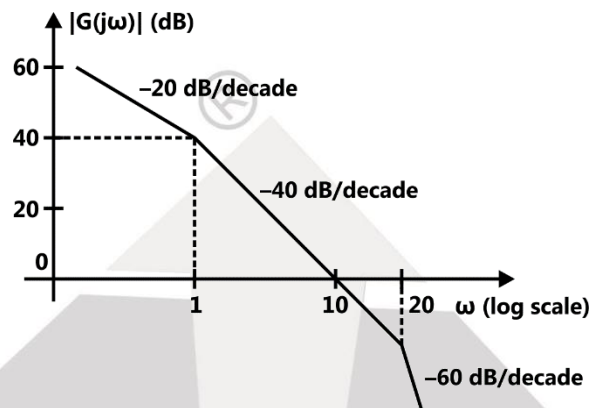


$$\tan \psi = \frac{V \sin \phi + I_x}{V \cos \phi + I_r} = \frac{0.6 + 1 \times 0.65}{0.8}$$

$$\psi = 57.38 = \delta + \phi$$

$$\delta = 20.5^\circ$$

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



Consider the following two statements.

Statement I: Transfer function $G(s)$ has three poles and one zero.

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

Which one of the following options is correct?

- (a) Statement I is true and statement II is false.
- (b) Statement I is false and statement II is true.
- (c) Both the statement are true.
- (d) Both the statement are false.

Ans: (b)

Solution:

Based on given Bode plot, there is a pole at $s=0$, another pole at $s=1$ & one more pole at $s=20$
Hence there are 3 poles but no zeroes

Each pole will contribute a phase shift of $-\frac{\pi}{2}$ $\omega \rightarrow \infty$ & hence total phase shift is $-\frac{3\pi}{2}$

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