Branch: Electrical Engineering

Time: 3 Hours **PRE- GATE-2020** **Marks: 100**

GATE-2020 General Aptitude (GA)

Q. 1 – Q. 5 carry ONE mark each.

01. **Fill in the blank with an appropriate phrase**

Jobs are hard to _____ these days

(A) Come by (B) Come down
(C) Come of (D) Come from

Ans: (A)

Sol: 'Come by' means to manage to get something.

02. ***The question below consists of a pair of related words followed by four pairs of words. Select the pair that best expresses the relation in the original pair.***

MONKEY : TROOP:

(A) sheep : hard
(B) elephant : Parliament
(C) bacteria : Colony
(D) wolves : School

Ans: (C)

Sol: Troop consists of monkeys just as a colony consists of bacteria.

03. ***Choose the most appropriate word from the options given below to complete the following sentence:***

If you had gone to see him, he _______ delighted.

(A) Would have been
(B) Will have been
(C) Had been
(D) Would be

Ans: (A)

Ans: 'A" conditional tense type 3 grammatical code is

If +had+V3, would +have+V3

04. Which of the following options is closest in meaning to the underlined word?

European intellectuals have long debated the consequences of the **hegemony** of American popular culture around the world.

(A) regimen (B) vastness

(C) dominance (D) popularity

Ans: (C)

Sol: Dominance means influence or control over another country, a group of people etc.

05. How many one-rupee coins, 50 paise coins 25 paise coins in total of which the numbers are proportional to 5, 7 and 12 are together work ₹115?

(A) 50, 70, 120 (B) 60, 70, 110

(C) 70, 80, 90 (D) None of these

Ans: (A)

Sol: $(5 \times 1+7\times0.5+12\times0.25)\ x = 115$

$(5+3.5+3)x = 115$

$11.5x = 115$

$x = 10$

$\therefore$ Number of one rupee coin $= 5x = 5\times10 = 50$

Number of 5-paise coin $= 7x = 7\times10 = 70$

Number of 25-paise coin $= 12x = 12\times10 = 120$

Q. 6 – Q. 10 carry TWO marks each.

06. Critical reading is a demanding process. To read critically, you must slow down your reading and, with pencil in hand, perform specific operations on the text mark up the text with your reactions, conclusions, and questions, then you read, become an active participant.

This passage best supports the statement that

(A) Critical reading is a slow, dull but essential process.

(B) The best critical reading happens at critical times in a person's life.

(C) Readers should get in the habit of questioning the truth of what they read.

(D) Critical reading requires thoughtful and careful attention.

Ans: (D)

Sol: Choice (A) is incorrect because the author never says that reading is dull.

Choice (B) and (C) are not support by the paragraph.

Choice (D) is correct as it is implied in the entire passage.

07. Anil's house faces east. From the back-side of the house, he walks straight 50 metres, then turns to the right and walks 50m again finally, he turns towards left and stops after walking 25 m Now Anil is in which direction from the starting point?

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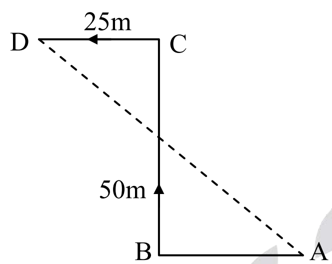
(A) South-east (B) South-west

(C) North-east (D) North- west

Ans: (D)

Sol: The movement of Anil are shown in the adjoining figure



He starts walking from back of his house (i.e) towards west now, the final position is D, which is to the north west of his starting point A.

08. A and B enter into a partnership, A puts in ₹ 50 and B puts in ₹ 45. At the end of 4 months, A withdraws half his capital and at the end of 5 months B withdraws $\frac{1}{2}$ of his, C then enters with a capital of ₹ 70. At the end of 12 months, the profit of concern is ₹ 254, how can the profit be divided among A, B and C?

(A) ₹ 76, ₹ 80 and ₹ 98

(B) ₹ 80, ₹ 76 and ₹ 98

(C) ₹ 76, ₹ 98 and ₹ 80

(D) None of these

Ans: (B)

Sol:

A's share	: B's share	: C's share
(50×4+25×8)	: (45×5+22.5×7)	: (70×7)
400	: 382.5	: 490
800	: 765	: 980
160	: 153	: 196

Total profit = ₹ 254

$$\text{Profit of A} = \frac{160}{160+153+196}\times 254$$

$$= \frac{160}{509}\times 254 = ₹80$$

$$\text{Profit of B} = \frac{153}{509}\times 254 = ₹76$$

$$\text{Profit of C} = \frac{196}{509}\times 254 = ₹98$$

∵ Hence option 'B' is correct.

09. A sum of ₹25400 was lent out in two parts, one of 12% and the other at $12\frac{1}{2}$% of the total annual income is ₹3124.2, the money lent at 12% is ________.

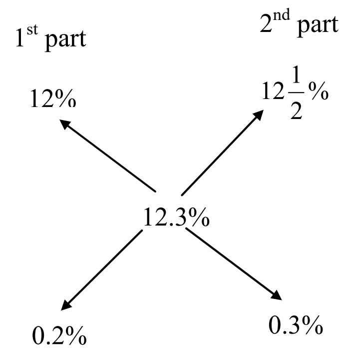
(A) ₹15240 (B) ₹25400

(C) ₹10160 (D) ₹31242

Ans: (C)

Sol: Overall rate of interest

$$\frac{3124.2}{25400}\times 100 = 12.3\%$$



$\therefore$ The sum will be divided in the ratio 0.2:0.3 (or) 2:3

$\therefore$ The sum lent at 12% $= 25400\times\frac{2}{5}$

$= ₹10160.$

10. The following question is to be answered on the basis of the table given below.

Category of personnel	Number of staff in the year-1990	Number of staff in the year-1995
Data preparation	18	25
Data control	5	8
Operators	18	32
Programmers	21	26
Analysts	15	31
Managers	3	3
Total	80	135

What is the increase in the sector angle for operators in the year 1995 over the sector angle for operators in the year 1990?

(A) 4° (B) 3°

(C) 2° (D) 1°

Ans: (A)

Sol: Sector angle for operators in the year 1990

$$=\frac{18}{80}\times 360° = 81°$$

Sector angle for operator in the year 1995

$$=\frac{32}{135}\times 360° = 85.33 \simeq 85\%$$

$\therefore$ Required difference = 85°– 81°= 4°

Q. 1 – Q. 25 carry ONE mark each.

01. A 2 winding transformer supplies a leading power factor load at rated secondary voltage. For a given load current, if magnitude of the load power factor varies, the core losses, as compared with the no load core losses, will

(A) remain unchanged.

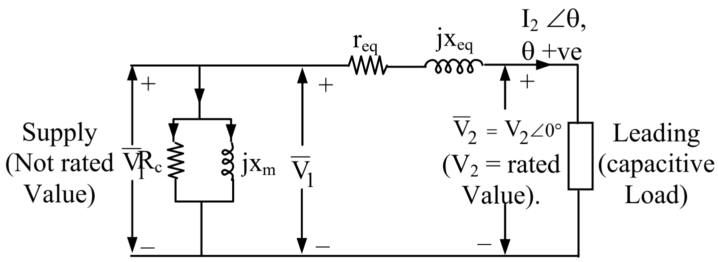
(B) increase.

(C) decrease.

(D) either increase, remain constant, or decrease.

Ans: (D)

Sol: Assume (for simplicity) that the approximate equivalent circuit shown in fig.1 correctly represents the transformer.



Equivalent circuit ref secondary.
Fig.1

An approximate but widely used expression for $(V_1 - V_2)$ is

$(V_1 - V_2) = I_2(r_{eq} \cos\theta - x_{eq} \sin\theta)$.

On no load, $I_2 = 0$.

$\therefore$ Drop across the impedance $(r_{eq} + jx_{eq})$ is zero and $V_1 = V_2$. No load core losses $= \dfrac{V_2^2}{R_c}$.

If cosθ is large, sin θ will be small. (Assume $0 \le \theta \le 90°$). $(V_1 - V_2)$ is positive. $V_1 > V_2$. core losses $\dfrac{V_1^2}{R_c} >$ no load core losses.

If cosθ is small, sin θ will be large. $(V_1 - V_2)$ is negative. $V_1 < V_2$. core losses $\dfrac{V_1^2}{R_c} <$ no load core losses.

There will be some θ for which $V_1 - V_2 = 0$.

Then core loss $\dfrac{V_1^2}{R_c}$ equals no load core loss.

02. The armature of a 2-pole, 200 V dc separately excited generator has 400 conductors and runs at 300 rpm. The number of field turns are 1200. Now the field circuit is opened. If the field flux dies away completely in 0.075 sec, average field induced emf during the 0.075 sec period is ___________ V.

Ans: (1600)

Sol: 1. $K = \dfrac{PZ}{2\pi A} = \dfrac{400}{2\pi} = \dfrac{200}{\pi}$.

2. Initial operation:

2.1. $\omega = 300 \times \dfrac{2\pi}{60} = 10\pi$ r/sec(mech)

2.2. Flux/pole = ϕ (unknown).

2.3. $E = \dfrac{200}{\pi} \phi (10\pi) = 200$

(from given data).

$\therefore \phi = 0.1$ Wb.

3. The field flux decreases from $\phi = 0.1$ Wb to zero in 0.075 sec.

$$\left.\frac{d\phi}{dt}\right|_{ave} = \frac{0.1}{0.075} = \frac{4}{3} \text{ Wb/sec.}$$

(Ignore the negative sign).

4. With 1200 field turns, average field induced emf during the period

$$= 1200 \times \frac{4}{3} = 1600\text{V}.$$

03. A 3-ϕ star connected 400 V (line to line), 8 kW (output) synchronous motor with full load efficiency of 88% operating with minimum possible current. The synchronous impedance per phase is 8 Ω with negligible resistance. The induced

emf/ph is

(A) 233.7 V (B) 238.7 V

(C) 248.7 V (D) 253.7 V

Ans: (D)

Sol: $V_L = 400\text{ V} \Rightarrow V_{ph} = \dfrac{400}{\sqrt{3}} = 231\text{ V}$

Motor output = 8 kW

$$P_{in} = \frac{P_{out}}{\eta} = \frac{8\text{ kW}}{0.88} = 9091\text{ W}$$

$P_{in} = \sqrt{3}\,V_L I_L \cos\phi$; current will be minimum at upf

$$\therefore I_L = \frac{P_{in}}{\sqrt{3}V_L} = \frac{9091}{\sqrt{3}\times 400} = 13.12\text{ A}$$

$$E = \sqrt{(V\cos\phi - I_a R_a)^2 + (V\sin\phi \mp I_a X_s)^2}$$

$$= \sqrt{(231\times 1 - 0)^2 + (231\times 0 + 13.12\times 8)^2}$$

$= 253.7$ V

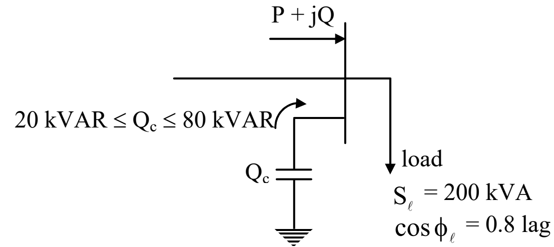
04. A variable shunt capacitor bank of reactive power rating 'Q_c' connected in parallel with a load.
The load consumes an apparent power of 200 kVA at 0.8 power factor lagging. The reactive power 'Q_c' varies as 20 kVAR $\le Q_c \le$ 80 kVAR. The combination of capacitor bank and load will draw the lowest apparent power from connected bus bar for any value of 'Q_c' is

(A) 165 kVA (B) 188 kVA

(C) 200 kVA (D) 212 kVA

Ans: (A)

Sol:



Load real and reactive power consumptions,

$P_\ell = S_\ell.\cos\phi_\ell = 200 \times 0.8 = 160$ kW

$Q_\ell = S_\ell.\sin\phi_\ell = 200 \times 0.6 = 120$ kVAR

Net real power drawn, $P = P_\ell = 160$ kW

Net reactive power drawn, $Q = Q_\ell - Q_C$

$= 120 - Q_C$

Net apparent power, $S = \sqrt{P^2 + Q^2}$

$= \sqrt{160^2 + (120 - Q_C)^2}$

Minimum net apparent power (S_{min}) occurs for lowest value of 'Q' or highest value of 'Q_C'

$$S_{min} = \sqrt{(160)^2 + (120-80)^2}$$

$= 165$ kVA

05. A 150 bus power system network consists 25 generator buses, 5 buses having fixed shunt capacitor banks, 3 buses having SVC's, 2 buses having STATCOM's and remaining buses are treated as load buses. How many number of equations to be solved in load flow analysis of this system by Gauss Seidel method and Newton Raphson method (rectangular form) respectively

(A) 150, 264 (B) 150, 298

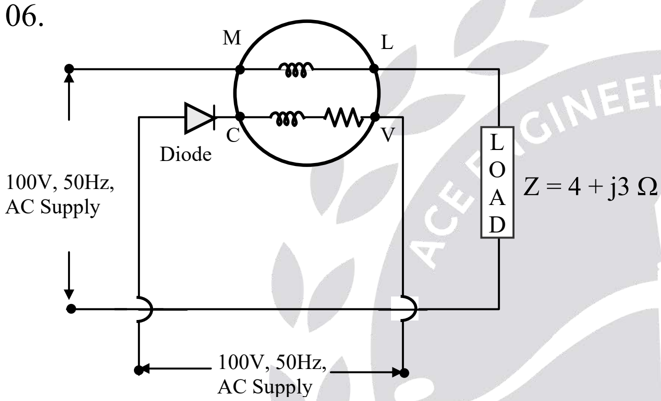
(C) 149, 269 (D) 149, 298

Ans: (D)

Sol: Number of equations to be solved in Gauss Seidel method = n – 1 = 149

Number of equations to be solved in Newton Raphson method (rectangular form) = 2n – 2 = 300 – 2 = 298

06.



The reading of wattmeter is

(A) 1600 W (B) 800 W

(C) 1414 W (D) 1131 W

Ans: (D)

Sol: Load current $I_L = \dfrac{V}{Z}$

$$= \frac{100}{\sqrt{4^2+3^2}} = \frac{100}{5} = 20\text{A}$$

$$V_{p.c} = \frac{100\times\sqrt{2}}{2}$$

[$\because$ Half wave sinusoidal, rms value is $\dfrac{V_m}{2}$]

$$\cos\phi = \frac{R}{Z} = \frac{4}{5} = 0.8$$

$P_{avg} = V_{rms} \times I_{rms} \times \cos\phi$

$$= \frac{100}{\sqrt{2}} \times 20 \times 0.8 = 1131.4 \text{ W}$$

07. A single phase one pulse converter with RLE load has the following parameter:

Supply voltage: 230 V at 50 Hz

Load: R = 2Ω, E = 120 V

Extinction angle, β = 275°

Firing angle, α = 25°

Find the PIV (Peak Inverse Voltage) for the SCR.

(A) 325.27 volt (B) 445.27 volt

(C) 444.03 volt (D) 650.54 volt

Ans: (C)

Sol: PIV for β > 270

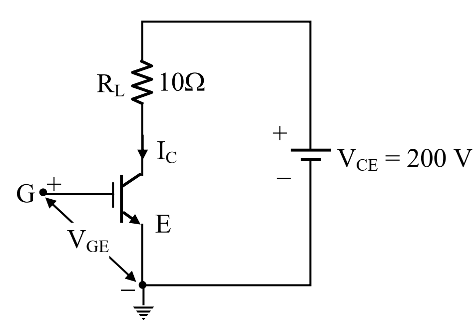
PIV = $|V_m \sin\beta - E|$

PIV = $\left|230\sqrt{2}\sin 275 - 120\right|$

PIV = 444.03 volt

08. The IGBT used in the circuit has the following data:

$t_{on} = 3\,\mu s$, $t_{off} = 1\,\mu s$, Duty cycle (D) = 0.7, $V_{CE(sat)} = 1.5$ V and $f_s = 1$ kHz.



The switching energy loss (in mJ) during turn on is ________ . (Give upto one decimal place)

Ans: 1.985 (Range: 1.9 to 2.1)

Sol: $I_C = \dfrac{V_{CC} - V_{CE(sat)}}{R_C}$

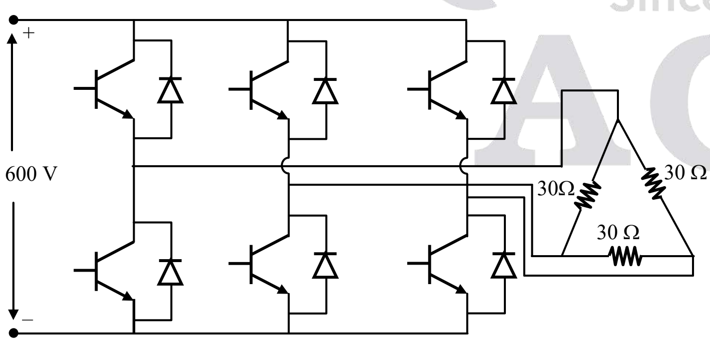
$= \dfrac{200-1.5}{10} = 19.85\text{ A}$

Turn ON energy loss $= \dfrac{V_{CC}I_C}{6} \times T_{on}$

$= \dfrac{200 \times 19.85}{6} \times 3 \times 10^{-6}$

= 1.985 mJ

09. A three-phase voltage source inverter (VSI) as shown in the figure is feeding a delta connected resistive load of 30Ω/phase. If it is fed from a 600 V battery, with 120° conduction of solid-state device, the power consumed by the load, in kW, is



(A) 12 (B) 18

(C) 24 (D) 8

Ans: (B)

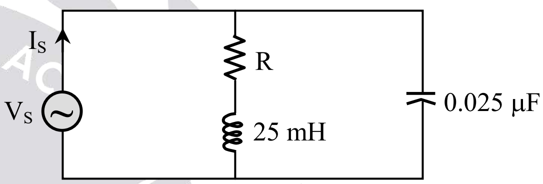
Sol: RMS value of phase voltage for 120° conduction mode is

$$V_L = V_{Ph} = \frac{V_{dc}}{\sqrt{2}} = \frac{600}{\sqrt{2}}\ \text{V}$$

Power delivered to load

$$P_o = 3 \times \frac{V_{ph}^2}{R} = 3 \times \frac{\left(600/\sqrt{2}\right)^2}{30} = 18\text{ kW}$$

10. Resonance will occur in the circuit shown only when



(A) R > 1000 Ω (B) R < 1000 Ω

(C) R > 2000 Ω (D) R < 2000 Ω

Ans: (B)

Sol: As resonance frequency

$$f_r = \frac{1}{2\pi\sqrt{LC}}\sqrt{1-\frac{R^2C}{L}}$$

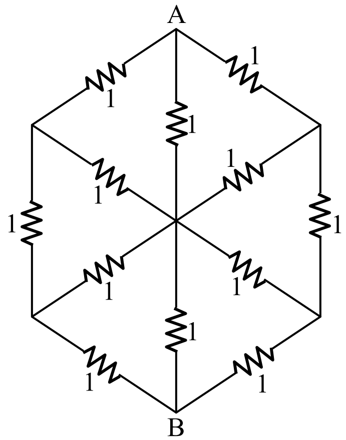
Resonance will occur in circuit only when

$$1-\frac{R^2C}{L} > 0,\ 1 > \frac{R^2C}{L},\ R^2 < \frac{L}{C}$$

$$R < \sqrt{\frac{L}{C}}$$

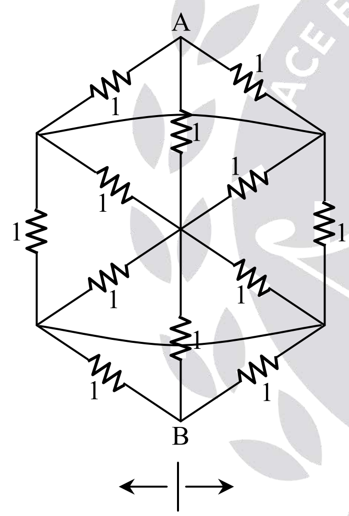
$$R < \sqrt{\frac{25\times10^{-3}}{0.025\times10^{-6}}} = 1000\ \Omega$$

11. The resistance between terminals A, B is __________ Ω.



Ans: 0.8 (Range: 0.75 to 0.85)

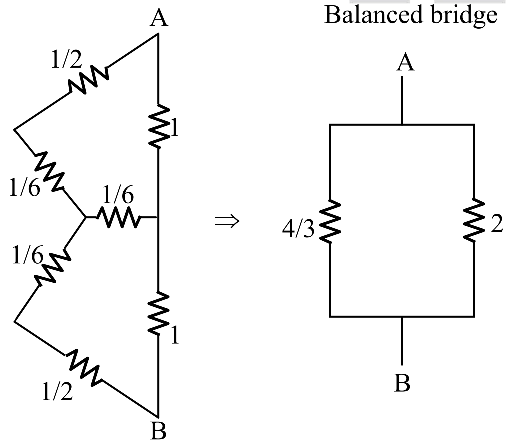
Sol: Joints nodes which one of same potential by mirror image symmetry



Mirror image

Delta-to star

Balanced bridge

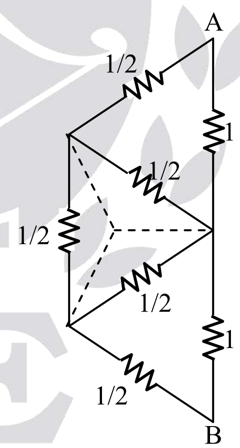


$$R_{AB} = 2 // \frac{4}{3} = \frac{\frac{8}{3}}{\frac{10}{3}} = \frac{4}{5} = 0.8\ \Omega$$

12. An electric field $(x^2 a_x + y a_y + 2z^3 a_z)$ N/C exists in free space. Corresponding charge density at the origin is _________ p C/m^3. (rounded off to two decimal places).

Ans: 8.85 (Range: 8.84 to 8.86)

Sol: It is useful to check that the given vector field $\overline{E}$ is indeed a static electric field (static because t does not appear in the field expression). Find$\nabla \times \overline{E}$. Is it zero? Then $\overline{E}$ is indeed a static electric field. (Otherwise the problem is wrongly framed).



$$\nabla \times \overline{E} = \begin{vmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ x^2 & y & 2z^3 \end{vmatrix}$$

$$= a_x\left\{\frac{\partial}{\partial y}(2z^3)-\frac{\partial}{\partial z}(y)\right\}+a_y\left\{\frac{\partial}{\partial z}(x^2)-\frac{\partial}{\partial x}\left(2z^3\right)\right\}$$

$$+a_z\left\{\frac{\partial}{\partial x}(y)-\frac{\partial}{\partial y}(x^2)\right\}$$

$$= 0$$

$\overline{E}$ is a static electric field.

Then, $\nabla.\overline{E} = \dfrac{\rho}{\varepsilon_0}$ (Gauss;s law)

But,

$$\Delta.\overline{E} = \left(\frac{\partial}{\partial x}a_x + \frac{\partial}{\partial y}a_y + \frac{\partial}{\partial z}a_z\right).\left(x^2a_x + ya_y + 2z^3a_z\right)$$

$$= 2x + 1 + 6z^2$$

At origin (0, 0, 0), $\nabla.\overline{E} = 1$.

$$\therefore \quad \frac{\rho_{(0,0,0)}}{\varepsilon_0} = 1$$

$\therefore$ $\rho_{(0,\,0,\,0)} = \varepsilon_0 = 8.854 \times 10^{-12}$ C/m^3

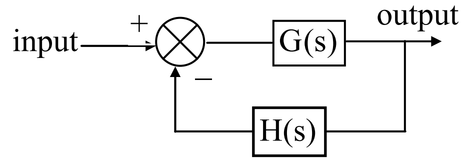
13. Negative feedback is employed in a control system then which one of the following statement (s) is/are true.

1. Gain increases
2. Bandwidth increases
3. Sensitivity of the output with respect to parameter changes in the forward path decreases.
4. Time constant of the system decreases

(A) 1, 2, 3, 4 (B) Only 2, 3, 4
(C) Only 3, 4 (D) Only 2,4

Ans: (B)

Sol:



$$\text{CLTF} = \frac{G(s)}{1+G(s)H(s)}$$

Negative feedback reduces gain of system

$S_G^M = \dfrac{1}{1+G(s)H(s)}$ is less than unity

i.e., less sensitive to the forward path parameter variations.

Bandwidth increases hence rise time decreases, speed increases, time constant decreases.

14. State space representation of a system is given as

$$\dot{x}(t) = \begin{bmatrix}-2 & 0\\ 0 & -4\end{bmatrix}x(t) + \begin{bmatrix}1\\ -1\end{bmatrix}u(t),\; y(t) = \begin{bmatrix}1 & 1\end{bmatrix}x(t)$$

. Where y(t) is the output and u(t) is the input. Then the undamped natural frequency of the system is _____ rad/sec. (round up to two decimal places).

Ans: 2.83 (Range 2.8 to 2.9)

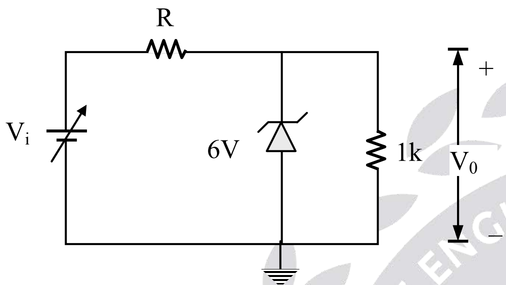
Sol: Characteristic equation (s+2) (s+4) = 0

$s^2 + 6s + 8 = 0$

$\omega_n^2 = 8$

$\omega_n = 2\sqrt{2}$ rad/sec = 2.83 rad/sec

15. The circuit shown used to provide regulated output voltage of 6V across 1kΩ resistor. Assume V_z = 6V, I_z (knee) = 4mA. The input voltage may vary by 10% from normal value of 10V. The required value of R for the satisfactory operation of the circuit is ______ Ω



Ans: 300

Sol: Given that $V_z = 6V = V_0$

I_z knee = I_z min = 4 mA

$V_i = (10 \pm 10\%)$ V

V_i range is 9V to 11V

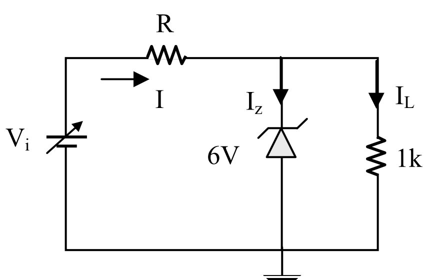
$$I_L = \frac{V_0}{R_L} = 6\,mA$$

As V_i varies, I → varies

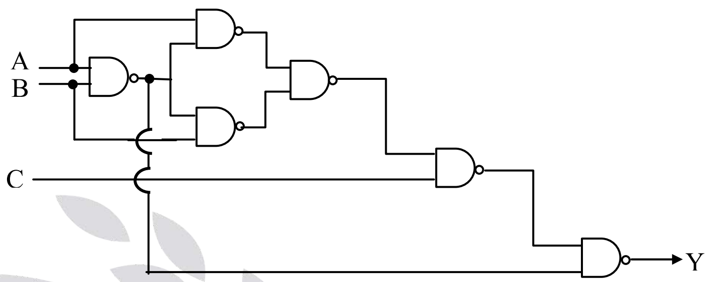
$I_{min} = I_{z(min)} + I_L = 10$ mA

$$\frac{V_{i(min)} - V_z}{R} = 10\times10^{-3}$$

$$\Rightarrow R = \frac{9-6}{10\times10^{-3}} = 300\Omega$$



16. A, B, and C are Input bits and 'Y' is the output bit in the circuit shown below. If the output 'Y' is set to logic '1', which of the following option can satisfies the input binary combinations.



(A) Two (or) more number of input's A,B, and C are '0'

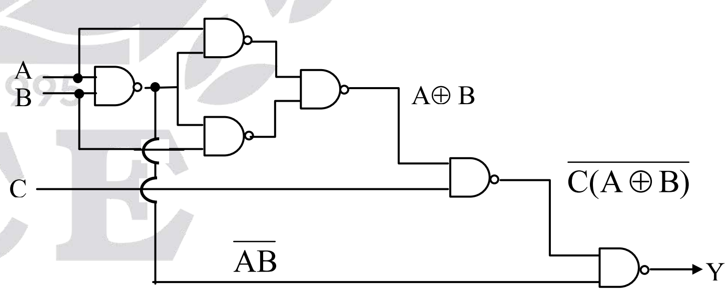
(B) Two (or) more number of input's A,B, and C, are '1'

(C) A = B ≠ C (or) A = C ≠ B

(D) A = B = C

Ans: (B)

Sol:



$$Y = \overline{\overline{C(A\oplus B)}.\overline{AB}}$$

$$Y = C(\bar{A}B + A\bar{B}) + AB$$

$$= \bar{A}BC + A\bar{B}C + AB(C+\bar{C})$$

$$= \underset{m_3}{\bar{A}BC} + \underset{m_5}{A\bar{B}C} + \underset{m_6}{AB\bar{C}} + \underset{m_7}{ABC}$$

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	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$			1	
A		1	1	1

$\Rightarrow$ Y=AB+BC+CA

If two more number of input's are '1' output (Y) = 1

Because Y = 1+(anything) = 1

17. For which of the following Boolean function the dual and complement values are same?

(A) $f = A \oplus B$

(B) $f = AB$

(C) $f = \bar{A}B$

(D) All of the above

17. Ans: (A)

Sol: Given $\bar{A}B + A\bar{B}$

$$f_{compt} = (A+\bar{B}).(\bar{A}+B)$$

$$= A\bar{A} + AB + \bar{B}\bar{A} + \bar{B}B$$

$$= 0 + AB + \bar{A}\,\bar{B} + 0$$

$$f_{compt} = AB + \bar{A}\,\bar{B}$$

Given $f = \bar{A}B + A\bar{B}$

$$f_{dual} = (\bar{A}+B)(A+\bar{B})$$

$$= 0 + \bar{A}\,\bar{B} + BA + 0$$

$$f_{dual} = AB + \bar{A}\bar{B}$$

$\therefore\ f_{compt} = f_{dual}$

18. The below program is stored from Address 0101H

```
      LXI    H, 7788 H
      MOV    A, L
      ANA    H
      JPO    SKIP
      ADD    L
SKIP: MOV    H,A
      DAD    H
      SHLD   1234H
      PCHL
```

From which address next instruction will be fetched?

(A) 0110H
(B) 1111H
(C) 1110H
(D) 1234H

Ans: (C)

Sol: ∗ (HL) = 7788H

∗ (A) ← (L) = 88H

$\Rightarrow$ (A) = 88H

$$\begin{array}{lcll} * (A) &=& 88H &= 1000\ 1000 \\ \wedge (H) &=& 77H &= 0111\ 0111 \\ \hline (A) &=& 00H &= 0000\ 0000 \end{array}$$

$CY = 0, P = 1, AC = 1, Z = 1, S = 0$

∗ JPO means Jump if parity odd

i.e., test for P = 0

This test fails as P = 1 because of ANA H

Therefore, μp does not jump but continues with next instruction.

∗ (A) ← (A) + (L)

$* \ (A) = 00H = 0000 \quad 0000$

$\underline{+(L)} = \underline{+88H} = \underline{1000 \ \ 1000}$

$\underline{(A)} \quad = \underline{88H} = \underline{1000 \quad 1000}$

$*$ (H) ← (A) = 88H

⇒ (H) = 88H

$(HL) = 8888H = 1000\ 1000\ \ 1000\ 1000$

$\underline{+(HL)} = \underline{8888H} = \underline{1000\ \ 1000\ \ 1000\ 1000}$

$\underline{(HL)} \quad = \underline{1110H} = \underline{0001\ \ 0001\ 0001\ \ 0000}$

$*$ (HL) = 1110 H stored into 2 locations 1234H And 1235H

$*$ (HL) = 1110 H copied into P.C

⇒ (P.C) = 1110H

∴ 8085 μP fetches next instruction from Address 1110H

19. An LTT system with impulse response

$h(t) = \frac{1}{\sqrt{t+2}}u(t+1)$ is

(A) Causal & Stable

(B) Causal & Unstable

(C) Unstable & Non causal

(D) Non causal & Stable

Ans: (D)

Sol: $h(t) = \frac{1}{\sqrt{t+2}}u(t+1)$

Because the signal (IR) starts at t = –1 ⇒ Non causal.

For the stability $\int_{-\infty}^{\infty} |h(t)|\,dt < \infty$

$\int_{-1}^{\infty} \frac{1}{\sqrt{t+2}}dt < \infty$ ∴ Stability

∴ The system is stable & NC

20. An FIR system with input x(n) and output y(n) related as y(n) = 0.2x(n) –0.5x(n –2) + 0.4x(n–3). If the input x(n) = {–1, 1, 0, 1} is applied then the output at n = 2 is ________

Ans: 0.5

Sol: y(n) = 0.2x(n) – 0.5 x(n–2) + 0.4 x(n–3)

y(2) = 0.2x(2) – 0.5 x(0) + 0.4 x(–1) …..(1)

x(n) = {–1,1,0,1}

x(0) = –1; x(1) = 1; x(2) = 0

x(3) = 1

Substituting in equation (1)

y(2) = 0.2(0) – 0.5 (–1) + 0.4 (0)=0.5

∴y(2) = 0.5

21. Two LTI systems with impulse response $h_1(n) = \delta(n)$ and $h_2(n) = \delta(n) - \delta(n-2)$ are connected in cascade. If the input x(n) = u(n) is applied then the output is

(A) δ (n) (B) δ (n–1)

(C) δ (n) +δ (n–1) (D) δ(n–1) + δ (n–2)

Ans: (C)

Sol: Two systems are connected in cascade the overall IR is

$h(n) = h_1(n) * h_2(n)$

$h(n) = \delta(n) * [\delta(n) - \delta(n-2)]$

$h(n) = \delta(n) - \delta(n-2)$

$y(n) = x(n) * h(n)$

$y(n) = u(n) * [\delta(n) - \delta(n-2)]$

$y(n) = u(n) - u(n-2)$

$= \{\underset{\uparrow}{1}, 1\}$

$y(n) = \delta(n) + \delta(n-1)$

22. For the function $f(x, y) = x^2 - y^2$, the point (0, 0) is

(A) a local minimum

(B) a saddle point

(C) a local maximum

(D) not a stationary point

Ans: (B)

Sol: Given $f(x, y) = x^2 - y^2$

$\Rightarrow f_x = 2x,\ f_y = -2y$ and

$f_{xx} = 2,\ f_{xy} = 0, f_{yy} = -2$

Consider $f_x = 0$ and $f_y = 0$

$\Rightarrow 2x = 0$ and $-2y = 0$

$\Rightarrow (0, 0)$ is a stationary point

At (0, 0), $f_{xx}\, f_{yy} - (f_{xy})^2 = -4 < 0$

$\therefore$ f(x, y) has neither a maximum nor minimum at (0, 0).

23. If directional derivative of $\phi = 2xz - y^2$, at the point (1, 3, 2) becomes maximum in the direction of $\bar{a}$, then magnitude of $\bar{a}$ is __________ . (Give upto two decimal place)

Ans: 7.48 (Range 7.45 to 7.50)

Sol: Given $\phi = 2xz - y^2$

$$\nabla\phi = \frac{\partial\phi}{\partial x}\bar{i} + \frac{\partial\phi}{\partial y}\bar{j} + \frac{\partial\phi}{\partial z}\bar{k}$$

$$= 2z\,\bar{i} - 2y\bar{j} + 2x\,\bar{k}$$

$\therefore$ Required direction vector = $\bar{a} = (\nabla\phi)$ at (1, 3, 2) = $(4\bar{i} - 6\bar{j} + 2\bar{k})$

Magnitude of $\bar{a} = \sqrt{16+36+4} = \sqrt{56}$

$= 7.48$

24. A continuous random variable X has a probability density function

$f(x) = e^{-x}$, $0 < x < \infty$. Then $P(X > 2)$ is

(A) 0.1353 (B) 0.2354

(C) 0.2343 (D) 1.1353

Ans: (A)

Sol: $P(X > 2) = \int_2^\infty f(x)\cdot dx$

$$= \int_2^\infty e^{-x} dx$$

$$= \left.\frac{e^{-x}}{-1}\right|_2^\infty$$

$$= e^{-2} = 0.1353$$

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25. The solution to $x^2y^{11} + xy^1 - y = 0$ is

(A) $y = C_1x^2 + C_2\,x^{-3}$

(B) $y = C_1 + C_2x^{-2}$

(C) $y = C_1\,x + \dfrac{C_2}{x}$

(D) $y = C_1\,x + C_2\,x^4$

Ans: (C)

Sol: Put $ln\,x = t$ so that $x = e^t$ and

Let $x\dfrac{dy}{dx} = Dy$, $x^2\dfrac{d^2y}{dx^2} = D(D-1)\,y$

Where $D = \dfrac{d}{dt}$

Given differential equation is

$$x^2y^{11} + xy^1 - y = 0$$

$\Rightarrow$ $D(D-1)y + Dy - y = 0$

$\Rightarrow$ $(D^2 - 1)\,y = 0$

Consider Auxiliary equation $f(D) = 0$

$\Rightarrow D^2 - 1 = 0$

$\Rightarrow D = 1, -1$ are different real roots

$\therefore$ The general solution of given equation is

$$y = c_1e^t + c_2e^{-t}$$

$$= c_1\,x + \frac{c_2}{x}$$

Q. 26 – Q. 55 carry TWO marks each.

26. Three identical 2-winding single-phase transformers are connected as shown in fig. 1.

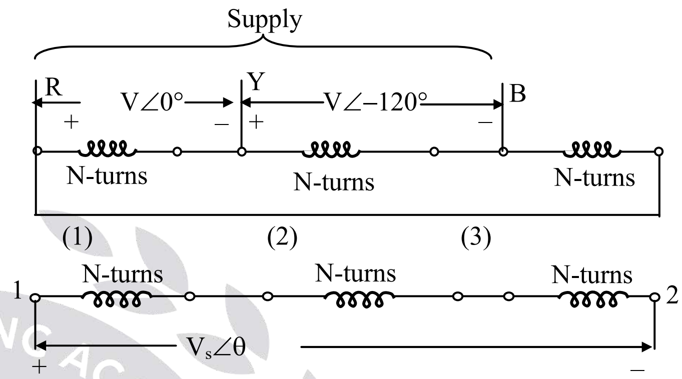


Fig.1

The two possible values for V_s are,

(A) 3V, V

(B) 0, 2 V

(C) 0, V

(D) $0,\ 2V\angle -60°$.

26. Ans: (B)

Sol: Fig. 1 of the question does not give any information about the relative polarities of the primary and secondary voltages. (This information is usually given by placing dots at the two windings of each of the transformers as per the dot convention. Such dots are not placed any where).

One meaning of dots (which is needed for this problem) is as follows:

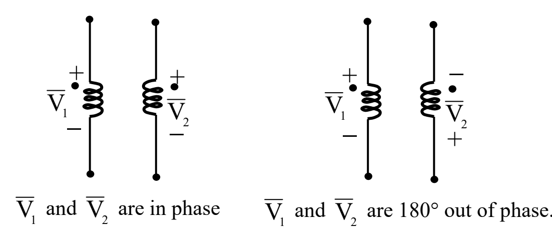
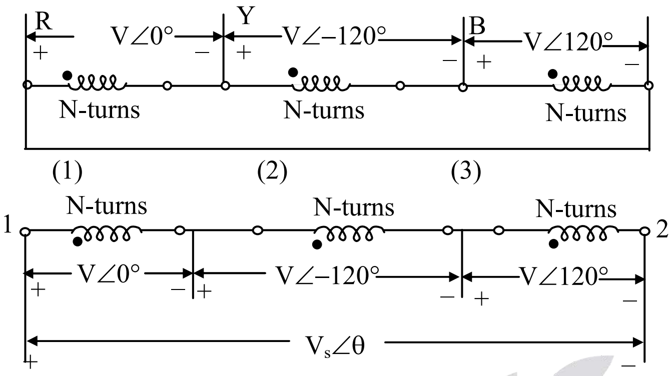


Fig. 2

(A) Let the dots be located as shown in fig.3.



$V_s\angle\theta = V\angle 0° + V\angle -120° + V\angle 120° = 0$

The terminals 1 & 2 can now be safely joined

Together to make a Δ – Δ transformer

Fig. 3

(B) Let the dots be located as shown in fig.4.

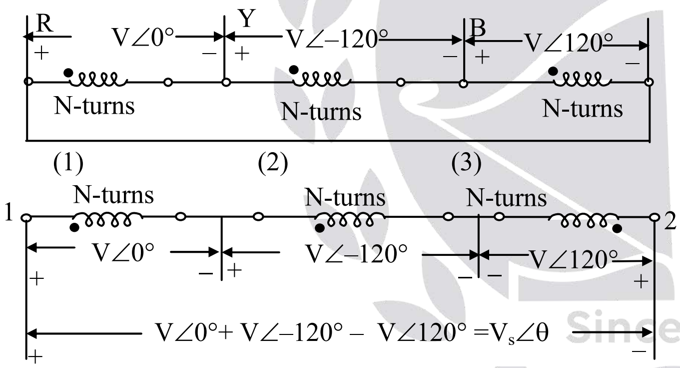
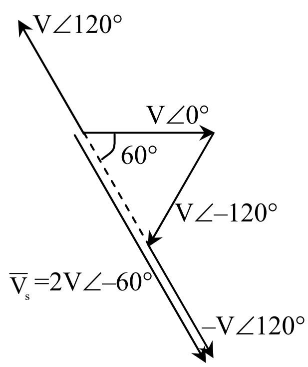


Fig.4

$V_s\angle\theta$ is determined in the phasor diagram of fig.4.



Terminals 1 and 2 of fig. 4 should not be joined

Fig. 5.

There are several other ways of connecting the three secondaries. Everyone of them leads to either $V_s = 0$ or $V_s = 2V$.

Thus there are only two possible values for V_s: Zero, and 2V.

27. A 100 kW, belt-driven dc shunt generator is running at 300 rpm in the clockwise direction, delivering power to a 200 V bus. Now the belt breaks, but the machine continues to run, drawing 4 kW from the supply. Neglect armature reaction. Armature and field resistances are 0.1 Ω and 100 Ω respectively. Its speed and direction of rotation after the belt breaks are, respectively.

(A) 238, clockwise

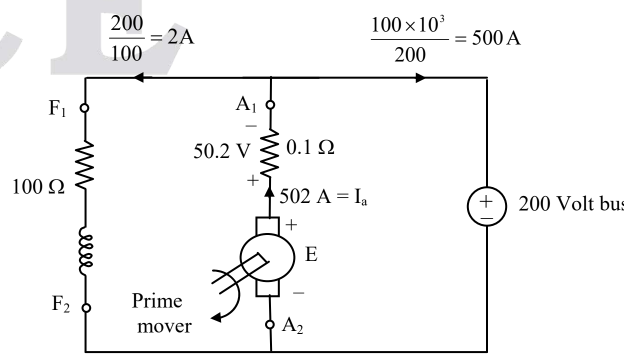
(B) 238, anti clockwise

(C) 242, clockwise

(D) 242, anti clockwise

Ans: (A)

Sol: 1. Initial operation:



$E - 50.2 = 200 \Rightarrow E = 250.2$ V.

Fig. 1

For a field current of 2A, let the flux/pole be ϕ Wb.

$$k\phi\left(300\times\frac{2\pi}{60}\right)=250.2 \Rightarrow k\phi=\frac{25.02}{\pi}.$$

The armature is given to be rotating in the cw direction.

2. Direction of developed torque during the initial operation:

With the armature and field currents directed as shown in fig.1, **the developed torque in the machine must be in the anti clock wise direction.** This is because the prime mover, in driving the armature in the clock wise direction, has to do mechanical work against the developed torque, which work is converted into electrical energy and losses by the machine.

3. Operation after the belt breaks:

Steady state conditions after the belt breaks are specified the problem. Corresponding circuit is as shown in fig. 2.

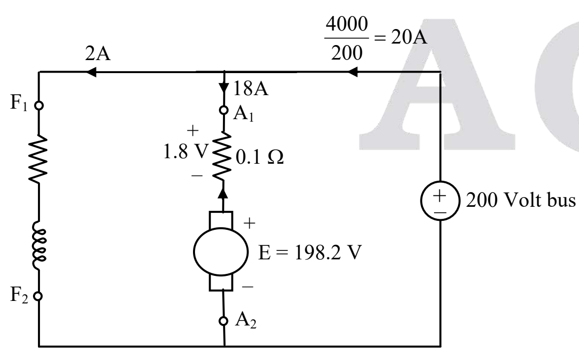


Fig. 2

With field current unchanged, $k\phi$ remains unchanged at $\frac{25.02}{\pi}$. (Since armature reaction is neglected, change in armature current from 502 A to 18 A does not affect the flux/pole in any way).

$$\left(\frac{25.02}{\pi}\right)N\left(\frac{2\pi}{60}\right)=198.2$$

$$\Rightarrow N = 237.65\text{rpm} \approx 238\,\text{rpm}.$$

When belt breaks, there is no prime mover anymore. However, the stored kinetic energy in the rotor keeps the rotor running in the clock wise direction, but with decreasing speed. The machine is in regenerative braking mode, which continues as long as E in fig.1 is greater than 200V, and I_a of fig. 1 is positive (developed torque will be in acw direction, it opposes motion and causes speed to fall). When E becomes less than 200 V, as in fig. 2, I_a reverses. With I_f continuing to be in the original direction, T_d is now in the clock wise direction, and drives the machine in the clock wise direction as a motor.

238 rpm, clock wise; is the correct answer.

28. A squirrel cage induction motor has slip of 4% at full load. Its starting current is five times the full load current. The stator impedance and magnetizing current may be neglected, the rotor resistance is assumed constant. The percentage of slip at which maximum torque occurs is _______.

Ans: 20 (No range)

Sol: We have

$$T_{em} = KI_2^2 \frac{R_2}{s} \text{ .... (1)}$$

From eq. (1)

$$T_{st} = KI_{st}^2 \frac{R_2}{1}$$

$$T_{fl} = KI_{fl}^2 \frac{R_2}{s_{fl}}$$

$$\frac{T_{st}}{T_{fl}} = \left(\frac{I_{st}}{I_{fl}}\right)^2 s_{fl} \text{ .... (2)}$$

Also we have

$$\frac{T_{st}}{T_{fl}} = \frac{s_{T\max}^2 + s_{fl}^2}{(s_{T\max}^2 + 1)s_{fl}} \text{ .... (3)}$$

From (2) & (3)

$$\left(\frac{I_{st}}{I_{fl}}\right)^2 s_{fl} = \frac{s_{T\max}^2 + s_{fl}^2}{s_{fl}(s_{T\max}^2 + 1)}$$

Given $I_{st} = 5I_{fl}$

$$\left(\frac{I_{st}}{I_{fl}}\right)^2 = \frac{s_{T\max}^2 + s_{fl}^2}{s_{fl}^2\left(s_{T\max}^2 + 1\right)}$$

$$\Rightarrow \left(\frac{5I_{fl}}{I_{fl}}\right)^2 = \frac{s_{T\max}^2 + 0.04^2}{0.04^2\left(s_{T\max}^2 + 1\right)}$$

$$\Rightarrow 25 = \frac{s_{T\max}^2 + 0.04^2}{0.04^2\left(s_{T\max}^2 + 1\right)}$$

Solving for

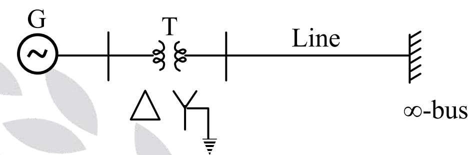
$S_{T\max} = 0.2$ or 20%

29. Consider the following single line diagram in which an alternator with emf of 15 kV supplying 150 MW real power to infinite bus of 400 kV voltage. The ratings of apparatus are given as

Generator (G): 11 kV, 200 MVA, $X_d = 0.5$ p.u,

Transformer (T): 11 kV/400 kV, 200 MVA, $X_t = 0.15$ p.u,

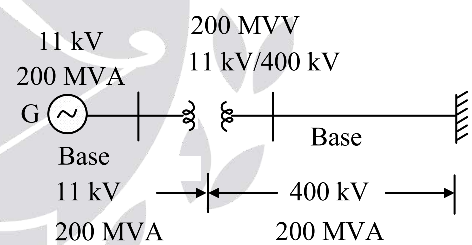
Transmission line: X = 40 Ω, R = 0, 400 kV



The stable angle made by rotor of alternator with respect to infinite bus is ______ electrical degrees

Ans: 22.64 (Range: 21.0 to 24.0)

Sol:



Let us choose common base as 11 kV, 200 MVA at 'G' location.

Line: $X_\ell = 40\,\Omega$

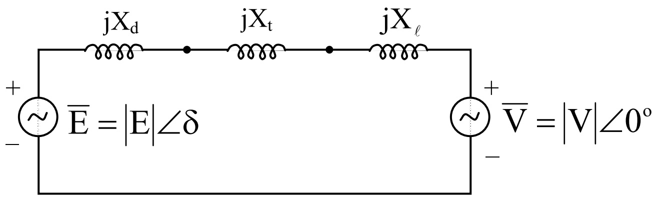
$$Z_{base} = \frac{(400\,k)^2}{200\,M} = 800\ \Omega$$

$$X_{\ell\,(p.u)} = \frac{40}{800} = 0.05 \text{ p.u}$$

G: $E_{p.u} = \frac{15}{11} = 1.3636$ p.u

Infinite bus: $V_{p.u} = \frac{400}{400} = 1$ p.u

The per phase equivalent circuit is given as,



Real power flow, P = 150 MW

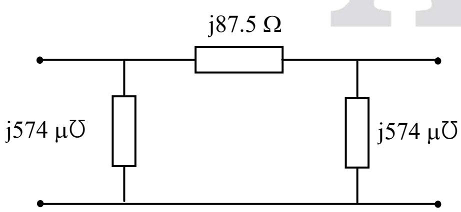
$$P_{(p.u)} = \frac{P}{S_{base}} = \frac{150}{200} = 0.75 \text{ p.u}$$

$$P = \frac{|E||V|}{X_{eq}}.\sin\delta$$

Where $X_{eq} = X_d + X_t + X_\ell = 0.7$ p.u

$$0.75 = \frac{1.3636 \times 1}{0.7}\sin\delta \Rightarrow \delta = 22.64°$$

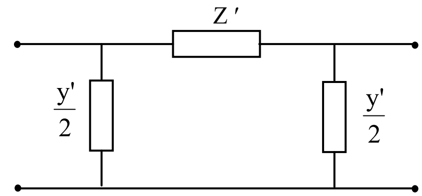
30. A 3-ϕ loss less transmission line has the propagation constant $\gamma = 0 + j1.06 \times 10^{-3}$ radians per km. The transmission line is represented in its equivalent π model as shown in the figure.



The approximate length of transmission line is ________ km.

Ans: 300 (Range: 295 km to 305 km)

Sol: Equivalent-π model,



Parameter $A = 1 + \frac{z'y'}{2}$

For transmission line, $A = \cos\beta\ell$

$$\therefore \cos\beta\ell = 1 + \frac{z'y'}{2}$$

$$= 1 + (j87.5 \times j574 \times 10^{-6})$$

$$= 0.9498$$

$$\beta\ell = \cos^{-1}(0.9498)$$

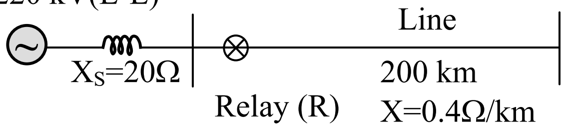
$$\beta\ell = 0.31828 \text{ radians}$$

Where $\beta = 1.06 \times 10^{-3}$ rad/km

$$\therefore \ell = \frac{0.31828}{1.06 \times 10^{-3}} \text{ km} = 300 \text{ km}$$

31. A transmission line of length 200 km with series reactance per km as 0.4 Ω is supplied by a source of 220 kV (LL) with source reactance of 20 Ω. The line is protected by a over current relay (R) with relay setting 80% and associated with a CT of ratio 2000/5A.

The relay will provide protection for ________ length of transmission line for three phase fault on transmission line.



(A) 175 km (B) 198.5 km
(C) 148.5 km (D) 108.77 km

Ans: (C)

Sol: CT ratio : 2000A/5A

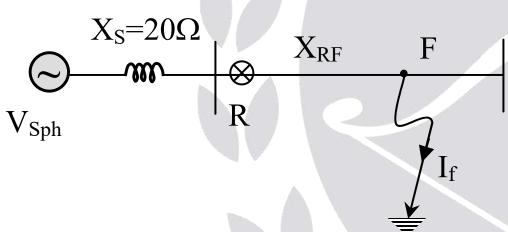
Relay setting = 0.8

Pickup current on primary side of CT

$= 0.8 \times 2000$

$= 1600$ A

The per phase model onto a 3-ϕ fault on transmission line



Let X_{RF} is the portion of line reactance upto which the relay can identify the fault.

For verge of operation, $I_f = 1600$ A

$$\frac{V_{S(ph)}}{X_S + X_{RF}} = 1600$$

$$\frac{\frac{220}{\sqrt{3}} \times 10^3}{20 + X_{RF}} = 1600$$

$X_{RF} = 59.388\ \Omega$

Line reactance, $X_l = 0.4\ \Omega$/km

The length of line protected by relay

$$= \frac{59.388}{0.4} \text{ km}$$

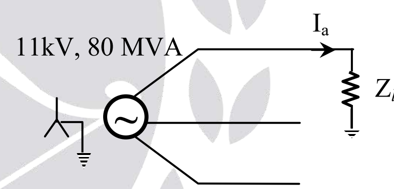
$= 148.47$ km

32. A solidly grounded neutral Y-connected alternator rated for 11 kV, 80 MVA has the resistance and reactances as $R_a = 0.1$ pu, $X''_d = 0.2$ pu, $X'_d = 0.4$ pu, $X_d = 0.8$ pu, $X_2 = 0.2$ pu, $X_0 = 0.05$ pu. The open circuit voltage of alternator is 14 kV(LL). A single phase load of impedance 1.5 + j0 Ω is connected at the terminals of alternator. The load current is

(A) 4.23 kA (B) 4.66 kA
(C) 4.85 kA (D) 5.39 kA

Ans: (B)

Sol:



$R_a = 0.1$ pu ; $Z_1 = 0.1 + j0.8$

$X_1 = X_d = 0.8$ pu ; $Z_2 = 0.1 + j0.2$

$X_2 = 0.2$ pu ; $Z_0 = 0.1 + j0.05$

$X_0 = 0.05$ pu

$$Z_{base} = \frac{(11)^2}{80} = 1.5125\ \Omega$$

Load impedance in per unit, $Z_{l\,pu} = \dfrac{Z_\ell(\Omega)}{Z_{base}}$

$$= \frac{1.5}{1.5125} = 0.9917 \text{ pu}$$

Open circuit voltage (or) internal unit of alternator, E_{a1} (LL) = 14 kV

$$E_{a1(pu)} = \frac{14}{11} = 1.2727 \text{ pu}$$

$$\text{Load current , } I_a = \frac{3E_{a1}}{Z_1 + Z_2 + Z_0 + 3Z_\ell}$$

$$= \frac{3 \times 1.2727}{0.3 + j1.05 + 2.975}$$

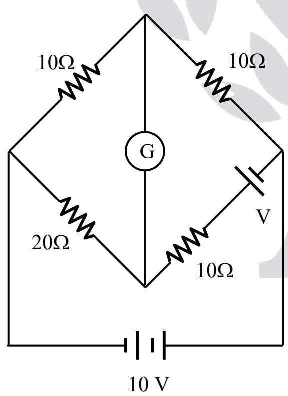
$$= \frac{3.8181}{3.275 + j1.05}$$

$$|I_a| = 1.11 \text{ pu}$$

$$I_a \text{ (kA)} = I_a\text{(p.u)} \times I_{base}$$

$$= 1.11 \times \frac{80}{\sqrt{3} \times 11} \text{kA} = 4.66 \text{ kA}$$

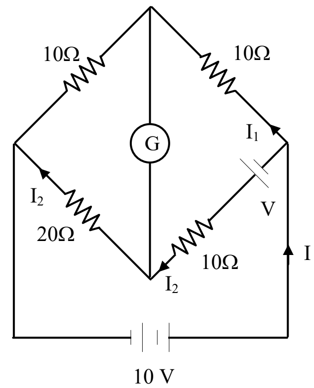
33. The resistance values of the bridge circuit shown in the figure are $R_1 = R_2 = R_3 = 10\ \Omega$ and R_4 is 20Ω. The bridge is balanced by introducing a voltage source of 'V' as shown in figure.



The value of voltage source is _______ volts.

Ans: – 2.5 (No range)

Sol:



$$I_2 \times 20 = 5$$

$$I_2 = \frac{5}{20} = 0.25\text{A}$$

$$I_2(10) - V = 5$$

$$0.25 \times 10 - V = 5$$

$$2.5 - V = 5$$

$$V = -2.5 \text{ V}$$

34. A time varying voltage signal V(t) = X + Ysinωt is measured by a single channel Analog CRO (operated with coupling mode set to DC) and also by Dual slope integrating DMM (operated with voltage Range set to AC). After measurement, DMM and CRO will display respectively are

(A) $\sqrt{\left(\frac{X}{\sqrt{2}}\right)^2 + \left(\frac{Y}{\sqrt{2}}\right)^2}$ & X+Y sinωt

(B) X & X+Y sinωt

(C) $\sqrt{X^2 + \left(\frac{Y}{\sqrt{2}}\right)^2}$ & Ysinωt

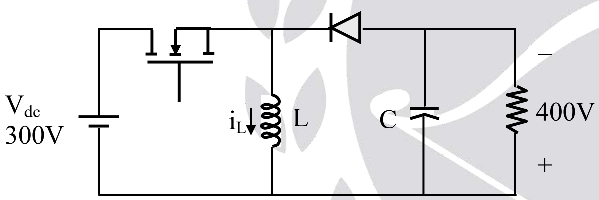
(D) X & Y sinωt

Ans: (B)

Sol: DMM measures average value. Therefore displays X

In DC coupling, the sensed signal as it is reaches to Y-input of CRO and hence displayed as X + Y sinωt.

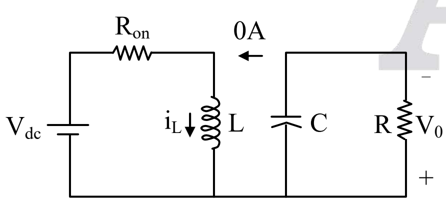
35. A Buck-Boost converter is shown in figure. Assume that inductor and capacitor are large enough to treat i_L and V_0 are ripple free. MOSFET has ON resistance of 0.5Ω during its conduction. To maintain output voltage of 400V at 10A to the load, the duty cycle ratio of converter will be _______ . (Give upto two decimal place)

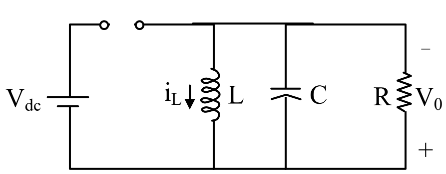


Ans: 0.58 (Range: 0.56 to 0.60)

Sol: During MOSFET ON:

During MOSFET OFF:





$$KVL: R_{on} i_L + L\frac{di_L}{dt} = V_{dc} \ldots\ldots \quad (1)$$

$$KVL: L\frac{di_L}{dt} = -V_0 \ldots\ldots (1)$$

$$KCL: C\frac{d\nu_0}{dt} + \frac{\nu_0}{R} = 0 \ldots\ldots (2)$$

$$KCL: C\frac{d\nu_0}{dt} + \frac{\nu_0}{R} = i_L \ldots\ldots (2)$$

Flux balance equation from KVL

$$\Rightarrow R_{on}.I_L.D + 0 = D.V_{dc} - V_0(1-D) \ldots\ldots (1)$$

Charge balance equation from

$$KCL \Rightarrow \frac{V_0}{R} = I_L(1-D) \ldots\ldots (2)$$

By substituting I_L value from equation (2) into equation (1), we will get

$$\Rightarrow R_{on}.\frac{V_0}{R(1-D)}D + V_0(1-D) = D.V_{dc}$$

$$\Rightarrow V_0\left[\frac{R_{on}}{R} \times \frac{D}{1-D} + (1-D)\right] = DV_{dc}$$

$$\Rightarrow \frac{V_0}{V_{dc}} = \frac{D}{\frac{R_{on}}{R}.\frac{D}{1-D} + (1-D)}$$

Now, substitute the given data

$$\frac{400}{300} = \frac{D}{\frac{0.5}{40} \times \frac{D}{1-D} + (1-D)}$$

$$\Rightarrow 560D^2 - 876D + 320 = 0$$

$\Rightarrow$ D = 0.983 (or) 0.5813

If D is near to unity, buck-boost converter will be unstable. Hence choose, 0.5813.

36. A single phase full wave half controlled rectifier is supplying an inductive load and assume current is ripple free at 10 A. It has been operated with firing angle delay of 45° then power factor on the AC supply lines is

(A) 0.9238 (B) 0.8869
(C) 0.707 (D) 0.52

Ans: (B)

Sol: Single phase full wave half controlled rectifier is a semi converter.

Power factor = C.D.F × D.F

$$\text{C.D.F} = \frac{I_{S1}}{I_{Sr}}$$

$$I_{S1} = \frac{2\sqrt{2}}{\pi} I_o \cos\frac{\alpha}{2}$$

$$= 0.9\ I_o \cos\frac{45^\circ}{2} = 8.315\ \text{A}$$

$$I_{Sr} = I_o\sqrt{\frac{\pi-\alpha}{\pi}}$$

$$= 10\sqrt{\frac{180-45}{180}} = 8.66\ \text{A}$$

$$\text{C.D.F} = \frac{8.315}{8.66} = 0.96$$

$$\text{D.F} = \cos\frac{\alpha}{2} = \cos\frac{45^\circ}{2} = 0.9238$$

Power factor = 0.96 × 0.9238 = 0.8869

37. A single phase 230V, 50Hz full wave rectifier consists of three diodes and one thyristor and supplying a resistive load of 10 Ω. The firing angle delay is so selected that the average output current 20.7 A, then the peak value of fundamental supply current is _________ A (Give upto two decimal places)

Ans: 32.52 (Range: 32 to 33)

Sol: A single phase full wave rectifier consists of three diodes and one thyristor and supplying a resistive load, then

$$V_0 = \frac{V_m}{2\pi}[3+\cos\alpha]$$

$$I_0 = \frac{V_o}{R} = \frac{V_m}{2\pi R}[3+\cos\alpha]$$

$$\Rightarrow 20.7 = \frac{230\times\sqrt{2}}{2\pi\times 10}[3+\cos\alpha]$$

$$\Rightarrow \cos\alpha = 1$$

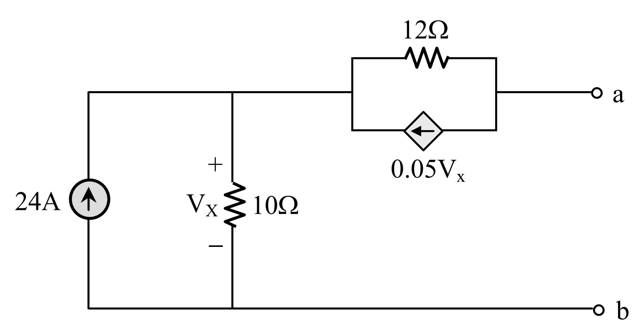
$$\Rightarrow \alpha = 0$$

If α =0, then the shape of the supply current is pure sinusoidal.

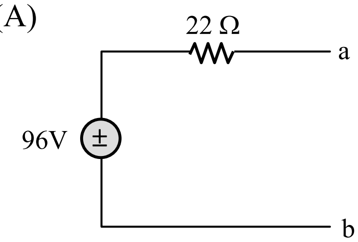
Peak value of the fundamental current component, $I_{S1} = \frac{V_m}{R} = \frac{230\times\sqrt{2}}{10}$

$= 32.52$ A

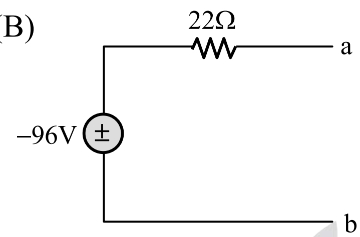
38. Obtain Thevinin's equivalent at terminals a – b



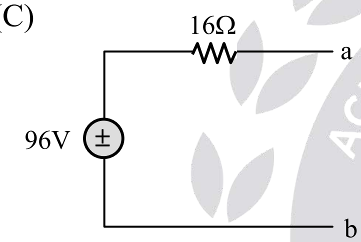
(A)



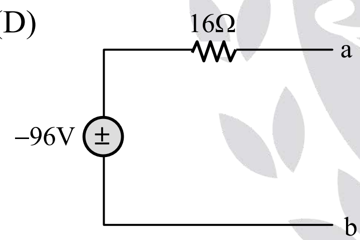
(B)



(C)

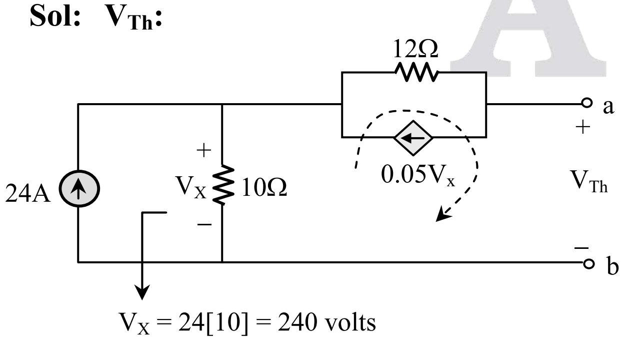


(D)



Ans: (C)

Sol: $\mathbf{V_{Th}}$**:**

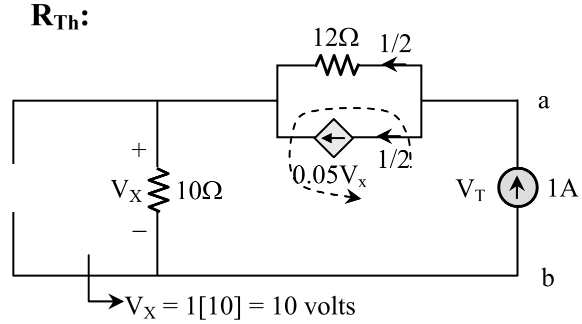


KVL:

$-240 + 12[0.05][240] + V_{Th} = 0$

$V_{Th} = 240 - 144 = 96$ volts

$\mathbf{R_{Th}}$**:**



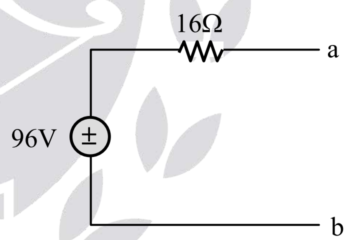
KVL:

$-V_T + \frac{1}{2}(12) + 10 = 0$

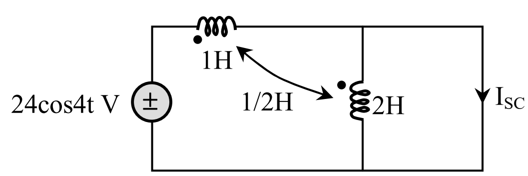
$V_T = 16$ volts

So, $R_{Th} = \frac{V_T}{1} = 16\ \Omega$

So, Thevenin's equivalent



39. Determine the RMS value of short circuit current I_{SC} in circuit shown

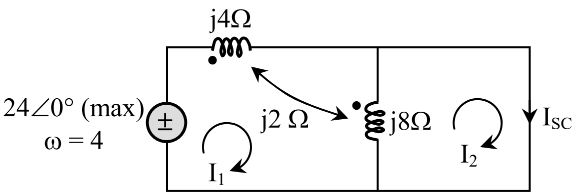


(A) 8.57 A (B) 6.06 A

(C) 2.4 A (D) 1.69 A

Ans: (B)

Sol: Mesh analysis



$-[24\angle 0] + j4I_1 + j8[I_1 - I_2] + j2[I_1 - I_2] + j2I_1 = 0$

$$j16I_1 - j10I_2 = 24$$

$$j8I_1 - j5I_2 = 12 \ldots\ldots\ldots\ldots\ldots (1)$$

$$j8[I_2 - I_1] - j2[I_1] = 0$$

$$4I_2 = 5I_1$$

$\ldots\ldots\ldots\ldots\ldots (2)$

Substitute (2) in (1) and solve for I_2

$$I_2\left[j8\left(\frac{4}{5}\right) - j5\right] = 12$$

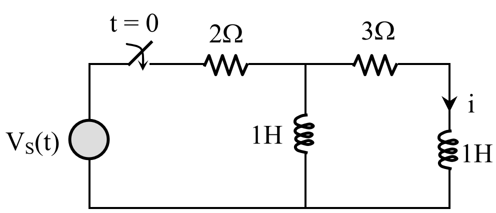
$$I_2\left[\frac{j7}{5}\right] = 12$$

$$I_2 = \frac{60}{7j} = 8.57\angle -90°$$

$$I_2 = 8.57\cos(4t - 90)$$

$$I_2 = \frac{8.57}{\sqrt{2}} = 6.06 = I_{SC}$$

40. The time constant of current 'I' in the circuit shown is

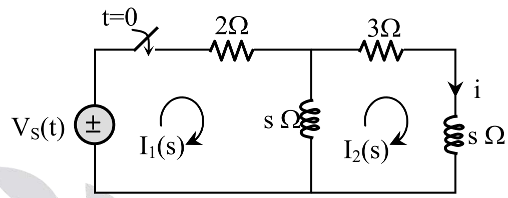


(A) 1 sec (B) 0.166 sec

(C) 0.2855 sec (D) 0.1 sec

40. Ans: (A)

Sol: Use Laplace



Mesh equations

$$-V_S(s) + I_1(s)\,2 + s[I_1(s) - I_2(s)] = 0$$

$$(s+2)\,I_1(s) - sI_2(s) = V_S(s) \ldots\ldots\ldots\ldots\ldots (1)$$

$$s[I_2(s) - I_1(s)] + (s+3)\,I_2(s) = 0$$

$$sI_1(s) = (2s+3)I_2(s) \ldots\ldots\ldots\ldots\ldots (2)$$

Substitute (2) in (1)

$$I_2(s)\left[(s+2)\left(\frac{2s+3}{s}\right) - s\right] = V_2(s)$$

Transfer function, $\dfrac{I_2(s)}{V_2(s)} = \dfrac{s}{s^2 + 7s + 6}$

Roots of characteristic equation

$$s_1\ s_2 = \frac{-7 \pm \sqrt{49 - 4(6)}}{2(1)} = \frac{-7 \pm \sqrt{25}}{2} = \frac{-7 \pm 5}{2}$$

$$s_1\ s_2 = -1, -6$$

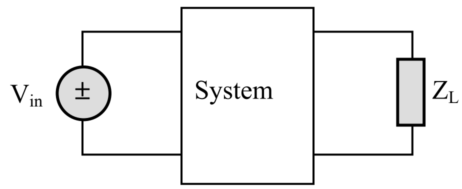
Roots are –ve, Real, unequal.

So, over damped response

$$\text{So, } T = \frac{-1}{\text{Dominant pole}}$$

$$T = -\frac{1}{(-1)} = 1 \text{ second.}$$

41.



A system has transmission matrix $\begin{bmatrix} 2 & 1+j \\ 1 & 1+\frac{j}{2} \end{bmatrix}$

If input voltage is 50 V (RMS) the maximum power transferred to the load is _______ W.

41. Ans: 312.5 (Range: 310 to 315)

Sol: $V_{Th} = \frac{V_{in}}{A} = \frac{50}{2} = 25$ V (RMS)

$$Z_{Th} = \frac{B}{A} = \left[\frac{1+j}{2}\right]\Omega$$

For P_{max} $Z_L = Z_{Th}^*$

$$Z_L = \left[\frac{1-j}{2}\right]\Omega$$

$$P_{max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{(25)^2}{4\left(\frac{1}{2}\right)}$$

$$= \frac{(25)(25)}{2}$$

$$= 312.5 \text{ W}$$

42. Choosing infinity as the reference point, the electric potential (in Joules/coulomb) at the origin considering only the electric field in the region outside ($r = r_2$) is

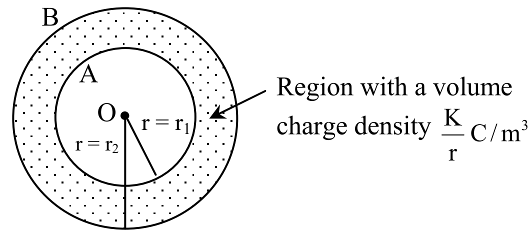


Fig. 1: Charge distribution in free space.

A & B: Spherical surfaces with radii as shown.

(A) 0 (B) $\frac{K}{2\varepsilon_0}\frac{\left(r_2^2 - r_1^2\right)}{r_2}$

(C) ∞ (D) $\frac{K}{6\varepsilon_0}\frac{r_2^3 - r_1^3}{r_2^2}$

Ans: (B)

Sol: i). Regions (1), (2) and (3) are shown in fig. 2. In each region, we can find the electric field. But in this problem, we need the field in region (1) only.

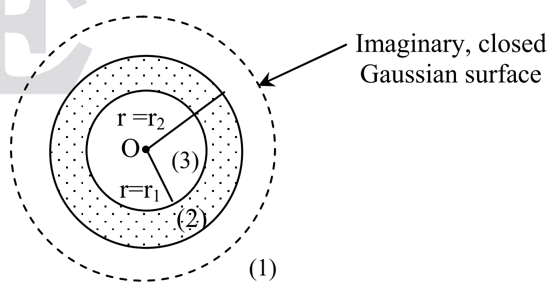


Fig. 2

Since charge density varies only with r, the problem has spherical symmetry and hence

Gauss's law methods can be used advantageously.

Region (1): Consider a spherical Gaussian surface (imaginary, closed) with center at O (origin) and radius $r > r_2$, as shown in fig. 2.

Total charge enclosed by this surface =

$$\int_{r=r_1,\theta=0,\phi=0}^{r_2,\pi,2\pi} \frac{K}{r} r^2 \sin\theta \, dr \, d\theta \, d\phi$$

$$= 4\pi K \int_{r=r_1}^{r_2} r dr = 2\pi K\left(r_2^2 - r_1^2\right) C$$

To any point on this Gaussian surface, this charge appears as a point charge at the origin. Hence electric field at a point (r, θ, ϕ) in region-1 = $\frac{2\pi K(r_2^2 - r_1^2)}{4\pi\varepsilon_0 r^2} a_r$ N/C

Potential at the origin, with infinity as reference is

$$V_0 = -\int_{r=\infty,\theta=0,\phi=0}^{r_2,\pi,2\pi} \frac{2\pi K\left(r_2^2 - r_1^2\right)}{4\pi\varepsilon_0 r^2} a_r . (dr\, a_r + r\, d\theta$$

$$a_\theta + r\sin\theta \, d\phi \, a_\phi) \text{ ……... (1)}$$

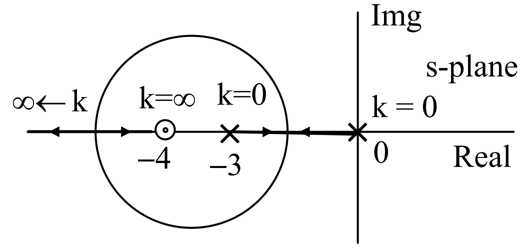
(Upper limit for r is r_2 because we are considering field in region-1 only).

$$= -\int_{r=\infty}^{r_2} \frac{2\pi K\left(r_2^2 - r_1^2\right)}{4\pi\varepsilon_0 r^2} dr$$

$$= \frac{2\pi K}{4\pi\varepsilon_0}\left(r_2^2 - r_1^2\right)\frac{1}{r}\Big]_\infty^{r_2}$$

$$= \frac{K\left(r_2^2 - r_1^2\right)}{2\varepsilon_0 r_2}$$

43. The root loci diagram of a system is given below



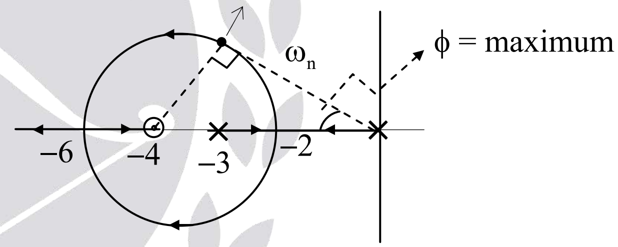
What is the value of 'k' to obtain a maximum peak overshoot to a unit step input

(A) k = 1 (B) k = 3

(C) k = 5 (D) k = 9

Ans: (B)

Sol:



Centre of circle = (–4, 0)

Break points, $\frac{dk}{ds} = 0$

$$\frac{d}{ds}\left(\frac{s(s+3)}{(s+4)}\right) = 0$$

$s^2 + 8s + 12 = 0$

s = –2, –6

Radius = $\frac{6-2}{2} = 2$

$$\omega_n = \sqrt{4^2 - 2^2} = \sqrt{12}$$

CE = s(s+3) + k(s+4) = 0

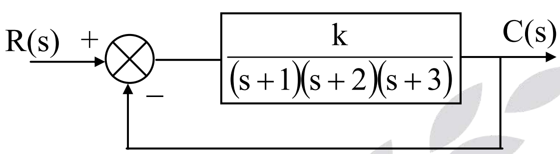
$$s^2 + 3s + ks + 4k = 0$$

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

$$\omega_n^2 = 4k = 12$$

$$k = 3$$

44. Consider the control system shown in figure below.



The minimum steady state error to a unit step input is

(A) 0.35 (B) 0.54

(C) 0.09 (D) 0.1

44. Ans: (C)

Sol: $CE = 1 + \dfrac{k}{(s+1)(s+2)(s+3)} = 0$

$s^3 + 6s^2 + 11s + 6 + k = 0$

(11) (6) = 6+k

k = 60

maximum value of 'k' for stability

= 59.9999 = 60

Steady state error $e_{ss} = \dfrac{1}{1+k_p}$

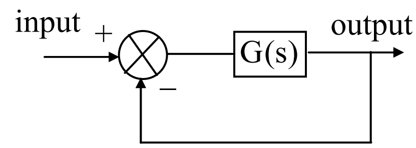
$$k_p = \underset{s\to 0}{Lt} \frac{k}{(s+1)(s+2)(s+3)} = \frac{k}{6}$$

$$e_{ss} = \frac{1}{1+\frac{k}{6}}$$

To obtain minimum e_{ss}, k = 60

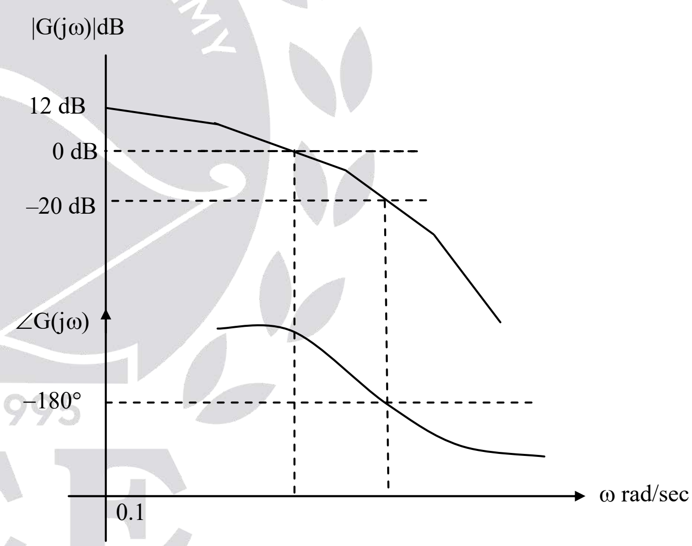
$$\therefore e_{ss} = \frac{1}{1+\frac{60}{6}} = 0.09$$

45. Consider the feedback control system shown in figure below.



where $G(s) = \dfrac{k}{s(1+sT_1)(1+sT_2)(1+sT_3)}$,

whose Bode plot is given below.



Then the maximum value of 'k' for stability of the system is ______ .

45. Ans: 4 (Range 3.9 to 4.1)

Sol: For maximum value of k, system should be marginally stable. So, GM = 0 dB.

⇒ Magnitude plot has to shift up by +20 dB

$20 \log k - 20 \log \omega|_{\omega=0.1} = 12 + 20 = 32$ dB

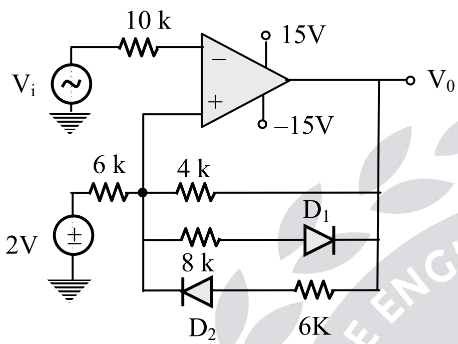
Hearty Congratulations to our GATE-2019 Top Rankers

	CE	ME	EE	EC	CS	IN	PI
TOP 10	5	6	7	9	5	10	10
TOP 100	44	60	71	74	28	74	49

$20 \log k = 12$ dB

$k = 4$

46. Assume diodes are ideal in the circuit shown. Find the UTP and LTP values of the circuit shown in figure.



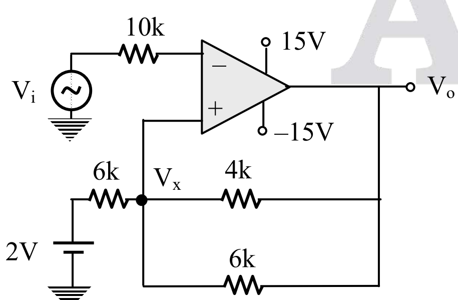
(A) – 9.8 V, 11.3V (B) 11.3 V, 9.8 V

(C) 11.3 V, – 9.8 V (D) 13.8 V, – 7.3 V

46. Ans: (C)

Sol: When op-amp operated in positive saturation region, the potential at non-inverting terminal is called UTP voltage and D_1 –OFF – O.C

D_2 –ON – S.C



⇒

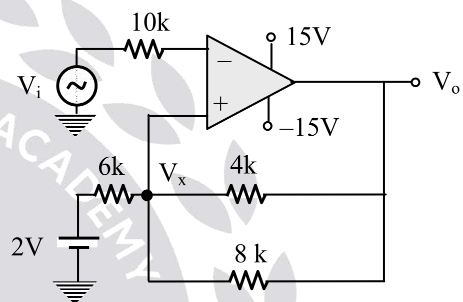
$$V_x = V_{UTP} = V_R + (V_{sat} - V_R)\frac{R_2}{R_1 + R_2}$$

$$= 2 + (15 - 2)\left(\frac{6k}{8.4k}\right)$$

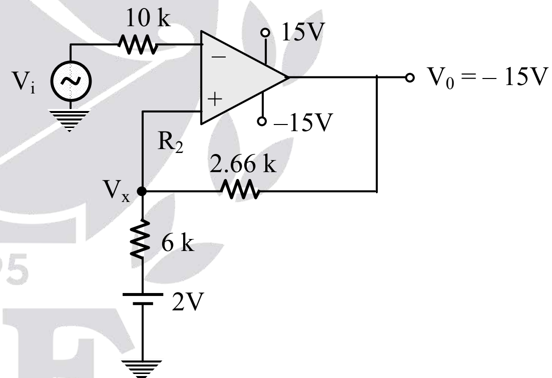
$$= 2 + 13\left(\frac{6}{8.4}\right) = 11.28V \approx 11.3V$$

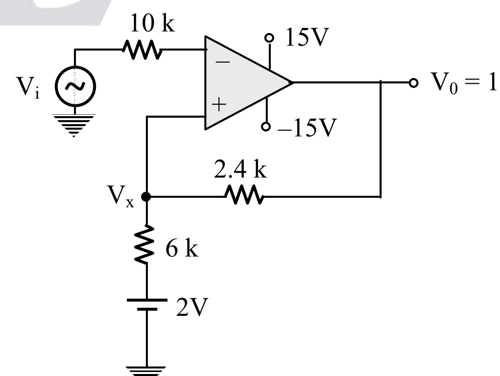
When the op-amp operated in negative saturation region, the voltage at non-inverting terminal is called LTP voltage. $V_0 = -15V$. D_1 – ON – (SC)

D_2 – OFF – (OC)



⇒





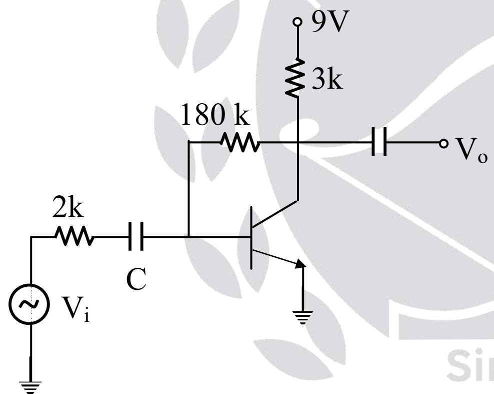
$$V_x = V_{LTP} = V_R + (-V_{sat} - V_R)\frac{R_2}{R_1 + R_2}$$

$$= 2 + (-15 - 2)\left(\frac{6k}{8.66k}\right)$$

$$\approx -9.8V$$

Therefore, $V_{UTP} = 11.3$ V and $V_{LTP} = -9.8$ V

47. For the 'Si' transistor circuit shown, $V_T = 26$ mV, $V_{BE} = 0.7$ V and β is very high, then the magnitude of voltage gain $|A| = \left(\frac{V_0}{V_i}\right)$ is _______.



Ans: 69.77 (Range 68 to 71)

Sol: Apply DC analysis to calculate r_e value

As $\beta \to$ Very high, $I_B \approx 0$

$$I_E \approx I_C = \frac{9 - 0.7}{3k} = 2.766mA$$

Then $r_e = \frac{V_T}{I_E} = \frac{26}{2.766} = 9.3975\ \Omega$

Now apply AC analysis

$A_I = -\beta \to$ very large,

$Z_i = \beta\, r_e \to$ very large

$$Z_L = \frac{R_c(R_B - r_e)}{R_C + R_B} = \frac{3 \times 180}{183} \times 10^3$$

$$= 2.9508\ k\Omega$$

$$A_V = \frac{A_I . Z_L}{Z_i}$$

$$= \frac{-2950.8}{9.3975} \Rightarrow A_V = -314$$

$$Z_i' = Z_i \,//\, R_{Mi}$$

$$R_{Mi} = \frac{R_B}{1 - A_V}$$

$$= \frac{180 \times 10^3}{315} = 571.428$$

$$Z_i' \approx R_{Mi}$$

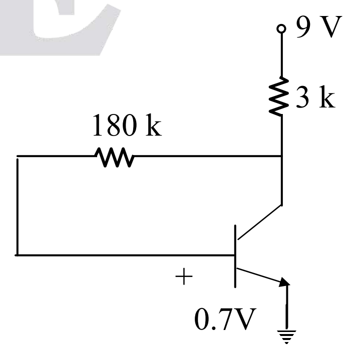
$$Z_i' \approx 571.428\Omega$$

$$A_{VS} = A = \frac{V_0}{V_i} = A_V\left(\frac{Z_i'}{Z_i' + R_s}\right)$$

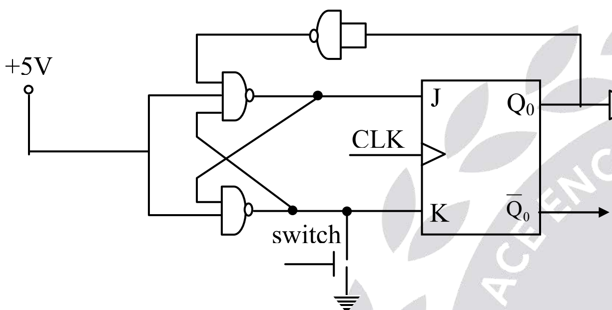
$$= -314\left(\frac{571.428}{2571.428}\right)$$

$$= -69.77$$

$$|A| \approx 69.77$$

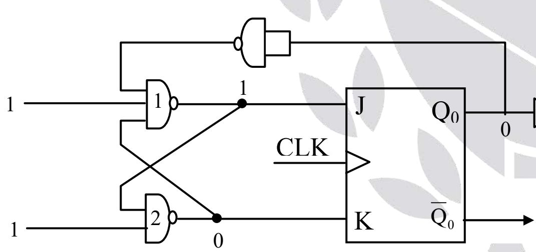


48. In the circuit shown, the input clock frequency is 9.7 MHz, the propagation delay of the logic gates and flip-flop's are 0 sec. Initially Q_0 is cleared to '0' and simultaneously the input 'K' is also cleared to '0'(with the help of push button toggle switch). The frequency of the wave form at 'Y_0' is _____ (Hz)



Ans: 0

Sol:



Observe the binary on the circuit as per given data

From the given data K = 0 (reset)

So NAND gate 1, output J = 1

Initially: J = 1, K = 0

$Q_0 = 0$, $Y_0 = 1$

After one clock edge

$Q_0 = 1$, $Y_0 = 0$

But still(from circuit) $\begin{cases} J = 1 \\ K = 0 \end{cases}$

Irrespective of number of clock pulses

$Q_0 = 1$, $Y_0 = 0$ (always)

J = 1, K = 0

$Y_0 = 0$ Hz (DC line with logic '0')

49. Let a signal x(t) be defined as $X(t) = e^{-\frac{t}{2}}u(t)$. Then the energy in the frequency band $-\pi/8 \le \omega \le \pi/8$ rad/sec is

(A) $\frac{1}{\pi}$ (B) $\frac{1}{2\pi}$

(C) $\frac{4}{\pi}$ (D) $\frac{2}{\pi}$

Ans: (D)

Sol: $x(t) = e^{-t/2}u(t)$

According Parseval's Theorem $E_t = E_\omega$

$$E_\omega = \frac{1}{2\pi}\int_{-\infty}^{\infty} |X(\omega)|^2 \, d\omega$$

$$E_\omega = \frac{1}{2\pi}\int_{-\frac{\pi}{8}}^{\frac{\pi}{8}} |X(\omega)|^2 \, d\omega$$

$$E_\omega = \frac{1}{\frac{1}{2} + j\omega} \Rightarrow |X(\omega)|^2 = \frac{1}{\frac{1}{4} + \omega^2}$$

$$\therefore E_\omega = \frac{1}{2\pi}\int_{-\frac{\pi}{8}}^{\frac{\pi}{8}} \frac{1}{\frac{1}{4} + \omega^2} d\omega$$

$$= \frac{1}{2\pi}.\frac{1}{\left(\frac{1}{2}\right)}\tan^{-1}\left(\frac{\omega}{\frac{1}{2}}\right)_{-\frac{\pi}{8}}^{\frac{\pi}{8}}$$

$$= \frac{2}{2\pi}\tan^{-1}(2\omega)_{-\frac{\pi}{8}}^{\frac{\pi}{8}}$$

$$= \frac{1}{\pi}[1-(-1)] = \frac{2}{\pi}$$

50. A discrete sequence y(n) is defined as y(n) = $x^2(n)$, where x(n) is another discrete sequence $x(n) = \left(\frac{1}{8}\right)^n u(n)$, then the value of $y(e^{j\pi})$ is _______ (Give up to 2 decimal value).

Ans: 0.98 (Range 0.97 to 0.99)

Sol: $y(n) = x^2(n) = \left[\left(\frac{1}{8}\right)^n u(n)\right]^2 = \left(\frac{1}{8}\right)^{2n} u(n)$

$$y(n) = \left(\frac{1}{64}\right)^n u(n)$$

Applying Z-transform both sides

$$y(z) = \frac{z}{z-\frac{1}{64}} \quad \text{but } z = e^{j\Omega}\,|_{r=1}$$

$$y(e^{j\Omega}) = \frac{e^{j\Omega}}{e^{j\Omega}-\frac{1}{64}}$$

$$y(e^{j\pi}) = \frac{e^{j\pi}}{e^{j\pi}-\frac{1}{64}} = \frac{-1}{-1-\frac{1}{64}}$$

$$y(e^{j\pi}) = \frac{1}{1+\frac{1}{64}} = \frac{64}{65}$$

$$y(e^{j\pi}) = \frac{64}{65} = 0.984$$

51. Given matrix $[A] = \begin{bmatrix} 4 & 2 & 1 & 3 \\ 6 & 3 & 4 & 7 \\ 2 & 1 & 0 & 1 \end{bmatrix}$, then the system AX = O, where $X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$ has

(a) no solution

(b) a unique solution

(c) only one independent solution

(d) two linearly independent solutions

Ans: (d)

Sol: Given $A = \begin{bmatrix} 4 & 2 & 1 & 3 \\ 6 & 3 & 4 & 7 \\ 2 & 1 & 0 & 1 \end{bmatrix}$

$R_2 \to 4R_2 - 6R_1$;

$R_3 \to 2R_3 - R_1$

$$\sim \begin{bmatrix} 4 & 2 & 1 & 3 \\ 0 & 0 & 10 & 10 \\ 0 & 0 & -1 & -1 \end{bmatrix}$$

$R_3 \to (10)R_3 + R_2$

$$\sim \begin{bmatrix} 4 & 2 & 1 & 3 \\ 0 & 0 & 10 & 10 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$\therefore\ \rho(A) = 2$

$\therefore$ Number of linearly independent solutions = Number of variables – Rank of A

= 4 – 2 = 2

52. The value of the double integral $\int_0^8 \left(\int_{y/2}^{(y/2)+1} \left(\frac{2x-y}{2} \right) dx \right) dy$, using the substitution $u = \left(\frac{2x-y}{2} \right)$ and $v = \frac{y}{2}$ or otherwise is ______.

52. Ans: 4 (No range)

Sol: Given $u = \frac{2x-y}{2}$ and $v = \frac{y}{2}$

$\Rightarrow du = dx,\ dv = \frac{dy}{2}$ and $dy = 2\,dv$

If $x = \frac{y}{2}$ then $u = 0$

If $x = \frac{y}{2}+1$ then $u = 1$

If $y = 0$ then $v = 0$

If $y = 8$ then $v = 4$

$$\int_0^8 \left[\int_{\frac{y}{2}}^{\frac{y}{2}+1} \left(\frac{2x-y}{2} \right) dx \right] dy = \int_{v=0}^{4} \int_{u=0}^{1} 2u\ du\,dv = 4$$

53. The surface integral $\iint_s (\bar{F}.\bar{n})\, dS$ over the surface S of the sphere $x^2 + y^2 + z^2 = 9$, where $F = (x+y)\bar{i} + (x+z)\bar{j} + (y+z)\bar{k}$ and $\bar{n}$ is the unit outward surface normal, yields ________.

Ans: 226.08 (Range 225 to 227)

Sol: $\vec{F} = (x+y)\vec{i} + (x+z)\vec{j} + (y+z)\vec{k}$

div $\vec{F} = 1 + 1 = 2$

$\iint_S \vec{F}.\vec{n}\, dS = \iiint_V \text{div}\,\vec{F}\, dx\, dy\, dz$ (By Gauss divergence theorem)

$= \iiint 2\, dx\, dy\, dz$

$= 2$

(Volume of the sphere $x^2 + y^2 + z^2 = 9$)

$= 2 \times \frac{4}{3}\pi(3)^3 = 72\,\pi$

$= 226.08$

54. The annual precipitation data of a city is normally distributed with mean and standard deviation as 1000 mm and 200 mm, respectively. The probability that the annual precipitation will be more than 1200 mm is

(A) 0.1587 (B) 0.3174

(C) 0.3456 (D) 0.2345

Ans: (A)

Sol: Let X = annual precipitation

We know area under normal curve in the interval $(\mu - \sigma, \mu + \sigma) = 0.6826$

Where μ is mean and σ is standard deviation

$\Rightarrow P(800 < X < 1200) = 0.6826$

Required probability = $P(X > 1200)$

$= \frac{1 - 0.6826}{2}$

$= 0.1587$

55. Consider the differential equation $\frac{dy}{dx} + 2xy = e^{-x^2}$ with initial condition $y(0) = 1$. The value of y(1) = _________.

55. Ans: 0.7357 (Range 0.73 to 0.74)

Sol: Given $\frac{dy}{dx} + 2xy = e^{-x^2}$ …….. (1)

with y(0) = 1 …….. (2)

$\therefore$ I. F. = $e^{\int 2x\,dx} = e^{x^2}$

Now, the general solution of (1) is

$\Rightarrow y.\ e^{x^2} = \int e^{x^2} .\ e^{-x^2}\,dx + c$

$\Rightarrow y.\ e^{x^2} = x + c$ …….. (3)

Using (2), (3) becomes

$\Rightarrow 1 = 0 + c \Rightarrow c = 1$

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

$y = (x + 1)\ e^{-x^2}$

$\therefore y(1) = 2 \times e^{-1} = 0.7357$

END OF THE QUESTION PAPER

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