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ESE 2018 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-5 : Basic Electronics Engineering + Analog Electronics + Electrical Materials

Electrical Machines - 1 + Power Systems - 2

Name: Ankit Tayal

Roll No: EE18MBDLA004

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Student's Signature

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

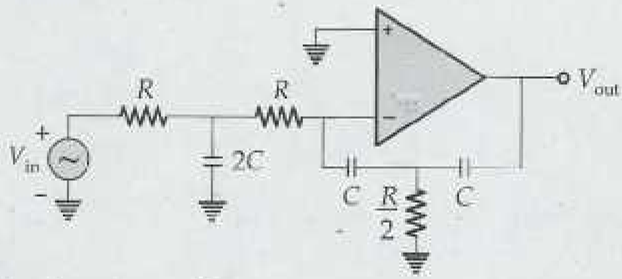
Question No.	Marks Obtained
Section-A	
Q.1	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	193

Signature of Evaluator: Vamsy

Cross Checked by: Vamsy

Section A : Basic Electronics Engg. + Analog Electronics + Electrical Materials

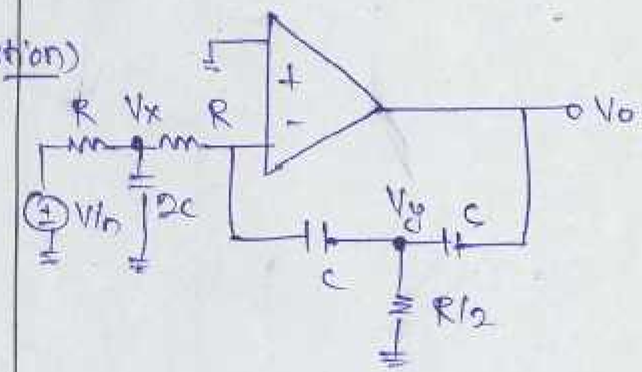
Q.1 (a) In the figure shown below



Calculate the transfer function of the system.

[12 marks]

Solution)



By virtual Ground concept $V^+ = V^- = 0V$

KCL at Vx Node

$$\frac{V_x - V_{in}}{R} + \frac{V_x}{1/2sC} + \frac{V_x - V^+}{R} = 0$$

$$\Rightarrow V_x\left[2sC + \frac{1}{R} + \frac{1}{R}\right] = \frac{V_{in}}{R}$$

$$\Rightarrow \boxed{V_x = V_{in}/(2 + 2sCR)} \quad -(1)$$

KCL at "Vy" Node

$$\frac{V_y - \cancel{V^+}^{0}}{1/sC} + \frac{V_y - V_o}{1/sC} + \frac{V_y - 0}{R/2} = 0$$

$$\Rightarrow V_y\left[sC + sC + \frac{2}{R}\right] = V_o(sC)$$

$$\Rightarrow V_y\left[\frac{2 + 2sCR}{R}\right] = V_o sC \quad -(1)$$

~~using (i) in (ii)~~

KCL at V^+ node

$$\frac{V^+ - V_x}{R} + \frac{V^+ - V_y}{1/SC} = 0$$

$$\Rightarrow \frac{-V_x}{R} - V_y(SC) = 0 \Rightarrow V_y(SC) = \frac{-V_x}{R}$$

$$\boxed{V_y = \frac{1}{RSC}\left[-V_{in}/(2+2SRC)\right]} \quad -(iii)$$

using (iii) in (ii)

$$\frac{1}{RSC}\left(\frac{-V_{in}}{2+\cancel{2SRC}}\right)\left(\frac{2+\cancel{2SCR}}{R}\right) = V_o SC$$

$$\Rightarrow V_o SC = \frac{-V_{in}}{R^2 SC}$$

$$\Rightarrow \boxed{\frac{V_o}{V_{in}} = \frac{-1}{(RSC)^2}} \text{ Ans.}$$

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Q.1 (b) (i) Explain the "Mass action law".

(ii) Explain the "Law of electrical neutrality of a semiconductor".

(iii) A small number of readily ionized donors with a concentration of N_D are added to an intrinsic semiconductor, such that $N_D < n_i$, where n_i is the intrinsic carrier concentration. Using the concepts involved in part (i) and (ii), find the thermal equilibrium concentrations of free electrons and holes in the semiconductor.

[12 marks]

Solution) (i) Mass Action Law:

mass action law states that the product of majority carrier concentration and minority carrier concentration always remains constant and equal to square of intrinsic carrier concentration.

$\therefore \boxed{np = n_i^2}$

- Valid for intrinsic & extrinsic semiconductors

where n_i = intrinsic carrier concentration at a particular temp T(K)

(ii) Law of Electrical Neutrality of a Semiconductor

This states that whether the semiconductor is doped with pentavalent impurity or trivalent impurity, the semiconductor always remains ~~electrical~~ electrically Neutral

Let Donor concentration = N_D

Acceptor concentration = N_A

8. $\boxed{p + N_D = n + N_A}$ ⇒ Law of electrical Neutrality in semiconductor

(ii) $N_D < n_i$

∵ $np = n_i^2$ —(i)

Also $p + N_D = n + N_A$ —(ii)

Donor is added to semiconductor

∴ $\boxed{N_A \simeq 0}$

eqn(ii) $p + N_D = n \Rightarrow \boxed{p = n - N_D}$ —(iii)

Substitute (iii) in (i)

$n(n - N_D) = n_i^2$

$\Rightarrow \boxed{n^2 - nN_D - n_i^2 = 0}$

$$\therefore \boxed{n = \frac{+N_D + \sqrt{N_D^2 + 4n_i^2}}{2}}$$ Ans.

∵ $N_D < n_i$ ∴ $N_D^2 << 4n_i^2$

$$\therefore \boxed{n = \frac{N_D + 2n_i}{2}}$$ Ans

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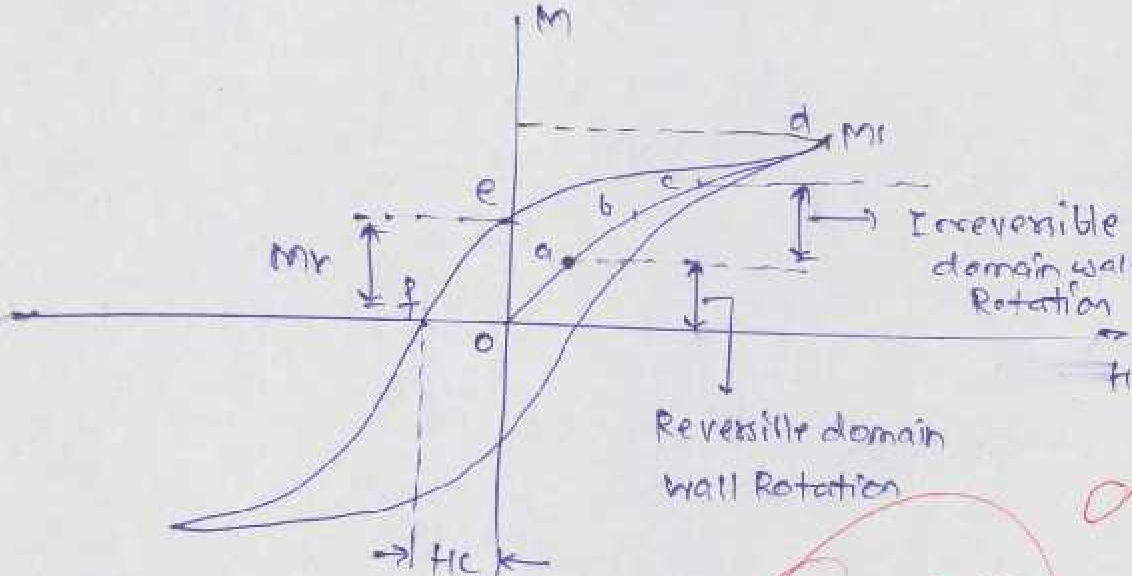
Now $p = \frac{n_i^2}{n}$ by equation (i)

$$\boxed{p = \frac{2n_i^2}{N_D + 2n_i^2}}$$ Ans

Q.1 (d) Write a short note on the ferromagnetic domains:

[12 marks]

Solution) Ferromagnetic materials show spontaneous magnetization and hysteresis curve dynamics as follows



8+1= 9

Hc : Coercive Field

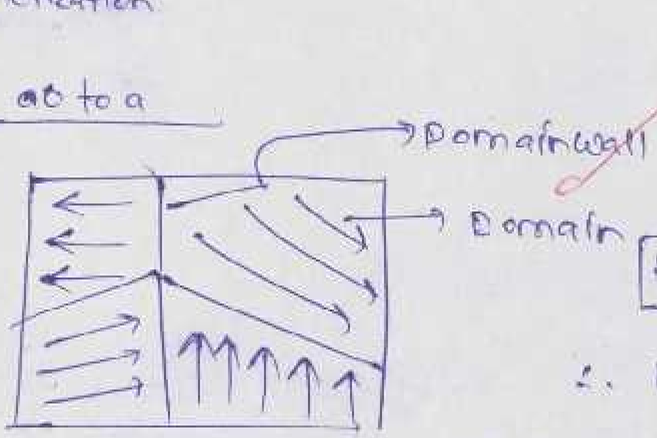
Mr : Remenant magnetisation

Ms : Saturation magnetisation.

Hc : Field required to Remove Remanent Magnetization

Mr : Even after the supply is switched off, some magnetisation remains in a Ferromagnetic material known as Remenant magnetization

(i) o to a



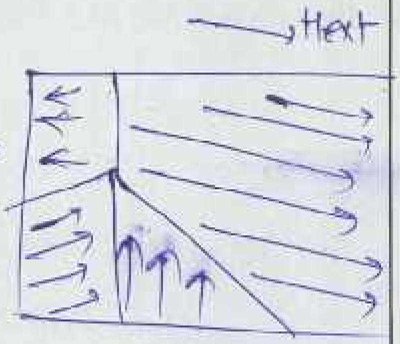
Initially

$\boxed{H_{ext} = 0}$

∴ Net magnetisation = 0

∵ All Domains are random in nature.

(ii) 0 to a

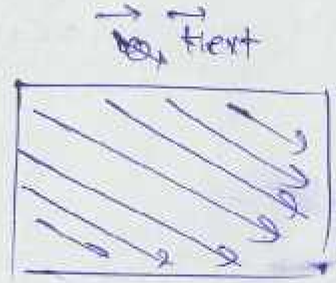


when $\vec{H}_{ext}$ is applied

initially domain wall rotation of unfavourable domains towards favourable domain takes place

- Reversible domain wall rotation

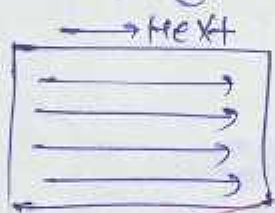
(iii) a to b to c



Here Non Reversible domain wall rotation takeplace until only Favourable domain remains

(iv) a to d

Here Rotation of Favourable domain wall takesplace along the external applied magnetic Field and at 'd' material reaches to magnetic Saturation



(v) From d to e

Now gradually magnetic field is removed but some remanant magnetization Still Remains . and coercive Field is applied in opposite direction to remove the Remanant magnetisation

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Q.1 (e) Explain in detail the Josephson effect in superconductors.

[12 marks]

Soln Josephson effect in Superconductors are ~~used to~~ in applications like

(i) Cryotron Switches etc

These Switches are based on magnetic principles Hence also called as magnetic Switches

0

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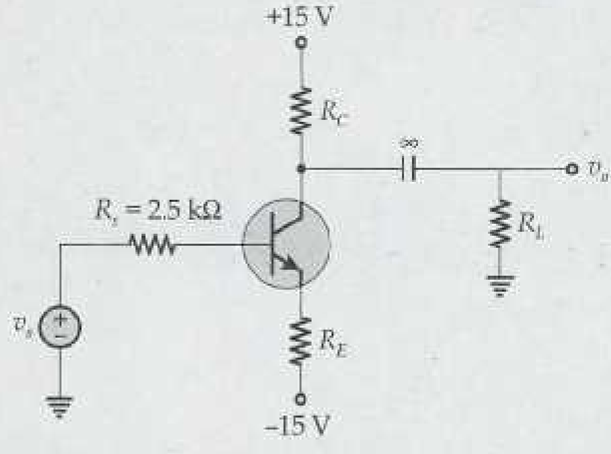
Q.4 (a) The transistor of the circuit shown in the figure below has $\beta = 99$. $I_{EQ} = 0.5$ mA and $V_{CQ} = 5$ V. Assume that I_{CO} is negligible, $V_{BE} = 0.7$ V and $V_T = 25$ mV.



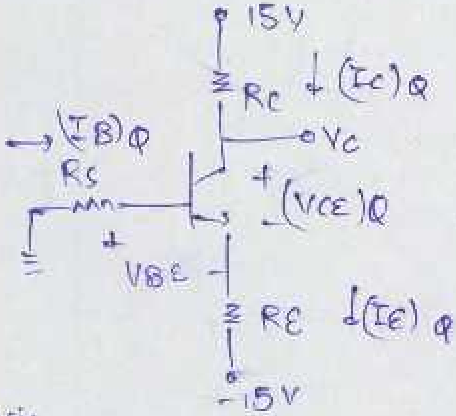
If v_s is a small sine-wave with zero average value, then

(i) Find the values of R_C and R_E.

(ii) For $R_L = 10$ kΩ and $r_o = 200$ kΩ, draw the small-signal equivalent circuit of the amplifier and determine its overall voltage gain.

[8 + 12 marks]

Solution) DC Analysis of given circuit : capacitors : open.
AC voltage source : grounded.



fig(i)

Given
$V_{CQ} = 5V$
$\beta = 99$
$I_{EQ} = 0.5mA$
$V_{BE} = 0.7V$

KVL in input loop

$$(I_B)_Q \cdot R_S + V_{BE} + (I_E)_Q R_E - 15 = 0$$

$$\Rightarrow \boxed{R_E = \frac{15 - (I_B)_Q \cdot R_S - V_{BE}}{I_{EQ}}} \quad -(i)$$

$\because$ $(I_E)_Q = 0.5mA$

$\therefore$ $(I_B)_Q = \dfrac{(I_E)_Q}{1+\beta} = 5\mu A$

$$\therefore R_E = \frac{15 - 5\times10^{-6}\times 2.5\times10^{3} - 0.7}{0.5\times10^{-3}}$$

$$\boxed{R_E = 28.575 K\Omega}$$ Ans.

Now $I_C = \left(\frac{\beta}{\beta+1}\right) I_E = 0.495 mA$

$$\therefore \frac{15 - (V_C)_Q}{(I_C)_Q} = R_C$$

$$\therefore R_C = \frac{15-5}{0.495} K\Omega$$

$$\boxed{R_E = 20.20 K\Omega}$$ Ans.

Now For small signal Analysis of BJT

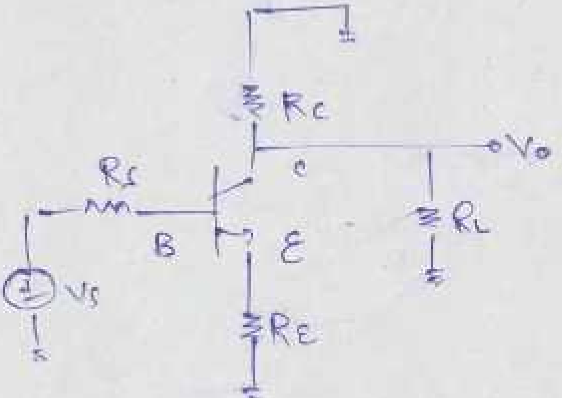
$$g_m = \frac{(I_C)_Q}{V_T} = \frac{0.495m}{26m} = 19.038 mS$$

$$\therefore r_\pi = \beta/g_m = 5.2K\Omega$$

$r_o = 200K\Omega$ (given)

17+1 = 18

Ac model



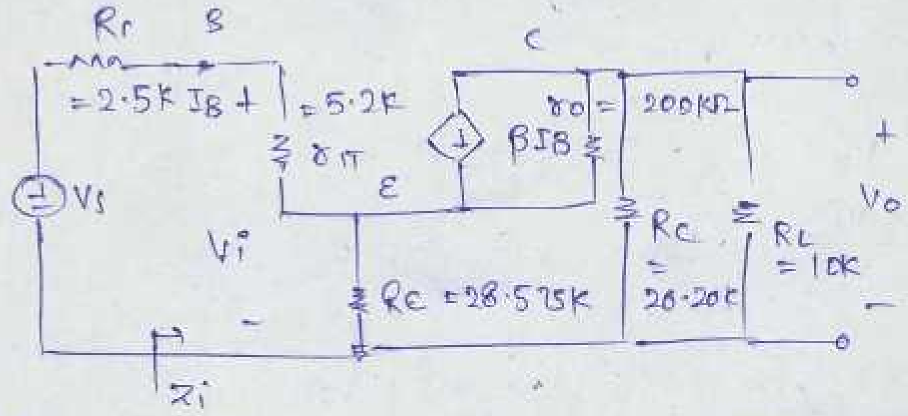
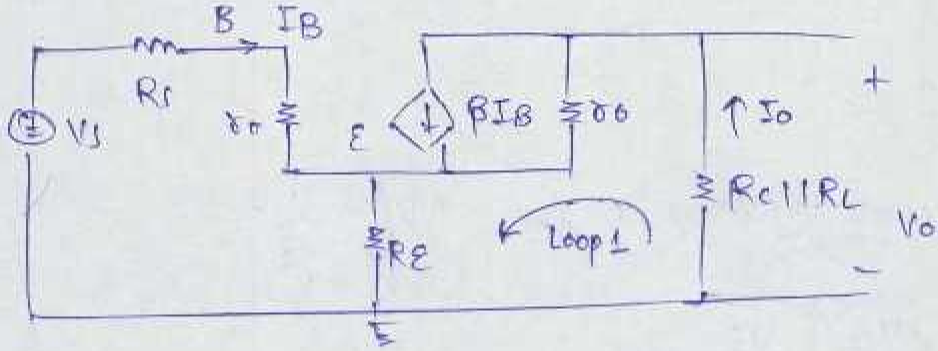


fig. Small signal equivalent model of BJT

Now



KVL in loop 1

$I_o(R_C \| R_L) + (I_o - \beta I_B) r_o + (I_o + I_B) R_E = 0$

$\Rightarrow \quad I_o[R_C \| R_L + r_o + R_E] = I_B[\beta r_o - R_E]$

$$\Rightarrow \boxed{I_o = \frac{I_B(\beta r_o - R_E)}{R_C \| R_L + r_o + R_E}} \quad -(i)$$

Now $V_o = -I_o(R_C \| R_L)$ — (ii)

$v_i = I_B(r_\pi) + (I_B + I_o) R_E$ —(iii)

by eqn(i) $I_o = \dfrac{I_B(99 \times 200K - 28.575K)}{20.20K \| 10K + 200K + 28.575K}$

$$\boxed{I_o = 84.04 I_B} \quad -(iv)$$

using (iv) in (ii) & (iii)

$$A_V = \frac{V_o}{V_i} = \frac{-I_o(R_C \| R_L)}{I_B r_\pi + (I_B + I_o)R_E}$$

$$\frac{V_o}{V_i} = \frac{-84.04\cancel{I_B}(20.20K \| 10K)}{\cancel{I_B}[5.2K + 85.04 \times 28.575K]}$$

$$\boxed{A_V = -0.23}$$

Now overall voltage gain $A_{VS} = \frac{V_o}{V_s}$

$$A_{VS} = \frac{V_o}{V_i} \cdot \frac{V_i}{V_s}$$

$$A_{VS} = -0.23 \times \frac{(r_\pi + 85.04 R_e)}{r_\pi + 85.04 R_e + R_s}$$

$$\boxed{A_{VS} = -0.229}$$

Ans

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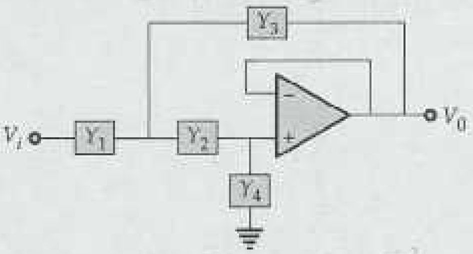
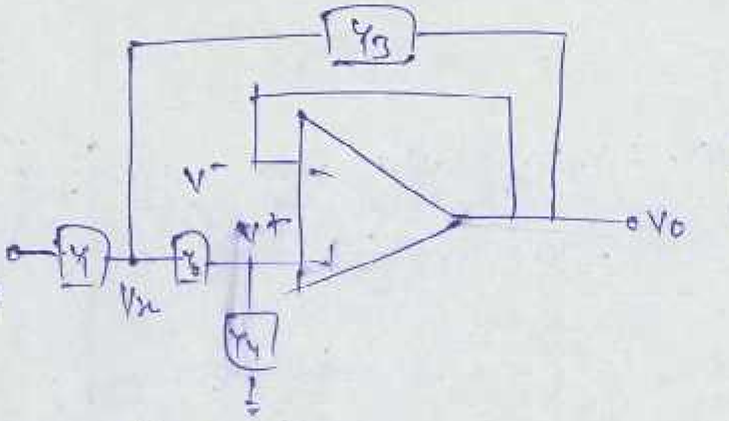
Q.4 (b) (i) Consider the circuit shown in the figure below:



Here Y_1, Y_2, Y_3 and Y_4 represents admittances of the respective elements. If the op-amp in the circuit is ideal, then determine the transfer function, $T(s) = \frac{V_0(s)}{V_i(s)}$ of the circuit.

[10 marks]

Solution)



$$\boxed{V^- = V_0}$$

KCL at "Vx" Node.

$$(V_x - V_i)Y_1 + (V_x - V^+)Y_2 + (V_x - V_0)Y_3 = 0$$

$$\Rightarrow \boxed{V_x(Y_1 + Y_2 + Y_3) - V_iY_1 - V^+Y_2 - V_0Y_3 = 0} \quad -(I)$$

KCL at V^+ Node

$$V^+Y_4 + (V^+ - V_x)Y_2 = 0$$

$$\Rightarrow V^+(Y_4 + Y_2) = V_xY_2$$

$$\therefore \boxed{V_x = \frac{V^+(Y_4 + Y_2)}{Y_2}} \quad -(II)$$

using (II) in (I)

$$\frac{V^+(Y_4+Y_2)(Y_1+Y_2+Y_3)}{Y_2} - V_i^o Y_1 - V^+ Y_2 - V_0 Y_3 = 0$$

$\because \boxed{V^+ = V^- = V_0}$

$$\therefore \quad V_i^o Y_1 = V_0 \left[\frac{(Y_4+Y_2)(Y_1+Y_2+Y_3)}{Y_2} - Y_2 - Y_3 \right]$$

$$\therefore V_i^o Y_1 = V_0 \left[\frac{Y_4Y_1 + Y_4Y_2 + Y_4Y_3 + Y_2Y_1 + \cancel{Y_2^2} + \cancel{Y_2Y_3} - \cancel{Y_2^2} - \cancel{Y_2Y_3}}{Y_2} \right]$$

$$\therefore \boxed{\frac{V_0}{V_i} = \frac{Y_1Y_2}{Y_4Y_1 + Y_4Y_2 + Y_4Y_3 + Y_2Y_1}}$$

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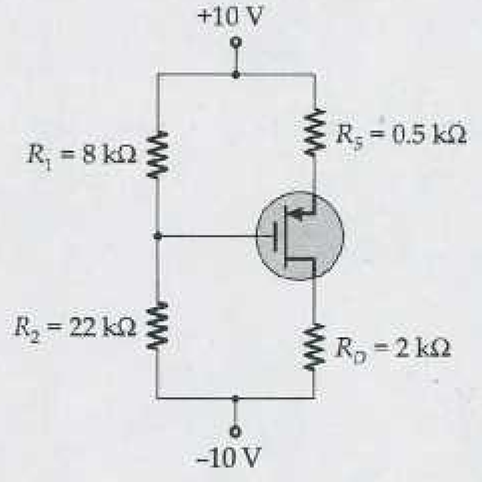
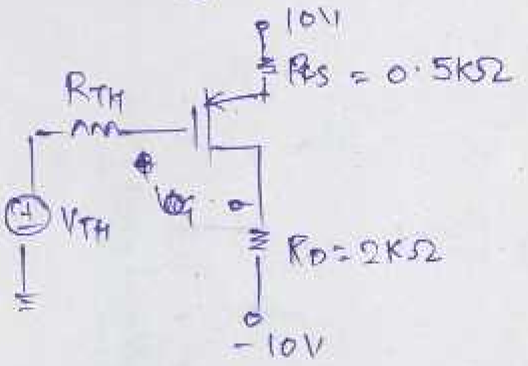
Q.4 (b) **(ii)** The PMOS transistor shown in the figure below has $V_{tp} = -1$ V, $\lambda = 0$ and $K_p = \frac{\mu_p C_{ox}}{2}\left(\frac{W}{L}\right) = 1\ \text{mA/V}^2$. Determine I_D, V_{SG} and V_{SD} of the transistor.



[10 marks]

Solution) Applying thevenin's theoram at input Terminal



where $R_{TH} = R_1 \| R_2$

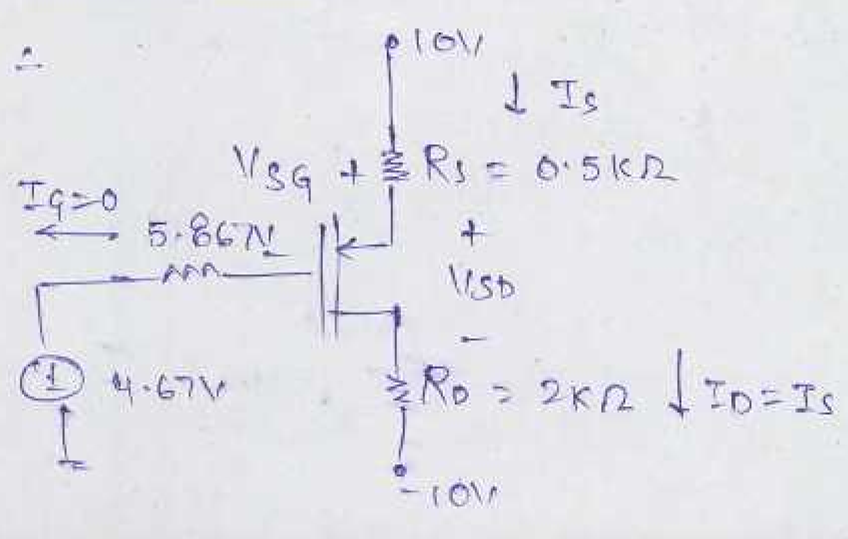
$= \frac{8 \times 22}{8+22} K\Omega$

$\boxed{R_{TH} = 5.867 K\Omega}$

$V_{TH} = \frac{+10(22K) + (-10)(8K)}{22K + 8K}$ (by superposition theoram)

$\boxed{V_{TH} = 4.67V}$

∴



KVL in input loop

$$-10 + I_S R_S + V_{SG} + 4.67 = 0 \quad -(i)$$

KVL in o/p loop

$$-10 + I_S R_S + V_{SD} + I_S \cdot R_D - 10 = 0 \quad -(ii)$$

Also, For enhancement mosfet:

$$I_D = K_p'(V_{GS} - V_T)^2$$

given $K_p' = 1mA/V^2$

$V_T = -1V$

$$\therefore \quad I_D = 1m(V_{GS}+1)^2 \quad -(iii)$$

by (i) & (iii)

$$\left(\frac{10 - 4.67 - V_{SG}}{R_S}\right) = 1m(V_{GS}+1)^2$$

$$\Rightarrow \frac{5.33 + V_{GS}}{0.5} \cancel{m} = \cancel{1m}(V_{GS}+1)^2$$

$$\Rightarrow \frac{5.33 + V_{GS}}{0.5} = V_{GS}^2 + 1 + 2V_{GS}$$

$$\Rightarrow 0.5V_{GS}^2 + 0.5 + \cancel{V_{GS}} - \cancel{V_{GS}} - 5.33 = 0$$

$$\Rightarrow V_{GS}^2 = \frac{5.33 - 0.5}{0.5} = 9.66V$$

$$\boxed{V_{GS} = \pm 3.108V}$$

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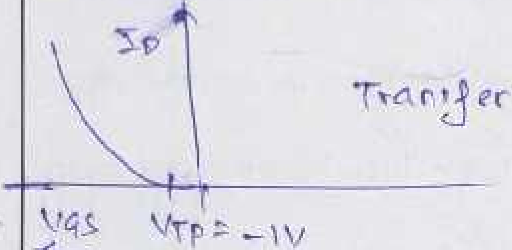
For P^+ enhacement Type MOSFET:



Transfer characterstics

$\therefore \boxed{V_{GS} = -3.108V}$

$\therefore$ by eq^n (III) $I_D = 1m(-3.108+1)^2$

$$\boxed{I_D = 4.44mA}$$

$\therefore \boxed{I_D = I_S = 4.44mA}$

by eq^n (I) $V_{SG} = +10 - 4.67 - 4.44 \times 0.5$

$\boxed{V_{SG} = 3.11V} \simeq 3.108V$ (True)

eq^n(II)

$$V_{SD} = 10 + 10 - I_S R_S - I_S R_D$$

$$= 20 - 4.44 \times 0.5 - 4.44 \times 2$$

$\boxed{V_{SD} = 8.9V}$ An.

$\therefore$ conclusion

$$\left.\begin{aligned} I_D = I_S &= 4.44mA \\ V_{SG} &= 3.108V \\ V_{SD} &= 8.9V \end{aligned}\right\} \text{An}$$

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Q.4 (c) Electron drift mobility in Indium (In) has been measured to be 6 $cm^2 V^{-1} s^{-1}$. The room temperature (27° C) resistivity of In is 8.37×10^{-8} Ω m, and its atomic mass and density are 114.82 $g mol^{-1}$ and 7.31 $g cm^{-3}$ respectively.

(i) Based on the resistivity value, determine how many free electrons are donated by each In atom in the crystal.

(ii) If the mean speed of conduction electrons in In is 1.74×10^8 $cm s^{-1}$, what is the mean free path?

(iii) Calculate the thermal conductivity of In at room temperature.

[20 marks]

Solution) For Indium

$\mu_e = 6 \, cm^2 V^{-1} s^{-1}$ (given) $= 6 \times 10^{-4} \, m^2 V^{-1} s^{-1}$

ρ (at 300K) $= 8.37 \times 10^{-8} \, \Omega m$

atomic mass $= 114.82$ g/mol

density $= 7.31$ g/cm³

(i) As we know

$\sigma = \frac{1}{\rho}$ where σ = conductivity of material.

$\boxed{\sigma = 1.194 \times 10^7 \, \Omega^{-1} m^{-1}}$

Now $\because$ $\boxed{\sigma = ne\mu}$

where n = carrier concentration /m³

$\therefore \; n = \frac{1.194 \times 10^7}{1.6 \times 10^{-19} \times 6 \times 10^{-4}}$

$\boxed{n = 1.24 \times 10^{29} \, /m^3}$, 1 Bn

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(ii) mean speed of conduction = $1.74 \times 10^{8}\ cm s^{-1}$

$= 1.74 \times 10^{6}\ m/sec$

∵ mean Free path = λ

Also $\boxed{V_d = \frac{\lambda}{\tau}}$ where τ = Relaxation time

Now $\mu = \frac{V_d}{E}$ -(i)

$\mu = \frac{e E \tau / m}{E}$ Also acceleration = $\frac{V_d}{\tau}$ -(ii)

⇒ Now $a =$

$ma = eE$ (by Force at equilibrium)

∴ $a = \frac{eE}{m}$ -(iii)

by (ii) & (iii)

$\frac{V_d}{\tau} = \frac{eE}{m} \Rightarrow V_d = \frac{eE\tau}{m}$ -(iv)

(iv) in (i)

$\mu = \frac{e\cancel{E}\tau/m}{\cancel{E}} \Rightarrow \boxed{\mu = \frac{e\tau}{m}}$

∴ $\tau = \frac{\mu m}{e} = \frac{6 \times 10^{-4} \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19}}$ sec.

$\boxed{\tau = 3.41 \times 10^{-15}\ sec}$

Now mean Free path $\lambda = v_d \cdot \tau$

$$\lambda = 1.74 \times 10^{6} \times 3.41 \times 10^{-15} \text{ m}$$

$$\lambda = 5.937 \times 10^{-9} \text{m}$$

$$\boxed{\lambda = 5.937 \text{nm}}$$ Ans.

(iii) Thermal conductivity $(K) = ?$

$$\because \boxed{\frac{K}{\sigma} = \frac{3}{2}\left(\frac{k}{e}\right)^2 \cdot T}$$ by wiedmann-Franz law

$$\therefore K = \sigma \times \frac{3}{2} \times$$

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Section B : Electrical Machines-1 + Power Systems-2

Q.5 (a) Two 3-phase transformers, rated at 500 kVA and 450 kVA respectively are connected in parallel to supply a load of 1000 kVA at 0.8 pf lagging. The per phase resistance and per phase leakage reactance of the first transformer is 2.5% and 6% respectively and of the second transformer is 1.6% and 7% respectively. Calculate the kVA load shared and power factor at which each transformer operates.

[12 marks]

Solution) load KVA S_L = 1000KVA at 0·8 lagg

$S_L = 1000 \angle \cos^{-1} 0{\cdot}8$ —(1)

T/F A : 500KVA

T/F B : 450KVA

$Z_A = (0{\cdot}025 + 0{\cdot}06i)$ PU at m/c Rating Bas

$Z_B = (0{\cdot}016 + 0{\cdot}07i)$ PU at m/c Rating Bas

Ref Base KVA : 500KVA

At S_b = 500KVA

$Z_A = (0{\cdot}025 + 0{\cdot}06i) = 0{\cdot}065 \angle 67{\cdot}38$ PU

$Z_B = (0{\cdot}016 + 0{\cdot}07i) \times \frac{500}{450} = 0{\cdot}07978 \angle 77{\cdot}124$ PU

∵ We know $\boxed{S_j^* = \dfrac{S_L^*}{Z_j \sum_{i=1}^{n} \frac{1}{Z_i}}}$

$$\therefore S_A^* = \frac{1000\angle -36.86}{1 + \frac{0.065\angle 67.38}{0.07978\angle 77.124}}$$

$$\bar{S_A}^* = 553.02\angle -32.486 \text{ KVA}$$

$\therefore$ T/F A : 553.02 KVA at 0.8435 pf lagg

Ans

For T/F B

$$S_B^* = \frac{1000\angle -36.86}{1 + \frac{0.07978\angle 77.124}{0.065\angle 67.38}}$$

$$S_B^* = 450.568\angle -42.23 \text{ KVA}$$

$\therefore$ S_B T/F B : 450.568 KVA at 0.7407 pf lagg

Ans.

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Do not write in this margin

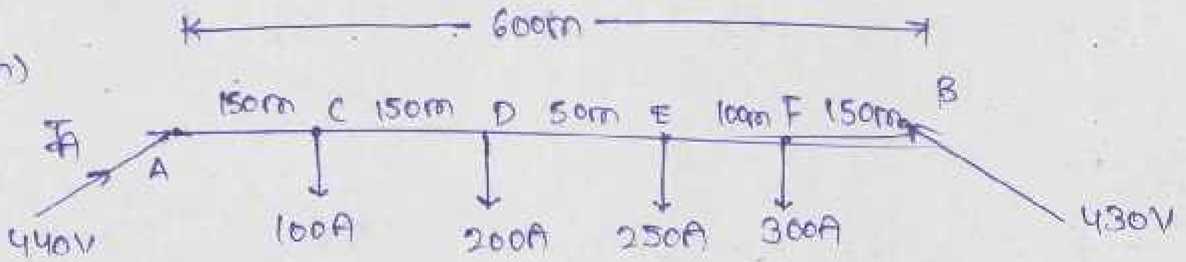
Q.5 (b) A dc two line distributor AB, 600 meters long is fed at 440 V from substation A and at 430 V from substation B, the loads are:

100 A at C, 150 meters from A
200 A at D, 150 meters from C
250 A at E, 50 meters from D
300 A at F, 100 meters from E

If each line conductor has a resistance of 0.01 Ω per 100 meters, calculate the currents supplied from substations A and B and the voltage at points C, D, E, and F.

[12 marks]

Solution)



For Each line conductor $r = 0.01\Omega/100m$

$\therefore \quad r = 0.01 \times 10^{-2}\ \Omega/m$

$\therefore$ loop Resistance $= 2r$

$$\boxed{r' = 2 \times 10^{-4}\ \Omega/m}$$

Now For DC distribution system.

$V_A - V_B =$ Voltage drop in distribution line

$\therefore 440 - 430 = I_A \times 150 \times 2 \times 10^{-4} + (I_A - 100)\, 150 \times 2 \times 10^{-4}$

$+ (I_A - 300)\, 50 \times 2 \times 10^{-4} + (I_A - 550) \times 2 \times 10^{-4}$

$\times 100 + (I_A - 850) \times 150 \times 2 \times 10^{-4}$

$10 = 2 \times 10^{-4} \Big[150 I_A + 150 I_A - 150 \times 100 + 50 I_A$

$- 300 \times 50 + 100 I_A - 550 \times 100$

$+ 150 I_A - 150 \times 850 \Big]$

$0 = 2\times10^{-4}(600 I_A - 212500)$

$\Rightarrow 600 I_A = 50{,}000 + 21{,}2500$

$\boxed{I_A = 437.5A}$

current supplied by substation A = 437.5A

current supplied by substation B = $850 - I_A$

$= 412.5A$ Ans

Now Voltages at C, D, E, F

$V_C = V_A - 150\times2\times10^{-4}\times I_A$

$\boxed{V_C = 426.875V}$ Ans.

$V_D = V_C - 150\times2\times10^{-4}(I_A - 100)$

$\boxed{V_D = 416.75V}$ Ans

$V_E = V_D - 50\times2\times10^{-4}(I_A - 300)$

10

$\boxed{V_E = 415.375V}$ Ans

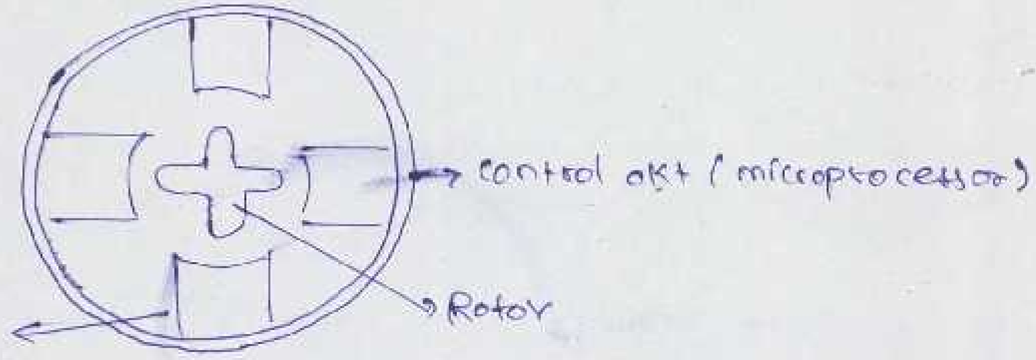
$V_F = V_E - 100\times2\times10^{-4}(I_A - 550)$

$\boxed{V_F = 417.625V}$ Ans

Q.5 (c) Explain principle of operation and working of variable reluctance stepper motor.

[12 marks]

Solution Variable Reluctance Stepper motor



Here let ~~No~~ No. of Stator poles : Ns

No. of Rotor poles : Nr.

Now from control circuit when, a control signal is provided to the stepper motor the Rotor rotates for a particular Angle of rotation known as step Angle.

As we can See

Rotor Has Irregular Slotted type Structure which leads to variable air gap between rotor and stator

Due to variable air gap between Stator and rotor, variable Reluctances are offered to the flux established inside the motor.

Now Step Angle $\boxed{\alpha = \frac{Ns - Nr}{Ns\,Nr} \times 360^\circ}$

Thus the rotor rotates for one step at a time (when control signal is provided) and then experiences low reluctance hence gets locked at the next location.

These are generally used in

(1) printers etc.

Q.5 (d) What are the Merits and Demerits of Nuclear power plants? Explain in brief:

[12 marks]

Solution) Merits of Nuclear power plant

(i) The Nuclear fission based Nuclear power plants Have very High efficiency of power generation

(ii) The amount of power generated is Huge when compared to coal based power plants for the same amount of raw material input.

(iii) Nuclear power plants are generally maintainence Free.

(iv) operating cost is less.

(v) Labour Requirement is minimal.

9

Demerits of Nuclear power plants

(i) The waste produced by Nuclear power plants is toxic in natural and leads to Hazardou pollution of enviroment

(ii) The toxic waste ~~is~~ ~~are~~ very difficult to be disposed

(iii) Nuclear power plants are generally located in remote areas thus cost of transmission of power increases

(iv) These have safety issues for manpower working in the plant

(v) malfunctioning leads to massive disasterous situation like in Japan (malfunctioning of coolant Happened)

(vi) Uranium is very costly as a Raw material

(vii) Setup cost is High.

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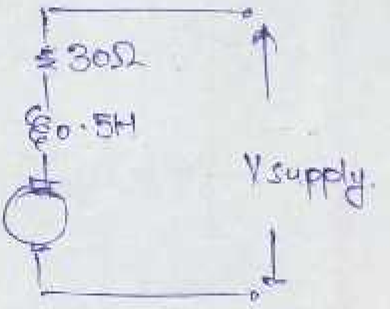
Q.5 (e) A universal series motor has a resistance of 30 Ω and an inductance of 0.5 H. When connected to a 250 V dc supply and loaded to take 0.8 A it runs at 2000 rpm. Calculate the speed, torque and power factor, when connected to a 250 V, 50 Hz ac supply and loaded to take the same current.

[12 marks]

Solution) Universal series motor



$R = 30\Omega$

$L = 0.5H$

when connected to 250V dc

$I_a = 0.8A$

$\therefore E_a = 250 - 0.8 \times 30 = 226V$

$N = 2000$ RPM

$\therefore$ $\because E = K\phi\omega_m$

$\therefore \boxed{E \propto I_a.\omega_m}$ (i)

when connected to AC

$I_a = 0.8A$ (same)

$Z = [R^2 + (\omega L)^2]^{1/2} = \{(30)^2 + (2\pi \times 50 \times 0.5)^2\}^{1/2}$

$Z = 159.918\Omega$

$\theta = \tan^{-1}\left(\frac{X_L}{R}\right) = 79.18°$

when connected to DC

$T = K\phi I_a = \frac{E_a I_a}{\omega_m}$

$T = \frac{226 \times 0.8}{\frac{2\pi}{60} \times 2000} = 0.8632$ Nm

7 − 2 = 5

When Connected to AC

$\because$ I_a is constant

$\therefore$ $T = K\phi I_a$

$T \propto I_a^2$ = constant

$\therefore$ $\boxed{\text{Torque}_{AC} = \text{Torque}_{dc} = 0.8632 \text{ Nm}}$

power Factor of Series motor = $\cos(79.18°)$

$= 0.1876$ pf lagg Ans.

Now $E_a = V - I_a(R_a + jX_a)$

$= 250 - 0.8\,(79.18)\,[30 + j\,2\pi \times 50 \times 0.5]$

E_a

Do not write in this margin

Q.6 (a) Three identical single phase transformers have their rated voltages of 200, 150 and 100 V respectively for the primary, secondary and tertiary windings. The primary is connected in star to a 3-phase sinusoidal supply of 433 volts. The secondary is also connected in star. The voltmeter when connected across the open circuited delta of the tertiary winding gave a reading of 120 V.

Determine the line and phase voltages on the secondary if the tertiary delta is

(i) open circuited and

(ii) closed circuited.

[20 marks]

Solution) 3 identical 1-ϕ T/F

200/150/100V

primary: connected to 3ph 433 VRms supply.

Secondary: λ connected.

open circuited Δ Voltmeter Reding = 120V

Q.6 (b) For the network shown in figure below, obtain the complex bus bar voltage at bus 2 at the end of the first iteration using the Gauss seidel method. Line impedances shown in figure are in p.u.

Given:

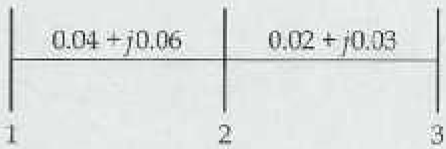
Bus 1 is slack bus with $V_1 = 1.0\angle 0°$ p.u.

$$P_2 + jQ_2 = (-5.96 + j1.46) \text{ p.u.}$$
$$|V_3| = 1.02 \text{ p.u.}$$

Assume:

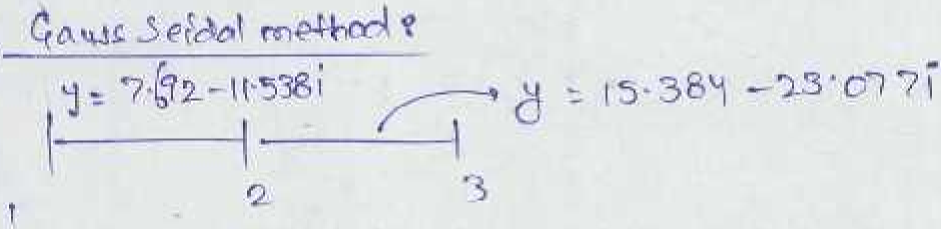
$$V_3^0 = 1.02\angle 0° \text{ p.u.}$$
and
$$V_2^0 = 1.0\angle 0° \text{ p.u.}$$

Take acceleration factor $\alpha = 1.4$



[20 marks]

Solution) Gauss Seidal method:



∴ ybus

$$[Y] = \begin{bmatrix} 13.867\angle -56.31 & +13.867\angle 123.69 & 0 \\ 13.867\angle 123.69 & 41.6\angle -56.31 & 27.734\angle 123.68 \\ 0 & 27.734\angle 123.68 & 27.734\angle -56.311 \end{bmatrix}$$

Now by Gauss Seidal iterative Technique

$$V_i^{(r+1)} = \frac{1}{Y_{ii}}\left[\frac{P_i - jQ_i}{(V_i)^{r*}} - \sum_{\substack{K=1 \\ K\neq i}}^{n} Y_{iK}V_K\right]$$

∴ $i = 2$, $r = 0$

$$V_2^{(1)} = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^{(0)*}} - \sum_{\substack{K=1 \\ K\neq 2}}^{3} Y_{2K}V_K\right]$$

$$V_2^{(1)} = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^{(0)*}} - Y_{21}V_1 - Y_{23}V_3\right]$$

$$\therefore V_2^{(1)} = \frac{1}{41.6\angle -56.31}\left[\frac{-5.96 - 1.46i}{1\angle 0} - 13.867\angle 123.69 \times 1\angle 0 - 27.734\angle 123.68 \times 1.02\right]$$

$$\boxed{V_2^{(1)} = 0.97303\angle -8.2^\circ \text{ PU}}$$

Now given Acceleration Factor $(\alpha) = 1.4$

$$V_{2\,acc}^{(1)} = V_{2\,acc}^{(0)} + \alpha\left(V_2^{(1)} - V_{2\,acc}^{(0)}\right)$$

$$= 1\angle 0 + 1.4\left[0.97303\angle -8.2 - 1\angle 0\right]$$

$$\boxed{V_{2\,acc}^{(1)} = 0.968\angle -11.57 \text{ PU}}$$

Ans.

16×2

$= 18$

Do not write in this margin

Q.6 (c) The resistance and reactance (equivalent) values of a double-cage induction motor for stator, outer and inner cage are 0.25, 1.0 and 0.15 ohm resistance and 3.5, zero and 3.0 ohm reactance respectively. Find the starting torque if the phase voltage is 250 V and the synchronous speed is 1000 rpm.

[20 marks]

Solution) For a Double Cage Induction motor

equivalent circuit referred to Stator side :

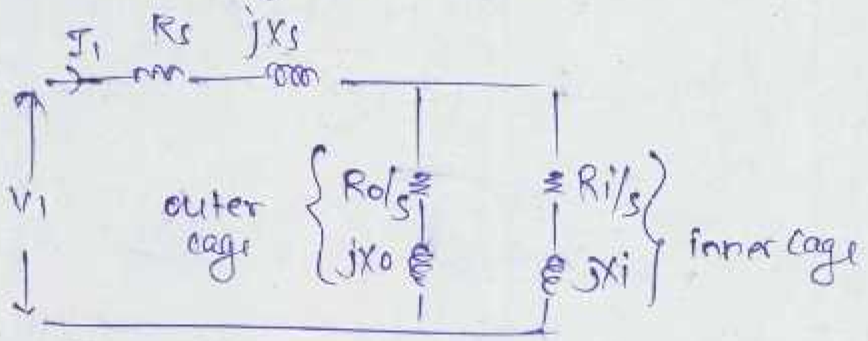


Fig. equivalent circuit w.r.t Stator.

~~Here $R_o + jX_o$~~ To Find : $T_{starting} = ?$

At Starting

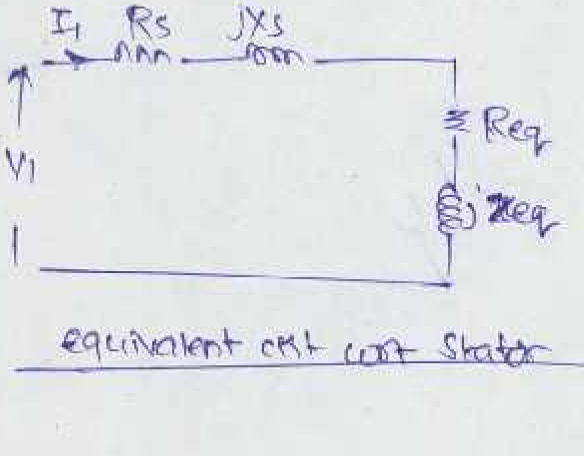
$\boxed{S = 1}$

$Z_o = R_o + jX_o = \cancel{1+0.15j}\ 1.0 + 0j = 1$

$Z_i = R_i + jX_i = 0.15 + 3j =$

$Z_S = R_S + jX_S = 0.25 + 3.5j$

i.e. $I_1 = \dfrac{V_1}{Z_{eq1}}$ where V_1 = phase Voltage.



$R_{eq} + jX_{eq} = Z_{eq} = Z_o \| Z_i$

equivalent ckt w.r.t Stator

$$\boxed{Z_{eq} = 0.9349 \angle 18.11\ \Omega} = (0.8885 + 0.2906i)\ \Omega$$

Now $T_{starting} = \dfrac{3}{\omega_{sm}} \times \dfrac{V_1^2}{(R_1 + R_{eq})^2 + (X_S + X_{eq})^2} \times (R_{eq})$

$$T_{starting} = \frac{3}{\frac{2\pi}{60} \times 1000} \times \frac{(250)^2 \times (0.888)}{(0.25 + 0.888)^2 + (0.2906 + 3.5)^2}$$

$$T_{starting} = \frac{60 \times 3}{2000\pi} \times 3543.225 \text{ Nm}$$

$$\boxed{T_{starting} = 101.5\text{Nm}}$$

Ans.

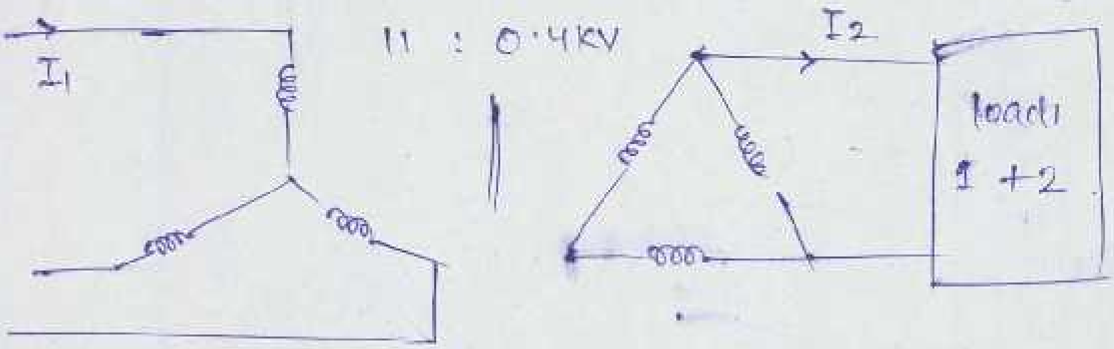
17

Q.7 (a) A 11/0.4 kV star-delta transformer is connected to a 3-phase balanced load of 300 kVA at unity pf and also to a single phase load of 60 kVA at unity pf. Calculate the values of the currents on the primary side. The no load current and the internal leakage impedance drops are neglected.

[20 marks]

Solution: 11/0.4 kV λ, Δ Transformer.

loads: 3ph 300 kVA, UPF + 1-ϕ 60 kVA, UPF



Y : Δ Transformer

No load current and internal leakage Impedance drops are Neglected

$\therefore$ Total load current at Δ side

= Due to 3ph load + Due to 1ϕ load

$$I_L = \frac{300\times10^3}{\sqrt{3}\times0.4\times10^3}\angle 0 + \frac{60\times10^3}{0.4\times10^3}\angle 0$$

$$\boxed{I_L = 583.012\angle 0 \text{ A}}$$

Now According to the above Figure.

$I_2 = I_L = 583.012\angle 0$ A

Now by power balance equation for Transformer

$\sqrt{3}V_1 I_1 = \sqrt{3}V_2 I_2$

$I_1 = \left(\frac{V_2}{V_1}\right) I_2 = \left(\frac{0.4\,kV}{11\,kV}\right) I_2$

$I_1 = 0.0363 I_2$

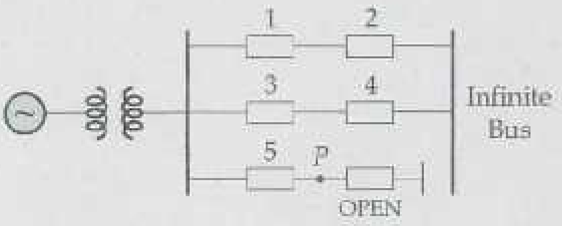
$\boxed{I_1 = 21.206\ A}$ Ans.

$\therefore$ primary currents in the Transformer will be

21.20 A Ans.

11 − 5 = 6

Q.7 (b) The single line diagram of a three-phase power system is given below. The generator is delivering 1.0 per unit power to the infinite bus. The pre-fault power angle equation is $P_e = 2.10 \sin \delta$. Calculate the critical clearing angle and critical clearing time when the system is subjected to a 3-phase fault at point P. The fault is cleared by opening the circuit breaker 5. (Given: Inertia constant $H = 5$ MJ/MVA)



[20 marks]

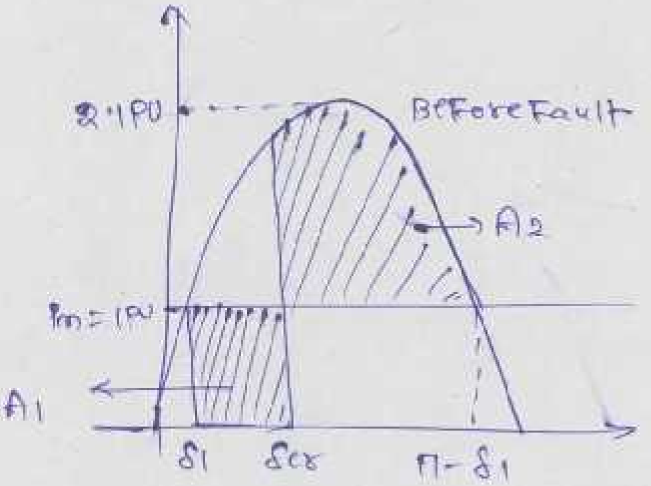
Solution) For the given SLD

$P_m = 1 PU$

$\therefore \quad 2.10 \sin\delta_1 = 1$

$$\boxed{\delta_1 = 28.43^\circ}$$

$$\boxed{\pi - \delta_1 = 151.563^\circ}$$



by equal Area criterian concept

$A_1 = A_2$

$$\Rightarrow \int_{\delta_1}^{\delta_{cr}} P_m \, d\delta = \int_{\delta_{cr}}^{\pi-\delta_1} (2.1\sin\delta - P_m)\, d\delta$$

$$\Rightarrow \int_{28.43^\circ}^{\delta_{cr}} 1 \cdot d\delta = \int_{\delta_{cr}}^{151.563^\circ} (2.1\sin\delta - 1)\, d\delta$$

$$\Rightarrow \cancel{\delta_{cr}} - \frac{28.43 \times \pi}{180} = -2.1\cos\delta \Big/_{\delta_{cr}}^{151.563} - \frac{151.563 \times \pi}{180} + \cancel{\delta_{cr}}$$

$$\Rightarrow \frac{\pi}{180}(151.563 - 28.43) = -2.1\cos(151.563) + 2.1\cos\delta_{cr}$$

$$\Rightarrow 2.1\cos\delta_{cr} = 2.149 + 2.1\cos(151.563)$$

$$\Rightarrow \boxed{\delta_{cr} = 81.718^\circ}$$ Ans

$\therefore$ critical clearing angle $= 81.718^\circ$

Now by swing equation

$$\frac{2H}{\omega_s}\frac{d^2\delta}{dt^2} = (P_m - P_e)\ pu$$

<u>during Fault</u> $P_e = 0$

$$\therefore \frac{2\times5}{2\pi\times50}\frac{d^2\delta}{dt^2} = 1 \quad -(i)$$

$$\Rightarrow \frac{d\delta}{dt} = 31.416t + c'$$

At $t=0^+$; $\left.\frac{d\delta}{dt}\right|_{t=0^+} = 0$

$\therefore \boxed{c' = 0}$

$$\therefore \frac{d\delta}{dt} = 31.416t \quad -(ii)$$

integrate ~~differentiate~~ again eq^n (ii)

$$\therefore \delta = \frac{31.416t^2}{2} + K$$

At $t=0$; $K = \delta|_{t=0} = \delta_0 = 28.43\times\frac{\pi}{180}$

$$\boxed{\delta = \frac{31.416}{2} t^2 + \delta_0} \quad \text{- (iii)}$$

Now For $\delta = \delta_{cr}$; $t = t_{cr}$.

$$\therefore \quad t_{cr} = \sqrt{\frac{\delta_{cr} - \delta_0}{\left(\frac{31.416}{2}\right)}}$$

$$\therefore \quad t_{cr} = \left[\frac{(81.718 - 28.43) \times \frac{\pi}{180} \times 2}{31.416}\right]^{1/2}$$

$$\boxed{t_{cr} = 0.2433 \text{ Sec}}$$

$\therefore$ critical clearing angle is $81.718°$ Ans.

critical clearing time is 0.2433 Sec Ans.

17+1 = 18

Q.7 (c) The standstill impedance of the outer cage of a double-cage induction motor is $(0.3 + j0.4)\Omega$ and that of the inner cage is $(0.1 + j1.5)\Omega$. Calculate the ratios of currents and torques of the two cages **(i)** at standstill, **(ii)** at a slip of 5%. Neglect stator impedance.

[20 marks]

Solution) Given outer cage: $(0.3 + j0.4)\,\Omega$

inner cage: $(0.1 + j1.5)\,\Omega$

(i) At standstill $\boxed{S=1}$

As we know $T = \frac{1}{\omega_{sm}} \times \frac{V_1^2}{\left(\frac{R_2'}{s}\right)^2 + (X_2')^2} \times \left(\frac{R_2'}{s}\right)$ -(i)

& current $I_2 = \frac{V_1}{\left(\frac{R_2'}{s}\right) + j(X_2')} = \frac{V_1}{\left[\left(\frac{R_2'}{s}\right)^2 + (X_2')^2\right]^{1/2}}$ -(ii)

$$\therefore \frac{(I_2)_{outer}}{(I_2)_{inner}} = \frac{\dfrac{\cancel{V_1}}{(R_{2o}^2 + X_{2o}^2)^{1/2}}}{\dfrac{\cancel{V_1}}{(R_{2i}^2 + X_{2i}^2)^{1/2}}}$$

$$= \left[\frac{(R_{2i}^2 + X_{2i}^2)}{(R_{2o}^2 + X_{2o}^2)}\right]^{1/2} = \left[\frac{(0.1)^2 + (1.5)^2}{(0.3)^2 + (0.4)^2}\right]^{1/2}$$

$$\boxed{\frac{I_2\,outer}{I_2\,inner} \simeq 3}$$ Ans

Now $T \propto \frac{R_2}{(R_2^2 + X_2^2)}$ (ω_{sm}, V are constant for both cages)

$$\therefore \frac{T_{outer}}{T_{inner}} = \frac{\dfrac{R_{2o}}{R_{2o}^2 + X_{2o}^2}}{\dfrac{R_{2i}}{R_{2i}^2 + X_{2i}^2}}$$

$$= \frac{0.3}{0.1} \times \left[\frac{(0.1)^2 + (1.5)^2}{(0.3)^2 + (0.4)^2}\right]$$

$$\boxed{\therefore \frac{T_{outer}}{T_{inner}} = 27.12}$$ Ans

(ii) At slip 's' = 0.05

$$\frac{I_{2\,outer}}{I_{2\,inner}} = \frac{\dfrac{V}{\left[\left(\frac{R_{2o}}{s}\right)^2 + (X_{2o})^2\right]^{1/2}}}{\dfrac{V}{\left[\left(\frac{R_{2i}}{s}\right)^2 + (X_{2i})^2\right]^{1/2}}}$$

$$= \left[\frac{(R_{2i}/s)^2 + (X_{2i})^2}{\left(\frac{R_{2o}}{s}\right)^2 + (X_{2o})^2}\right]^{1/2}$$

$$\frac{I_{2\,outer}}{I_{2\,inner}} = \left\{\frac{\left(\frac{0.1}{0.05}\right)^2 + (1.5)^2}{\left(\frac{0.3}{0.05}\right)^2 + (0.4)^2}\right\}^{1/2}$$

17+1 = 18

$$\Rightarrow \boxed{\frac{I_{2\,outer}}{I_{2\,inner}} = 0.4157}$$ Ans

$\Rightarrow$

Now $$\frac{T_{outer}}{T_{inner}} = \frac{\dfrac{(R_{2o}/s)}{\left(\frac{R_{2o}}{s}\right)^2 + (X_{2o})^2}}{\dfrac{(R_{2i})/s}{\left(\frac{R_{2i}}{s}\right)^2 + (X_{2i})^2}}$$

$$\frac{T_{outer}}{T_{inner}} = \left(\frac{R_{2o}}{R_{2i}}\right) \times \frac{(R_{2i}/s)^2 + (X_{2i})^2}{(R_{2o}/s)^2 + (X_{2o})^2}$$

$$\frac{T_{outer}}{T_{inner}} = \frac{0.3}{0.1} \times \frac{\left(\frac{0.1}{0.05}\right)^2 + (1.5)^2}{\left(\frac{0.3}{0.05}\right)^2 + (0.4)^2}$$

$$\boxed{\frac{T_{outer}}{T_{inner}} = 0.5185}$$ Ans.