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ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-4 : Electrical Machines + Power Systems-1 + Digital Electronics-2 + Microprocessor-2

Name : ....

Roll No :

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. 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.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	55
Q.2	30
Q.3	
Q.4	51
Section-B	
Q.5	30
Q.6	35
Q.7	
Q.8	
Total Marks Obtained	201

Signature of Evaluator: Sourabh kumar

Cross Checked by: ....

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IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

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Section A : Electrical Machines

Q.1 (a) A 4-pole, 3-ϕ Slip Ring Induction Motor (SRIM) is used as a frequency changer. Its stator is excited from 3-phase, 50 Hz supply. A load requiring 3-phase, 20 Hz supply is connected to the star-connected rotor through three slip rings of SRIM.

(i) At what two speeds the prime mover should drive the rotor of this SRIM?

(ii) Find the ratio of two voltages available at the slip rings at the two speeds.

[12 marks]

$f_s = 50\text{ Hz}$

$f_r = 20\text{ Hz} = s f_s$

$\Rightarrow s = \frac{20}{50} = \pm 0.4$

$s = +0.4 \Rightarrow$ Motoring mode

$s = -0.4 \Rightarrow$ Generating mode

synchronous speed $N_s = \frac{120f}{P} = \frac{120 \times 50}{4}$

$= 1500$ rpm

i) so $N_r = N_s(1-s)$

@ $s = +0.4$

$\Rightarrow N_r = 1500(1-0.4) = 900$ rpm

@ $s = -0.4$

$\Rightarrow N_r = 1500(1-(-0.4)) = 1500 \times 1.4$

$= 2100$ rpm

Hence two speeds are 900 rpm and 2100 rpm.

ii) we know

$V = 4.44 f_r \Phi N$ where $4.44 \Phi N = K$

$= K \times s$

so $\frac{V_1}{V_2} = \frac{S_1}{S_2} = \frac{+0.4}{-0.4}$

$\Rightarrow \boxed{\frac{V_1}{V_2} = -1}$ Ans

11

Good Approach

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Q.1 (b) The speed of a 4-pole induction motor is controlled by varying the supply frequency while maintaining the ratio of supply voltage to supply frequency (V/f) constant. At rated frequency of 50 Hz and rated voltage of 400 V its speed is 1440 rpm. Find the speed at 30 Hz, if the load torque is constant.

[12 marks]

Given: $\frac{V}{f} \rightarrow$ const.

@ 50 Hz, 400 V $\rightarrow N_r = 1440$ rpm

$N_s = \frac{120 \times 50}{4} = 1500$ rpm

$S = \frac{N_s - N_r}{N_s} = \frac{60}{1500} = \frac{2}{50} = 0.04$

in case Variable voltage variable frequency control the slip speed is constant.

slip speed $= SN_s$ or $N_s - N_r = 60$ rpm

and $T \propto \frac{SV^2}{R_2 f}$

$\frac{V}{f} \rightarrow$ const.

$\Rightarrow T \propto SV$

Now at $f = 30$ Hz

as $V_{30Hz} = 30 \times \frac{400}{50}$

$V_{30Hz} = 240V$

let slip be S_2

as $T \rightarrow$ const.

$\Rightarrow S_1 V_1 = S_2 V_2$

$\Rightarrow S_2 = \frac{0.04 \times 400}{240} = \frac{0.4}{6}$

$S_2 = 0.0667$

Do not write in this margin

$N_{s2} = \frac{120f}{P} = \frac{120 \times 30}{4} = 900$ rpm

$\Rightarrow N_{r2} = 900(1 - 0.0667)$

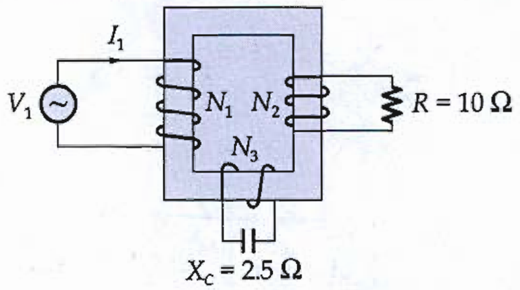
$N_{r2} = 840$ rpm

so rotor speed at 30 Hz is 840 rpm.

(11)

Good Approach

Q.1 (c) The figure shows an ideal three winding transformer windings are wound on the same core as shown. The turns ratio $N_1 : N_2 : N_3$ is 4 : 2 : 1. A resistor of 10 Ω is connected across winding-2. A capacitor of reactance 2.5 Ω is connected across winding-3. Winding-1 is connected across a 400 V, as supply. If the supply voltage phasor $V_1 = 400\angle 0°$ V, find the supply current phasor I_1.



[12 marks]

Given: $N_1 : N_2 : N_3 = 4 : 2 : 1$

$V_1 = 400\angle 0°$

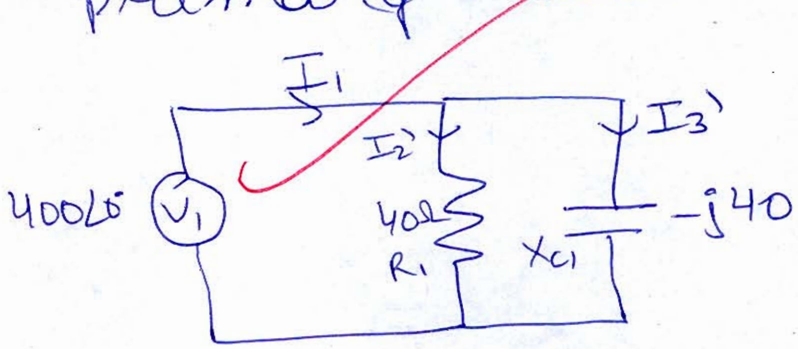
now referring $R = 10\,\Omega$ and $X_C = -j2.5\,\Omega$ to primary side.

$R_1 = 10 \times \left(\frac{4}{2}\right)^2 = \underline{\underline{40\,\Omega}}$

$|X_{C1}| = 2.5 \times \left(\frac{4}{1}\right)^2 = 40\,\Omega$

$\Rightarrow \boxed{X_{C1} = -j40\,\Omega}$

so equivalent ckt refer to primary side is:



$\Rightarrow I_2' = \frac{400}{40} = 10\,A$

Do not write in this margin

$$I_3' = \frac{400}{-j40} = j10 \text{ A}$$

so by KCL:

$$I_1 = I_2' + I_3'$$
$$= 10 + j10$$

$$\Rightarrow \boxed{I_1 = 14.14\angle 45^\circ} \text{ A}$$

11

Improve presentation

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Q.1 (d) A single-phase 50 kVA, 250 V/500 V two winding transformer has an efficiency of 95% at full load, unity power factor. If it is reconfigured as a 500 V/750 V autotransformer, find its efficiency at its new rated load at unity power factor.

[12 marks]

$$\eta = \frac{\text{Output}}{\text{Output} + \text{losses}} \times 100$$

rearranging

$$\Rightarrow \text{losses} = \text{Output}\left(\frac{1}{\eta} - 1\right)$$

Given: two wdg T/F : 50 KVA, 250/500 V, $\eta = 0.95$ @ Full load & UPF

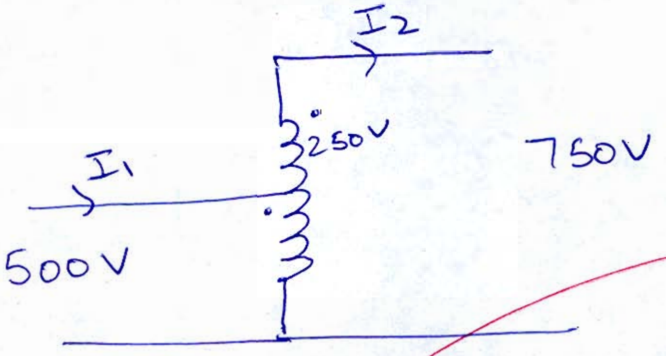
$$\Rightarrow \text{Output} = 1 \times 50 \times 1 = 50 \times 10^3$$

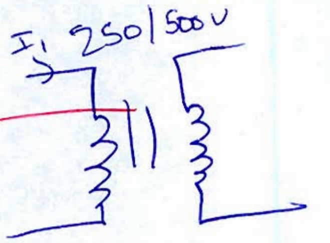
$$\Rightarrow \text{losses} = 50 \times 10^3 \left(\frac{1}{0.95} - 1\right)$$

$$\text{losses} = 2631.58 \text{ W}$$

when reconfigured as 500/750V autotransformer the losses remains same.

@ UPF





as current through wdg remains same

$I_2 = 200$ A

$pf = UPF$ [given]

$V_1 I_1 = S$

$I_1 = \frac{50 \times 10^3}{250}$

$I_1 = 200$ A

so Output $= V_2 I_2 PF$

$= 750 \times 200 \times 1$

$= 150\ KW$

so

$$\eta = \frac{O/P}{O/P + losses} \times 100$$

$$= \frac{150 \times 10^3}{150 \times 10^3 + 2631.58} \times 100$$

$$\Rightarrow \boxed{\eta = 98.275\ \%}$$

11

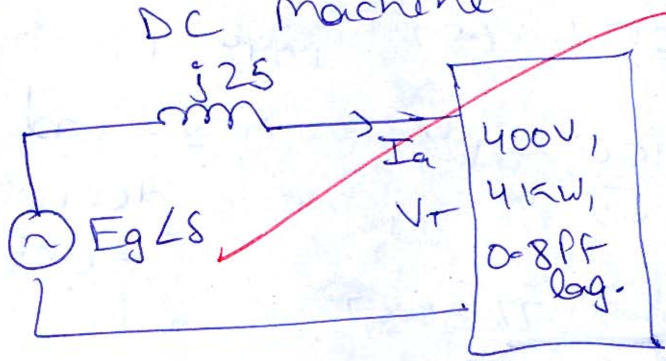
Good Approach

Q.1 (e) A 5 kVA, 400 V, 50 Hz synchronous generator having synchronous reactance of 25 Ω is driven by a dc motor and is delivering 4 kW, to a 400 V mains at 0.8 power factor lagging. The field current of the dc motor is gradually increased till it begins to act as a generator delivering power to dc mains, while the synchronous machine acts as a motor drawing 4 kW from the ac mains. What is the total change in the power angle of the synchronous machine in this process? The field current of the synchronous machine is kept constant through out. Neglect all losses.

[12 marks]

Synch. (G) : $X_s = j25\ \Omega$

Case 1 : Synch. (G) deliver power to DC machine



$V_T = \frac{400}{\sqrt{3}}$

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

$I_a = \frac{4\times10^3}{\sqrt{3}\times400\times0.8}$

$= 7.217$ A

$\theta = \cos^{-1}(0.8) = 36.87°$

$\Rightarrow I_a = 7.217\angle-36.87°$ as lag. PF

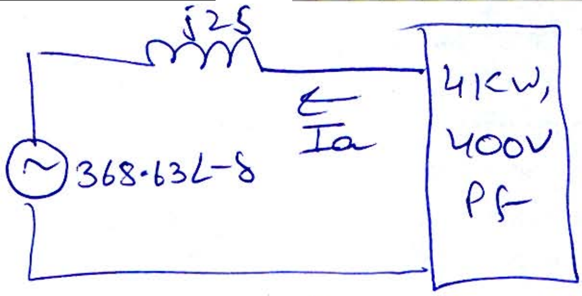
$\Rightarrow E_g\angle\delta = V_T + jI_aX_s = \frac{400}{\sqrt{3}} + j\times25\times7.217\angle-36.87$

$E_g\angle\delta = 368.63\angle23.05°$

so $E_g = 638.48$ V line to line

now I_f of DC (M) is ↑ and act as (G) and synch. M/c act as (M) with $E_g \rightarrow$ const.

ie



~~as P same ⇒ Ia cos Φ = const.~~

$$I_a = \frac{4\times10^3}{\sqrt{3}\times400\times Pf}$$

~~Pf same = 0.8~~

let Pf angle be θ

so ~~Ia cos θ~~ $|E| = \sqrt{(V\cos\Phi)^2 + (V\sin\Phi + I_a X_s)^2}$

or

$$E = \frac{400}{\sqrt{3}}\angle 0 - j25\times I_a = 368.63\angle-\delta$$

~~& $I_a = 7.217\angle-36.87°$~~

~~so $E = \frac{400}{\sqrt{3}} - j25$~~

now Pf becomes 0.8 lead as m/c delivers Power.

so $I_a = 7.217\angle 36.87°$

so

$$E = \frac{400}{\sqrt{3}}\angle 0 - j25\times7.217\angle36.87°$$

$E_2\angle-\delta_2 = 368.63\angle-23.05°$

$E_2 = E_1$ same [given is ques. also]

$\Rightarrow \delta_2 = -23.05°$

so Total change in Power angle

$= 23.05 - (-23.05)$

$= \underline{\underline{46.1°}}$

11

Good Approach

Q.2 (a) (i) For the 150 kVA, 2400/240 V transformer whose circuit parameters are given:

$R_1 = 0.2\ \Omega$; $R_2 = 2 \times 10^{-3}\ \Omega$

$X_1 = 0.45\ \Omega$; $X_2 = 4.5 \times 10^{-3}\ \Omega$

$R_i = 10\ k\Omega$; $X_m = 1.6\ k\Omega$ (as seen from 2400 V side)

Draw the circuit model as seen from the HV side. Determine there from the voltage regulation and efficiency when the transformer is supplying full load at 0.8 lagging power factor on the secondary side at rated voltage. Under these conditions calculate also the HV side current and its power factor.

[15 marks]

referring R_2 and X_2 to HV side

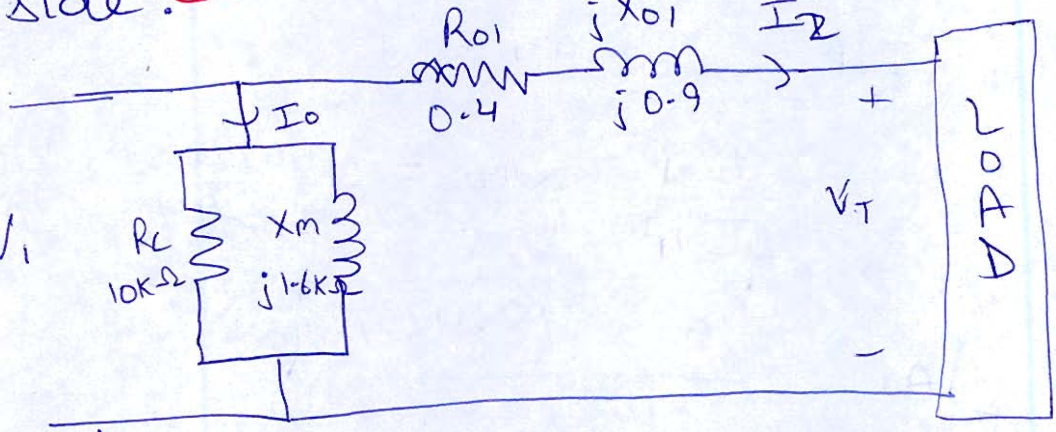
$$R_2' = 2 \times 10^{-3} \times \left(\frac{2400}{240}\right)^2 = 0.2$$

$$X_2' = 4.5 \times 10^{-3} \times \left(\frac{2400}{240}\right)^2 = 0.45$$

so $R_{01} = R_1 + R_2' = 0.4\ \Omega$

$X_{01} = X_1 + X_2' = j0.9\ \Omega$

so equivalent circuit refer to HV side:



full load : $V_T = 2400V$, 150 KVA, 0.8 pf lag [refer to HV side]

so $V_2' I_2' \cos\phi = 150 \times 10^3$

$$\Rightarrow I_2' = \frac{150 \times 10^3}{2400 \times 0.8}$$

$$I_2' = 78.125 \angle -36.87\ A$$

so $V_1 = V_2' + I_2'(R_{01} + jX_{01})$

$= 2400 + (0.4 + j0.9) \times 78.125\angle -36.87$

$V_1 = 2467.47\angle 0.87°$

and $I_0 = \frac{2467.47\angle 0.87}{10 \times 10^3} + \frac{2467.47\angle 0.87}{j1.6 \times 10^3}$

$I_0 = 1.561\angle -80°$

so by KCL: $I_1 = I_0 + I_2' =$ ~~79.27∠-36.84~~

$\Rightarrow I_1 = 79.27\angle -37.64°$ A

so angle btw V_1 & I_1 $= 0.87 - (-37.64)$

$= 38.51°$

$\Rightarrow$ Pf $= \cos 38.51 = 0.782$ lagg

Power I/P $= V_1 I_1 \cos\phi = 2467.47 \times 79.21 \times 0.782$

I/P $= 152.94$ KW

$\Rightarrow \eta = \frac{O/P}{I/P} \times 100 = \frac{150 \times 0.8}{152.94} \times 100$

(6)

$\eta = 78.46\%$

and

Voltage Reg $= \frac{|V_1| - |V_2'|}{|V_2'|} \times 100 = \frac{2467.47 - 2400}{2400}$

$\Rightarrow$ V.R $= 2.811\%$

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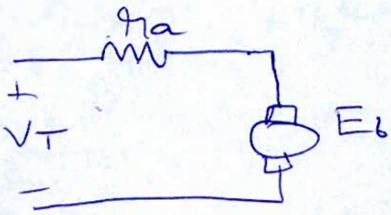
Q.2 (a) **(ii)** The armature resistance of a permanent magnet dc motor is 0.8 Ω. At no load, the motor draws 1.5 A from a supply voltage of 25 V and runs at 1500 rpm. Find the efficiency of the motor while it is operating on load at 1500 rpm drawing a current of 3.5 A from the same source.

[5 marks]

$r_a = 0.8$



@ no load:

$V_T = 25V$, $N = 1500 rpm$

$E_b = 25 - 1.5 \times 0.8 = 23.8V$

and rotational loss $= E_b I_a = 23.8 \times 1.5$
$= 35.7 W$

@ load, 1500 rpm:

$I_a = 3.5 A$

$\Rightarrow E_{b2} = 25 - 3.5 \times 0.8 = 22.2V$

$\Rightarrow P_{net} = E_{b2} I_{a2} = 3.5 \times 22.2$
$= 77.7 W$

$\Rightarrow P_{SH} = P_o = P_{net} - \text{rotational loss}$
$= 77.7 - 35.7$
$= 42 W$

$P_{I/P} = 25 \times 3.5 = 87.5 W$

So $\eta = \frac{O/P}{I/P} \times 100$

$= \frac{42}{87.5} \times 100 = 48\%$

$\Rightarrow \boxed{\eta = 48\%}$

5

Good Approach

Q.2 (b) (i) The following data are taken from the open circuit and short circuit characteristics of a 45 kVA, 3-ϕ, Y-connected, 220 V(L-L), 6 pole, synchronous machine. From the open circuit characteristics :

Line-to-line voltage (V_L) = 220 V

Field current (I_f) = 2.84 A

From the short circuit characteristics :

Armature current (A):	118	152
Field current (A):	2.20	2.84

From the air gap line :

Field current (I_f) = 2.20 A; Line to line voltage (V_L) = 202 V

Compute the unsaturated value of synchronous reactance, its saturated value at rated voltage and short circuit ratio.

Express the synchronous reactance in ohm per phase and in per unit on machine rating as base.

(ii) A 325 MVA, 26 kV, 60 Hz, 3-ϕ, salient synchronous generator is observed to be operating at power output of 250 MW and a lagging power factor of 0.89 at a terminal voltage of 26 kV. The generator synchronous reactances are X_d = 1.95 and X_q = 1.18, both in per unit. Calculate generated emf and load angle between the generator terminal voltage and generated emf.

[12 + 8 marks]

i) @ $I_f = 2.84$ $V_{oc} = 220V$ line to line

and $I_a = 152 A$

so

X_s saturated $= \frac{V_{oc}/\sqrt{3}}{152} = \frac{220/\sqrt{3}}{152} = 0.835\ \Omega$

Xs unsaturated is found using actual air gap line.

@ $I_f = 2.2$; $V_{oc} = 202$

$I_a = 118 A$

X_s unsaturated $= \frac{202/\sqrt{3}}{118} = 0.988\Omega$

Short circuit ratio (SCR) $= \frac{I_f \text{ for } V_{oc}}{I_f \text{ for rated } I} = \frac{I_{f1}}{I_{f2}}$

rated $I = \frac{45\times10^3}{\sqrt{3}\times220} = 118\ A$

so $I_{f2} = 2.2\ A$ & $I_{f1} = 2.84$

$\Rightarrow SCR = \frac{I_{f1}}{I_{f2}} = \frac{2.84}{2.2}$

(11) $\Rightarrow$ $\boxed{SCR = 1.29}$

now $Z_{base} = \frac{KV^2}{MVA} = \frac{220^2}{45\times10^3}$

Good Approach

$= 1.0755$

so

X_s saturated PU $= \frac{actual}{base} = \frac{0.835}{1.0755} = 0.776\ PU$

X_s unsaturated PU $= \frac{0.988}{1.0755} = 0.918\ PU$

---

ii) given: salient synch. (G)

325 MVA, 26 KV, 60 Hz 3 φ

$P_o = 250\ MW$ @ 0.89 lagg. pf

$V_T = 26\ KV$

$X_d = 1.95$ and $X_q = 1.18\ PU$

let base be 325 MVA, 26 KV

so $P_o = \frac{250}{325} = 0.769\ PU$

or $Z_b = \frac{26^2}{325} = 2.08$

actual values

$\Rightarrow X_d = 4.056\ \Omega$

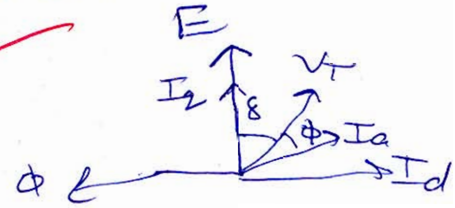
$X_q = 2.454\ \Omega$

$\sqrt{3} V_t I_a \cos\phi = 250\times10^6$

$\Rightarrow I_a = \frac{250\times10^6}{\sqrt{3}\times26\times10^3\times0.89}$

$I_a = 6237.57\ A$

and $\phi = \cos^{-1}(0.89) = 27.126°$



now

$I_q = I_a \cos\psi$

$I_d = I_a \sin\psi$

and

$\tan\psi = \frac{V_T \sin\phi + I_a X_q}{V_T \cos\phi + I_a R_a}$

$= \frac{\frac{26\times10^3}{\sqrt{3}}\times0.456 + 6237.57\times2.454}{\frac{26\times10^3}{\sqrt{3}}\times0.89 + 0}$

$\tan\psi = 1.658$

$\Rightarrow \psi = 58.9°$

and $\psi = \phi + \delta$

$\Rightarrow \delta = 58.9 - 27.126$

$\boxed{\delta = 31.78°}$

where δ is the load angle ie angle btw generated emf and voltage.

so $I_q = 6237.57 \cos 58.9 = 3221.91\ A$

$I_d = 6237.57 \sin 58.9 = 5341.02\ A$

so

$$E = V\cos\delta + I_q R_a + I_d X_d$$

$$\Rightarrow |E| = \frac{26\times10^3}{\sqrt{3}} \cos 31.78 + 5341.02\times 4.056$$

$$|E| = 34423.8\ V$$

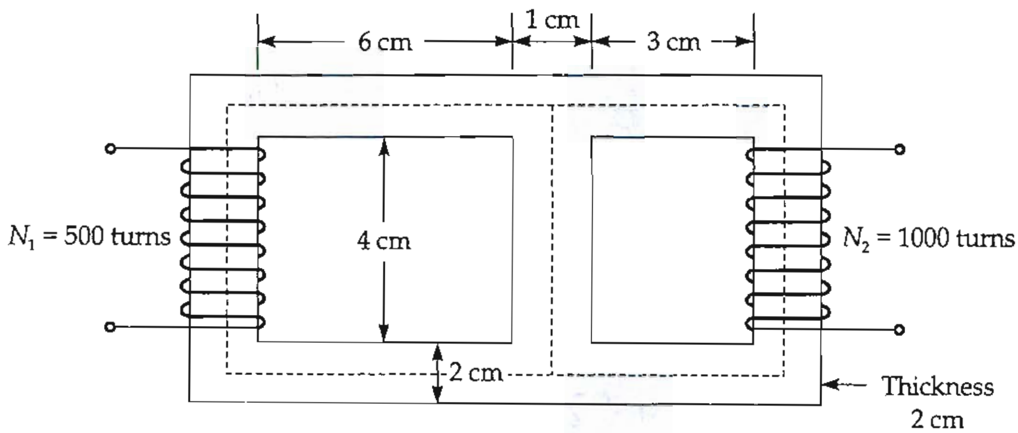
so $E = 34423.8 \angle 31.78^\circ$ = 34.42kV

so $E_{line} = 59623.76\ V$

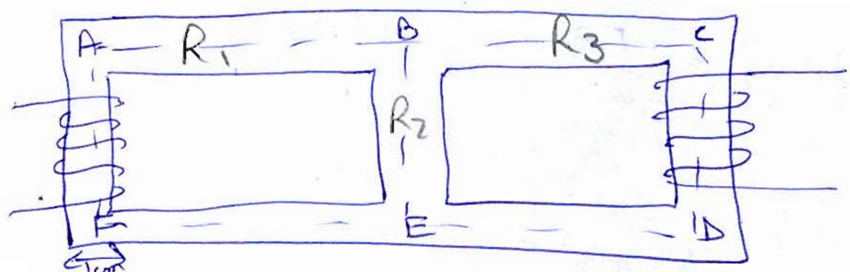
(8)

Good Approach

Q.2 (c) For the magnetic circuit shown below, find the self inductances and mutual inductance between the two coils (core permeability = 1600).



[20 marks]



so $l_{cR_1} = l_{AB} + l_{AF} + l_{FE} = 7 + 6 + 7 = 20\,cm$

$l_{cR_2} = l_{BE} = 6\,cm$ | $A_c = 4 \times 10^{-4}$

$l_{cR_3} = l_{BC} + l_{CD} + l_{DC} = 4 + 6 + 4 = 14\,cm$

$\Phi = \dfrac{Ni}{R_c}$ so $R_{c1} = \dfrac{1}{\mu_0 \mu_r} \dfrac{l_{cR_1}}{A}$

$= \dfrac{1}{4\pi \times 10^{-7} \times 1600} \times \dfrac{20 \times 10^{-2}}{4 \times 10^{-4}}$

$R_{c1} = 248679.6$

and

$R_{c2} = \dfrac{1}{\mu_0 \mu_r} \dfrac{l_{cR_2}}{A_c} = \dfrac{1}{4\pi \times 10^{-7} \times 1600} \times \dfrac{6 \times 10^{-2}}{4 \times 10^{-2}}$

$= 74603.88$

$R_{c3} = \dfrac{1}{\mu_0 \mu_r} \dfrac{l_{cR_3}}{A_c} = \dfrac{1}{4\pi \times 10^{-7} \times 1600} \times \dfrac{14 \times 10^{-2}}{4 \times 10^{-2}} = 174075.72$

let 1 A source be connected to i_1

$$\Phi_1 = \frac{N}{R_c} = \frac{500\times 1}{248679}$$ so $$R_{eff} = R_1 + \frac{R_2\times R_3}{R_2+R_3}$$

$$R_{eff} = 300902.316$$

so $$\Phi_1 = \frac{N_1 i_1}{R_{eff}} = \frac{500}{300902.316} = 1.66\times10^{-3}\ Wb$$

and flux in coil 2 due to 1

$$\Phi_{12} = \Phi_1 \times \frac{R_2}{R_2+R_3} = 4.985\times10^{-4}\ Wb$$

now $N\Phi = Li$

$$\Rightarrow \underline{L_1} = \frac{\Phi_1\times N}{i_1} = \frac{500\times1.66\times10^{-3}}{1} = \underline{0.83H}$$

now $$\underline{L_{12}} = \frac{N_2\Phi_2}{i_1} = 1000\times4.985\times10^{-4} = \underline{0.4985H}$$

now when i_2 is exited by 1 A source.

$$R_{eff} = R_3 + \frac{R_1\times R_2}{R_1+R_2} = 231463.32$$

(6) so $$\Phi_{net} = \Phi_2 = \frac{1000\times1}{231463.32} = 4.32\times10^{-3}\ Wb$$

and flux in coil 1 due to 2

(8) $$\Phi_{21} = \Phi_2\times\frac{R_2}{R_1+R_2} = 0.9969\times10^{-3}\ Wb$$

so $$L_2 = \frac{N_2\Phi_2}{i_2} = \frac{1000\times4.32\times10^{-3}}{1} = 4.32H$$

$$\Rightarrow \boxed{L_2 = 4.32\ H}$$ Wrong value calculated

and $$L_{21} = \frac{N_1\Phi_{21}}{i_2} = \frac{500\times0.9969\times10^{-3}}{1}$$

& $\boxed{L_1 = 0.83H}$ $\Rightarrow$ $\boxed{L_{21} = 0.498H}$

Q.3 (a) **(i)** The following data pertain to a 250 V DC series motor :

$$Z = 180, \frac{P}{A} = 1$$

$$\text{Flux/pole} = 3.75 \text{ mWb/field amp}$$

Total armature circuit resistance = 1 Ω

The motor is coupled to a centrifugal pump whose load torque is

$$T_L = 10^{-4}n^2 \text{ Nm where } n = \text{Speed in rpm}$$

Calculate the current drawn by the motor and the speed at which it will run for given load.

[15 marks]

Q.3 (a) (ii) A 4-pole, separately excited, wave wound DC machine with negligible armature resistance is rated for 230 V and 5 kW at a speed of 1200 rpm. If the same armature coils are reconnected to form a lap winding, what is the rated voltage (in volts) and power (in kW) respectively at 1200 rpm of the reconnected machine if the field circuit is left unchanged?

[5 marks]

Do not write in this margin

Q.3 (b) A 400 V, 4 pole, 1450 rpm, 50 Hz, Y-connected wound-rotor induction motor has the following circuit model parameters:

$R_1 = 0.3\ \Omega$; $R_2' = 0.25\ \Omega$; $X_1 = X_2' = 0.6\ \Omega$;

$X_m = 35\ \Omega$; Rotational loss = 1500 W

(i) Calculate the starting torque and current when the motor is started direct on full voltage.

(ii) Calculate the full-load current, power factor and torque.

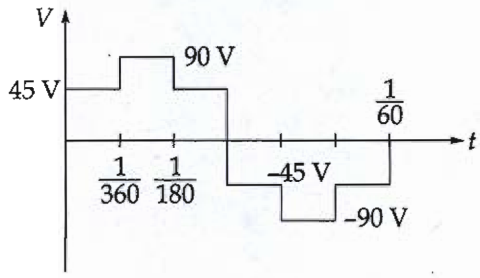
Also find internal efficiency and overall efficiency internal efficiency is defined as P_{out} (gross)/P_{in}; P_{out}(gross) = $(1 - s)P_G$.

(iii) Find the slip for maximum torque and the value of the maximum torque.

[20 marks]

Do not write in this margin

Q.3 (c) **(i)** A six-step voltage of frequency 60 Hz, as shown in figure, is applied on a coil wound on a magnetic core. The coil has 500 turns. Find the maximum value of flux and sketch the waveforms of voltage and flux as a function of time.



(ii) Find the number of series turns required for each phase of a 3-ϕ, 50 Hz, 10-pole alternator with 90 slots. Winding is to be connected to give a line voltage of 11 kV. The flux/pole is 0.16 Wb.

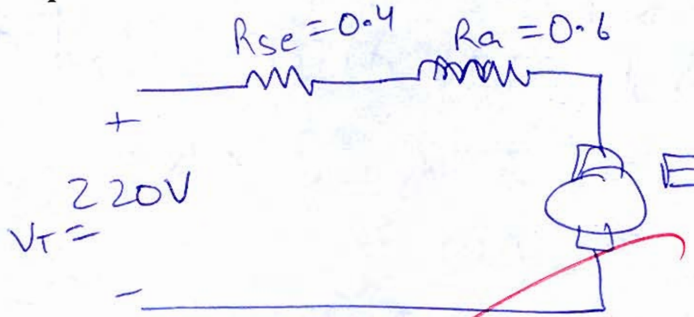
[15 + 5 marks]

Q.4 (a) (i) A 220 V, 7.5 kW series motor is mechanically coupled to a fan. When running at 400 rpm the motor draws 30 A from the mains (220 V). The torque required by the fan is proportional to the square of speed. $R_a = 0.6\ \Omega$, $R_{se} = 0.4\ \Omega$. Neglect armature reaction and rotational loss. Also assume the magnetization characteristic of the motor to be linear.

1. Determine the power delivered to the fan and torque developed by the motor.
2. Calculate the external resistance to be added in series to the armature circuit to reduce the fan speed to 200 rpm. Calculate also the power delivered to the fan at this speed.

[12 marks]

i) 1)



@ 400 rpm : $I_a = 30$ A

so $E_b = V_T - I_a(R_a + R_{se})$

$= 220 - 30(0.4 + 0.6)$

$E_b = 190$ V

$P_{out} = E_b \times I_a = 190 \times 30 = 5700$ W

as rotational loss neglected.

$\Rightarrow$ $P_{delivered\ to\ fan} = P_{out} = 5700$ W

and $T = \frac{60}{2\pi N} \times P_o = \frac{60}{2\pi\, 400} \times 5700$

$T = 136.07$ N m

2) Let Rext be added resistance

s.t $N' = 200$ rpm

$E_b \propto N\phi$ and $\phi \propto I_a$

so $\frac{E_{b2}}{190} = \frac{\cancel{200} \times I_{a2}}{2\,\cancel{400} \times 30}$

$\boxed{E_{b2} = 3.167\, I_{a2}}$

and $E_{b2} = V_T - I_a(R_a + R_{se} + R_{ext})$

also $T \propto N^2$

and $T \propto \phi I$ and $\phi \propto I_a$

$\Rightarrow T \propto I_a^2 \propto N^2$

$\Rightarrow I_a \propto N$

so $I_{a2} = 30 \times \frac{200}{400} = 15\,A$

$\Rightarrow E_{b2} = 47.5\,V$

$\Rightarrow 1 + R_{ext} = \frac{220 - 47.5}{15} = 11.5$

$\Rightarrow \boxed{R_{ext} = 10.5\,\Omega}$

and

$\boxed{P_{del} = P_{out} = 47.5 \times 15 = 712.5\,W}$

Good Approach

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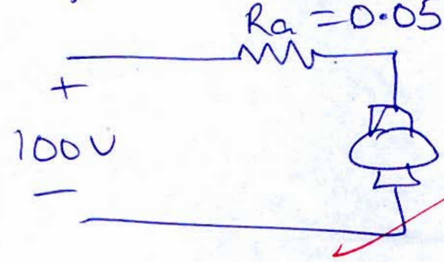
Q.4 (a) **(ii)** A separately excited DC motor has an armature resistance $R_a = 0.05\ \Omega$. The field excitation is kept constant. At an armature voltage of 100 V, the motor produces a torque of 500 Nm at zero speed. Neglecting all mechanical losses, the no-load speed of the motor (in radian/s) for an armature voltage of 150 V.

[8 marks]

ii) $I_f \rightarrow$ const. $\Rightarrow \phi \rightarrow$ const.



@ 100V, T = 500Nm
@ N = 0
$\Rightarrow E_b = 0$

so $I_a = \frac{100}{0.05} = 2000$

$T \propto \phi I_a$ as $\phi \rightarrow$ const.

$\Rightarrow T = K I_a$

$\Rightarrow K = \frac{500}{2000} = 0.25$

@ $V_T = 150V$

$E_b \propto N$ and $T \propto I_a$

$T = \frac{P}{\omega} = \frac{E_b I_a}{\omega}$

(8)

$E_b = 150 - I_a \times 0.05$

at no load $I_a = 0$

Good Approach

$\Rightarrow E_b = V_T = 150V$

and $E_b = K\omega$

$\Rightarrow \boxed{\omega = \frac{150}{0.25} = 600 \text{ rad/s}}$

Do not write in this margin

Q.4 (b) (i) A 100 kVA, 415 V (line-line), star-connected synchronous machine generates rated open circuit voltage of 415 V at a field current of 15 A. The short circuit armature current at a field current of 10 A is equal to the rated armature current. Find the per unit saturated synchronous reactance.

[8 marks]

i) $V_{OC(l-l)} = 415\text{V} \ @ \ I_f = 15\text{ A}$

$@ \ I_f = 10\text{ A} \rightarrow I_{a\,rated} = \dfrac{100 \times 10^3}{\sqrt{3} \times 415}$

$I_a = 139.12\text{ A}$

$@ \ I_f = 15\text{ A}$

$\Rightarrow I_a = 139.12 \times \dfrac{10}{15}$

$I_a = 92.747\text{ A}$

so

$X_{s\,saturated} = \dfrac{V_{OC} @ I_f = 15A}{I_a @ I_f = 15A}$

$= \dfrac{415/\sqrt{3}}{92.747} = 2.583\ \Omega$

and $Z_{base} = \dfrac{415^2}{100 \times 10^3} = 1.722$

$\Rightarrow X_{s\,sat}\ PU = \dfrac{\text{actual}}{\text{base}} = \dfrac{2.583}{1.722}$

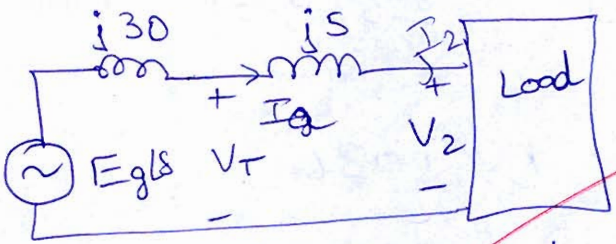
(5)

$\Rightarrow \boxed{X_{s\,sat} = 1.5\ PU}$

Q.4 (b) (ii) A 3-phase, 11 kV, 10 MVA synchronous generator is connected to an inductive load of power factor $(\sqrt{3}/2)$ via a lossless line with a per-phase inductive reactance of 5 Ω. The per-phase synchronous reactance of the generator is 30 Ω with negligible armature resistance. If the generator is producing the rated current at the rated voltage, find the power factor at the terminal of the generator.

[12 marks]

$Pf = \cos\phi = \frac{\sqrt{3}}{2} \Rightarrow \phi = 30^\circ$



Pf @ terminal of Generator

Generator produces rated current at rated voltage

so $I_a = \frac{S}{\sqrt{3}V_L} = \frac{10\times10^6}{\sqrt{3}\times10^3} = 524.86$ A

$V_T = \frac{11}{\sqrt{3}}\times10^3$ V

Let Pf angle be ϕ

~~Let V_T be $V_T\angle0^\circ$ as ref.~~

so $V_2 = V_T\angle\theta - I_a(j5)$

given angle btw V_2 and I_2 is 30° ie if $V_2 \to V_2\angle0^\circ$ then $I_2 \to I_2\angle{-30^\circ}$

now $|I_2| = |I_a|$

so $I_a = 524.86\angle{-30^\circ}$

$\because$ inductive load so lagg Pf

so

$V_T = V_2\angle0^\circ + j5\times524.86\angle{-30^\circ}$

$\frac{11}{\sqrt{3}}\times10^3\angle\theta = V_2\angle0^\circ + 2624.32\angle60^\circ$

$$\Rightarrow \frac{11\times10^3}{\sqrt{3}}\angle\theta = V_2\angle0^\circ + 2624.32\angle60^\circ$$

seperate real and img parts

$$\frac{11\times10^3}{\sqrt{3}}\cos\theta = V_2 + 2624.32\cos60$$

and

$$\frac{11\times10^3}{\sqrt{3}}\sin\theta = 2624.32\sin60^\circ$$

$$\Rightarrow \sin\theta = 0.35786$$

$$\Rightarrow \theta = 20.968^\circ$$

$$\Rightarrow V_T = V\angle20.968^\circ$$

and $I_a = 524.86\angle-30^\circ$

so Power factor angle at generator terminal $= 20.968 + 30^\circ$

$= 50.968$

$\Rightarrow$ Pf $= \cos 50.968 = \underline{0.63\text{ Pf lagg.}}$

Good Approach

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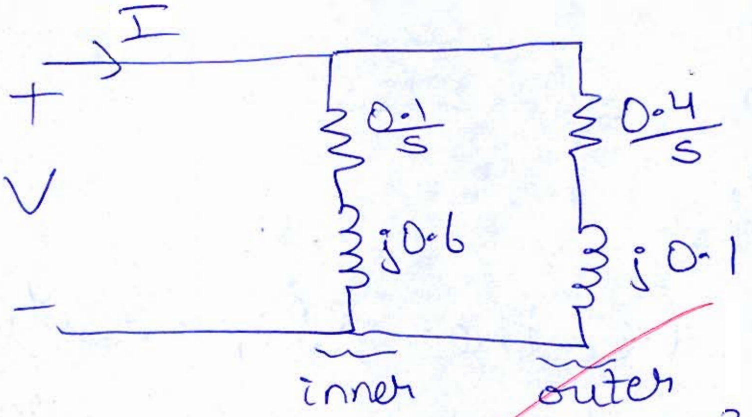
Do not write in this margin

Q.4 (c) A double cage, three-phase, 6-pole, *Y*-connected induction motor has an inner cage impedance of $(0.1 + j0.6)\ \Omega$/phase and an outer cage impedance of $(0.4 + j0.1)\ \Omega$/phase. Determine the ratio of the torque developed by the two cages at standstill and 5% slip. What is the slip at which the torque developed by the two cages is the same?

[20 marks]



$\frac{T_{inner}}{T_{outer}} = ?$

wk $T = \frac{3 \times 60}{2\pi N_s} \times \frac{V^2}{\left(\frac{R_2}{s}\right)^2 + X_2^2} \times \frac{R_2}{s}$

$\Rightarrow T \propto \frac{R_2/s}{\left(\frac{R_2}{s}\right)^2 + X_2^2}$

i) at standstill $s = 1$

$\Rightarrow T_{inner} \propto \frac{0.1}{(0.1)^2 + (0.6)^2} = 0.270$

$T_{outer} \propto \frac{0.4}{(0.4)^2 + (0.1)^2} = 2.353$

so

$\frac{T_{inner}}{T_{outer}} = \frac{0.270}{2.353}$

$\Rightarrow \boxed{\frac{T_{outer}}{T_{inner}} = 8.714}$

Wrong value calculated

ii) @ $s = 0.05$

$T_{outer} \propto \frac{\frac{0.4}{0.05}}{\left(\frac{0.4}{0.05}\right)^2 + 0.1^2} = 0.125$

$$T_{inner} \propto \frac{\frac{0.1}{0.05}}{\left(\frac{0.1}{0.05}\right)^2 + (0.6)^2} = 0.4587$$

$$\Rightarrow \boxed{\frac{T_{outer}}{T_{inner}} = 0.2725}$$

iii) Let s be the slip at which T developed by two cages is same

$$\Rightarrow \frac{T_{outer}}{T_{inner}} = \frac{0.4/s \Big/ \left(\frac{0.4}{s}\right)^2 + 0.1^2}{0.1/s \Big/ \left(\frac{0.1}{s}\right)^2 + 0.6^2} = 1$$

$$= \frac{0.4}{0.1} \times \frac{\left(\frac{0.1}{s}\right)^2 + 0.6^2}{\left(\frac{0.4}{s}\right)^2 + 0.1^2} =$$

$$= \frac{0.04 + 1.44s^2}{0.16 + 0.01s^2} = 1$$

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$$1.44s^2 - 0.01s^2 = 0.16 - 0.04$$

$$1.43s^2 = 0.12$$

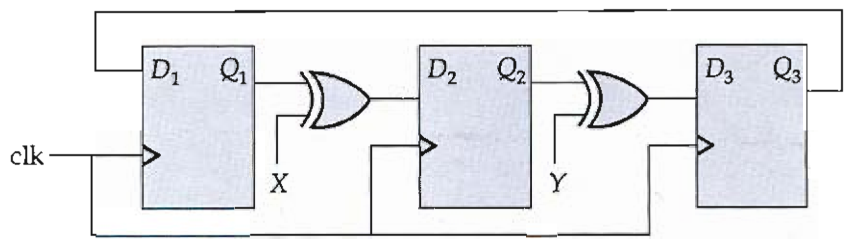
$$\Rightarrow s = \pm 0.2896$$

$$\Rightarrow \boxed{s = 28.96\%}$$ @ which torque developed by both is same.

Do not is @

Section B : Power Systems-1 + Digital Electronics-2 + Microprocessors -2

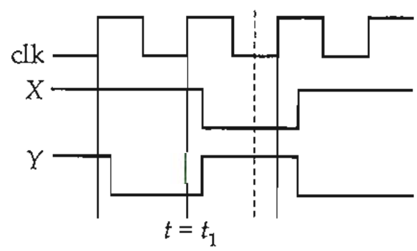
Q.5 (a) Consider the sequential circuit shown below:



(i) Fill in the table for the next state values of the three flip-flops for the given current state of the flip-flops and the inputs X and Y. Assume setup and hold times are synchronized with flip-flop inputs.

Q_1	Q_2	Q_3	X	Y	Q_1^+	Q_2^+	Q_3^+
0	0	0	0	1			
1	1	0	1	1			
0	0	1	1	0			

(ii) For the timing diagram shown below, what is the value of Q_1, Q_2 and Q_3 at the time indicated by the dashed line in the figure if the value at $t = t_1$ for $Q_1Q_2Q_3 = 001$? (Assume the flip-flops are negative edge triggered)



[12 marks]

i) so from sequential circuit.

$D_1 = Q_3$; $D_2 = Q_1 \oplus X$; $D_3 = Q_2 \oplus Y$

for D-Flip flop excitation eq^n is $Q^+ = D$

so

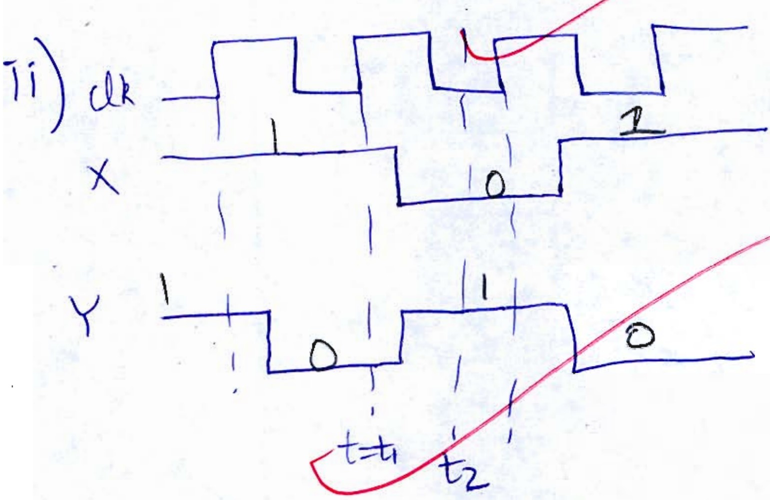
~~Q_1 Q_2 Q_3 X Y Q_1^+ Q_2^+ Q_3^+~~

so table

now $Q_1^+ = D_1$; $Q_2^+ = D_2$ and $Q_3^+ = D_3$

Q_1	Q_2	Q_3	X	Y	D_1	D_2	D_3	Q_1^+	Q_2^+	Q_3^+
0	0	0	0	1	0	0	1	0	0	1
1	1	0	1	1	0	0	0	0	0	0
0	0	1	1	0	1	1	0	1	1	0

ii)



to find Q_1, Q_2 and Q_3 at $t = t_2$

8

@ $t = t_1$: $Q_1 Q_2 Q_3 = 001$

and $X = 1$ and $Y = 0$

so $D_1 = 1$; $D_2 = 1$; $D_3 = 0$
$= Q_1$ $\quad = Q_2$ $\quad = Q_3$

so $Q_1^+ Q_2^+ Q_3^+ = 110$

at $t = t_2$ $X = 0$ and $Y = 1$

so $D_1 = Q_3 = 0$

$D_2 = Q_1 \oplus X = 1 \oplus 0 = 1$

$D_3 = Q_2 \oplus Y = 1 \oplus 1 = 0$

$\Rightarrow$ at $t = t_2$

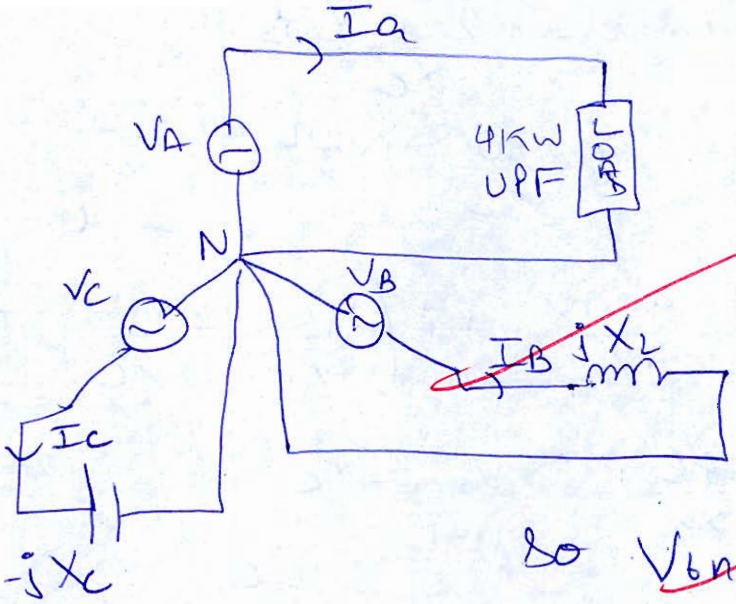
$\boxed{Q_1 = D_1 = 0}$; $\boxed{Q_2 = D_2 = 1}$

and $\boxed{a_3 = b_3 = 0}$

Do not write in this margin

Q.5 (b) A 230 V (Phase), 50 Hz, three-phase, 4-wire, system has a sequence *ABC*. A unity power-factor load of 4 kW is connected between phase *A* and neutral *N*. It is desired to achieve zero neutral current through the use of a pure inductor and pure capacitor in the other two phases. Find the value of inductor and capacitor.

[12 marks]



given:

$V_{an} = 230\angle 0$

as balanced 3 phase

so $V_{bn} = 230\angle -120°$

and $V_{cn} = 230\angle +120°$

so $I_a = \frac{4\times 10^3}{230\times 1} = 17.39\angle 0 \text{ A}$

let Pure inductor and capacitor be connected in phase B and C

now neutral current

$I_N = I_{an} + I_{bn} + I_{cn}$

reqd. $I_N = 0$

so $I_B = \frac{V_B}{jX_L} = \frac{230\angle -120°}{X_L\angle 90°}$

$= \frac{230}{X_L}\angle -210°$

and $I_C = \frac{V_C}{-jX_C} = \frac{230}{X_C}\angle +210°$

$\Rightarrow 17.39 + \frac{230\angle -210}{X_L} + \frac{230\angle +210}{X_C} = 0$

seperate in real and img. parts

$17.39 + \frac{230}{X_L}\cos 210 + \frac{230}{X_C}\cos 210$

$-j\frac{230}{X_L}\sin 210 + j\frac{230}{X_C}\sin 210 = 0$

$\left(17.39 - \frac{199.18}{X_L} - \frac{199.18}{X_C}\right) + j\left(\frac{115}{X_L} - \frac{115}{X_C}\right) = 0$

$\Rightarrow \frac{115}{X_L} = \frac{115}{X_C} \Rightarrow X_L = X_C$

$\omega L = \frac{1}{\omega C}$

$\Rightarrow \boxed{L = \frac{1}{(2\pi 50^2)C}}$ — ①

and using ①

$17.39 - \frac{199.18}{X_L} - \frac{199.18}{X_L} = 0$

$\Rightarrow 17.39 = \frac{2\times 199.18}{X_L}$

$\Rightarrow X_L = \frac{2\times 199.18}{17.39} = 13.706 = X_C$

$\Rightarrow L = \frac{13.706}{2\pi 50}$

$\Rightarrow \boxed{L = 43.627\ mH}$

and $\frac{1}{2\pi 50\times C} = 13.706 \Rightarrow \boxed{C = 0.232\ mF}$

or

$\boxed{C = 232.24\ \mu F}$

6

Do not write in this margin

Q.5 (c) Estimate the corona loss for a three-phase 110 kV, 50 Hz, 150 km long transmission line consisting of three conductors each of 10 mm diameter and spaced 2.5 m apart in an equilateral triangle formation. The temperature of air is 30°C and the atmospheric pressure is 750 mm of mercury. Take the irregularity factor as 0.85. Ionization of air may be assumed to take place at a maximum voltage gradient of 30 kV/cm.

[12 marks]

$r = 5 \times 10^{-3}\, m$

$D = 2.5\, m = 250\, cm$

as critical disruptive voltage is given as:

$V_c = m_o g r \delta \ln \frac{d}{r}$

given: $m_o = 0.85$

$g = \frac{30}{\sqrt{2}} = 21.21$ KV/cm (rms)

$r = 0.5$ cm $\quad b = 750\, mm = 750 \times 10^{-3} \times 100 = 75$ cm

$\delta = \frac{3.92 b}{T + 273} = \frac{3.92 \times 75}{30 + 273}$

$\delta = 0.97$

so substituting values

$V_c = 0.85 \times 21.21 \times 0.5 \times 0.97 \ln \frac{2.5 \times 10^2}{0.5}$

$= 8.7465 \ln 5 \times 10^2$

$\boxed{V_c = 54.356\, KV} \Rightarrow \boxed{V_c = 94.147\, KV}$ line to line

now $V_{ph} = \frac{110}{\sqrt{3}} = 63.5$ KV.

as $V_{ph} > V_c$ hence corona loss will occur now

$$P_c = 242.2 \times 10^{-5} \times \frac{(f+25)}{\delta} \sqrt{\frac{r}{d}} (V_{ph} - V_c)^2$$

$$P_c = 242.2 \times 10^{-5} \times \frac{75}{0.95} \times \sqrt{\frac{0.5}{250}} \times (63.5 - 54.356)^2$$

$$\boxed{P_c = 0.715 \text{ KW/Phase}}$$

for 3 Phase

$$\boxed{P_c = 2.145 \text{ KW}}$$

where P_c is corona Power loss

(8)

Wrong value calculated

Q.5 (d) Explain the mathematical function that is performed by the following instructions of 8085 microprocessor :

MVI A, 07H
RLC
MOV B, A
RLC
RLC
ADD B

[12 marks]

MVI A, 07H ⇒ Accumulator contains 07H ie 7 = 00000111

RLC → rotate ACC 1 bit left without carry.

ACC : 00001110

MOV B, A : content of ACC moved into register B

B = 00001110
ACC = 00001110

10

RLC → ACC : 00011100

RLC → ACC : 00111000

ADD B → ADD ACC with reg. B & store in ACC

ACC : 00111000
B : 00001110

ACC 01000110

so [ACC] = 0100 0110 = 46H
(0100 = 4, 0110 = 6)

so [ACC] = 46H

Q.5 (e) Show the RIM instruction format and discuss the same.

[12 marks]

RIM: is used to read Interrupt Mask of maskable interrupt.

In 8085 there are two types of Interrupts → maskable and Non maskable.

→ Non Maskable interrupts are: ~~RST~~ NMI | RST 4.5

→ Maskable interrupts are: RST 7.5, RST 6.5, RST 5.5 and INTR

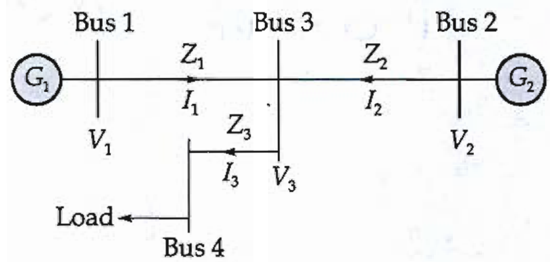
8

so with RIM instruction we can read the status of these maskable interrupts.

→ Maskable interrupts are those interrupts which can be ignored.

Q.6 (a) (i) Calculate the power loss in the transmission system given in the following figure. The numerical values of transmission system are :

$I_1 = 0.75\angle 0°$ pu, $I_2 = 0.8\angle 0°$ pu,
$V_3 = 1.2\angle 0°$ pu, $Z_1 = (0.07 + j0.15)$ pu,
$Z_2 = (0.06 + j0.20)$ pu, $Z_3 = (0.05 + j0.06)$ pu



[10 marks]

Power loss occurs in resistances.

so

loss in $Z_1 = I_1^2 r_1 = 0.75^2 \times 0.07$
$= 0.04$ PU

loss in $Z_2 = I_2^2 r_2 = 0.8^2 \times 0.06$
$= 0.0384$ PU

by KCL at bus 3:

$I_3 = I_1 + I_2 = 0.75\angle 0 + 0.8\angle 0$
$= 1.55\angle 0$

so loss in $Z_3 = I_3^2 r_3 = 1.55^2 \times 0.05$
$= 0.1201$ PU

so

Total Power loss $= 0.04 + 0.0384 + 0.1201$

$= 0.1985$ PU

Ans

9

Good Approach

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Q.6 (a) (ii) Calculate the real and reactive power at sending end of a transmission line while delivering 10 MVA load at 0.85 lagging power factor at receiving end of line. The line parameters are $A = 1$, $B = 12.12\angle 64.64^\circ\ \Omega$, $D = 1$ and receiving end voltage of line is 33 kV. (Assume the single phase line)

[10 marks]

$V_R = 33\,KV$

so $I_R = \dfrac{10\times10^6}{33\times10^3\times0.85} = 356.5\angle{-31.78^\circ}$

given $A = 1$; $B = 12.12\angle 64.64^\circ$, $D = 1$

short line, $Y = 0 \Rightarrow C = 0$

so $V_S = AV_R + BI_R$

$= 33\times10^3 + (356.5\angle{-31.78})(12.12\angle 64.64)$

$\boxed{V_S = 36.704\angle 3.66^\circ\ KV}$

(4)

and $I_S = CV_R + DI_R$

$\Rightarrow \boxed{I_S = I_R = 356.5\angle{-31.78^\circ}}$

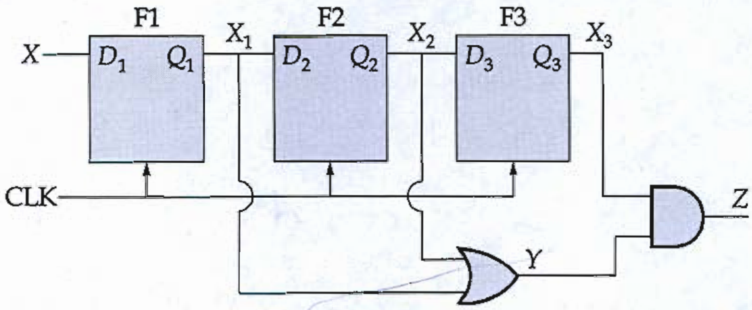
so $S = VI^* = (36.704\angle 3.66)(356.5\angle{-31.78})^*$ KVA

$= 10.66 + 7.587$ MVA

so $P_S = 10.66$ MW

& $Q_S = 7.587$ MVAR

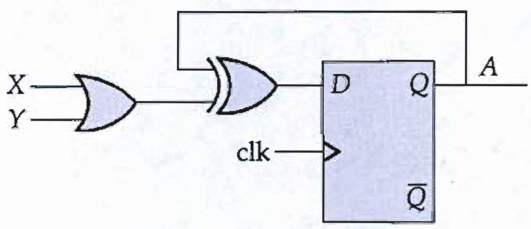
Q.6 (b) (i) A digital design is implemented by the circuit given below:



The design has D-type flip flops, F1, F2 and F3 driven by the clock 'CLK'. It has one input 'X' and one output 'Z'.

1. Find output logic expression for 'Z'.
2. Identify the functionality of the given circuit.

(ii) Analyze the logic circuit shown below and also draw the state diagram for the given circuit.



[10 + 10 marks]

i) $D_1 = X$; $D_2 = Q_1 = X_1$;

$D_3 = Q_2 = X_2$ and $Q_3 = X_3$

$Z = Q_3 \cdot Y$

and $Y = Q_1 + Q_2$

~~so truth table~~

so $\boxed{Z = Q_3(Q_1 + Q_2)}$

~~seeing truth table~~

let initial states of F_1 F_2 & F_3 be 0 0 0

let i/p applied in diff. clks be 0 1 0 1

when clk 1: $X = 0$; $Q_1 = D_1 = 0$

$Q_2 = D_2 = 0$; $D_3 = Q_3 = 0$

$Z = 0$

clk 2: $X = 1$

$Q_1 = D_1 = 1$; $Q_2 = 0$, $D_2 = 0$, $Z = 0$

clk 3: $X=0$; $Q_1=0$; $Q_2=1$, $Q_3=0$
$Y=1$; $Z=0$

clk 4: $X=1$; $Q_1=1$; $Q_2=0$, $Q_3=1$
$Y=1$ and $Z=1$

it behaves like shift register &
O/P → 1 when $Q_3=1$ and
~~out~~ either of Q_2 and Q_1 is 1.

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ii) truth table   let $Q_0=0$

X	Y	D	A
0	0		
0	1		
1	0		
1	1		

$D = A \oplus (X+Y)$

~~$D = A \oplus (X+Y)$~~

	Q	X	Y	D	$Q^+ = A$
0	0	0	0	0	0
1	0	0	1	1	1
2	0	1	0	1	1
3	0	1	1	1	1
4	1	0	0	1	1
5	1	0	1	0	0
6	1	1	0	0	0
7	1	1	1	0	0

	$\bar{X}\bar{Y}$	$\bar{X}Y$	XY	$X\bar{Y}$
$\bar{Q}$	0	1 (1)	1 (3)	1 (2)
Q	1 (4)	(5)	(7)	(6)

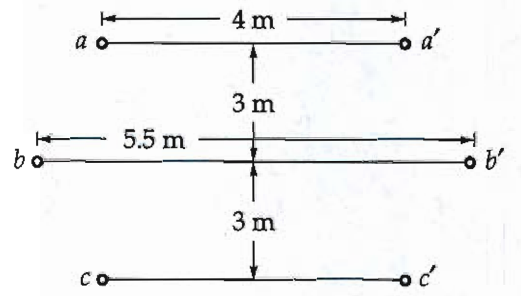
$$\Rightarrow \quad A = Q\bar{X}\bar{Y} + \bar{Q}Y + \bar{Q}X$$

$$A = Q\bar{X}\bar{Y} + \bar{Q}(Y+X)$$

6

Improve presentation

Q.6 (c) (i) Find the inductance per phase per km of double circuit 3-phase line shown in figure. The conductors are transposed and are of radius 0.75 cm each. The phase sequence is ABC.



[12 marks]

$r = 0.75 \times 10^{-2} m$

$$L = 2\times10^{-7} \ln \frac{D_m}{D_s}$$

where $D_m \to$ Mutual GMD
$D_s \to$ Self GMR

$D_m = (D_{m1} D_{m2} D_{m3})^{1/3}$

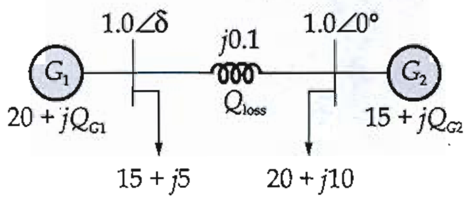
$D_s = (D_{s1} D_{s2} D_{s3})^{1/3}$

(1)

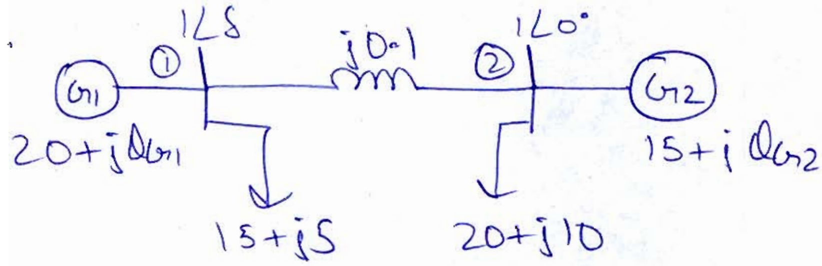
Incomplete solution

Do not write in this margin

Q.6 (c) (ii) Consider the two bus power system network with given loads as shown in the figure below. All the values shown in the figure are in per km unit. The reactive power supplied by generator G_1 and G_2 are Q_{G1} and Q_{G2} respectively. Find the per unit values of Q_{G1}, Q_{G2}, and line reactive power loss (Q_{loss}).



[8 marks]



@ bus ① Power balance

$P_{G1} = P_{D1} + P_{line}$

$P_{line} = 20 - 15 = 5$ — ①

and $Q_{G1} = 5 + Q_{line}$ — ②

Power balance at bus 2:

$P_{G2} = P_{D1} + P_{line}$

~~15 = 20~~ $P = 5$ PU supplied to load @ bus 2 by G1

reactive Power balance @ bus 2:

$Q_{G2} = Q_{line21} + 10$ — ③

reactive Power balance @ bus ①:

$Q_{G1} = 5 + Q_{line12}$ — ④

$Q_{line12} = Q_{line21}$

eq^n ③ − eq^n ④

$Q_{G2} - Q_{G1} = 5$ — ⑤

$P_{loss\,line} = 0 \Rightarrow I_{12} = \frac{1\angle\delta - 1}{j0.1}$

$S = 1\angle\delta\, I_2^* = 1\angle\delta\left(\frac{1\angle\delta - 1}{j0.1}\right)^*$

$= \frac{1\angle\delta-\delta+90}{0.1} - \frac{1\angle\delta+90}{0.1}$

$S_{12} = 10j + 10\sin\delta - j10\cos\delta$

~~now sinδ~~ so Acc. to Power flow

$10\sin\delta = 5.$

8

Good Approach

$\Rightarrow \delta = \sin^{-1}\left(\frac{1}{2}\right) = 30°$

&

$Q_{flow} = 10j - 10j\cos 30 = 1.34$ PU

so $I_{12} = \frac{1\angle 30 - 1}{j0.1} = 5 + j1.34$

$= 5.176\angle 15°$

so $Q_{loss} = I^2 X_C = 5.176^2 \times 0.1$

$Q_{loss} = 2.67$ PU

$\Rightarrow Q_{12} = Q_{21} = 1.335$ PU

$\Rightarrow$ in eq^n ③ $Q_{G2} = 10 + 1.335$

$Q_{G2} = 11.335$ PU

in eq^n ④ $Q_{G1} = 5 + 1.335 \Rightarrow Q_{G1} = 6.335$ PU

Q.7 (a) (i) Draw a schematic arrangement of Hydroelectric plant and explain its working in brief.

[10 marks]

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Q.7 (a) **(ii)** An overhead transmission line having a surge impedance of 500 Ω branches into two lines having a surge impedance of 40 Ω and 60 Ω respectively. If a travelling wave of vertical front and magnitude 100 kV travels along the overhead line, calculate the magnitude of voltage and current in the overhead line and in the two branches immediately after the travelling wave has reached the fork.

[10 marks]

Do not write in this margin

Q.7 (b) Design a digital sequence detector circuit to detect the sequence 0110 in a serial input signal, using D flip-flops. The sequence detector should produce an output 1 whenever it detects the sequence 0110 in the serial input signal, e.g.,

Serial Input X : 00110101101

Output Y : 00001000010

[20 marks]

Q.7 (c) Calculate 3-zone setting for

(i) Reactance relay,

(ii) Mho relay of 60°, for the following data :

CT : 400/1 A

PT : 132 kV/110 V

Impedance for first section is $(2.5 + j5)\Omega$ and that of second section is $(3.5 + j7)\Omega$. Assume first zone cover 80% of first section. Second zone covers first section plus 30% of the second section. The third zone covers the entire first zone plus 120% of the second section.

[20 marks]

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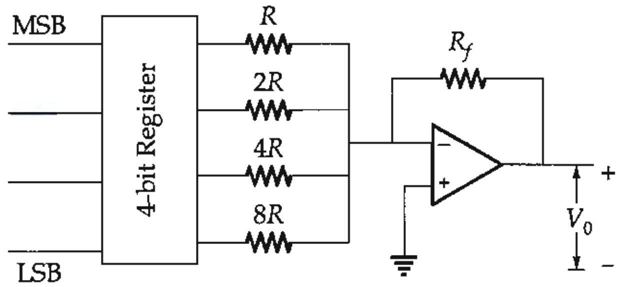
Q.8 (a) (i) Calculate the output voltage for an input code word 0110 if a logic 1 is 10 V and logic 0 is 0 V. Assume $R = R_f = 1\ k\Omega$.



[10 marks]

Q.8 (a) **(ii)** Describe memory segmentation in 8086 microprocessor with the help of block diagram.

[10 marks]

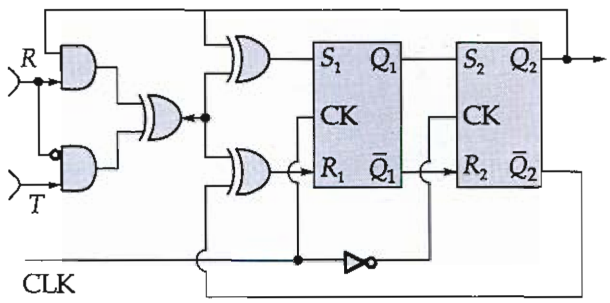
Q.8 (b) (i) In case of a circuit breaker, define the terms 'restriking voltage' and 'RRRV', and express their maximum values in terms of system voltage.

(ii) Which circuit breaker is preferred for voltages 132 kV and above?

(iii) In a 132 kV system, the reactance per phase up to the location of circuit breaker is 5 Ω and capacitance to earth is 0.03 μF. Calculate the maximum value of restriking voltage, the maximum value of RRRV and frequency of transient oscillation.

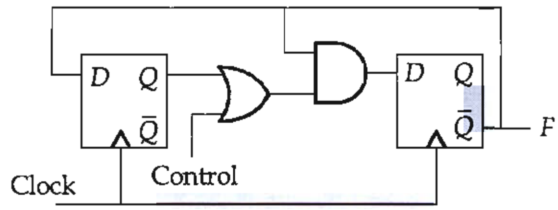
[20 marks]

Q.8 (c) (i) For the sequential logic circuit shown in figure express S_1 and R_1 as function of Q_2, R and T.



[10 marks]

Q.8 (c) (ii) The clock frequency of the digital circuit shown in the figure is 12 MHz. Find the frequencies of the output (F) corresponding to Control = 0 and Control = 1.



[10 marks]

OOOO

Space for Rough Work

$T \alpha SV$

$T \alpha \frac{SV^2}{R^2 r}$

Space for Rough Work