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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 :

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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	51
Q.2	
Q.3	45
Q.4	
Section-B	
Q.5	44
Q.6	40
Q.7	
Q.8	32
Total Marks Obtained	212

Signature of Evaluator: Sourabh kumar

Cross Checked by ....

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IMPORTANT INSTRUCTIONS

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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.
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4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

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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.
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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]

$E = 4.44 f N \phi$

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

For 20 Hz supply

$N_r = \frac{120 \times 20}{4} = 600$ rpm

(i) So There are two speed motor rotate to drive SRIM

$= N_s + N_r = 1500 + 600 = 2100$

$= N_s - N_r = 1500 - 600 = 900$

So 2 speeds are 2100 rpm & 900 rpm

11

Good Approach

(ii) at $N_r = 2100$, $s = \frac{N_s - N_r}{N_s} = \frac{1500 - 2100}{1500}$

$s_1 = \frac{-600}{1500} = -2/5$

at $N_r = 900$ $s_2 = \frac{1500 - 900}{1500} = \frac{600}{1500} = \frac{2}{5}$

$\frac{E_2}{E_1} = \frac{4.44 f_2 N \phi}{4.44 f_1 N_1 \phi_1} = \frac{s_2 f_2}{s_1 f_1} = \frac{s_2}{s_1} = \frac{-2/5}{2/5}$

$\boxed{\frac{E_2}{E_1} = -1}$ → Ans

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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]

if load torque = constant
so slip speed = constant means

$N_{s1} - N_{r1} = N_{s2} - N_{r2}$ —(1)

at rated freq = 50 Hz

$N_{s1} = \frac{120 \times 50}{4} = 1500$ rpm

$N_{r1} = 1440$ rpm

At speed 30 Hz $N_s = \frac{120 f}{P}$

$= \frac{120 \times 30}{4} = 900$ rpm

By eqn (1)

$1500 - 1440 = 900 - N_{r2}$

$60 = 900 - N_{r2}$

$N_{r2} = 840$ rpm → Ans

11

Good Approach

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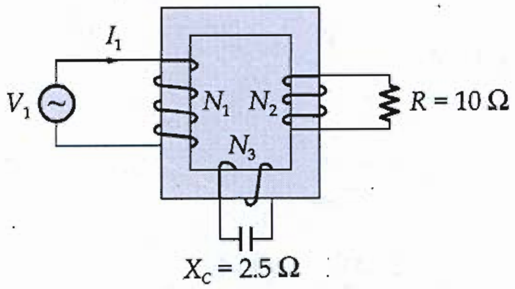
Q.1 (c) The figure shows an ideal three winding transformer windings are wound on the same core as shown. The turns ratio $N_1 : N_2 : N_3$ is 4 : 2 : 1. A resistor of 10 Ω is connected across winding-2. A capacitor of reactance 2.5 Ω is connected across winding-3. Winding-1 is connected across a 400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



[12 marks]

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

$V_1 = 400\angle 0°$

$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{4}{2} \Rightarrow V_2 = \frac{2}{4} V_1 = \frac{1}{2} \times 400\angle 0$

$V_2 = 200\angle 0°$

$\frac{V_1}{V_3} = \frac{N_1}{N_3} = \frac{4}{1} \Rightarrow V_3 = \frac{V_1}{4} = 100\angle 0$

$I_2 = \frac{V_2}{R} = \frac{200\angle 0}{10} = 20\angle 0$ Amp

$I_3 = \frac{V_3}{-jX_c} = \frac{100\angle 0}{2.5\angle -90} = 40\angle 90°$

As we know complex power addition formula

$\vec{S_1} = \vec{S_2} + \vec{S_3}$

$V_1 I_1^* = V_2 I_2^* + V_3 I_3^*$

$I_1^* = \frac{V_2}{V_1} I_2^* + \frac{V_3}{V_1} I_3^* = \frac{N_2}{N_1} I_2^* + \frac{N_3}{N_1} I_3^*$

$I_1^* = \frac{200}{400} I_2^* + \frac{100}{400} I_3^* = \frac{I_2^*}{2} + \frac{I_3^*}{4}$

$I_1^* = \frac{I_2^*}{2} + \frac{I_3^*}{4}$

$= \left(\frac{20}{2}\right)^* + \left(\frac{40\angle 90}{4}\right)^* = 10 + 10\angle -90$

$= 10 - 10j = 10\sqrt{2}\angle -45$

$I_1 = 10\sqrt{2}[\angle 45]$

$\boxed{I_1 = 10 + 10j}$ → Ans

7

Good Approach

Do not write in this margin

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]

1ϕ.

50 KVA, 250/500 V 2wdg X^r $\eta = 95\%$ fL upf.

For Auto X^r 500/750 V.

To find η at new rated load of upf.

Now for 500/750 Auto x^r

$$a = \frac{750}{500}$$

$$KVA_{auto} = \frac{a}{a-1} \times KVA_{2wdg}$$

$$= \frac{750}{750-250} \times 50 = 150\,KVA.$$

$$\text{Also } \eta = 0.95 = \frac{50 \times 10^3 \times 1}{50 \times 10^3 + \text{losses}}$$

$$\text{Loss} = 50 \times 10^3 \left(\frac{1}{0.95} - 1\right) = 2.63 \times 10^3\,W$$

Losses remained same if same 2wdg X^r reconfigured as auto X^r.

Now new efficiency of Auto X^r $\eta = \frac{P_{out}}{P_{in}}$

$$\eta = \frac{150 \times 10^3}{150 \times 10^3 \times 1 + \text{Loss}} = \frac{150 \times 10^3 \times 1}{150 \times 10^3 + 2.63 \times 10^3}$$

$$\boxed{\eta = 98.27\%}$$

Good Approach

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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]

Given: 5 KVA · X = 25 Ω } Sync. Gr.
400V
50Hz

deliver
Dc motor · 4kW
400V at 0.8 pf lag.

$I_{motor} = \frac{4000}{400 \times 0.8} = 10\angle -36.86 \cdot 12.5 \angle 36.86$

$E_g = V_t + I_a Z_s = V_t + j I_a X_s$

$= \frac{400}{\sqrt{3}} + 7.216\angle -36.86 \times 25\angle 90 = 368.61\angle 23.07°$ V

$I_{asq} = \frac{5 \times 10^3}{\sqrt{3} \times 400} = 7.216$

Now for motor

$E_b = V - I_a r_a = 400V - I_a(0) = 400$

Now for $E_b = E_g$

$E_g = V_t + I_a Z_s$

$400 \angle \delta =$

$I_{motor} = 12.5\angle{-36.86}$

$E_g = V_t + I_a Z_s$

$= 400 + 12.5\angle{-36.86}\,(25\angle{90}) = 638.45\angle{23.05}$

So change in Power Angle

$= 23.05 - 0 = 23.05$

↳ Ans

7

Try to avoid overwriting

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

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

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

$R_i = 10\ \text{k}\Omega$; $X_m = 1.6\ \text{k}\Omega$ (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]

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]

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

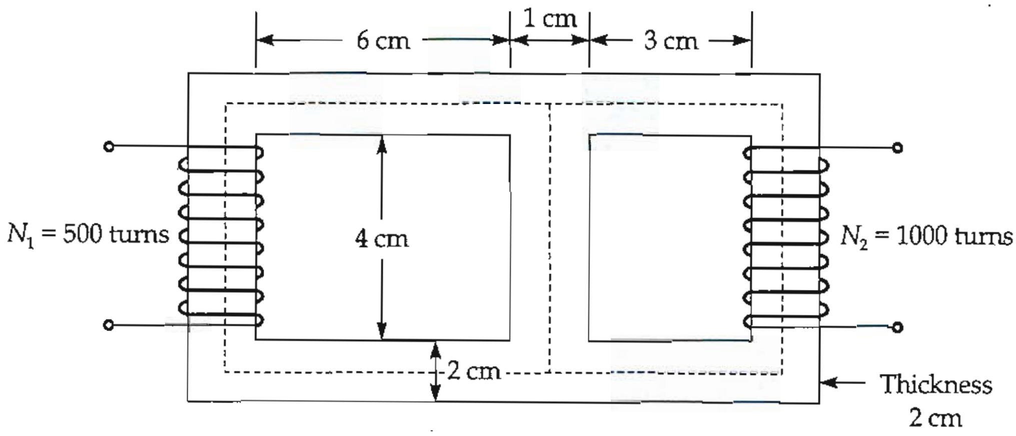
Compute the unsaturated value of synchronous reactance, its saturated value at rated voltage and short circuit ratio.

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]

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]

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

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

Flux/pole = 3.75 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]

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

$\phi/\text{pole} = 3.75 \times 10^{-3} \frac{\text{wb}}{\text{field Amp}}$ $\Rightarrow \phi = 3.75 \times 10^{-3} I_a$

$r_a = 1\Omega$

$T_L = 10^{-4} n^2$ Nm

$E_b = V - I_a r_a$ (Emf equation for DC Series moto

$E_b = 250 - I_a(1)$ — (1)

$E_b = \frac{NP\phi}{60}\frac{Z}{A} = \frac{P}{A} \cdot n \frac{Z\phi}{60} = 1 \times \frac{180}{60} \phi n$

$E_b = 3\phi n = 3n \times 3.75 \times 10^{-3} I_a$

Torque Eqn $= \frac{E_b I_a}{\omega}$

$\frac{(3n \times 3.75 \times 10^{-3} I_a) I_a}{2\pi \frac{n}{60}} = T_e$ (electromagnetic torque)

$0.107 I_a^2 = T_e$

Also At steady state

$T_L = T_e$

$10^{-4} n^2 = 0.107 I_a^2$

$$\frac{n^2}{I_a^2} = \frac{0.107}{10^{-4}}$$

$n = 32.77 I_a$

$$E_b = \frac{3n \times 3.75}{1000} I_a = 0.368 I_a^2.$$

Put Above value of Eb in eq^n(1)

$0.368 I_a^2 = 250 - I_a.$

$0.368 I_a^2 + I_a - 250 = 0$

$I_a = 24.74, -27.45$ Amp

So Current drawn by motor at

$= 24.74A.$ → Ans

Also speed at which Run

$= n = 32.77 I_a =$

$= 810.729$ rpm

→ Ans

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Good Approach

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]

$P = 4$, $A = 2$

$V = 230V$, $P = 5kW$ $N = 1200 rpm$

If same Arm. connected lap winding

$E_b = \frac{NP\phi}{60}\frac{Z}{A} = \frac{1200 \times 4}{60} \times \frac{Z\phi}{A}$

$\frac{E_{b\,lap}}{E_{b\,wave}} = \frac{A_{wave}}{A_{lap}} = \frac{2}{P} = \frac{2}{4}$

~~$E_{b\,wave} = 230V - I_a r_a$~~

$I_a = \frac{P}{V} = \frac{5000}{230} = 21.73$

$R = \frac{V^2}{P} = 10.58$

~~$E_{b\,wave} = 230 - 21.73 \times 10.58 = 229.90$~~

$E_{b\,lap} = E_{b\,wave} \times \frac{1}{2} = 115V$ ↳ Ans

Power $= I_{lap}^2 R_{lap} = V_{lap} I_{lap} = V_{wave} I_{wave}$

so Power remain same in lap winding

$= 5kW$

↳ Ans

5

Good Approach

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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 $P_{out}\,(\text{gross})/P_{in}$; $P_{out}(\text{gross}) = (1-s)P_G$.

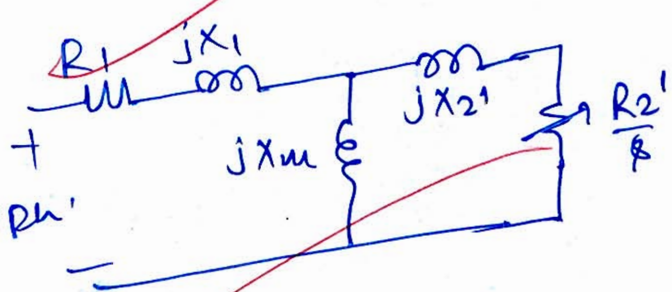
(iii) Find the slip for maximum torque and the value of the maximum torque.

[20 marks]

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

$N_r = 1450\ \text{rpm}$

$s = \frac{N_s - N_r}{N_s} = \frac{1500 - 1450}{1500} = \frac{50}{1500} = \frac{1}{30}$



$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94$ volt

Ist current $= \frac{V_{ph}}{R_1 + jX_1 + Z_{eq}}$

$Z_{eq} = jX_m \parallel \left(jX_2' + \frac{R_2'}{s}\right)$

At starting $s = 1$

$Z_{eq} = j35 \parallel (j0.6 + 0.25) = \frac{(0.25 + j0.6)(j35)}{0.25 + j35.6}$

$= 0.639\angle 67.78$

$$I_{st} = \frac{230.94\angle 0}{0.3 + j0.6 + 0.639\angle 67.78}$$

$$\boxed{I_{st} = 176.43\angle -65.55 \text{ A}}$$

$$T_{st} = \frac{3}{\omega_s} I_{st}^2 \frac{R_2'}{s}.$$

$$\omega_s = \frac{4\pi f}{P} = 50\pi = 157.07 \text{ rad/sec}.$$

$$T_{st} = \frac{3}{157.07} \times (176.43)^2 \times 0.25$$

$$\boxed{T_{st} = 148.62 \text{ Nm}} \leftarrow \text{Ans.}$$

(ii) To find I_{fl}, pf & Torque.

$$\frac{R_2'}{s_{fl}} = \frac{0.25}{1/30} = 7.5\Omega.$$

$$Z_{eq} = jX_m \parallel (7.5 + j0.6) = j35 \parallel (7.5 + j0.6).$$

$$= 7.238\angle 16.47 = 6.941 + j2.05$$

$$I_{fl} = \frac{V_{ph}}{R_1 + jX_1 + Z_{eq}} = \frac{230.94\angle 0}{0.3 + j0.6 + 7.238\angle 16.47}$$

$$\boxed{I_{fl} = 29.94\angle -20.11 \text{ Amp.}}$$

$$\text{Power factor} = \cos \angle V \,\&\, I_{fl}$$

$$= \cos[0 - (-20.11)] = 0.939 \text{ lagging}$$

$$\text{Torque} = \frac{3}{\omega_s} I_{fl}^2 \frac{R_2'}{s_{fl}}.$$

$$= \frac{3}{157.07} (29.94)^2 \times 7.5 = 128.4 \text{ Nm}.$$

$P_{in} = \sqrt{3} V_L I_L \cos\phi = \sqrt{3} \times 400 \times 29.94 \cos 20.11$

$= 19.478$ kW

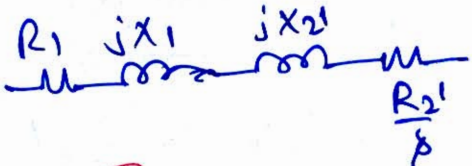
$P_{dev} = P_g(1-s) = 3 I_{2}'^2 \frac{R_2}{s}(1-s) = 18.046$

$P_{shaft} = P_{dev} - \text{Rot Loss} = 18.046 - 1.5 = 16.546$

Internal efficiency $= \frac{P_{out,gross}}{P_{in}} = \frac{18.046}{19.478} = 92.64\%$ → Ans

Overall efficiency $= \frac{P_{sh}}{P_{in}} = \frac{16.546}{19.478} = 84.94\%$ → Ans

(iii) Slip for Max^m Torque



$S_{MT} = \frac{R_2'}{\sqrt{R_1^2 + (X_1+X_2')^2}}$

$= \frac{0.25}{\sqrt{0.3^2+(0.6+0.6)^2}} = 0.202$

$T_{max} = \frac{3V_{th}^2}{2\omega_s X_2'} = \frac{3 \times 230.94^2}{2 \times 157.07 \times 0.6}$

$= 848.877$ N-m → Ans

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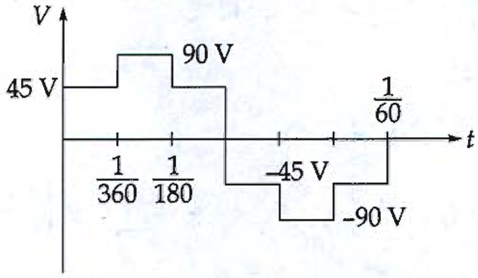
Q.3 (c) (i) A six-step voltage of frequency 60 Hz, as shown in figure, is applied on a coil wound on a magnetic core. The coil has 500 turns. Find the maximum value of flux and sketch the waveforms of voltage and flux as a function of time.



(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]

(ii) No of Series turns

$f = 50 Hz$

$P = 10 \quad S = 90$

$V_L = 11 kV \quad \phi/pole = 0.16 wb$

$E_{ph} = 4.44 f N \phi K_w$

$K_w = K_c K_d$

$E_{line} = \sqrt{3} E_{ph}$

$E_{ph} = \frac{11 \times 10^3}{\sqrt{3}} = 4.44 \times 50 \times N_{se} \times 0.16 K_{eq}$

$K_d = \frac{\sin \frac{m\beta}{2}}{m \sin \frac{\beta}{2}}$, $\quad \beta = \frac{180}{\frac{slot}{pole}} = \frac{180}{\frac{90}{10}} = 20$

$m = slot/pole/phase$

$= 90/10/3 = 3$

$K_d = \frac{\sin\left(\frac{3 \times 20}{2}\right)}{3 \sin\left(\frac{20}{2}\right)}$

$= \frac{1}{6 \sin 10} = 0.959$

$6350.85 = 4.44 \times 50 \times 0.16 \times 0.959 \times N_{se}$

$N_{se} = 186.34$

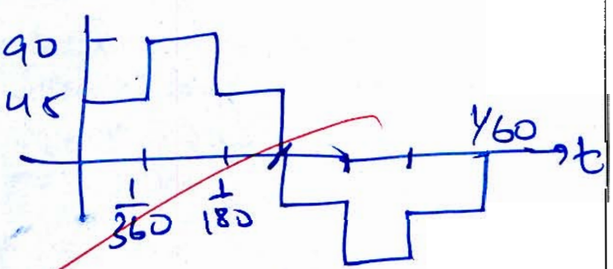
No of series turns required = 186 turns ↳ Ans

187

(5)

4) $f = 60Hz$, $N = 500$

To find Max^m value of flux as f^n of time



we know

$E = N\frac{d\phi}{dt}$

$E_{max} = N\frac{d\phi}{dt}$

$N d\phi = V dt$

$500 d\phi =$ Area under V-t curve

$\frac{1}{360} = \frac{1}{6 \times 60}$

$\frac{1}{180} = \frac{1}{3 \times 180}$

$\frac{1}{120} =$

Total Area for +ve cycle

$= 45 \times \left(\frac{1}{360} - 0\right) + (90-45)\left[\frac{1}{180} - \frac{1}{360}\right] + 45\left[\frac{1}{120} - \frac{1}{180}\right]$

$= \frac{45}{360} + 45\left[\frac{1}{360}\right] + 45\left[\frac{3-2}{360}\right]$

$= \frac{3 \times 45}{360} = \frac{135}{360} = \frac{9}{24} = \frac{3}{8}$

$d\phi = \frac{3}{8 \times 500} = \frac{3}{4000}$

$\int d\phi = \frac{3}{4000}$

$\phi_{max} = 0.75$ mweb → Ans

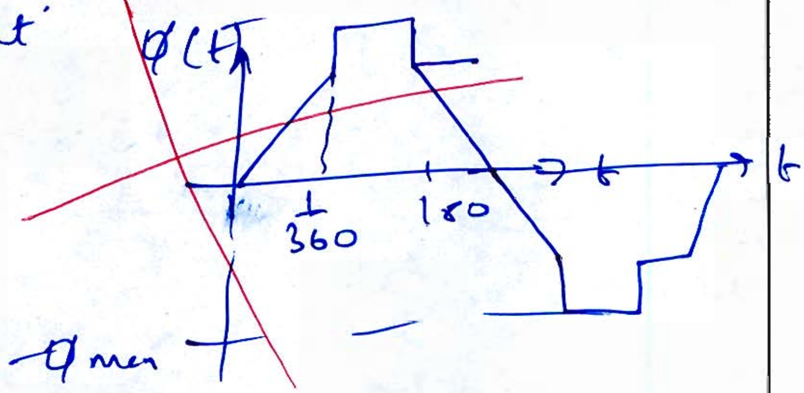
for $0 < t < \frac{1}{360}$ $v(t) = 45$

$\int N d\phi = \int 45\, dt$

$\phi = \frac{45}{500} dt = 0.09t$

$\frac{1}{360} < t < \frac{1}{180}$

$N d\phi = (10 - 45)\, dt$



6

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]

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]

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]

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.

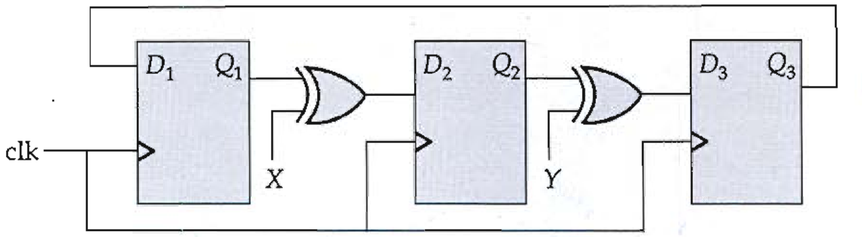
[12 marks]

Q.4 (c) A double cage, three-phase, 6-pole, Y-connected induction motor has an inner cage impedance of $(0.1 + j0.6)\ \Omega/\text{phase}$ and an outer cage impedance of $(0.4 + j0.1)\ \Omega/\text{phase}$. 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]

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

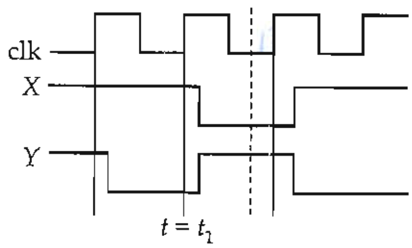
Q.5 (a) Consider the sequential circuit shown below:



(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]

$D_2 = Q_1 \oplus X$

$D_3 = Q_2 \oplus Y$

$D_1 = Q_3$

Present State

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

↳ Ans

$X=0, Y=1$ D_1 0 | $D_2 = Q_1 \oplus X = 0 \oplus 0 = 0$ | $D_3 = Q_2 \oplus Y = 0 \oplus 1 = 1$.

$X=1, Y=1$ $D_1 = Q_3$ 0 | $D_2 = Q_1 \oplus X = 1 \oplus 1 = 0$ | $D_3 = Q_2 \oplus Y = 1 \oplus 1 = 0$

$X=1, Y=0$ $D_1 = Q_3$ 1 | $D_2 = Q_1 \oplus X = 0 \oplus 1 = 1$ | $D_3 = Q_2 \oplus Y = 0 \oplus 0 = 0$

We know characteristics Eq^n of D-flip flop

$Q_{n+1} = D$

ii) To find $Q_1 Q_2 Q_3$

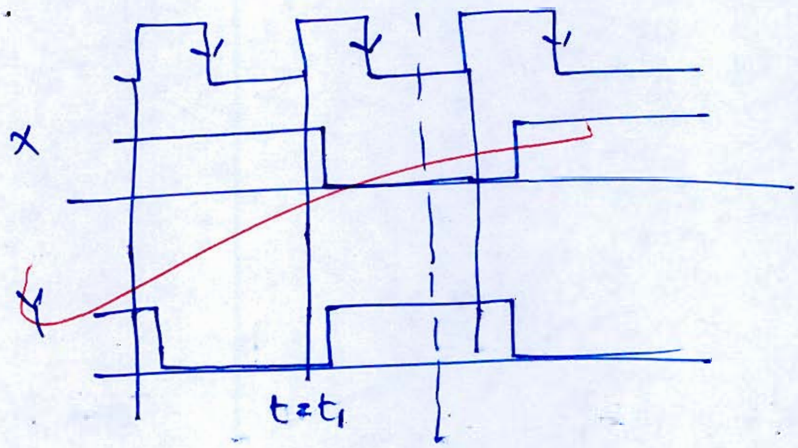
If $t = t_1$ $Q_1 Q_2 Q_3 = 001$, | at t_1 $X=1, Y=0$ By seeing figure

	Q_1	Q_2	Q_3	X	Y	Q_1^+	Q_2^+	Q_3
at t_1	0	0	1	1	0	1	1	0.

So at dashed line:

$X=0, Y=1$ (By observing figure).

If flip flop -ve edge triggered.



At dashed line previous state

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

so After Applying -ve edge

$Q_1 Q_2 Q_3$ at dashed line = 101

↳ Ans

11

Good Approach

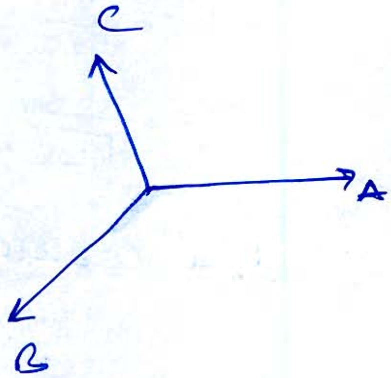
Do not write in this margin

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

$V_{ph} = 230V$ 50 Hz 4 wire



$I_{AN} = \frac{V_{AN}}{Z_{AN}}$

For acheive zero neutral current

Condition is $I_N = I_{a0} = \frac{1}{3}(I_a + I_b + I_c) = 0$

$I_A + I_B + I_C = 0$

$\frac{V_{AN}}{Z_{AN}} + \frac{V_{BN}}{Z_{BN}} + \frac{V_{CN}}{Z_{CN}} = 0$

let L connect at phase B & C connect at phase C

$V_{AN} = V\angle 0 = 230\angle 0$

$V_{BN} = V\angle -120$

$V_{CN} = V\angle 120$

A/c to Q^n upf load = 4 kW = 4000

$P = \frac{3V_{ph}^2}{R} \Rightarrow \frac{3 \times 230^2}{4000} = R \Rightarrow, \quad R = 39.675\Omega$

$\frac{V\angle 0}{R} + \frac{V\angle -120}{j\omega L} + \frac{V\angle 120}{\frac{-j}{\omega C}} = 0$

$\frac{1}{R} + \frac{1}{\omega L}\angle -120-90 + \omega C\angle 120+90 = 0$

$\frac{1}{R} + \frac{1}{\omega L}[\angle -210] + \omega C\angle 210 = 0$

$\frac{1}{R} + \frac{1}{\omega L}[\cos 210 - j\sin 210] + \omega C[\cos 210 + j\sin 210] = 0$

Do not write in this margin

$\frac{1}{R} + \frac{\cos 210}{\omega L} + \omega C \cos 210 = 0$
$-\frac{1}{\omega L} \sin 210 + \omega C \sin 210 = 0$
} by equating real & imaginary terms.

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

$\omega = \frac{1}{\sqrt{LC}}$

$\frac{1}{R} + \cos 210 \left[\frac{1}{\omega L} + \omega C\right] = 0$

$\frac{1}{R} + \cos 210 \left[\frac{2}{\omega L}\right] = 0$

$\frac{1}{R} - \frac{\sqrt{3}}{2} \times \frac{2}{\omega L} = 0 \Rightarrow \frac{1}{R} = \frac{\sqrt{3}}{\omega L}$

$\omega L = \sqrt{3} R$

$L = \frac{R\sqrt{3}}{\omega} = \frac{39.675\sqrt{3}}{2\pi 50} = 0.218 H$

$C = \frac{1}{\omega^2 L} = \frac{1}{4\pi^2 (50)^2 \times 0.218} = 46.47 \mu F$

So $R = 39.675 \Omega$, $L = 0.218 H$, $C = 46.47 \mu F$
↳ Ans

6

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]

$T = 30°C = 30 + 273 = 303 K.$

$m = 0.85$

$E_{max} = 30 \frac{kV}{cm}.$

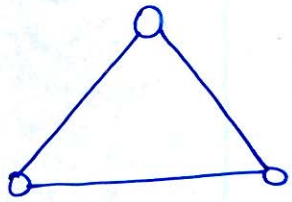
$\delta = \frac{3.92b}{T+273}$ = $\frac{3.92 \times 750 \times 10^{-3}}{303}$ = $9.7 \times 10^{-3} \times 746$ = 7.236"

corona loss formulae

$P = 242.5 \left[\frac{f+25}{\delta}\right] \sqrt{\frac{r}{d}} (V_{ph} - V_c)^2 \times 10^{-5}$ kW/km/ph

(d = 10 mm diameter)

$d = 2.5 m$



$r = \frac{10 mm}{2} = 5 mm$

$\sqrt{\frac{r}{d}} = \sqrt{\frac{5 mm}{2.5 m}} = \sqrt{\frac{1}{500}}$

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{110 kV}{\sqrt{3}} = 63.5 kV$

$V_c = m g \delta r \ln\frac{d}{r} = 0.85 \times 21.2 \frac{kV}{cm} \times 9.7 \times 10^{-3} \times 5 \times 10^{-3} \times \ln\frac{d}{r}.$

$= 0.85 \times 21.2 \times 10^{-2} \times 9.7 \times 10^{3} \times 5 \times 10^{-3} \ln\sqrt{500}$

$= 2715.69 \times 10^{-2-3-3}$

$V_c = 20.25$ kV.

$P_c = 242.5 \left(\frac{50+25}{7.236}\right) \sqrt{\frac{1}{500}} (63.5 - 20.25)^2 \times 10^{-5}$ kW/km/ph.

$P_{corona} = 2.1$ kW/km/ph

For 3ϕ-, 180 km

| $P_{corona} = 946.18$ kW | → Ans

(6)

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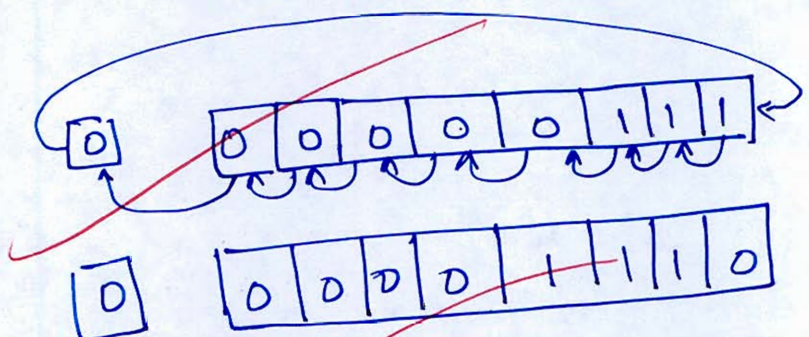
Q.5 (d) Explain the mathematical function that is performed by the following instructions of 8085 microprocessor :

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

[12 marks]

[A] = 07H = 0000 0111.

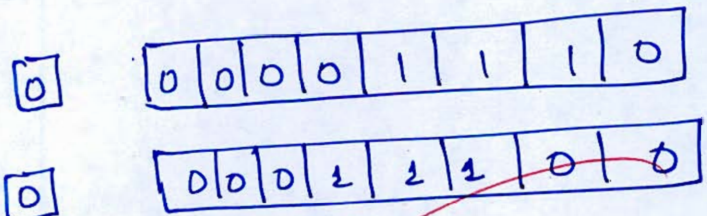
• RLC



[A] = 0EH

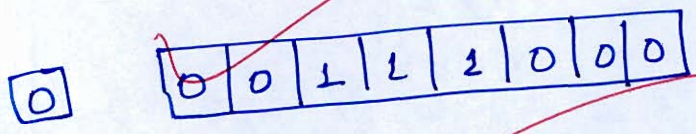
• MOV B, A [B] = 0EH.

• RLC



[A] = 1C

• RLC



[A] = 38H

• ADD B

So [A] = [A] + [B] = 38 + 1C.

0011 1000
0001 1100
―――――――
0101 0100

[A] = 54H. Ans

11

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

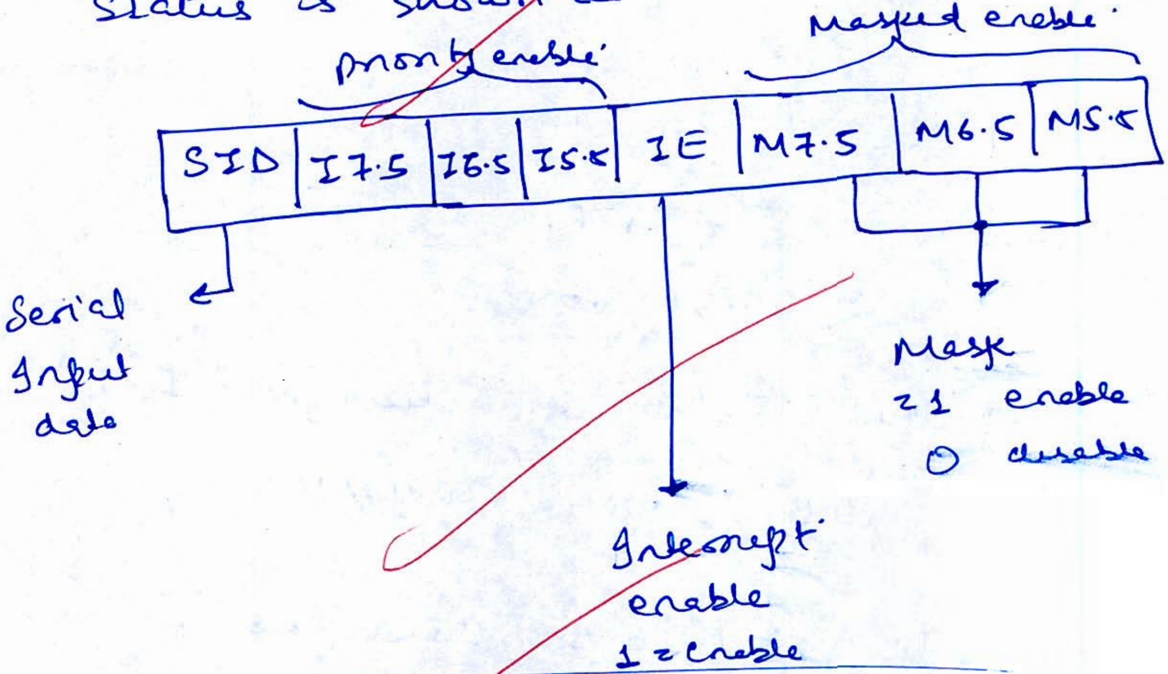
[12 marks]

RIM → Rim instruction

RIM stands for Read Interrupt Mask.

In microprocessor 8085. RIM function

Status is shown as



I7.5, I6.5 I5.5 = 1 enable

0 disable

For Masked enable

M7.5, M6.5 M5.5 = 1 enable

= 0 disable

10

Good Approach

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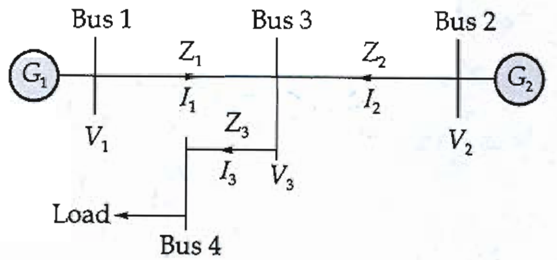
Q.6 (a) (i) Calculate the power loss in the transmission system given in the following figure. The numerical values of transmission system are :

$I_1 = 0.75\angle 0°$ 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]

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

Power loss in $Z_1 = I_1^2 R_1 = (0.75)^2 (0.07)$

$= 39.375 \times 10^{-3}$ (pu)

Power loss in Z_2 (Between Bus 2 & 3) $= I_2^2 R_2$

$= (0.8)^2 (0.06) = 38.4 \times 10^{-3}$ pu

Power loss at load or Between Bus 3 & 4

$= I_3^2 R_3 = (1.55)^2 (0.05) = 120.125 \times 10^{-3}$ pu

Total Power loss in Transmission system

$= P_1 + P_2 + P_3 = 39.375 + 38.4 + 120.125$

$= 197.9 \times 10^{-3}$ pu ↳ Ans

(9)

Good Approach

$= 197.9 \times 10^{-3} = 0.1979$ pu.

↳ Ans.

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]

Load:
10MVA 0.85 lag

A/c to Qn line is single phase so $S = V_{ph} I_{ph}$, $S \neq \sqrt{3} V_L I_L$.

$A = D = 1$
$B = 12.12\angle 64.64^\circ$
$V_R = 33\,kV$

$S = VI \Rightarrow \frac{10\times10^6}{33\times10^3} = I_R$

$I_R = 303.03\angle -\cos^{-1}0.85 = 303.03\angle -31.78$ Amp

$V_S = AV_R + BI_R$

$= 1\times33\times10^3\angle 0 + 12.12\angle 64.64 \times 303.03\angle -31.78$

$= 33000\angle 0 + 3672.72\angle 32.85$

$V_S = 36.14\angle 3.16$ kV, $I_S = I_R$

Real Power

$P_R = \frac{V_S V_R}{B}\cos(\beta-\delta) - \frac{A}{B} V_R^2 \cos(\beta-\alpha)$

$= \frac{33\times36.14}{12.12}\cos(64.64-\delta) - \frac{1}{12.12}\times 33^2 \cos(64.64-0)$

Reactive Power

$Q_R = \frac{V_S V_R}{B}\sin(\beta-\delta) - \frac{A}{B} V_R^2 \sin(\beta-\alpha)$

$= \frac{33\times36.14}{12.12}\sin(64.64-\delta) - \frac{1}{12.12} 33^2 \sin(64.64-0)$

$P_S = \frac{D}{B} V_S^2 \cos(\beta-\alpha) - \frac{V_S V_R}{B}\cos(\beta+\delta)$

Also $S_{S} = V_S I_S^*$.

$= 36.14\angle 3.16 \times (303.03\times10^{-3}\angle -31.78)^*$ MVA

$= 10.95\angle 34.94$

$= 8.976 + j\,6.271$ MVA

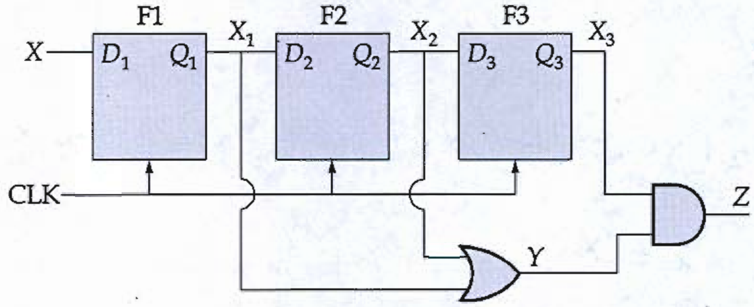
So Real Power = 8.976 MW
Reactive Power = 6.271 MVAR. } Ans

9

Fo.

Good Approach

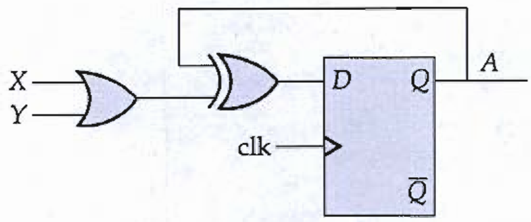
Q.6 (b) (i) A digital design is implemented by the circuit given below:



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) $Q_1 =$ o/p of flipflop F1

Characteristics Equation of D flip flop $= Q_{n+1} = D$

$Q_1 = D_1 = X$. so $X_1 = X$.   As $Q_1 = X_1$

$Q_2 = X_2$

$Q_2 = D_2 = X_1$ so $X_2 = X_1$ $Q_3 = X_3$

$Q_3 = D_3 = X_2$ so $X_3 = X_2$.

Now $Y = X_2 + X_1 = Q_2 + Q_1 = X_1 + X = X + X = X$.

$Z = X_3 \cdot Y = X_3 \cdot (X_2 + X_1) = X_2 (X_1 + X) =$

Q

Functionality given

$Y = X$

$Z = X_2(X_1 + X) = X_1(X + X) = X_1 X = X.$

$Y = X, \quad Z = X.$

It is buffer circuit

Q_3 $(=X_3$	Q_2 X_2	Q_1 $X_1)$	D_3 X_2	D_2 X_1	D_1 X	Q_3^+	Q_2^+	Q_1^+	Y
0	0	0	0	0	X				0
0	0	X	0	X	X				X
0	X	X	X	X	X				X
X	X	X	X	X	X				X

$Y = X_2 + X_1$

If $X = 1$, $Z = Y \cdot X_3$

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

so $Y = X_1 + X_2 = X.$

$Z = Y \cdot (X_3) = (X_1 + X_2) X_3 = X_3 \cdot X$ (3)

If $X_3 = 0$ $\quad Z = 0$

$X_3 = 1$ $\quad Z = X.$

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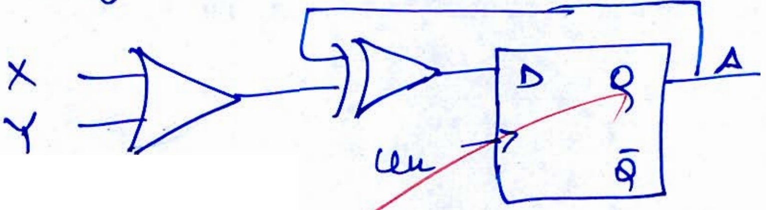
(ii) To find state diagram



From characteristics eqn

$Q_{n+1} = D$.

& $D = X + Y \oplus A$.

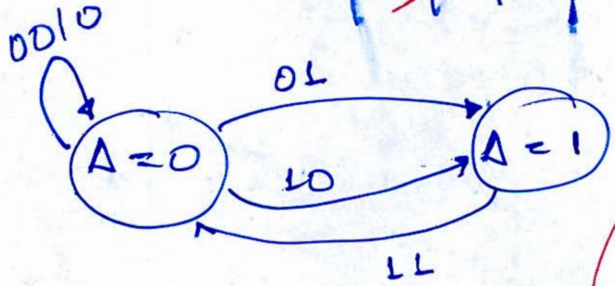
$Q_{n+1} = [X+Y] \oplus A$. ⇒ $A_{n+1} = [X+Y] \oplus A$.

~~A X Y~~

X	Y	A	$Q_{n+1} = D$		Output = A = Q_{n+1}
0	0	0	0	A	
0	0	1	1		
0	1	0	1	$\bar{A}$	
0	1	1	0		
1	0	0	1	$\bar{A}$	
1	0	1	0		
1	1	0	1	$\bar{A}$	
1	1	1	0		

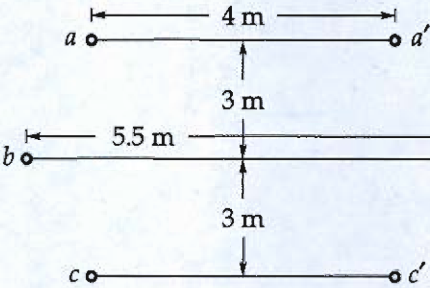
EXOR

0	0	0
0	1	1
1	0	1
1	1	0

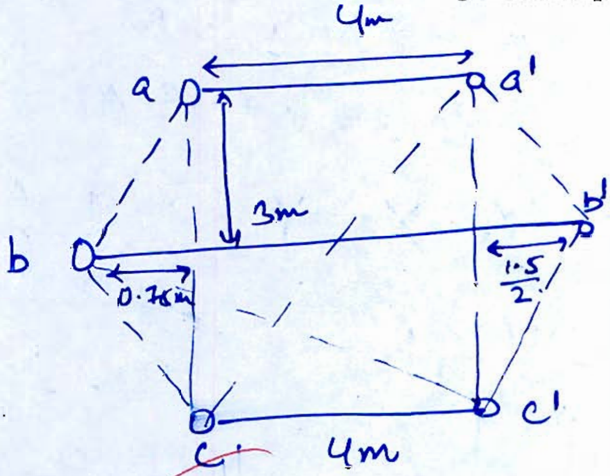


2

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]



$D_{ab} = D_{a'b'} = D_{bc} = D_{b'c'}$
$= \sqrt{3^2 + 0.75^2}$
$= 3.092 m$

$D_{a'c} = D_{ac'}$
$= \sqrt{4^2 + 6^2} = 7.211 m$

$D_{a'b} = D_{ab'} = D_{cb'} = D_{bc'}$
$= \sqrt{3^2 + 4.75^2} = 5.618 m$

Conductor radius = 0.75 cm

Self GMD $D_a = (0.7788 r_a \times D_{aa'})^{1/2} = [0.7788 \times 0.75 \times 10^{-2} \times 4]^{1/2}$
$= 0.15285 m$

$D_b = (0.7788 r_b \times D_{bb'})^{1/2} = [0.7788 \times 0.75 \times 10^{-2} \times 5.5]^{1/2}$
$= 0.1792 m$

$D_c = (0.7788 r_c \times D_{cc'})^{1/2} = 0.15285 m$

Overall self GMD $= (D_a \times D_b \times D_c)^{1/3} = 0.16118 m$

Mutual GMD

$GMD)_a = (D_{ab} \times D_{ac} \times D_{ab'} \times D_{ac'})^{1/4}$

$GMD)_b = (D_{ba} \times D_{ba'} \times D_{bc} \times D_{bc'})^{1/4}$

$GMD)_c = [(D_{ca} \times D_{ca'}) \times (D_{cb} \times D_{cb'})]^{1/4}$

$GMD)_a = (3.092 \times 6 \times 5.618 \times 7.211)^{1/4} = 5.235m$

$GMD)_b = (3.092 \times 5.618 \times 3.092 \times 5.618)^{1/4}$
$= 4.167m$

$GMD)_c = (6 \times 7.211 \times 3.092 \times 5.618)^{1/4}$
$= 5.235m$

Overall Mutual GMD $= [GMDa \times GMDb \times GMDc]^{1/3}$
$= 4.852m$

Inductance / phase

$= \frac{\mu_0}{2\pi} \ln\left(\frac{\text{Mutual GMD}}{\text{Self GMD}}\right)$

$= 0.2 \ln\left(\frac{4.852}{0.16118}\right) \frac{mH}{km}$

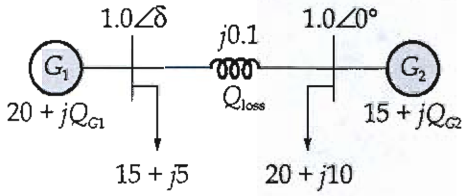
$L_{/ph} = 0.68 \times 10^{-3} \frac{H}{km}$

Inductance / ph / km $= 0.68 \times 10^{-3}$ H.

11

Good Approach

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]

$P_{G1} = 20$, $P_{G2} = 15$

$P_{D1} = 15$ $P_{D2} = 20$

Real Power = $P = \frac{V_{G1} \times V_{G2}}{X_{eq}} \sin(\delta - 0)$

$P = \frac{1 \times 1}{0.1} \sin\delta$

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

$P_{line} = 20 - 15 = 5$ pu

So $5 = \frac{1 \times 1}{0.1} \sin\delta \Rightarrow \delta = \sin^{-1} 0.5 = 30°$
$= \frac{\pi}{6}$ rad

$Q_{G1} = \frac{V_S}{X}[V_S - V_R\cos\delta] = \frac{V_1}{X}[V_1 - V_2\cos\delta]$

$= \frac{1}{0.1}[1 - \cos 30] = 1.339$ pu → Ans

Now $Q_{G2} = \frac{V_R}{X}[V_S\cos\delta - V_R]$

$= \frac{1}{0.1}[\cos 30 - 1] = -1.339$ pu → Ans

Line reactive Power loss

$Q_{loss} = Q_{G1} - Q_{G2} = 1.339 - (-1.339)$

$\Rightarrow 2.679$ pu
↳ Ans

6

Improve presentation

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

[10 marks]

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]

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 :

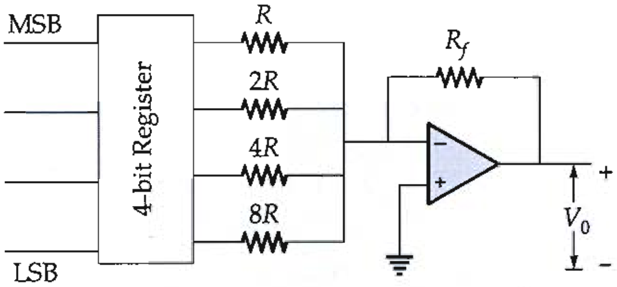
CT : 400/1 A

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.

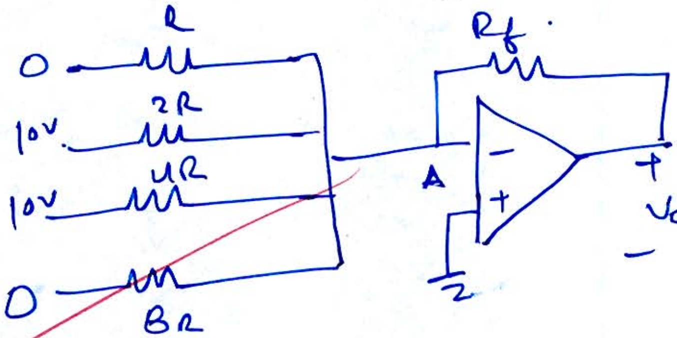
[20 marks]

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]

4 bit I/P code 0110



Apply KCL at node A

$$\frac{V_A - 0}{R} + \frac{V_A - 10}{2R} + \frac{V_A - 10}{4R} + \frac{V_A}{8R} + \frac{V_A - V_o}{R_f} = 0$$

By Virtual Ground concept $V_A = 0$.

$$-\frac{10}{2R} - \frac{10}{4R} + \frac{0 - V_o}{R_f} = 0 \Rightarrow \frac{10}{2} + \frac{10}{4} + V_o = 0$$

$R = R_f = 1\,k\Omega \Rightarrow$ so $V_o = -(5 + 2.5)$.

$V_o = -7.5$ volt

Ans

9

Good Approach

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

[10 marks]

memory segmentation 8086

Different types of Addressing

Immediate Addressing

opcode, fetch, Memory Read, Memory write

Here different memory

IP, SP.

Instruction pointer

Stack pointer.

3

Incomplete Solution

Do not write in this margin

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]

i) Restriking voltage: Maximum voltage appears across Circuit Breaker for very few second or it is governed by LC parameters of transient die out instantly.

RRRV :- It defines as Rate of rise of restriking voltage.

It tell us that whenever oscillation appear. How much rate in increment in terms of restriking voltage. for a very small amount of time.

Usually it is denoted in $\frac{kV}{\mu s}$.

Now Mathematical expression

- Restriking = V_{st} = ARV(1-cosωt) = $V_m(1-\cos\omega t)$ $K_1K_2K_3 \sin\phi$

ARV = Active Recovery voltage = $K_1K_2K_3 V_m \sin\phi$.

Max^m Restriking voltage occur at ωt = π

& $K_1K_2K_3\sin\phi = 1$

$$V_{st\,max} = 2V_m = 2\sqrt{2}V_{ph} = \frac{2\sqrt{2}\,V_L}{\sqrt{3}} \quad (kV)$$

- $RRRV = \frac{dV_{st}}{dt} = \frac{d}{dt}(V_m(1-\cos\omega t)) = \omega V_m \sin \omega t$

RRRV)max occur when $\omega t = \frac{\pi}{2}$.

RRRV)avg = $\omega V_m = \omega\sqrt{2}V_{ph} = \omega\frac{\sqrt{2}}{\sqrt{3}}V_L$.

$= 2\pi f\frac{\sqrt{2}V_L}{\sqrt{3}}$

RRRV)avg = $\frac{\text{Max}^m \text{ value of Restriking voltage}}{\text{time taken to reach max}^m \text{ value}}$

$= \frac{2V_m}{\frac{\pi}{2\omega_0}} = \frac{2V_m}{\frac{1}{2f_0}}$

$\omega t = \frac{\pi}{2}$

RRRV)max = ωV_m. $\frac{kV}{\mu s}$.

ii) For 132 KV & Above.
usually SF_6 CB is preferred while
Air Blast CB can also be used

iii) Given 132 KV system
$X = 5\Omega$, $C = 0.03\ \mu F$

To find
frequency of transient oscillation

$f_0 = \frac{1}{2\pi\sqrt{LC}}$

$X_L = \omega L \Rightarrow 5 = 2\pi f L \Rightarrow L = \frac{5}{2\pi f} = 0.0159\ H$.

$f_0 = \frac{1}{2\pi\sqrt{0.0159 \times 0.03\times10^{-6}}} = 7.287\ kHz$ ↳ Ans

Max^m value of Restriking voltage = $2V_m$

$$= \frac{2\sqrt{2}}{\sqrt{3}} V_L = 1.632 \times 132 = 215.55 \text{ KV}$$

↳ Ans

Max^m value of RRRV = ωV_m

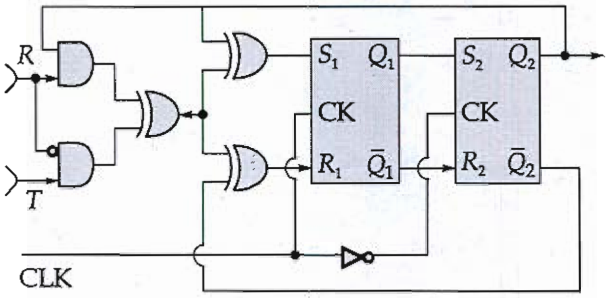
$$= 2\pi f V_m = 2\pi(50)\sqrt{\frac{2}{3}} \times 132$$

$$= 33.859 \ \frac{\text{KV}}{\text{sec}}$$

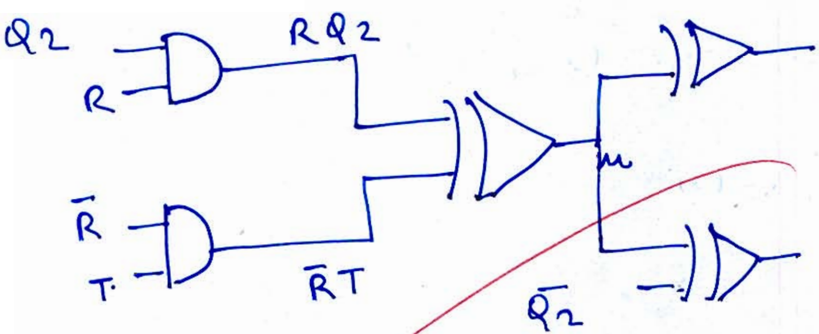
↳ Ans

15

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]



O/P of $S_1 = Q_2 \oplus m = Q_2 \oplus [RQ_2 \oplus \bar{R}T]$

O/P of $R_1 = \bar{Q}_2 \oplus m = \bar{Q}_2 \oplus [RQ_2 \oplus \bar{R}T]$.

(3)

Characteristics Eq^n of S-R FF

$Q_{n+1} = S + \bar{R}Q_n$.

$Q_2^{*} = S_2 + \bar{R}_2 Q_1 = Q_1 + Q_1 Q_1 = Q_1$

$m = RQ_2 \oplus RT'$

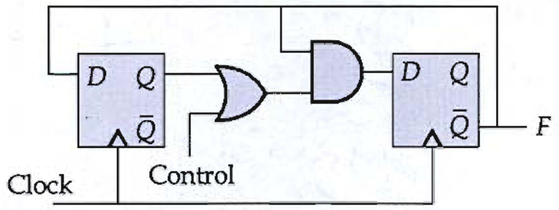
$Q_1 = S_1 + \bar{R}_1 Q_0 =$

$S_1 = Q_2 \oplus RQ_2 \oplus \bar{R}T = Q_2 \oplus R \oplus \bar{R}T = Q_2 \oplus T$

$R_1 = \bar{Q}_2 \oplus RQ_2 \oplus \bar{R}T = Q_2 \oplus \bar{Q}_2 \oplus T = T \oplus 1 = \bar{T}$

So $S_1 = Q_2 \oplus T$
$R_1 = \bar{T}$ } Ans

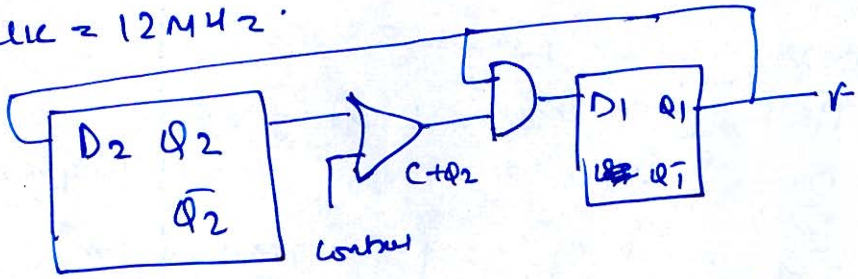
Q.8 (c) **(ii)** The clock frequency of the digital circuit shown in the figure is 12 MHz. Find the frequencies of the output (F) corresponding to Control = 0 and Control = 1.



[10 marks]

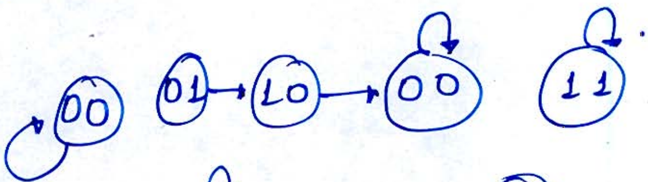
Given:

$f_{clk} = 12 MHz$.

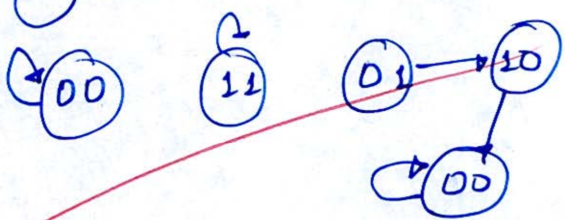


Present State			Flip flops i/p		Next State	
Control C	Q_2	Q_1	$D_2 = Q_1$	D_1 $(C+Q_2)\cdot Q_1$	Q_2^+	Q_1^+
0	0	0	0	0	0	0
0	0	1	1	0	1	0
0	1	0	0	0	0	0
0	1	1	1	1.	1	1
1	0	0	0	0	0	0
1	0	1	1	1	1	1.
1	1	0	0	0	0	0
1	1	1	1	1.	1	1.

If control = 0.

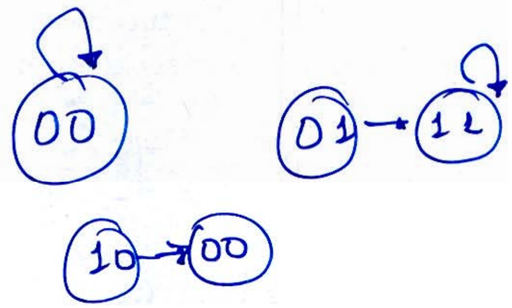


If clock applied



If control = 1

clock applied



No unique state

00 → 00
11 → 11
01 → 10
10 → 00

} so control = 0

~~$f_{o/p} = 12$ MHz $= \frac{f_{clk}}{\text{no of unique states}}$~~

~~$f_{op} = 12$ MHz ↳ Ans~~

For control = 1

00 → 00
01 → 11
11 → 11
10 → 00

} ~~$f_{op} = \frac{f_{clk}}{\text{no of unique state}} = \frac{12}{1}$~~

~~= 12 MHz ↳ Ans~~

Here is Above the condition of Lockout condition

(2)

Space for Rough Work

Space for Rough Work