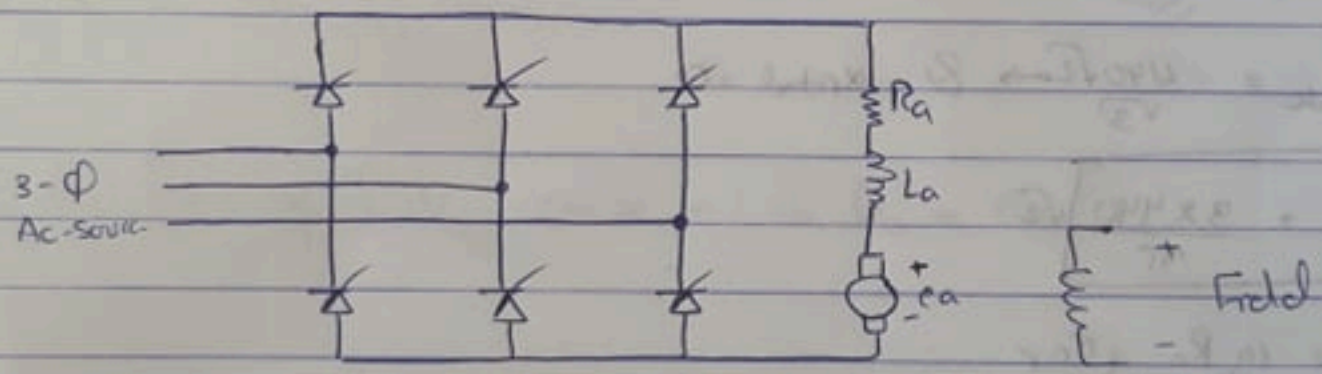
Q2: Separately excited DC Motor

- $P_{out} = 25\,kW$ $\quad V_{L-L} = 600\,V$ $\quad \eta_m = 1500\,rpm$
  $R_a = 0.4$

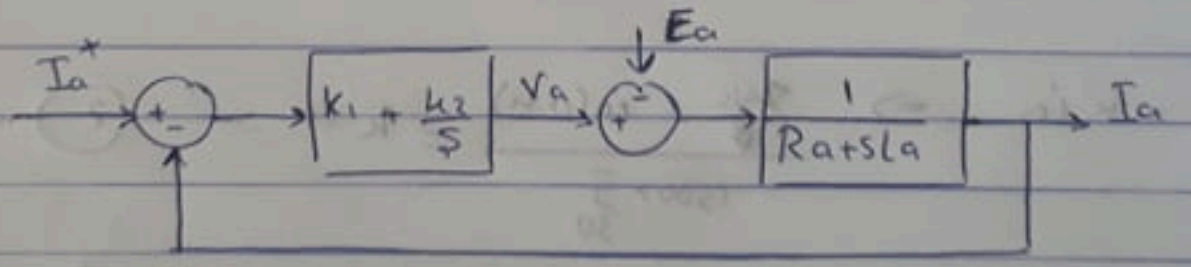
- speed range : $\frac{1}{2}\omega_m \longrightarrow \omega_m$

- Control method : Three-phase full-wave controlled rectifier.
  From :
  $V_{L-L} = 440\,Volt$: $f = 60\,Hz$

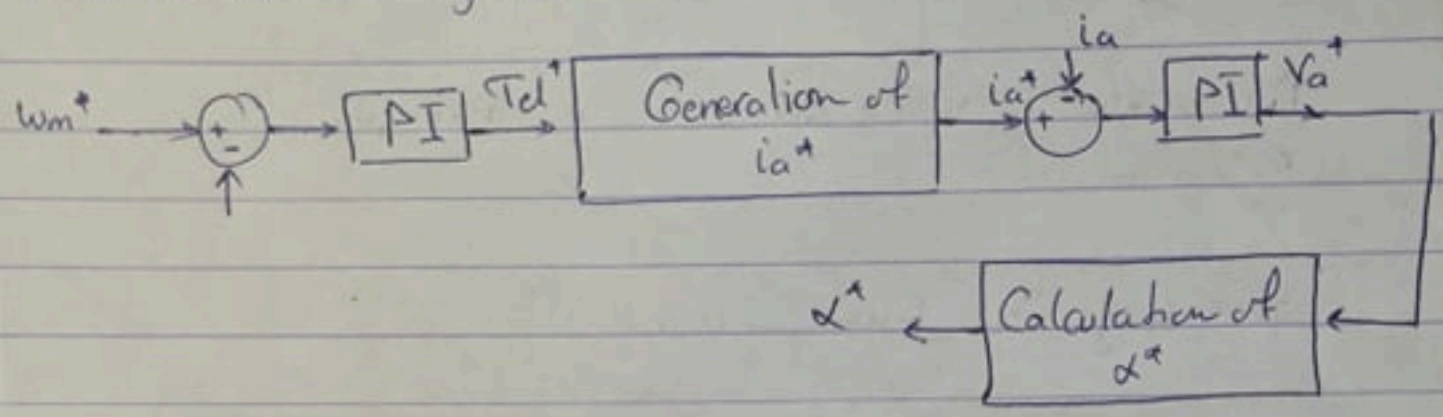
a) Drive Circuit



b) Current controller in S-domain:



c) Armature Control system:



d) Motor's rated current:

$$V_a = \frac{3\sqrt{3}}{\pi} V_{\phi\,Peak} \cos\alpha$$

$$V_{\phi\,Peak} = \frac{440\sqrt{2}}{\sqrt{3}} \rightarrow \text{\&} \quad \alpha_{rated} = 0.$$

$$\boxed{V_{a,r} = \frac{3 \times 440}{\pi}\sqrt{2}}$$

$$- V_{ar} = i_{a_r} R_a + e_{ar}.$$

$$\frac{440 \times 3\sqrt{2}}{\pi} \; i_{a_r}(0.4) + e_a \quad \text{——} (1)$$

$$\frac{P_{AG}}{\omega_m} = k\, i_a \Rightarrow \frac{\frac{25k}{4} - i_a(0.4)}{1500 \times \frac{\pi}{30}} = k\, i_a \quad \text{——} (2)$$

$$e_a = k\omega_m \Rightarrow e_a = k\left(1500 \times \frac{\pi}{3}\right) \quad \text{——} (3)$$

$$\frac{(2)}{(3)} \rightarrow \frac{\left[\frac{25k}{4} - i_a(0.4)\right] e_a}{50\pi} = \frac{i_a}{50\pi}$$

$$e_a = \frac{i_a}{25k - 0.4\, i_a} \quad \text{——} (4)$$

(4) in (1) ⇒ ~~$440\sqrt{3}$~~

$$\frac{440 \times 3\sqrt{2}}{\pi} = 0.4\, i_a + \frac{i_a}{25k - 0.4 i_a}$$

~~$\frac{440 \times 3}{4}$ i_a $0.4 i_a$~~

$$594.2\,(25k - 0.4 i_a) = (25k - 0.4 i_a)\, i_a + i_a$$

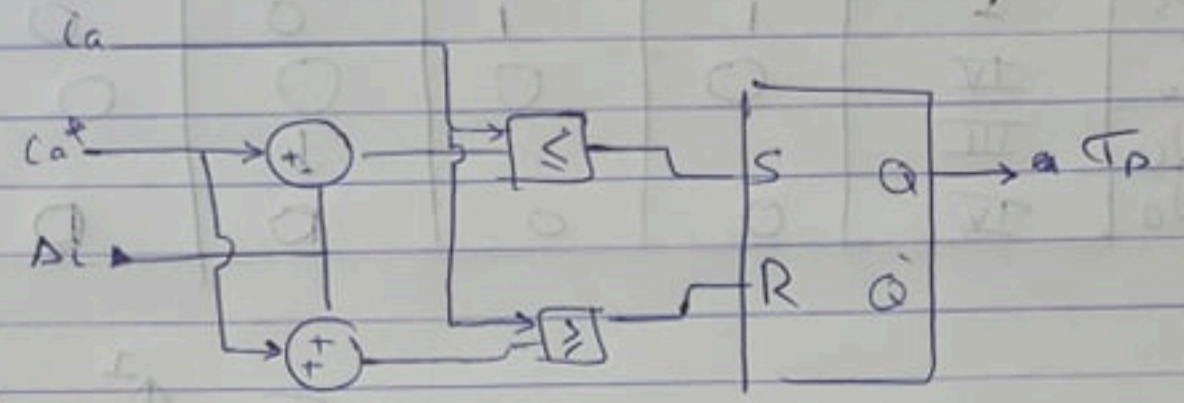
$$i_a = 594\ A$$

e) α @ $\frac{1}{2}\,\omega_{m,r}$.

$$V_a = \frac{3\sqrt{3}}{\pi} V_{\phi_{P\text{-}N}} \cos\alpha = i_a R_a + e_a$$

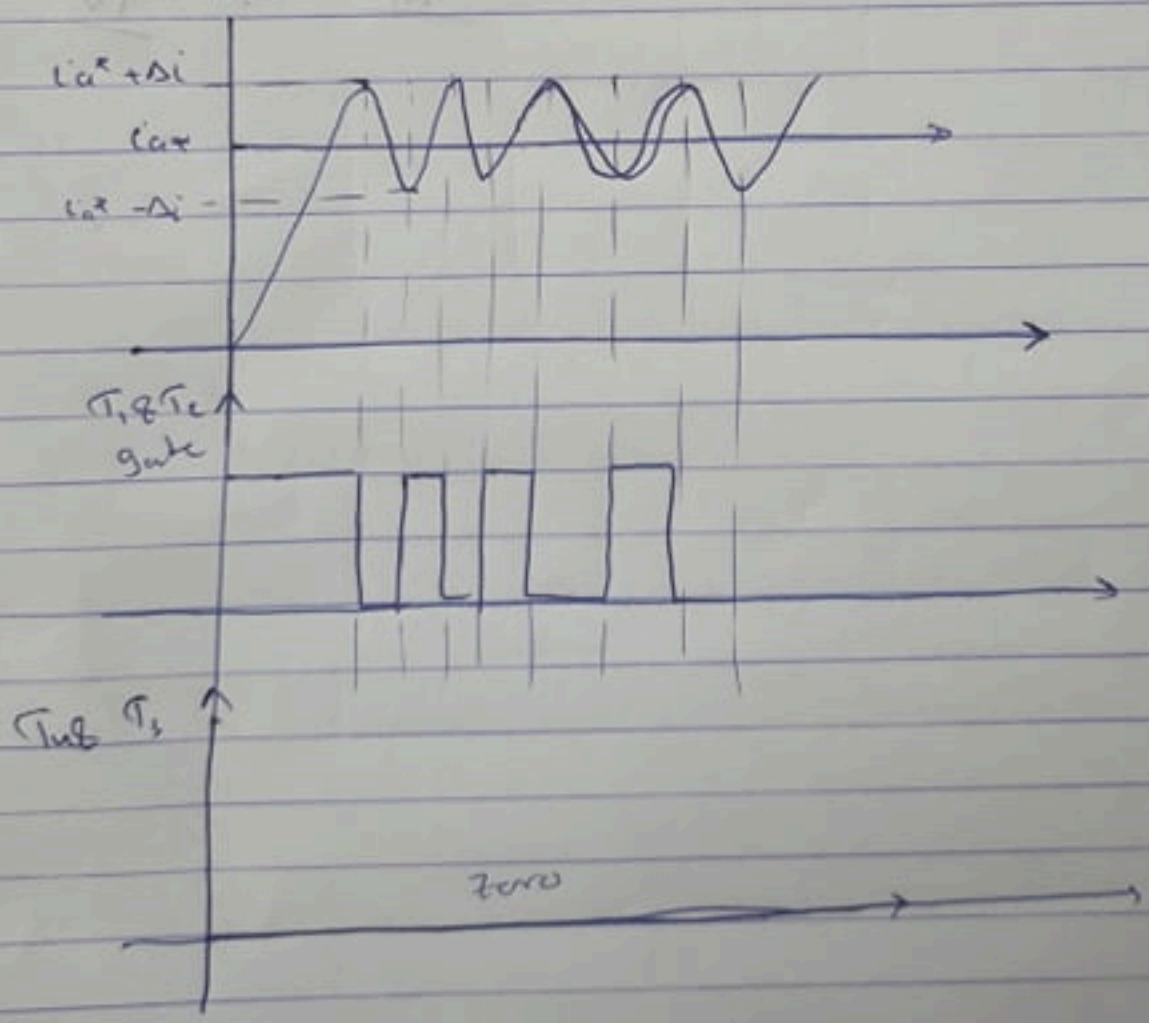
$$\frac{e_{ar}}{e_a} = \frac{\omega_{mr}}{\omega_m} \rightarrow$$

Q2 Part (2):



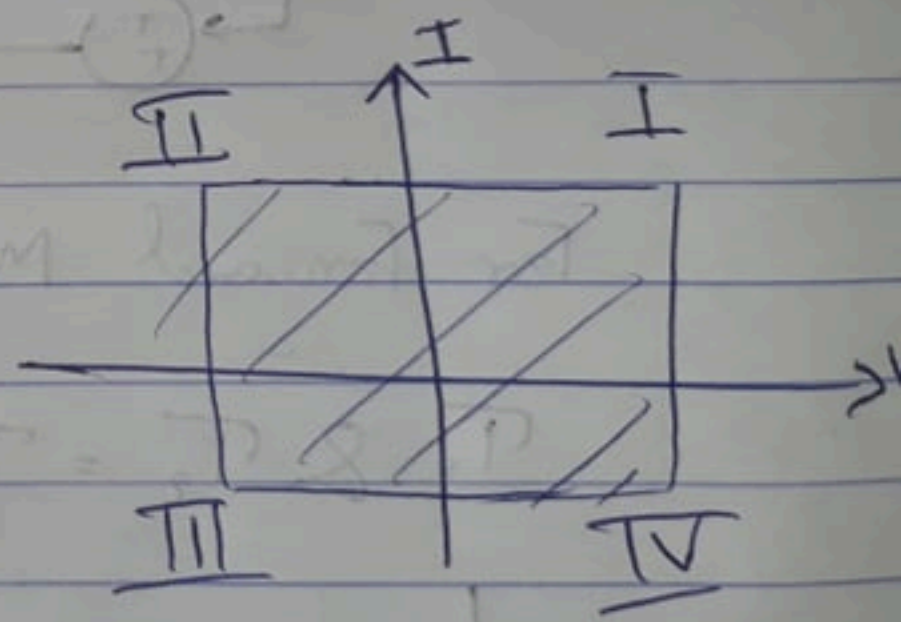
For Forward Motoring:

T_1 & T_2 = T_P.



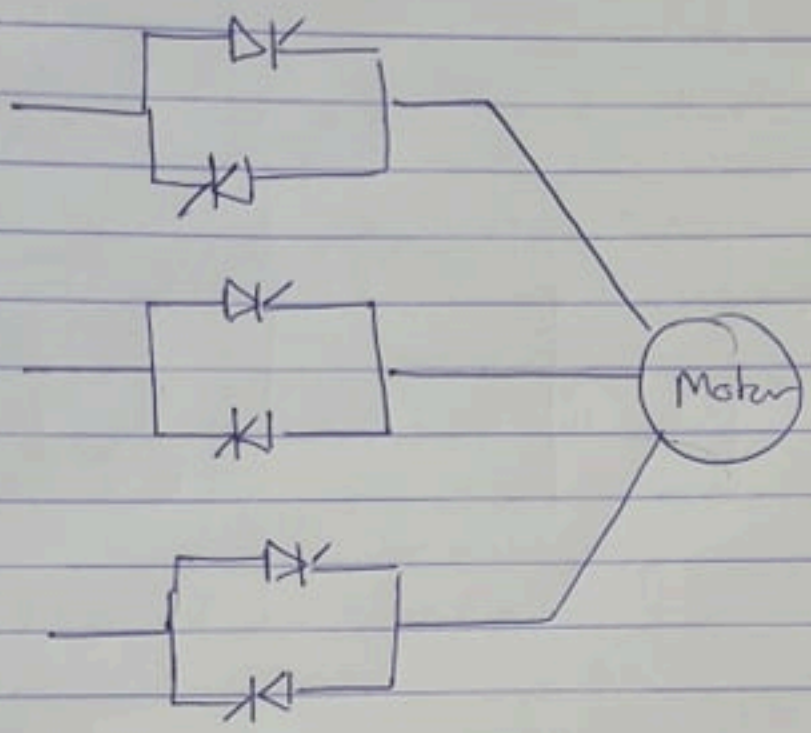
b)

ω_m	i_a	Quad	T_1	T_2	T_3	T_4
Yes	Yes	I	1	1	0	0
Yes	No	IV	0	0	0	0
No	No	III	0	0	1	0
Yes	No	IV	0	0	0	0

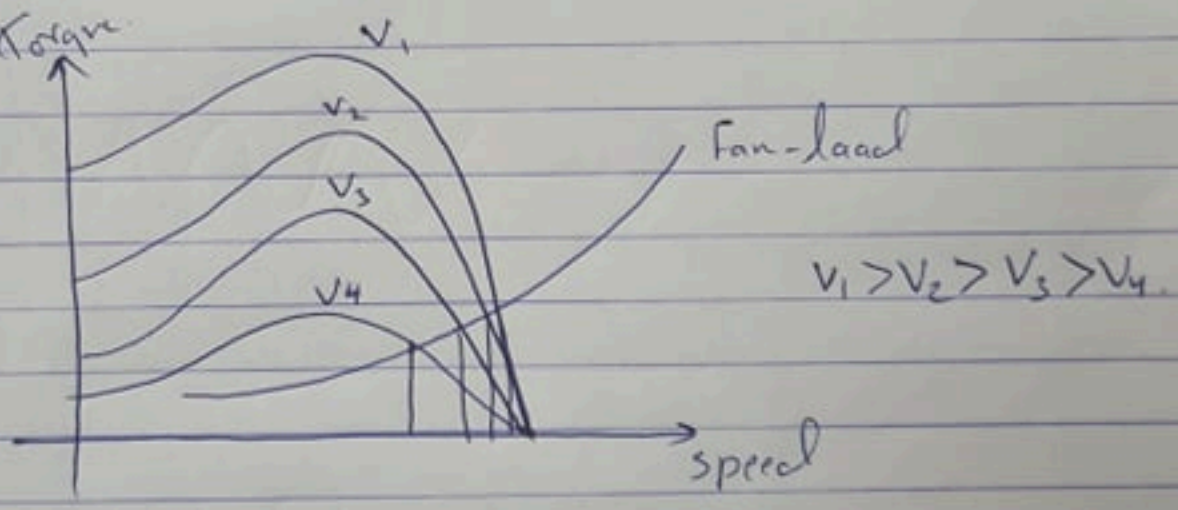


①

Q3: a)



b)



$V_1 > V_2 > V_3 > V_4$.

c) $\omega_s = \frac{\omega_e}{p} \rightarrow \frac{2\pi(50)}{2} = 50\pi$ r/sec.

$\sigma_r = \frac{1500 - 1400}{1500} \rightarrow \frac{1}{15}$

$\sigma = \frac{1500 - 1200}{1500} \rightarrow \frac{1}{5}$

$$\left.\begin{aligned} T_{el} &= T_L = C\omega_m^2 \\ T_{el,r} &= T_{L,r} = C\omega_{m,r}^2 \end{aligned}\right\} \rightarrow \frac{T_{el}}{T_{el,r}} = \left(\frac{\omega_m}{\omega_{m,r}}\right)^2$$

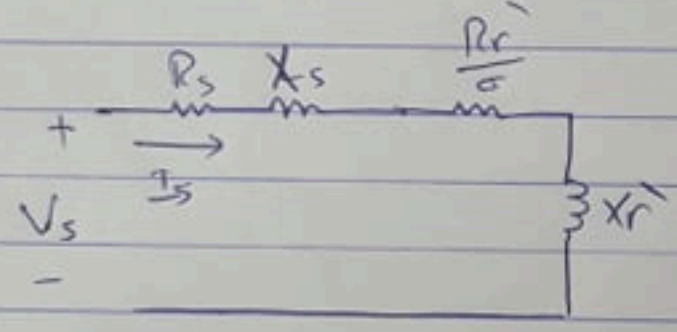
$\Rightarrow$

$$\rightarrow Tel = \left(\frac{1200}{1400}\right)^2 \times \frac{7500}{1400 \times \frac{\pi}{30}} = 37.58 \text{ N.m}$$

$$T = \frac{3V^2 \left(\frac{R_r'}{\sigma}\right)}{\omega_s \left[\left(R_r'/_6 + R_s\right)^2 + (X_{eq})^2\right]}$$

$$37.58 = \frac{3V^2 \left(\frac{6}{\lambda_s}\right)}{50\pi \left[\left(\frac{6}{\lambda_s} + 2\right)^2 + 10^2\right]}$$

$$V = 271.519 \text{ Volt}$$



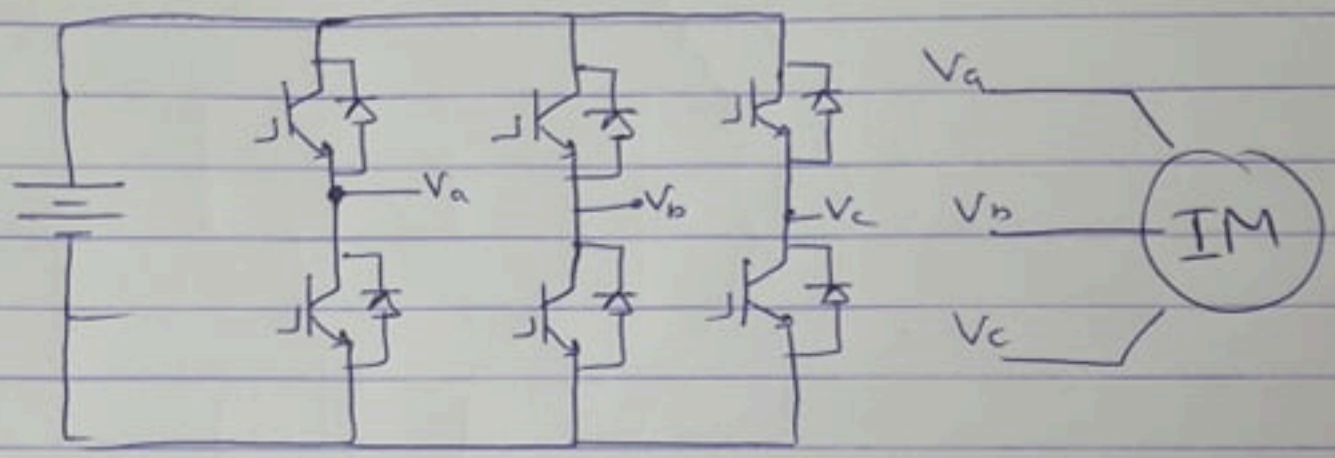
$$I_s = \frac{V_s}{\left(R_s + \frac{R_r'}{\sigma}\right) + j\left(X_s + X_r'\right)}$$

$$= \frac{271.519}{\left(2 + \frac{6}{0.2}\right) + j(10)}$$

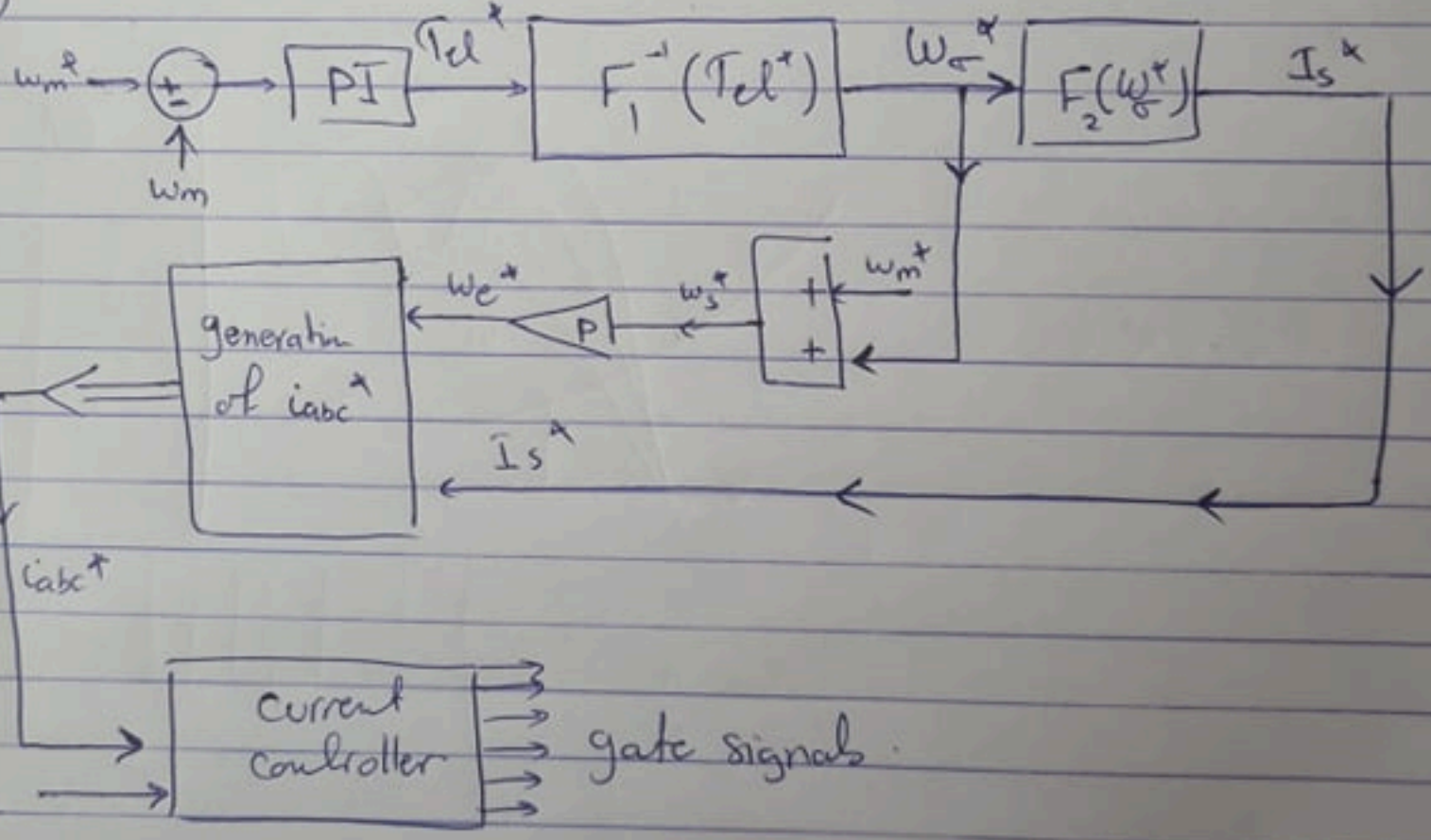
$$= 7.73 - 2.41i \Rightarrow 8.098 \angle -17.35 \text{ A}$$

Q3: (2)

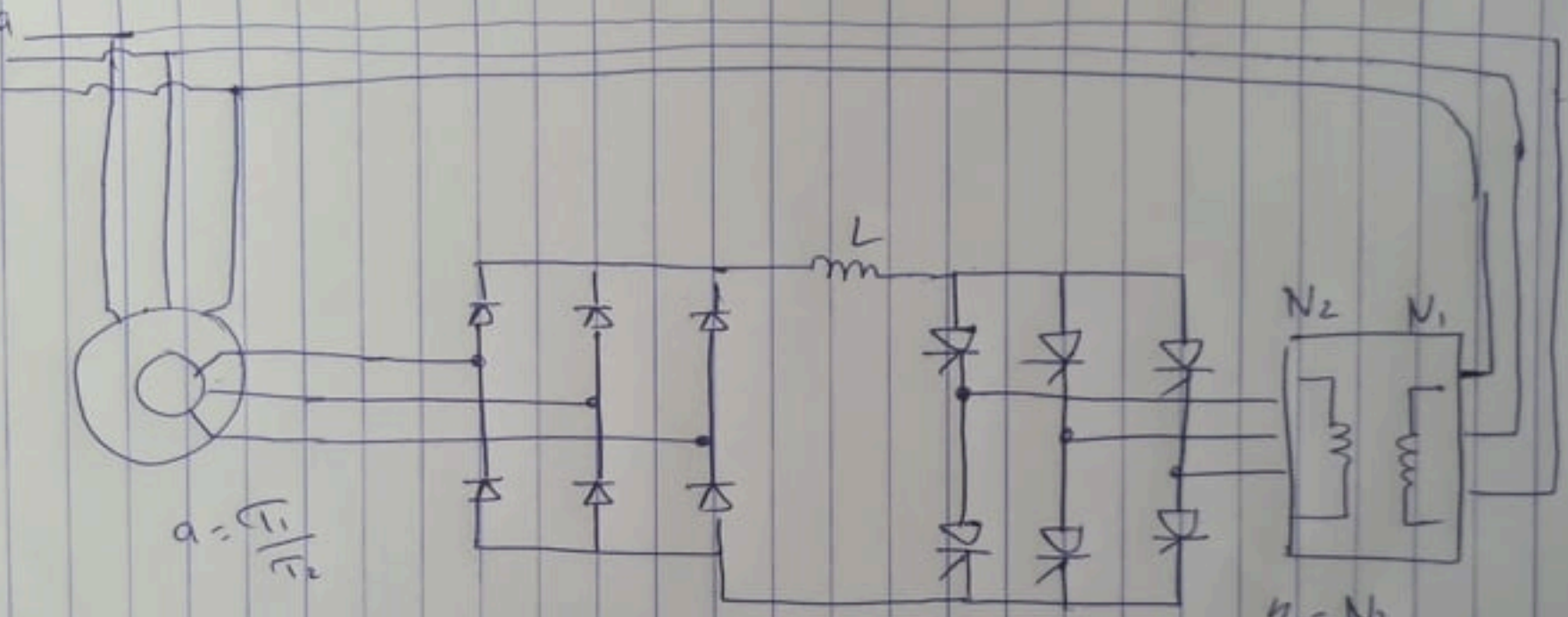
a) Drive circuit



b)

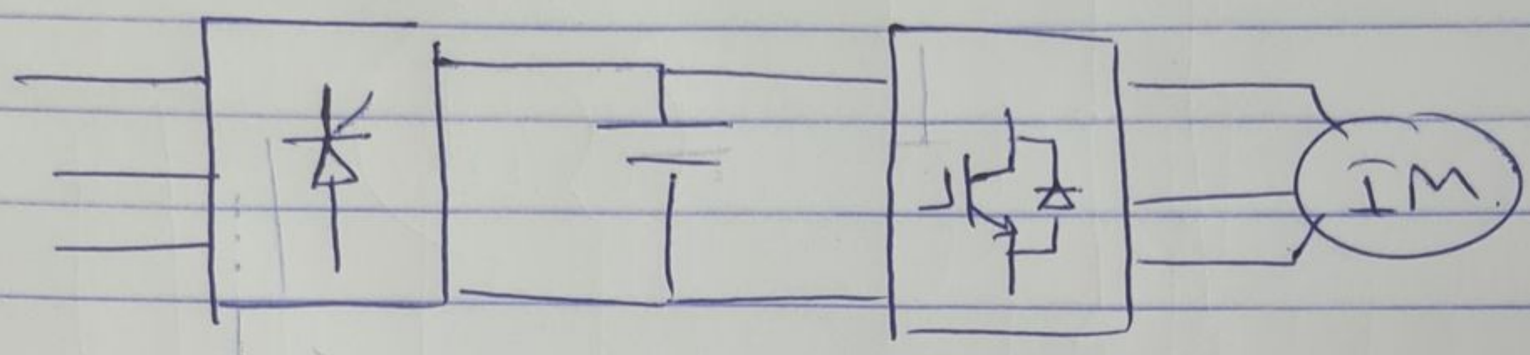


Q3 (3)

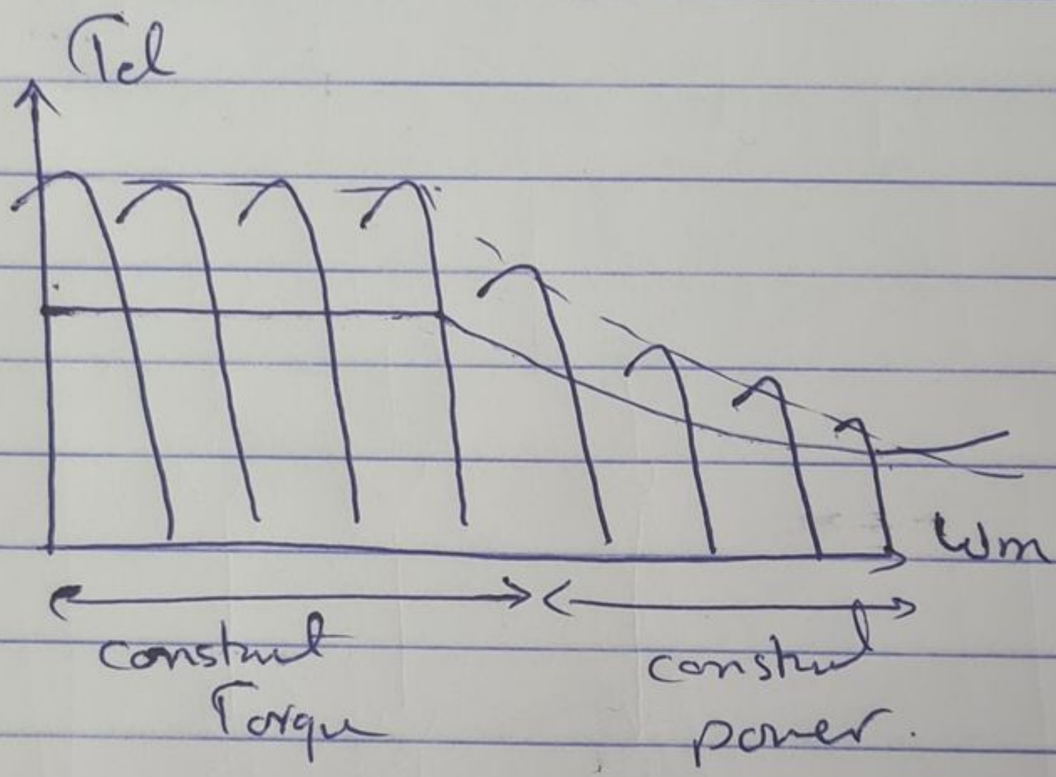


Q3 (4)

(1) Drive circuit :



(2)

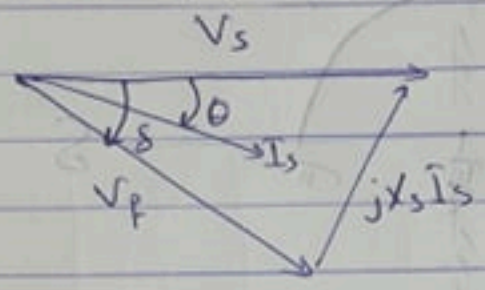


(3)

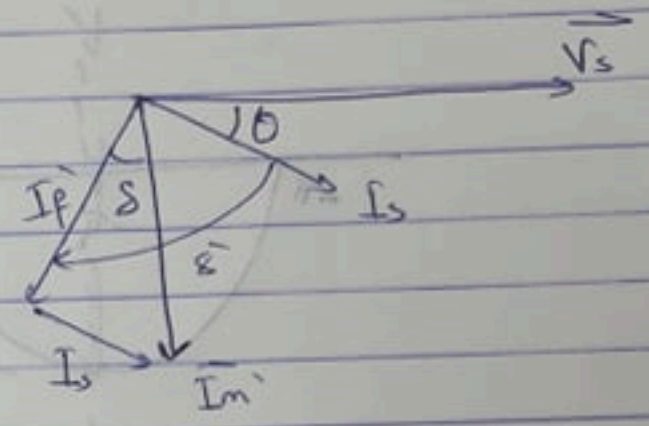
Q4

① Phasor Diagram:

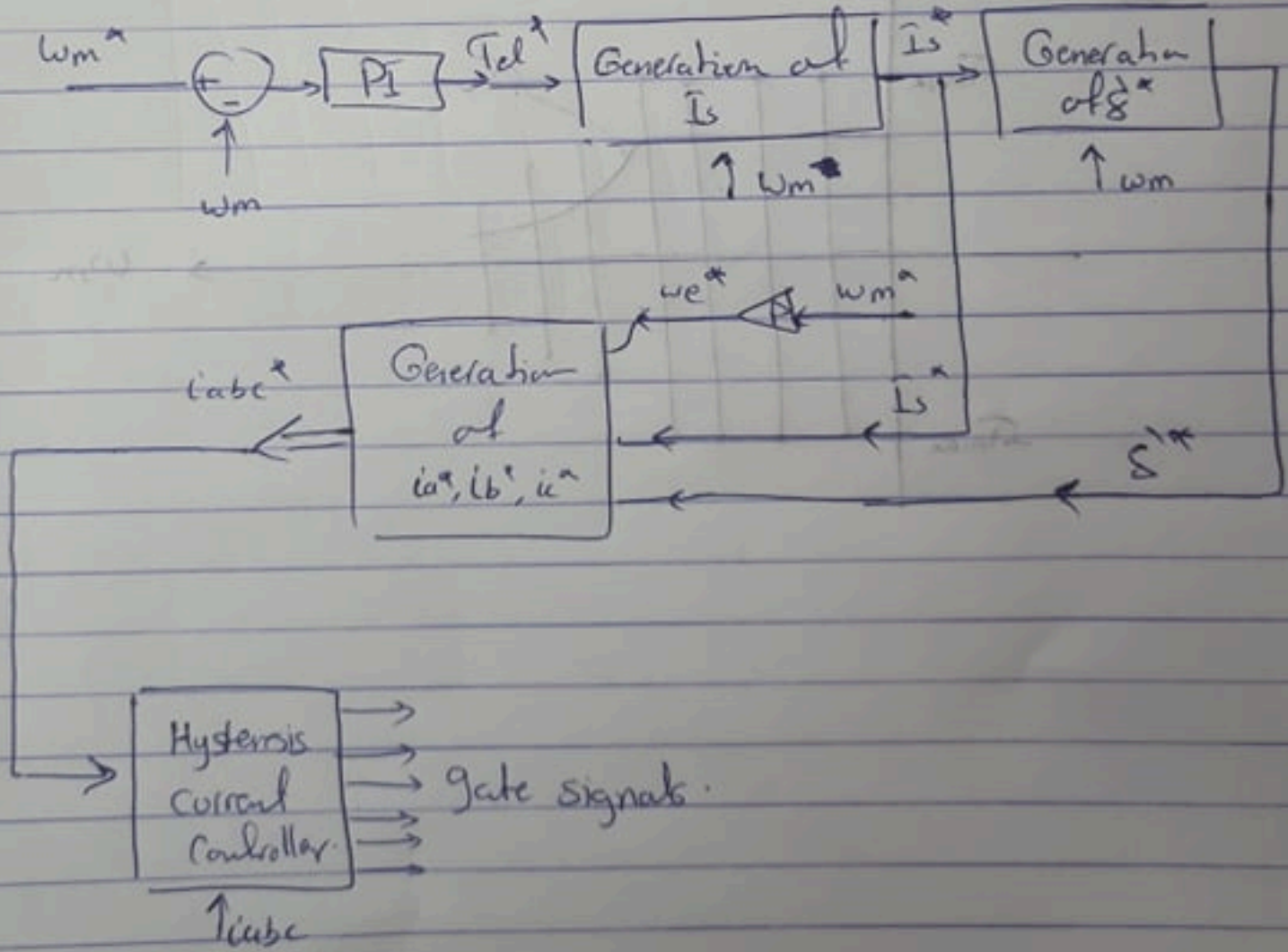
a)



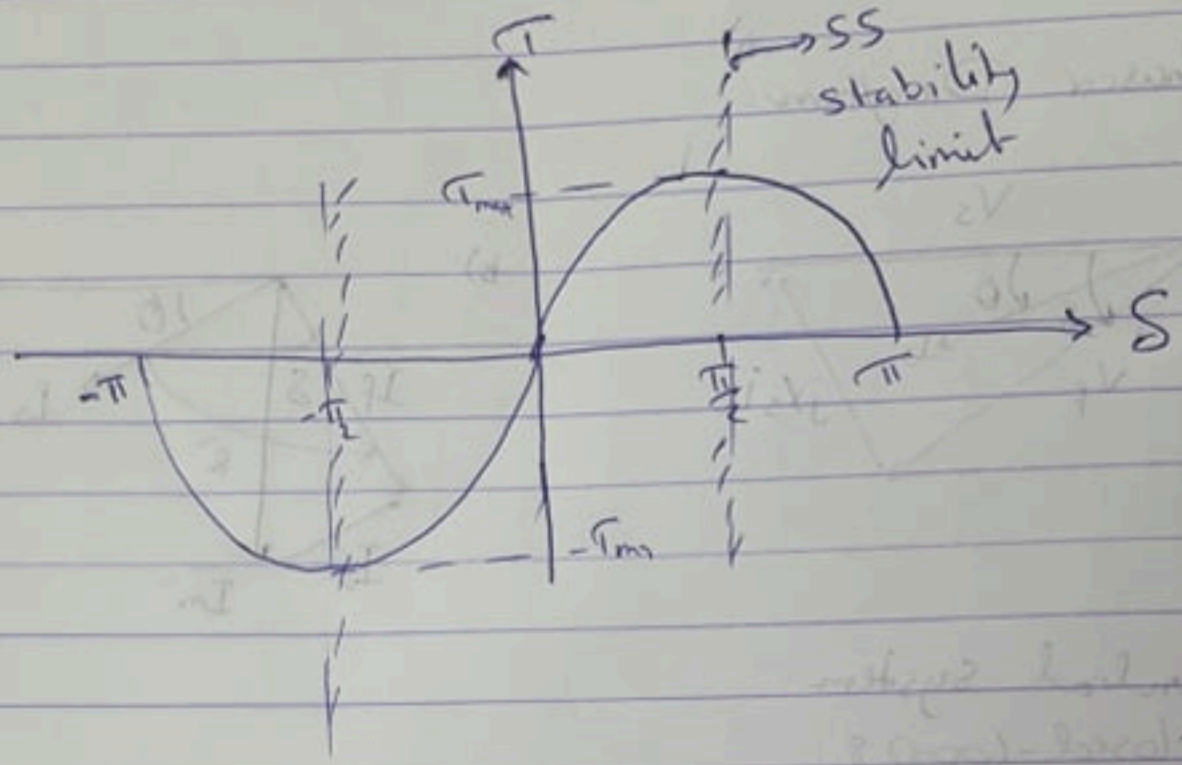
b)



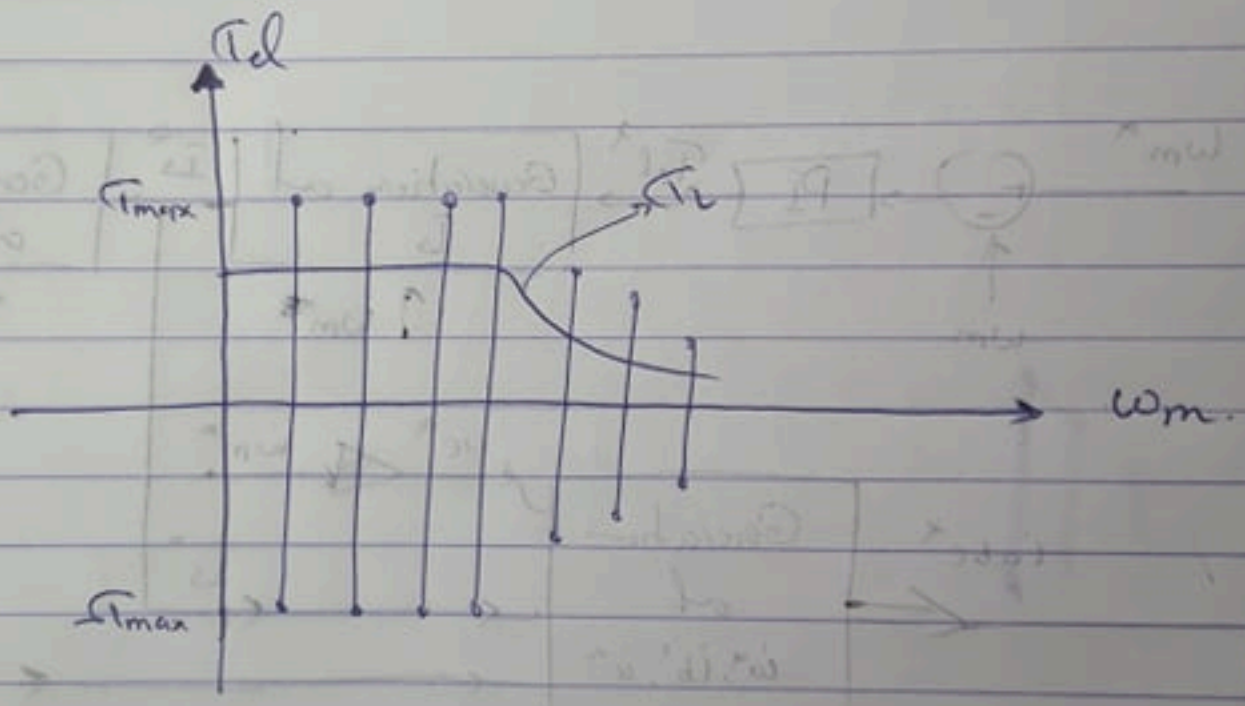
② Control system:
closed-loop:



c)


T
SS
stability
limit
T_{max}
S
$-\pi$
$-\frac{\pi}{2}$
$\frac{\pi}{2}$
π
$-T_m$

d)


T_d
T_{max}
T_L
ω_m
T_{max}

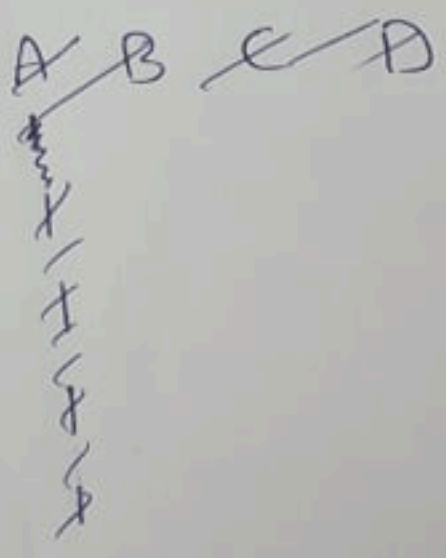
Q5:

a) $\beta = \frac{N_s - N_r}{N_s N_r} 360^\circ$

$= \frac{8-6}{8 \times 6} 360^\circ$

$= 15^\circ$

b)



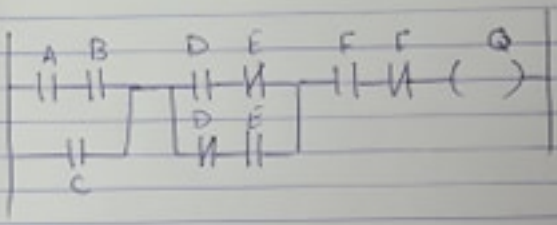
A	B	C	D
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

c) $\eta = \frac{\beta \times f}{360^\circ} = \frac{15 \times 100}{360} = 4.1667$ rps

η in rpm $= \frac{4.1667}{60}$ rpm.

Q6:

① $(AB+C)(D\overline{GE})\overline{(F)}(\overline{F})=Q$



②