Solution

BIRZEIT UNIVERSITY

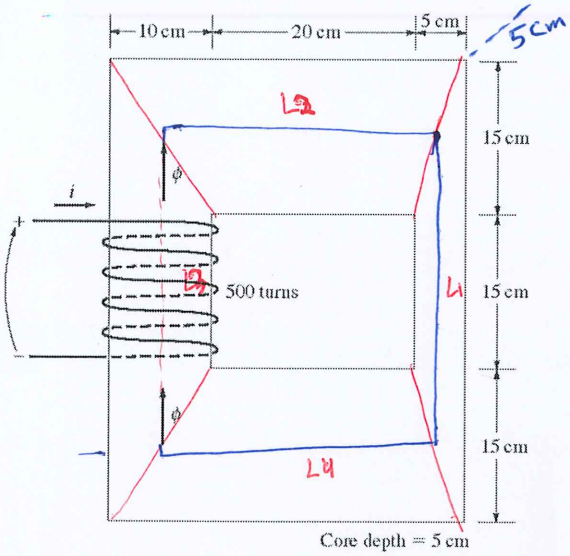
Electrical and Computer Engineering Department

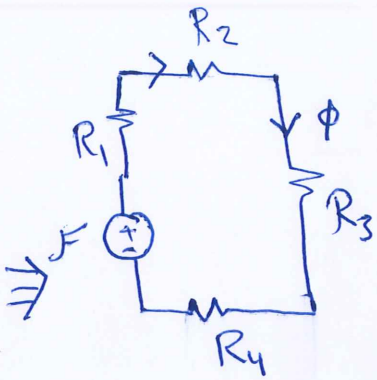
Electrical Machines ENEE 2408

Short Exam # 1 (10*mins*)

Student Name: **ID:** **11th March, 2024**

A ferromagnetic core is shown in Figure P1-2. The depth of the core is 5 cm. The other dimensions of the core are as shown in the figure. Find the value of the current that will produce a flux of 0.005 Wb. With this current, what is the flux density at the top of the core? What is the flux density at the right side of the core? Assume that the relative permeability of the core is 800.





(1.5) $R_1 = \frac{L_1}{\mu A_1} = \frac{(7.5+15+7.5)/100}{800(4\pi\times10^{-7})(0.1\times0.05)} = 59.713\,K$ (0.5 الوحدات)

(1.5) $R_2 = \frac{L_2}{\mu_r\mu_0 A_2} = \frac{(5+20+2.5)/100}{800(4\pi\times10^{-7})(0.15\times0.05)} = 36.491K$

(1.5) $R_3 = \frac{L_3}{\mu_r\mu_0 A_3} = \frac{(7.5+15+7.5)/100}{800(4\pi\times10^{-7})(0.05\times0.05)} = 119.426K$

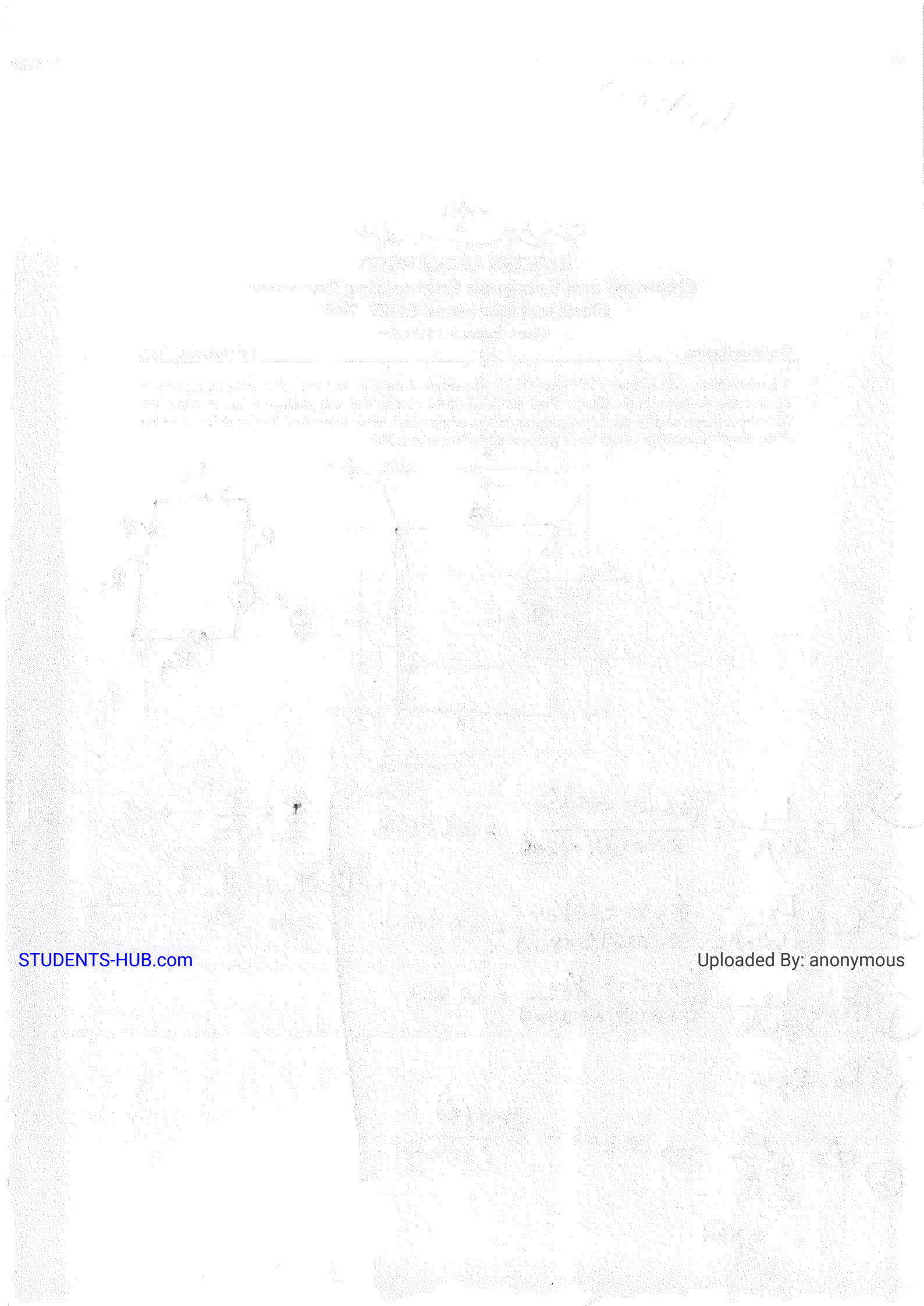
(1.5) $R_4 = R_2 =$

(2) $\phi = \frac{F}{\sum R}$ (1) $\Rightarrow 0.005 = \frac{500(i)}{?252.121}$

$i = 2.52A$ (0.5)

$B_{top} = \frac{\phi}{A_2} = \frac{0.005}{0.0075} = 0.666\,T$ (0.5) (0.5)

(2) $B_{Right} = \frac{\phi}{A_3} = \frac{0.005}{0.0025}$ (0.5) (0.5)



Key Solution

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Short Exam # 2 (10*mins*)

Student Name: ID: March 27, 2024

A 30-kVA 8000/230-V distribution transformer has an impedance referred to the primary of $20 + j100\ \Omega$. The components of the excitation branch referred to the primary side are $R_C = 100\ \text{k}\Omega$ and $X_M = 20\ \text{k}\Omega$.

(a) If the primary voltage is 7967 V and the load impedance is $Z_L = 2.0 + j0.7\ \Omega$, what is the secondary voltage of the transformer? What is the voltage regulation of the transformer?

(b) If the load is disconnected and a capacitor of $-j3.0\ \Omega$ is connected in its place, what is the secondary voltage of the transformer? What is its voltage regulation under these conditions?

$a = 8000/230 = 34.78$ (2)

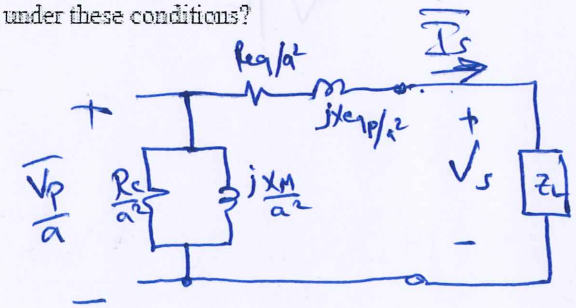
$Req_s = \frac{20}{(34.78)^2} = 0.0165\ \Omega$ (0.5)

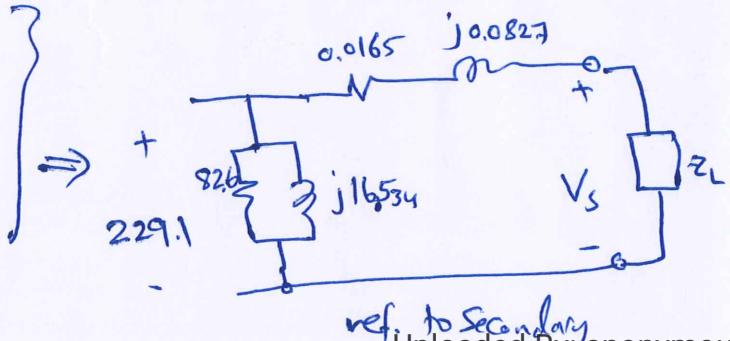
$Xeq_s = \frac{100}{(34.78)^2} = 0.0827\ \Omega$ (0.5)

$R_c' = \frac{100K}{(34.78)^2} = 82.669\ \Omega$

$X_M' = \frac{20K}{(34.78)^2} = 16.534$

$V_p' = \frac{V_p}{a} = \frac{7967}{34.78} = 229.1\ \text{V}$ (1)





$\therefore \bar{V}_s = \frac{Z_L}{Z_L + Req_s + jXeq_s} \cdot 229.1$ (2)

Case 1

$\bar{V}_{s_1} = \frac{2+j0.7}{2+j0.7+0.0165+j0.0827} \cdot 229.1$

$= \frac{(2+0.7j)}{(2.0165+0.7827j)} (229.1)$

$2.16 \angle 21.21^\circ \quad 2.11 \angle 19.3^\circ$

$= 223.79 \angle -1.91$

Case 2

$\bar{V}_{s_2} = \frac{-j3}{(-j3 + 0.0165 + j0.0827)} \cdot 229.1 = 235.6 \angle -0.33\ \text{V}$

$2.917 \quad \angle -89.67$

Case 1

$$VR = \frac{V_{P/a} - V_{s_1}}{V_{s_1}} \times 100\% \quad (1)$$

$$= 2.37\%$$

Case 2

$$VR = \frac{V_{P/a} - V_{s_2}}{V_{s_2}} \times 100\% \quad (1)$$

$$= -2.75\%$$

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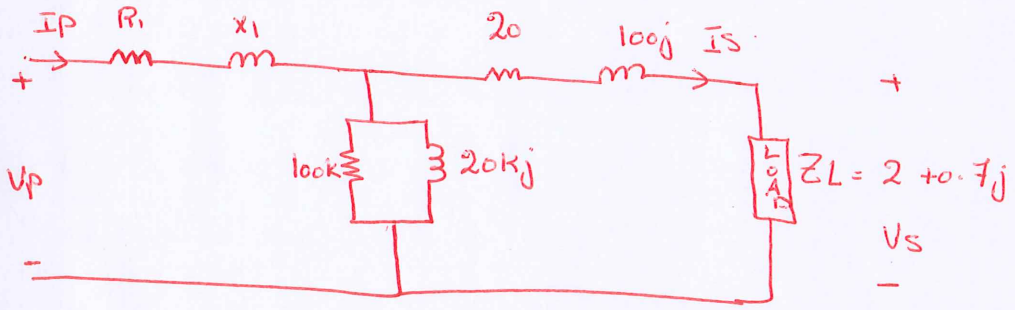
A 30-kVA 8000/230-V distribution transformer has an impedance referred to the primary of $20 + j100\ \Omega$. The components of the excitation branch referred to the primary side are $R_C = 100\ k\Omega$ and $X_M = 20\ k\Omega$.

(a) If the primary voltage is 7967 V and the load impedance is $Z_L = 2.0 + j0.7\ \Omega$, what is the secondary voltage of the transformer? What is the voltage regulation of the transformer?

(b) If the load is disconnected and a capacitor of $-j3.0\ \Omega$ is connected in its place, what is the secondary voltage of the transformer? What is its voltage regulation under these conditions?

Referred to primary :



$$V_R = \frac{V_p - V_s'}{V_s'} = \frac{7967 - 7688.7}{7688.7} = V_R = 3.6\%$$

a) $V_p = 7967\ V$

$$a = \frac{V_p}{V_s} = \frac{8000}{230} = 34.78$$

$$Z_L' = a^2 * Z_L = (34.78)^2 * (2 + 0.7j) = 2.419K + 846.7j$$

$$I_S' = \frac{V_p}{Z_p + Z_L'} = \frac{7967\ \angle 0}{(20 + 100j) + (2.419K + 846.7j)} = \frac{7967\ \angle 0}{2439 + 946.7} =$$

$$I_S' = \frac{7967\ \angle 0}{2616.28\ \angle 21.21^\circ} = 3\ \angle -21.21^\circ\ A$$

$$V_S' = (I_S')(Z_L') = (3\ \angle -21.21)(2562.9\ \angle 19.29^\circ) = 7688.7\ \angle -1.92$$

$$V_S = \frac{V_S'}{a} = \frac{7688.7\ \angle -1.92}{34.78\ \angle 0} = 221\ \angle +1.92$$

b)

$$Z_L' = a^2 Z_L = (34.78)^2(-3j) = -362.89j \quad (1)$$

$$I_S' = \frac{U_P}{Z_P + Z_L'} = \frac{7967\angle 0}{(20+100j)+(-362.89j)} = \frac{7967\angle 0}{263.64\angle -85.64} = 30.2\angle 85.64 \text{ A} \quad (1)$$

$$V_S' = I_S' Z_L' = (30.2\angle 85.64)(-362.89j) = 10.959\text{k}\angle -4.36 \quad (a.5)$$

$$V_S = \frac{V_S'}{a} = \frac{10.959\text{k}\angle -4.36}{34.78} = 315.1\angle -4.36 \text{ V} \quad (a.5)$$

$$V_R = \frac{U_P - V_S'}{V_S'} = \frac{7967 - 10.959\text{k}}{10.959\text{k}} = -2.420/0. \quad (1)$$

Solution.

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Short Exam # 4 (10*mins*)

Student Name: **ID:** **May 15, 2024**

A 480V, 50Hz, 100hp, 0.85 leading PF, 8 poles, Y- connected Synchronus motor has a synchronous reactance of 0.8Ω, and a negligible armature resistance. Ignore its friction, windage, and core losses;

a) If the motor is initially supplying 40hp power at 0.85 leading PF, what are magnitudes and angles of E_A, and I_A? **Note, 1 hp is 746W**

b) Calulate the induced torque of the motor under the condition in a)

c) If the field current is kept constant, caluate the pullout (maximum) value of the motor torque

d) Plot the phasor diagram of motor's voltage for both cases of torque

(a)

No losses:

$P_{out} = 40 \times 746 = 29840\,W$

$P_{out} = P_{conv} = P_{in} = \sqrt{3} V_L I_L \cos\theta$

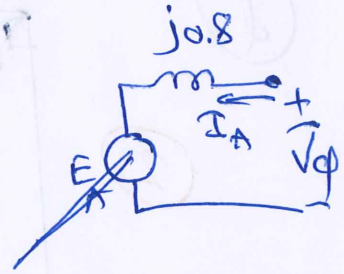
$29840 = \sqrt{3}(480) I_L (0.85)$

$I_L = 42.23A$

(2)

$I_A = 42.23 \angle +\cos^{-1} 0.85$

$\bar{I}_A = 42.23 \angle +31.8\,A$



$V_\phi = \frac{480}{\sqrt{3}} = 277.13\,V$

$\bar{E}_A = \bar{V}_\phi - jX_s \bar{I}_A$

$= 277.13 - j0.8(42.23 \angle 31.8)$

$= 277.13 + 33.78 \angle -58.2 \Rightarrow \bar{E}_A = 277.13 + 17.8 - j28.71$

$= 294.93 - j28.71$

(2)

$E_A = 296.32 \angle -5.56\,V$

b) $\tau_{ind} = \frac{P_{conv}}{\omega_s}$

$\omega_s = \frac{120f}{P} \times \frac{2\pi}{60} = \frac{120 \times 50}{8} \cdot \frac{2\pi}{60} = 78.54 \text{ rad/s}$ (750 rpm)

2

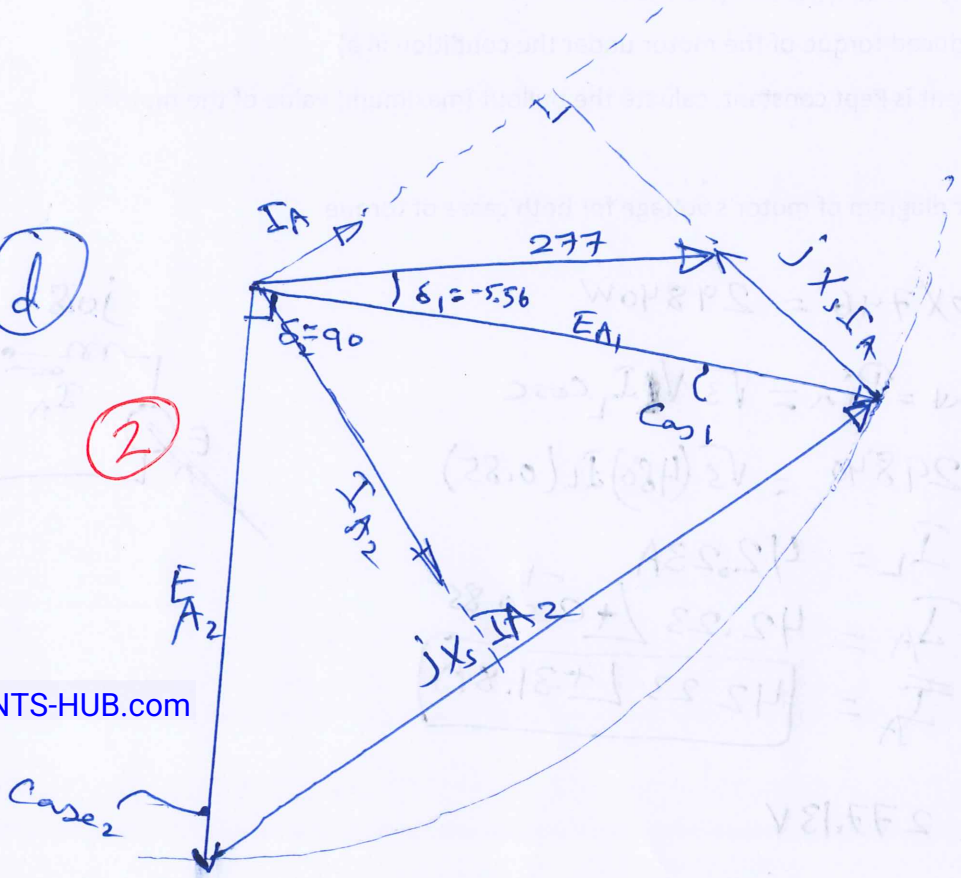
$\therefore \tau_{in} = \frac{29840}{78.54} = 379.93 \text{ N.m}$

c) $\tau_{max} = \frac{3 E_A V_\phi}{\omega_s X_s} = \frac{3(296.32)(277.13)}{78.54(0.8)}$

@ $\delta = 90$

2 $\tau_{max} = 3{,}920.9 \text{ N.m}$

d)



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