University of Jordan
Dept. of Elect. Engg.

Electric Machines 0903371
First Examination

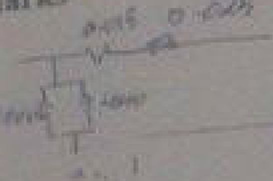
24.3.2014
Time 1 Hour

Name (in Arabic) [illegible]

Student Number 0110478

1. A single phase, 100 kVA, 2000/400V transformer, the per unit resistance of the transformer is 0.015 and the reactance is 0.025. The core resistance referred to the high voltage side is 4000Ω and the magnetizing reactance is 1000 Ω. **6marks**

(i) Find the approximate equivalent parameters referred to the low voltage side.



$a = \frac{2000}{400} = 5$

in per unit the resistance and reactance same in LV and HV.

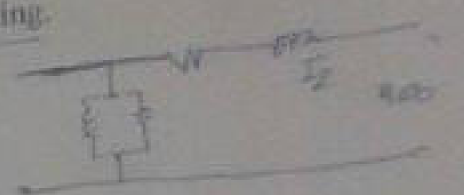
$R_{c_2} = 4000/a^2 = \frac{4000}{25} = 160\ \Omega$

$X_{m_2} = 1000/a^2 = \frac{1000}{25} = 40\ \Omega$

$R_{eq_2} = 0.015 \times \left(\frac{400^2}{100 \times 10^3}\right) = 0.024$

$X_{eq_2} = 0.025\left(\frac{400^2}{100 \times 10^3}\right) = 0.04$

(ii) Find the voltage regulation at full load and 0.8 power factor lagging.



$VR = I_{pu}\,[R_{eq\,pu}\cos\theta + X_{eq}\sin\theta]$

$= 1\,[0.015\,(0.8) + 0.025\,(0.6)]$

$= 2.7\ \%$

(iii) Draw the phasor diagram

(iii) Find the maximum efficiency at 0.9 power factor lagging

$K = \sqrt{\frac{P_{c\,pu}}{R_{eq\,pu}}} = \sqrt{\frac{\frac{1}{100}}{0.015}} = 0.816$

$\eta_{max} = \frac{V I_{max}\cos\theta}{V I_{max}\cos\theta + 2P_c} = \frac{K\cos\theta}{K\cos\theta + 2P_{c\,pu}}$

$= \frac{0.816\,(0.9)}{0.816\,(0.9) + 2\times\left(\frac{1}{100}\right)} = 97.34\ \%$

5

(iv) Find all day efficiency given that load is:

8hours for 1/2 load at 0.9 power factor lagging
6hours for full load at 0.8 power factor lagging
6hours for 1/4 load at unity power factor
4hours at no load

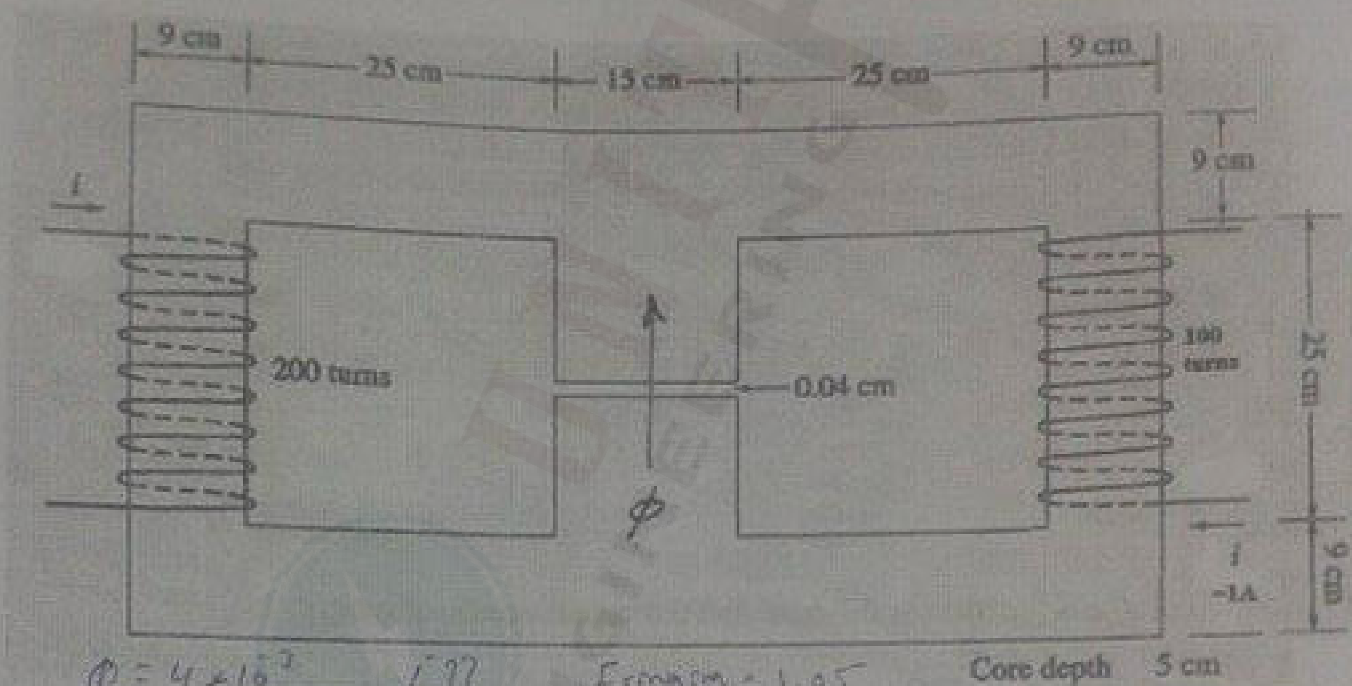
$P_{c\,pu} = \frac{1}{100}$

all day eff $= \frac{\sum \text{energy in 24 hrs}}{\sum \text{energy in 24 hrs} + \sum \text{loss in 24 hrs}}$

$= \frac{(8 \times \frac{1}{2} \times 0.9) + (6 \times (1) \times (0.8)) + (6 \times \frac{1}{4} \times 1) + (0)}{9.9 + 24\,(0.01) + (8(\frac{1}{2})^2 + 6(1)^2 + 6(\frac{1}{4})^2 + 0)}$ $= 85.13$

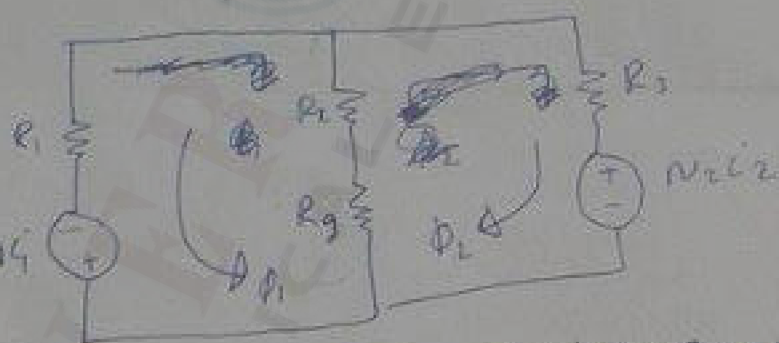
2. The magnetic circuit below is made of iron whose characteristics is shown below. Find the current (i) so that 4mwb flux crosses the airgap in upward direction. The fringing factor of the airgap is 1.05. Find the current i.

7 marks



$\Phi_g = 4\times10^{-3}$ i ??   Fringing = 1.05

$Hl_c = Ni$



Nonlinear

$N_1 i_1 = (R_1 + R_2 + R_g)\phi_1 + (R_2 + R_g)\phi_2$

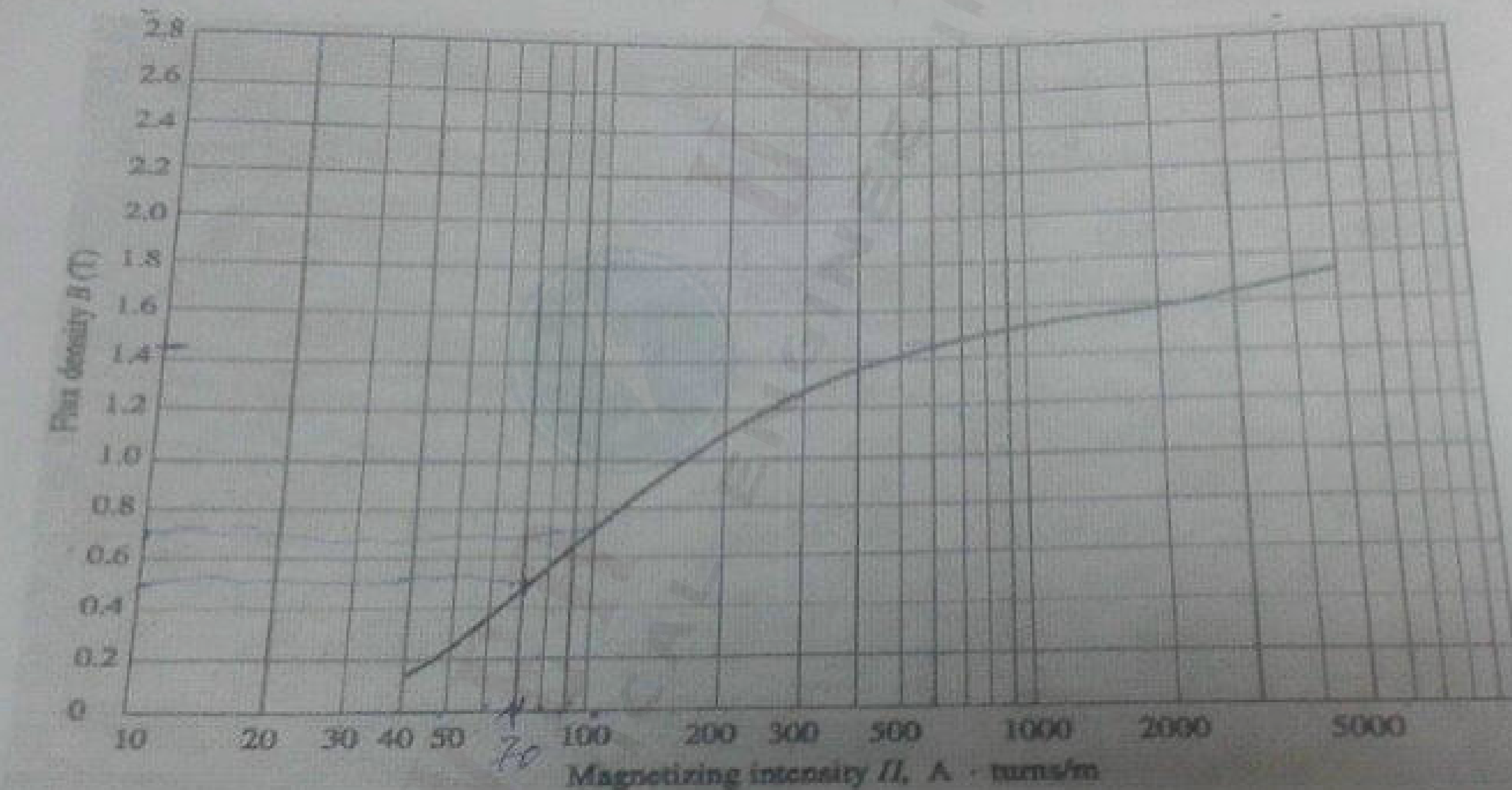
$N_2 = (R_2 + R_2 + R_g)\phi_2 + (R_2 + R_g)\phi_1$

1

$\phi_g = AB \rightarrow B_g = \dfrac{4\times10^{-3}}{1.05\times15\times5\times10^{-4}} = 0.507 \Rightarrow H = 8$

$Hl_c = N_1 i_1 + N_2 I_2$

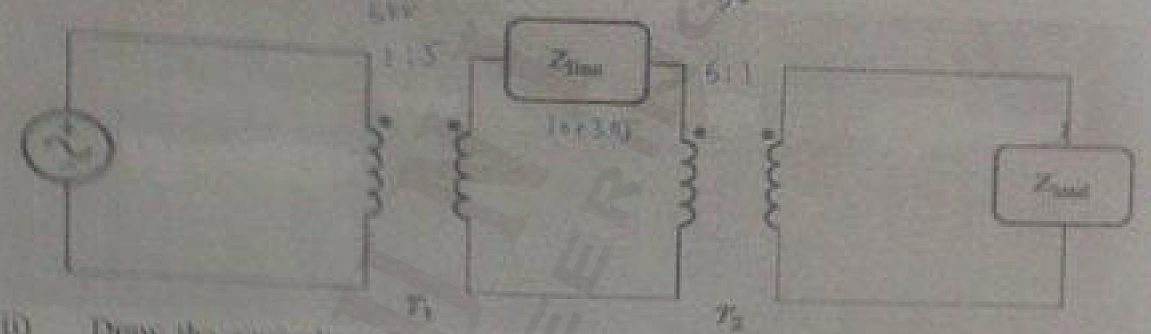
$85\times34\times10^{-2} = 200\,i + 100$



Flux density B (T)
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
10
20
30
40
50
100
200
300
500
1000
2000
5000
Magnetizing intensity H, A · turns/m

3. A power system consisting of a source, a step up transformer T1, a feeder, a step down transformer T2 and a load. The load is supplied at 250V.
The load impedance is 10+j5 Ω
T1 is 5kVA of 1:5 transformation ratio and an equivalent impedance referred to the low voltage side of 0.2+j0.5 Ω
T2 is 5kVA of 5:1 transformation ratio and of a per unit equivalent impedance of 0.01+j0.02
The feeder is of 10+j30 Ω

(i) Sketch a diagram showing the system **7marks**

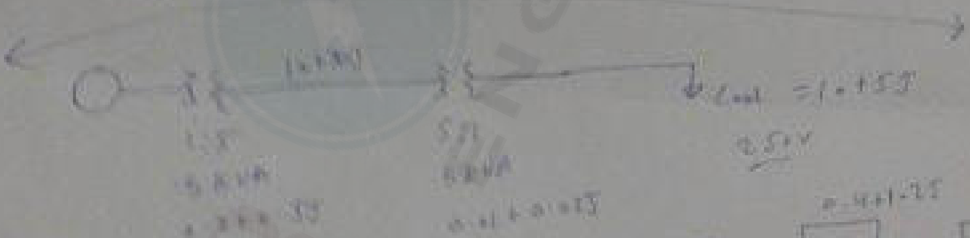


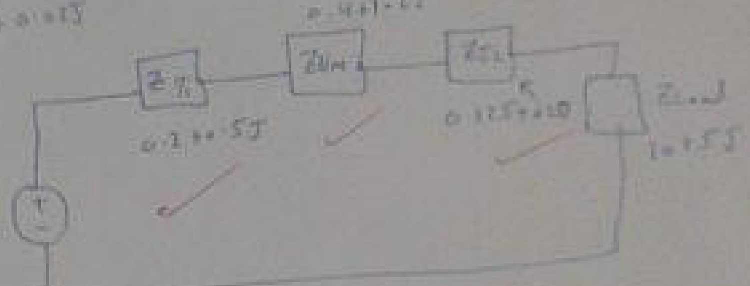
(ii) Draw the equivalent circuit of the system referred to the low voltage side indicating values

$Z_{T_2} = 0.01 + j0.02$ pu

5kVA

$Z_{T_1} = 0.2 + 0.5J$





$Z_{load} = 10 + 5J \times \left(\frac{5}{1}\right)^2 \times \left(\frac{1}{5}\right)^2 = \boxed{10 + 5J}$

$V_{T_2} = 250 \times \frac{5}{1} = 1250$

$Z_{T_2} = 0.01 + 0.02J \times \left(\frac{1250^2}{5000}\right) = 3.125 + 6.25J$

$Z_{T_2} \times \left(\frac{1}{5}\right)^2 = \boxed{0.125 + 0.25J}$

$Z_{line} = (10 + 30J) \times \frac{1}{25} = \boxed{0.4 + 1.2J}$

$Z_{T_1} = 0.2 + 0.5J$

$V_{load} = 250 \times \frac{5}{1} \times \frac{1}{5} = 250$

$I_{Load} = \frac{250}{10 + 5J} = 22.3 \angle -26.56$

3. A power system consisting of a source, a step up transformer T1, a feeder, a step down transformer T2 and a load. The load is supplied at 250V.

The load impedance is 10+j5 Ω

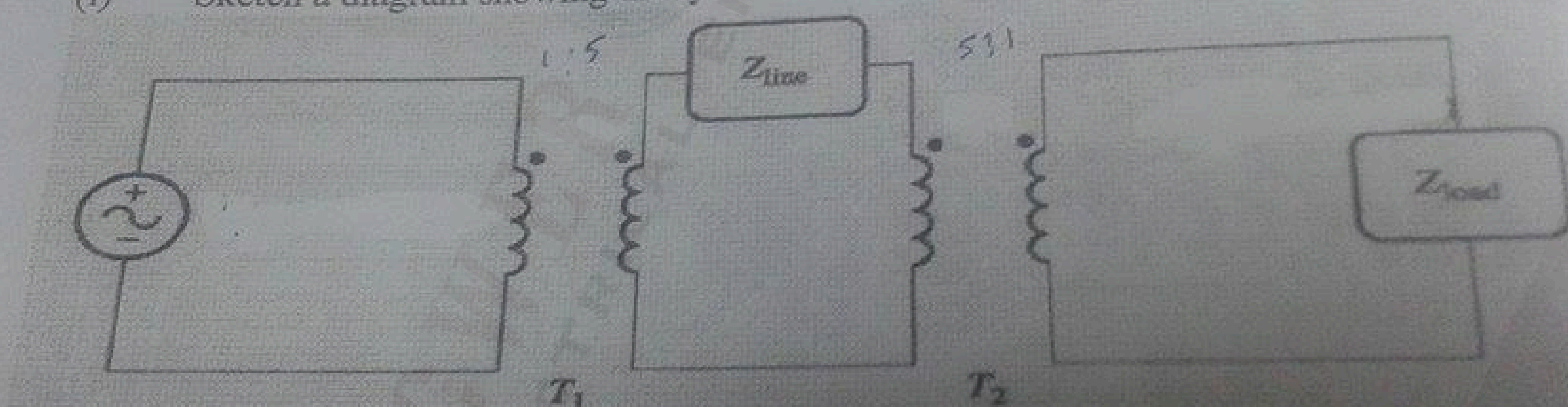
T1 is 5kVA of 1:5 transformation ratio and an equivalent impedance referred to the low voltage side of 0.2+j0.5 Ω

T2 is 5kVA of 5:1 transformation ratio and of a per unit equivalent impedance of 0.01+j0.02

7marks

The feeder is of 10+j30 Ω.

(i) Sketch a diagram showing the system



(ii) Draw the equivalent circuit of the system referred to the low voltage side indicating values

(iii) Find the supply voltage

$V_s = 250 + 22.3\angle -26.56\,(0.2 + 0.5j + 0.4 + 1.25j + 0.125 + 0.25j)$

$V_s = 285.67\angle 6.36$

(iv) Find the power loss in the two transformers and in the feeder

$P_{loss} = (22.3)^2 (0.2 + 0.4 + 0.125)$

$= 360.535$

(v) Find the efficiency of the system

$\eta = \dfrac{P_{out}}{P_{in}} = \dfrac{VI\cos\theta}{VI\cos\theta + 360.535} = \dfrac{22.3 \times 250\cos(26.56)}{[illegible] + 360.535}$

$= 93.25\,\%$

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