12

Jordan University
Electrical Engineering Department
1^{st} *Exam, Spring* Term
Electric Machines, 0973373

Student Name:.......................................Student Number:........................ Section:.............. Date: *March.* 23^{th}, 2011............ time allowed: $1\frac{1}{4}$h

Problem 1: A wrought iron bar is 30 cm long and 2 cm in diameter is bent into a circular shape as shown in Fig. 2. It is then wound with 500 turns of wire. Calculate the current required to produce a flux of 0.5 mWb in the magnetic circuit in each of the following cases:

4/4

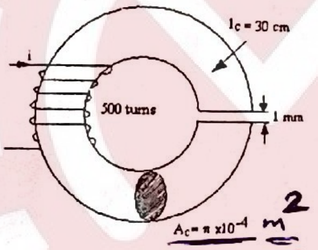
(a) The structure has no air gap and $\mu_r = 4000$ (assumed constant)

(b) The structure has an air gap of 1 mm, and $\mu_r = 4000$ (assumed constant)

2 (c)) The structure has an air gap of 1 mm, and B-H charteristics are given in the table below.

The structure has an air gap of 1 mm, and B-H charteristics are given in the table below.

H(At/m)	2500	3000	3500	4000
B(Tesla)	1.550	1.590	1.600	1.615



$\phi = 0.5 \times 10^{-3}$ wb $= \frac{B \cdot A}{}$

$N = 500$ turn.

$F_i = Ni = \phi R = \frac{\phi L}{\mu A}$, $\mu = \mu_r \mu_0$.

for N=400

$400 i = 0.5 \times 10^{-3} R = \frac{0.5\times10^{-3}(0.3)}{\mu_0 \mu_r \times \pi \times 10^{-4}}$

Solution:

$R = \frac{L}{\mu A}$

$400 i = \frac{0.5\times10^{-3}(0.3)}{4\pi\times10^{-7}\times4000\times\pi\times10^{-4}}$

$\therefore 400 i = 94.988$

$\Rightarrow i = 0.2374$ A # 1).

2) $\phi = 0.5\times10^{-3} = B \cdot A = B \times \pi \times 10^{-4}$

$\therefore B = 1.591$ T

$R|_{core} = \frac{L_c}{\mu_r \mu_0 A} = 189977.21$

$R|_{gab} = \frac{L_g}{\mu_0 \cdot A} = \frac{1\times10^{-3}}{4\pi\times10^{-7} \times \pi\times10^{-4}}$

$= 2533029.59$

$R_{Tot} = 2723006.8$

$400 i = 0.5\times10^{-3}(2723006.8)$

$i = 3.403$ A #

$F_i = Ni = H_g l_g + H_c l_c$

from $B_c = 1.59 \approx H\ 3000$ $\frac{At}{m}$

$\therefore B_c = B_g = 1.59$

$\therefore H_g = \frac{B}{\mu_0} = \frac{1.59}{4\pi\times10^{-7}}$

$\therefore H_g = 1265281.7$ At/m.

$\therefore$

$400 i = [1265281.7 \times 1\times10^{-3}] + [3000 \times 0.3]$

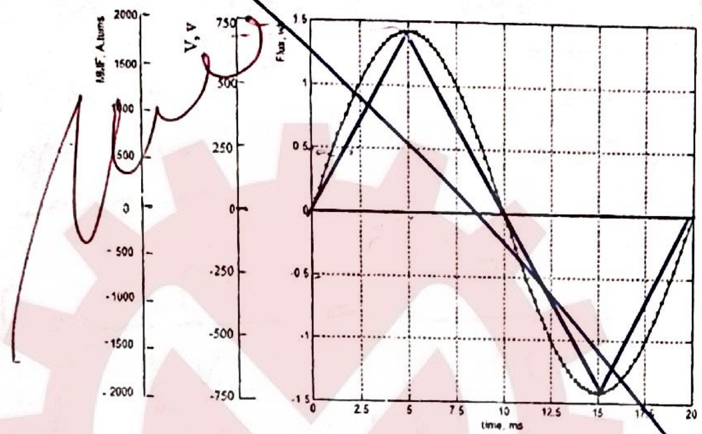
$400 i = 2165.28$

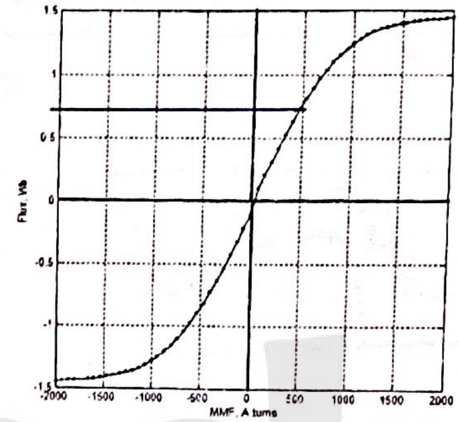
$I = 5.413$ A #

$$F_i = Ni = HL = H2\pi r = \frac{LB}{\mu} = \phi R = \frac{\phi l}{\mu A}$$

Problem 2 Figure show $\phi = f(t)$ on the left and Flux ϕ versus MMF on right. Assume ~~500~~ 1 Turns.

1. Draw the $v(t)$ on the appropriate place.
2. Drive the magnetization current from the two figures given?





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

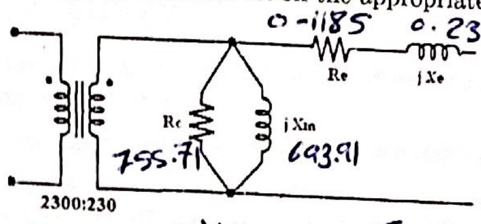
$$= 1\,\frac{1.45-0}{5-0} = \underline{0.29}$$

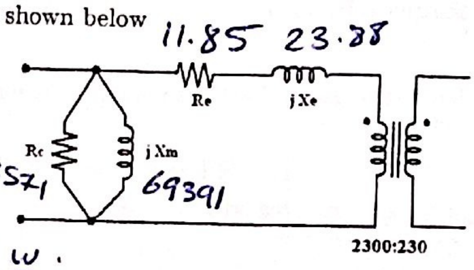
$R + x \quad V_s / I_s \cos^{-1} p.f$

Problem 3 The following data were obtained from tests carried out on a 10 kVA, 2300/230 V 50 Hz distribution transformer: Open circuit test: 230 V, 0.45 A, 70 W. Short circuit test: 120 V, 4.5 A, 240 W.

Find R_e, X_e, R_c, X_m and label all on the appropriate sketch shown below

$\frac{4}{4}$

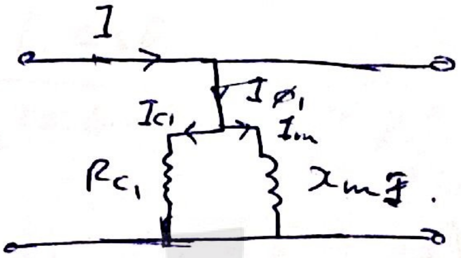




Solution:

$\qquad V \qquad I\ A \qquad P\ W.$

for open circuit:- $230\,V,\ 0.45,\ 70$



$$p.f = \frac{P_{oc}}{I_{oc} V_{oc}} = \frac{70}{0.45(230)} = 0.6763$$

$$\therefore I = \frac{1}{R_c} + \frac{1}{x_m} J = \frac{I_o}{V_o} \angle -\cos^{-1} p.f$$

$$= \frac{0.45}{230} \angle -\cos^{-1} 0.6763$$

$$= 1.32325 \times 10^{-3} - 1.4411 \times 10^{-3} J$$

$$\therefore \frac{1}{R_c} = 1.32325 \times 10^{-3} \Rightarrow R_c = 755.71\,\Omega \quad \#$$

$$\frac{1}{x_m} J = 1.4411 \times 10^{-3} J \Rightarrow x_m = 693.91\,\Omega \quad \#$$

for ~~short circuit~~

Refer to hightvoltage:-

$$R_c' = R_c \left(\frac{N_1}{N_2}\right)^2 = 755.71 \left(\frac{2300}{230}\right)^2$$

$$= 75571\,\Omega \quad \#$$

$$x_m' = x_m (10)^2 = 69391\,\Omega \quad \#$$

for short circite:- $\quad p.f = \frac{P_{sc}}{I_{sc} V_{sc}} = \frac{240}{120(4.5)} = 0.445$

$$\therefore Z_{eq} = R_{eq} + x_{eq} i = \frac{V_{sc}}{I_{sc}} \angle \cos^{-1} p.f = \frac{120}{4.5} \angle \cos^{-1} 0.445$$

$$= 11.85 + 23.88 J$$

$$\therefore R_{eq} = 11.85\,\Omega \#, \quad x_{eq} = 23.88\,\Omega \#$$

Problem 4: A single-phase, 3 kVA, 220/110 V, 50 Hz transformer has a HV winding resistance of 0.3Ω, a LV winding resistance of 0.06 Ω, a HV leakage reactance of 0.8 Ω and a LV leakage reactance of 0.2 Ω. The core loss at $\boxed{\text{rated voltage is 45 W}}$. The copper loss at rated load is 100 W. Neglect the exciting current of the transformer and use the *per unit* circuit to:

(a) Find the per-unit voltage regulation when the transformer is supplying full load at 110 V and 0.9 lagging power factor.

(b) Calculate the transformer efficiency when delivers 2.7 kW at 0.90 lagging PF.

(c) Find the all-day efficiency for the following loading: 3.5 kVA, 0.95 PF for 3 H; 3.0 kVA, 0.9 PF for 8 H; 2.4 kVA, 0.8 PF for 4 H; 1.0 kVA, 0.95 PF for 9 H.

1.16   1   0.8   0.33

Solution:

2) $\eta = \dfrac{P_{out}}{P_{in}} = \dfrac{P_{out}}{P_{out} + P_{loss}} = \dfrac{V_2 I_2 \cos\theta}{V_2 I_2 \cos\theta + P_{o.c} + I_2^2 R_{eq_2}}$

$I_{FL_2} = \dfrac{3000}{110} = 27.27$

$\eta = \dfrac{(110)(0.9)(27.27)}{(27.27)(110)(0.9) + 2700 + 100} = 35.71\%$

$P_{out} = 3000(0.9) \Rightarrow 2.7 \approx$

$\dfrac{3000(0.9)}{3000(0.9) + P_{oc} + P_{cu}}$

$\therefore P_{oc} = P_c = 45W$

$2.7/3 = 90\%$ of full load

$P_{cu} = I^2 R_{eq} = 100 \times (0.9^2) = 81$

$\eta = \dfrac{2700}{100(2.7) + 45 + 81} = 95.5\%$

$P_{core} = (1.16^2 \times \frac{3}{1000} \times 3) + (1^2 \times 3\times10^{-3} \times 8) + (0.8^2 \times 3\times10^{-3} \times 4) + (0.33^2 \times 3\times10^{-3} \times 9)$

$= 0.0467$ kwh.

3) $\eta_{AD} = \dfrac{\sum_{24} P_{out}}{\sum}$

percent $= 116\%, 100\%, 80\%, 33\%$

$\sum_{24} = (\cancel{3.5 \times 0.95 \times 3 \times 1.16}) + (\cancel{3 \times 0.9 \times 8 \times 1}) + (\cancel{2.4 \times 0.8 \times 4 \times 0.8}) + (\cancel{0.33})$

$= (3.5 \times 0.95 \times 3) + (3 \times 0.9 \times 8) + (2.4 \times 0.8 \times 4) + (1 \times 0.95 \times 9)$

$= 9.975 + 21.6 + 7.68 + 8.55 = 47.805$

$= (1.16^2 \times 3 \times 4) + ($

$P_{cu} = \dfrac{100}{1000} \times 24 = 2.4$ kwh. $= P_{core}$

$\eta_{dy} = \dfrac{47.805}{47.805 + 2.4 + 0.0467}$

$\eta_{day} = 95.13\%$

$V.S > V_L \rightarrow$

Problem 5: A10 kVA 480/100 V conventional (isolated winding) transformer is to be as auto transformer. The source voltage is 480 V, the load operates at 380 V.

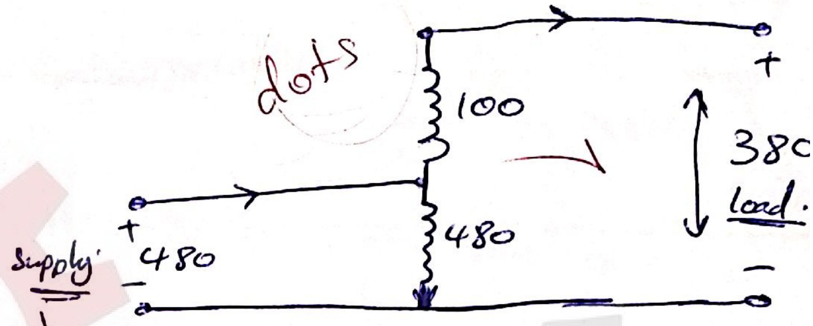
(a) Sketch the transformer connection that will do the required job.

(b) Find the kilo-volt-ampere rating of the transformer in the configuration

(c) Find the maximum primary and secondary currents under these configuration

$S = 10kVA, \quad V_{source} = 480V, \quad V_{Load} = 380V.$

480/100



$$S_{auto} = S\left(\frac{380}{100}\right)$$

$$= 10\left(\frac{380}{100}\right) = 38kVA.$$

$$I_{max @480\ Primary} = \frac{38000}{480} = 79.1667\ A$$

$$I_{max @380} = \frac{38000}{380} = 100\ A$$

$$\cancel{I_{RL} = \frac{10000}{480} = 20.83\ A}$$

$$\cancel{= \frac{10000}{100} = 100\ A}$$