UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

Department of Electrical and Electronic Engineering

MAIN EXAMINATION
First Semester 2017

Title of the Paper:

Electrical Machines

Course Number: EE451
Time Allowed: Three Hours.

Instructions:

1. The answer has to be written in the space provided in the question book; else the answer ignored. Use the answer book as a scratch pad.
2. Mark the ID on both question and scratch book and hand-in both.
3. Answer all questions, no optional
4. This paper has 6 pages, including this page.

DO NOT OPEN THE PAPER UNTIL
PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR.

Q1, 20 pts: It is desired to achieve a time-varying magnetic flux density in the air gap of the magnetic circuit of Fig. Q1-1 of the form:

$$B_g = B_0 + B_1 \cdot \sin(\omega t)$$

where $B_0 = 0.5T$ and $B_1 = 0.25T$. The DC field B_0 is to be created by a neodymium-iron-boron magnet ($B_m = 1.25 + 1.33*10^{-6} H_m$), whereas the time-varying field is to be created by a time-varying current, $i(t) = I_1 \cdot \cos(\omega t)$.

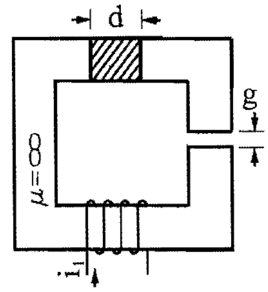

Fig. Q1-1

For $A_m = A_g = 6$ cM^2, g = 0.4 cM, and N= 200 turns, find:

(i)(10 pts). the magnet length d that will achieve the desired dc air-gap flux density and minimum magnet volume.

(ii)(5 pts). the peak value of the time-varying current, I_1, required to achieve the desired time-varying air-gap flux density.

(iii)(5 pts). If replace the magnet with a dc current, I_0, in the coil, find I_0.

Q2, 20 pts: In Fig. Q2-1, shows the fluxes of a typical transformer. From the given fluxes, derive the transformer equivalent circuit, which explicitly shows the transformer voltage ratio and the core and the leakage flux impedance, X_c and X_{01}, X_{02}. which are directly related to the voltage regulation and power efficiency.

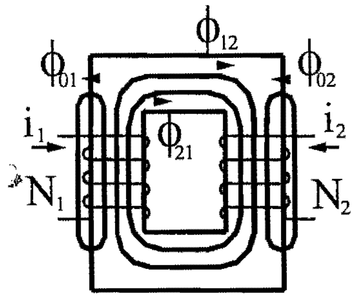

Fig. Q2-1

(i)(4 pts). Find X_c and X_{01}, X_{02} from the given fluxes in the figure.

(ii)(8 pts). Derive the equivalent circuit as said above. The wire copper resistances r_1 and r_2 and core loss is R_c.

(iii)(8 pts). Derive the voltage regulation in terms of parameters of the equivalent circuit, if the load is resistive R_L such that R_c and X_c are both large compared with the load.

Q3, 20 pts: Given a 3-φ, Y connected induction motor is rated at 380 V, 15 KW, 50Hz, and 4-pole. The friction windage and core loss is assumed to be a constant independent of load at 400 W. The motor is operated under rated terminal voltage and frequency. The motor constants are:

R_1=0.6, R_2=0.3, X_1=2.7, X_2=0.5, and X_M=27 Ω

Evaluate the performance at a rated slip of 5% (Equivalent ckt is essential and helpful): (5 pts each)

(i). motor speed,

(ii). stator current,

(iii). out put shaft torque and power,

(iv). motor power factor and efficiency.

Q4, 20 pts: A system shown in Fig. Q4-1 is energized under the 50 Hz power source. The synchronous motor has 4 poles and drives the interconnected shaft in the clockwise direction. The induction machine has 6 poles and its stator windings are connected to the source such that as to produce a counter-clockwise rotating field (in opposite to the rotation of the synchronous motor). The machine has a wound rotor whose terminals are brought out through slip rings.

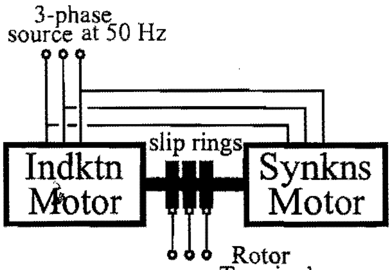

Fig. Q4-1

(i)(4 pts). At what speed does the motor run?

(ii)(8 pts). What is the frequency of the voltage produced at the slip rings of the induction motor? What is "s" now and in what operating mode if rotor is shorted properly?

(iii)(8 pts). What will be the frequency of the voltages produced at the slip rings of the induction motor if two leads of the induction motor stator are interchanged, reversing the direction of rotation of the resultant rotating field? Again what is "s" now and in what operating mode if rotor is shorted properly?

Q5, 20 pts: The torque of a 2-phase permanent magnet stepping motor of the form in Fig. Q5-1 can be expressed as:

$$T_{mch} = T_0 (I_a \cdot \cos\theta_m + I_b \cdot \sin\theta_m)$$

where T_0 is a positive constant that depends upon the motor geometry and properties of the permanent magnet.

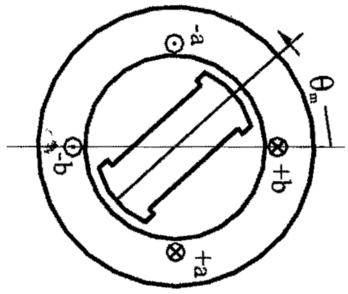

Fig. Q5-1

(i)(10 pts). Calculate, in a list table, the rest (zero torque) positions which will result if the motor is driven by a DC current such that each phase current can be set equal to three values $-I_0$, 0, and $+I_0$.

(ii)(5 pts). Using such a drive what is the motor step-size?

(iii)(5 pts). What is the current code sequence (I_b, I_a) when rotating in CCW direction. (No pts for CW).

(i).

I_b	I_a	θ_m