UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE AND ENGINEERING
Department of Electrical and Electronic Engineering

July 2015
SUPPLEMENTARY EXAMINATION

Title of the Paper:
EE451
Electrical Machines
Time Allowed: Three Hours

Instructions:

1. The answer has to be written in the space provided in this question paper. Consider only the material in the answer space be the answer. If need more space, the previous page is the best option. Use the answer book as a scratch pad. Both books must be marked with the student identity
2. There are 7 questions in the question book. Pick 100 pts and mark the not picked question with a big X in the answer space; or leave the grading person to pick according to the worst case first.
3. This paper has 8 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 DC current I_0, whereas the time-varying field is to be created by a time-varying current, $i(t) = I_1 \cdot \cos(\omega t)$.

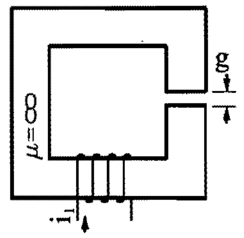

Fig. Q1-1

For $A_g = 6\ cM^2$, $g = 0.4\ cM$, and $N = 500$ turns, find:

(i). the DC current I_0 that will achieve the desired dc air-gap flux density.

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

Q2, 20 pts: There are 2 coils in a magnetic circuit, N_1, and N_2 carrying respectively a current I_1, and I_2. The polarities among the coils are shown in Fig. Q2-1 by the reference of the core and winding direction. Find:

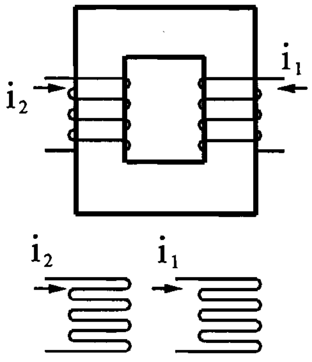

Fig. Q2-1

(i). At the bottom of Fig. Q2-1, there is no reference of winding direction and hence a "dot" convention is adopted to show coupling direction. On Fig. Q2-1, mark the proper terminals of coil 1 and 2 with a 'dot' to carry the direction information from the top to the bottom figure.

(ii). The flux Φ_2 and Φ_{2t}

(iii). L_2, and L_{21}

Q3, 20pts: A given transformer has the specs: 50-KVA, 2400/240-V, copper loss=617 W, and iron loss=186 W. The short-circuit test readings for transformer are 48V, 20.8A. An open-circuit test gives instrument readings: 240V, 5.41A. Find:

(i). the series parameters of the transformer

(ii). the parallel parameters of the transformer

(iii). Are you able to divide the primary and the secondary series components values under reasonable tolerance. Draw the equivalent circuit of the transformer.

Q4, 20 pts: Fig. Q4-1 shows an electrostatic volt-meter, which is a capacitive system consisting of a movable and a fixed electrode. The movable electrode can rotate on a pivot to keep a constant air gap "d" between two electrodes. Consider only ideal case with no fringing flux. A torsional spring is connected to the movable electrode to balance the movable electrode torsion. Its torque is: $T_{spg} = -K_s \varphi$. Set $\varphi=0$ at $T_{spg}=0$ and $V=0$.

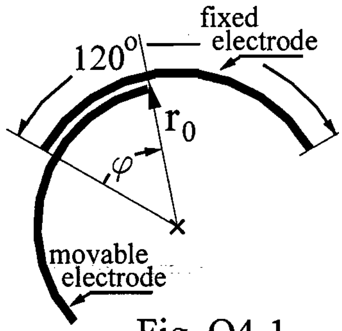

Fig. Q4-1

(i). find $C(\varphi)$

(ii). find the energy $En(V,\varphi)$.

(iii). find the relation between measured voltage V_m and φ

Q5, 20 pts: Fig. Q5-1 shows a cross-sectional sketch of a machine having a rotor winding f and two identical stator windings "a" and "b" with turns N whose axes are in quadrature. The uniform air gap between rotor and stator is "g", its equivalent cross-sectional area "Ag", and the material of the core $\mu \rightarrow \infty$. The stator windings are energized by a balanced two-phase currents:

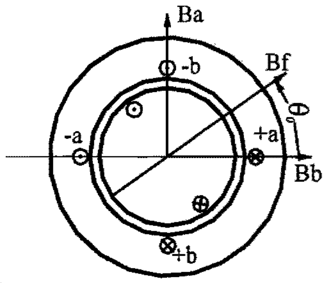

Fig. Q5-1

$i_a = I_a \cdot \sin \omega t \quad i_b = I_b \cdot \cos \omega t$

(i). Derive the resultant flux density in the air gap B_g

(ii). Prove the field will revolving and give its rotation direction.

Q6, 20 pts: A system shown in Fig. Q6-1 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 clockwise rotating field (in the same rotation direction of the synchronous motor). The machine has a wound rotor whose terminals are brought out through slip rings.

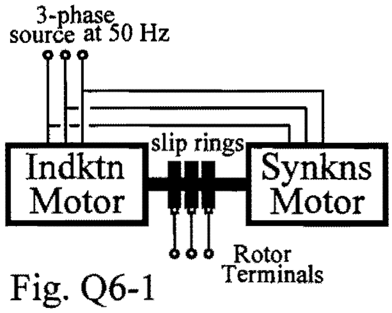

Fig. Q6-1

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

(ii). 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?

Q7, 20 pts: The torque of a 2-phase permanent-magnet stepping motor of the form in Fig. Q7-1 can be expressed as:

$$T_{mch} = T_0(i_1 \cdot \cos\theta_m + i_2 \cdot \sin\theta_m)$$

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

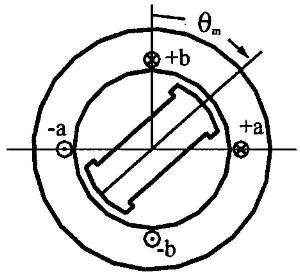

Fig. Q7-1

Calculate the rest (zero torque) positions which will result if the motor is driven by a drive such that each phase current can be set equal to the values (i) $\pm I_0$. List the rest positions and their associated phase currents; what is the motor step size? (ii) to the values 0, and $\pm I_0$, what is the motor step size? (iii) To improve a small step size, what is your advice?