UNIVERSITY OF ESWATINI

MAIN EXAMINATION, DECEMBER 2018

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER :	**ELECTRICAL MACHINES**
COURSE NUMBER:	**EE451 / EEE451**
TIME ALLOWED :	**THREE HOURS**

INSTRUCTIONS:

1. There are six questions in this paper. **Answer All Questions.**
2. Each question carries its own mark as shown in all questions.
3. Marks for different sections are shown on the right hand margin.
4. Show the steps clearly in all your calculations including any assumptions made.

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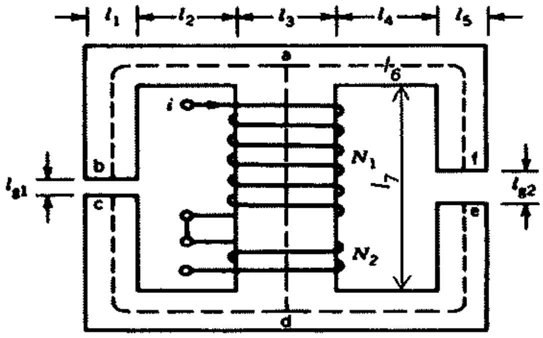
THIS PAPER HAS FOUR (4) PAGES INCLUDING THIS PAGE

QUESTION 1 ***(15 marks)***

The magnetic shape given in Fig. 1 provides flux in the two air gaps. The coils (N_1=500 turns, N_2=200 turns) are connected in series and carry a current of 1 A. The relative permeability of the iron is 3000 H/m. Neglect leakage flux, and the fringing effect in this shape. Determine:

a- The total flux, *(7-marks)*
b- Flux density in air gaps, and *(4-marks)*
c- Inductance of coils. *(4-marks)*



L_{g1} = 2mm, L_{g2} = 6mm
L_1 = L_5 = 20mm, L_2 = L_4 = 40mm, L_3 = 50mm
L_6 = 10mm, L_7 = 80mm
Depth of core = 20mm

Fig. 1.

QUESTION 2 ***(15 marks)***

a- A 16 ohms resistive load is connected to a 10:1 ideal transformer as shown in the Fig. 2. Calculate the following:

i- secondary voltage V_s *(2-marks)*
ii- secondary current I_s, and *(2-marks)*
iii- primary current I_P *(2-marks)*

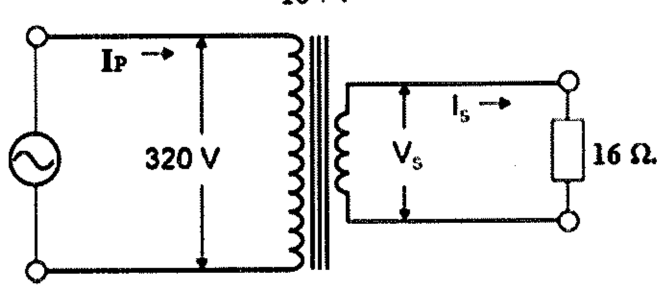


Fig. 2.

b- Three single phase transformers are connected in delta –delta to step down a line voltage of *138 kV* to *4160 V* to supply power to a manufacturing plant. The plant draws *21 MW* at a lagging power factor of *86%*. Calculate:

i- Apparent power drawn by plant *(2-marks)*
ii- Current in HV line *(2-marks)*
iii- Current in LV lines, and *(2-marks)*
iv- Currents in primary and secondary windings of each transformer. *(3-marks)*

QUESTION 3 ***(20 marks)***

A reluctance motor with four rotor poles is shown in Fig. 3. The reluctance ($\mathcal{R}$) of the magnetic system can be assumed to be a sinusoidal varying function of (θ) and is given by:

$$\Re(\theta) = 3x10^4 - 10^4 \sin(5\theta)$$

The coil has 300 turns and negligible resistance and is connected to a 220 V, 50 Hz, single-phase supply.

a- Obtain an expression for the flux (Φ) as a function of time. (Hint: $v = N\frac{d\phi}{dt}$). *(5-marks)*

b- If the torque ($T = \frac{1}{2}i^2\frac{dL}{d\theta}$) relationship is used, then show that the torque developed is: *(5-marks)*

$$T = -\frac{1}{2}\phi^2\frac{d\Re}{d\theta}$$

c- Determine the values of speed (ω_m) of the rotor at which the machine will develop an average torque. *(5-marks)*

d- Determine the maximum torque and power (mechanical) that could be developed by the machine at each speed. *(5-marks)*

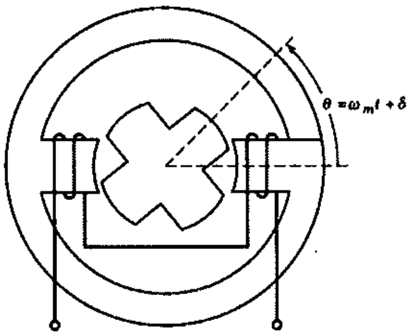


Fig. 3.

QUESTION 4 ***(15 marks)***

a- A shunt motor rotating at 1500 rpm is fed by a 120 V power supply. The armature winding resistance (R_a) is 0.4 Ω and the field winding resistance (R_f) is 40 Ω. If the back emf (CEMF) developed is 100 V, find the following:

i-	shunt field winding current,	*(2-marks)*
ii-	armature current,	*(2-marks)*
iii-	input power to the motor,	*(2-marks)*
iv-	mechanical power produced by the armature, and	*(2-marks)*
v-	motor torque.	*(2-marks)*

b- A shunt dc motor has an armature resistance of 1.2 ohm. It is connected across 400 volt supply. The armature current taken by the motor is 30 amperes and the motor runs at 900 r.p.m. Calculate the additional resistance to be inserted in series with the armature to reduce the speed to 500 r.p.m. Assume that there is no change in armature current. *(5-marks)*

QUESTION 5 ***(20 marks)***

A three-phase, 400 V, 1400 rpm, 50 Hz, four-pole wound rotor induction motor has the following parameters per phase:

$R_1 = 0.25\ \Omega$, $R_2' = 0.35\ \Omega$

$X_1 = X_2 = 0.5\ \Omega$ $X_m = 4\ \Omega$

If the rotor terminals short-circuit, find:

a. Speed of the rotating air gap field, *(2-mark)*
b. frequency of the rotor circuit, *(2-mark)*
c. starting current when started direct on full voltage, *(2-mark)*
d. starting torque, *(2-marks)*
e. full-load current, *(2-marks)*
f. ratio of starting current to full-load current, *(2-marks)*
g. slip at which maximum torque is developed, *(2-marks)*
h. maximum torque developed, and *(2-marks)*
i. how much external resistance per phase should be connected in the rotor circuit so that maximum torque occurs at 150 rpm. *(4-marks)*

QUESTION 6 ***(15 marks)***

A 400 V, 50 Hz, Y-connected six-pole synchronous generator has a per-phase synchronous reactance of 1.0 Ω. Its full-load armature current is 50 A at 0.8 PF lagging. Its friction and windage losses are 1.5 kW and core losses are 1.0 kW at 50 Hz at full load. Assume that the armature resistance (and, therefore, the I^2R losses) can be ignored. The field current has been adjusted such that the no-load terminal voltage is 400 V. find the following:

a. What is the speed of rotation of this generator? *(3-marks)*
b. What is the terminal voltage of the generator if:
    1. It is loaded with the rated current at 0.8 PF lagging; *(2-marks)*
    2. It is loaded with the rated current at 1.0 PF *(2-marks)*
    3. It is loaded with the rated current at 0.8 PF leading. *(2-marks)*
c. What is the voltage regulation of this generator at?
    1. 0.8 PF lagging, *(2-marks)*
    2. 1.0 PF, and *(2-marks)*
    3. 0.8 PF leading. *(2-marks)*

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