UNIVERSITY OF ESWATINI
MAIN EXAMINATION, DECEMBER 2019

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER:	**ELECTRICAL MACHINES**
COURSE NUMBER:	**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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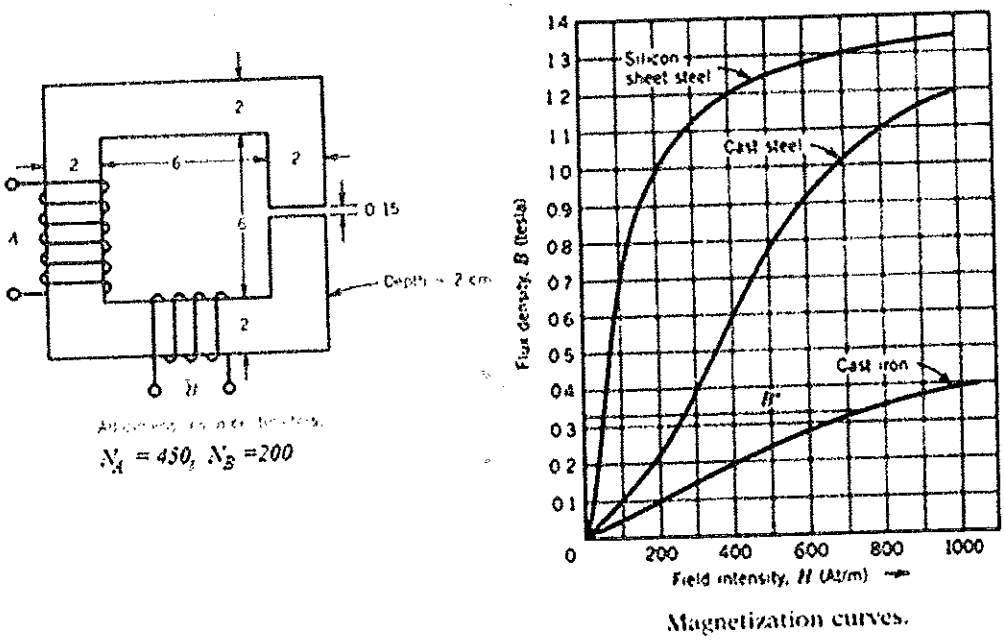
THIS PAPER HAS FOUR (5) PAGES INCLUDING THIS PAGE

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

An inductor is made of two coils, A and B, having 450 and 200 turns, respectively. The coil are wound on a cast steel core and in directions as shown in Fig. 1. The two coils are connected in series to a dc voltage. Given that all the dimensions of the shape in Fig. 1 is in centimeters.

a. Determine the two possible values of current required in the coils to establish a flux density of 0.5 T in the air gap. *(5-marks)*
b. Determine the self-inductance L_A and L_B of the two coils. Neglect magnetic leakage and fringing. *(4-marks)*
c. If Coil B is now disconnected and the current in coil A is adjusted to 2 A, determine the mean flux density in the air gap. *(6-marks)*



Magnetization curves.

Fig. 1.

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

a. Calculate voltages E_1, I_1, and I_2 in the circuit shown in Fig.2, if the primary to secondary turns ratio 2:25. *(7-marks)*

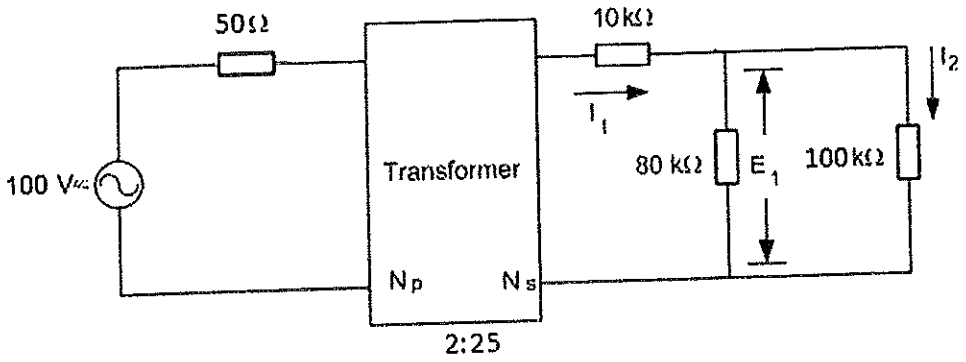


Fig. 2.

b. Three single phase transformers are connected in delta –delta to step down a line voltage of 66 kV to 3300 V to supply power to a manufacturing plant. The plant draws 10 MW at a lagging power factor of 88%. 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. *(2-marks)*

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

a. An electromagnet lift system is shown in Fig. 3. The coil has 2500 turns. The flux density in the air gap is 1.25 T. Assume that the core material is ideal. For an air gap, g = 8 mm, determine the following:
   1- the coil current, *(3-marks)*
   2- the energy stored in the magnetic system, *(3-marks)*
   3- the force on the load (Silicon sheet of steel in Fig. 1), and *(2-marks)*
   4- the mass of the load (acceleration due to gravity = 9.81 m/sec^2). *(2-marks)*

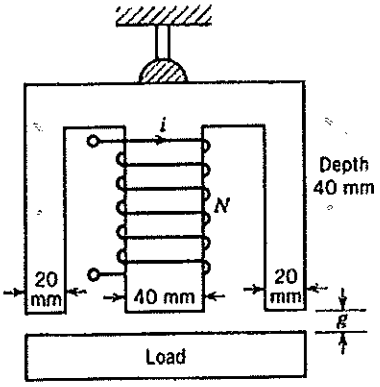


Fig. 3.

b. Fig. 4 shows the two-pole cylindrical rotating machine, If the currents in the two winding are:

$$i_s = I_{sm}\cos\omega_s t \qquad \text{and} \qquad i_r = I_{rm}\cos(\omega_r t + \alpha)$$

The position of the rotor at any instant is $\theta = \omega_m t + \delta$ the mutual inductance between the stator and the rotor is $L_{sr} = M\cos\theta$. Find the average torque of this machine and determine the average speed at the non-zero instant time of the average torque?*(10-marks)*

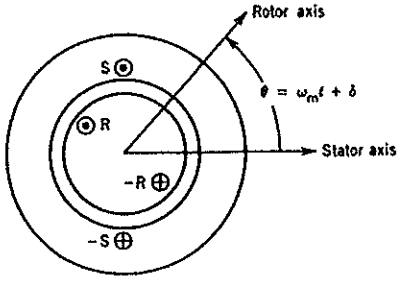


Fig. 4.

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

a- A shunt motor rotating at 1500 rpm is fed by a 220 V power supply. The armature winding resistance (R_a) is 5 Ω and the field winding resistance (R_f) is 45 Ω. If the back emf (CEMF) developed is 180 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 series motor with armature resistance and series field resistance of 0.03 ohm and 0.07 ohm respectively is connected across the 220 volts mains. The armature takes 40 amperes with a speed of 900 r.p.m. Determine the speed when the armature current is 75 amperes and the excitation is decreased by 25 %. *(5-marks)*

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

a. A three-phase, 480 V, 50 Hz, four-pole wound-rotor induction motor drives a constant load of 150 N.m at speed 1400 rpm when the rotor terminals are short-circuited. It is required to reduce the speed of the motor to 850 rpm by inserting resistance in the rotor circuit. Determine the value of the resistance if the rotor winding resistance per phase is 0.3 ohms. Neglect rotational losses. The stator-to-rotor turns ratio is unity. *(10-marks)*

b. The rotor current at start of a three-phase, 400 volt, 925 rpm, 50 Hz, 6 pole, squirrel-cage induction motor is five times the rotor current at full load. *(10-marks)*

1. Determine the starting torque as percent of full load torque.
2. Determine the slip and speed at which the motor develops maximum torque.
3. Determine the maximum torque developed by the motor as percent of full load torque.

(given that : $T = \frac{I_2^2 R_2}{\omega_{syn}}$ and $\frac{T_{max}}{T} = \frac{s_{max}^2 + s^2}{2 s_{max} s}$)

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

a. A 200 kVA, 480 V, 50 Hz, Y-connected synchronous generator with a rated field current of 5 A was tested and the following data were obtained: *(5-marks)*

1. $V_{T,OC} = 540$ V at the rated I_F.
2. $I_{L,SC} = 300$ A at the rated I_F.
3. When a DC voltage of 10 V was applied to two of the terminals, a current of 25 A was measured.

Find the generator's equivalent circuit at the rated conditions (i.e., the armature resistance and the approximate synchronous reactance)?

b. Two generators are set to supply the same load. Generator 1 has a no-load frequency of 51.5 Hz and a slope sp1 of 1 MW/Hz. Generator 2 has a no-load frequency of 51.0 Hz and

a slope sp2 of 1 MW/Hz. The two generators are supplying a real load of 2.5 MW at 0.8 PF lagging. Then; *(10-marks)*

1. Determine the excitation voltage and the power angle when the machine is delivering rated kVA at 0.8 PF lagging.
2. Draw the phasor diagram for this condition.
3. Find the system frequency and power supplied by each generator.
4. Assuming that an additional 1 MW load is attached to the power system, find the new system frequency and powers supplied by each generator.
5. With the additional load attached (total load of 3.5 MW), find the system frequency and the generator powers, if the no-load frequency of G2 is increased by 0.5 Hz.

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