UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

MARKS	**Final Examination, 9:30 a.m., April 26, 2001**
1	**Third Year - Program 03**
2	
3	Examiner: ***A. Konrad***
4	**MIE347S - ELECTROMECHANICAL ENERGY CONVERSION**
5	
	NAME:
TOTAL	
	(Family name) Please **PRINT** (Given names)
	STUDENT NUMBER:

EXAMINATION: Type D

Aids allowed: One original copy of Stephen J. Chapman, *Electric Machinery Fundamentals,* Third Edition, WCB/McGraw-Hill, 1999. Photocopies of this copyrighted text **are not permitted** in the Examination room. One copy of the 12-page Supplementary Study Material (*Theory*) posted on the MIE347S course web site. No other aids are allowed.

CALCULATORS: **All types permitted. No computers allowed.**

INSTRUCTIONS

All questions have equal weight. The answers to all ***FIVE*** questions constitute a complete paper. **Write in ink!** Answers to each question should be placed on the sheet containing the question, using ***both*** sides of the sheet, if necessary. Three additional blank sheets are attached at the end. One or more of these can be detached and used for rough work, in which case they will not be handed in. The blank sheet(s) left attached can be used as extensions to the answers, if needed.

(1) A Δ-connected load consists of three identical impedances $Z_{\Delta} = (45\angle 60°)\ \Omega$ per phase. This load is connected to a three-phase, Y-connected, 208-V (line-to-line) voltage-source by a three-phase, balanced line with per-phase conductor impedance given by $Z_{line} = (1.2 + j1.6)\ \Omega$.

5% **(a)** Calculate the line-to-line voltage (magnitude and phase) at the load terminals.

5% **(b)** A Δ-connected capacitor bank with a reactance of 60 Ω per phase is connected in parallel with the load at its terminals. Find the resulting line-to-line voltage (magnitude and phase) at the load terminals.

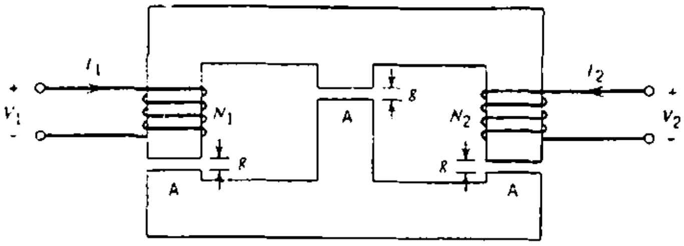
(2) The magnetic circuit shown below has a magnetic core of infinite relative permeability. Fringing and leakage flux are negligible. The following quantities are given: $V_1 = 120V$, $N_1 = 50$ turns, $R_1 = 10\ \Omega$, $V_2 = 208V$, $N_2 = 104$ turns, $R_2 = 20.8\ \Omega$, $g = 1.4$ mm, $A = 400\ mm^2$. Compute

3% (a) The magnetic flux densities B_{left}, B_{center} and B_{right} in the left, center and right air gaps, respectively. Give your results in Wb/m^2.

3% (b) The flux linkages λ_{left} and λ_{right} of the left and right coils, respectively. Give your results in Wb.

2% (c) The self inductances L_{left} and L_{right} of the left and right coils, respectively. Give your results in henries.

2% (d) The mutual inductance M of the two coils. Give your result in henries.

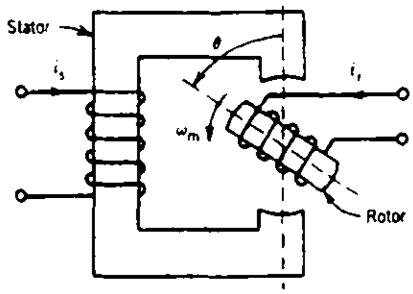


(3) A reluctance machine of the form shown below has no rotor winding. The inductace in henries of the stator winding is given by the following expression: $L_{ss} = 0.1 - 0.3 \cos 2\theta - 0.2 \cos 4\theta$. The stator coil carries a current of 10 A rms at 60 Hz.

4% (a) Determine the values of mechanical angular speed of the rotor (in rad/s) at which the machine will develop an average torque.

4% (b) Determine the maximum torque (in N·m) and mechanical power (in W) that could be developed by the machine at each speed obtained in part (a).

2% (c) Determine the maximum torque (in N·m) at zero speed.



(4) A shunt dc motor has the following nameplate data:

$P_{rated} = 7.5$ hp	$R_a = 0.12\ \Omega$
$V_{a,rated} = 120$ V	$R_f = 40\ \Omega$
$I_{a,rated} = 60$ A	$0 \le R_{f,ajd} \le 100\ \Omega$
$n_{rated} = 1000$ rpm	

The magnetization curve for this motor, **taken at rated speed**, is given by the following sequence of straight line interpolations:

$$E_a = (91.25\, I_f + 5.00)\ [V] \quad \text{for} \quad 0.00 \le I_f \le 0.80\ [A]$$
$$E_a = (85.00\, I_f + 10.00)\ [V] \quad \text{for} \quad 0.80 \le I_f \le 1.00\ [A]$$
$$E_a = (60.71\, I_f + 34.29)\ [V] \quad \text{for} \quad 1.00 \le I_f \le 1.28\ [A]$$
$$E_a = (37.50\, I_f + 64.00)\ [V] \quad \text{for} \quad 1.28 \le I_f \le 1.44\ [A]$$
$$E_a = (5.56\, I_f + 110.00)\ [V] \quad \text{for} \quad 1.44 \le I_f \le 3.00\ [A]$$

Assume that $R_{f,ajd}$ is set to 50 Ω. Armature reaction and stray losses may be ignored in this machine.

1% **(a)** What is the rated output torque of this motor?

2% **(b)** What is the rpm of this motor when it is running at rated voltage and rated armature current?

2% **(c)** What are the copper losses and rotational losses in the motor at full load?

1% **(d)** What is the efficiency of the motor at full load?

1% **(e)** If the motor is now unloaded with no changes in terminal voltage or R_{adj}, what is the no-load speed of the motor?

1% **(f)** Suppose that the motor is running at the no-load conditions described in part **(e)**. What would happen to the motor if its field circuit were to open? Ignoring armature reaction, what would the final steady-state speed of the motor be under those conditions?

2% **(g)** What range of no-load speeds is possible in this motor, given the range of field resistance adjustments available with R_{adj}?

(5) A 208-V, four-pole, 10-hp, 60-Hz, Y-connected, three-phase induction motor develops its full-load induced torque at 3.8 percent slip when operating at 60 Hz and 208 V. The per-phase circuit model impedances of the motor are

$$R_1 = 0.33\ \Omega \qquad X_M = 16\ \Omega$$
$$X_1 = 0.42\ \Omega \qquad X_2' = 0.42\ \Omega$$

Mechanical, core, and stray losses may be neglected in this problem.

1% (a) Draw the equivalent circuit for this motor. Show the values of all known parameters.

1% (b) Find the Thevenin impedance (Z_{TH}) and the Thevenin voltage ($\tilde{V}_{TH}$).

2% (c) Find the value of the rotor resistance R_2'.

3% (d) Find τ_{max}, s_{max}, and *the rotor rpm* at maximum torque for this motor.

1% (e) Find the starting torque of this motor.

2% (f) Find the locked-rotor kVA per horsepower value of this motor. With reference to the Table on page 407 of your textbook, what code letter factor should be assigned to this motor?

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