Professional Engineers Ontario

Electromagnetic Energy Conversion Exam

98-Elec-A6

DECEMBER 2005

Notes:

1. Attempt 5 questions. If more than 5 questions are attempted, clearly indicate which questions should be marked; otherwise, the first 5 found will be marked.

2. You may use one of the approved Casio or Sharp calculators.

3. This is a closed book exam. Candidates are allowed to bring ONE aid sheet 8.5" X 11"hand-written on both sides containing notes and formulae. Note, no example or solution problems, and no figures allowed. The aid sheet must be submitted with the written exam paper.

4. All ac voltages and currents are rms values unless noted otherwise. For three-phase circuits, all voltages are line-to-line voltages unless noted otherwise.

5. You should use pencil.

Question 1 - Magnetic circuits

The core of the magnetic circuit illustrated in Figure 1 is made of cold-rolled steel with a uniform depth of 5 cm. Leakage flux and fringing at the air gap can be neglected. The B-H curve for cold-rolled steel is shown in Figure 2 on the next page.

a. Calculate the value of direct current entering coil *AB* at *A* to produce a flux of 8 mWb in the 1.0 mm air gap. The coil has 400 turns. Note that no current flows in coil *CD*.

b. With the current flowing in part (a) flowing in coil *AB*, determine the magnitude and direction of the current required in the second coil, *CD*, wound on the right hand limb, if the air gap flux is to be reduced to zero. Coil *CD* has 100 turns.

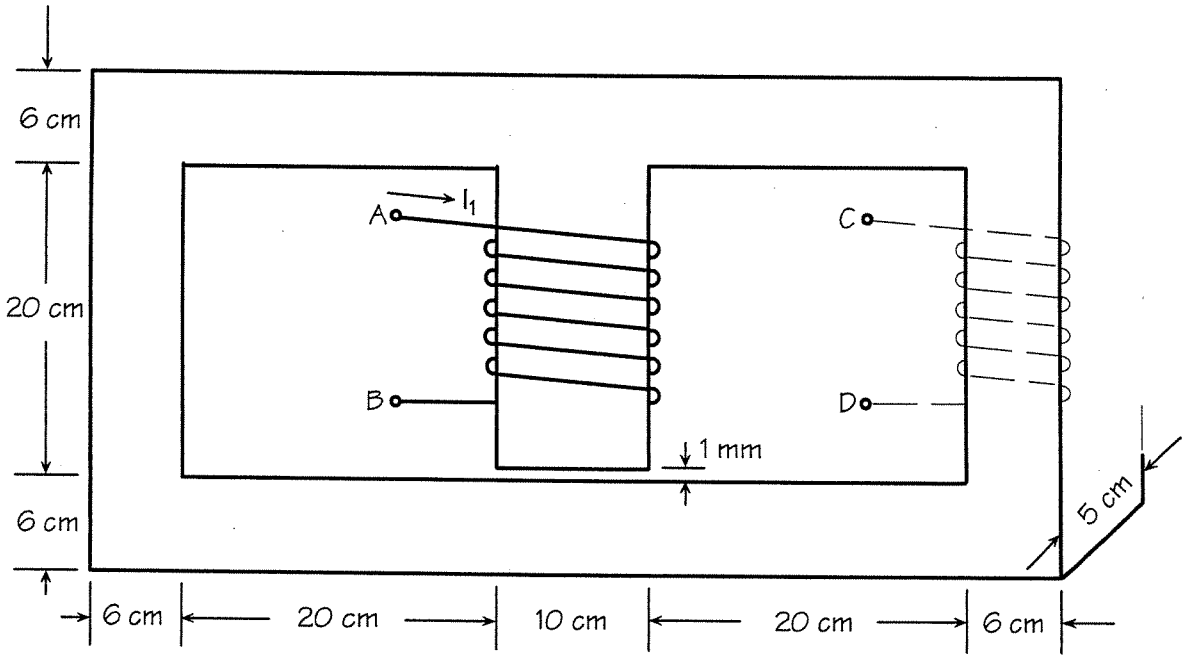

Figure 1

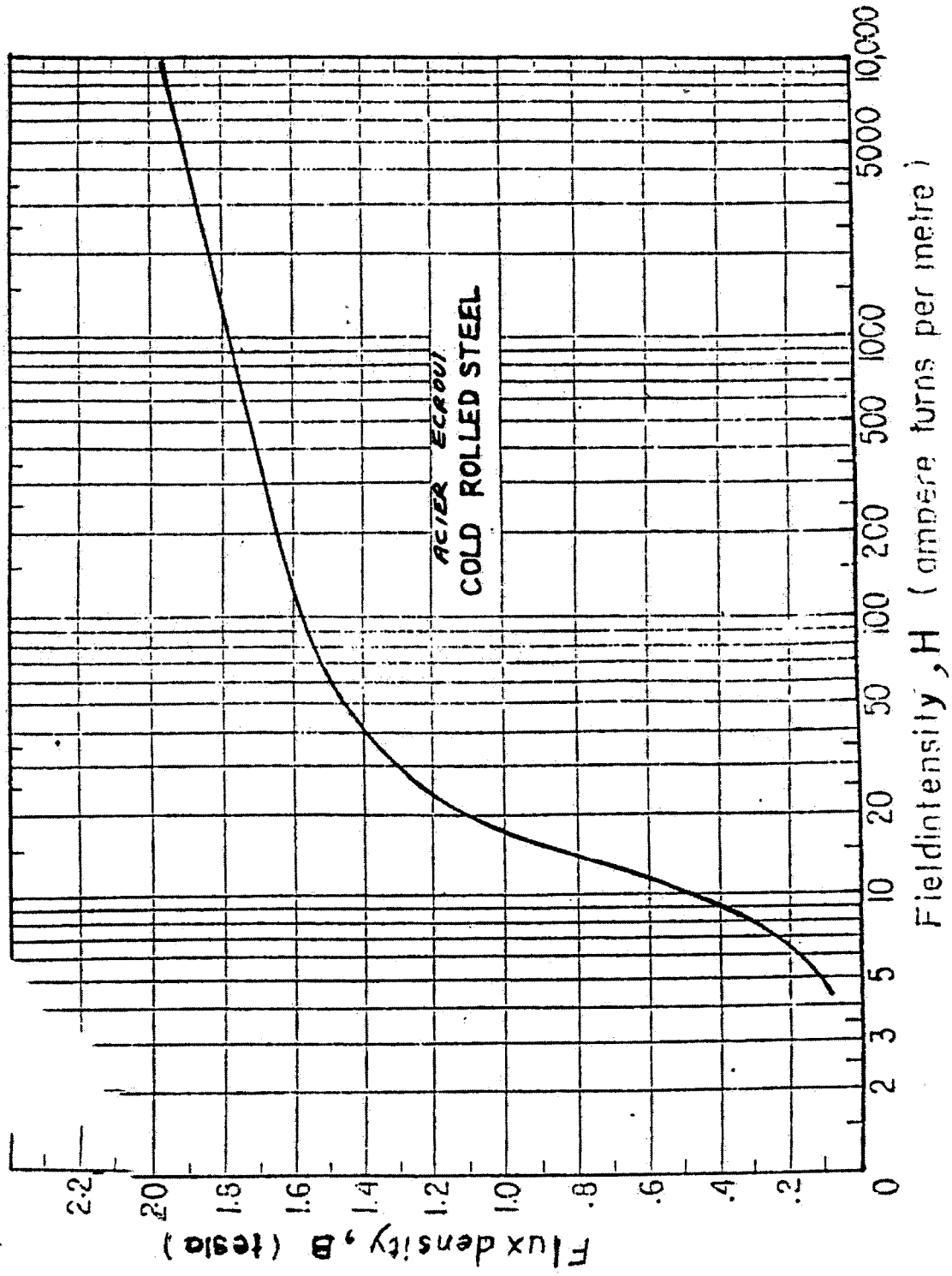
ACIER ECROUI
COLD ROLLED STEEL
Field intensity, H (ampere turns per metre)
0
2
3
5
10
20
50
100
200
500
1000
5000
10,000
Flux density, B (tesla)
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2

Figure 2

Question 2 - Three-phase power

A 208 V, 3-phase, 60 Hz system supplies the following loads:

i. a 10 hp induction motor working at full-load and having a power factor of 0.7, at an efficiency of 75%;

ii. a delta-connected load, each phase of which consists of a resistor of 5.5 Ω in series with an inductor of 20 mH; and,

iii. a balanced Y-connected capacitor bank.

Determine:

a. the value of the capacitor per phase so that the overall power factor is 0.9 lagging;

b. the S, P and Q of the total system load; and,

c. the readings of two wattmeters used to measure the total load power.

Question 3 - Transformers

A 4 kVA, 200/400 V single-phase transformer gave the following test results:

Test	Voltage (V)	Current (A)	Power (W)
Open-circuit test	200	0.7	60
Short-circuit test	9	10	21.6

Determine:

a. the equivalent circuit for this transformer;

b. the voltage which must be applied to the high voltage side so that 200 V will be across full load at 0.8 power factor lagging; and,

c. the efficiency of the transformer for the conditions of (b).

Question 4 - ac Induction motors

a. Show/explain how a constant magnitude rotating field can be obtained in the stator of a three-phase machine.

b. A 100 hp, 3-phase, Y-connected, 440 V, 60 Hz, 8 pole, squirrel cage induction motor has the following equivalent circuit parameters per phase referred to the stator:

Stator: $R_S = 0.085\ \Omega$,	$X_S = 0.196\ \Omega$
Rotor: $R_R = 0.067\ \Omega$,	$X_R = 0.161\ \Omega$
Magnetizing reactance:	$X_S = 6.65\ \Omega$

Iron losses are 1.9 kW and rotational losses are 0.5 kW, and can be considered constant. Determine the horsepower output (may be different than the rated value) and efficiency at rated voltage for a slip of 3.00 percent.

Question 5 - DC machines

A 250 V shunt motor has an armature current of 20 A when running at 1000 rpm against full-load torque. The armature resistance is 0.5 Ω.

a. If the field current is lowered such that the flux drops by 20%, what will be the new speed, assuming the torque remains constant?

b. Find the value of resistance to be inserted in series with the armature to reduce the speed to 500 rpm if the field current is at its full value and the load is full load torque.

c. If the conditions are as in (b), but the load torque is halved, find the new speed.

Question 6 - Synchronous machines

A 2500 hp, 2300 V, Y-connected, three-phase, 60 Hz, 60 pole synchronous motor is supplied with power from a 2000 kVA, 2300 V, Y-connected, three-phase, 60 Hz, synchronous generator. The synchronous reactances of the motor and generator are 2 Ω and 1.5 Ω/phase, respectively. For the purposes of this problem, all losses may be neglected. The excitations of the generator and motor are both adjusted to the values which result in rated terminal voltage when the power delivered to the motor is 2000 kW at unity power factor. The frequency is then 60 Hz, and the field currents are held constant.

a. Find the generator and motor line currents.

b. Find the torque developed by the synchronous motor.

c. What is the maximum torque that can be delivered by the motor without loss of synchronism.

END OF THE EXAM