# Professional Engineers Ontario

## Exam

## 07-Elec-A6 Power Systems and Machines

## Fall 2010

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**Notes:**

1. **FIVE (5)** questions constitute a complete exam paper. Unless you indicate otherwise, the first five questions as they appear in the answer book will be the only ones marked. All questions are of equal value.

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

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

**If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.**

**Question 1**

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 2**

For a terminal voltage of 220 V DC, a DC shunt motor has a rated armature current of 50 A and a field current of 1.5 A, and a speed of 1000 rpm. No-load tests indicate the rotational losses at this speed are 1100 W. The armature resistance is 0.4 Ω. Determine:

a. the no-load speed;

b. the output power and torque under rated conditions;

c. the full-load efficiency; and,

d. the resistance that must be inserted in the armature winding during start up to limit the current to twice the rated value.

**Question 3**

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.

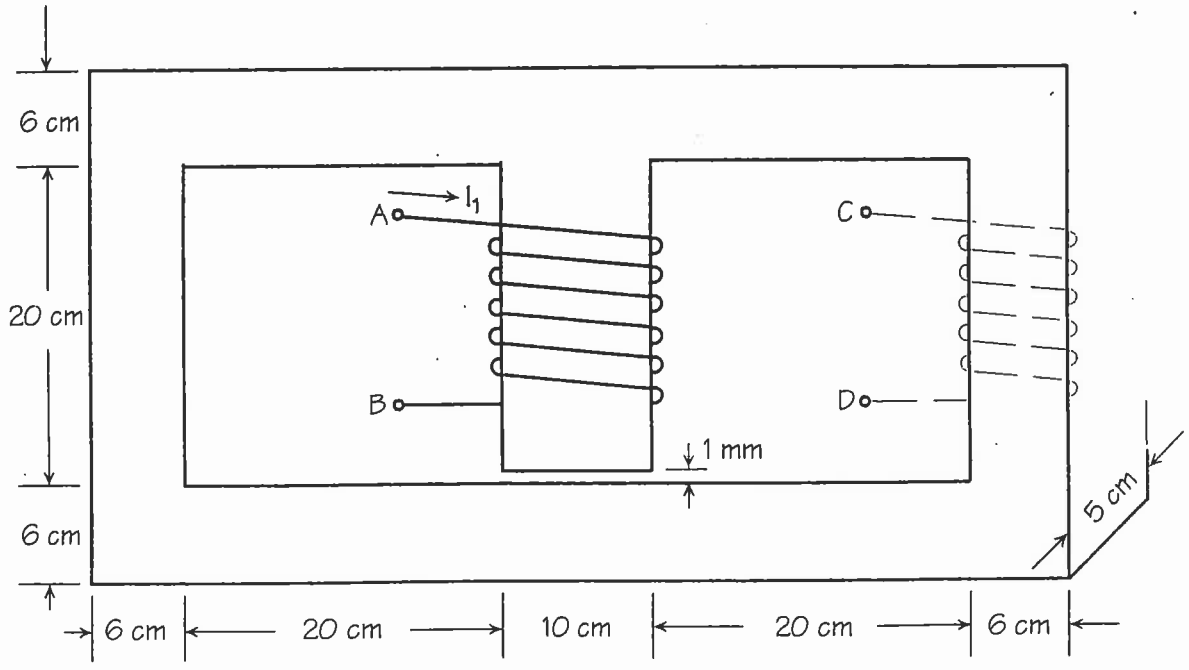


**Figure 1**

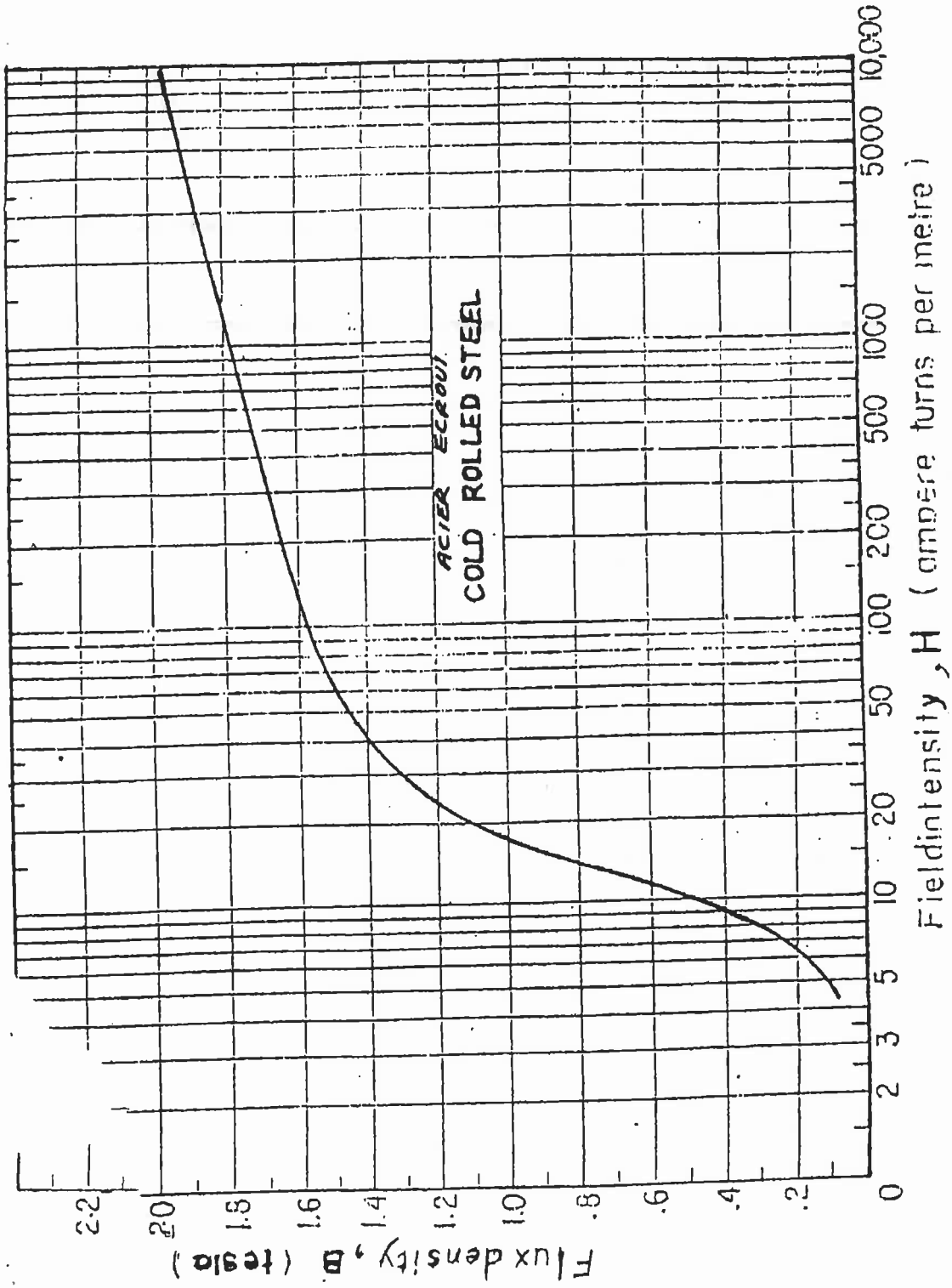
ACIER ECROUI
COLD ROLLED STEEL
Flux density, B (tesla)
Field intensity, H (ampere turns per metre)
0
2
3
5
10
20
50
100
200
500
1000
5000
10,000
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2

**Figure 2**

**Question 4**

A 208V/120 V, 60 Hz, 1800 VA transformer has the following parameters:

$R_C = 416\ \Omega$ (HV side) $R_{eq} = 0.21\ \Omega$ (LV side)

$X_m = 172\ \Omega$ (HV side) $X_{eq} = 0.98\ \Omega$ (LV side)

(Note: HV = high voltage side; LV = low voltage side)

The transformer is to be used as a step-down transformer.

a. If an open-circuit and short-circuit test were performed on this transformer, what would be the wattmeter reading for each test condition? You may place the measuring instruments in either winding.

b. Determine the efficiency and percent voltage regulation if a 1200 W load with a power factor of 0.67 lagging connected to the low voltage side, and the voltage across the load is the rated voltage, i.e., 120 V.

c. Repeat part (b) if the load is changed to a capacitive impedance of 12 Ω.

**Question 5**

A 11.5 kV/2.3 kV transformer is rated at 150 kVA as a two-winding transformer. If the two windings are connected in series to form an autotransformer, what will be the voltage ratio and the output. Note that there are two cases to be considered.

**Question 6**

A 4-pole, 208 V, 3ϕ, 60 Hz, 10 hp, Y-connected SCIM has the following characteristics:

$R_1 = 0.4\ \Omega$ $X_1 = 0.35\ \Omega$

$R_2' = 0.14\ \Omega$ $X_1' = 0.35\ \Omega$ $X_m = 16\ \Omega$

Rotor losses are 360 W. Draw an equivalent circuit showing the given parameters, and, at a motor speed of 1746 rpm, calculate, *on a per-phase basis*, the following:

a. the stator armature current;
b. the rotor current;
c. stator input power;
d. stator copper loss;
e. rotor power input;
f. rotor power developed;
g. total output power in watts and horsepower;
h. motor efficiency; and,
j. output torque.

**Question 7**

A 600 V, 100 kVA, 6-pole, 60 Hz, Y-connected synchronous motor has a synchronous reactance of 4.5 Ω per phase at rated voltage and negligible armature resistance.

a. The motor runs at no load when connected to rated supply drawing a current of 12.0 A at a power factor of 0.05 leading. Determine:

   i. the excitation emf and the power angle of the motor; and,
   ii. the motor losses.

b. If the mechanical load is increased while keeping the excitation constant until the power factor is unity, determine:

   i. the new power angle; and,
   ii. the new line current and power input.

END OF THE EXAM