UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: August 2015

Module Number: EE3304 **Module Name: Electrical Machines**

[Three Hours]

[Answer **all questions**, each question carries **10 marks**]

Q1 a) i) Explain the significance of the magnetic field for proper operation of electric machines.

ii) What are the types of losses occurred in a magnetic core?

iii) Discuss the methods that can be used to reduce the losses mentioned in part ii) above.

[4 Marks]

b) A core with three legs is shown in Figure Q1 (a). Its depth is 5 cm and there are 400 turns on the center leg. The remaining dimensions are shown in the figure. The core is composed of a steel having the magnetization curve shown in Figure Q1 (b).

i) Calculate the current required to produce a flux density of 0.5 T in the center leg of the core.

ii) What are the reluctances of the central and right legs of the core under the conditions in part i)?

iii) Calculate the current required to produce a flux density of 1.0 T in the center leg of the core.

iv) What are the reluctances of the central and right legs of the core under the conditions in part iii)?

v) What conclusion can you make about the reluctance of a real magnetic core based on the answers for parts ii) and iv)?

[6 Marks]

Q2 a) i) Discuss the advantages of using transformers in electric power systems.

ii) What are the types of losses occurred in a transformer operating in an electric system.

iii) Define the voltage regulation of a transformer.

[2 Marks]

b) A single phase 10 kVA, 480/120 V transformer is tested to determine its equivalent circuit parameters. The results of the tests are given in Table Q2. Find the equivalent circuit of this transformer referred to the low-voltage side of the transformer.

Table Q2: Results of the open-circuit and short-circuit tests

Open-Circuit Test (measured on low voltage side)	Short-Circuit Test (measured on high voltage side)
$V_{OC} = 120$ V $I_{OC} = 1.6$ A $P_{OC} = 38$ W	$V_{SC} = 10.0$ V $I_{SC} = 10.6$ A $P_{SC} = 25$ W

[4 Marks]

c) A 1000 VA, 230/115 V transformer has the following equivalent circuit parameters referred to its low voltage side. Note that all symbols have their usual meanings.

$R_{eq,s} = 0.126\ \Omega$ $X_{eq,s} = 0.476\ \Omega$

$R_{c,s} = 3383\ \Omega$ $X_{m,s} = 1099\ \Omega$

i) Find the transformer's voltage regulation when the transformer supplies its rated power with 0.8 power factor lagging at its rated voltage.

ii) Determine the transformer's efficiency at above loading condition.

[4 Marks]

Q3 a) i) Describe the term "commutation" related to DC machines.

ii) What phenomena affect the commutation process in a real DC machine?

iii) How the effects mentioned in part ii) over commutation process can be minimized?

[2 Marks]

b) The equivalent circuit of a DC shunt generator is shown in Figure Q3 (a) and its open circuit characteristics is shown in Figure Q3 (b). The rated speed of the generator is 1800 rpm and the adjustable resistance in the field circuit is adjusted to 140 Ω.

i) Determine the no load terminal voltage of the generator when it is turning at its rated speed. Neglect the voltage drop across the armature resistance due to the field current at no load.

ii) At full load, generator supplies 100 A load current. Neglecting armature reaction and assuming that the generator is turning at its rated speed, estimate the terminal voltage. Note that field current can be neglected compared to the full load current.

iii) If the armature reaction of the generator at full load is equal to 100 A.turns, what will be the terminal voltage for the same full load current?

[4 Marks]

c) Assume that the DC machine described in part b) is operated as a DC shunt motor with a supply of 240 V.

i) What will be the no load speed of the motor?

ii) What will be the starting current of the motor?

iii) Determine the values of the resistances required in the starter box such that the armature current is constrained within 100 A to 200 A during start up.

[4 Marks]

Q4 a) i) Describe the types of synchronous machines by comparing them each other.

ii) What are the different types of excitation methods employed in synchronous generators?

iii) Explain why a synchronous machine expected to operate as a motor cannot self-start unless a special starting mechanism is utilized.

iv) Discuss two techniques that can be used to start a synchronous motor.

[2 Marks]

b) A 13.8 kV, 50 Hz, four pole, Y-connected synchronous generator has a synchronous reactance of 2.5 Ω and an armature resistance of 0.2 Ω. At full load it delivers 50 MVA at 0.9 power factor lagging. At full load its friction and windage losses are 1 MW, and its core losses are 1.5 MW. The field current has been adjusted to achieve rated voltage at full load condition.

i) Calculate the speed of rotation of the generator.

ii) What is the efficiency of the generator at full load? State any assumption you make.

iii) What is the voltage regulation at full load?

[4 Marks]

c) A 208 V, Y-connected synchronous motor is drawing 50 A at unity power factor from a 208 V power system. The field current flowing under these conditions is 2.7 A. Its synchronous reactance is 1.6 Ω and armature resistance is ignored. Assume a linear open-circuit characteristics.

i) Sketch the phasor diagram of the synchronous motor for above operating condition.

ii) Calculate the internal generated voltage E_A of the synchronous motor.

iii) Find the torque angle δ.

iv) How much field current would be required to make the motor operate at 0.8 power factor leading? Note that the motor consumes the same amount of active power.

[4 Marks]

Q5 a) i) Explain why an induction motor can never operate at its synchronous speed.

ii) What are the types of losses occur in an induction motor. Explain with the help of the power flow diagram.

iii) What is the major problem with starting a large induction motor?

iv) Explain the methods that can be applied to overcome the problem mentioned in iii).

[2 Marks]

b) A 208 V, six pole, Y-connected, 25 hp, design class B induction motor is tested in the laboratory, with the following results.

No load test:	208 V, 24.0 A, 1400 W, 60 Hz
Locked rotor test:	24.6 V, 64.5 A, 2200 W, 15 Hz
DC test:	13.5 V, 64 A

For class B induction motors, the ratio between stator reactance X_1 and the stator referred rotor reactance X_2 is 2:3. Find the equivalent circuit of this motor.

[4 Marks]

c) A 460 V, 50 Hz, 75 hp, four pole, Y-connected induction motor has the following parameters. Note that all symbols have their usual meanings.

$R_1 = 0.058\ \Omega$	$R_2 = 0.037\ \Omega$	$X_M = 9.24\ \Omega$
$X_1 = 0.320\ \Omega$	$X_2 = 0.386\ \Omega$	
$P_{f\&w} = 650$ W	$P_{misc} = 150$ W	$P_{core} = 600$ W

For a slip of 0.01, find

i) the line current I_L

ii) the induced torque and the load torque

iii) the overall efficiency of the motor.

[4 Marks]

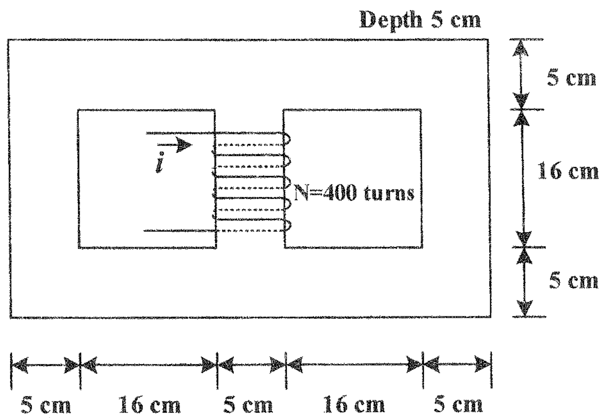

Figure Q1 (a)

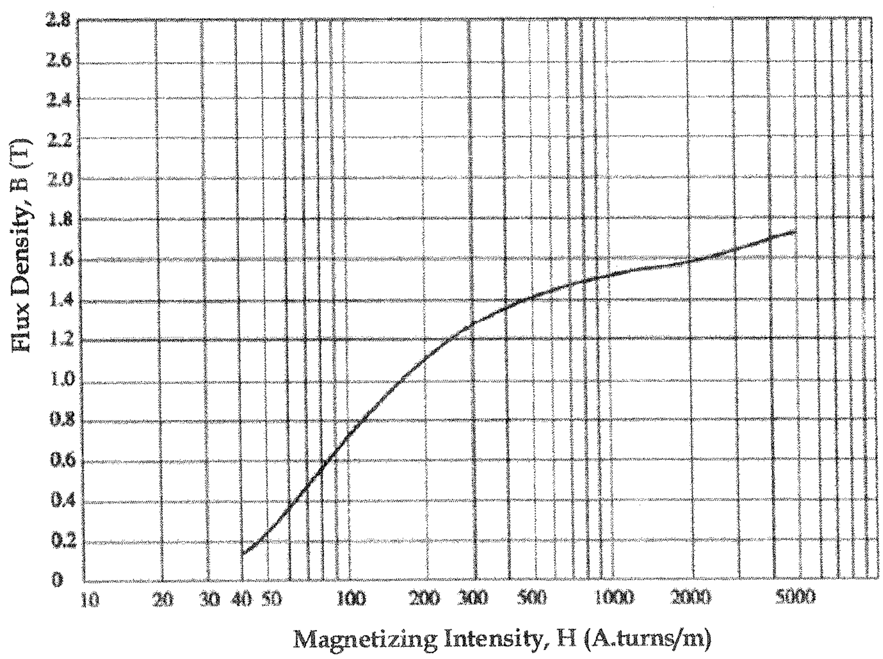

Figure Q1 (b)

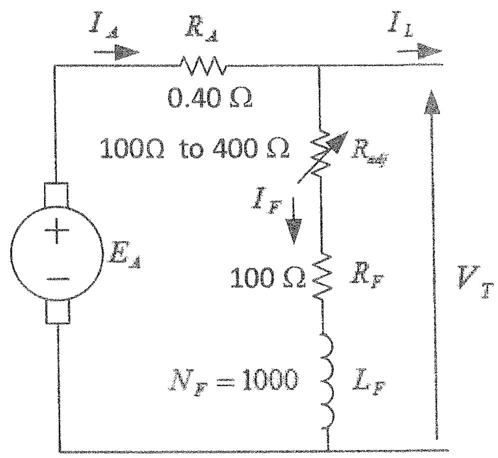

Figure Q3 (a)

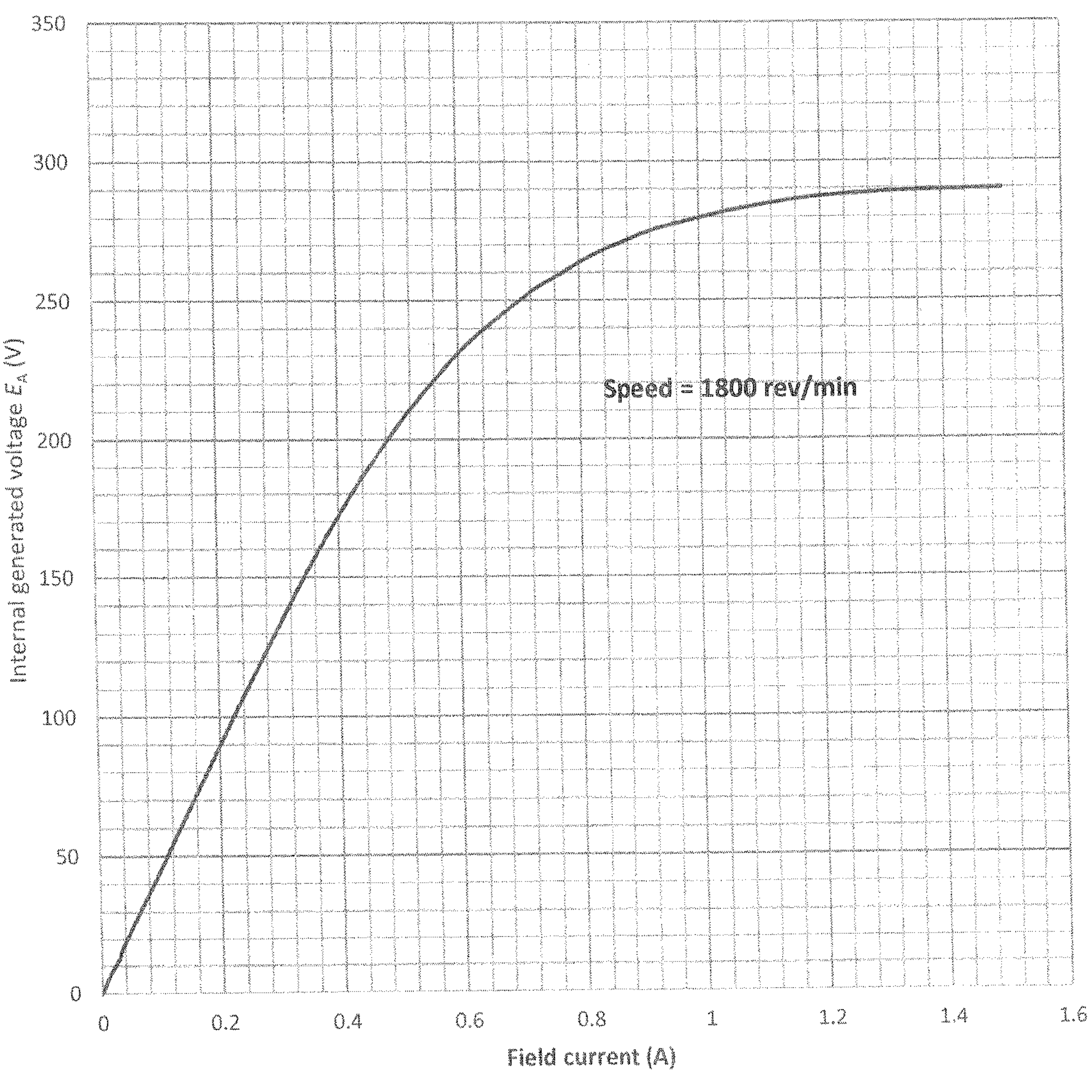

Figure Q3 (b)

Note: Detach this page and attach with your answer script.