# UNIVERSITY OF RUHUNA

**Faculty of Engineering**

End-Semester 4 Examination in Engineering: February 2020

**Module Number: EE4304** **Module Name: Electric Machines I**

**[Three Hours]**

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

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Q1 a) i) State two advantages of using electromagnets instead of permanent magnets in electric machines.

ii) What are the factors to be considered while selecting a material for an electric machine's core?

iii) Name three ferromagnetic materials used for manufacturing electric machine's core.

[3 Marks]

b) A core with three legs is shown in Figure Q1. Its depth is 5 cm, and there are 100 turns on the leftmost leg. The relative permeability of the core material is 2000. Assume 5% increase in the effective area of the air gap due to fringing effect. Take the permeability of air as $4\pi \times 10^{-7}$ H/m and assume core doesn't saturate.

i) Calculate the flux exists in each of the three legs of the core.

ii) Calculate the flux density in each of the legs.

iii) Calculate the flux in each of the legs, if the air gap on the centre leg does not exist.

iv) Calculate the current required to have a flux density of 0.5 T in the rightmost leg of the core when the air gap on the centre leg does not exist.

[7 Marks]

Q2 a) i) Discuss the main advantage of using transformers in a power system.

ii) What are the different types of losses occur in a transformer?

iii) Explain the measures taken during manufacturing to reduce different types of losses in a transformer.

[3 Marks]

b) A 10 kVA, 2200/220 V, 50 Hz, single phase, step-down transformer is tested to determine its equivalent circuit parameters. The results of the tests are given in Table Q2.

i) Find the approximate equivalent circuit of the transformer referred to the primary side.

ii) Calculate the voltage regulation and the efficiency when the transformer delivers its rated load with 0.8 power factor lagging at the rated voltage.

iii) Draw the phasor diagram corresponding to the transformer operation described in part ii).

iv) Explain why the open circuit test is performed on the low voltage side keeping the high voltage side open and the short circuit test is performed on the high voltage side keeping the low voltage side shorted.

[7 Marks]

Q3 a) i) Draw a sketch of a DC machine indicating its main components.

ii) Briefly explain how the armature reaction affects the commutation process of a DC machine.

iii) Explain the corrective measures taken in DC machine construction to eliminate or partially correct the problems created by armature reaction.

[3 Marks]

b) The armature resistance of a 10 hp, 230 V DC shunt motor is 0.3 Ω. The field resistance is 160 Ω. The motor draws a line current of 3.938 A on no load at a speed of 1200 rpm. At full load, the armature current is 40 A. Assume no armature reaction.

i) Find the armature current at no load at the speed of 1200 rpm.

ii) Find the power developed by the armature on no load at the speed of 1200 rpm.

iii) Find the full load efficiency of the motor.

iv) Find the full load speed of the motor.

[4 Marks]

c) An automatic starter circuit is to be designed for a DC shunt motor rated at 20 hp, 240 V, and 75 A. The armature resistance of the motor is 0.12 Ω, and the shunt field resistance is 40 Ω. The motor is to start with no more than 250% of its rated armature current, and as soon as the current falls to rated value, a starting resistor stage is to be cut. Determine the number of stages of starting resistance needed, and the value of the resistance of each stage.

[3 Marks]

Q4 a) i) Three phase induction motors are very popular in the industry. List down five favorable characteristics of three phase induction motors.

ii) Briefly explain three speed control methods used in induction motors.

iii) Draw the typical torque-speed characteristic curve of an induction motor indicating its salient features.

[3 Marks]

b) A 460 V, 50 Hz, 1470 rpm, Y-connected wound-rotor induction motor has the following equivalent circuit parameters referred to its stator. All notations carry their usual meanings.

$R_1 = 0.641\ \Omega$ $R_2 = 0.332\Omega$ $X_1 = 1.106\ \Omega$ $X_2 = 0.464\ \Omega$ $X_M = 26.3\ \Omega$

The total rotational losses are 1100 W and are assumed to be constant. The core loss is lumped with rotational losses.

i) Calculate the number of poles and the slip at rated speed.

ii) Calculate the input line current, induced torque and the efficiency at the rated speed of the motor.

iii) Determine the maximum torque of this motor. At what speed and slip does it occur?

iv) How much additional resistance (referred to the stator side) should be added to the rotor circuit in order to get the maximum torque at the starting of the motor?

[7 Marks]

Q5 a) i) Giving reasons, briefly explain the types of synchronous machines used in hydro power plants and thermal power plants.

ii) Draw a schematic diagram of an exciter arrangement that can be used in synchronous machines to make excitation completely independent from any external power source.

iii) What are the conditions to be satisfied in order to connect a synchronous generator to an existing system?

[3 Marks]

b) A 480 V, 210 kVA, 0.8 power factor lagging, 50 Hz, four-pole, Y-connected synchronous generator has a synchronous reactance of 0.25 Ω and an armature resistance of 0.03 Ω. The field circuit has a DC voltage of 200 V, and the maximum field current is 10 A. The open circuit characteristic curve of this generator is shown in Figure Q5.

i) What is the speed of rotation of this generator?

ii) How much field current must be supplied to the generator to make the terminal voltage 480 V at no load?

iii) What is the internal generated voltage of this machine at rated conditions?

iv) How much field current is required to make terminal voltage equal to 480 V when the generator is running at rated conditions?

v) Calculate the efficiency of the generator under rated conditions if it has a total rotational loss of 6 kW and a total core loss of 3 kW.

vi) How much torque must be supplied by the generator's prime mover at the rated condition?

[7 Marks]

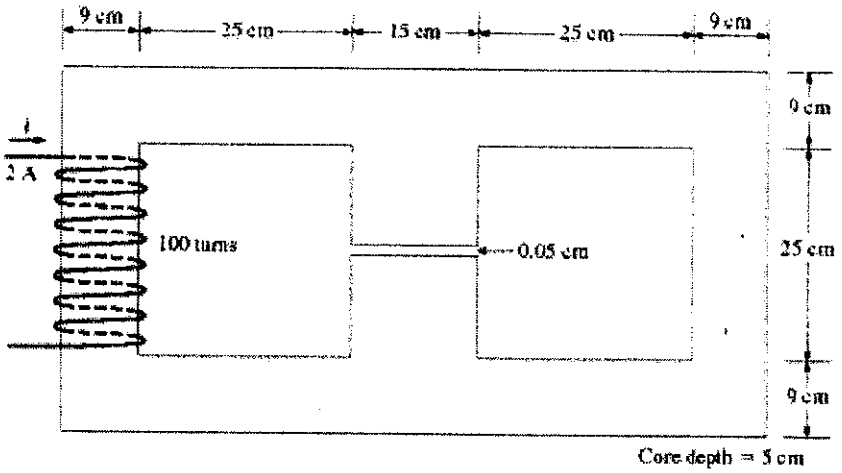


**Figure Q1**

**Table Q2**

| **Open-circuit Test** (high voltage side open) | **Short-Circuit Test** (low voltage side shorted) |
|---|---|
| $V_{OC}$ = 220 V | $V_{SC}$ = 150 V |
| $I_{OC}$ = 2.5 A | $I_{SC}$ = 4.55 A |
| $P_{OC}$ = 100 W | $P_{SC}$ = 215 W |

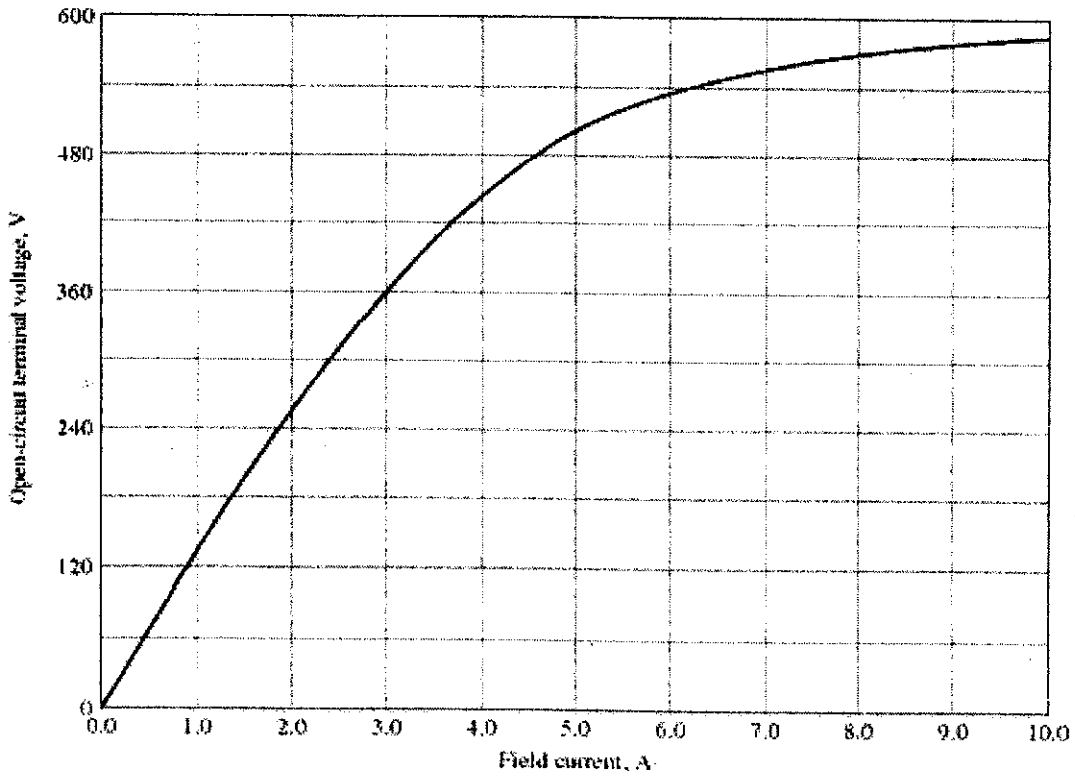


**Figure Q5**