UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: July 2017

Module Number: ME 5302 **Module Name: Electrical power and machines**

[Three Hours]

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

Q1 a) The following Figure Q1 shows a cross section of an electromechanical actuator. The air gap is 1 mm as shown in the figure. The model has a depth of 10 cm. The mean length of AB+BC+CD is 300 cm and the mean length of AB+BC+CD is equal to the mean length of AE+EF+FD. The mean length of the path AD is 30 cm. The relative permeability of the material used is 7000 and the permeability of free space is $\mu_0 = 4\pi \times 10^{-7}\, Hm^{-1}$. A magnetic flux of 150 mWb is required at the air gap near point A. (Note: The given mean lengths include air gap length.)

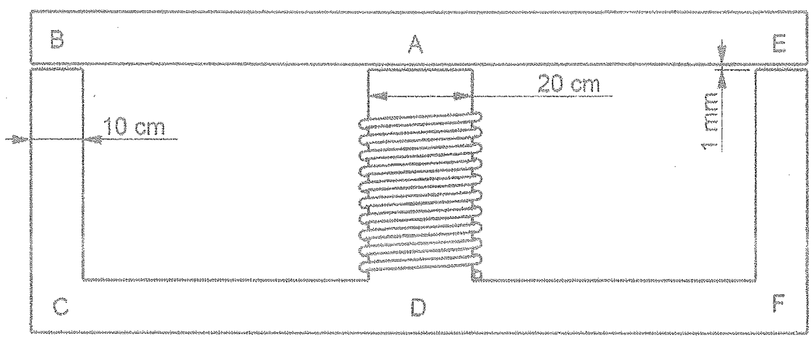

Figure Q1

I) Calculate mmf required from the coil to establish the required 150 mWb flux in AD path only (including the air gap).

[2.0 Marks]

II) Calculate the flux density required near air gap B to establish the required flux at the air gap near point A.

[1.0 Mark]

III) Calculate the total mmf required from the coil to establish the required flux at the air gap near point A.

[4.0 Marks]

IV) State any assumptions you made for above calculations.

[1.0 Mark]

b) A pump having an output power of 1750 W is used to circulate water in a large fish tank. The owner of the tank requires changing water circulation speed automatically, each hour and requires long-term unattended operation capability. What type of motor and controller will you use? What are the advantages of the motor and controller you suggested?

[4.0 Marks]

Q2 a) A three-phase, 1.2 MVA, 50 Hz transformer has star connected primary winding with rated voltage of 21 kV and delta connected secondary winding with rated voltage of 6 kV. Per phase resistance and reactance of the primary winding are 1.2 Ω and 11.5 Ω, respectively while per phase resistance and reactance of the secondary winding are 0.1 Ω and 1.5 Ω, respectively.

I) Calculate per phase equivalent resistance and reactance of the transformer referred to the primary.

[1.0 Mark]

II) Calculate full load primary current.

[1.0 Mark]

III) For a test, the transformer secondary winding was short-circuited and full load primary current was allowed through primary winding by applying a voltage to the primary winding. Calculate the applied primary line voltage.

[2.0 Marks]

IV) Calculate the power input during the test in (III).

[1.0 Mark]

V) State any assumptions used for calculations.

[1.0 Mark]

b) A 6 kVA, 1.2 kV / 230 V transformer has 0.4 Ω resistance and 6.9 Ω reactance referred to the primary. This transformer is used to supply power to an inductive load. During the steady operation at the rated primary voltage, measured primary power was 3 kW and measured primary current was 12 A. Calculate the load voltage.

[3.0 Marks]

c) State 3 different power losses in a real transformer and briefly describe them.

[3.0 Marks]

Q3 a) A shunt DC motor connected to a mechanical load draws a current of 35 A from a 190 V source while having 800 rpm rotor speed. The motor has armature resistance of 0.6 Ω and field resistance of 80 Ω. The motor has 1 V drop at brushes. Neglect the effect of armature reaction. The no-load current of the motor is 3.5 A.

I) Calculate the back-emf of the loaded motor.

[1.0 Mark]

II) Calculate the no-load speed of the motor.

[1.0 Mark]

III) Calculate the percentage reduction of flux per pole to achieve 850 rpm and 30 A armature current while under the same load.

[2.0 Marks]

b) Name and briefly describe four operating modes of a DC motor.

[2.0 Marks]

Q3. is continued to next page

c) A DC 110 V DC motor has series connected field and rotor windings. The motor has 0.15 Ω armature resistance and 0.12 Ω field resistance. The motor draws 30 A current during the steady-state operation and has 30W rotational loss.

I) Calculate the brush voltage.

[1.0 Mark]

II) Calculate the back emf.

[1.0 Mark]

III) Calculate the power loss in the armature.

[1.0 Mark]

IV) Calculate the mechanical power output and the efficiency of the motor.

[1.0 Mark]

d) Briefly explain the PWM technique used to control speed of a DC motor and its advantages using appropriate figures.

[2.0 Marks]

Q4 a) A delta connected three-phase induction motor has a star connected rotor. The motor is rated as 400 V, 60 Hz. The phase transformation ratio of this motor is 4.6. The rotor resistance is 0.1 Ω and the rotor reactance when the rotor is locked is 0.8 Ω. The motor has slip rings to facilitate connecting of an external resistor to the rotor.

I) Calculate the starting rotor current and rotor power factor when the slip rings are short-circuited.

[2.0 Marks]

II) If the motor has 3% slip during steady-state operation while slip rings are shorted, calculate the rotor current and rotor power factor.

[3.0 Marks]

III) The maximum stator supply current should not exceed 15 A. The slip rings were used to connect an external resistor to the rotor winding to limit stator starting current. Calculate the external per phase rotor resistance.

[4.0 Marks]

b) Explain different starting methods of a single phase induction motor with characteristics of each method and application areas.

[3.0 Marks]

Q5 A synchronous generator is rated at 900 kVA, 33 kV and 50 Hz. The generator has three-phase star connected winding and DC excitation. The per phase armature resistance, armature leakage reactance, and armature reactance are 0.9 Ω, 3 Ω and 18 Ω, respectively. This generator is connected to a load of 850 kVA.

a) Draw the per phase equivalent circuit and mark parameters of the circuit.

[1.0 Mark]

Q5. is continued to next page

b) Calculate the phase voltage and load current.

[1.0 Mark]

c) Calculate the percentage voltage regulation for 0.9 lagging and 0.9 leading power factors.

[2.0 Marks]

d) If an application requires voltage regulation to be zero, find the corresponding power factor.

[6.0 Marks]

e) If this generator is required to run at 3000 rpm, what type of rotor is preferred? Give reasons for your selection.

[2.0 Marks]