UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: Oct/Nov 2019

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

[Three Hours]

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

Q1 a) Figure Q1(a) shows a part of an electromechanical actuator (not in scale). This actuator has a square cross-section and the thickness into the page is 20 mm. The arrows shown in upper and lower parts of the core shows the direction of applied flux using two separate coils wound around upper and lower arms. Each coil consists of 75 turns and carries 5 A current. Use symbols G1 and G2 to represent the air gaps as shown in figure Q1(a). G1 air gap exists at both sides of the plunger as shown and has 0.8mm gap at each side. Assume that the core and plunger are made of **ideal** core material and the permeability of free space and air is assumed to be $\mu_0 = 4\pi \times 10^{-7} Hm^{-1}$.

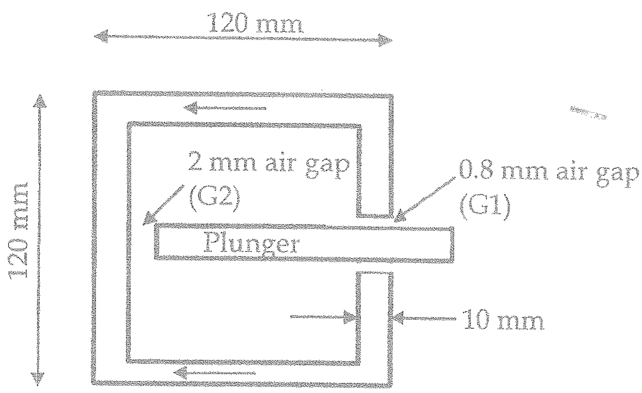

Figure Q1 (a).

i) Briefly describe ideal reluctance. (Using a maximum of 4 sentences and State value and SI unit of ideal reluctance in your answer.)

[2.0 Marks]

ii) Draw equivalent magnetic circuit.

[1.0 Mark]

iii) Calculate the total magnetic reluctance of the circuit.

[2.0 Marks]

iv) Calculate magnetic flux density in G2 airgap.

[2.0 Marks]

v) "It is not necessary to assume linearity and non-saturated core during the above calculations." Is this statement accurate? Explain with reasons. (Maximum of 3 sentences expected.)

[1.0 Mark]

b) It is required to design a small permanent magnet DC motor and motor driver for a model aircraft having an approximate flying weight of 1 kg. You must achieve fast rotating speed reaching 10,000 rpm. How would you build such motor? State qualitative details about coil, magnets, brushes, and number of turns of coil compared to low rpm motor. Explain how you can control the speed of the motor using your motor driver and compare amount of current delivered to the designed motor compared to a low-speed motor of same size. How would you select components for the motor driver based on amount of current needed to be handled? (Maximum of half-page answer expected.)

[4.0 Marks]

Q2 a) A single-phase transformer has a core loss branch of 350 Ω and magnetization branch of 175 Ω. The total impedance of the transformer referred to primary is $0.2 + j0.8$ Ω. The transformer is connected to an inductive load having $7.0 + j5.0$ Ω impedance referred to primary. Secondary to primary turns ratio is 10 (i.e. $K = N_S/N_P = 10 = Transformation\ ratio$). The primary supply voltage is 230 V. (Present your answers in complex number format: $a + jb$).

I) Draw the equivalent circuit.

[1.0 Mark]

II) Calculate no load impedance of the transformer.

[1.0 Mark]

III) Calculate the no-load current of the transformer.

[1.0 Mark]

IV) Calculate the primary current.

[2.0 Marks]

V) Calculate secondary terminal voltage.

[2.0 Marks]

b) A 230 V/23 V Step down transformer experiences a voltage drop of 1.5% due to reactance and 1% due to resistance. Find the maximum voltage regulation and the power factor at that operating point.

[5.0 Marks]

Q3 a) A shunt DC motor rated at 230 V has armature resistance of 1 Ω. When this motor is operated at full load, armature draws 15 A current while achieving 400 rpm. Assume that this motor will be modified by inserting 0.2 Ω resister in armature circuit and the modified motor will be used to run a load demanding 50% of full load torque of non-modified motor,

I) Calculate the speed of the modified motor driving 50% of full load.

[2.0 Marks]

II) Calculate the stalling torque to the full load torque ratio.

[2.0 Marks]

b) A DC series motor is driving a load at 300 rpm while drawing 30 A current undersupply of 300 V. This motor has armature resistance of 0.1 Ω and field resistance of 0.5 Ω. The load of the motor was reduced for a test and during the reduced load operation, motor was drawing 20 A current.

I) Calculate percentage change of torque.

[3.0 Marks]

II) Calculate the speed of the motor under reduced load.

[2.0 Marks]

c) What is the mode of operation under deceleration, if DC motor is used to drive a typical hybrid car? Briefly explain (in point form) the mode of operation used in this scenario (Use circuit diagrams and figures where necessary).

[3.0 Marks]

Q4 a) A 1200 V, 50 Hz delta connected induction motor has a star connected rotor. The motor uses slip rings so that external resistors can be added to the rotor circuit. The induced voltage in the rotor circuit when the rotor is locked is 300 V. The rotor resistance and reactance are 0.05 Ω and 0.3 Ω respectively. Neglect magnetizing branch current and stator impedance. Determine (state your answers in complex number format),

I) starting rotor current at the start when slip rings are shorted,

[1.0 Mark]

II) rotor power factor at start when slip rings are shorted,

[1.0 Mark]

III) rotor current under 6% slip while slip rings shorted,

[2.0 Mark]

IV) rotor power factor under 6% slip while slip rings shorted,

[1.0 Mark]

V) external rotor resistance per phase required to limit starting current magnitude to 80 A in stator supply lines.

[3.0 Marks]

b) A 600 V three-phase induction motor draws 74 A current at 0.8 lagging power factor. The motor is connected to a 50 Hz supply. The stator and the rotor lose power of 1000 W and 500 W respectively due to winding resistance. The estimated friction and windage losses are 300 W. Core losses are 2 kW. Stray losses are negligible. Determine,

I) air gap power,

[1.0 Mark]

II) converted power,

[1.0 Mark]

III) the efficiency of the motor.

[2.0 Marks]

Q5. Is on the next page.

Q5 a) A 3-phase synchronous generator has the following information on the name tag.
Star connected
1500 kVa
15000 V
Rated current 150 A
Winding resistance per phase 0.5 Ω
Synchronous impedance per phase 4 Ω

I) Obtain the open circuit phase voltage when the power factor is 0.75 lagging. [3.0 Marks]

II) Obtain percentage regulation when the power factor is 0.75 lagging. [1.0 Mark]

III) Obtain percentage regulation when the power factor is 0.75 leading. [2.0 Marks]

b) The starting torque of a 3-phase induction motor is 200% of full load torque and maximum torque is 400% of full load torque. Neglect the stator impedance. Given that $\frac{T_f}{T_{Max}} = \frac{2aS_f}{a^2+S_f^2}$ using standard notations.

I) Obtain the ratio of rotor resistance to rotor standstill reactance. [2.0 Marks]

II) Obtain the percentage change in rotor circuit resistance required to achieve a full load slip of 5%. [4.0 Marks]