



UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2022

Module Number: ME 6303

Module Name: Electric Machines

[Three Hours]

[Answer all questions, each question carries twelve marks]

- Q1 a) The following figure shows a soft magnetic steel core having a relative permeability of 2800. The depth of the core into the page is 5 cm. The coil shown in the figure has 301 turns and the middle section of the core has a 0.04 cm air gap as shown. The coil carries a 2.95 A current in the direction shown. The reluctance of the air gap (only) is R_3 and the reluctances of each part of the core are shown in the figure as R_1 , R_2 , and R_4 , where R_1 is taken along ABCD path, R_2 is taken along AD path but airgap is omitted, and R_4 is taken along AFED path. Note that R_1 to R_4 has no overlapping core sections. Take $\mu_0 = 4\pi \times 10^{-7} \text{ Hm}^{-1}$.

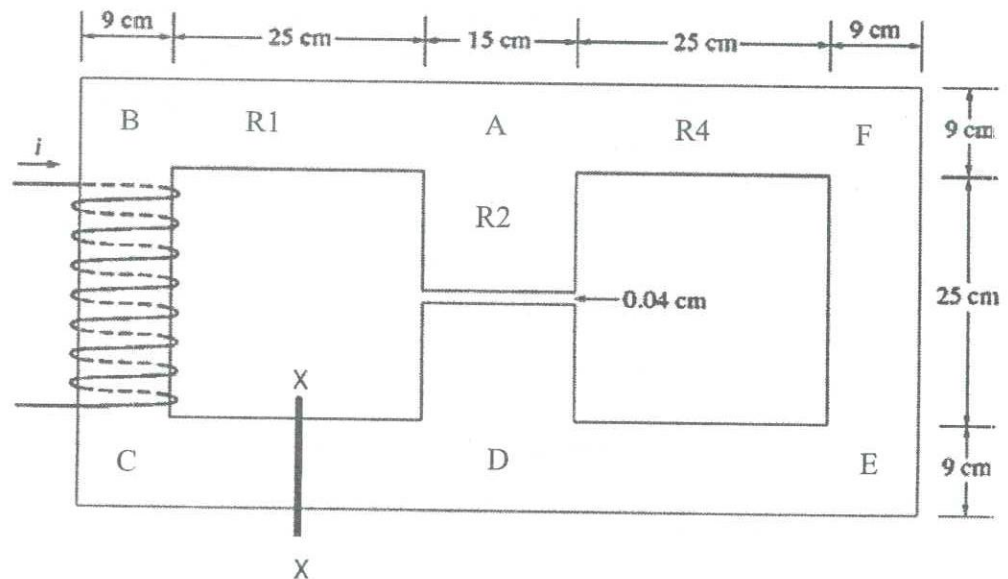


Figure Q1 (a)

- Calculate R_1 to R_4 in A.turns/Wb. [1.0 Mark]
- Draw the equivalent magnetic circuit indicating MMF and reluctance of each branch and simplify the circuit as much as possible. [1.0 Mark]
- Calculate the total reluctance of the circuit as seen by the MMF of the current carrying coil. [1.0 Mark]

- iv) Calculate the flux density of the core across XX cross-section and indicate the direction. [2.0 Marks]
- v) List all the assumptions made during your calculations. [1.0 Mark]
- b) Briefly describe reluctance and ideal reluctance. (Use maximum of 5 sentences/statements, in point form. Include value and SI unit of ideal reluctance and major factors that decide reluctance in an object along with definition of reluctance in your answer.) [2.0 Marks]
- c) With the increase of electricity tariff in Sri Lanka, people tend to use power-saving devices. There are many different types of **power-saving devices** that are available in the market. Two such devices are described below. State whether you would buy each device for your home use and explain (**in point form**) your reasons relating to your engineering and scientific knowledge.
- i) A device used to reduce the electricity consumption of domestic refrigerators and air conditioners by disconnecting power at the wall outlet (Plug-Point) at night and at other preset times. The price of the device is about Rs. 8,500/- [2.0 Marks]
- ii) A device claimed to perform power factor correction and save electricity. The user manual instructs you to connect the device to a wall outlet at your home, one device per floor of the house. The price of the device is approximately Rs. 10,000/- and available to purchase as readymade product. [2.0 Marks]
- Q2 a) Three 11000 V/230 V transformers connected as delta-delta supplies power to a resistive load of 500kW. Calculate,
- i) the primary line current. [1.0 Mark]
- ii) the secondary phase current. [1.0 Mark]
- iii) the primary phase current. [1.0 Mark]
- iv) Suddenly one of the transformers got damaged and other two transformers started to supply full power to the load. Calculate the new primary phase current. [2.0 Marks]
- v) Compare losses between when all 3 transformers are operational and only 2 are operational. (Which is higher and why) [1.0 Mark]

- b) A 3-phase delta connected load has per phase inductive reactance of 40Ω and resistance of 25Ω . This load is connected to a star connected secondary of a transformer having phase voltage of 240 V.
- i) Draw the circuit diagram of the system indicating relevant parameters. [1.0 Mark]
 - ii) Calculate the current in each phase of the load. [1.0 Mark]
 - iii) Calculate the voltage across each phase of the load. [1.0 Mark]
 - iv) Calculate the current in the secondary windings of the transformer. [1.0 Mark]
 - v) Calculate the **power factor** of total power taken from the supply. [1.0 Mark]
 - vi) Calculate the total **power** taken from the supply. [1.0 Mark]
- Q3 a) A 50kW DC Generator has shunt field resistance of 100Ω and rotor resistance of 0.05Ω . The generator requires 0.06 Wb flux per pole to produce terminal voltage of 230V at 1050 rpm rotor speed. At rated full load speed of 1000 rpm, the terminal voltage is 250 V.
- i) Calculate the generated EMF at full load. [2.0 Marks]
 - ii) Calculate the flux per pole at full load. [2.0 Marks]
- b) A DC series motor drives a pump. The torque of this machine varies as square of speed. The motor takes 15 A current to drive the pump at 600 rpm speed. An external shunt resistor with same resistance as series field resistance was connected in parallel with the series field (series field only) of the motor to evaluate the motor.
- i) Draw the equivalent circuit diagram of DC motor with above mentioned shunt and mark relevant parameters. [2.0 Marks]
 - ii) Calculate the motor current when shunt resistor is connected. [4.0 Marks]
 - iii) Calculate the motor speed when shunt resistor is connected. [1.0 Marks]
 - iv) State any specific assumptions made during above calculations. [1.0 Mark]

- Q4 An induction motor name plate indicates following data.
 3 phase star connected rotor, Line voltage is 460V, full load 1740 rpm rated speed, 60Hz, 4 pole, wound rotor.
 The motor has per phase parameters as follows using standard notations.
 $R_1 = 0.25 \Omega$, $R'_2 = 0.2 \Omega$, $X_1 = 0.5 \Omega$, $X'_2 = 0.5 \Omega$, $X_m = 30 \Omega$.
 Rotational losses are 1700 W.
- i) Draw the per phase equivalent circuit referred to stator with relevant parameters. [1.0 Mark]
 - ii) Calculate the starting current. [2.0 Marks]
 - iii) Calculate starting torque. [3.0 Marks]
 - iv) Calculate full load slip. [1.0 Mark]
 - v) Calculate full load current. [2.0 Marks]
 - vi) Calculate full load power factor. [1.0 Mark]
 - vii) Calculate full load torque. [1.0 Mark]
 - viii) Calculate motor efficiency at full load. [1.0 Mark]
- Q5 a) A 3-phase synchronous generator has the following information on the name tag.
 Star connected, 1500 kVA, 15000 V, rated full load current 150 A, Winding resistance per phase 0.5Ω , Synchronous impedance per phase 4Ω .
- 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. [2.0 Marks]
 - iii) Obtain percentage regulation when the power factor is 0.75 leading. [2.0 Marks]
- b) There are two major types of synchronous generator constructions. Name and compare these two types of synchronous generators. Use a table or point form sentences to present your answer. (Do not write paragraphs.) [5.0 Marks]