THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

NOVEMBER / DECEMBER 2020

EEE 3352

ELECTROMACHANICS AND ELECTRICAL MACHINES

TIME	:	Three (3) hours
INSTRUCTIONS	:	Answer any five (5) questions
ADDITIONAL INFORMATION	:	*permeability of free space* $\mu_0 = 4\pi \times 10^{-7}$ H/m
		permittivity of free space $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

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Question 1.

(a) Derive, from basic principles, the expression for the capacitance of a parallel plate capacitor in terms of its dimensions and dielectric properties.

[4 marks]

(b) A parallel plate capacitor is immersed in an alcohol of relative permittivity 26. The plates are charged to a potential difference of 20 kV and the distance between them is 15 mm. Determine the force per unit area exerted on the plates.

[6 marks]

(c) A 1-km, 10-kV, 50-Hz concentric cable has an inner conductor of 12 mm diameter, a dielectric of radial thickness 8 mm and relative permittivity 4 and an earthed metal sheath. Calculate

(i) the capacitance of the cable;

[6 marks]

(ii) the peak stored energy in the electrostatic field;

[2 marks]

(iii) the rms value of the capacitive current.

[2 marks]

Question 2.

(a) Prove, from first principles, that the energy stored in a magnetic field is $\frac{B^2}{2\mu}$, defining all terms.

[5 marks]

(b) The magnetic circuit in figure Q2 includes an air-gap of 1 mm and a cross-section of 159 mm^2 throughout. The reluctances of the various iron portions are

$S_A = 3x10^6$ At/Wb
$S_B = 9x10^6$ At/Wb
$S_c = S_D = 2x10^6$ At/Wb

The coil has 100 turns and carries a current of 20 A. Calculate the

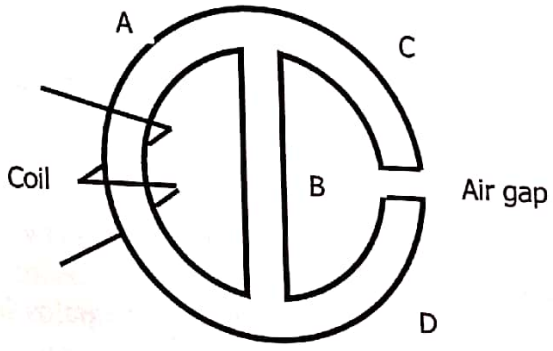

Figure Q2.

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(i) air-gap reluctance;

(ii) coil inductance; [2 marks]

(iii) total flux driven by the coil mmf; [3 marks]

(iv) air-gap flux density; [2 marks]

(v) total stored energy; [3 marks]

(vi) energy stored in the air-gap. [2 marks]

Question 3. [3 marks]

(a) Explain the causes of voltage drop in a power transformer on load.

[5 marks]

(b) A 75-kVA transformer rated at 11000/240 V requires 310 V across the primary to circulate full-load current on short-circuit, with the power absorbed being 1.6 kW.

(i) Determine the voltage regulation at full-load 0.8 power factor lagging.

[5 marks]

(ii) What is secondary terminal voltage at this condition, when rated primary voltage is used?

Question 4. [5 marks]

(a) Explain the advantages of having a three-phase system compared to a single-phase system in a power network.

[6 marks]

(b) A star-connected balanced load is supplied from a three-phase supply with a line voltage of 416 V at a frequency of 50 Hz. Each phase of the load consists of a resistance and a capacitor connected in series and the two wattmeters connected to measure load power supplied read 782 W and 1980 W, both positive. For this circuit, what is the

(i) power factor;

(ii) line current; [5 marks]

(iii) capacitance of each capacitor? [5 marks]

Question 5. [4 marks]

(a) From "$v = Blu$", where l is the length of a conductor, cutting a magnetic field of density B at constant speed u, and experiences an induced voltage v, derive the expression for the brush terminal voltage for a commutator machine.

[8 marks]

(b) A separately-excited generator has the magnetisation characteristic which gives a no-load voltage of 131 V when driven at 6000 rpm with field excitation of 2000 ampere-turns. The total armature circuit resistance is 0.08 Ω. If the generator supplies a load current of 120 A, determine the

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(i) terminal voltage;

(ii) power output; **[3 marks]**

(iii) the electromagnetic power; **[3 marks]**

(iv) electromagnetic torque input. **[3 marks]**

[3 marks]

Question 6.

(a) Three phase ac machines operate on the principle of a "rotating" magnetic flux. Describe the principal features which establish the ac machine as either an induction machine or a synchronous machine.

[4 marks]

(b) A 3-phase, 6-pole induction motor operates on a 50-Hz supply. The frequency of the rotor-induced current is 4 Hz. What is the

(i) slip;

[2 marks]

(ii) speed of the rotor;

[2 marks]

(iii) speed of the rotor mmf with respect to the rotor and with respect to the stator?

[2 marks]

(c) With the help of mmf, voltage and current phasor diagrams explain the operation of an ideal synchronous machine in generating mode.

[10 marks]

Question 7.

(a) With the help of equivalent circuits, predict the torque-speed characteristic of the DC Shunt motor.

[6 marks]

(b) Describe the problem of starting d.c. machines and explain, with a suitable sketch, how it is overcome in practice.

[4 marks]

(c) The no-load armature current of a 230-V d.c. shunt motor is 2 A at a speed of 1200 r/min. If the full-load armature current is 40 A, find the full-load speed and the torque developed. Assume that the armature resistance is 0.25 Ω and the field flux remains unchanged.

[10 marks]

END OF EEE 3352 EXAMINATION

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