THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

November 2019

EEE 3352

ELECTROMECHANICS 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. [20 marks]

(a) Derive from basic principles the expression for the energy density in an electric field.

[6 marks]

(b) A concentric cable has an inner conductor of 3 mm diameter and an earthed metal sheath of 10 mm diameter, with relative permittivity and resistivity of the insulation being 3 and 2×10^9 Ωm, respectively. Calculate

(i) the capacitance per unit length of the cable;

[4 marks]

(ii) the conductance per unit length of the insulation of the cable;

[4 marks]

(iii) the values of electric field intensity and energy density at the surface of the conductor, if dc voltage of 600 V is applied between the conductor and earth sheath.

[6 marks]

Question 2. [20 marks]

(a) Show that the reluctance of composite magnetic circuits are evaluated in the same way as the resistance of composite electric circuits.

[8 marks]

(b) A magnetic core, in the form of a closed circular iron ring, has a mean length of 30 cm and a cross-sectional area of 1 cm^2. The relative permeability of iron is 2400.

(i) What dc current is needed in the coil of 2000 turns wound around the ring to create a flux of 0.20 mWb in iron?

[6 marks]

(ii) If an airgap of 1 mm is cut through the core perpendicular to the direction of the flux, what current is needed to have the same flux in the air gap as in the iron found in (i)?

[6 marks]

Question 3. [20 marks]

(a) Explain the causes of voltage variations at the output of a power transformer on load.

[8 marks]

(b) The results in Table Q3 were obtained for a 50-Hz, 200/400-V transformer.

Table Q3

	Side	Voltage (V)	Current (A)	Power (W)
Open circuit test	Low voltage	200	0.7	70
Short circuit test	High voltage	15	10	85

What is the voltage on the high-voltage side of the transformer, when delivering 5 kW at 0.8 power factor lagging, the primary voltage being 200 V?

[12 marks]

Question 4. [20 marks]

(a) From the basic expression for induced voltage v in a conductor of length l, moving at a speed u in a uniform magnetic field of flux density B, given as $v = Blu$, show that the average value of the voltage at the commutator terminals is $V = \frac{2pZ}{c} n\phi$, where the symbols have their usual meaning.

[8 marks]

(b) A 100-kW, 220-V shunt generator has armature and field resistances of 0.04 Ω and 50 Ω, respectively. The machine has total mechanical losses of 1.5 kW. For full-load conditions, calculate the

(i) induced voltage;

[4 marks]

(ii) power from the prime mover;

[4 marks]

(iii) generator efficiency.

[4 marks]

Question 5. [20 marks]

(a) Derive the torque-speed characteristics of the DC shunt and DC series motor, carefully stating any assumptions.

[8 marks]

(b) A 220-V dc series motor delivering rated torque runs at a speed of 800 r/min and draws 100 A. What is the speed of the motor when developing half the torque? Total resistance of the armature and field is 0.1 Ω.

[12 marks]

Question 6. [20 marks]

(a) Prove that a set of balanced three-phase sinusoidal currents of peak value I_m in coils of N turns on the stator produces a "rotating" magnetomotive force F of constant magnitude given by $|F| = \frac{3}{2} N I_m$.

[10 marks]

(b) A three-phase, 4-pole, induction motor operates from a 50-Hz supply and runs at a slip of 4%. What is the

(i) speed at which the magnetic field of the stator is rotating?

[2 marks]

(ii) speed of the rotor?

[4 marks]

(iii) frequency of the rotor currents?

[4 marks]

Question 7. [20 marks]

(a) Show the connections of the two-wattmeter method for measuring power in a three-phase system. Prove that this method gives total power even in a general unbalanced situation.

[10 marks]

(b) Each phase of a three-phase, delta-connected load consists of an impedance $Z_L = 20\angle 60^\circ\ \Omega$. The line voltage is 440 V at 50 Hz.

(i) What is the total power consumed by the loads?

[4 marks]

(ii) What are the readings of the two wattmeters connected to measure the power?

[6 marks]

END OF EEE 3352 EXAMINATION

$W = \int P \, dI$ $\quad \frac{1}{2} L I^2 = \frac{1}{2} B H = \frac{1}{2} B^2 / \mu$

$W = \int L \, dI$ $\quad$ Unit Work $= \frac{1}{2} \left(\frac{\Phi}{A}\right) \left(\frac{NI}{L}\right)$