



THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

NOVEMBER 2021

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 $\epsilon_0 = 8.85 \times 10^{-12}$ F/m

Question 1. [20 marks]

- (a) Derive from basic principles the expression for force per unit area due to an electric field. [8 marks]
- (b) Two identical copper plates measuring 15 cm and 10 cm acting as electrodes tightly enclose a slab of mica of thickness 5 mm and relative permittivity of 2.5. Find the
- (i) capacitance of the arrangement from the point of view of the electrodes; [4 marks]
 - (ii) force on the plates, if 600 V dc is applied between the electrodes; [4 marks]
 - (iii) steady-state value of the current through the mica, if 600 V ac at 50 Hz is applied between the electrodes. [4 marks]

Question 2. [20 marks]

- (a) Derive the expression of the reluctance S of a uniform magnetic circuit of constant cross-sectional area A , relative permeability μ_r , length l . Hence derive the expression for inductance L , if the coil round the magnetic circuit has N turns. [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 3000.
- (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 two gaps of 1 mm and 0.5 mm, respectively, are cut through the core perpendicular to the direction of the flux and positioned at diametric ends, 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 20 kVA, 50-Hz, 2200/220-V transformer.

Table Q3

	Side	Voltage (V)	Current (A)	Power (W)
Open circuit test	Low voltage	220	4.2	148
Short circuit test	High voltage	86	10.5	360

What is the regulation of the transformer, when delivering full load at 0.8 power factor lagging and rated primary voltage?

[12 marks]

Question 4.

(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;

(iii) capacitance of each capacitor?

[5 marks]

[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 0.08Ω . If the generator supplies a load current of 120 A, determine the

(i) terminal voltage;

(ii) power output;

(iii) the electromagnetic power;

(iv) electromagnetic torque input.

[3 marks]

[3 marks]

[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.

(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 [4 marks]

(i) slip;

(ii) speed of the rotor;

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

[2 marks]

[2 marks]

- (c) With the help of mmf, voltage and current phasor diagrams explain the operation of an ideal synchronous machine in generating mode. [2 marks]
- [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 0.25Ω and the field flux remains unchanged. [10 marks]

Question 8.

- (a) Deduce the expression for the relation between the illumination E and any point on a plane surface due to a light source of luminous intensity I , suspended at height h from the surface. [6 marks]
- (b) Two lamps with a rating of 500 W each, with a lamp efficacy of 25 lm/W, are mounted on two lamp posts 10 m apart. The posts have heights of 3 m and 5 m, respectively. Calculate the illuminance at a point mid-way between the lamp posts. [8 marks]
- (c) It is required to provide an illuminance of 100 lx in a factory hall of area 30 m x 12 m. Assume that the maintenance factor is 0.8 and the utilisation factor is 0.4 and the efficacy of the proposed 100-W lamps is 14 lm/W. Calculate the number of lamps. [6 marks]

END OF EEE 3352 EXAMINATION