THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF ELECTRICAL & ELECTRONIC ENGINEERING
UNIVERSITY SEMESTER I EXAMINATIONS JUNE/JULY 2006

EE321

ELECTROMECHANICS & ELECTRICAL MACHINES

Time: **Three hours.**
Answer five questions.

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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1.

A certain amount of dielectric material can be shaped into either a cylinder of length ***l*** with space for a central cylindrical electrode or a sphere with space for a spherical electrode.

(a) If the electrode has radius r_1 and the earthing is applied at a radius of r_2, derive the expression of the capacitance of the cylinder and the sphere in terms of the given dimensions and the physical constants.

[8 marks]

(b) in the case of the cylindrical arrangement

(i) what is the relationship between r_1 and r_2 to achieve the "minimum" possible maximum electric field in the insulation?

[6 marks]

(ii) for the condition of "minimum" maximum electric field and given that the outer diameter of the cylinder is 10 cm what is the ultimate maximum stress in the insulation of relative permittivity of 2.5 if the electrode is connected to a single phase a.c. supply of 10 kV?

[6 marks]

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 1 includes an air-gap of 1 mm and a cross-section of 159 mm^2 . The reluctances of the various iron portions are

$S_A = 3 \times 10^6$ At/Wb
$S_B = 9 \times 10^6$ At/Wb
$S_c = S_D = 2 \times 10^6$ At/Wb

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

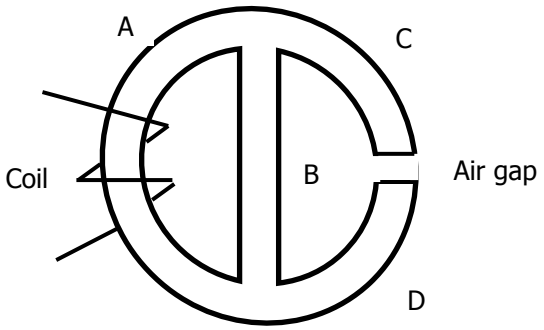

Figure 1.

(i) air-gap reluctance
[2 marks]

(ii) coil inductance
[3 marks]

(iii) total flux
[2 marks]

(iv) air-gap flux density
[3 marks]

(v) total stored energy
[2 marks]

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

3.

(a) Explain the shape of the waveform of the input current of a transformer on no-load.
[5 marks]

(b) Explain the causes of voltage drop in a power transformer on load.
[5 marks]

(c) A 75-kVA transformer rated at 11000/240 V on no-load requires 310 V across the primary to circulate full-load currents on short-circuit, with the power absorbed being 1.6 kW. Determine the voltage regulation at full-load 0.8 power factor lagging. What is secondary terminal voltage at this condition, when rated primary voltage is used?
[10 marks]

4.

(a) Explain the advantages of having a three-phase system compared to a single-phase system in a power system.
[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. Calculate the power factor and the line current of the circuit. What is the capacitance of each capacitor?
[14 marks]

5.

(a) From "$\boldsymbol{v = Blu}$", where $\boldsymbol{l}$ is the length of a conductor, cutting a magnetic field of density $\boldsymbol{B}$ at constant speed $\boldsymbol{u}$, and experiences an induced voltage $\boldsymbol{v}$, 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

(i) terminal voltage
(ii) power output
(iii) the electromagnetic power
(iii) electromagnetic torque input. [12 marks]

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.

(i) What is the slip?

[2 marks]

(ii) What is the speed of the rotor?

[2 marks]

(iii) What is the 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]

7.

(a) With the help of equivalent circuits, predict the torque-speed characteristics 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 rpm. If the full-load armature current is 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]

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 illumination 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 EE321 EXAMINATION