THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF ELECTRICAL & ELECTRONIC ENGINEERING
UNIVERSITY SEMESTER I EXAMINATIONS AUGUST/SEPTEMBER 2007

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) Using suitable examples from uniform electromagnetic fields, derive expressions for resistance, capacitance, and reluctance.

[6 marks]

(b) Prove, from first principles, that the energy stored in an electric field is $\frac{1}{2}\varepsilon E^2$, defining all terms.

[6 marks]

(c) A 5-μF capacitor having a paper dielectric has to operate on a peak voltage of 500 V. This capacitor is to be charged from a dc source. Determine the minimum spacing and corresponding plate area if the maximum permissible stress in the paper is 250 kV/m and the relative permittivity is 6.

[8 marks]

2.

(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 inductance ***L***, if the coil round the magnetic circuit has ***N*** turns.

[6 marks]

(b) The cross-sectional area for the iron in the magnetic circuit of figure 1 is 200 mm^2. The circuit consists of ten identical portions of steel. The relative permeability is 1000. The length of each portion is 150 mm. Neglecting complications at the corners, calculate

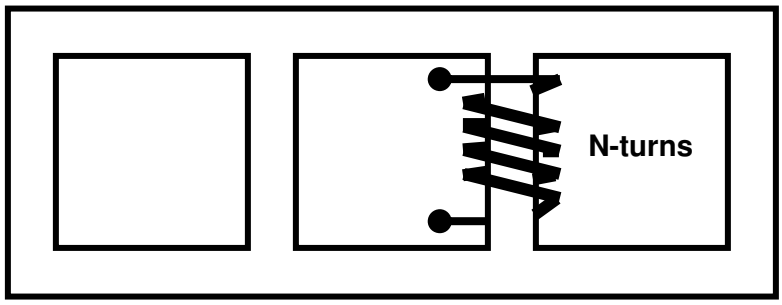

Figure 1

(i) the reluctance of the whole magnetic circuit as seen from the position of the coil,

[6 marks]

(ii) the inductance of the coil which has 2000 turns,

[2 marks]

(iii) the dc current in the coil required to produce a flux of 0.15 mWb.

[4 marks]

(iv) If a 120-V, 50-Hz sinusoidal voltage is supplied to the coil, obtain the maximum value of the magnetic flux density in the portion containing the coil.

[2 marks]

3.

(a) Define the "regulation" of a single-phase transformer and state its practical importance. Derive an expression for regulation carefully defining all terms.

[8 marks]

(b) The primary of a transformer is supplied with a constant voltage of 1000 V, and the secondary voltage on no load is 100 V. When supplying a pure resistance with 20 A the voltage falls to 96 V and when supplying a pure capacitance with 10 A the voltage rises to 104 V.

(i) Draw an equivalent circuit of the transformer, showing numerical values of the series components.

[6 marks]

(ii) What is the percent regulation of this transformer when supplying 20 A to an inductive load of 0.8 power factor?

[6 marks]

4.

(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.

[8 marks]

(b) A 380-V line feeds two balanced three-phase loads. The first load is at 5 kVA at 0.8 lagging power factor while the second is a 10-kVA load at 0.9 lagging power factor. What is the line current measured at the line terminal? Determine the readings of two wattmeters connected at the terminals to measure the total power.

[12 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 dc generator has an open circuit characteristic given by such that $V_{oc} = \frac{200 I_f}{k + I_f}$ the open circuit voltage V_{oc} is 150 V when the field current is 1.5 A. Find the open circuit voltage when the field resistance is 200 Ω. If the armature resistance of the generator is 0.5 Ω, calculate the terminal voltage and the load current when the armature is connected to a load of resistance 10 Ω with the field resistance at 100 Ω.

[12 marks]

6.

(a) Show how a constant speed "rotating" magnetic field of fixed magnitude is produced from a set of balanced three-phase sinusoidal currents.

[8 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) Describe the principal features which establish the three phase ac machine as either an induction machine or a synchronous machine.

[6 marks]

7.

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

[10 marks]

(b) A 400-V dc shunt motor takes 50 A on full-load, and the speed is then 1000 rev/min. For this full-load condition, the field current is 2 A, and the windage, friction and iron losses amount to 600 W. If the armature resistance is 0.5 Ω calculate the total losses, the efficiency and output torque.

[10 marks]

8.

(a) State the two basic laws of illumination.

[2 marks]

(b) Deduce an 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]

(c) A tennis court is 20 m wide and 40 m long including the boundary walkway. It is desired to use four 7-metre poles for lighting, one at each corner, to produce an average of 400 lx at the center of the court. If 250-W high pressure sodium lamps, each giving a luminous flux of 25000 lumens, are used, determine the minimum number of lamps per pole if

(i) no reflector of any kind is used

[6 marks]

(ii) reflectors which direct 40 % of the light uniformly on the court are used.

[6 marks]

END OF EE321 EXAMINATION