# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

November 2018

# EEE 3352

## ELECTROMECHANICS AND ELECTRICAL MACHINES

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| **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]**

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]**

(b) A 1-km, 10-kV, 50-Hz concentric cable has an inner conductor of 12 mm diameter, a dielectric of radial thickness 8 mm, 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) Demonstrate, using basic principles, the analogy of magnetic circuits to electric circuits in the way composite reluctances are combined.

**[6 marks]**

(b) The magnetic circuit shown in Fig. Q2 is 100 mm thick and is made of a material with relative permeability of 2000. A 1000-turn coil is wound on the centre limb. All other dimensions are in mm. Find the

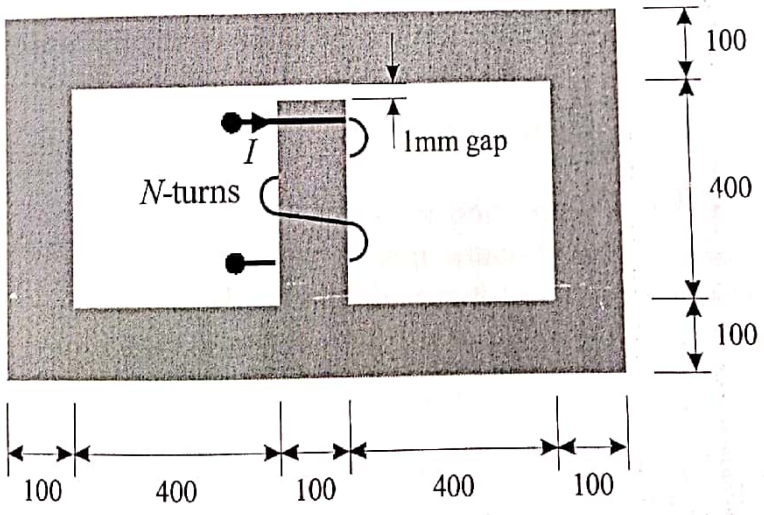


Figure Q2

(i) inductance of the coil;

**[10 marks]**

(ii) current in the coil required to produce a flux density in the centre limb of 1.4 T.

**[4 marks]**

**Question 3.**

(a) Transformer losses may be given as $a+bI^2$, where $I$ is the current of the transformer.

(i) Identify the constants $a$ and $b$;

**[4 marks]**

(ii) Show that the efficiency of a transformer is a maximum when both the load power factor is unity and the load current is at such a value as to make the copper loss equal the iron loss.

**[8 marks]**

(b) A 60-MVA transformer has iron losses of 300 kW and full-load copper losses of 600 kW.

Determine

(i) the maximum efficiency and the load at which it occurs;

**[4 marks]**

(ii) the efficiency at half full-load and 0.7 power factor lagging.

**[4 marks]**

**Question 4.**

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

**[6 marks]**

(b) Show, by suitable derivations, how the power factor of a 3-phase load can be determined from the readings of two wattmeters.

**[6 marks]**

(c) Find the readings of the two wattmeters used to measure real power on a 3-wire, 240-V system with a balanced delta-connected load of $20\underline{/80^{o}}\ \Omega$.

**[8 marks]**

**Question 5.**

(a) Derive the torque-speed characteristic of a dc series motor.

**[8 marks]**

(b) A dc series motor, connected to a 440-V supply, runs at 600 rpm when taking a current of 50 A. Calculate the value of a resistor which, when inserted in series with the motor, will reduce the speed to 400 r/min, the gross torque being then half its previous value. Resistance of the motor armature is 0.2 Ω. Assume the flux is proportional to the field current.

**[12 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?

**[4 marks]**

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

**[8 marks]**

**Question 7.**

(a) Differentiate between the terms ***luminance*** and ***illuminance***.

**[4 marks]**

(c) Derive and discuss the significance of the cosine law of illumination.

**[6 marks]**

(c) It is desired to illuminate a horizontal circular space 10 m in diameter by a lamp suspended at a height of 5 m. The illuminance must not be less than 120 lx at any point. Estimate the power consumption of the lamp required if the lamp is suspended over the centre of the area, the lamp having an efficacy of 20 lm/W and being fitted with a reflector which directs light output over the surface to be illuminated and gives uniform luminous intensity over this angle.

**[10 marks]**

**END OF EEE 3352 EXAMINATION**