MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF EDUCATION (SCIENCE)

BACHELOR OF SCIENCE (MATHEMATICS)

BACHELOR OF SCIENCE (ANALYTICAL CHEMISTRY)

SPH 201: ELECTRICITY AND MAGNET ISM II

DATE: 10/12/2021 **TIME: 2.00-4.00 PM**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

CONSTANTS

- Take: Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12} \mathrm{C}^2/\mathrm{N.m}^2$
- Dielectric constant for paper = 3.7
- Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$

SECTION A (COMPULSORY)
QUESTION ONE (30 MARKS)

a) (i) State Gauss's law and use it to deduce Coulombs law of electrostatics. (3 marks)

(ii) State the difference between Gauss's law and Coulombs law. (2 marks)

b) A conducting cylinder of radius R_0 and length l, and carrying charge $-2q$, is surrounded by a conducting cylindrical shell of radius R carrying charge q . Using gauss's law or otherwise, determine the expression for:

i) the electric field strength at a point r between the two cylinders (3 marks)

ii) the electric field strength at appoint r outside the conducting shell (2 marks)

iii) the charge on the inner and outer surfaces of the conducting shell (2 marks)

c) State Biot-Savart law and Amperes law (2 marks)

d) State two physical properties that a dielectric material should have (2 marks)

e) Explain what happens to the capacitance of a capacitor when the temperature of the dielectric material in between the plates increases. (2 marks)

f) A long, straight wire of radius R carries a steady current I_0 that is uniformly distributed through the cross-section of the wire as shown in Figure 1. Calculate the magnetic field a distance r from the center of the wire in the regions $r \geq R$ and $r < R$ (3 marks)

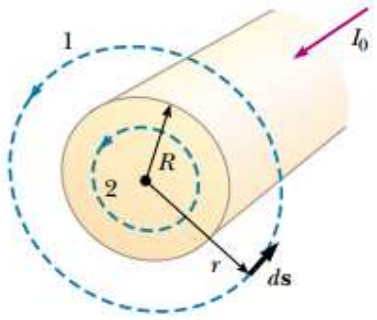

Figure 1

g) Distinguish between impedance and reactance (2 marks)

e) A parallel-plate capacitor has plates of dimensions 2.0 cm by 3.0 cm separated by a 1.0 mm thickness of paper. Find its capacitance (3 marks)

h) Distinguish between a vector and a phasor (2 marks)

i) Describe the relationship between the voltage across and current through an inductor connected to alternating voltage (2 marks)

SECTION B: ANSWER ANY TWO QUESTIONS

QUESTION TWO (20 MARKS)

a) Give a microscopic account of how a dielectric material increases the capacitance of a capacitor (4 marks)

b) A parallel-plate capacitor has an area, $A = 2.00 \times 10^{-4}\text{m}^2$ and a plate separation $d = 1.00$ mm. Find its capacitance (4 marks)

c) A capacitor consists of two parallel circular plates each of diameter 16.4 cm and separation 5 cm. The capacitor is charged by a battery to 100 V. The charging battery is removed and a dielectric slab of thickness 5 mm and dielectric constant 1.3 inserted between the capacitor. Find:

i) the electric field inside and outside the dielectric material (3 marks)

ii) the displacement current inside and outside the dielectric material (3 marks)

iii) the electric polarization inside and outside the dielectric material and (3 marks)

iv) the final potential difference across the plates (3 marks)

QUESTION THREE (20 MARKS)

a) (i) Define self inductance and mutual inductance. (2 marks)

(ii) State the factors that influence the inductance of an inductor. Explain how each of the factors influences inductance. (3 marks)

iii) A coil of 100 turns and cross sectional area $4.5 \times 10^{-5}\ m^2$ is placed in the middle of a solenoid of 7000 turns and cross sectional area $2.3 \times 10^{-3}\ m^2$ and length 0.82 m, such that the solenoid carries a current, i, given by:

$$i = 4t^3 + 2t^2 + 19$$

Calculate the emf induced in the coil after three seconds if only 80% of the flux produced by the solenoid links the coil. (4 marks)

b) A 2.0 H solenoid is connected in series with a resistor to a 2.0 V d.c supply, so the total resistance is 0.5.

i) Sketch the graph of current against time when the current is switched on (2 marks)

ii) Calculate the final current reached (2 marks)

iii) Calculate the initial rate of change of current with time (2 marks)

iv) Calculate the rate of change of current when the current is 2.0 A (3 marks)

v) Explain why an excess of 2.0 V will be produced when the current is switched off. (2 marks)

QUESTION FOUR (20 MARKS)

a) i) The alternating voltage connected across a solenoid of radius 0.6 cm, length 6mm and 2×10^6 turns is given by $\varepsilon = 34.42\sin 318t$ where t has its normal meaning. Calculate the reactance of the coil. (3 marks)

ii) A resistor, inductor and voltage sources are connected in series. When a voltmeter is connected across the inductor, it indicates a reading of 260 volts and when connected across the resistor, it reads 124 volts. Find the value of the source voltage. (3 marks)

iii) An alternating voltage $V = V_0 \sin \omega t$, where all the symbols have their usual meaning is connected across an inductor of inductance L. Show that the inductance, X_L of the inductor is given by:

$$X_L = \frac{1}{\omega}$$ (3 marks)

b) A coil having inductance and resistance is connected to an oscillator giving a fixed sinusoidal output voltage of $5.00\ V_{r.m.s}$. With the output set at a frequency of 50 Hz, the r.m.s current in the coils is 1.0 A and a frequency of 100 Hz, the r.m.s current is 0.625 A

i) Determine the inductance of the coil (4 marks)

ii) Calculate the ration of the powers dissipated in the coil in the cases (1 mark)

c) A 100 kHz, 943 $V_{r.m.s}$ source, 1.178 kΩ resistor, 0.008 H inductor and 0.5 nF are connected in series. Find:

i) the voltmeter reading across the capacitor (4 marks)

ii) the phase angle between the source voltage and circuit current (2 marks)

QUESTION FIVE (20 MARKS)

a) Show that for a hypothetical closed cylinder of radius R immersed in a uniform electric field $\vec{E}$, the cylinder axis being parallel to the field, the total flux for this closed surface is 0.

(5 marks)

b) A small sphere of mass 10^{-3}gm and charge 4×10^{-8} coulombs hangs from silk thread at 60° with a large charged conducting sheet. Calculate the surface density for the sheet.

(10 marks)

c) In the circuit in figure 2 below, A and B have equal ohmic resistance but B is of negligible self-inductance whilst A has a high self-inductance. Describe how the currents through A and B change with time when (i) switch S is closed, and (ii) when it is opened. (5 marks)

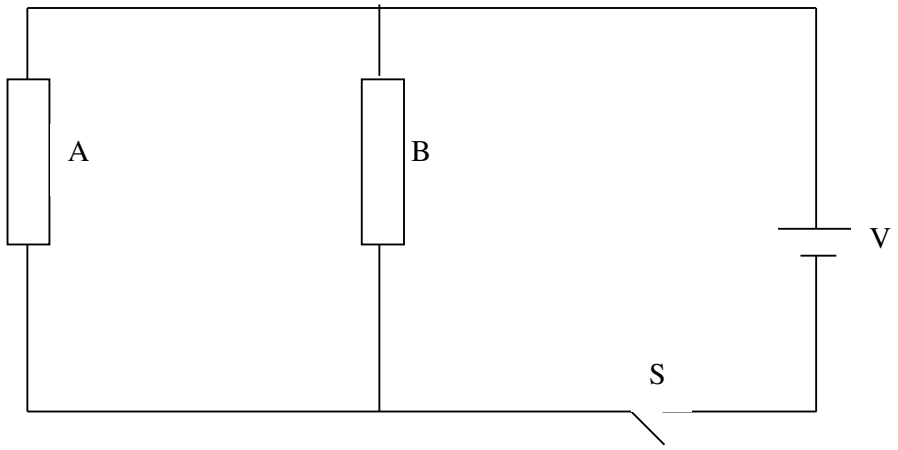

Figure 2