



MACHAKOS UNIVERSITY

University Examinations 2022/2023 Academic year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION
TECHNOLOGY)

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

BACHELOR OF SCIENCE (ANALYTICAL CHEMISTRY)

BACHELOR OF EDUCATION (SPECIAL NEEDS)

BACHELOR OF SCIENCE (MATHEMATICS)

BACHELOR OF EDUCATION (SCIENCE)

SPH 201/ SPT204: ELECTRICITY AND MAGNETISM II

DATE: 17/4/2023

TIME: 8:30 – 10:30 AM

INSTRUCTIONS:

Answer QUESTION ONE and ANY OTHER TWO questions.

Question 1 carries **30** marks and the others carry **20** marks each.

You may need to use the following constants

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

$$k = 1/(4\pi\epsilon_0) = 8.99 \times 10^9$$

$$\text{Electron charge, } q_e = -1.6 \times 10^{-19} \text{ C}$$

$$\text{Proton charge, } q_p = +1.6 \times 10^{-19} \text{ C,}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ Tm/A,}$$

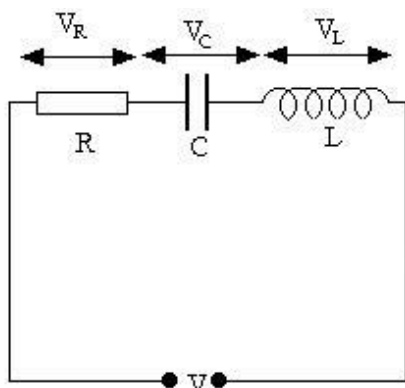
$$1\text{eV} = 1.6 \times 10^{-19} \text{ J}$$

QUESTION ONE (30 MARKS)

- a) State and write the mathematical expression for Gauss's law. (2 marks)
- b) Three charges $-3\mu C$, $12\mu C$ and $-4\mu C$ are placed in a sphere of radius $r = 3cm$. Determine the electric field associated with them. (3 marks)
- c) Sketch a graph of the magnitude of electric charge on either plate of a capacitor versus the magnitude of the potential difference between the plates. What does its slope indicate based on this curve? (3 marks)
- d) If $\vec{E} = 3\hat{i} + 4\hat{j} - 5\hat{k}$, calculate the electric flux through a surface of area 50 m^2 in the j - z plane. (2 marks)
- e) For a parallel plate capacitor, show that the energy density in any electric field is proportional to the square of the magnitude of the electric field at a given point. (4 marks)
- f) Show that at a point where the electric field is zero, then the electric field potential need not to be zero (2 marks)
- g) A transmitting circuitry contains a coil with an inductance of 3 mH and is to generate a signal of 2 MHz . Calculate the value of the used capacitor. (4 marks)
- h) A 50 turns coil with a radius of 25 cm carries a current of 4.5 A .
- What is the magnitude of its magnetic dipole moment? (2 marks)
 - What is a torque on the coil if it is in a uniform magnetic field of 0.02 T with an angle of 20° between moment and field? (2 marks)
- i) A circuit consist of an inductor of $200\mu H$ and resistance 10Ω in series with a variable capacitor and a 10 V , 2 MHz supply. Calculate;
- The capacitance that gives resonance (2 marks)
 - The p.d's across the inductor at resonance (2 marks)
- j) State Ampere's law (2 marks)

QUESTION TWO (20 MARKS)

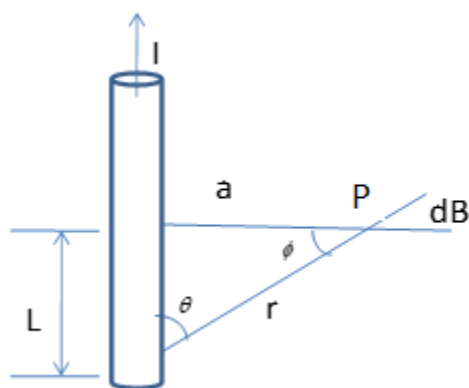
- a) Define a ballistic galvanometer and describe how it is calibrated. (5 marks)
- b) Show that the magnetic force on a current carrying conductor of length L where charges are drifting with a velocity v is given by $F = I\vec{L} \times \vec{B}$ (5 marks)
- c) An alternating current signal is connected in series with a resistor, capacitor and inductor with respective voltages as shown in the figure.



- Show that its impedance is given by $Z = \sqrt{R^2 + (\chi_L - \chi_C)^2}$ (4 marks)
- Calculate its phase angle if $R = 8 \Omega$, $L = 200 \mu\text{H}$, $C = 0.5 \mu\text{F}$, $f = 1 \text{ MHz}$ (3 marks)
- Calculate the current flowing if the circuit is connected to a 26 V supply. (3 marks)

QUESTION THREE (20 MARKS)

- An electron is moving with a velocity of $v = 10^6 \hat{i} \text{ m/s}$ in a region where the force of electromagnetism is being felt. If $E = 10^5 \text{ N/C}$ and $B = 10^{-2} \hat{j} \text{ T}$. Calculate the magnitude and direction of the force experienced. (4 marks)
- A coaxial cable connecting a TV to an antenna socket is 3 m long. The inner conductor has an outer radius of 0.5 mm, the outer conductor has an inner radius of 3 mm. The space between the conductors is filled with plastic with $\kappa = 2.6$. Derive the expression to be used and use it to determine the capacitance of this cable? (7 marks)
- State Biot-Savart law for a current element (2 marks)
 - Consider a straight infinitely long wire carrying a steady current I . Calculate magnetic field at a point P at a distance R from the wire as shown below in the figure. (7 marks)



QUESTION FOUR (20 MARKS)

- a) Determine the magnetic field at a distance R for an infinitely straight wire of radius r that is carrying current I and where;
- i) $R \gg r$ (2 marks)
 - ii) $R \ll r$ (2 marks)
- b) An electron in a television picture tube moves toward the front of the tube with a speed of 8.0×10^6 m/s along the x axis. Surrounding the neck of the tube are coils of wire that create a magnetic field of magnitude 0.025 T, directed at an angle of 60° to the x axis and lying in the x - y plane. Calculate the magnetic force on the electron and its direction. (3 marks)
- c) A parallel-plate capacitor measuring 3×5 cm is connected to a 14 V power supply during its charging. If the plates are separated by 3 mm, calculate;
- i) Its capacitance (2 marks)
 - ii) Its capacitance when a dielectric with $\epsilon_r = 2.7$ (2 marks)
 - iii) Its stored charge (1 mark)
 - iv) Electric field (1 mark)
 - v) Stored energy (2 marks)
- d) Using Gauss' law, show that for a parallel-plate capacitor with area of the plates, A and plate separation d ; (5 marks)

$$C = \epsilon_0 \frac{A}{d}$$

QUESTION FIVE (20 MARKS)

- a) Consider two parallel wires separated by a distance a and carrying currents I_1 and current I_2 of lengths L_1 and L_2 respectively. Show that at current balance, $\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi a}$ (8 marks)
- b) Show that for a positively charged particle moving in a uniform magnetic field $\mathbf{B}$ with the initial velocity vector $\mathbf{V}$ of the particle perpendicular to the field;
- i) The radius of the orbit $\mathbf{R}$ is directly proportional to the velocity $\mathbf{V}$ (4 marks)
 - ii) its period of revolution is inversely proportional to $\mathbf{B}$ (4 marks)
 - iii) An electron with K.E. of 10^3 eV moves perpendicular to the lines of uniform field $\mathbf{B} = 10^{-3}$ T. Calculate the period and the radius of the orbit (4 marks)