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**UNIVERSITY EXAMINATIONS
2022/2023 ACADEMIC YEAR**

**THIRD YEAR SECOND SEMESTER
SUPPLEMENTARY EXAMINATIONS**

FOR THE DEGREE OF B.SC (PHYSICS)

COURSE CODE: SPC 322

COURSE TITLE: ELECTROMAGNETISM

DURATION: 2 HOURS

DATE: 15/8/2023

TIME: 2:00-4:00PM

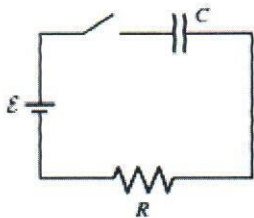
INSTRUCTIONS TO CANDIDATES

- Answer **QUESTION ONE** (Compulsory) and any other two (2) Questions.
- The following constants might be used: $K_e=9.0 \times 10^9 \text{ N.m}^2/\text{C}^2$; $M_e=9.1 \times 10^{-31} \text{ kg}$; $M_p=1.6 \times 10^{-27} \text{ kg}$;
 $e=1.60 \times 10^{-19} \text{ C}$

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QUESTION ONE [30 Marks]

- a) State Ampere's law. [2]
- b) Two equal positive charges $q_1 = q_2 = 2.0 \mu\text{C}$ are located at $x = 0, y = 0.30\text{m}$ and $x = 0, y = -0.30\text{m}$ respectively. What are the magnitudes and direction of the total electric force that q_1 and q_2 exert on a third charge $Q = 4.0 \mu\text{C}$ at $x = 0.40\text{m}, y = 0$? [4]
- c) What is the meaning of "potential energy of a system of charges"? [2]
- d) An alpha particle has a mass $6.64 \times 10^{-27} \text{kg}$ and charge $q = +2e = 3.2 \times 10^{-19} \text{C}$. Compare the magnitude of the electric repulsion between two alpha particles with that of gravitational attraction between them. [4]
- e) Show that electric potential of two point charges q and q_0 is given by $U = \frac{1}{4\pi\epsilon_0} \frac{qq_0}{r}$ when q_0 is brought from infinity to r . [3]
- f) State the principle of conservation of electric charge. [1]
- g) Two point charges are located on the x -axis $q_1 = -e$ at $x = 0$ and $q_2 = +e$ at $x = a$. Find the work that must be done by an external force to bring a third point charge $q_3 = +e$ from infinity to $x = 2a$. Also work out the total potential energy of the system of three charges. [4]
- h) A battery is connected to an RC circuit as shown. The switch is initially open, and the charge on the capacitor is initially zero. If the switch is closed at $t=0$, find the charge on the capacitor as a function of time. [4]



- i) Give the Faraday's law of Induction. [2]
- j) The distance between the two protons in helium nucleus could be at one instant as much as 10^{-15}m . How large is the force of electrical repulsion between two protons at the distance? [4]

QUESTION TWO [20 Marks]

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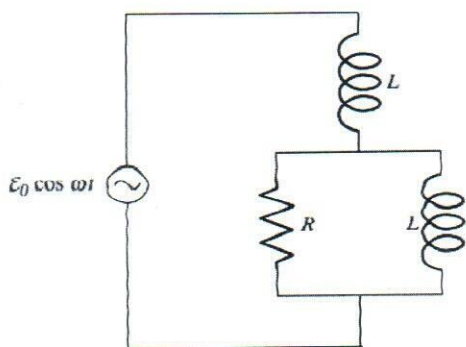
- a) Charge Q is uniformly distributed a round a conducting ring of radius a . Find the electric field at a point P on the ring axis at a distance x from its center. [12]
- b) The electric field equals the negative gradient of the potential, i.e. $\vec{E} = -\nabla\phi$. Show that $\nabla \times \vec{E} = 0$. [4]
- c) A charge $2q$ is at the origin, and a charge $-q$ is at $x = a$ on the x-axis. Find the point on x-axis where the electric field is zero. [4]

QUESTION THREE [20 Marks]

- a) Give an expression for Biot-savart law. [2]
- b) Prove that the vector potential \vec{A} for a long straight wire carrying a current I is given
- $$\vec{A} = -\hat{z} \frac{\mu_0 I}{2\pi} \ln r. \quad [5]$$
- c) Use Biot-savart law to calculate the field at a distance b from an infinite straight wire carrying current I . [13]

QUESTION FOUR [20 Marks]

- a) The circuit shown has two equal inductors L and a resistance R . The frequency of emf source, $\varepsilon_0 \cos \omega t$, is chosen to be $\omega = \frac{R}{L}$.



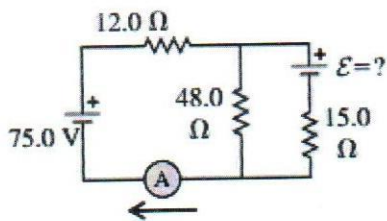
- i. What is the total complex impedance of the circuit? Give it in terms of R only. [4]
- ii. If the total current through the circuit is written as $I_0 \cos(\omega t + \phi)$, what are I_0 and ϕ ? [4]
- iii. What is the average power dissipated in the circuit? [4]
- b) State Kirchhoff's junction rule. [1]
- c) Show that the equivalent resistance for resistors in a parallel circuit is given by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \quad [4]$$

- d) A $10\text{-M}\Omega$ resistor is connected in series with a $1.0\ \mu\text{F}$ capacitor and a battery with emf $12.0\ \text{V}$. Before the switch is closed at a time $t=0$, the capacitor is uncharged. What is the time constant? [3]

QUESTION FIVE [20 Marks]

- a) In the circuit shown, both batteries have insignificant internal resistance and the idealized ammeter reads $1.50\ \text{A}$ in the direction shown. Find the emf \mathcal{E} of the battery. [6]



- b) Write down the complete set of Maxwell's equations. [4]
- c) State the three properties of electromagnetic waves. [3]
- d) A proton is moving in a circular orbit of radius $14\ \text{cm}$ in a uniform $0.35\ \text{T}$ magnetic field perpendicular to the velocity of the proton. Find the linear speed of the proton. [3]
- e) Define electric field at a point in space. [2]
- f) What is capacitance of a capacitor? [2]

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