BINDURA UNIVERSITY OF SCIENCE EDUCATION

PHYSICS AND ENGINEERING DEPARTMENT

PH103: ELECTRICITY AND MAGNETISM

DURATION: THREE HOURS AUG 2024

Answer **ALL** parts of Section A and any **THREE** questions from Section B.
Section A carries 40 marks and Section B carries 60 marks.

Electronic charge, q = 1.6 x 10^{-19} C
Permittivity of free space, ε_0 = 8.85 x 10^{-12} Fm^{-1}
Permeability of free space, $\mu_0 = 4\pi x10^{-7}$ Hm^{-1}
Mass of electron, m_e = 9.11 x 10^{-31} kg
Mass of proton, m_p = 1.67 x 10^{-27} kg
Avogadro constant, N_A = 6.02 x 10^{23} mol^{-1}
Universal Gravitation Constant, G = 6.67 x 10^{-11} Nm^2kg^{-2}
Acceleration due to gravity, g = 9.81 ms^{-2}

SECTION A

1. (a) A charged particle may experience a force in an electric field and in a magnetic field. State two differences between the forces experienced in the two types of field. [4]

(b) A wire carries a current of 10 A in a direction that makes an angle of 30° With the direction of the magnetic field of strength 0.3 T. Find the magnitude of the force on a 5 m length of the wire. [3]

(c) (i) Write down the mathematical statement of Coulomb's law of electrostatics in vector form, naming all symbols used. [6]

(ii) Two charges $q_1 = 4\mu C$ and $q_2 = 3\mu C$ are fixed in place, with a separation $r = 3m$. Calculate the Coulomb force between them. [3]

(d) A proton, travelling in a vacuum at a speed of $4.5\times10^6 ms^{-1}$, enters a region of uniform magnetic field of flux density 0.12 T. The path of the proton in the field is a circular arc, as shown in Figure 1.1.

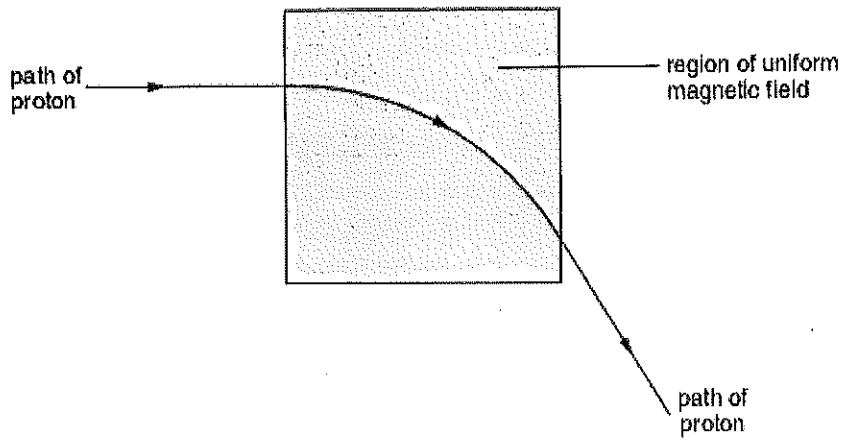

Figure 1.1. The path of a proton.

(i) State the direction of the magnetic field. [1]

(ii) Calculate the radius of the path of the proton in the magnetic field. [3]

(e) The quantity of charge q in (Coulombs) passing through a surface of area $7.25m^2$ varies with time according to the equation:

$$q = 3.00t^4 + 5.00t^2 - 700.00$$

where t is in seconds.

Calculate:

(i) the *instantaneous current* through the surface at $t = 2.00$ s. [4]

(ii) the corresponding *current density*. [3]

(f) A series LCR circuit with L = 2 H, C = 2 μF and R = 20 Ω is driven by an ac source of maximum emf, 100 V and of variable frequency. Find the resonance frequency ω_0, the phase ϕ and maximum current I_{max} when the ac source angular frequency is 400 rads^{-1}. [10]

(g) A solenoid is 30 cm long with 1000 turns per metre and carries a current of 5.0 A. What is the magnitude of the *magnetic field* through the centre of this solenoid? [3]

SECTION B

2. (a) Write down and explain three main characteristics for each of the RLC series and parallel circuits. [6]

(b) State Kirchhoff's junction and loop rules. [4]

(c) Use Kirchhoff's junction and loop rules to find the currents flowing through the two cells (in Figure 2.1), indicating their directions on a diagram. [10]

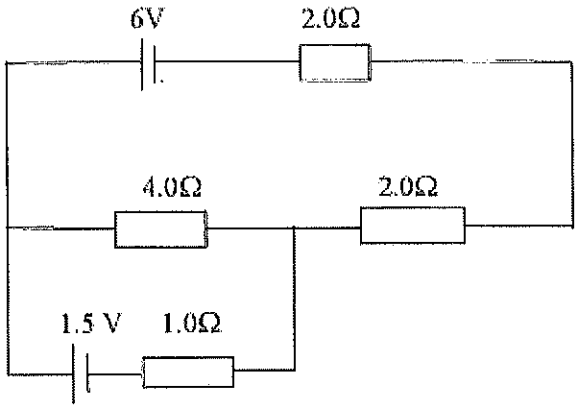

Figure 2.1. An electric circuit.

3. (a) Define electric flux. [2]

(b) State Gauss' law in words and in its mathematical form. [5]

(c) Consider a uniform electric field oriented in the x-direction. Find the electric flux through each surface of a cube with edges L oriented as shown in Fig. 3.1, and the net flux. [13]

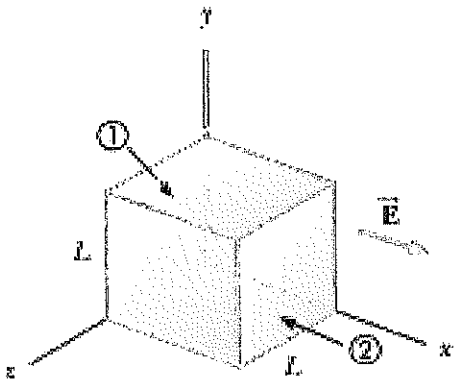

Figure 3.1. Electric flux through a cube.

4. Consider three point charges at the corners of a triangle, as shown in Figure 4.1, where $q_1 = 6.00\,nC$, $q_2 = -2.00\,nC$ and $q_3 = 5.00nC$.

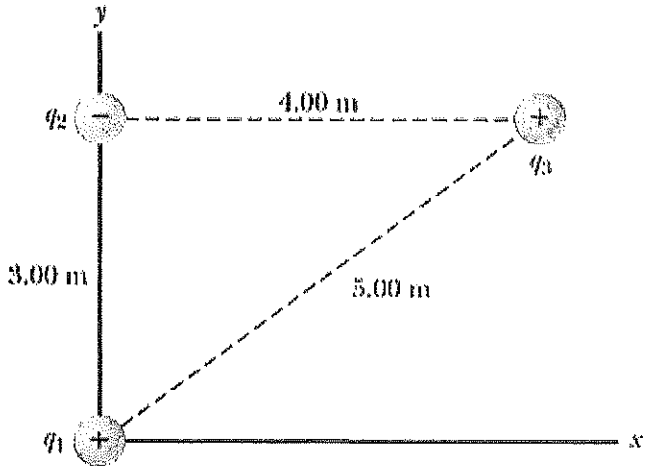

Figure 4.1. Three point charges.

(a) Find the components of the force $\vec{F}_{23}$ exerted by q_2 on q_3. [5]

(b) Find the components of the force $\vec{F}_{13}$ exerted by q_1 on q_3. [5]

(c) Find the resultant force on q_3, in terms of components and also in terms of magnitude and direction. [10]

5. (a) Explain the similarities and differences between electric forces and gravitational forces. [6]

(b) A $90pF$ capacitor is connected to a 12V battery and charged to 12V. How many electrons are transferred from one plate to another? [4]

(c) Four 2 μF capacitors are connected as shown in Figure 5.1.

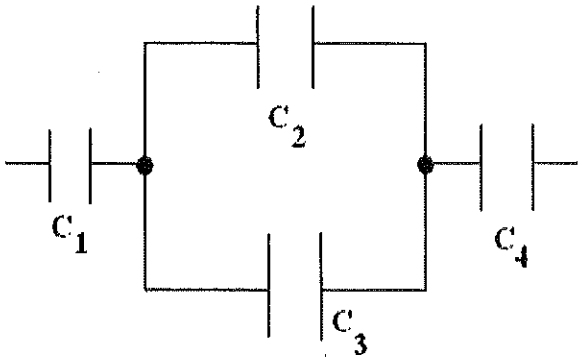

Figure 5.1. Electric circuit.

Calculate the total capacitance. [10]

6. (a) A 15 cm diameter circular loop of wire is placed in a 0.50 T magnetic field.

(i) When the plane of the loop is perpendicular to the field lines, what is the magnetic flux through the loop? [3]

(ii) The plane of the loop is rotated until it makes a 35^0 angle with the field lines. What is the angle θ in the equation $\Phi_B = BA\cos\theta$ for this situation? [2]

(iii) What is the magnetic flux through the loop at this angle? [3]

(b) A generator rotates at 85 Hz in a magnetic field of 0.030 T. It has 1000 turns and produces an rms voltage of 150 V and an rms current of 70.0 A.

(i) What is the peak current produced? [3]

(ii) What is the area of each turn of the coil? [3]

(c) An LCR circuit has L = 14.8 mH and R = 4.40 Ω.

(i) What value must C have to produce resonance at 3600 Hz? [3]

(ii) What will be the maximum current at resonance if the peak external voltage is 150 V? [3]

END OF EXAMINATION