BINDURA UNIVERSITY OF SCIENCE EDUCATION

PHYSICS AND ENGINEERING DEPARTMENT

PH103: ELECTRICITY AND MAGNETISM

DURATION: THREE HOURS   5ᵗ AUG 2023

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, $q = 1.6 \times 10^{-19}$ C

Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ Fm⁻¹

Permeability of free space, $\mu_0 = 4\pi x 10^{-7}$ Hm⁻¹

Mass of electron, $m_e = 9.11 \times 10^{-31}$ kg

Mass of proton, $m_p = 1.67 \times 10^{-27}$ kg

Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol⁻¹

Universal Gravitation Constant, $G = 6.67 \times 10^{-11}$ Nm²kg⁻²

Acceleration due to gravity, $g = 9.81$ ms⁻²

SECTION A

1. (a) (i) State Coulomb's law of electrostatics in its vector form, defining 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]

   (b) Given that 1kJ is required to carry a 10C charge from one point to the other,

   what is the potential difference between these two points?   [3]

   (c) A $90pF$ capacitor is connected to a 12V battery and charged to 12V. How
   many electrons are transferred from one plate to another?   [5]

   (d) Three $20\mu C$ charges are placed on the corners of a square of side 2m.

   Calculate:

   (i) the potential V at the fourth, unoccupied corner of the square, and   [3]

   (ii) the work needed to bring the fourth positive charge of $20\mu C$ from

   infinity and place it on the fourth corner of the square.   [3]

   (e) 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]

(f) 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]

(g) 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:

(i)   the resonance frequency ω_0, [2]

(ii)   the maximum current I_{max} when the ac source angular frequency is 400 rads^{-1}, and [7]

(iii)   the phase ϕ . [2]

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]
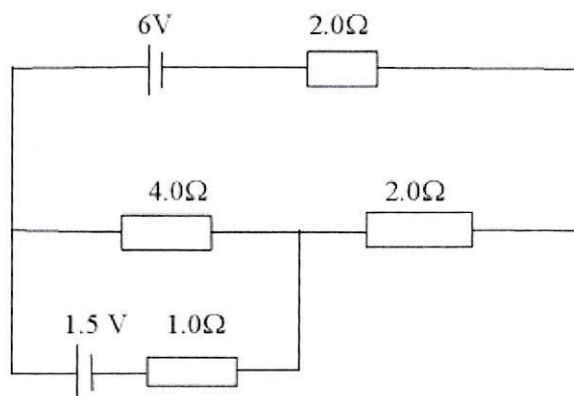
Figure 2.1. An electric circuit.

3. Consider three point charges at the corners of a triangle, as shown in Figure 3.1, where $q_1 = 6.00\,nC$, $q_2 = -2.00\,nC$ and $q_3 = 5.00nC$.
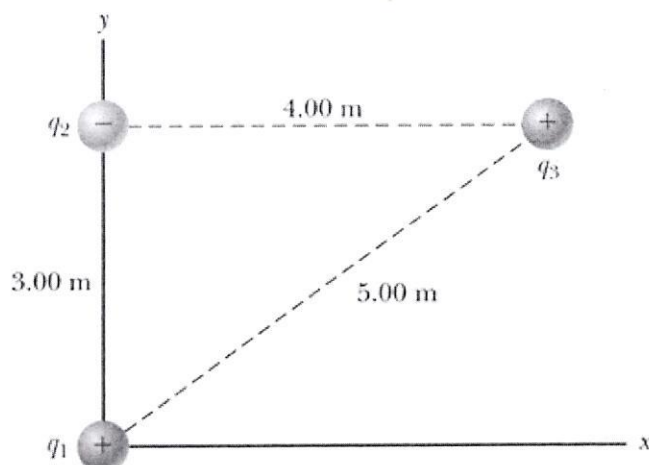

Figure 3.1. Three point charges.

(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]

4. (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]

5. (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. 5.1, and the net flux. [13]
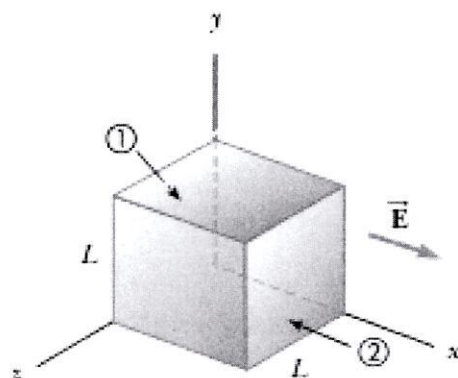

Figure 5.1. Electric flux through a cube.

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

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

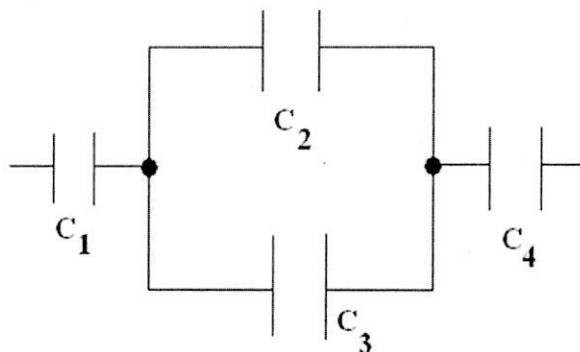(c) Four 2 μF capacitors are connected as shown in Figure 6.1.

Figure 6.1. Electric circuit.

Calculate the total capacitance. [10]

END OF EXAMINATION