Data Provided: Formula Sheet

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2006-2007 (2 hours)

Electric and Magnetic Fields 2

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. Figure 1 shows the cross-section at $z = 0$ of two infinitely long charged wires which are 4m apart. Both wires have a radius of 1cm and a charge per unit length as given in the diagram.

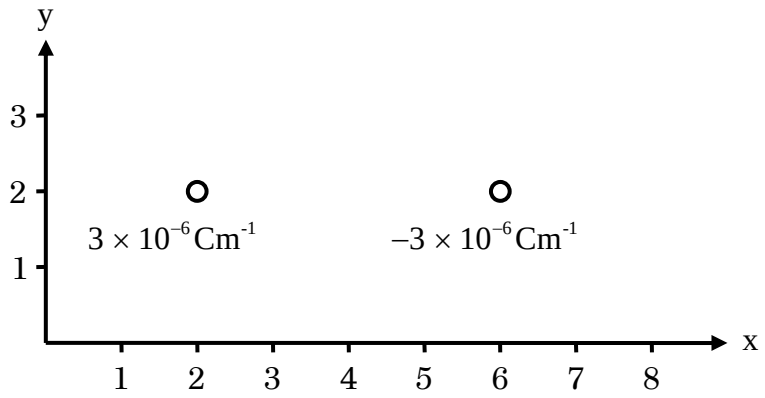

Figure 1

a. Redraw the diagram and show the field lines and lines of equipotential. **(2)**

b. Show that the equation for the electric field due to an infinitely long charged wire is given by:-

$$|\underline{E}| = \frac{q_l}{2\pi r \varepsilon_o}$$

State any assumptions which you make. **(6)**

c. Calculate the electric fields at the following points, giving your answers as vectors.

i) (4,2,0) m **(2)**

ii) (0,0,0) m **(2)**

iii) (2,2,0) m **(2)**

d. By integrating the expression for total electric field along a suitable path, find the potential difference between the two wires. **(6)**

2. **a.** Using the equation for electric field due to an infinite charged sheet, and stating any assumptions you make, show that the capacitance of an air-filled parallel plate capacitor is given by the expression:-

$$C = \frac{\varepsilon_0 A}{d}$$

(6)

b. Figure 2 shows a capacitor connected to a 12V battery. The area of the plates, A, is 1×10^{-2} m^3, and the separation distance, d, is 1mm with an air dielectric.

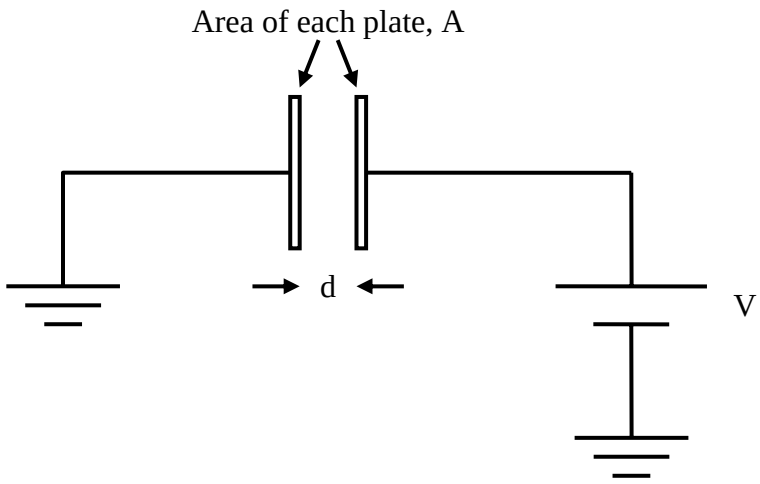

Figure 2

i) Calculate the capacitance of the capacitor **(2)**

ii) Calculate the charge on the positive plate **(2)**

iii) Calculate the energy stored in the capacitor **(2)**

iv) Calculate the energy density inside the capacitor **(2)**

c. If the plate separation is decreased to 0.5mm over a period of 1ms, calculate the average current which flows during this time. State the direction in which the current flows, explaining your answer. **(6)**

3. a. With reference to the movement of charge carriers, show that the force experienced by a conductor carrying a current I, placed in a magnetic field with flux density $\underline{B}$ is given by the expression:-

$$\underline{F} = I \oint \underline{dl} \times \underline{B}$$

You should define any quantities used in your derivation, and state any assumptions made. **(6)**

b. Figure 3 shows a single square loop, which is free to rotate about its axis, placed in a uniform magnetic field. The loop forms the basis of a dc motor.

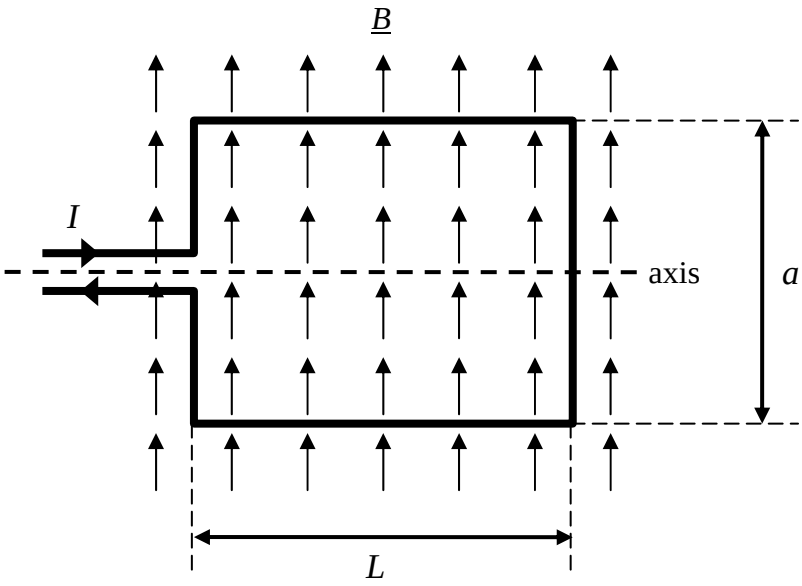

Figure 3

i) Assuming $a = 2$ cm, $L = 5$ cm, $B = 0.5$ T, and $I = 100$ mA, calculate the force on each of the top, bottom, and right hand sides of the loop. State the direction of the force in each case. **(4)**

ii) Derive an expression for the torque on the loop as a function of θ, where θ describes the angle the loop has been rotated around the axis. $\theta = 0$ when the plane of the loop is parallel with the field, as shown in the diagram. Sketch a graph of this torque for $0° \le \theta \le 360°$ **(6)**

iii) With reference to the graph, describe two problems which would prevent continuous rotation. Suggest modifications which would overcome these problems. **(4)**

4. **a.** Using Ampère's Law, derive expressions for the B-field at a distance r from the centre of a current carrying wire of radius a for the following cases. You should define any quantities used in your derivations, and state any assumptions made.

i) outside the wire ($r \geq a$) **(5)**

ii) inside the wire ($r \leq a$) **(5)**

b. Figure 4 shows the cross-section of three parallel wires each carrying the current indicated. The direction of all three currents is into the page.

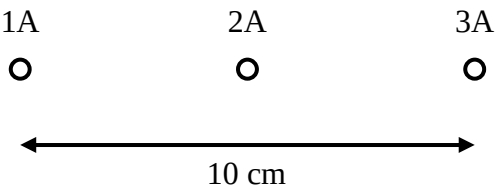

Figure 4

i) Calculate the forces on each of the wires, assuming the centre wire to be midway between the other two wires. **(6)**

ii) The centre wire is now moved closer to one of the other wires (but keeping the three wires in line.) At what position would it experience no force? **(4)**

JLW / JBW