Data Provided: Formula Sheet

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2008-2009 (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. a. In Figure 1(a) two small charged beads A and B are free to slide without friction on a ring of radius a. If the beads carry equal positive charge Q, what is their equilibrium position? Assume that the ring is horizontal so that gravitational forces can be ignored. What forces act on the beads in this equilibrium position?

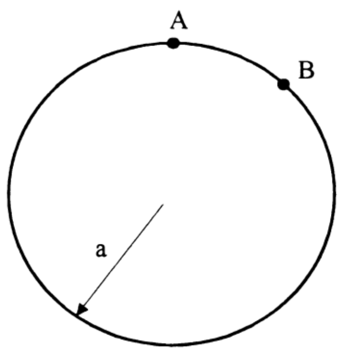

Figure 1 (a)

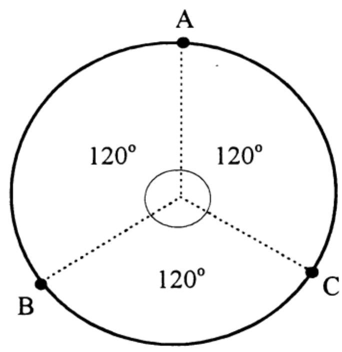

Figure 1 (b)

(7)

b. In this equilibrium position what is the potential at the position of B due to the charge on A? If B is moved from this position to that in Figure 1(b), what work is done? **(7)**

c. What is the potential at point C in Figure 1(b)? What would be the change in stored energy if a third charge Q is placed at C? **(6)**

2. **a.** Explain how you would use the expression

$$E = \frac{q_s}{2\varepsilon_0}$$

for the field of an infinite sheet of charge to deduce an expression for the capacitance of a parallel plate capacitor.

(7)

b. Figure 2 shows a parallel plate capacitor charged to a potential difference V. If the separation of the plates is increased from d_1 to d_2, derive an expression for the change in the charge on the capacitor.

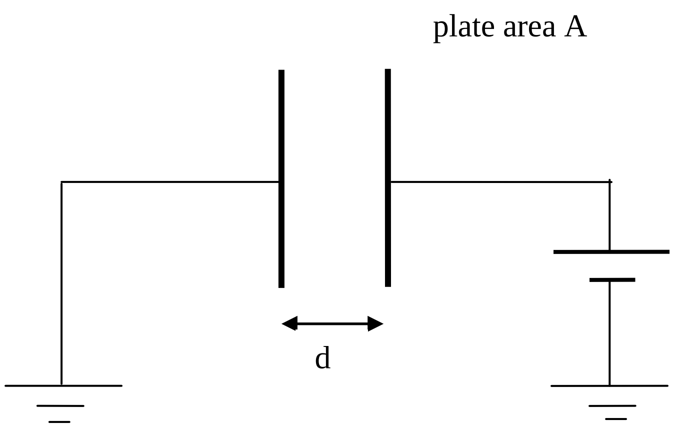

Figure 2

(7)

c. If the plates have an area of $20 \times 10^{-4} m^2$ and V=10V, and the separation changes from 0.1mm to 1.1mm in 0.1 second, what is the magnitude of the current that flows? **(6)**

3. **a.** Explain how you would use Ampere's law to show that the B field due to a long straight wire is given by

$$B = \frac{\mu_0 I}{2\pi r}$$

(6)

b. Figure 3 shows the cross-section of four long straight wires A, B, C and D placed at the corners of a square of side t. The wires carry currents as shown, where a positive current is into the plane of the figure. Show that the components F_x and F_y of the force per unit length acting on wire B are given by

$$F_x = \frac{\mu_0 I_1}{2\pi t}\left(\frac{I_1}{2} - I_2\right)$$

$$F_y = \frac{\mu_0 I_1}{2\pi t}\left(\frac{I_1}{2} + I_2\right)$$

(8)

c. If t=20mm, I_1=3A and I_2=1A, calculate the magnitude and direction of the force per unit length acting on B. Using symmetry calculate the force acting on C.

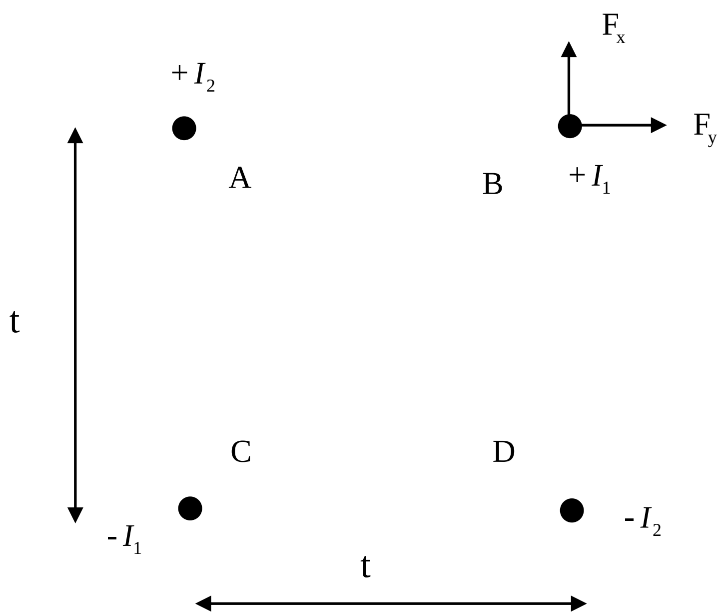

Figure 3

(6)

4. **a.** A current of magnitude *I* flows through a circular *N*-turn loop of radius *a* which is located at the origin in the x-y plane. Use the Bio-Savart law to show that the field along the axis of the loop is given by

$$B = \frac{\mu_0 N I a^2}{2\left(a^2 + z^2\right)^{3/2}}$$

(10)

b. Figure 4 shows a detour in an otherwise infinitely long straight wire carrying a current I. Use superposition to derive an expression for the flux density at P, and evaluate it for I=10^3 A and d=0.1m.

Note that the magnetic field a perpendicular distance y from a straight wire of length L carrying a current I is given by - $B = \frac{\mu_0 I}{2\pi y}\left[\frac{1}{1+\left(2y/L\right)^2}\right]^{1/2}$

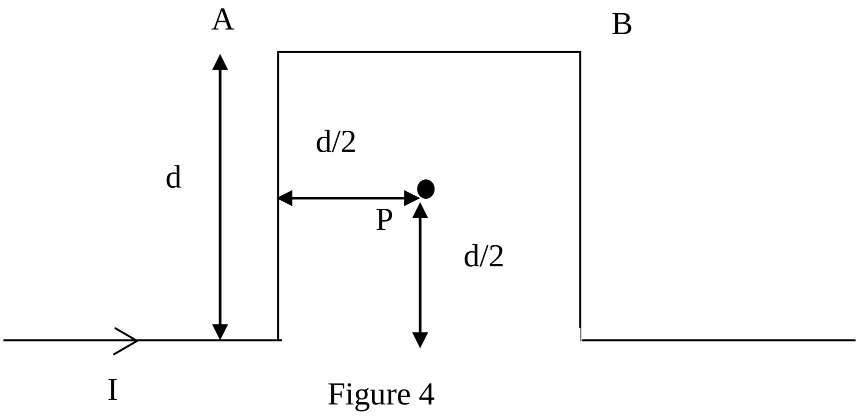

Figure 4

(10)

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