Data Provided: Formula Sheet

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2010-2011 (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.** Sketch the form of the field lines and equi-potential surfaces of an electric dipole **(2)**

b. A point charge of magnitude 15μC is located at the origin and a second point charge of magnitude 7μC is located 1 metre to the right of the origin on the horizontal x-axis. Calculate the position on the x-axis at which the magnitude of the electric field is zero. A third charge of magnitude 3μC is positioned 1 metre above the origin on the vertical y-axis. Calculate the magnitude and direction of the force acting on the third charge. **(8)**

c. A semi-circular ring of charge of radius a is centred at the origin in the x-y plane as shown in Figure 1.1. The total charge on the ring is Q. Assuming that this charge is uniformly distributed around the ring, determine an expression for the electric field at the origin.

An infinite wire is now placed in the x-y plane parallel to the y-axis and a distance $2a$ from the origin. If the wire carries a charge q_l Coulombs per unit length, calculate the total field at the origin due to the combination of the infinite wire and the semi-circular ring of charge. **(10)**

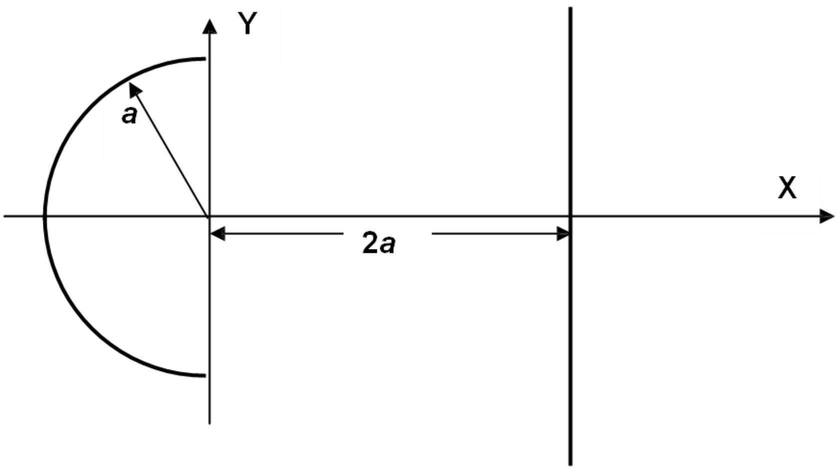


Figure 1.1

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. In this expression q_s is the surface charge density, and ε_0 is the permittivity of free space. **(7)**

b. Figure 2.1 shows a parallel plate capacitor charged to a potential difference V. If the separation of the plates is increased from $d = d_1$ to $d = d_2$, derive an expression for the change in the charge on the capacitor.

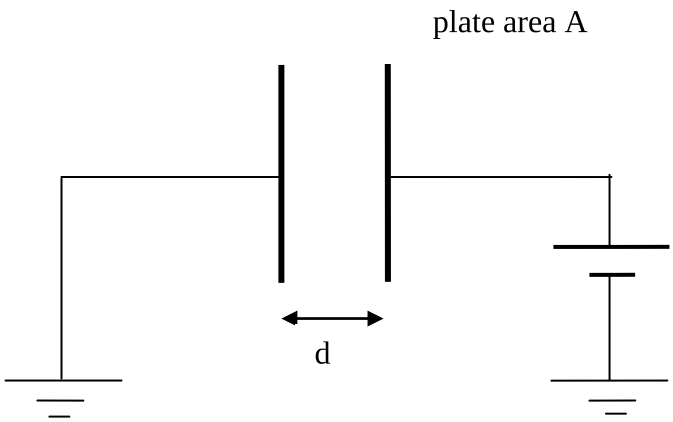


Figure 2.1

(7)

c. If the plates have an area of $8\times10^{-3}\ m^2$ and V=5 V, and the separation changes from 1mm to 1.2mm in 0.3 seconds, what is the magnitude of the current that flows? **(6)**

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

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

Where q_l is the line charge density, r is the distance from the wire, and ε_0 is the permittivity of free space. State any assumptions which you make. **(6)**

b. Figure 3.1 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.

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

i. (7,3,0) m

ii. (0,1,0) m

iii. (2,2,0) m **(6)**

c. By integrating the expression for total electric field along a suitable path, find the potential difference between the two wires.

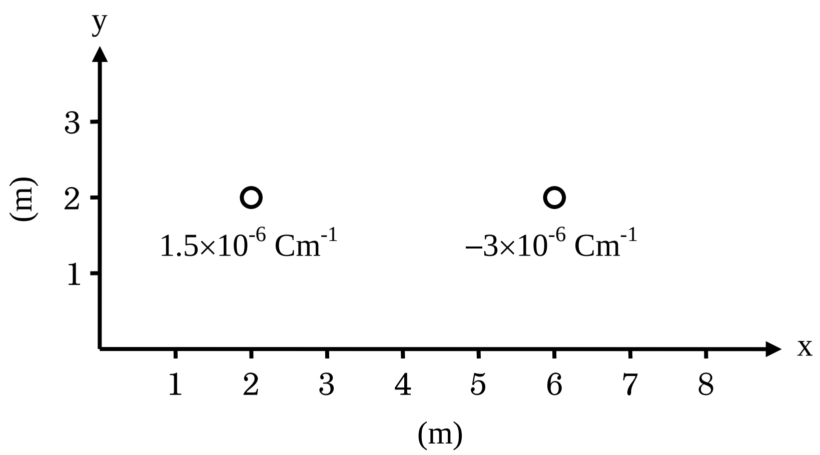


Figure 3.1

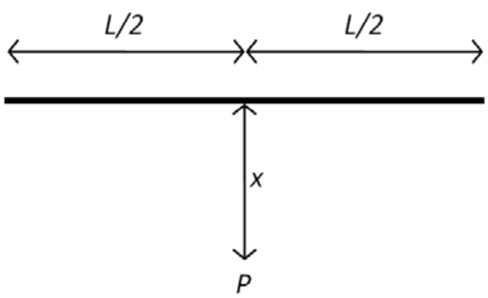
(8)

4. **a.** The following equation gives the magnetic flux density at a point P which is a perpendicular distance x from the centre of a thin straight conductor (as shown in Figure 4.1). The conductor has a length L and carries a current I.

$$B = \frac{\mu_0 I}{2\pi x}\left[\frac{1}{1+(2x/L)^2}\right]^{1/2}$$

Use this expression to deduce an expression for the B field at the centre of a square circuit of side L carrying a current I. **(6)**

b. Figure 4.2 shows part of a circuit in the form of a regular plane polygon of n sides carrying a current I. The distance from the centre of the polygon to the vertices is a. Deduce an expression for the B field at the centre of the polygon. Use this result to find an expression for the B field at the centre of a circular loop.



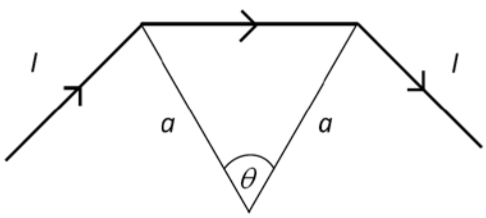


Figure 4.2

Figure 4.1

(6)

c. The circuit shown in Figure 4.3 consists of a square of side $3a$ carrying a current I_s and a circular loop of radius b carrying a current I_c. The directions of the currents are defined in the diagram. Derive an expression for the magnetic field at the common centre of the two loops. If $b = a\sqrt{2}$ and I_c = 4.5, determine the value of I_s required to produce zero magnetic field at the common centre of the two loops. **(8)**

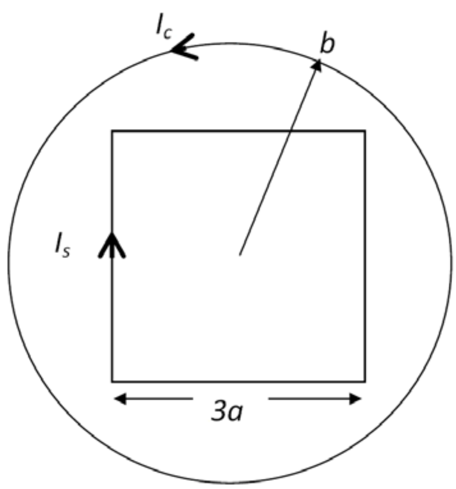


Figure 4.3

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