Data Provided: Formula Sheet

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2011-12 (2.0 hours)

EEE220 Electric and Magnetic Fields

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.** Using Gauss' law, show that the electric field resulting from an infinite plane sheet carrying a charge q_s per unit area has a magnitude

$$E = \frac{q_s}{2\varepsilon_0} \text{ V/m, and is directed away from the sheet.}$$

(5)

b.

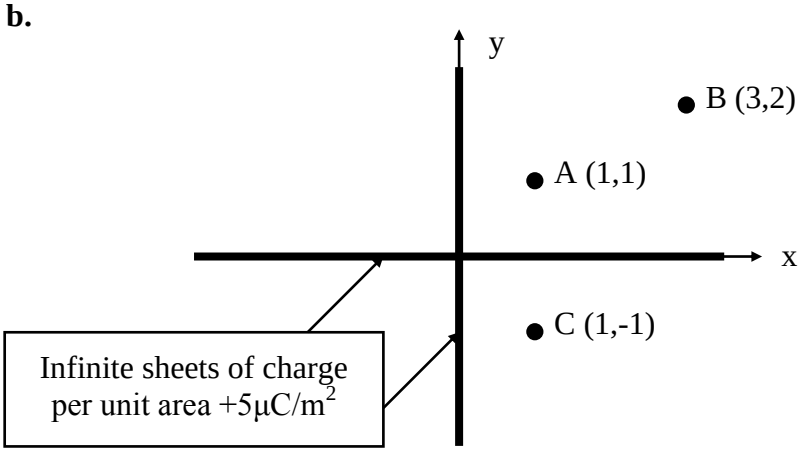

Figure 1

Two such infinite plane sheets with $q_s = 5\mu C/m^2$ are placed perpendicular to each other in the planes x = 0 and y = 0, as shown in Figure 1. Calculate the x- and y-components of the electric fields at the points A, B, and C. **(6)**

c. Redraw the above diagram, sketching in electric field lines and surfaces of equi-potential. **(3)**

d. Calculate the potential difference between points A and B. **(6)**

2. a.

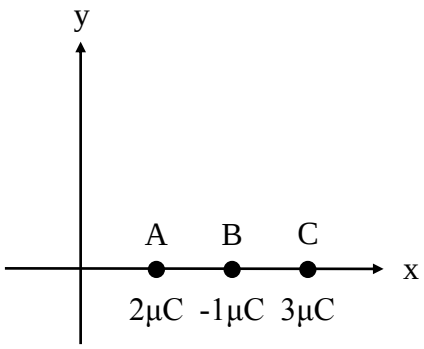

Figure 2a

i. Three point charges are placed at coordinates (1,0,0), (2,0,0), and (3,0,0) as shown in Figure 2a, where the unit of length is 1m. Calculate the force exerted on charge B due to charges A and C. **(5)**

ii. Rearrange the charges (by swapping their positions) to produce the largest magnitude of electric field at the origin. What is the magnitude and direction of this field? **(5)**

b.

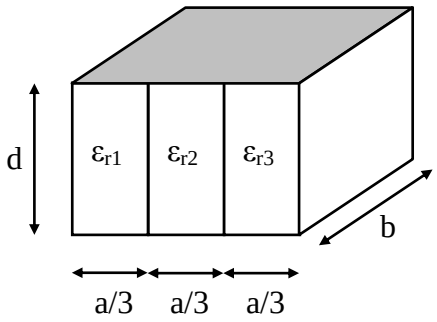

Figure 2b

i. A parallel plate capacitor consists of two rectangular plates of area $a \times b$ separated by a distance d and contains three materials with different dielectric constants, ε_{r1}, ε_{r2}, ε_{r3}, as shown in the figure 2b. Ignoring fringing fields, derive an expression for the total capacitance of this arrangement. **(6)**

ii. If the capacitor is charged to 12V, calculate the energy stored in the capacitor when $a = 0.01\text{m}$, $b = 0.005\text{m}$, $d = 0.002\text{m}$, $\varepsilon_{r1} = 4$, $\varepsilon_{r2} = 5.5$, $\varepsilon_{r3} = 3$. **(4)**

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 wire, current carrying loop of length L and width a which is placed in a magnetic field B.

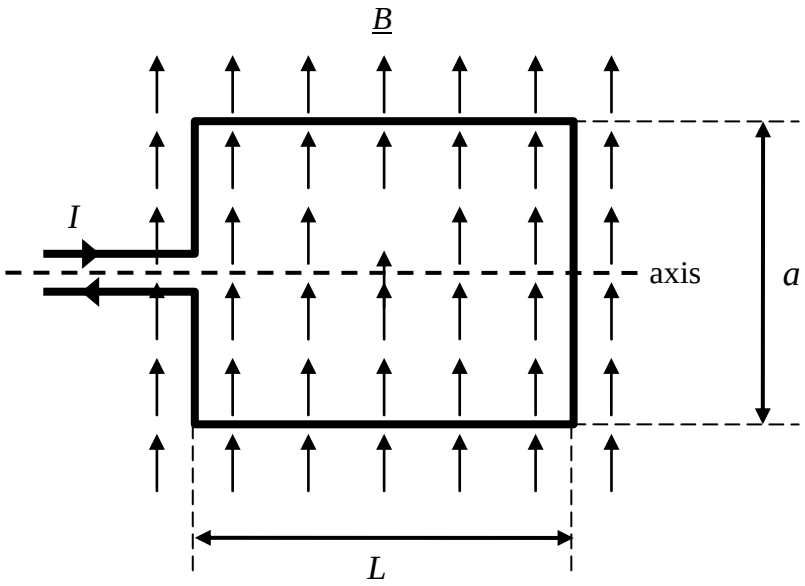

Figure 3

i. Assuming $a = 2\text{ cm}$, $L = 5\text{ cm}$, $B = 0.5\text{ T}$, and $I = 100\text{ mA}$, 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 rotation angle the loop about the axis. When $\theta = 0$ the plane of the loop is parallel with the field, as shown in the Figure 3. 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.

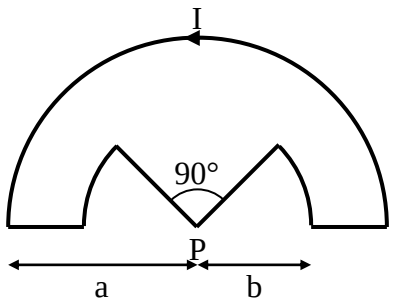

Figure 4a

Figure 4a shows a loop circuit consisting of circular arcs and straight radial lines. The arcs have a common centre, P and radii *a* and *b*. The circuit carries a current I in the direction shown. Use the Biot-Savart rule to find an expression for the B-field at the point P. **(10)**

b.

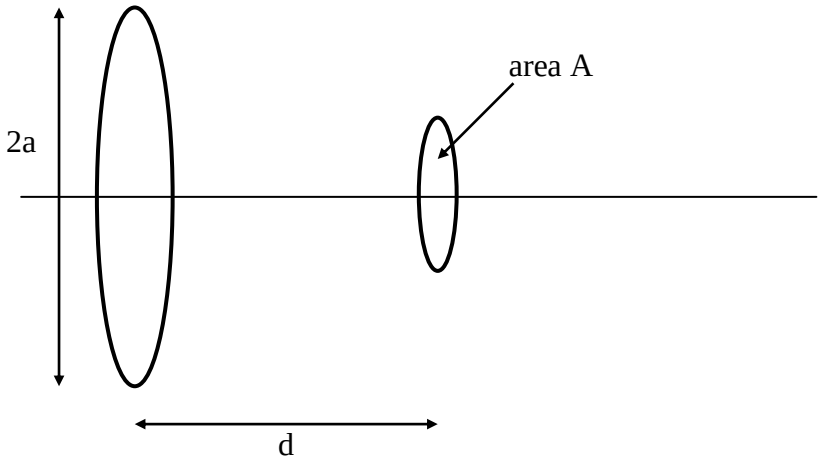

Figure 4b

Figure 4b shows two circular loops of wire positioned a distance *d* apart. The loop on the left has N turns of radius *a*. The smaller loop on the right has only one turn of area A. Assuming the loops are parallel and that $A << d^2$, deduce an expression for the mutual inductance between the two loops. Evaluate this inductance for a = *0.2m, N = 150, d = 0.1m* and $A = 10^{-4}m^2$**.** **(10)**

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