Electricity and Magnetism study handout 3

Covering sections 4.3 - 5.2

Revisits learning outcomes 1 - 3, 5, 6, 8 - 11, 14, 15

Covers learning outcomes 16 - 19

Non-assessed questions

1. Can a normal contact force ever be conservative?

2. Which of the discussions developed in sections 4 and 5 could apply to masses in gravitational fields? Which discussions couldn't? Is there such a thing as gravitational capacitance and if so how would it work?

3. Why is the potential inside a conductor in equilibrium always zero? What do the equipotential lines look inside?

4. What are the equipotential lines for (a) an infinite line of charge? (b) an infinite sheet of charge?

5. Calculate the field strength due to an electric dipole along the axis and perpendicular bisector using the potential method instead of forces.

6 Why does the capacitance of a coaxial cable become large as the inner radius becomes close to the outer radius?

7. A capacitor of $4\ \mu\text{F}$ is charged to $20\ \text{V}$ and then placed in series with another capacitor of $6\ \mu\text{F}$. Describe what happens and find the final charges on the plates and potential differences across each capacitor.

8. By considering the PD across the plates and the current through the circuit, when a battery is connect across them, find the equivalent capacitance of (a) N capacitors in series (b) N capacitors in parallel.

9. A potential difference of magnitude V_0 is placed across a resistor R is series with a capacitor C. Find the following as a function of time: (a) the PD across the plates of the capacitor, (b) the charge on the plates of the capacitor, (c) the current flowing through the circuit.

10. Find an expression for the capacitance per unit length of two parallel, infinitely long straight wires of radius a and separation d for the case when $d \gg a$.

E&M long question 1

This is an assessed question where marks are awarded for showing all working and for providing words of explanation.

This question concerns two point charges of values $+3\ C$ and $-1\ C$. The two charges are fixed in position with a separation of exactly 1 metre. Consider the positive charge to be placed at the origin and the negative charge to be placed at $(x = 1\ \mathrm{m}, y = 0, z = 0)$ with the location given in Cartesian coordinates.

Surd format and multiples of π and ϵ_0 are acceptable forms for the final answers. SI units must still be included.

Mark breakdowns have deliberately been omitted from this question sheet.

1. Find the following**:**

(a) the mutual force of attraction between the charges

(b) the binding energy of the two charges

(c) the electrostatic potential energy shared between the two charges

(d) the single position in Cartesian coordinates where the electric field strength due to the two charges is exactly zero

(e) the work required to bring an electron in from a large distance away from the charges to a final position midway between them if it is (I) brought in straight along the perpendicular bisector between the charge e.g. along the line $x = \frac{1}{2}\ m$ (II) brought in along following a spiral shape of decreasing distance from the charges until it reaches the midpoint.

2. Show that the equipotential surface for the two charges where the potential is exactly zero is a sphere of radius $\frac{3}{8}\ m$ centred at $(x = \frac{9}{8}\ m, y = 0, z = 0)$. What is the electrostatic flux through this sphere?

   (It may assist to recognise that the equation for a circle in the xy plane in Cartesian coordinates is given by $(x - x_0)^2 + (y - y_0)^2 = r^2$ where r is the radius of the circle.)

3. Sketch a $2D$ representation in the xy plane of the electric field lines and equipotential lines due to the two charges. Both sets of lines should appear on the same diagram.

Electromagnetism discussion problem 3, 19th - 23th February, explanation of certain concepts related to electromagnetism

Overview

The discussion problem focuses on clarity of expression in written and verbal explanations in physics. Most of the questions pertain to material from the first half of the first year electromagnetism course. They are all the sort of question that could form part of the first year exam, or perhaps part of a comprehensive paper question in the third year.

In my (VT's) experience, these are the sort of questions that are generally answered relatively poorly when an individual attempts them in an exam (and in fact are often left blank) but are answered well when given in a group exercise in a tutorial when the group has to provide a presentation to give the answer. How the tutorial runs is up to the tutor on the day though.

While I will post answers to these questions on Blackboard after the tutorial week as normal, bear in mind that although there is a certain amount of basic physics that needs to be put across in the explanation there is no right or wrong style of answering the question.

(i) Explain why a bird landing on an overhead electricity wire does not receive an electric shock

(ii) Explain why dielectric materials are usually placed between the plates of capacitors. Go on to explain what the physical characteristics of optimal dielectric would be.

(iii) Is it possible to make a conservative force field with a frictional force?

(iv) If we refer to the direction of a current as being in the direction of the flow of a positive charge (or opposite to the direction of flow of a negative charge) why do we also say that current is a scalar quantity?

(v) What can Gauss's law be useful for in (a) its differential form and (b) its integral form?