Question 1 [10 marks]

Two capacitors, $C_1 = C$ and $C_2 = 3C$, are each charged to a voltage V by an external power supply. Once fully charged the power supply is disconnected from each capacitor.

(a) What is the resultant energy stored on the two capacitors when they are fully charged? [2 marks]

Now the two capacitors are connected together, with positive plate to negative plate and negative plate to positive plate. Find, once equilibrium has been reached:

(b) The charge on each capacitor. [2 marks]

(c) The potential difference across each capacitor. [2 marks]

(d) The total energy stored on these capacitors now [2 marks]

(e) Account for the differences in your answers to (a) and (d). [2 marks]

Question 2 [10 marks]

Charged particles of mass 238u and charge -2e are to be used in a mass spectrometer. These particles are first accelerated through a potential difference of magnitude 105kV.

(a) Assuming the particles are initially at rest, what is the approximate speed of these particles after passing through this potential difference? [2 marks]

These particles then pass into a region of magnetic field of strength *B* = 520mT, directed as shown in Figure Q2.

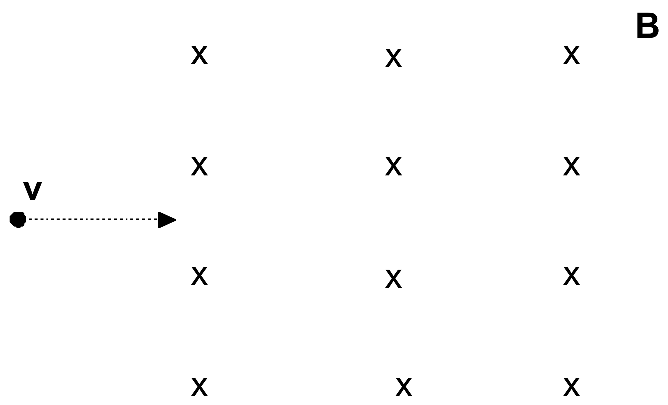

Figure Q2

(b) Determine the magnitude and direction of the magnetic force on these charged particles at the instant they enter this region of magnetic field. [2 marks]

(c) The particles follow a circular path in this region. Calculate the radius of the circular path. [3 marks]

Instead, suppose this region was to form part of a velocity selector.

(d) Determine the magnitude and direction of an externally applied electric field such that there would be no net force on these particles. [3 marks]

Question 3 [10 marks]

A light ray of wavelength λ = 557nm, initially in air, strikes an 78° prism at P, as shown in Figure Q3. This ray is refracted there at P and at Q to such an extent that it just grazes the right-hand prism surface at Q. The refractive index of the glass is n = 1.58.

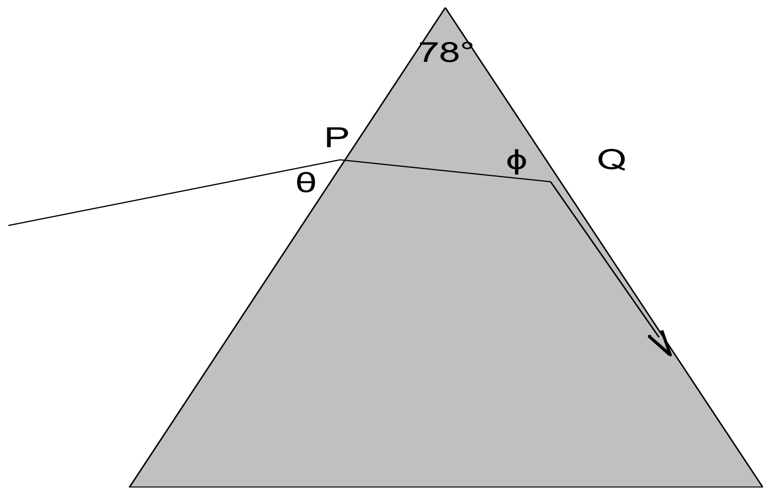

Figure Q3

(a) Determine the value of the angle ϕ at Q. [3 marks]

(b) Determine the grazing angle of incidence to the prism at P, θ. [3 marks]

(c) Show, by ray diagrams, what happens if the grazing angle of incidence at P is slightly greater and slightly less than θ. [2 marks]

The incident light at P is unpolarised.

(d) Describe the polarisation state of the light after Q, giving reasons for your answer. [2 marks]

Question 4 [10 marks]

An oil drop (n = 1.20) floats on a water (n = 1.33) surface and is observed from above by reflected light., as shown in Figure Q4.

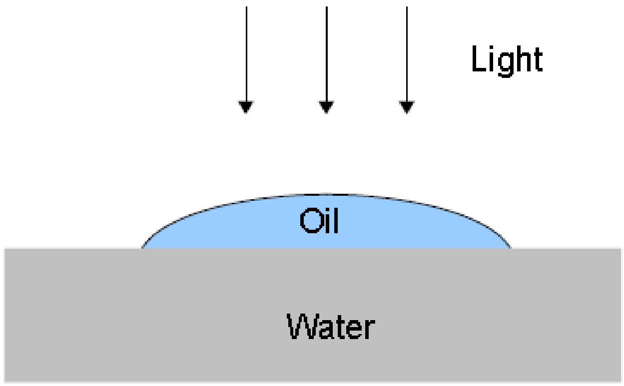

Figure Q4

(a) Will the outer (thinnest) regions of the drop correspond to a bright or dark region? Explain [3 marks]

(b) How thick is the oil film where one observes the third blue region (wavelength 350nm), counting from the outside of the drop? [5 marks]

(c) Why do the colours gradually disappear as the oil thickness becomes larger? [2 marks]

Question 5 [10 marks]

Satellites and spacecraft in orbit about the Earth can become charged due, in part, to the loss of electrons caused by the photoelectric effect induced by sunlight on the space vehicle's outer surface. Suppose that a satellite is coated with platinum, whose work function is ϕ = 5.32eV.

(a) Find the smallest frequency photon that can eject a photoelectron from platinum. [3 marks]

(b) In order to minimise this effect on a satellite, is it better to choose a metal with a larger or smaller work function? Explain your answer. [2 marks]

(c) Would this induced charge create an Electric field inside the satellite? Why/why not? [2 marks]

Suppose the intensity of radiation emitted by the Sun arriving at the spacecraft with a frequency equal to that which you found in (a) is 1.38 $\mathrm{mW/m^2}$.

(d) How many photons per second, per $\mathrm{m^2}$, will be striking the surface of the spacecraft at this frequency? [3 marks]

Question 6 [10 marks]

Bohr's model of the Hydrogen atom was very important in the early development of Quantum Theory.

(a) Clearly state Bohr's postulates for the Hydrogen atom. [3 marks]

(b) Use Bohr's theory to show that the energy of the *n*th orbital is given by

$$E_n = -\frac{m_e e^4}{8\varepsilon_o^2 h^2}\frac{1}{n^2}$$

where all symbols have their usual meanings. [5 marks]

(c) Explain one important success of Bohr's model. [2 marks]