Mass Spectrometer etc

1. An electron is fired at 5% of the speed of light into a magnetic field of flux density 10T (path is perpendicular to field).
    a. Calculate the force on the electron from the magnetic field.

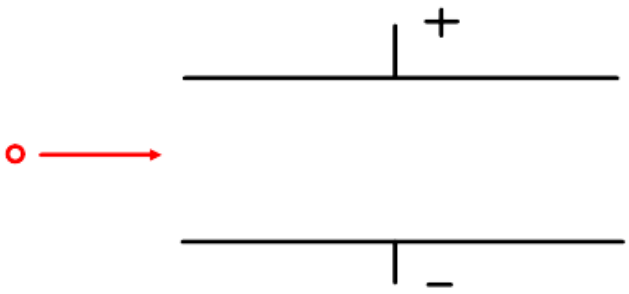
    b. Calculate the radius of the electron's orbit.

    c. Calculate the time period for one complete orbit of the electron.

    d. Calculate the circumference of one orbit.

    e. Calculate the work done on the electron by the field after one orbit.

2. Mass spectrometers contain **velocity selectors** which reject ions that are moving at the wrong speed. They consist of a magnetic field and an electric field which exert opposing forces on a charged particle passing through.



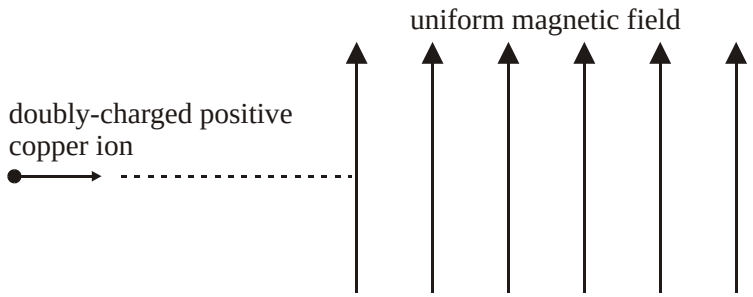
a. The diagram above shows a charged particle entering a velocity selector. The magnetic field has not been labelled – add to the diagram so that the direction of the magnetic field is clear.

A singly charged positive ion of carbon-12 enters the selector with 5keV of energy and emerges undeflected. The mass of the ion is 2.0×10^{-26} kg.

b. Calculate the speed of the ion.

c. The magnetic flux density is 2T. The plates that produce the electric field are separated by 15mm. Calculate the voltage across the plates that results in the velocity selection calculated in part b.

3. (a)



The diagram above shows a doubly-charged positive ion of the copper isotope $^{63}_{29}\mathrm{Cu}$ that is projected into a vertical magnetic field of flux density 0.28 T, with the field directed upwards. The ion enters the field at a speed of 7.8×10^5 m s^{-1}.

(i) State the initial direction of the magnetic force that acts on the ion.

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(ii) Describe the subsequent path of the ion as fully as you can.
Your answer should include both a qualitative description and a calculation.

mass of $^{63}_{29}\mathrm{Cu}$ ion = 1.05×10^{-25} kg

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(5)

(b) State the effect on the path in part (a) if the following changes are made separately.

(i) The strength of the magnetic field is doubled.

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(ii) A singly-charged positive $^{63}_{29}\mathrm{Cu}$ ion replaces the original one.

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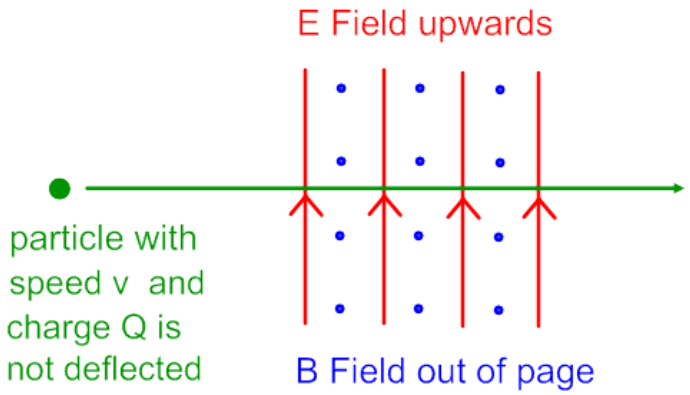
(3)
(Total 8 marks)

4. The velocity selector has an electric and magnetic field such that only particles moving at a particular velocity are not deflected.



Find an expression for this velocity, v, in terms of the electric field strength E and magnetic field strength B. Show that v does not depend on the charge, Q, of the particle.

If the E field is produced by two plates which are 1cm apart, what voltage should be applied to them to achieve a field strength of $1000 NC^{-1}$?

5. Particles with charge Q, mass m and speed v are fired into a uniform magnetic field B.

They are deflected in a semi-circular path and hit a detector.

Derive an expression for the distance, d, between the point the particle enters the field and where it hits the detector, in terms of the quantities listed above.