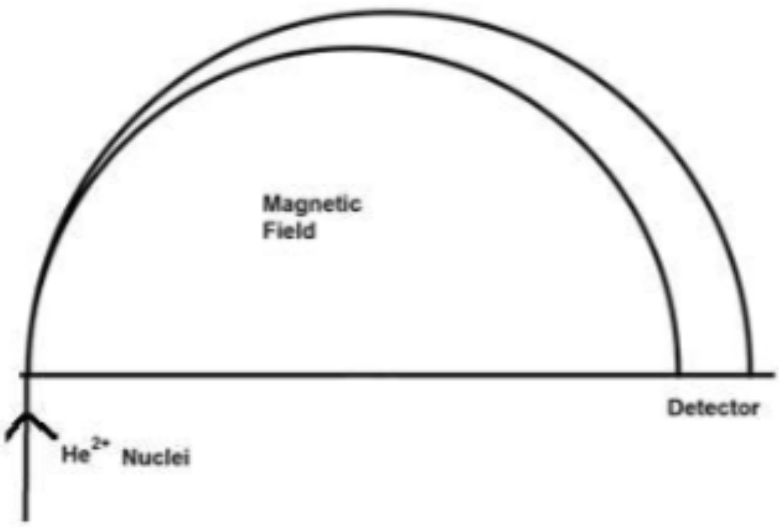
2018 Physics ATAR

Electromagnetism I

Electric fields
Particles in B Fields

Revision package

A mass spectrometer is used to calculate the mass of charged particles. One such machine is being used to measure the proportion of $^{3}_{2}He^{2+}$ and $^{4}_{2}He^{2+}$ nuclei in a beam of particles that have been accelerated to a speed of 5.11 x 10^{6} m s^{-1}. The magnetic field strength is 5.21 x 10^{-1} T.



a) Show the direction of the magnetic field on the diagram. (1 mark)

b) Place a "4" on the path followed by the $^{4}_{2}He^{2+}$ nucleus. (1 mark)

c) Calculate the mass of the $^{4}_{2}He^{2+}$ given that the radius of its path is 2.01 x 10^{-1} m. (3 marks)

d) **Estimate** the radius of the path followed by the $^{3}_{2}He^{2+}$ nucleus. (2 marks)

The volume of a hydrogen atom is 1.99×10^{-31} m^3. Assume the atom is a sphere and the electron travels along its surface.

Volume of a sphere $V = \frac{4}{3}\pi r^3$

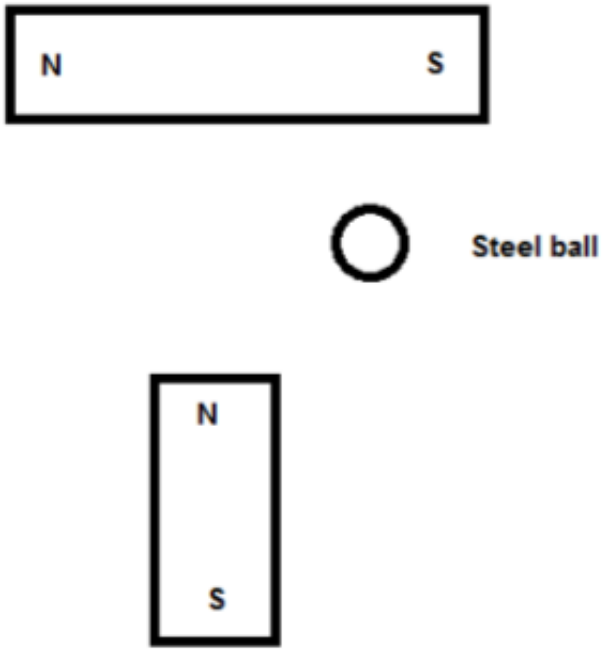
Calculate the force between the proton and the electron:

a) Gravitational. (4 marks)

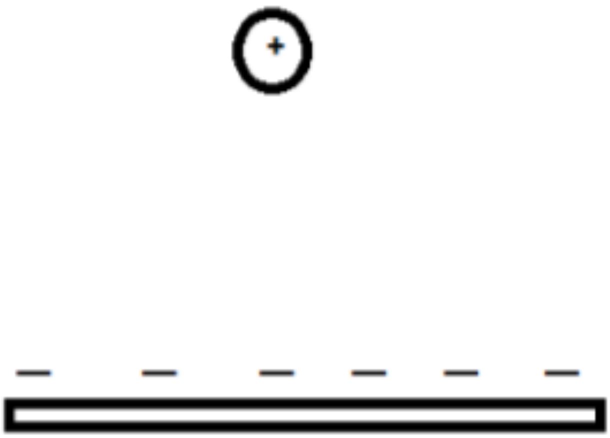
b) Electromagnetic. (2 marks)

c) Net force. (1 mark)

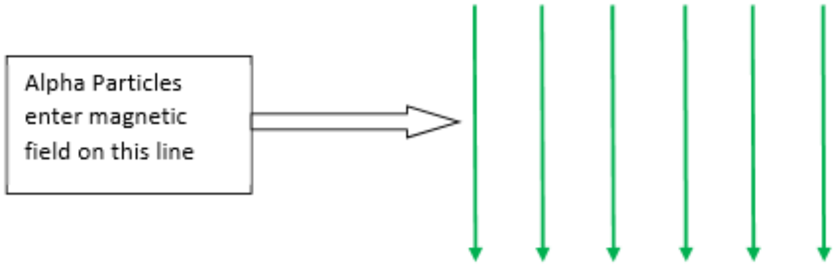
a) On the following diagram, draw the magnetic fields. Draw at least ten lines.
(4 marks)



b) Draw the electric fields of the following diagram. Draw at least ten lines.
(2 marks)



A source of radiation emits alpha particles (He^{2+}) which are fed into a uniform magnetic field as indicated in the diagram below. They enter with a speed of 2.80×10^{7} m s^{-1} and experience a magnetic force of 6.54×10^{-12} N.



a) Calculate the magnetic flux density of the magnetic field. (3 marks)

b) State the direction of force on the alpha particles as they enter the field. Circle a response. (1 mark)

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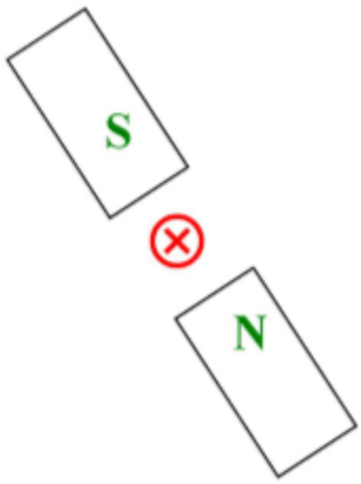
a) The diagram shows the cross section of a single conducting wire placed between 2 magnetic poles.

i. Sketch at least six field lines to show the magnetic field between the magnetic poles, including induced magnetic field. (2 marks)

ii. Place an arrow on the diagram to indicate the direction of magnetic force experienced by the wire and label it 'force'. (1 mark)

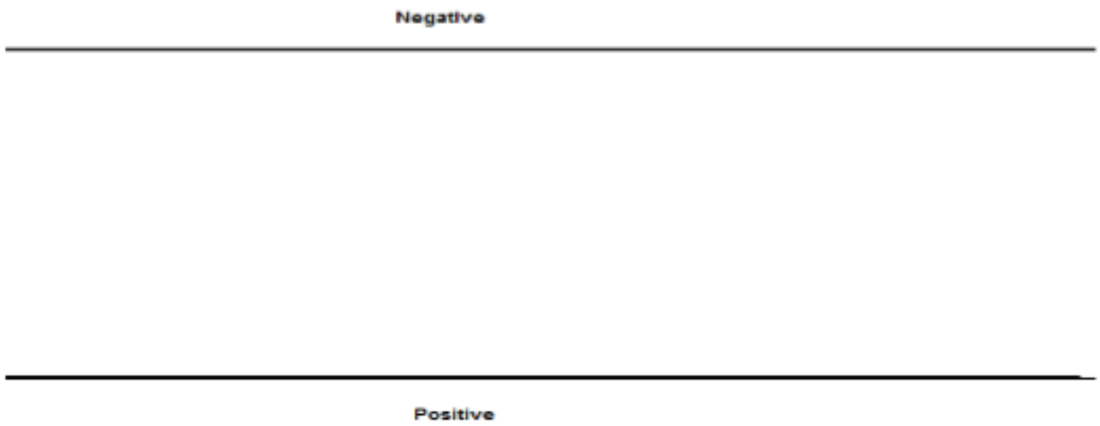


b) The length of wire in the magnetic field is 8.00 cm. The wire is part of a series loop of resistance 4.00 Ω and has a potential difference of 12.0 V across it. It experiences a force of 18.0 mN.

Calculate the magnetic flux density in the region around the wire. (3 marks)

Two parallel charged plates are set up as in the diagram below.

a) Draw the electric field between the plates. (3 marks)



b) A proton is fired, with a velocity of 8.67×10^7 m s^{-1}, into the space between the 0.500 m long plates as shown below. The plates are 20.0 mm apart and the potential difference between the plates is 3.00×10^3 V.

The experiment is placed vertically to the ground and the proton is effected by gravity.

Calculate the total force acting on the proton as it travels between the plates.

(4 marks)

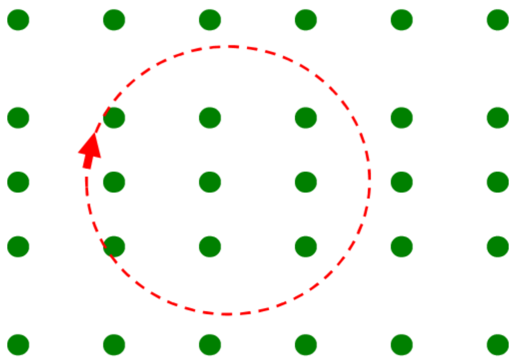
c) Calculate the velocity at which the proton leaves the gap between the plates.

(5 marks)

d) Calculate the vertical displacement of the proton whilst it is between the plates.

(2 marks)

A particle of charge q and mass m has gone into clockwise circular motion in a uniform magnetic field B within a vacuum chamber. It is moving at speed ***v*** with a radius ***r***. The situation is shown in the diagram below.



a) State whether the particle has a positive or negative charge. Answer: ____________________

(1 mark)

b) Show by clear algebraic steps and with reference to equations on the data sheet, that the following relationship for the period of circular motion is true.

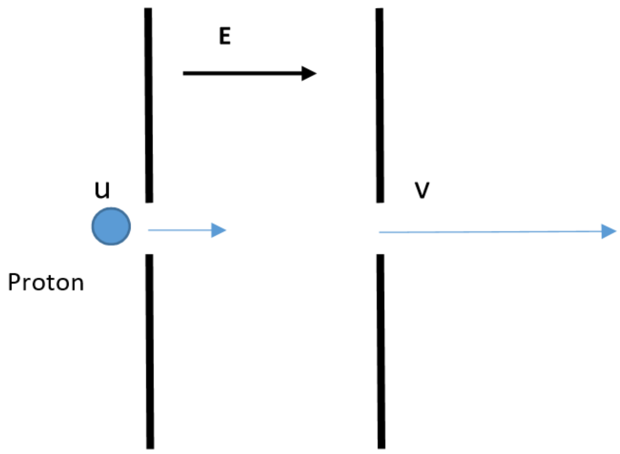
(3 marks)

$$T = \frac{2\pi m}{qB}$$

c) The particle has a mass of 4.14×10^{-12} kg and a charge of 5.80 nC. The magnetic field has a flux density of 95.0 mT. Calculate how many times the particle goes around in a circle in a time of 4.00 seconds.

(3 marks)

d) A proton moving with an initial velocity ***u***, has an initial kinetic energy $KE_{initial}$. It enters a uniform electric field with field strength ***E***, as shown in the diagram below. The proton's final kinetic energy KE_{final} is equal to $4KE_{initial}$.



The electric field is now tripled (it becomes ***3E***). If another proton, having an initial kinetic energy $KE_{initial}$ enters the field, determine this proton's final kinetic energy in terms of $KE_{initial}$. You should ignore the effects of gravity.

(4 marks)

A wire is conducting a DC current of 1.50 A. At point X a magnetic flux density of 3.86 x 10-6 T is detected. Calculate the distance between the current carrying wire and point X. You can ignore the effects of the Earth's magnetic field in this question.

Two point charges are shown in the diagram below. Their relative charges are -2Q and +Q. On the diagram show the relative shape of the net electric field established around and between the point charges. You should draw at least 12 field lines on the diagram.

A proton has been accelerated to 95% of the speed of light in the Large Hadron Collider. Calculate its gain in energy. Assume initial speed is 0.

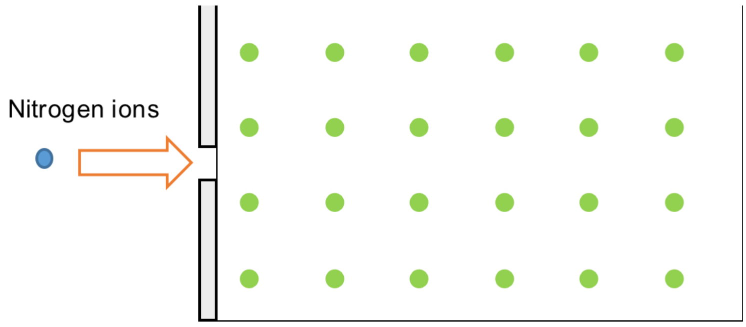
Nitrogen-14 ions (N3-) of mass 2.33 x 10-26 kg and triple negative charge are accelerated from rest in a potential difference established between 2 charged parallel plates. The parallel plates have a potential difference of 5000 V across a gap of 8.00 cm. You can ignore the effects of gravity and air resistance in this question.

a)Calculate the electric field strength between the parallel plates. (2 marks)

b)Calculate the magnitude of the electric force that acts on the Nitrogen ions in this electric field. (2 marks)

c) Calculate the maximum speed reached by the Nitrogen ions as they move between the parallel plates

The nitrogen ions are fed into a uniform magnetic field within a mass spectrometer. The ions enter at a speed of 4.54 x 105 m s-1. The magnetic field has a uniform flux density of 123 mT. The set up and the direction of the magnetic field is shown in the diagram below.

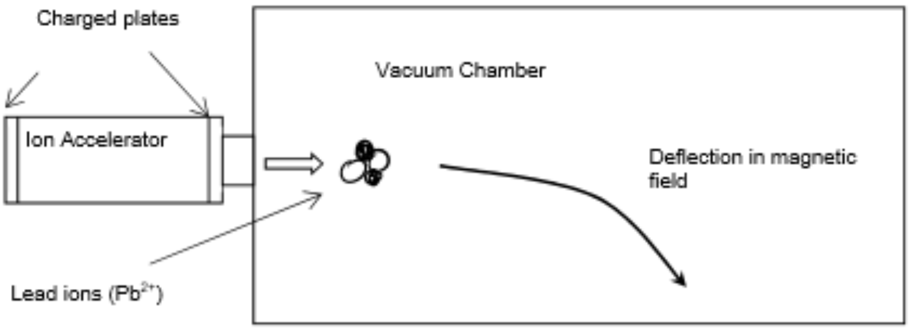


d) Draw an arrow on the diagram to show the general direction that the nitrogen ions will follow.
(1 marks)

e) Calculate the radius of the path taken by the nitrogen ions in the mass spectrometer. (3 marks)

f) Explain what is causing the nitrogen ions to go into circular motion. You must refer to physics principles and equations in the formulae and data booklet.
(3 marks)

Lead ions (Pb^{2+}) of mass 3.44×10^{-25} kg are doubly charged positive ions. They are accelerated through an electric field between charged parallel plates before entering a vacuum chamber where they are deflected by a magnetic field as shown on the diagram.



a) Calculate the potential difference between the charged plates in the Ion Accelerator that will give the lead ions a maximum velocity of 6.40×10^{5} m s^{-1}.

(3)

b) State the direction of the magnetic field within the vacuum chamber that will cause the deflection shown. Circle your response.

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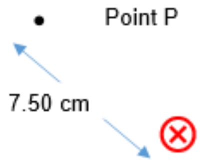
(1)

c) Calculate the magnitude of the magnetic flux density that will deflect the lead ions on a circular path of diameter 24.0 m.

(3)

The diagram shows the cross section of a single conducting wire carrying a current of 5.32 A

a) Determine the magnetic flux density due to the current at point P which is 7.50 cm from the wire.

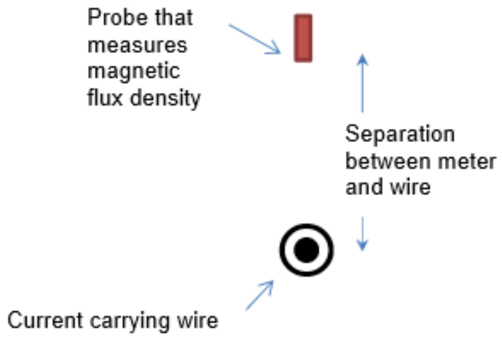


(2)

b) Draw an arrow through point P on the diagram to show the direction of the magnetic field due to the current carrying wire.

(1)

5. Some university students are investigating the circular magnetic field formed around a long straight wire carrying electrical current. They use a probe that measures magnetic flux density at different radii of separation from the wire. The students know that the magnetic flux density decreases with increasing distance from the wire. The students put a 90.0 cm straight length of wire between two clamps such that no objects (other than the probe) are closer than 40 cm to the centre of the wire. A steady current of 2100 A is fed into the wire from an external power supply. The probe that measures magnetic flux density is placed at set distances from the middle of the wire and measurements recorded.



The magnetic flux density B, due to a current I, passing in a wire is given by the expression:

$$B = \frac{\mu_0 I}{2\pi r}$$

Where

μ_0 = the permeability of free space (N A^{-2}), which is a measure of the extent to which the surrounding medium reinforces the magnetic field.

r = radius of separation (m)

The results obtained are as follows:

Radius of separation (m)	**$\frac{1}{r}$ (m^{-1})**	**Magnetic Flux Density (x 10^{-3} T)**
0.065	1	6.70
0.080		6.10
0.100		4.50
0.125		3.50
0.200		2.30
0.500		1.10

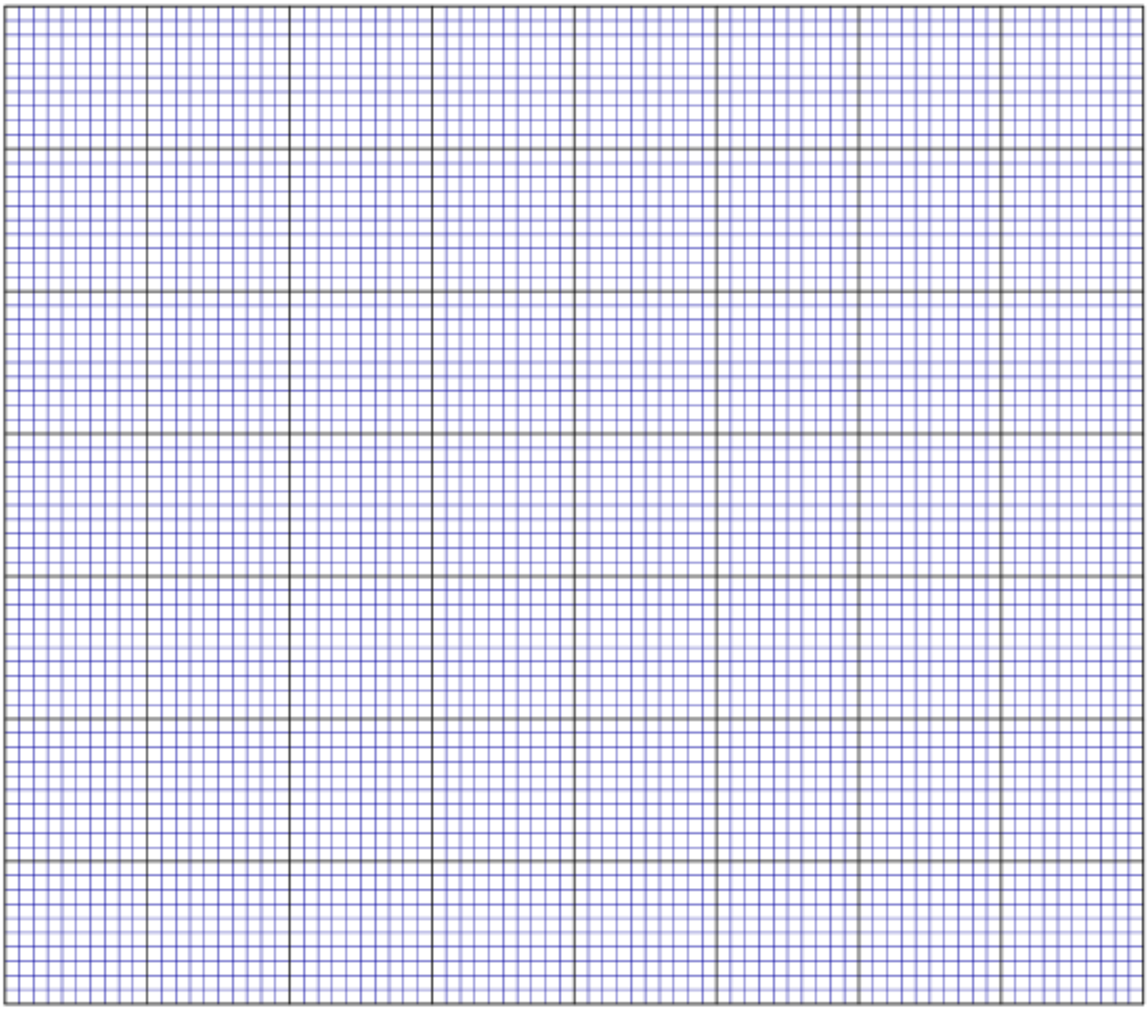
Answer the following questions:

a) Complete the second column of the table $\frac{1}{r}$, so that you can plot a straight line graph.

[1]

b) Plot a graph of Magnetic Flux Density (B) on the vertical axis versus on the horizontal axis. You must include a line of best fit.

[5]



c) Calculate the gradient, including a unit, of your line of best fit from your graph showing all working.

[3]

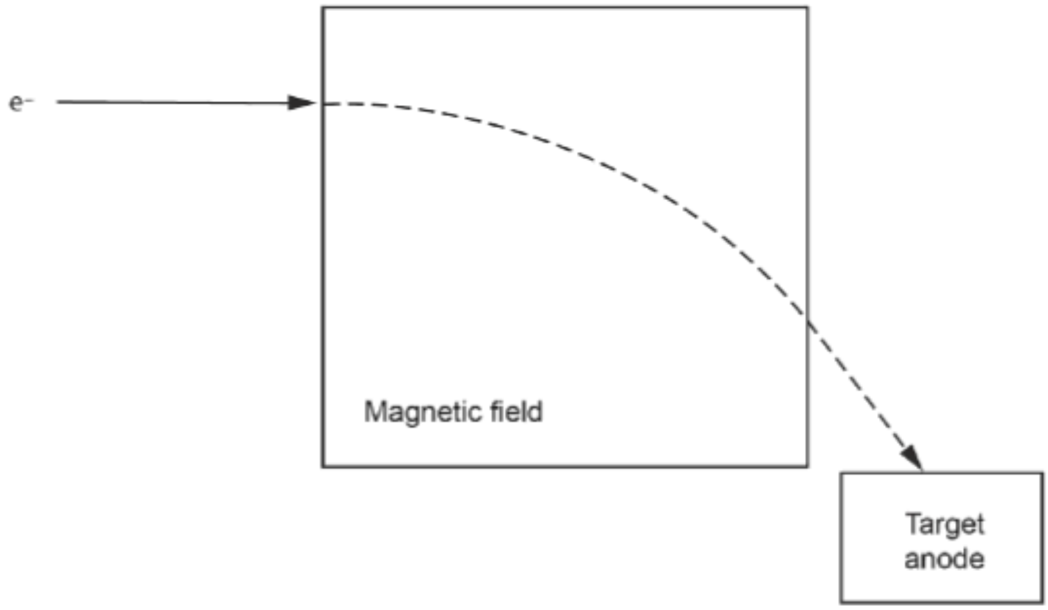
Gradient: ____

d) Determine the value of the permeability of free space, $\boldsymbol{\mu_0}$, from the value of the gradient that you obtained. (If you could not determine the gradient, use the numerical value 4.40 x 10^{-4}).

[3]

$\boldsymbol{\mu_0}$: ____

6. An electron moving at 0.850 c enters a region of space and follows a path that has a constant radius of 0.335 m while in the magnetic field shown on the diagram, before striking a target anode.



a) Draw the magnetic field enclosed in the indicated space.

[1]

b)

i) Derive the formula

[2]

$$B = \frac{mv}{qr}$$

ii) Hence, calculate the magnetic field required to do so.

[2]

Magnetic field:

iii) Describe how each of the changes below affect the charged particle's path in the magnetic field.

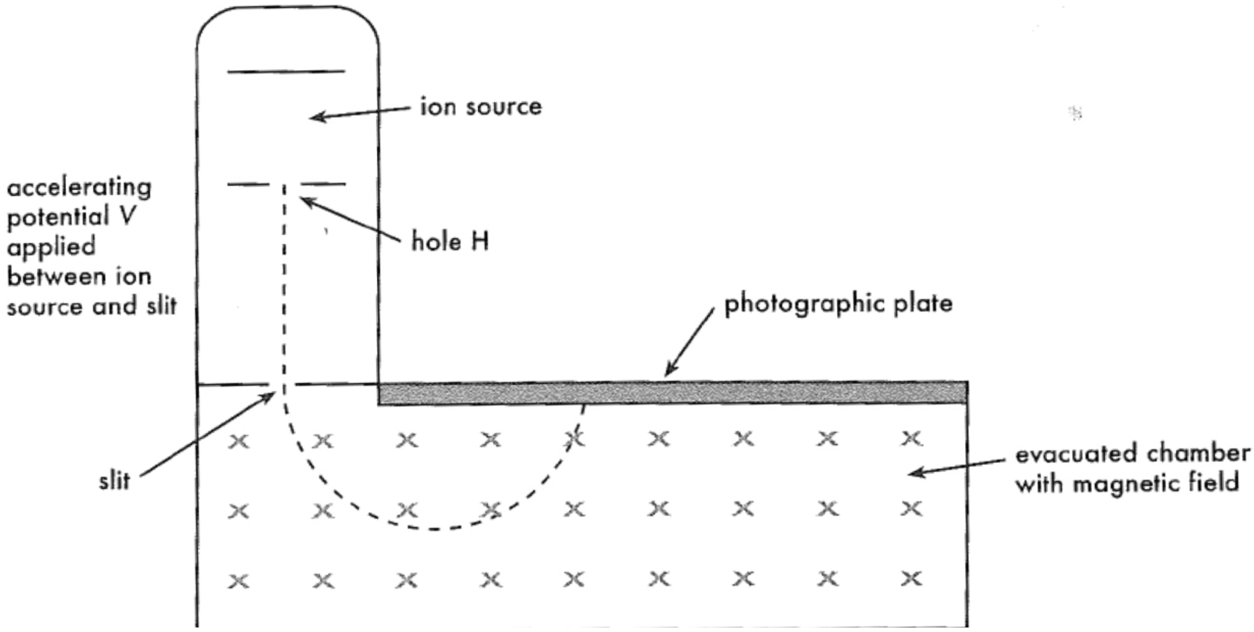
[4]

Property changed	**Effect on radius of the path**
Particle's charge is reversed	
Particle's charge is increased by factor of 2	
Particle's velocity is decreased by factor of 2	
Magnetic field is increased by factor of 3	

7. The Earth's magnet plays a significant role in protecting living things from high energy charged particles. Explain how the magnet works using physics terminologies that you have learnt.

[3]

The simplified diagram below shows a mass spectrometer (used to separate charged particles (ions of differing masses). The ion source produces ions which exit through hole H with negligible velocity. They are then accelerated by an accelerating voltage V and kept moving in a straight line path by a series of electric/magnetic fields. The ions then pass through a slit into the chamber which has a vacuum and a magnetic field.



a)What type of charge is carried by the ions in the diagram above? (1 mark)

b)For a positive charge q and mass m, derive the following formula to show that the value of x is given by:

x2 = 8mV/qB^2 where x = diameter of the path in the magnetic field and V is the accelerating voltage . (4 marks) c)Do a calculation to show that the value of the accelerating voltage to give a proton a velocity of 3.00 x 106 m s-1 at the slit is 4.70 x 104 volts.

(2 marks)

d)Using the same value for the accelerating voltage (V = 4.70 x 104 volts) you calculated in (c) above , and the formula you derived in (b) , calculate the separation distance (shown on photographic plate) due to charge for two negatively charged 17O2- and 18O2- ions that are separately injected into the vacuum chamber containing a magnetic field of 0.229 T. Assume that the velocities of the ions are negligible at hole H and that the masses of 17O2- and 18O2- ions are 2.84 x 10-26 kg and 3.01 x 10-26 kg, respectively.

(5 marks)

e)What simple modification needs to made to the apparatus in order to capture negatively charged ions on the photographic plate?