

1 Rutherford designed an experiment to see what happened when alpha particles were directed at a piece of gold foil. Summarise the observations and state the conclusions Rutherford reached about the structure of gold atoms.

(5)

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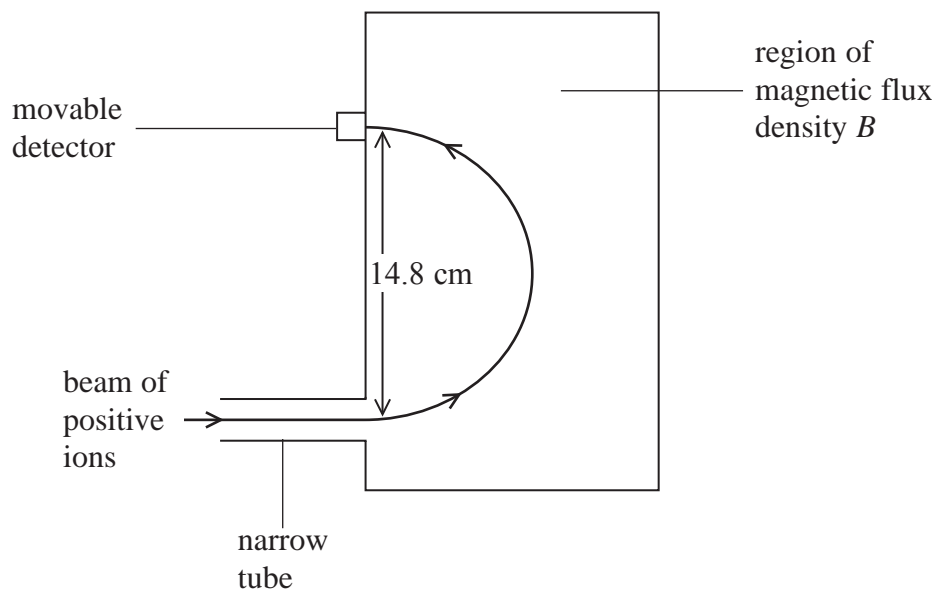
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(Total for Question = 5 marks)

- 2 A mass-spectrometer is an instrument that is used to measure the masses of molecules. Molecules of a gas are ionised and travel through a vacuum in a narrow tube. The ions enter a region of uniform magnetic flux density B where they are deflected in a semicircular path as shown.



(a) State why it is necessary for the molecules to be ionised.

(1)

(b) State the direction of the magnetic field.

(1)

- (c) The ions have a charge of $+e$ and a speed of $1.20 \times 10^5 \text{ m s}^{-1}$. When B has a value of 0.673 T , the ions are detected at a point where the diameter of the arc is 14.8 cm .

Calculate the mass of an ion.

(3)

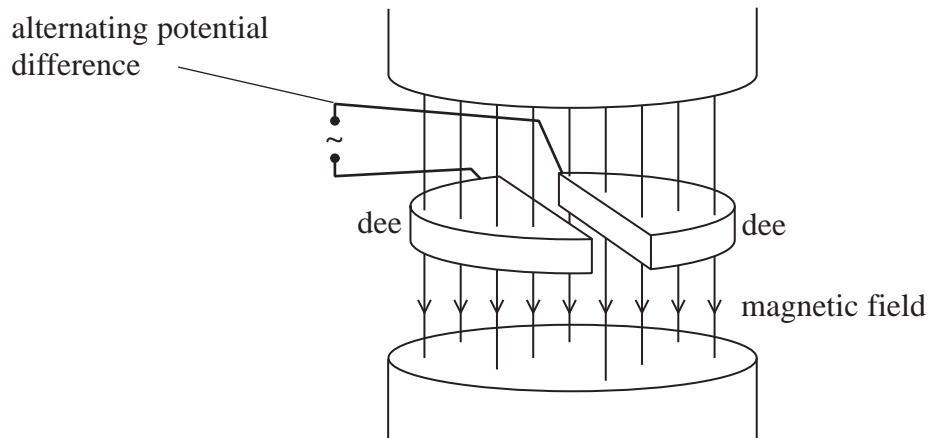
Mass of an ion =

- (d) Ions with a smaller mass but the same charge and speed are also present in the beam.
On the diagram sketch the path of these ions.

(1)

(Total for Question = 6 marks)

*3 The diagram shows the basic structure of a cyclotron.



With reference to the magnetic field and the alternating potential difference explain how the cyclotron produces a beam of high speed particles.

(4)

(Total for Question = 4 marks)

4 Subatomic particles such as pions are produced after collisions between protons that have been accelerated in a cyclotron.

*(a) Explain briefly the role of electric and magnetic fields in the cyclotron.

(5)

(b) The mass of a pion is 2.5×10^{-28} kg.

Calculate the mass of a pion in GeV/c^2 .

(3)

Mass =

GeV/c^2

(c) The table shows the charge of some quarks.

Type of quark	Charge/ e
u	$+2/3$
d	$-1/3$
s	$-1/3$

Explain what is meant by a charge of $+2/3$

(1)

(d) The omega (Ω) minus particle consists of three strange quarks and is produced by the following interaction.



Kaons are mesons and consist of a strange quark and either an up or a down quark.

(i) Complete the table to show a possible quark combination for each kaon.

(3)

Particle	Quark combination
K^-	
K^+	
K^0	

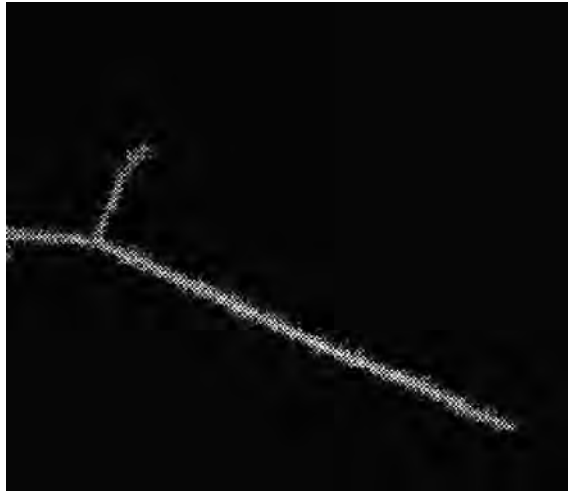
(ii) The total mass of the particles produced in this interaction is greater than the total mass of the two particles that collided.

Explain this increase in mass.

(3)

(Total for Question = 15 marks)

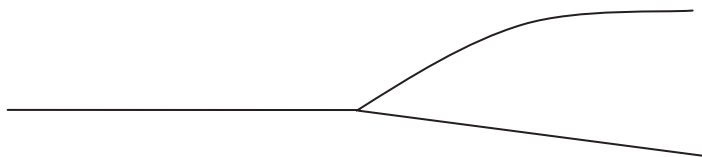
- 5 A low-energy particle collides elastically with a stationary particle of the same mass.
The particle enters from the left of the photograph.



- (a) State what is meant by collides *elastically*. (1)
- (b) Sketch a labelled vector diagram to show how the momentum of the initial moving particle relates to the momenta of the two particles after the collision. (2)
- (c) Use your answers to (a) and (b) to confirm that the angle between the subsequent paths of both particles must be 90° . (2)

- (d) (i) Explain the process by which a proton is given energy in a particle accelerator. (3)

The diagram shows a collision between a high-energy proton (track from the left) and a stationary proton in a particle accelerator experiment.



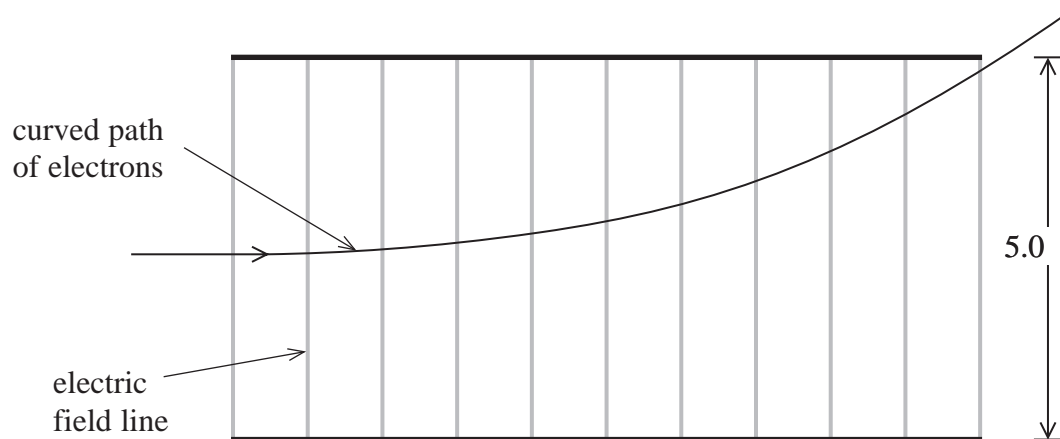
- (ii) Explain why the angle between the two paths is not 90° . (2)

- (e) Deduce the direction of the magnetic field in this particle accelerator experiment. Circle the correct direction from those given below. (1)

left to right across the paper out of the plane of the paper into the plane of the paper

(Total for Question = 11 marks)

- 6 A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.



- (a) Mark on the diagram the direction of the electric field.

(1)

- (b) The conducting plates are 5.0 cm apart and have a potential difference of 160 V across them.

Calculate the force on the electron due to the electric field.

(3)

Force =

- (c) Explain why the path of the electron is curved between the plates and straight when it has left the plates.

(3)

(d) The electron was initially released from a metal by thermionic emission and then accelerated through a potential difference before entering the region of the electric field.

(i) State what is meant by thermionic emission.

(1)

(ii) In order to be able to just leave the plates as shown, the electron must enter the electric field between the plates with a speed of $1.2 \times 10^7 \text{ m s}^{-1}$.

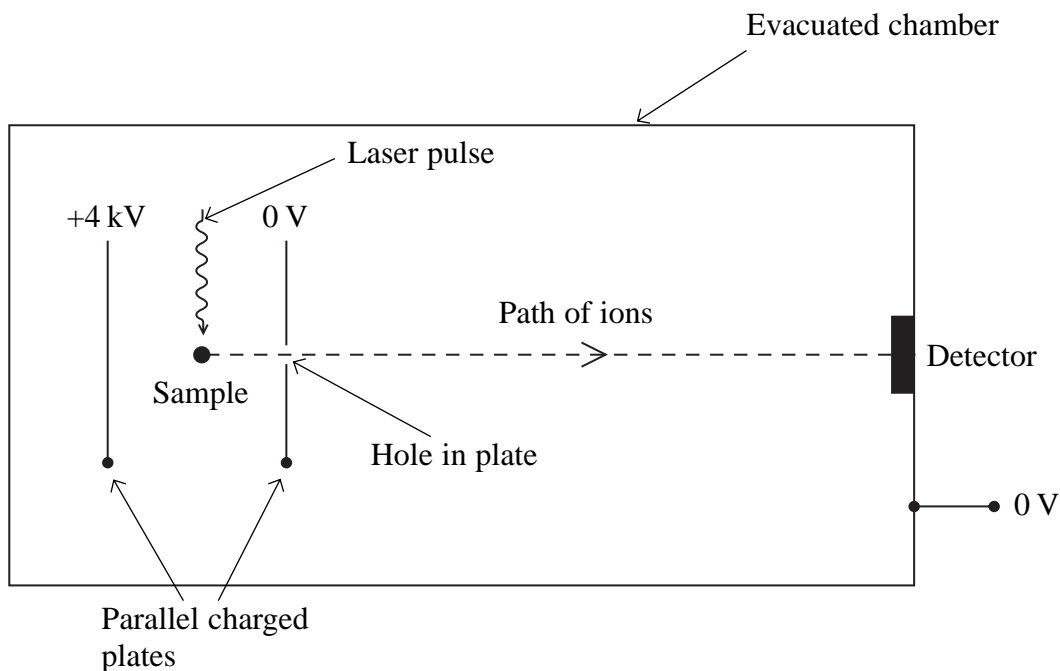
Calculate the potential difference required to accelerate an electron from rest to this speed.

(3)

Potential difference =

(Total for Question = 11 marks)

- 7 Time-of-flight mass spectroscopy uses the arrangement below to measure the mass of molecules. A laser pulse knocks an electron out of a molecule in a sample leaving it as a positively charged ion.



- (a) Add to the diagram to show the electric field lines between the two plates. (3)
- (b) The sample is midway between the charged plates. Show that the speed, v , of an ion as it reaches the hole in the plate is given by

$$v = \sqrt{\frac{6.4 \times 10^{-16} \text{ joule}}{m}}$$

where m is the mass of the molecule in kg.

(3)

- (c) The distance between the hole in the plate and the detector is 1.5 m. The time taken for a molecule to cover this distance is 23 μs .

Calculate the mass of this molecule.

(3)

Mass =

- (d) There is some uncertainty in the time a molecule with a particular mass will take to cover this distance.

Suggest **two** reasons for this.

(2)

1

2

(Total for Question = 11 marks)