Access Tuition

A-Level Physics

Electric Fields

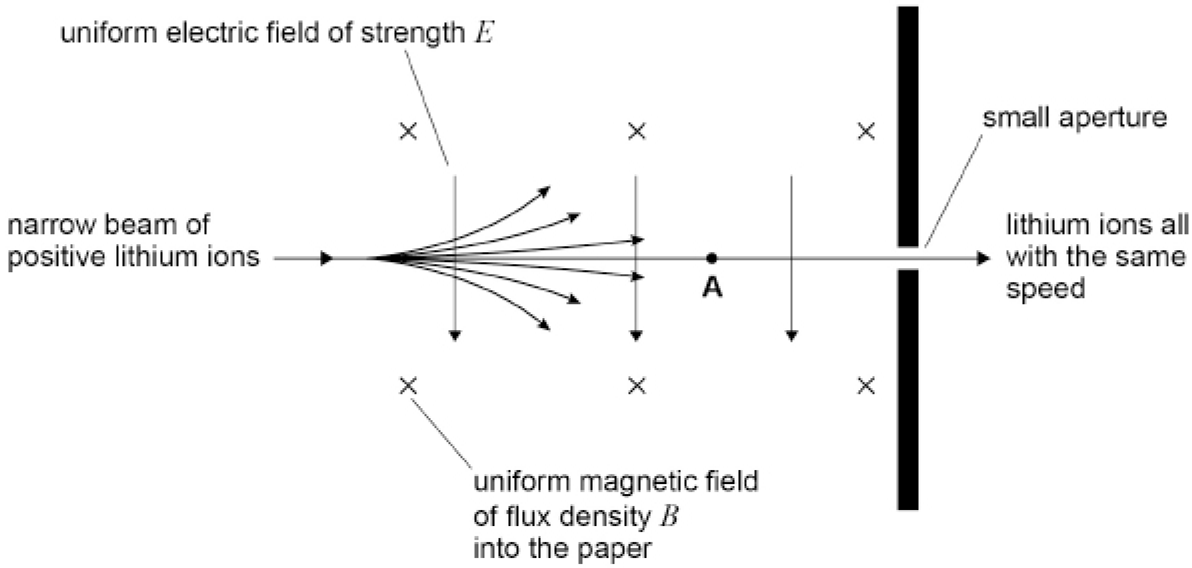
Question Paper

Time available: 84 minutes
Marks available: 60 marks

1. Mass spectrometers are used to measure the masses of ions.

Figure 1 shows one part of a mass spectrometer.

Figure 1



A narrow beam consists of positive lithium ions travelling at different speeds.
The beam enters a region where there is an electric field and a magnetic field.
The directions of the uniform electric field of strength E and the uniform magnetic field of flux density B are shown on **Figure 1**.

Most ions are deflected from their original path.
Lithium ions that travel at one particular speed are not deflected, and pass through the small aperture.

(a) The positive lithium ion **A** in **Figure 1** moves at a speed v.

Draw **two** labelled arrows on **Figure 1** to show the directions of the electric force F_E and the magnetic force F_M acting on **A**.

(1)

(b) Lithium ions travelling at 1.5×10^5 m s^{-1} pass through the small aperture.

Calculate E.

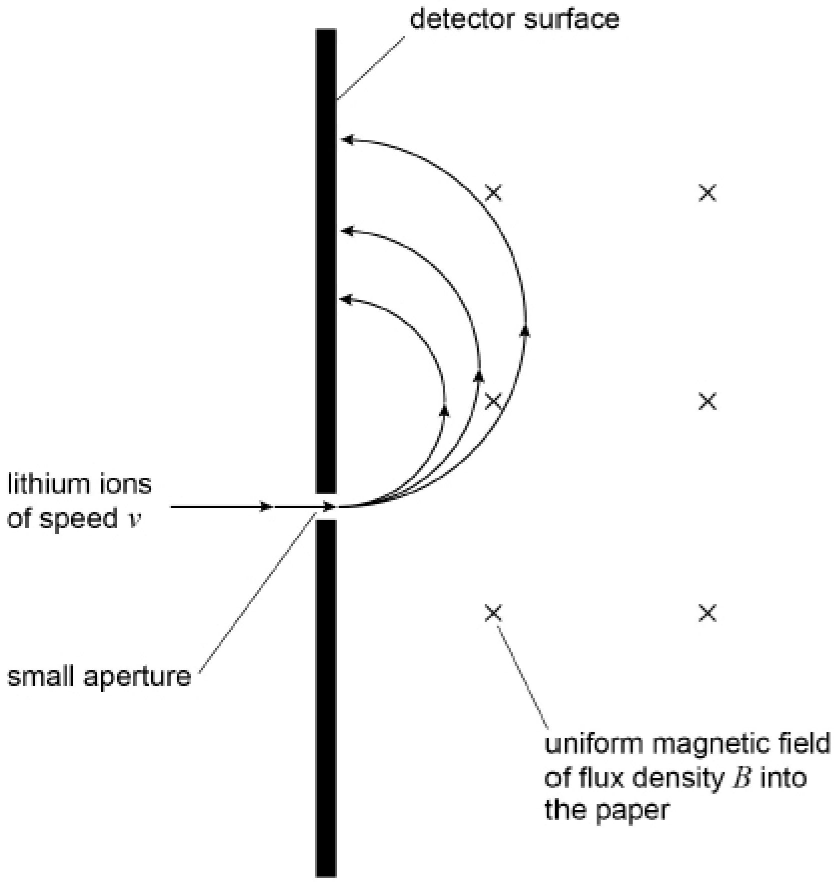
$B = 0.12$ T

E = ________________ V m^{-1}

(2)

(c) Ions that pass through the small aperture enter a second uniform magnetic field of flux density B.
Ions of different mass are separated because they follow different paths as shown in **Figure 2**.

Figure 2



Ions of mass m and charge q travelling at speed v follow a circular path in the uniform magnetic field.

Show that the radius r of the circular path is given by

$$r = \frac{mv}{Bq}$$

(1)

(d) The ions of different mass are deflected and strike the detector surface at different distances from the small aperture as shown in **Figure 2**.

A singly-charged lithium ion ($^{6}_{3}Li^{+}$) passes through the small aperture.

Calculate the distance between the small aperture and the point where this ion strikes the detector surface.

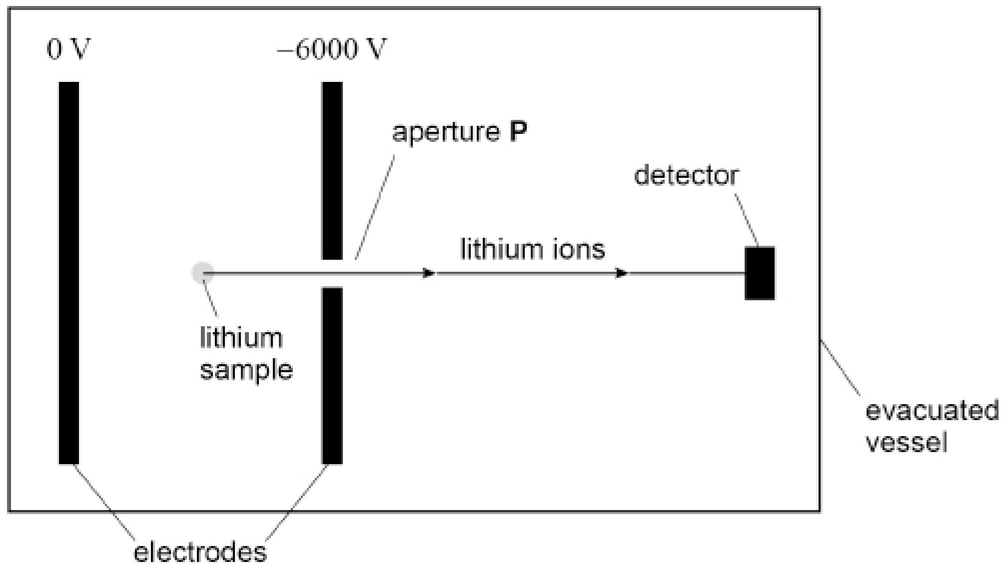
v = 1.5 × 10^{5} m s^{-1}
B = 0.12 T
mass of $^{6}_{3}Li^{+}$ ion = 1.0 × 10^{-26} kg

distance = _______________ m

(2)

(e) **Figure 3** shows a different type of mass spectrometer working with lithium ions.

Figure 3



A stationary $^{7}_{3}\mathrm{Li}^{+}$ ion in the lithium sample is at the mid-point between the parallel electrodes. The $^{7}_{3}\mathrm{Li}^{+}$ ion accelerates towards aperture **P**.

Determine the speed of the ion when it emerges through aperture **P**.

mass of $^{7}_{3}\mathrm{Li}^{+}$ ion = 1.2×10^{-26} kg

speed = ________________ m s^{-1}

(3)

(f) $^{6}_{3}Li^{+}$ and $^{7}_{3}Li^{+}$ ions are produced in the sample simultaneously and travel a distance L from aperture **P** to the detector.
For each type of ion, the time interval between production and detection is measured.

Discuss how the masses of the ions can be deduced from the measurement of these time intervals.

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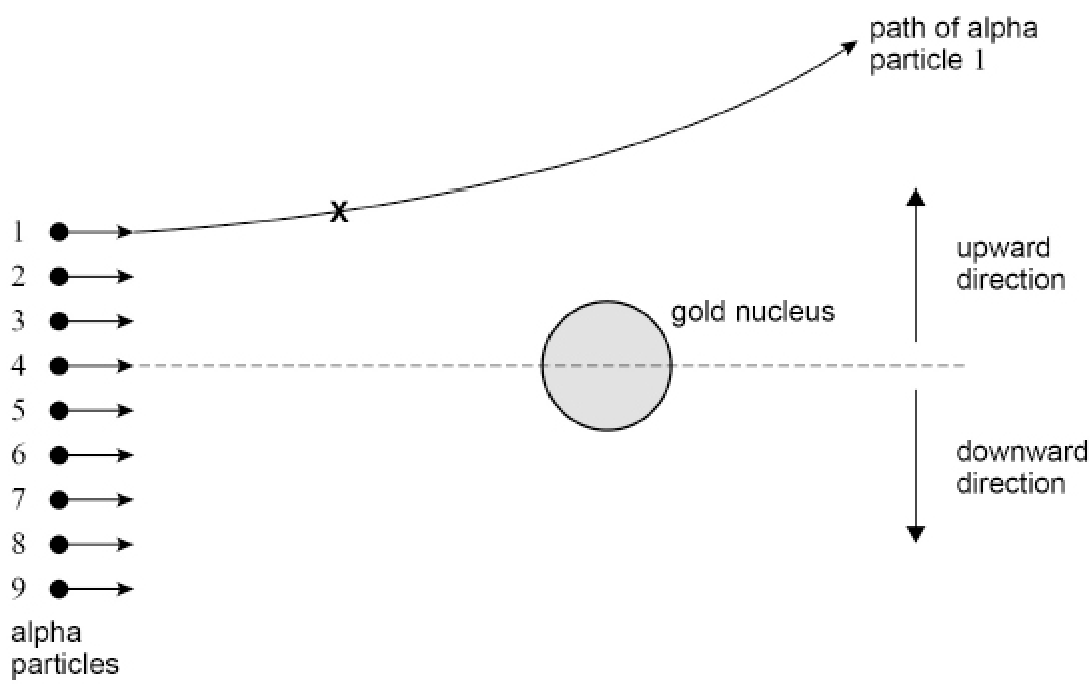
(2)
(Total 11 marks)

2. The diagram shows alpha particles all travelling in the same direction at the same speed. The alpha particles are scattered by a gold ($^{197}_{79}Au$) nucleus.
The path of alpha particle **1** is shown.



(a) State the fundamental force involved when alpha particle **1** is scattered by the nucleus in the diagram.

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(1)

(b) Draw an arrow at position **X** on the diagram above to show the direction of the rate of change in momentum of alpha particle **1**

(1)

(c) Suggest **one** of the alpha particles in the diagram above which may be deflected downwards with a scattering angle of 90°

Justify your answer.

alpha particle number = _______________

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(2)

(d) Alpha particle **4** comes to rest at a distance of 5.5×10^{-14} m from the centre of the $^{197}_{79}\mathrm{Au}$ nucleus.

Calculate the speed of alpha particle **4** when it is at a large distance from the nucleus. Ignore relativistic effects.

mass of alpha particle = 6.8×10^{-27} kg

speed = _______________ m s^{-1}

(3)

(e) The nuclear radius of $^{197}_{79}\mathrm{Au}$ is 6.98 × 10^{-15} m.

Calculate the nuclear radius of $^{107}_{47}\mathrm{Ag}$.

radius = _______________ m

(2)

(f) All nuclei have approximately the same density.

State **one** conclusion about the nucleons in a nucleus that can be deduced from this fact.

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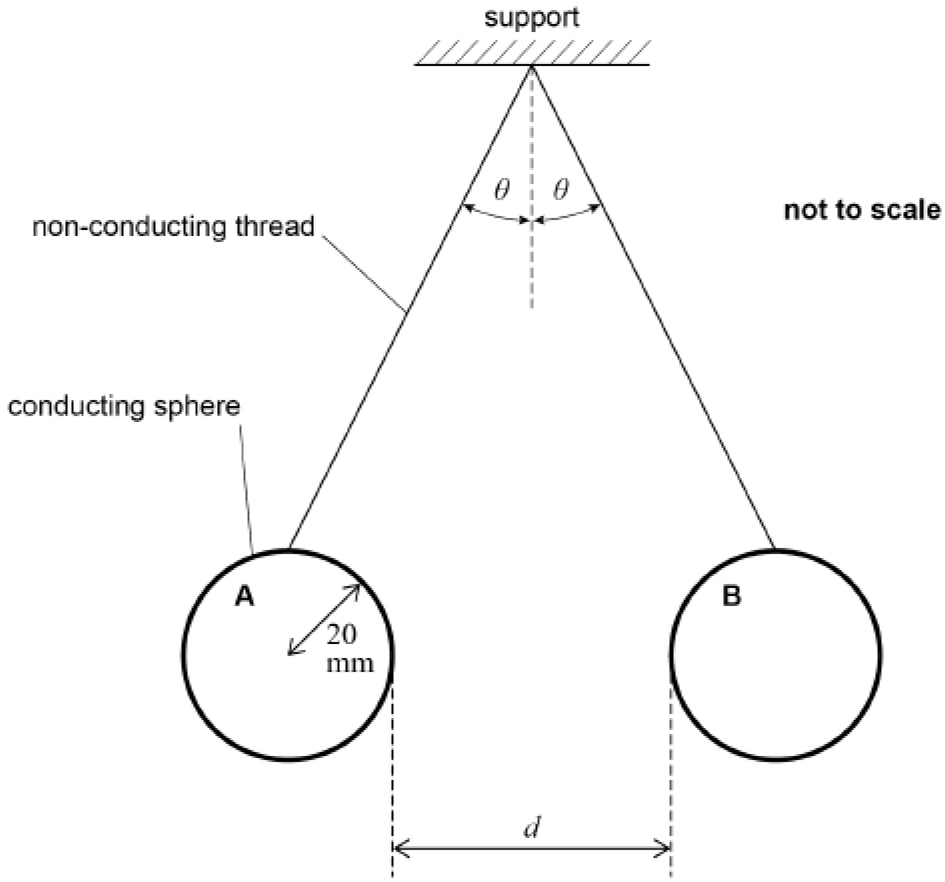
(1)

(Total 10 marks)

3. The diagram shows an arrangement used to investigate the repulsive forces between two identical charged conducting spheres.
The spheres are suspended by non-conducting thread.



Each sphere has a mass of 3.2×10^{-3} kg and a radius of 20 mm.
The distance d is 40 mm.

The capacitance of a sphere of radius r is $4\pi\varepsilon_0 r$.

Each sphere is charged by connecting it briefly to the positive terminal of a high-voltage supply, the other terminal of which is at 0 V.
After this has been done the charge on each sphere is 52 nC.

(a) Calculate the potential of one of the spheres.

potential = ____________________ V

(3)

(b) The charged spheres in the diagram above are at equilibrium.

Draw labelled arrows on the diagram to show the forces on sphere **B**.

(2)

(c) Suggest a solution to **one** problem involved in the measurement of d in the diagram.

(2)

(d) Show that the magnitude of the electrostatic force on each sphere is about 4×10^{-3} N.

(3)

(e) A student measures the angle θ when the apparatus in the diagram above is at equilibrium. The student records θ as 7°.

Discuss whether this measurement is consistent with the other data in this investigation.

(2)

(f) The student says that the gravitational force between the two spheres has no **significant** effect on the angle at which the spheres are in equilibrium.

Deduce with a calculation whether this statement is valid.

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(2)

(Total 14 marks)

4. Read the following passage and answer the questions that follow.

A mass spectrometer is an instrument for measuring the masses of isotopes. The main working parts of the instrument are shown in **Figure 1**.

Figure 1

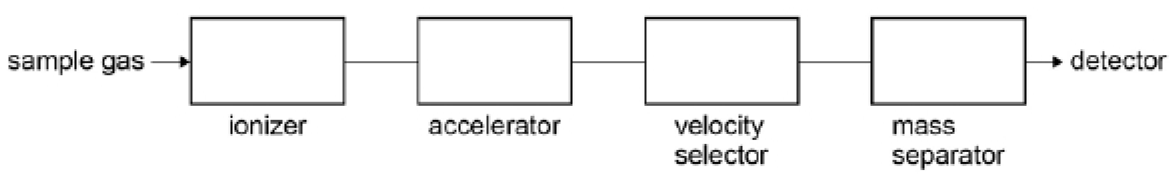
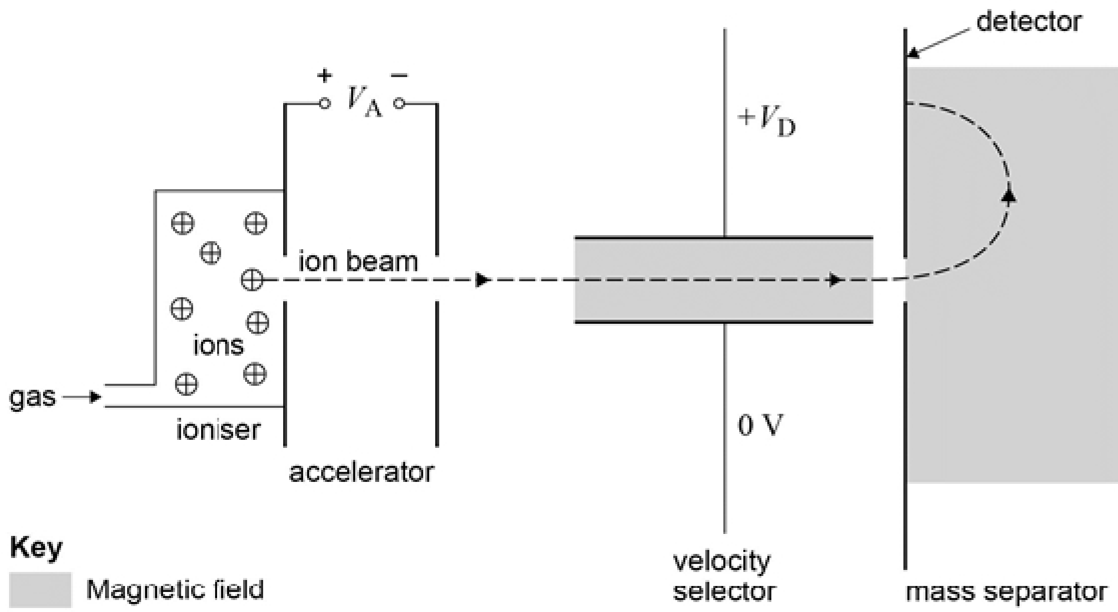


Figure 2 shows the components in more detail. Positive ions are created in the ionizer. Some of these ions enter the accelerator where they are accelerated by a potential difference V_A. The ions emerge from the accelerator with different speeds and enter the velocity selector.

The velocity selector contains a region where there is a uniform magnetic field at right angles to an electric field. This electric field is formed between two parallel plates held at a potential difference V_D. This combination of fields only allows ions of a particular velocity to enter the mass separator. Here ions of different mass are separated by a uniform magnetic field. Finally the ions are detected.

Figure 2



(a) Explain what is meant by ionisation.

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(1)

(b) Discuss the energy transfers that take place in the accelerator as the ion passes through it. Assume the ions are in a perfect vacuum.

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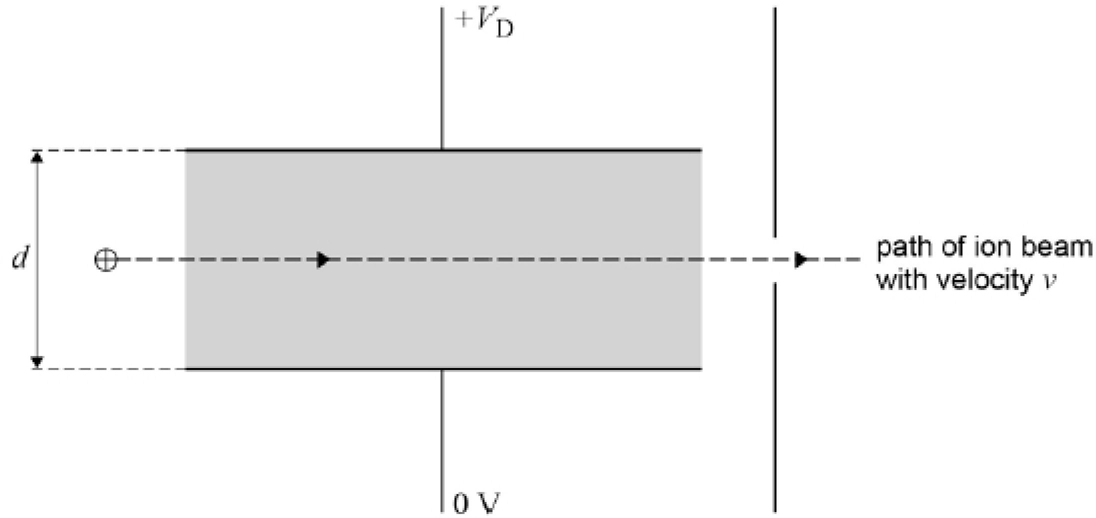
(3)

(c) **Figure 3** shows the path taken by an ion that moves through the velocity selector at a velocity *v*.

Figure 3



Discuss how the path changes when an ion enters the velocity selector with a velocity greater than *v*.

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(3)

(d) Draw, on **Figure 3**, the path of the ion that is suggested by your answer to part **(c)**.

(1)

(e) Ions created in the ioniser may have the same charge but a different number of nucleons.

Discuss how the path of an ion in the mass separator is affected when it has more nucleons.

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(2)

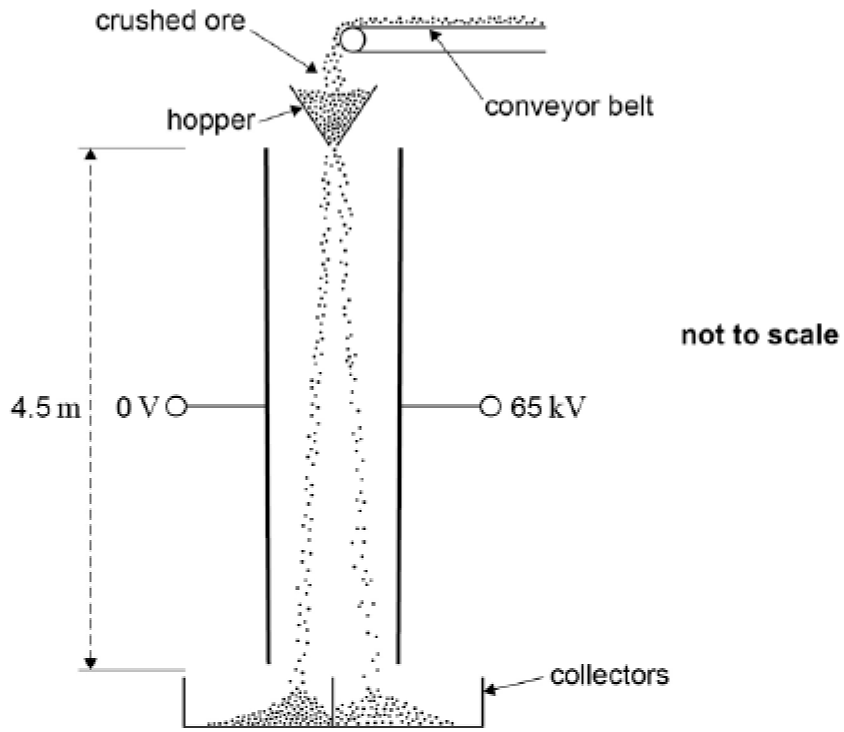
(f) Some ions are created with the same mass but a double charge. The path of the ions shown in **Figure 2** is that of a singly charged ion.

Compare, with justification, the path of a doubly charged ion through the mass spectrometer with that of a singly charged ion of the same mass.

(3)

(Total 13 marks)

5. The figure below shows a system that separates two minerals from the ore containing them using an electric field.



The crushed particles of the two different minerals gain opposite charges due to friction as they travel along the conveyor belt and through the hopper. When they leave the hopper they fall 4.5 metres between two parallel plates that are separated by 0.35 m.

(a) Assume that a particle has zero velocity when it leaves the hopper and enters the region between the plates.

Calculate the time taken for this particle to fall between the plates.

time taken = ______________s

(2)

(b) A potential difference (pd) of 65 kV is applied between the plates.

Show that when a particle of specific charge 1.2×10^{-6} C kg^{-1} is between the plates its horizontal acceleration is about 0.2 m s^{-2}.

(3)

(c) Calculate the total horizontal deflection of the particle that occurs when falling between the plates.

horizontal deflection = ______________m

(1)

(d) Explain why the time to fall vertically between the plates is independent of the mass of a particle.

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(2)

(e) State and explain **two** reasons, why the horizontal acceleration of a particle is different for each particle.

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(4)

(Total 12 marks)