1)

(a) An electric field always exists around a charged particle.

Explain what is meant by an *electric field*.

....

.... **[1]**

(b) State **one** difference and **one** similarity between the electric field of a point charge and the gravitational field of a point mass.

difference ....

....

similarity ....

.... **[2]**

(c) Fig. 1.1 shows the uniform electric field between two vertical parallel plates **A** and **B**.

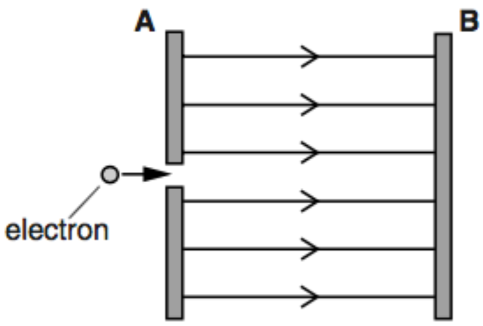


Fig. 1.1

The potential difference between the plates is 6V. An electron of kinetic energy 4eV is fired in a direction parallel to the electric field through a tiny hole in plate **A**.

Describe and explain the subsequent motion of the electron in the space between **A** and **B**. The weight of the electron has negligible effect on its motion between the plates.

....

....

....

....

....

....

.... **[3]**

(d) Two different minerals acquire opposite charges when they are crushed into tiny particles. These oppositely charged mineral particles fall from a conveyor belt through the uniform electric field between two vertical parallel plates, as shown in Fig. 1.2.

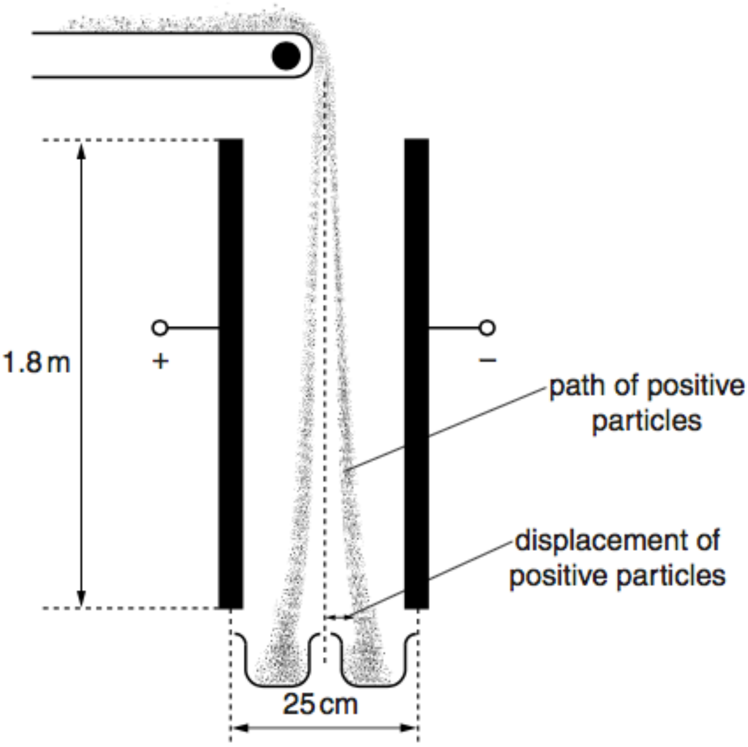


Fig. 1.2

The potential difference across the plates is 60 kV. The separation between the plates is 25 cm and each plate has length 1.8 m. The mineral particles fall through the air between the plates with a terminal velocity of $1.2\,m\,s^{-1}$. Each mineral particle has a charge of magnitude 1.5×10^{-13} C and a mass of 8.0×10^{-7} kg.

(i) Calculate the horizontal electric force experienced by a positively charged mineral particle as it falls between the plates.

force = ... N **[2]**

(ii) Calculate the horizontal displacement of a positively charged mineral particle after a 1.8 m fall through the electric field of the plates. Ignore any horizontal drag forces due to air.

displacement = ... m **[3]**

2)

(a) Fig. 1.1 shows a negatively charged metal sphere close to a positively charged metal plate.

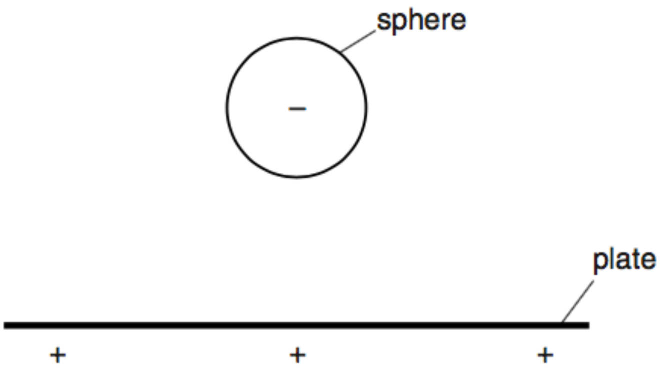


Fig. 1.1

On Fig. 1.1, draw a minimum of five field lines to show the electric field pattern between the plate and the sphere. **[2]**

(b) Fig. 1.2 shows two positively charged particles **A** and **B**.

Fig. 1.2

Fig. 1.3

At point **X**, the magnitude of the **resultant** electric field strength due to the particles **A** and **B** is zero.

(i) State, with a reason, which of the two particles has a charge of greater magnitude.

....

....

.... **[1]**

(ii) On Fig. 1.3 sketch the variation of the resultant electric field strength E with distance d from the particle **A**. **[3]**

(c) Fig. 1.4 shows a stationary positively charged particle.

Fig. 1.4

This particle creates both electric and gravitational fields in the space around it. Explain why the **ratio** of the electric field strength E to the gravitational field strength g at any point around this charge is independent of its distance from the particle.

....

....

....

.... **[1]**

[Total: 7]

3)

Fig. 2.1 shows two identical negatively charged conducting spheres.

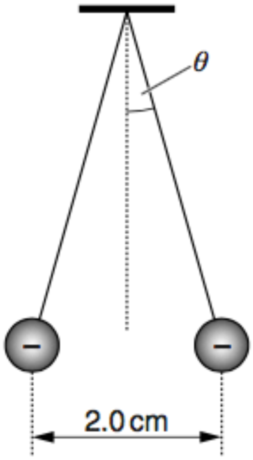


Fig. 2.1

The spheres are tiny and each is suspended from a nylon thread. Each sphere has mass 6.5×10^{-5} kg and charge -2.8×10^{-9} C. The separation between the centres of the spheres is 2.0 cm.

(a) Calculate the number of excess electrons on the surface of each sphere.

number = ... **[1]**

(b) Calculate the repulsive electrical force acting on each sphere.

force = ...N **[2]**

(c) **(i)** Each sphere is in equilibrium and experiences three forces. One of the forces acting on each sphere is the electrical force. State the other **two** forces acting on each sphere.

....

.... **[1]**

(ii) Use your knowledge of vectors to determine the angle θ made by each thread with the vertical.

θ = ...° **[3]**

[Total: 7]

4)

Fig. 3.1 shows an arrangement used to accelerate electrons.

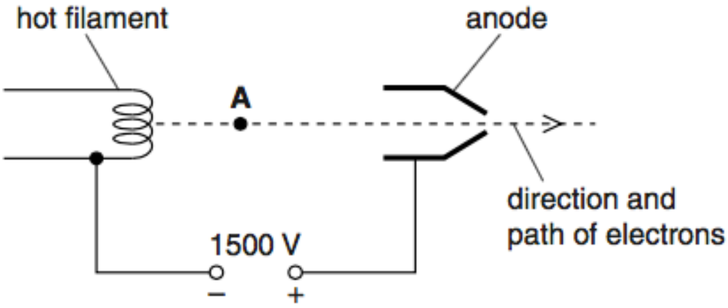


Fig. 3.1

(a) Draw an arrow on Fig. 3.1 to show the direction of the electric field at point **A**. **[1]**

(b) The potential difference between the filament and the anode is 1500V. The speed of an electron at the filament is negligible.

(i) Determine the kinetic energy in electronvolts (eV) of an electron at the anode.

kinetic energy = ... eV **[1]**

(ii) Calculate the speed v of an electron at the anode.

v = ... $m s^{-1}$ **[3]**

5)

(a) Fig. 1.1 shows a circuit consisting of two parallel plates **A** and **B** connected to a high voltage power supply.

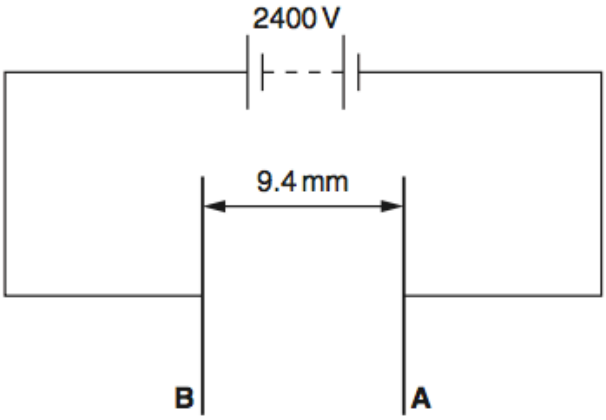


Fig. 1.1

The separation of the plates is 9.4 mm and the p.d. across the plates is 2400 V. There is a vacuum between the plates. Electrons are accelerated from plate **A** to plate **B**.

Calculate

(i) the force acting on an electron when it is between the plates

force = ... N **[2]**

(ii) the gain in kinetic energy of an electron when it travels from **A** to **B**

kinetic energy = ... J **[2]**

(iii) the speed of the electron when it reaches plate **B**. Assume that the speed of the electron is initially zero at plate **A**.

speed = ... m s^{-1} **[1]**

(b) The separation between the plates is doubled but the p.d. across the plates is kept the same. Explain how this would affect the answer to **(a)(ii)**.

....

....

....

.... **[2]**

[Total: 7]

6)

Fig. 1.1 shows a close up of the two electrodes of a spark plug.

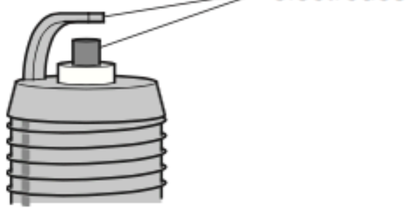


Fig. 1.1

The electrodes may be considered as two parallel plates. The electric field strength between the electrodes is almost uniform.

(a) Define *electric field strength*.

....

.... **[1]**

(b) The separation between the electrodes is 1.3 mm. An electric spark is produced when the electric field strength is $3.0 \times 10^6\,\mathrm{V\,m^{-1}}$.

(i) Estimate the potential difference V between the electrodes when the spark is produced.

V = ... V **[2]**

(ii) The electric spark lasts for 4.0×10^{-2} s and produces an average current of 2.7×10^{-9} A.

1 Calculate the charge transferred between the electrodes.

charge = ...C **[2]**

2 Calculate the number of electrons transferred between the electrodes.

number = ... **[1]**

(iii) Estimate the total energy transferred by the electrons in **(ii)**.

energy = ... J **[2]**

[Total: 8]

7)

An alpha particle is fired at high speed directly towards a stationary nucleus of a gold atom. At its distance of closest approach to the gold nucleus, the alpha particle stops and the gold nucleus has a small velocity, see Fig. 4.1. The alpha particle and the gold nucleus both have positive charges.

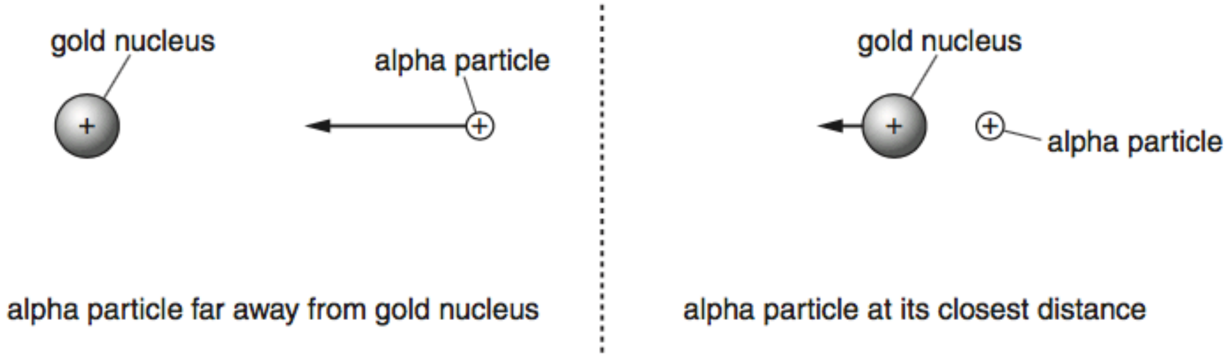


Fig. 4.1

(a) Explain why, at this distance of closest approach, the gold nucleus has a velocity and the alpha particle does not.

....

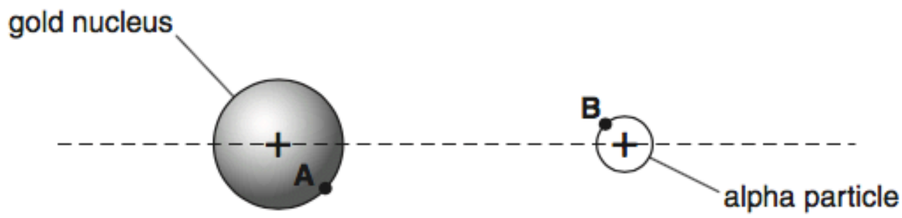
....

....

....

.... **[2]**

(b) Fig. 4.2, shows the alpha particle at its closest distance to the gold nucleus. Draw one electric field line from point **A** and one from point **B**. For each field line, show the direction of the field.

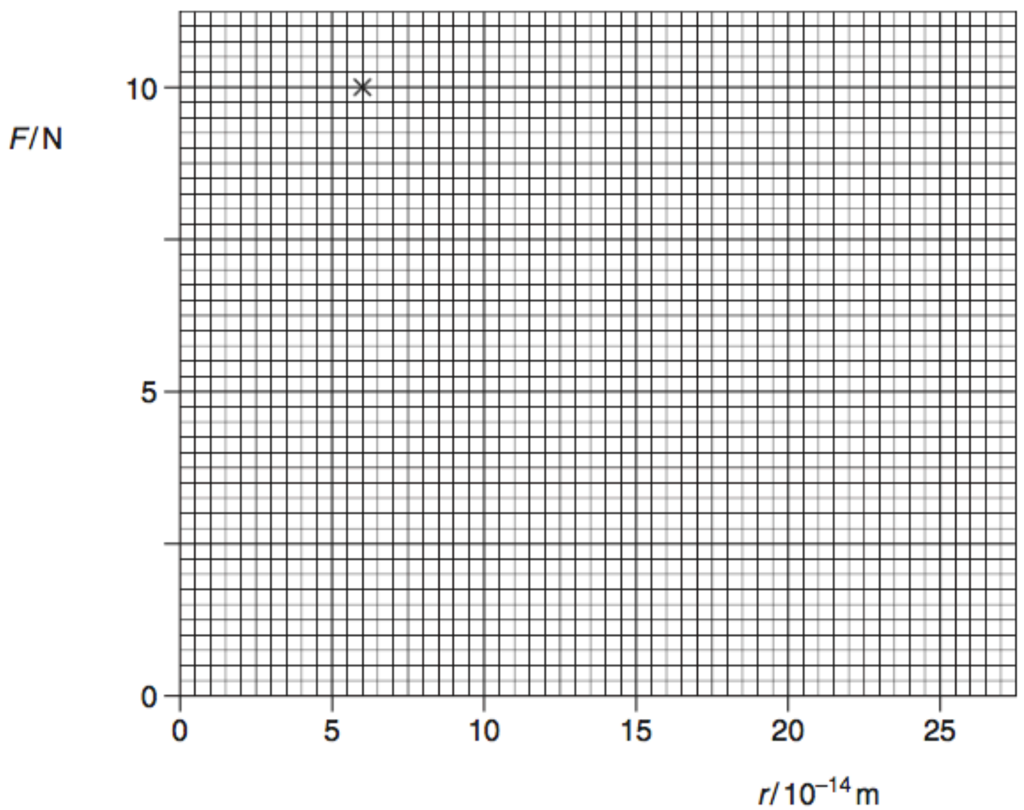


[2]

(c) Show that the electrical force experienced by the alpha particle at its closest distance of 6.0×10^{-14} m to the gold nucleus is about 10 N. The gold nucleus has 79 protons and the alpha particle has 2 protons.

[3]

(d) On Fig. 4.3, sketch a graph to show the variation of the electrical force *F* on the alpha particle with distance *r* from the centre of the gold nucleus. The value of *F* at the distance of closest approach has been marked on the graph.



[2]

Fig. 4.3

[Total: 9]

8)

(a) Define *electric field strength.*

....

.... **[1]**

(b) Fig. 3.1 shows two horizontal, parallel metal plates **A** and **B**.

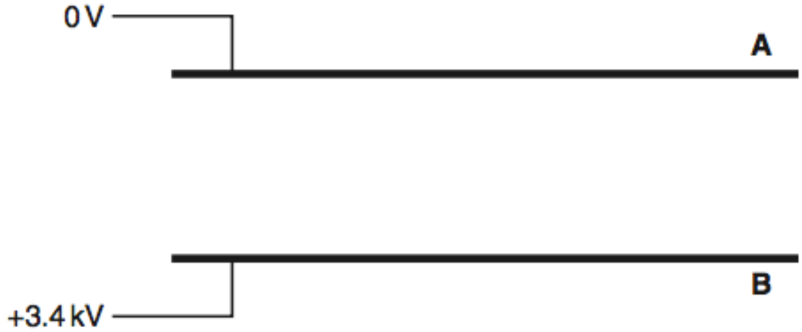


Fig. 3.1

The potential difference across the plates is 3.4 kV and the arrangement provides a uniform electric field between the plates.

On Fig. 3.1 draw at least six lines to represent the electric field between the plates. **[2]**

(c) A beam of electrons enters between the plates at right angles to the electric field. The horizontal velocity of the electrons is $4.0 \times 10^7\,\mathrm{m\,s^{-1}}$. The path of the electrons is shown on Fig. 3.2. The horizontal length of each plate is 0.080 m and the separation of the plates is 0.050 cm. **P** is a point 0.040 m from where the beam enters the plates.

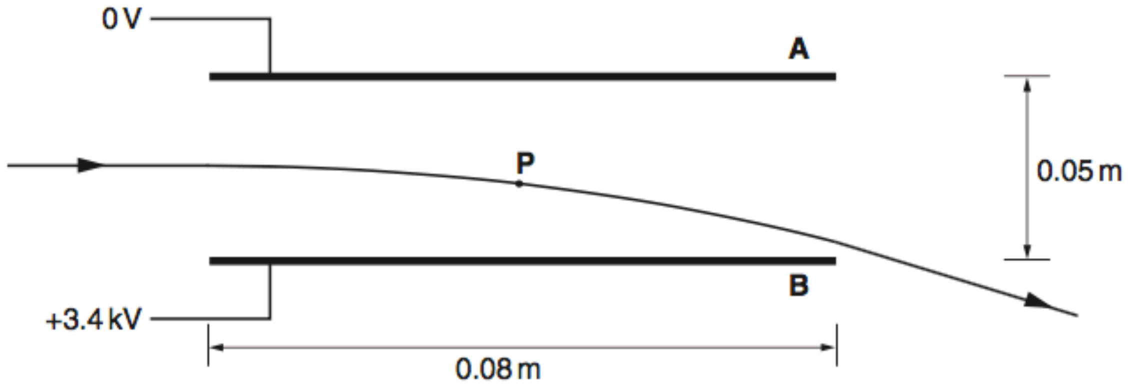


Fig. 3.2

(i) Draw an arrow on Fig. 3.2 to show the direction of the acceleration of an electron at **P**. **[1]**

(ii) Show that the acceleration of an electron between the plates is about $1 \times 10^{16}\,\text{m}\,\text{s}^{-2}$.

[2]

(iii) Calculate the time taken for an electron on entering the plates to reach **P**.

time = ... s **[1]**

(iv) Show that the vertical velocity of the electron at **P** is $1.2 \times 10^{7}\,\text{m}\,\text{s}^{-1}$.

[1]

(v) Calculate the magnitude of the resultant velocity of the electron at **P**.

magnitude of the velocity = ... $\text{m}\,\text{s}^{-1}$ **[2]**

(vi) Calculate the kinetic energy of the electron at **P**.

kinetic energy = ... J **[2]**

(vii) On Fig. 3.3 sketch the variation of kinetic energy E_k of the electron with the horizontal distance x it travels through the electric field and beyond. No calculations are required.

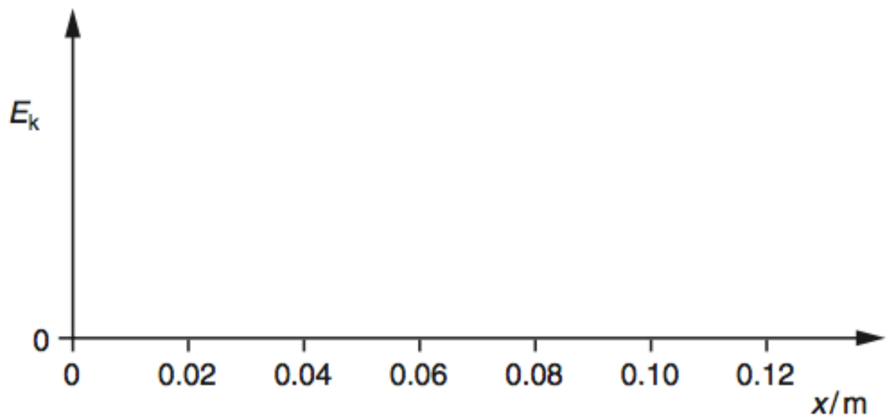


Fig. 3.3

[3]

[Total: 15]

9)

A small, charged metal sphere **A** is hung from an insulating string. The charge on **A** is +5.0 nC. Fig. 4.1 shows the effect on **A** when a charged sphere **B** on an insulated rod is positioned close to it. The string makes an angle θ with the vertical.

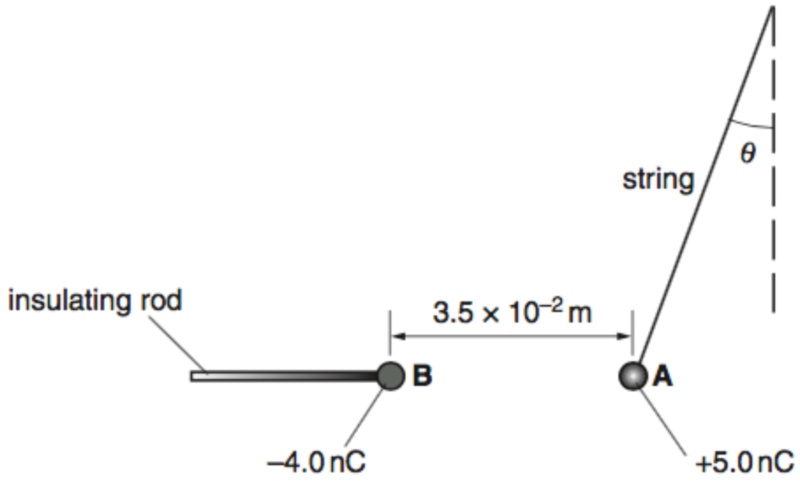


Fig. 4.1

The charge on **B** is –4.0 nC. The separation between the centres of the two spheres is 3.5×10^{-2} m.

(a) Determine the magnitude and direction of the electric field strength at the **midpoint** between the two charged spheres.

electric field strength = ... NC^{-1}

direction = ...

[4]

(b) Show that the electric force on **A** is 1.5×10^{-4} N.

[2]

(c) The mass of sphere **A** is 4.5×10^{-5} kg. Use the method of resolving vectors or a vector triangle to determine the angle θ made by the string with the vertical.

θ = ...° **[3]**

[Total: 9]

10)

(a) Fig. 3.1 shows two charged horizontal plates.

Fig. 3.1

The potential difference across the plates is 60 V. The separation of the plates is 5.0 mm.

(i) On Fig. 3.1 draw the electric field pattern between the plates. **[2]**

(ii) Calculate the electric field strength between the plates.

electric field strength = ... $V\,m^{-1}$ **[1]**

(b) Positive ions are accelerated from rest in the horizontal direction through a potential difference of 400 V. The charged plates in **(a)** are then used to deflect the ions in the vertical direction. Fig. 3.2 shows the path of these ions.

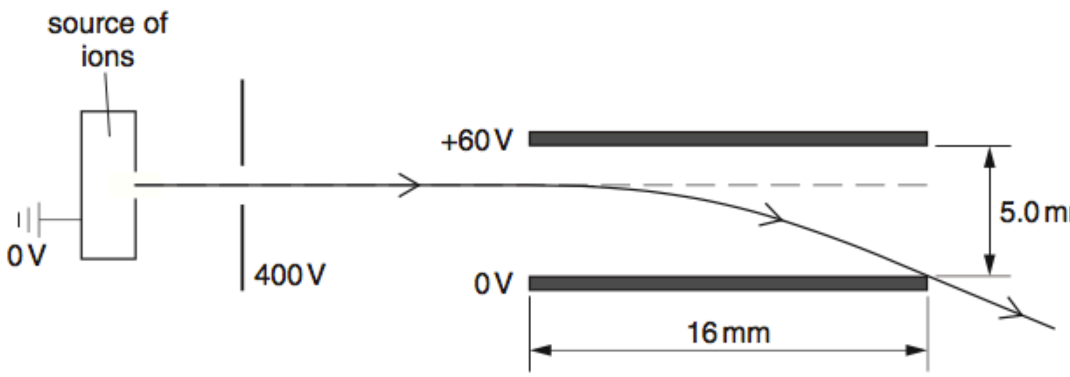


Fig. 3.2

Each ion has a mass of 6.6×10^{-27} kg and a charge of 3.2×10^{-19} C.

(i) Show that the horizontal velocity of an ion after the acceleration by the 400 V potential difference is $2.0 \times 10^{5}\,\text{m}\,\text{s}^{-1}$.

[2]

(ii) The ions enter at right angles to the uniform electric field between the plates. Calculate the vertical acceleration of an ion due to this electric field.

acceleration = ... $\text{m}\,\text{s}^{-2}$ **[2]**

(iii) The length of each of the charged plates is 16 mm.

1 Show that an ion takes about 8.0×10^{-8} s to travel through the plates.

[1]

2 Calculate the vertical deflection of an ion as it travels through the plates.

deflection = ... m **[2]**

11)

A proton travelling at a high velocity is fired at a stationary proton. It stops momentarily at a distance of 2.0×10^{-15} m from the stationary proton.

(a) Calculate the electrostatic force acting on each proton when separated by 2.0×10^{-15} m.

force = ... N **[2]**

(b) The two protons fuse together. Explain how the protons are able to remain together.

....

.... **[1]**

(c) Explain why the proton must have a very large velocity for the fusion to occur and the protons to remain together.

....

....

....

.... **[2]**

[Total: 5]

12)

(a) Define *electric field strength* at a point in space.

....

.... **[1]**

(b) Fig. 2.1 shows an evenly spaced grid.

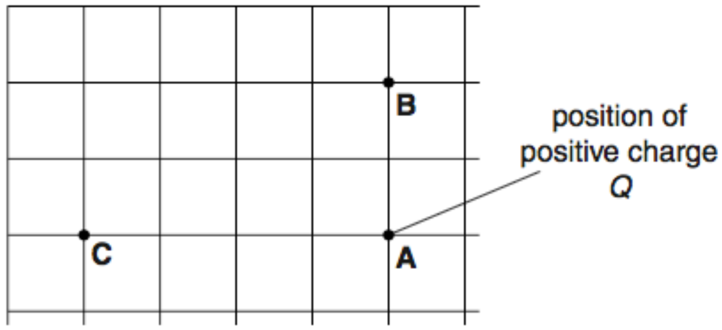


Fig. 2.1

A, **B** and **C** are points on the grid. A positive charge *Q* is placed on the grid at point **A**. The magnitude of the electric field strength at point **B** due to the charge *Q* is $8.0 \times 10^5\,\mathrm{N\,C^{-1}}$.

(i) Apart from the magnitudes of the electric field strength, state another difference between the electric field at points **B** and **C**.

....

.... **[1]**

(ii) Determine the magnitude of the electric field strength at point **C**.

electric field strength = ... $\mathrm{N\,C^{-1}}$ **[2]**

(c) The simplest atom is that of hydrogen with one proton and one electron, see Fig. 2.2.

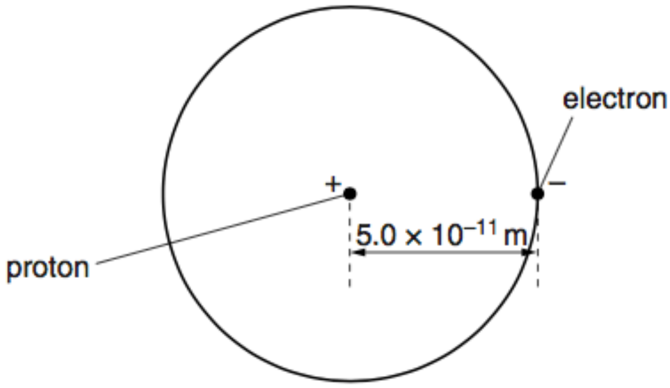


Fig. 2.2

The mean separation between the proton and the electron is shown in Fig. 2.2.

(i) Calculate the magnitude of the electrical force F_E acting on the electron.

F_E = ...N **[3]**

(ii) The gravitational force F_G acting on the electron due to the proton is very small compared with the electrical force F_E it experiences.

Calculate the ratio $\frac{F_E}{F_G}$.

ratio = ... **[2]**

(iii) A simplified model of the hydrogen atom suggests that the de Broglie wavelength of the electron is four times the mean separation between the proton and the electron shown in Fig. 2.2.

Estimate

1 the momentum p of the electron

p = ... kg m s^{-1} **[3]**

2 the kinetic energy E_k of the electron.

E_k = ... J **[3]**

[Total: 15]