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Electric fields: 8

TOPIC-Electric field strength, Force,

Motion of charged particles in a uniform electric field

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1 (a) Define *charge*.

.... [1]

(b) A heater is made from a wire of resistance 18.0 Ω and is connected to a power supply of 240 V. The heater is switched on for 2.60 Ms.

Calculate

(i) the power transformed in the heater,

power = ... W [2]

(ii) the current in the heater,

current = ... A [1]

(iii) the charge passing through the heater in this time,

charge = ... C [2]

(iv) the number of electrons per second passing a given point in the heater.

number = ... s^{-1} [2]

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2 **(a)** Define *electric field strength*.

....

.... [1]

(b) A potential difference of 2.5 kV is applied across a pair of horizontal metal plates in a vacuum, as shown in Fig. 2.1.

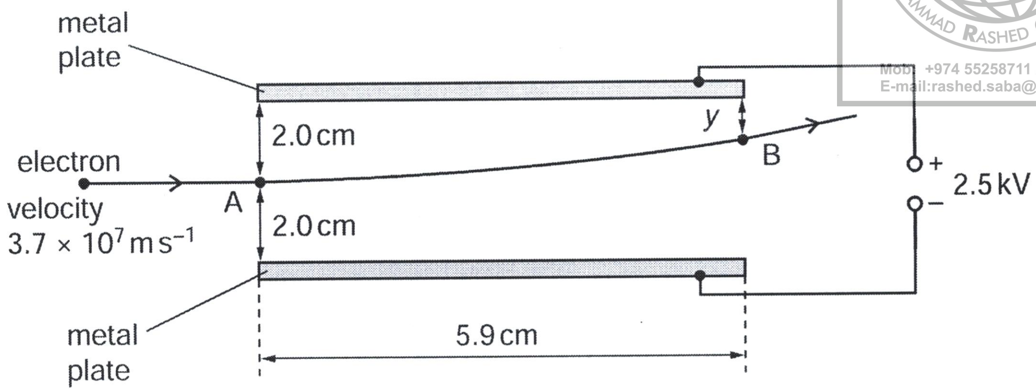

Fig. 2.1 (not to scale)

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Each plate has a length of 5.9 cm. The separation of the plates is 4.0 cm. The arrangement produces a uniform electric field between the plates.
Assume the field does not extend beyond the edges of the plates.

An electron enters the field at point A with horizontal velocity 3.7×10^7 m s^{-1} along a line mid-way between the plates. The electron leaves the field at point B.

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(i) Calculate the time taken for the electron to move from A to B.

time taken = ... s [1]

(ii) Calculate the magnitude of the electric field strength.

field strength = ... N C^{-1} [2]

(iii) Show that the acceleration of the electron in the field is 1.1×10^{16} m s^{-2}.

[2]

(iv) Use the acceleration given in **(iii)** and your answer in **(i)** to determine the vertical distance y between point B and the upper plate.

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y = ... cm [3]

(v) Explain why the calculation in **(iv)** does not need to include the gravitational effects on the electron.

....

....[1]

(vi) The electron enters the field at time $t = 0$.

On Fig. 2.2, sketch graphs to show the variation with time t of

1. the horizontal component v_X of the velocity of the electron,
2. the vertical component v_Y of the velocity of the electron.

Numerical values are not required.

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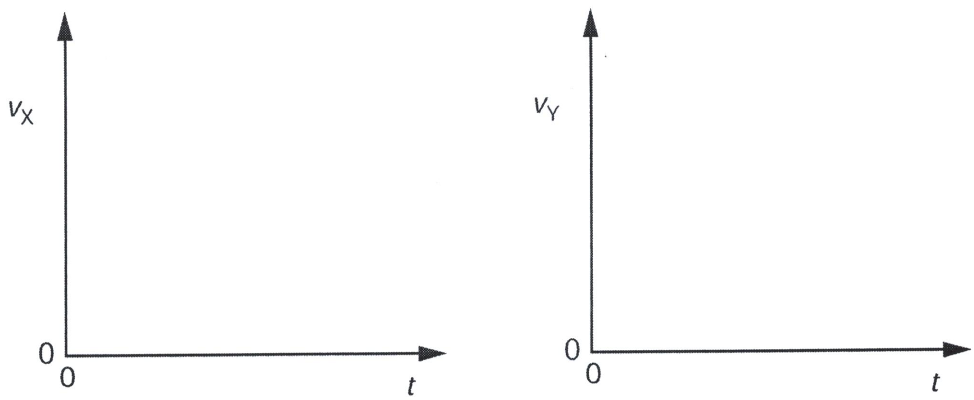

Fig. 2.2

[2]

[Total: 12]

3 **(a)** Define *electric field strength.*

....

.... [1]

(b) A sphere S has radius 1.2×10^{-6} m and density $930\,\text{kg}\,\text{m}^{-3}$.

Show that the weight of S is 6.6×10^{-14} N.

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[2]

(c) Two horizontal metal plates are 14 mm apart in a vacuum. A potential difference (p.d.) of 1.9 kV is applied across the plates, as shown in Fig. 3.1.

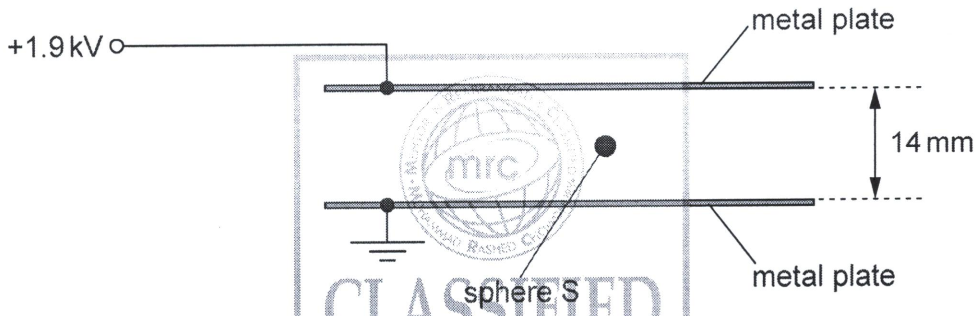

Fig. 3.1

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A uniform electric field is produced between the plates.
The sphere S in **(b)** is charged and is held stationary between the plates by the electric field.

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

electric field strength = ... $\text{V}\,\text{m}^{-1}$ [2]

(ii) Calculate the magnitude of the charge on S.

charge = ... C [2]

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(iii) The magnitude of the p.d. applied to the plates is increased.
Explain why S accelerates towards the top plate.

....

....[2]

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4 (a) Define *electric field strength*.

....

....[1]

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(b) Two horizontal metal plates are 20 mm apart in a vacuum. A potential difference of 1.5 kV is applied across the plates, as shown in Fig. 4.1.

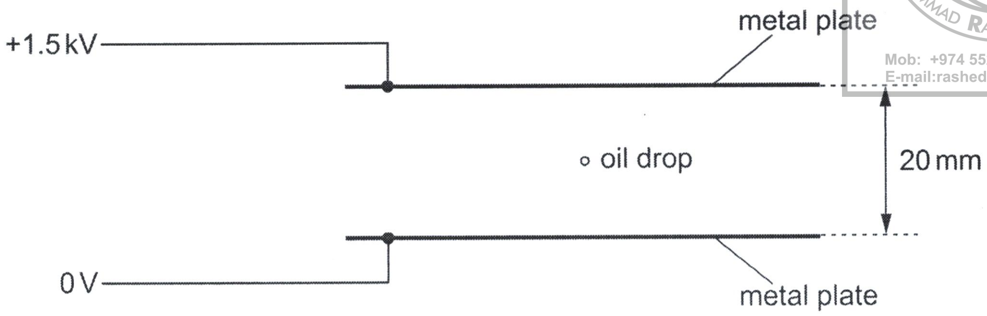

Fig. 4.1

A charged oil drop of mass 5.0×10^{-15} kg is held stationary by the electric field.

(i) On Fig. 4.1, draw lines to represent the electric field between the plates. [2]

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

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

(iii) Calculate the charge on the drop.

charge = ... C [4]

(iv) The potential of the upper plate is increased. Describe and explain the subsequent motion of the drop.

....

....

....[2]

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5 An electron is travelling in a straight line through a vacuum with a constant speed of $1.5 \times 10^7\,m\,s^{-1}$. The electron enters a uniform electric field at point A, as shown in Fig. 5.1.

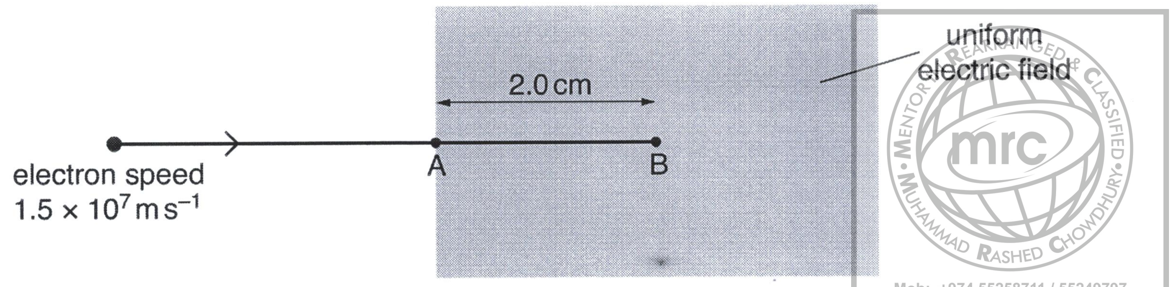

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Fig. 5.1

The electron continues to move in the same direction until it is brought to rest by the electric field at point B. Distance AB is 2.0 cm.

(a) State the direction of the electric field.

....[1]

(b) Calculate the magnitude of the deceleration of the electron in the field.

deceleration = ... $m\,s^{-2}$ [2]

(c) Calculate the electric field strength.

electric field strength = ... $V\,m^{-1}$ [3]

(d) The electron is at point A at time $t = 0$.

On Fig. 5.2, sketch the variation with time t of the velocity v of the electron until it reaches point B. Numerical values of v and t do not need to be shown.

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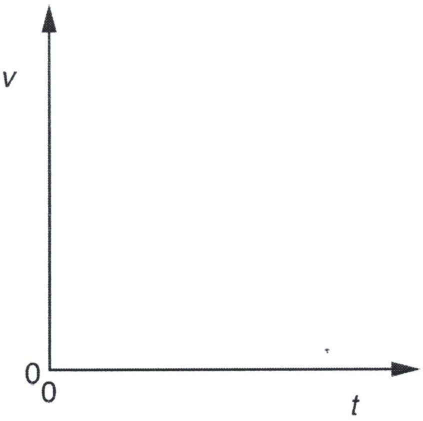

Fig. 5.2

[1]

[Total: 7]

6 Two horizontal metal plates X and Y are at a distance 0.75 cm apart. A positively charged particle of mass 9.6×10^{-15} kg is situated in a vacuum between the plates, as illustrated in Fig. 6.1.

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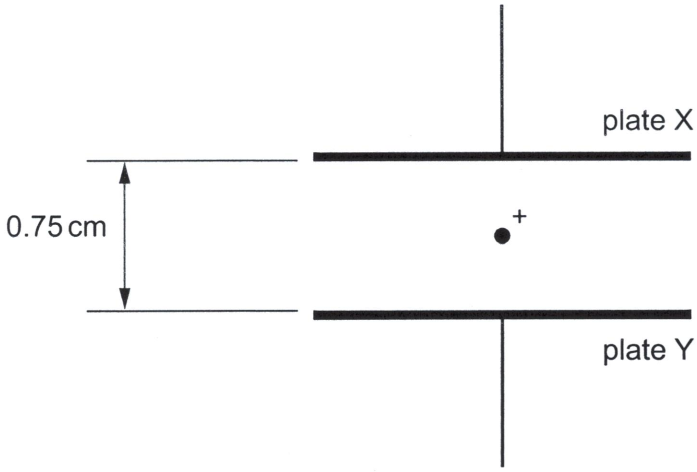

Fig. 6.1

The potential difference between the plates is adjusted until the particle remains stationary.

(a) State, with a reason, which plate, X or Y, is positively charged.

....

....

.... [2]

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(b) The potential difference required for the particle to be stationary between the plates is found to be 630 V. Calculate

(i) the electric field strength between the plates,

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

(ii) the charge on the particle.

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charge = ... C [3]

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7 Two oppositely-charged parallel metal plates are situated in a vacuum, as shown in Fig. 7.1.

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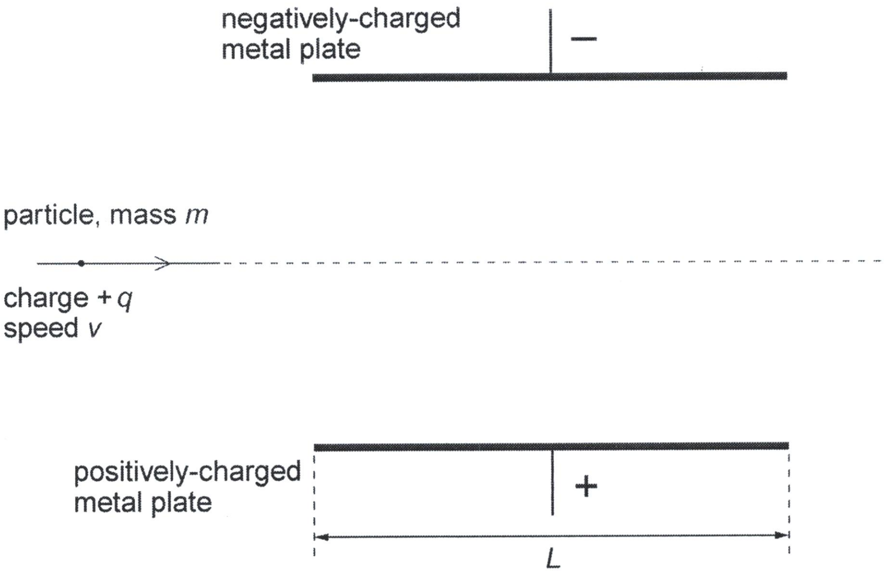

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Fig. 7.1

The plates have length *L*.
The uniform electric field between the plates has magnitude *E*. The electric field outside the plates is zero.

A positively-charged particle has mass *m* and charge +*q*. Before the particle reaches the region between the plates, it is travelling with speed *v* parallel to the plates.
The particle passes between the plates and into the region beyond them.

(a) **(i)** On Fig. 7.1, draw the path of the particle between the plates and beyond them. [2]

(ii) For the particle in the region between the plates, state expressions, in terms of *E*, *m*, *q*, *v* and *L*, as appropriate, for

1. the force *F* on the particle,

.... [1]

2. the time *t* for the particle to cross the region between the plates.

.... [1]

(b) **(i)** State the law of conservation of linear momentum.

....

....

.... [2]

(ii) Use your answers in **(a)(ii)** to state an expression for the change in momentum of the particle.

.... [1]

(iii) Suggest and explain whether the law of conservation of linear momentum applies to the particle moving between the plates.

....

....

.... [2]

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0 6 **(a)** Define *electric field strength.*

....

....[1]

(b) Two flat parallel metal plates, each of length 12.0 cm, are separated by a distance of 1.5 cm, as shown in Fig. 2.1.

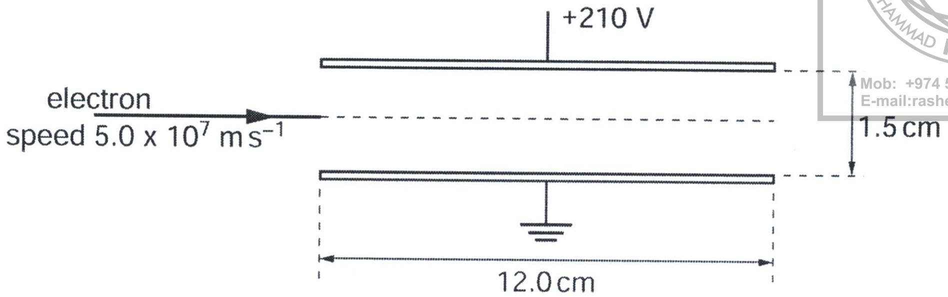

Fig. 2.1

The space between the plates is a vacuum.
The potential difference between the plates is 210 V. The electric field may be assumed to be uniform in the region between the plates and zero outside this region.
Calculate the magnitude of the electric field strength between the plates.

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field strength = ... N C^{-1} [1]

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(c) An electron initially travels parallel to the plates along a line mid-way between the plates, as shown in Fig. 2.1. The speed of the electron is $5.0 \times 10^7\ \mathrm{m\,s^{-1}}$.

For the electron between the plates,

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(i) determine the magnitude and direction of its acceleration,

acceleration = ... $\mathrm{m\,s^{-2}}$

direction ....[4]

(ii) calculate the time for the electron to travel a horizontal distance equal to the length of the plates.

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time = ... s [1]

(d) Use your answers in **(c)** to determine whether the electron will hit one of the plates or emerge from between the plates.

[3]

09 An electron travelling horizontally in a vacuum enters the region between two horizontal metal plates, as shown in Fig. 6.1.

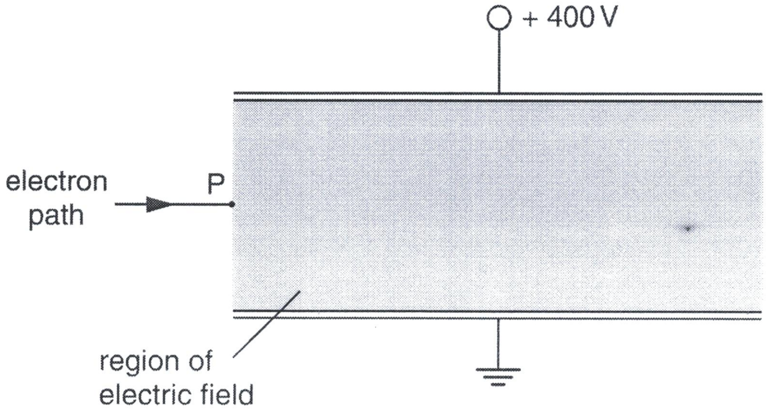

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Fig. 6.1

The lower plate is earthed and the upper plate is at a potential of + 400 V. The separation of the plates is 0.80 cm.

The electric field between the plates may be assumed to be uniform and outside the plates to be zero.

(a) On Fig. 6.1,

(i) draw an arrow at P to show the direction of the force on the electron due to the electric field between the plates,

(ii) sketch the path of the electron as it passes between the plates and beyond them. [3]

(b) Determine the electric field strength E between the plates.

E = ... V m^{-1} [2]

(c) Calculate, for the electron between the plates, the magnitude of

(i) the force on the electron,

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force = ... N

(ii) its acceleration.

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acceleration = ... $m\,s^{-2}$

[4]

(d) State and explain the effect, if any, of this electric field on the horizontal component of the motion of the electron.

....

....

....[2]

10 **(a)** Two horizontal metal plates are connected to a power supply, as shown in Fig. 7.1.

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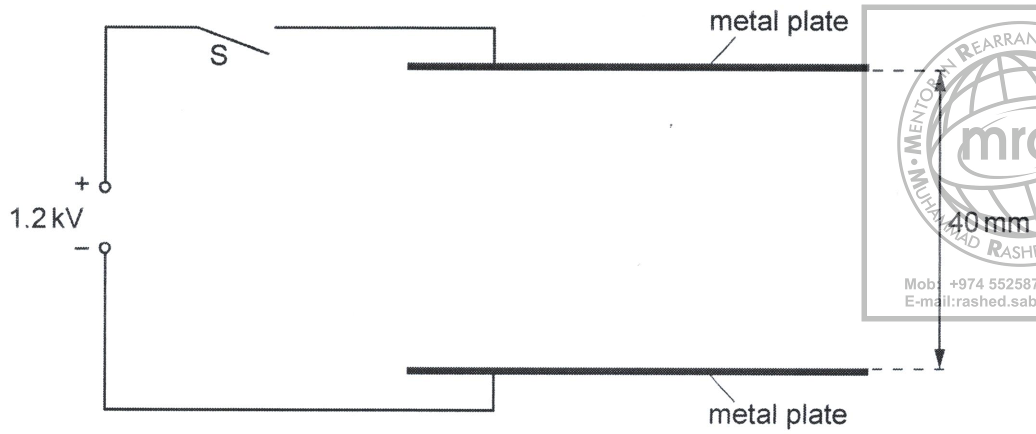

Fig. 7.1

The separation of the plates is 40 mm.

The switch S is then closed so that a potential difference of 1.2 kV is applied across the plates.

(i) On Fig. 7.1, draw six field lines to represent the electric field between the metal plates. [2]

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

E = ... $V m^{-1}$ [2]

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(b) The switch S is opened and the plates lose their charge. Two very small metal spheres A and B joined by an insulating rod are placed between the metal plates as shown in Fig. 7.2.

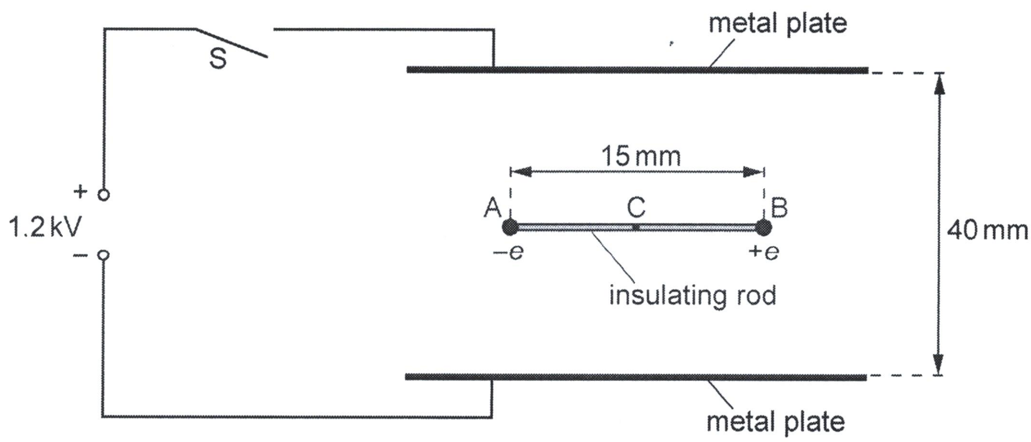

Fig. 7.2

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Sphere A has charge $-e$ and sphere B has charge $+e$, where e is the charge of a proton. The length AB is 15 mm. The rod is supported at its centre C so that the rod is horizontal and in equilibrium.

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The switch S is then closed so that the potential difference of 1.2 kV is applied across the plates.

(i) There is a force acting on A due to the electric field between the plates. Show that this force is 4.8×10^{-15} N.

[2]

(ii) The insulating rod joining A and B is fixed in the position shown in Fig. 7.2. Calculate the torque of the couple acting on the rod.

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torque = ... unit .... [3]

(iii) The insulating rod is now released so that it is free to rotate about C. State and explain the position of the rod when it comes to rest.

....

....

....

.... [2]

11 **(a)** Explain what is meant by an *electric field*.

....

.... [1]

(b) A uniform electric field is produced between two vertical metal plates AB and CD, as shown in Fig. 7.1.

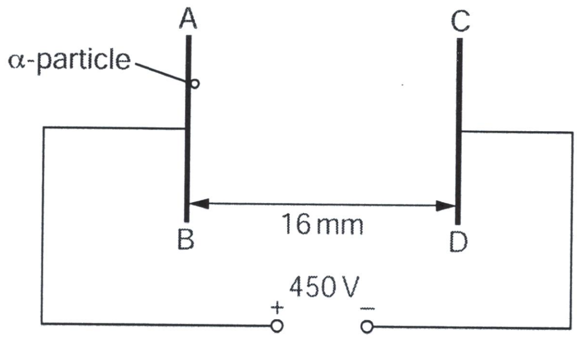

Fig. 7.1

The potential difference between the plates is 450 V and the separation of the plates is 16 mm.

An α-particle is accelerated from plate AB to plate CD.

(i) On Fig. 7.1, draw lines to represent the electric field between the plates. [2]

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

electric field strength = ... $V m^{-1}$ [2]

(iii) Calculate the work done by the electric field on the α-particle as it moves from AB to CD.

work done = ... J [3]

Question 7 continues on page 16.

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(iv) A β-particle moves from AB to CD. Calculate the ratio

$$\frac{\text{work done by the electric field on the } \alpha\text{-particle}}{\text{work done by the electric field on the } \beta\text{-particle.}}$$

Show your working.

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ratio = ... [1]

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12 Two vertical parallel metal plates are situated 2.50 cm apart in a vacuum. The potential difference between the plates is 350 V, as shown in Fig. 6.1.

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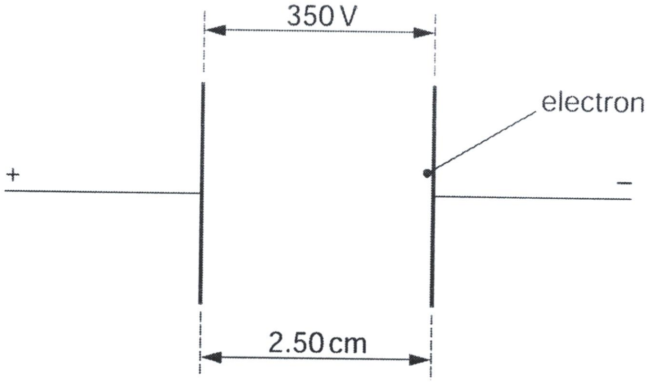

Fig. 6.1

An electron is initially at rest close to the negative plate and in the uniform electric field between the plates.

(a) **(i)** Calculate the magnitude of the electric field between the plates.

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

(ii) Show that the force on the electron due to the electric field is 2.24×10^{-15} N.

[2]

(b) The electron accelerates horizontally across the space between the plates. Determine

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(i) the horizontal acceleration of the electron,

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acceleration = ... $m s^{-2}$ [2]

(ii) the time to travel the horizontal distance of 2.50 cm between the plates.

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time = ... s [2]

(c) Explain why gravitational effects on the electron need not be taken into consideration in your calculation in **(b)**.

....

....

.... [2]

13 Two vertical parallel metal plates are situated 2.50 cm apart in a vacuum. The potential difference between the plates is 350 V, as shown in Fig. 6.1.

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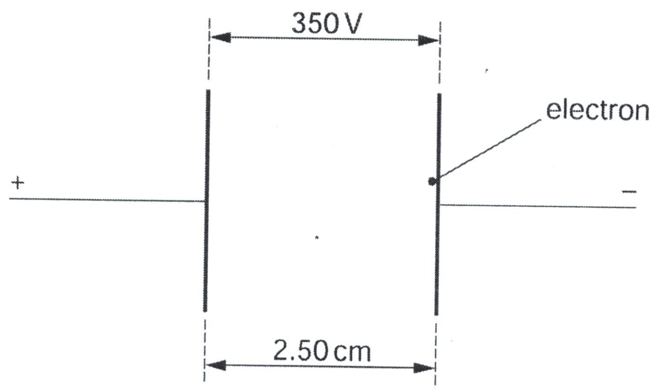

Fig. 6.1

An electron is initially at rest close to the negative plate and in the uniform electric field between the plates.

(a) **(i)** Calculate the magnitude of the electric field between the plates.

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electric field strength = ... NC^{-1} [2]

(ii) Show that the force on the electron due to the electric field is 2.24×10^{-15} N.

[2]

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(b) The electron accelerates horizontally across the space between the plates. Determine

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(i) the horizontal acceleration of the electron,

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acceleration = ... $m s^{-2}$ [2]

(ii) the time to travel the horizontal distance of 2.50 cm between the plates.

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time = ... s [2]

(c) Explain why gravitational effects on the electron need not be taken into consideration in your calculation in **(b)**.

....

....

.... [2]

14 Two parallel plates P and Q are separated by a distance of 7.6 mm in a vacuum. There is a potential difference of 250 V between the plates, as illustrated in Fig. 4.1.

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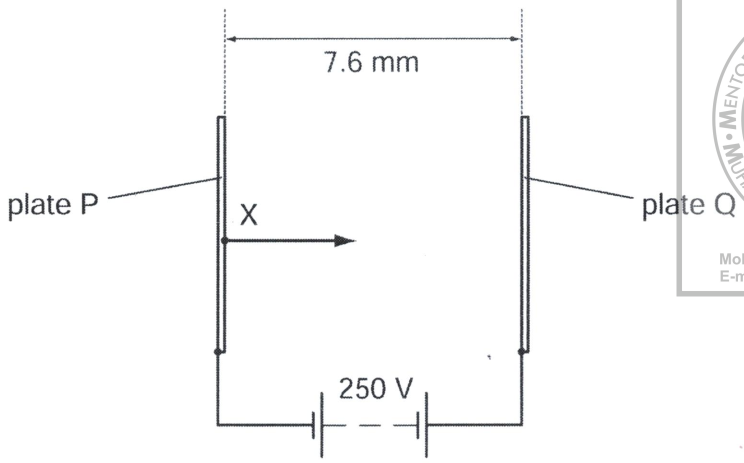

Fig. 4.1

Electrons are produced at X on plate P. These electrons accelerate from rest and travel to plate Q.
The electric field between the plates may be assumed to be uniform.

(a) **(i)** Determine the force on an electron due to the electric field.

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force = ... N [3]

(ii) Show that the change in kinetic energy of an electron as it moves from plate P to plate Q is 4.0×10^{-17} J.

[2]

(iii) Determine the speed of an electron as it reaches plate Q.

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speed = ... $m\,s^{-1}$ [2]

(b) The positions of the plates are adjusted so that the electric field between them is not uniform. The potential difference remains unchanged.
State and explain the effect, if any, of this adjustment on the speed of an electron as it reaches plate Q.

....

....

....

.... [3]

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15 Two large flat metal plates A and B are placed 9.0 cm apart in a vacuum, as illustrated in Fig. 5.1.

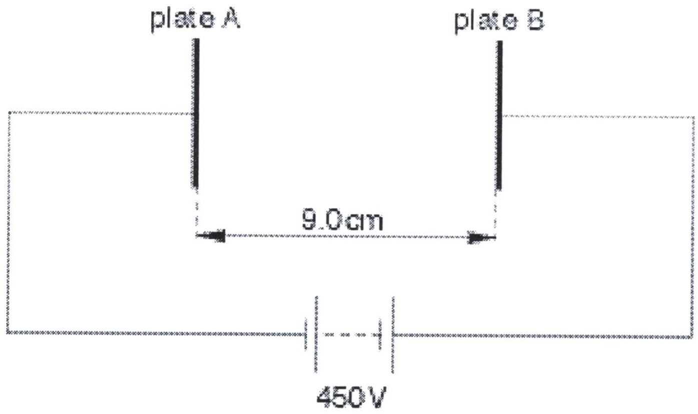

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Fig. 5.1

A potential difference of 450 V is maintained between the plates by means of a battery.

(a) **(i)** On Fig. 5.1, draw an arrow to indicate the direction of the electric field between plates A and B.

(ii) Calculate the electric field strength between A and B.

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field strength = ... N C^{-1} [3]

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(b) An electron is released from rest at the surface of plate A.

(i) Show that the change in electric potential energy in moving from plate A to plate B is 7.2×10^{-17} J.

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(ii) Determine the speed of the electron on reaching plate B.

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speed = ... m s^{-1} [4]

(c) On the axes of Fig. 5.2, sketch a graph to show the variation with distance d from plate A of the speed v of the electron. [1]

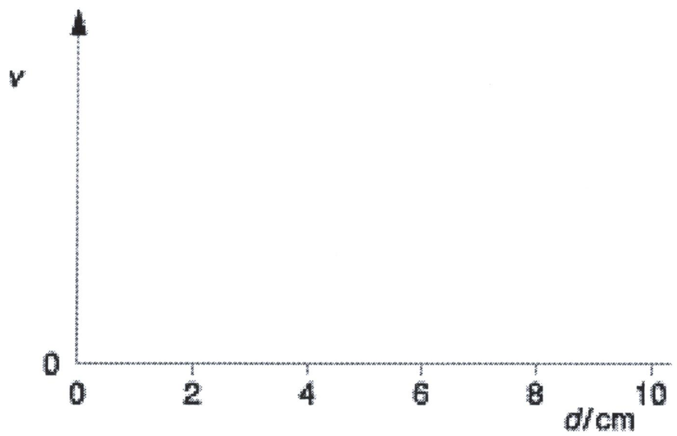

Fig. 5.2

6 Two parallel metal plates P and Q are situated 8.0 cm apart in air, as shown in Fig. 6.1.

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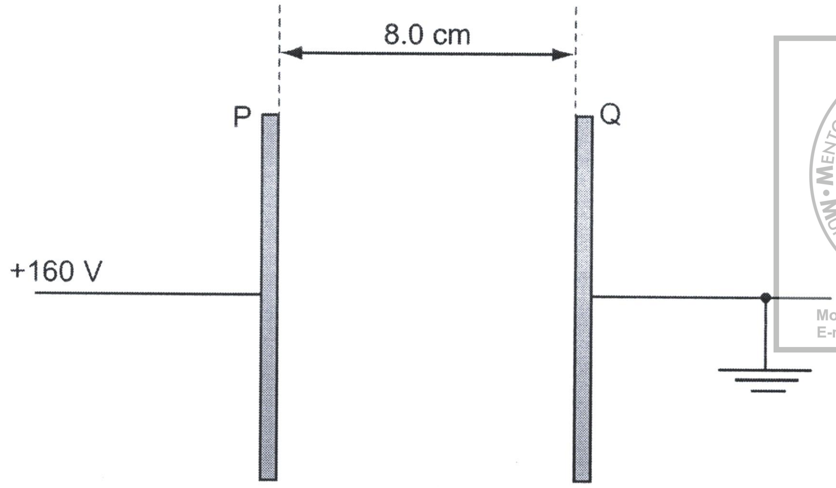

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Fig. 6.1

Plate Q is earthed and plate P is maintained at a potential of +160 V.

(a) **(i)** On Fig. 6.1, draw lines to represent the electric field in the region between the plates. [2]

(ii) Show that the magnitude of the electric field between the plates is $2.0 \times 10^3\,V\,m^{-1}$.

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[1]

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(b) A dust particle is suspended in the air between the plates. The particle has charges of $+1.2 \times 10^{-15}$ C and -1.2×10^{-15} C near its ends. The charges may be considered to be point charges separated by a distance of 2.5 mm, as shown in Fig. 6.2.

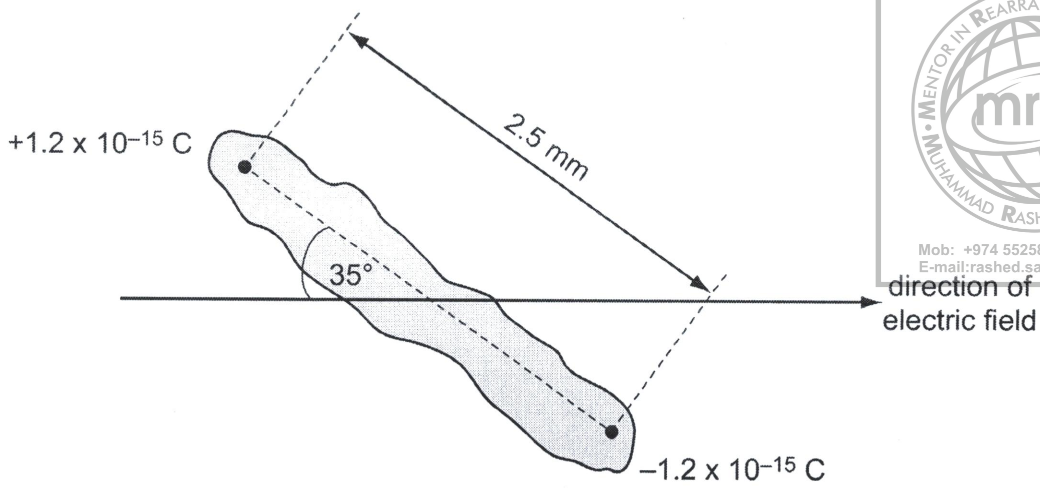

Fig. 6.2

The particle makes an angle of 35° with the direction of the electric field.

(i) On Fig. 6.2, draw arrows to show the direction of the force on each charge due to the electric field. [1]

(ii) Calculate the magnitude of the force on each charge due to the electric field.

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force = ... N [2]

(iii) Determine the magnitude of the couple acting on the particle.

couple = ... N m [2]

(iv) Suggest the subsequent motion of the particle in the electric field.

....

....

....[2]

17 **(a)** State what is meant by an *electric field*.

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....

....[1]

(b) The electric field between an earthed metal plate and two charged metal spheres is illustrated in Fig. 5.1.

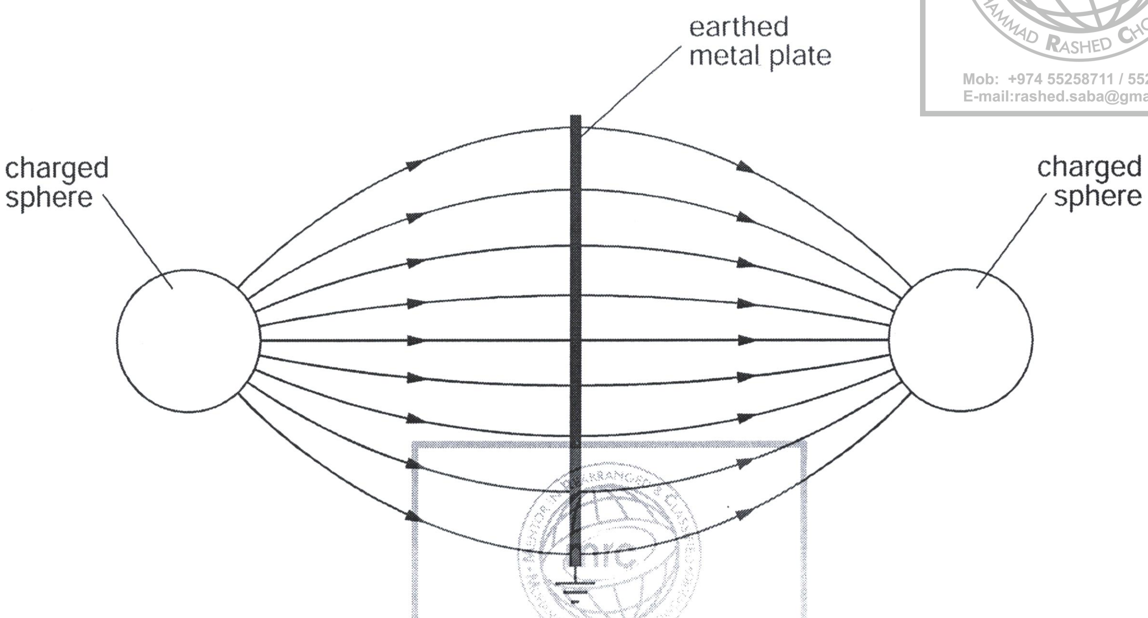

Fig. 5.1

(i) On Fig. 5.1, label each sphere with (+) or (–) to show its charge. [1]

(ii) On Fig. 5.1, mark a region where the magnitude of the electric field is

1. constant (label this region C), [1]

2. decreasing (label this region D). [1]

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(c) A molecule has its centre P of positive charge situated a distance of 2.8×10^{-10} m from its centre N of negative charge, as illustrated in Fig. 5.2.

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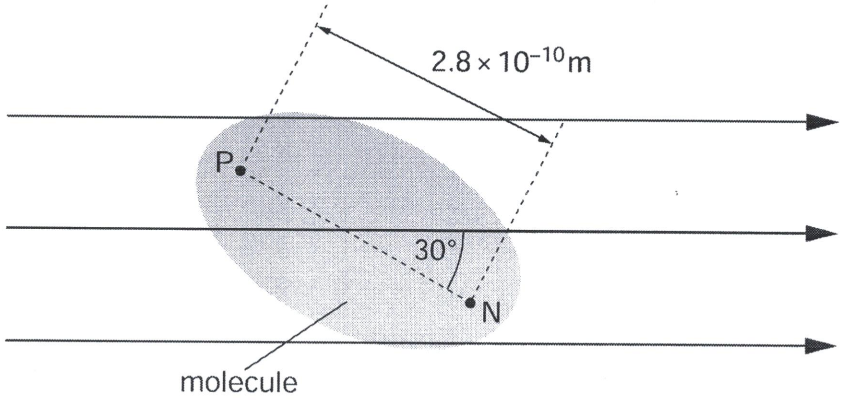

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Fig. 5.2

The molecule is situated in a uniform electric field of field strength 5.0×10^4 V m^{-1}. The axis NP of the molecule is at an angle of 30° to this uniform applied electric field. The magnitude of the charge at P and at N is 1.6×10^{-19} C.

(i) On Fig. 5.2, draw an arrow at P and an arrow at N to show the directions of the forces due to the applied electric field at each of these points. [1]

(ii) Calculate the torque on the molecule produced by the forces in **(i)**.

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torque = ... N m [2]

18 (a) Define *electric field strength.*

....

....[1]

(b) An electron is accelerated from point A to point B by a uniform electric field, as illustrated in Fig. 3.1.

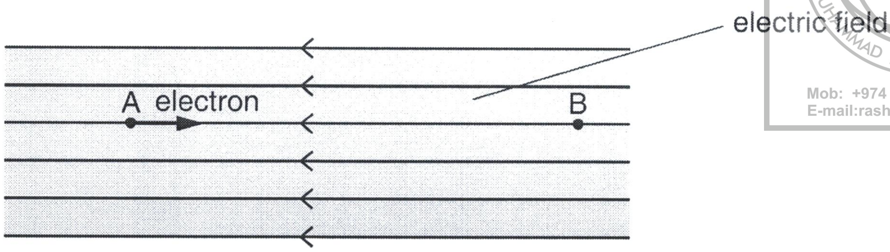

Fig. 3.1

The distance between A and B is 12 mm. The velocity of the electron at A is $2.5\,\text{km s}^{-1}$ and at B is $18\,\text{Mm s}^{-1}$.

Calculate

(i) the acceleration of the electron,

acceleration = ... m s^{-2} [2]

(ii) the change in kinetic energy of the electron,

change in kinetic energy = ... J [3]

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(iii) the electric field strength.

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electric field strength = ... $V\,m^{-1}$ [3]

(c) An α-particle moves from A to B in the electric field in **(b)**.

Describe and explain how the change in the kinetic energy of the α-particle compares with that of the electron. Numerical values are not required.

....

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....

....

....[3]

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