1 **(a) (i)** Define *electric field strength* at a point.

.....

..... [1]

(ii) State the relationship between electric field strength at a point and electric potential at the point.

.....

..... [1]

(b) Two point charges A and B are separated by a distance of 7.0 cm in a vacuum, as illustrated in Fig. 3.1.

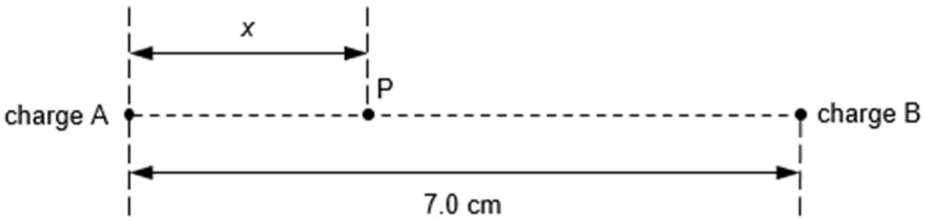

Fig. 3.1

The charge of A is -2.0×10^{-9} C.

A point P lies on the line joining charges A and B. Its distance from charge A is x.

1 The variation with distance x of the electric potential V at point P is shown in Fig. 3.2.

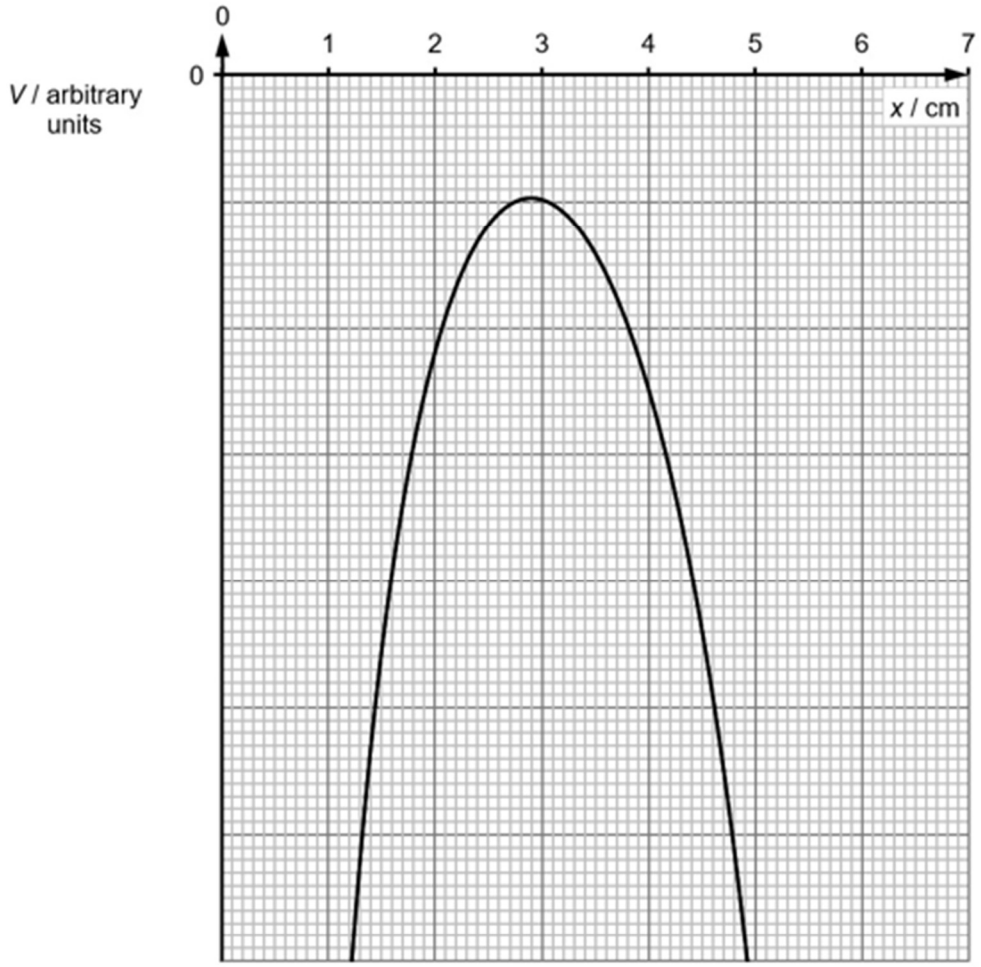

Fig. 3.2

(i) State the value of x where V is a maximum.

x = ... cm [1]

1

(ii) Hence, determine the charge of B.

charge = ... C [3]

(iii) An electron is initially at rest at point P where x = 2.0 cm.

Describe the subsequent motion of the electron.

.....

.....

.....

.....

..... [3]

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

.....

..... [1]

(b) An electron is travelling in a straight line through a vacuum with a constant speed of 1.5×10^7 m s^{-1}. The electron enters a uniform electric field at point A, as shown in Fig. 6.1.

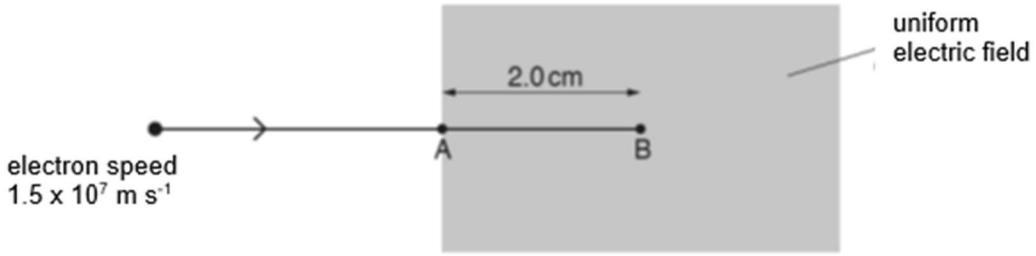

Fig. 6.1

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.

(i) State the direction of the electric field.

.....[1]

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

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

(iii) Calculate the electric field strength of the uniform electric field.

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

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

2 On Fig. 6.2, 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.

[1]

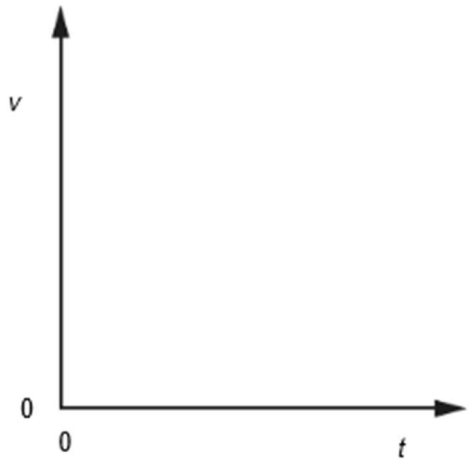

Fig. 6.2

3 **(a)** Fig. 6.1 shows an electron in an electric field, in a vacuum, at an instant when the electron is stationary.

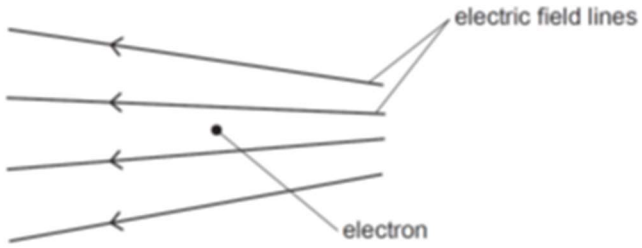

Fig. 6.1

(i) On Fig. 6.1, draw an arrow to show the direction of the electric force acting on the stationary electron. [1]

(ii) The electric field causes the electron to move from its initial position.

Describe and explain the acceleration of the electron due to the field, as the electron moves through the field.

.....

.....

..... [2]

(iii) A stationary proton is now placed in the same electric field at the same initial position that was occupied by the electron.

Compare the initial electric force acting on the proton with the initial electric force that acted on the electron.

.....

.....

.....

..... [2]

3 **(b)** Two point charges A and B are separated by a distance of 12.0 cm in a vacuum, as illustrated in Fig. 6.2.

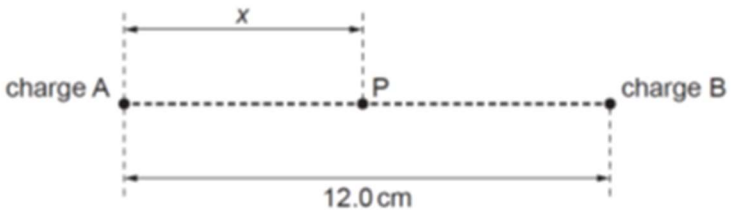

Fig. 6.2

The charge of A is $+2.0 \times 10^{-9}$ C.

A point P lies on the line joining charges A and B. Its distance from charge A is x.

The variation with distance x of the electric potential V at point P is shown in Fig. 6.3.

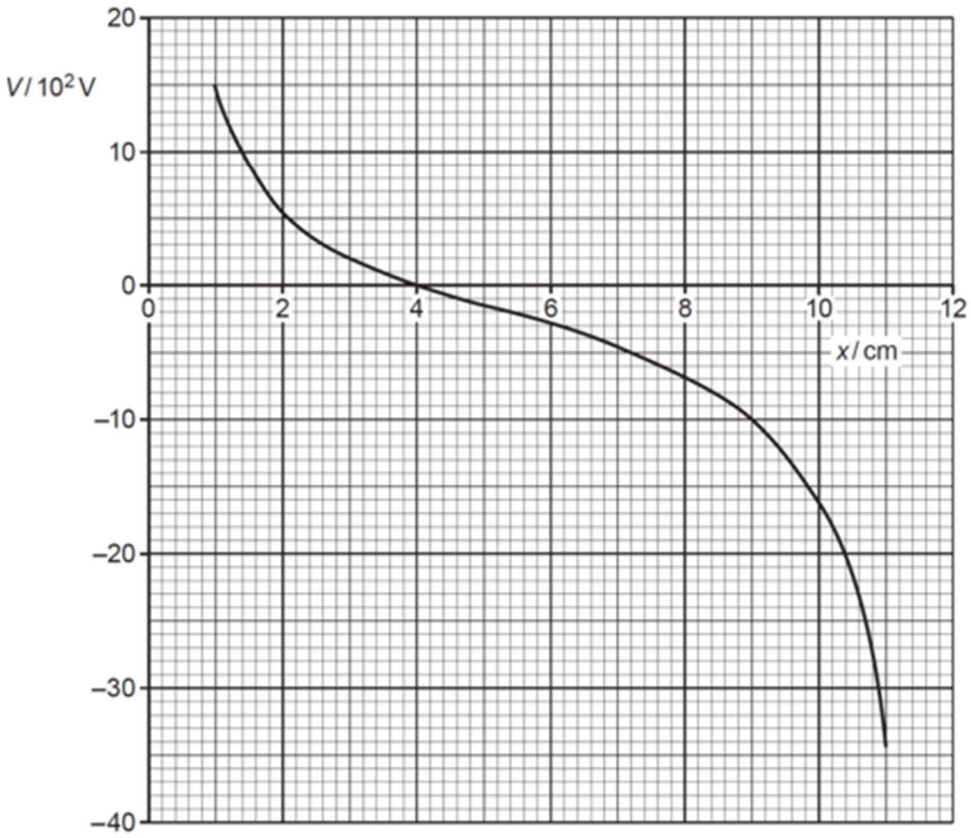

Fig. 6.3

3 **(i)** A proton moves along the line joining point charges A and B in Fig. 6.2.

The proton moves from the position where x = 9.0 cm and just reaches the position where x = 3.0 cm.

Calculate the speed v of the proton at the position where x = 9.0 cm.

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

(ii) State and explain the value of x where the proton experiences the smallest electric force.

.....

.....

..... [2]

[Total: 10]

4 **(a)** **(i)** Define *electric field strength*.

.....

.....

..... [1]

(ii) Fig. 4.1 shows a charge $+q$ at point X in a uniform electric field of electric field strength E.

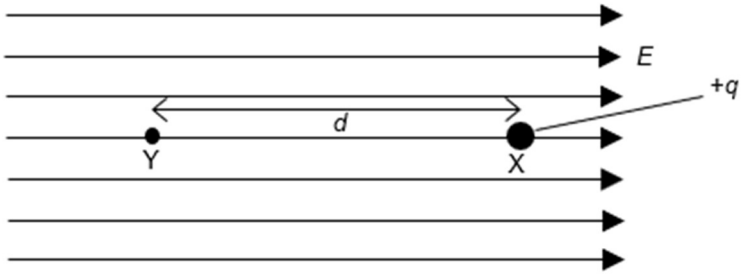

Fig. 4.1

The charge at point X is moved to point Y through a distance d. Using your answer to **(i)**, deduce an expression for the work done on the charge by the electric force.

work done by electric force = ... [1]

(iii) The potential difference between points X and Y is V. Using your answer from **(ii)**, deduce an expression for V in terms of E and d.

V = ... [1]

(iv) Draw a line in Fig. 4.1 joining points which are at the same electric potential as point X. [1]

(v) Between X and Y, state the point which is at a higher electric potential.

..... [1]

4 **(b)** In the vacuum of an X-ray tube, electrons are accelerated from rest through a potential difference of 10 kV between the cathode and the anode.

Calculate

(i) the speed of electrons arriving at the anode.

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

(ii) the minimum wavelength X-rays that are produced.

minimum wavelength = ... m [2]

[Total: 9]

5 In an adapted version of the Millikan's oil-drop experiment, oil drops are injected at 1.5 m s^{-1} horizontally into a vacuum chamber between two parallel plates, as shown in Fig. 4.1. The plates are 60 mm long and 20 mm apart.

The potential difference between the plates is adjusted so that the oil drops travel horizontally between the two plates.

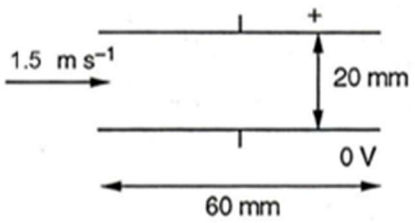

Fig. 4.1

(a) For an oil drop of mass 2.0×10^{-14} kg, carrying a charge of -7.85×10^{-18} C, calculate the potential difference ΔV between the two plates.

ΔV = ... V [3]

(b) The potential difference is now increased to two times the original value.

(i) Explain whether the time taken for the oil drop to pass through the plates is affected by this change.

.....

.....

.....

..... [2]

5 **(ii)** Hence show that the oil drop emerges from the plates at a speed of 1.55 m s^{-1}.

[3]

6 **(a)** State Coulomb's law.

.....

.....

..... [1]

(b) Two charged metal spheres A and B are situated in a vacuum, as illustrated in Fig. 5.1.

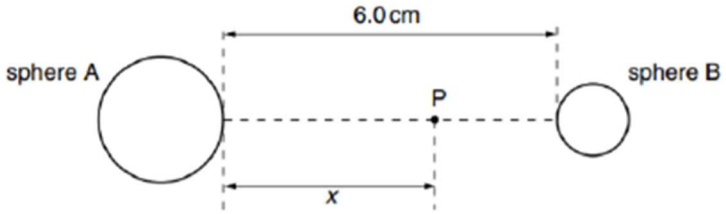

Fig. 5.1

The shortest distance between the surfaces of the spheres is 6.0 cm.

A movable point P lies along the line joining the centres of the two spheres, a distance x from the surface of sphere A.

The variation with distance x of the electric field E at point P is shown in Fig. 5.2.

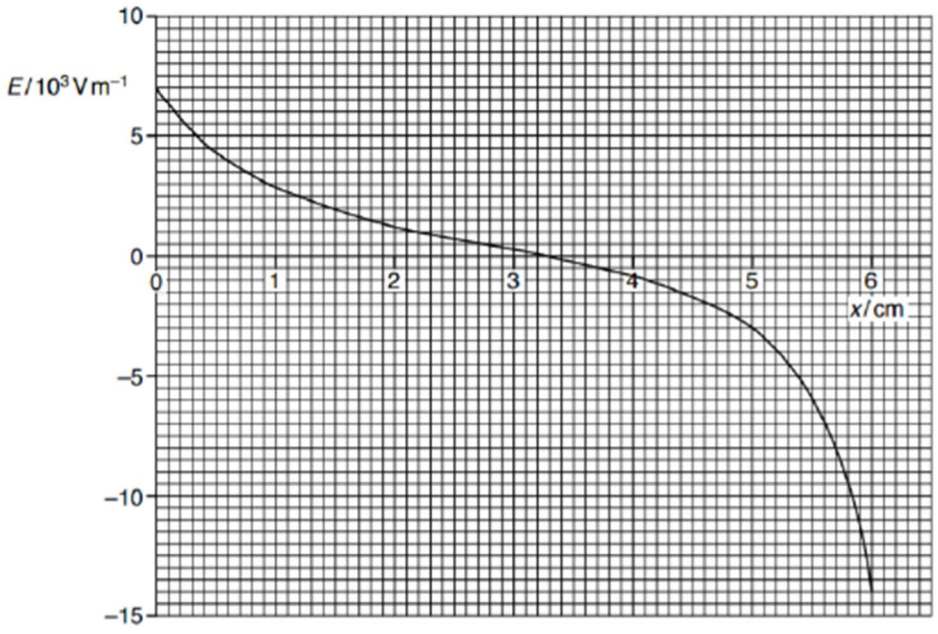

Fig. 5.2

6 **(i)** Use Fig. 5.2 to explain whether the two spheres have charges of the same, or opposite sign.

.....

.....

.....

..... [2]

(ii) A proton is at rest at point P where x = 5.0 cm.

1. Use data from Fig. 5.2 to determine the magnitude of the acceleration of the proton.

acceleration = ... m s^{-2} [3]

2. Use data from Fig. 5.2 to estimate the speed of the proton at x = 3.3 cm.

maximum speed = ... m s^{-1} [3]

[Total: 9]

7 An isolated spherical conductor has charge q, as shown in Fig 5.1.

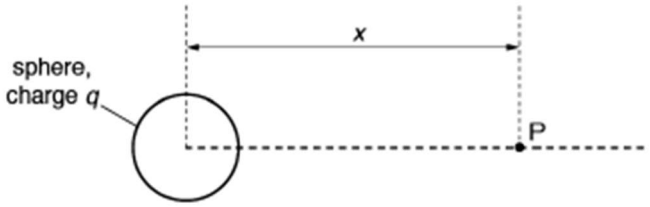

Fig. 5.1

Point P is a movable point with a distance of x from the centre of the sphere. The variation with distance x of the electric potential V at a point P due to the charges on the sphere is shown in Fig. 5.2.

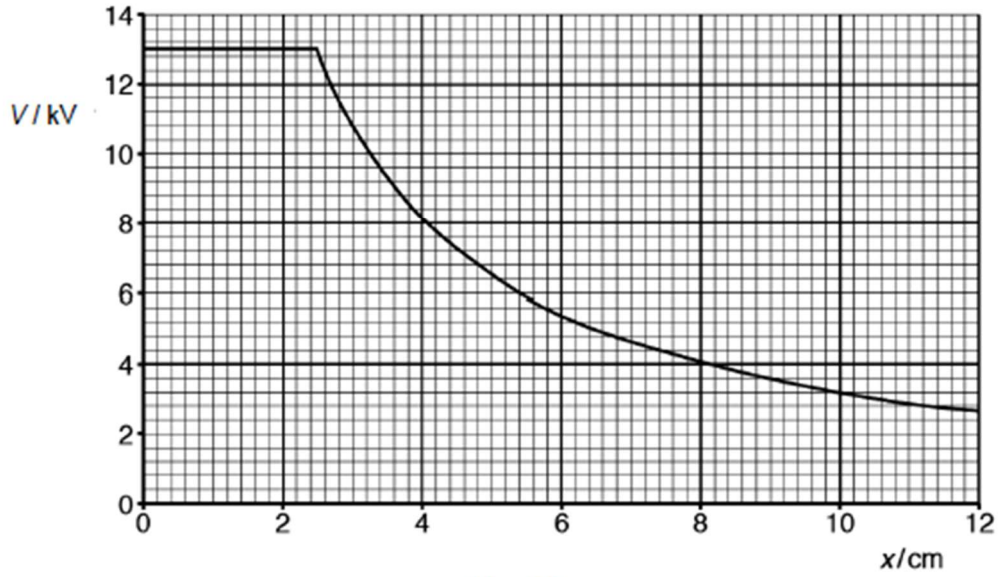

Fig. 5.2

(a) By making reference to the electric field, explain why the potential is constant for $x = 0$ cm to $x = 2.5$ cm.

.....

.....

.....

.....[2]

7

(b) Use Fig. 5.2 to determine the acceleration of a proton at point P where $x = 5.0$ cm.

acceleration = ... m s^{-2} [3]

(c) Describe and explain the variation of the speed of the proton when it moves from $x = 5.0$ cm to $x = 9.0$ cm.

.....

.....

.....

.....[2]

(d) If the proton has a speed of 1.3×10^5 m s^{-1} initially at $x = 5.0$ cm, calculate the speed of the proton when it is at $x = 9.0$ cm.

speed = ...m s^{-1} [3]

[Total: 10]

8 Fig. 5.1 shows two small metal spheres X and Y each weighing 1.5×10^{-4} N carrying a charge of –3.2 nC and –1.6 nC respectively. Sphere X is fixed at its position while sphere Y is suspended from an insulating string that is attached to a fixed point P.

An external force *F* is applied on sphere Y in the direction shown. Sphere Y settles at equilibrium where the string makes an angle of 10° with the vertical and the centre of the two spheres are separated by a horizontal distance 0.050 m. The line joining the centres of X and Y is horizontal.

The diameter of each of the spheres is negligible compared to the separation between them.

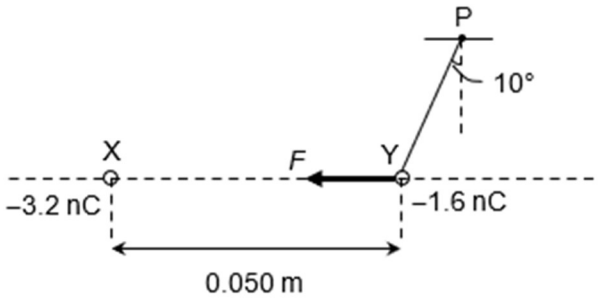

Fig. 5.1 (not to scale)

(a) (i) Calculate the electric force acting on sphere Y.

electric force = _____ N [2]

(ii) Calculate the magnitude of *F*.

F = _____ N [3]

8 **(a)** **(iii)** State and explain whether your answer in **(a)(ii)** would be larger, smaller or unchanged if the diameter of each of the spheres is no longer negligible compared to the separation of the spheres.
Assume that the weight of the spheres remains unchanged.

.....

.....

.....

..... [2]

(b) The force *F* is now removed. Sphere Y swings downwards and moves past point Q, which is located vertically below point P as shown in Fig. 5.2.

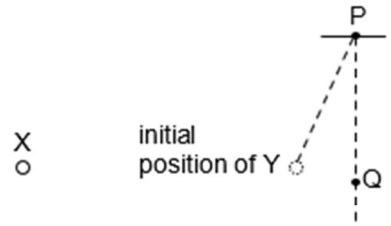

Fig. 5.2 (not to scale)

Explain why the gain in kinetic energy of sphere Y is **not** equal to the loss in gravitational potential energy as it moves from its initial position to Q.

.....

..... [1]

9 **(a)** Define the electric potential at a point in an electric field.

.....

.....

.....

..... [2]

(b) Fig. 4.1 shows part of the region between two charges of the same magnitude but opposite sign.

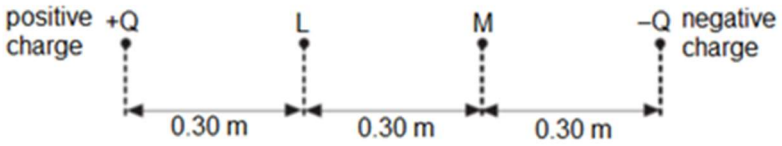

Fig. 4.1

(i) The electric potential at point **L** due to the positive charge **only** is +3.0 V.

Calculate the magnitude Q of the positive charge.

Q = ... nC [1]

(ii) Hence or otherwise, calculate the **net** electric potential at point **L**.

net electric potential = ... V [2]

(iii) Calculate the **resultant** electric field strength at point **M**.

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

9

(c) R and S are two charged parallel plates, 0.60 m apart, as shown in Fig. 4.2. They are at potentials of + 3.0 V and + 1.0 V respectively.

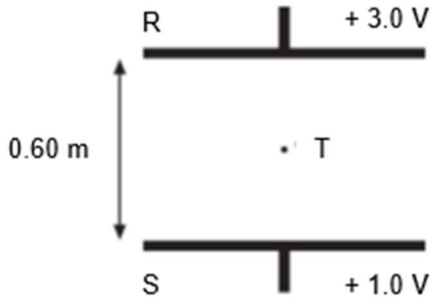

Fig. 4.2

(i) On Fig. 4.2, sketch the electric field between R and S, showing its direction. [1]

(ii) Point **T** is mid-way between R and S.

Calculate the electric field strength at **T**.

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

(iii) A charged oil drop is suspended at point T.
State the sign of the charge and sketch an arrow on Fig. 4.2 showing the direction of the electric force.

sign of charge = ... [1]

10 **(a)** Define *electric potential* at a point.

.....

..... [2]

(b) Two point charges A and B are separated by a distance of 12.0cm in a vacuum, as illustrated in Fig. 4.1.

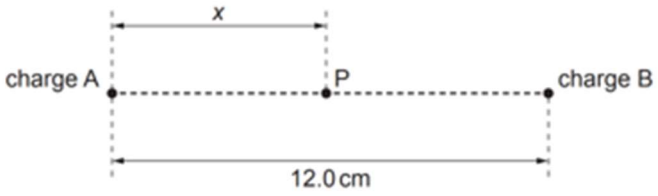

Fig. 4.1

The charge of A is $+2.0 \times 10^{-9}$ C.

A point P lies on the line joining charges A and B. Its distance from charge A is x.

The variation with distance x of the electric potential V at point P is shown in Fig. 4.2.

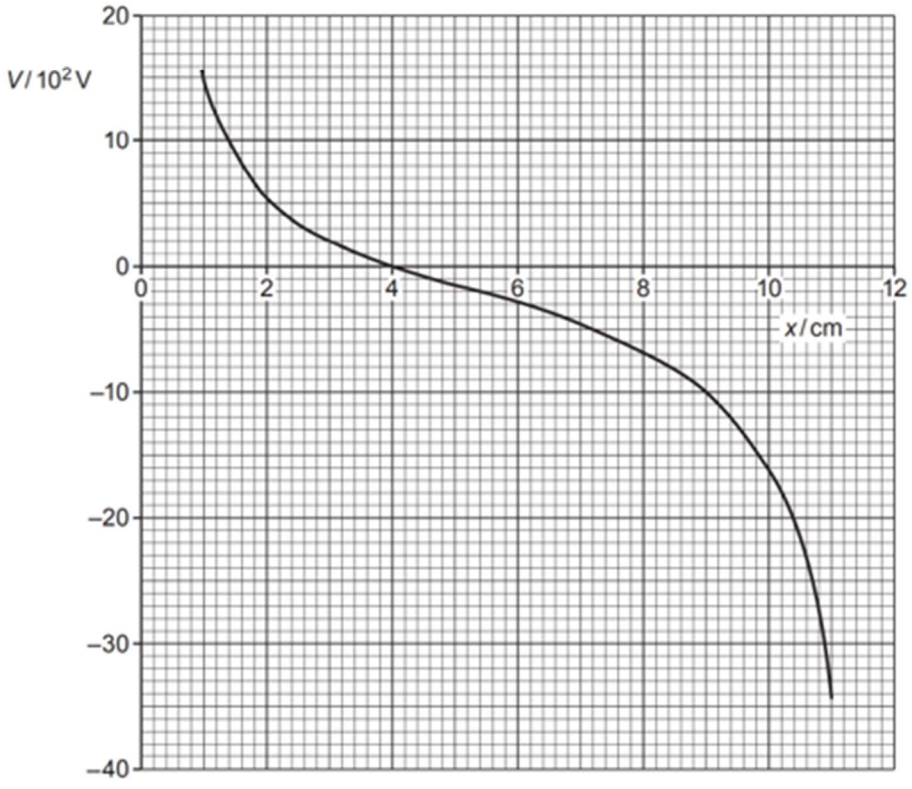

Fig. 4.2

10 **(i)** Using Fig. 4.2, determine the charge of B.

charge = ... C [2]

(ii) An alpha-particle (mass $4u$, charge $+2e$) moves along the line joining point charges A and B in Fig. 4.1.

The alpha-particle moves from the position where $x = 9.0$ cm and just reaches the position where $x = 3.0$ cm.

Calculate the speed v of the alpha-particle at the position where $x = 9.0$ cm.

v = ... m s^{-1} [2]

(c) **(i)** State what is meant by an *electric field*.

.....

..... [1]

(ii) State one similarity and one differences between an electric field due to a point charge and the gravitational field due to a point mass.

similarity: .....

.....

.....

difference: .....

.....

.....

[2]

10 **(d)** An isolated solid metal sphere of radius 0.15m is situated in a vacuum, as illustrated in Fig. 4.3.

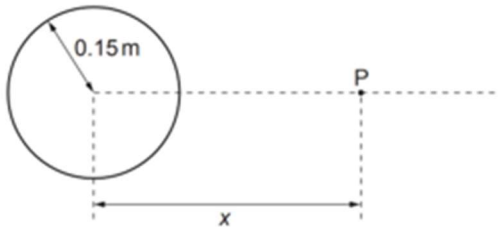

Fig. 4.3

The electric field strength at the surface of the sphere is 84 V m^{-1}.

Determine:

(i) the charge Q on the sphere

charge = ... C [1]

(ii) the electric field strength at a distance 0.10 m from the centre of the sphere.

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

11 **(a)** Define *electric potential* at a point.

.....

.....

..... [1]

(b) Two spherical conductors of radii r_1 and r_2 are separated by a distance *much larger* than the radius of either sphere. Initially, the charges on the spheres are q_1 and q_2 and the potentials are V_1 and V_2 respectively, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The spheres are then connected by a conducting wire as shown in Fig. 3.2.

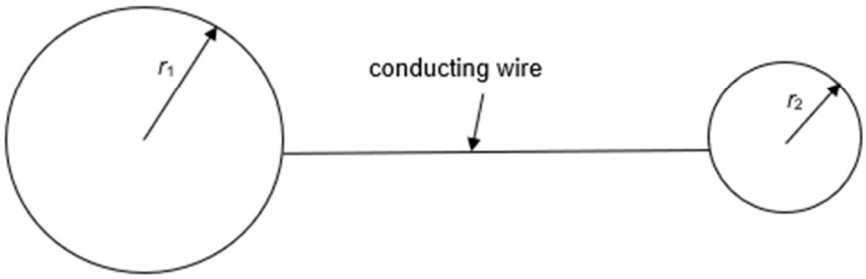

Fig. 3.2 (not to scale)

(i) State and explain what happen to the potentials of the spheres upon connecting them with the conducting wire.

.....

.....

.....

.....

..... [2]

11 **(ii)** Derive an expression for the electric potential V at the surface of the larger sphere, after the wire is connected, in terms of V_1, V_2, r_1 and r_2.

State one assumption made in your derivation.

Assumption:

.....

..... [3]

(c) Three identical small spheres A, B and C, each carrying equal charge $+q$, are connected to three light non-conducting strings as shown in Fig. 3.3. Spheres A and C are deflected at the same angle θ with the vertical and the length of the strings connected to both spheres is L.

The three spheres lie on the same horizontal axis.

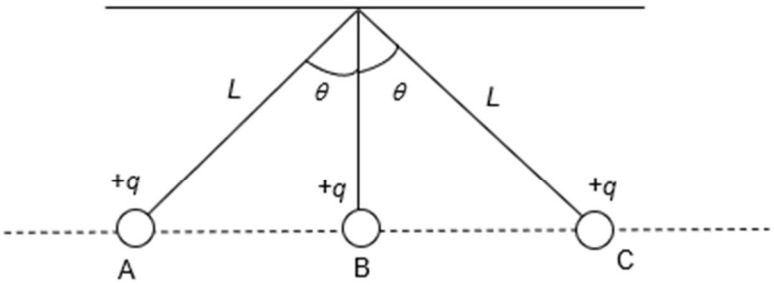

Fig. 3.3 (not to scale)

(i) Write down an expression for the electric force F acting on A in terms of q, θ and L.

[2]

11 **(ii)** Derive an expression for the tension T in the string supporting A in terms of q, θ and L.

[2]

(iii) The charge on sphere B is increased. State the change, if any, in the positions of each of the spheres immediately after.

.....

.....

.....

.....

.....

..... [2]

[Total: 12]

12 **Fig. 5.1** shows the top view of two large, parallel metal plates P and Q. The plates are placed 10.0 cm apart in vacuum, with P at a potential of +12.0 V and Q at −12.0 V. Each plate has a length of 15.0 cm.

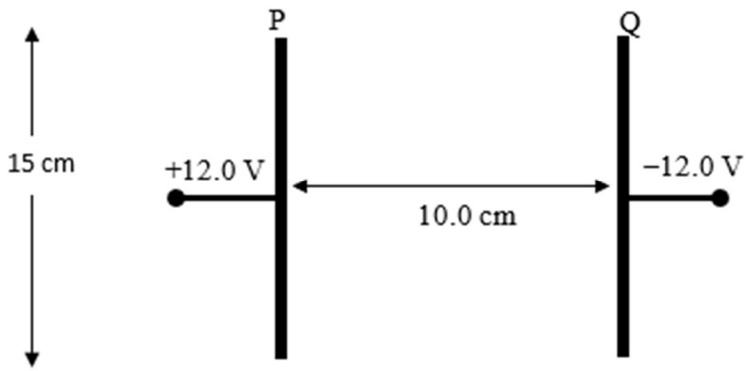

Fig. 5.1 (plan view)

(a) Draw, on **Fig. 5.1**, at least five arrows to represent the electric field inside the plates. [1]

(b) A beam of electrons enters the field along a horizontal path, parallel to the plates and equidistant to the plates as shown in **Fig. 5.2**. Each electron has a velocity of 4.5×10^6 m s^{-1}.

(i) Show quantitatively that the electrons would clear the plates.

[4]

12

(ii) Sketch on **Fig. 5.2** the path of the electron beam between and beyond the plates. State an assumption made in drawing the path.

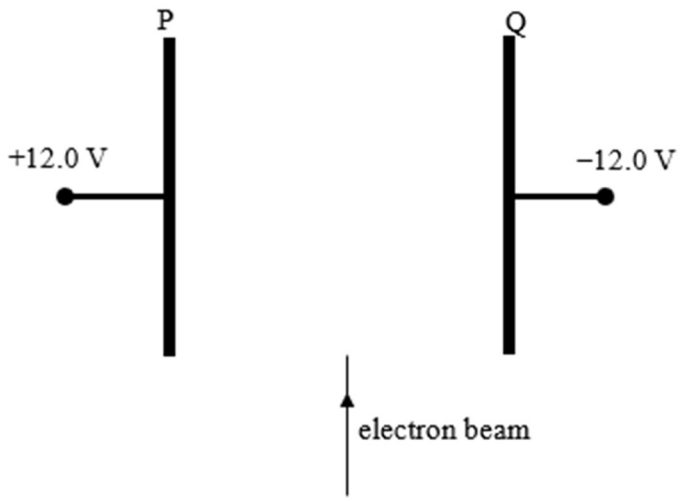

Fig. 5.2 (plan view)

Assumption: .....

.....[3]

(c) If a beam of protons were to enter the plates with the same velocity as the electrons in **Fig. 5.2,** state and explain whether they can clear the plates.

.....

.....

.....

.....

.....

..... [2]