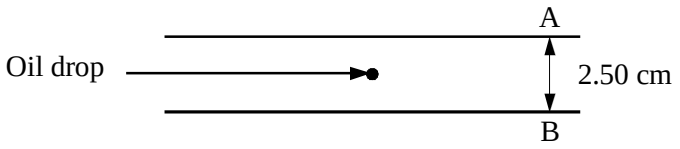
Questions on Electric Fields

1. The diagram shows a positively charged oil drop held at rest between two parallel conducting plates A and B.



The oil drop has a mass 9.79 x 10^{-15} kg. The potential difference between the plates is 5000 V and plate B is at a potential of 0 V. Is plate A positive or negative?

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Draw a labelled free-body force diagram which shows the forces acting on the oil drop. (You may ignore upthrust).

(3)

Calculate the electric field strength between the plates.

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Electric field strength =……

(2)

Calculate the magnitude of the charge Q on the oil drop.

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Charge =……

How many electrons would have to be removed from a neutral oil drop for it to acquire this charge?

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(3)

(Total 8 marks)

2. A beam of electrons is directed at a target. They are accelerated from rest through 12 cm in a uniform electric field of strength 7.5×10^5 N C^{-1}.

Calculate the potential difference through which the electrons are accelerated.

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Potential difference = ...

Calculate the maximum kinetic energy in joules of one of these electrons.

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Maximum kinetic energy = ...

(4)

Calculate the maximum speed of one of these electrons.

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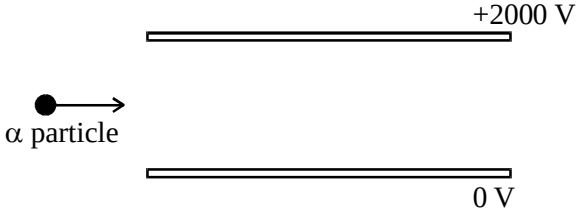
Maximum speed = ...

(2)

Draw a diagram to represent the electric field close to an isolated electron.

(2)
(Total 8 marks)

3. The diagram shows a high-speed alpha particle entering the space between two charged plates in a vacuum.



Add to the diagram the subsequent path of the alpha particle as it passes between the plates and well beyond them.

(3)

The gap between the plates is 10 mm. Calculate the magnitude of the electric force on the alpha particle as it passes between the plates.

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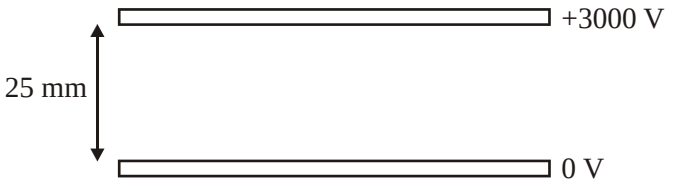
Electric force = ...

(3)

(Total 6 marks)

4. The diagram shows two parallel plates with a potential difference of 3000 V applied across them. The plates are in a vacuum.



On the diagram sketch the electric field pattern in the region between the plates.

(2)

On the same diagram sketch and label two equipotential lines.

(1)

The plates are 25 mm apart. Show that the force experienced by an electron just above the bottom plate is about 2×10^{-14} N.

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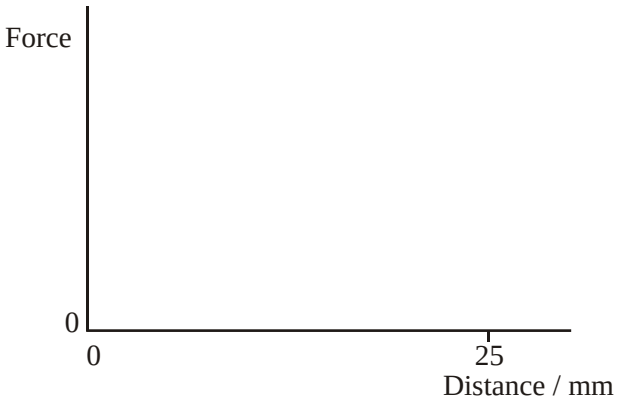
(3)

Complete the graph to show how the force on the electron varies with the distance of the electron from the bottom plate.



(2)

This force causes the electron to accelerate.

The electron is initially at rest in contact with the bottom plate when the potential difference is applied. Calculate its speed as it reaches the upper plate.

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Speed = ...

(3)

(Total 11 marks)

5. An acetate rod is rubbed with a duster. The rod becomes positively charged.

Describe what happens during this process.

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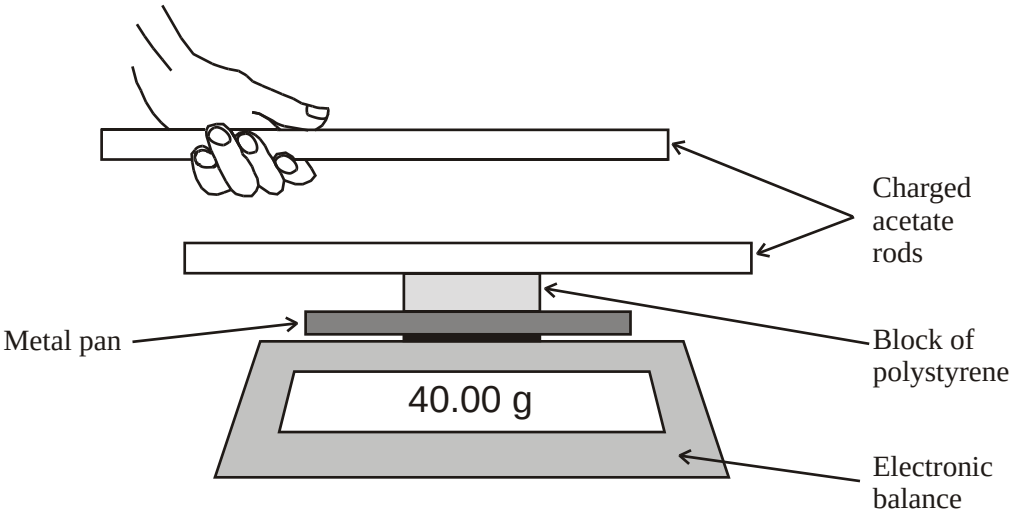
(2)

The rod is then lowered, at constant speed, towards another positively charged rod that rests on an electronic balance.



Explain why it is necessary to have the block of polystyrene beneath the bottom rod.

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(2)

Describe and explain what would happen to the reading on the balance as the top rod slowly approaches, and comes **very close** to, the bottom rod. You may be awarded a mark for the clarity of your answer.

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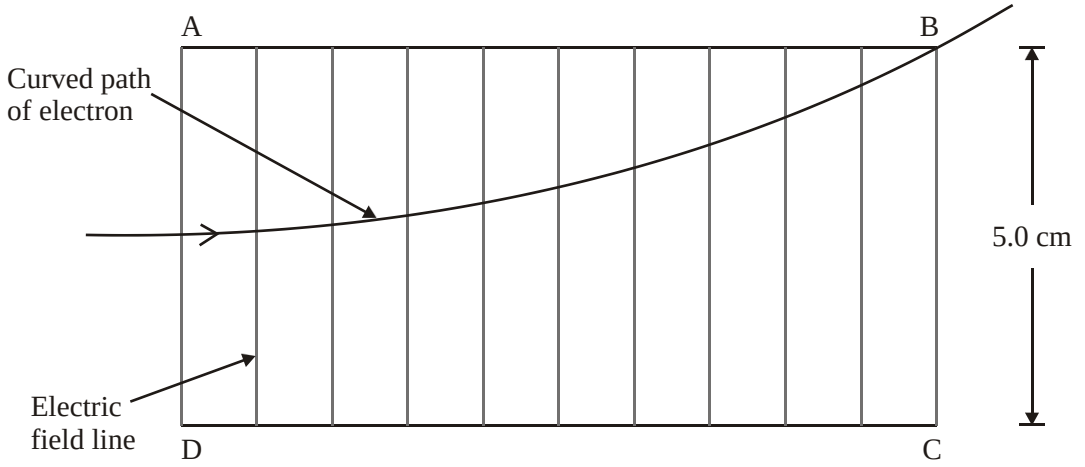
(4)
(Total 8 marks)

6. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates AB and CD. The electron enters the field at a point midway between A and D. It leaves the field at B.



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

(1)

(b) (i) The conducting plates are 5.0 cm apart and have a potential difference of 250 V between them. Calculate the force on the electron due to the electric field.

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Force = ...

(3)

(ii) State the direction of this force on the electron and explain why it does not affect the horizontal velocity of the electron.

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(2)

(c) To leave the electric field at B the electron must enter the field with a speed of 1.30×10^7 m s^{-1}. Calculate the potential difference required to accelerate an electron from rest to this speed.

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Potential difference = ...

(3)

(d) A very thin beam of electrons enters a uniform electric field at right angles to the field. The electrons have a range of speeds.

(i) Draw a diagram to show the shape of the beam as it moves through the field.

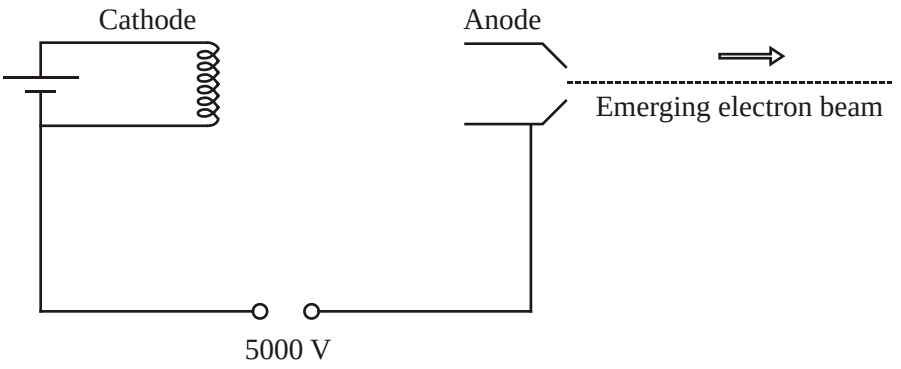
(ii) On your diagram label which electrons have the fastest speed.

(2)

(Total 11 marks)

7. Electrons are accelerated from rest from the cathode to the anode of a vacuum tube through a potential difference of 5000 V.

Figure 1



(a) Show that the speed v of an electron as it leaves the anode is approximately 4×10^7 m s^{-1}.

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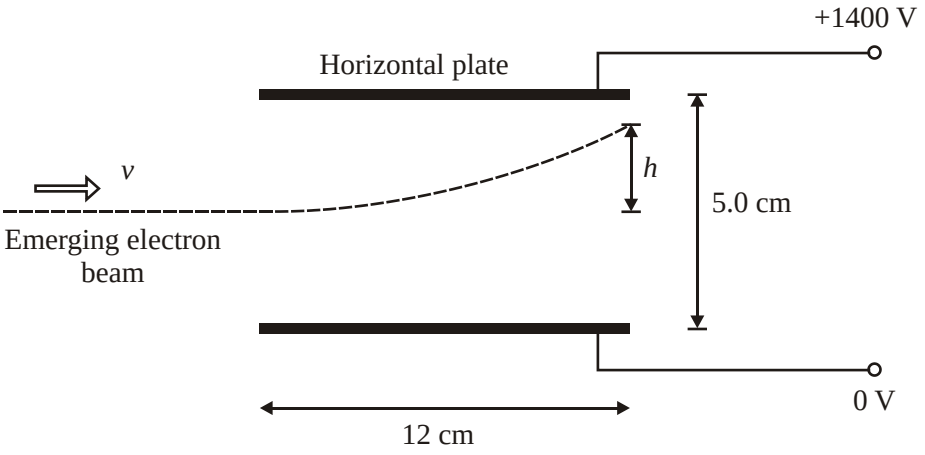
(3)

(b) The emerging beam of electrons follows a parabolic path as it passes between a pair of horizontal parallel plates 5.0 cm apart with a potential difference of 1400 V between them.

Figure 2



(i) Calculate the strength E of the uniform electric field between the horizontal plates.

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E = ...

(1)

(ii) Hence determine the force F exerted by this field on each electron.

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F = ...

(1)

(c) An electron experiences an upward acceleration a as it travels between the plates. Its vertical displacement h after a time t is given by

$$h = \frac{1}{2}at^2$$

Calculate the value of h as the electron leaves the plates.

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h = ...

(4)

(d) (i) Add to Figure 2 the path that the electron beam would follow if the potential difference between the horizontal plates were decreased. Label this path A.

(1)

(ii) Add to Figure 2 the path that the electron beam would follow if the potential difference between the cathode and the anode were decreased. Label this path B.

(1)

(Total 11 marks)

8. Draw diagrams to represent

(i) the gravitational field near the surface of the Earth,

(ii) the electric field in the region of an isolated negative. point charge.

(4)

How does the electric field strength E vary with distance r from the point charge?

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(1)

Give an example of a region in which you would expect to find a uniform electric field.

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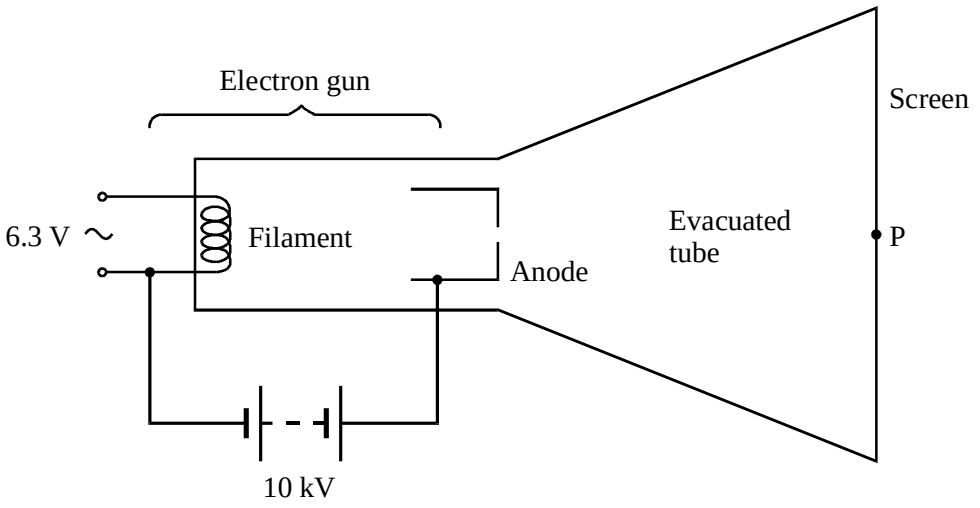
(1)

(Total 6 marks)

9. The diagram is of a simplified cathode ray tube.



An electron beam is produced by the electron gun in the tube. A beam of electrons emerges from the hole in the anode and strikes the screen at point P.

Explain why electrons are emitted from the surface of the filament.

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(2)

Explain why the electrons move from the filament towards the anode.

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(1)

The potential difference between the filament and the anode is 10 kV. Calculate the energy in joules of an electron emerging from the hole in the anode.

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Energy = ... H

(2)

The electron beam forms a current of 1.5 mA. Show that the number of electrons passing through the hole in the anode is about 9×10^{15} per second.

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(2)

Hence calculate the rate at which energy is being delivered to the screen by the beam of electrons.

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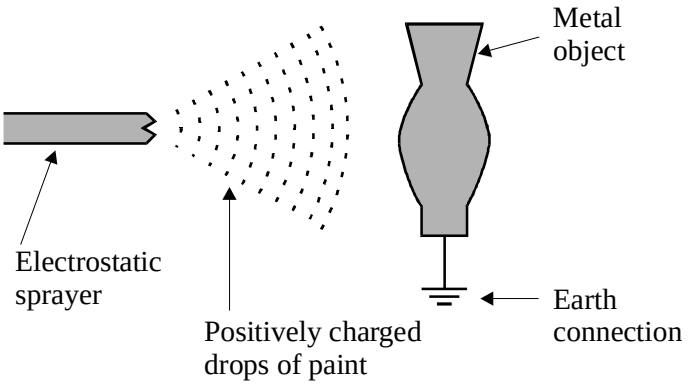
Rate = ...

(2)

(Total 9 marks)

10. The diagram shows an electrostatic paint sprayer, used to obtain a uniform coat of paint on a metal object. The paint drops are charged positively by the sprayer. The metal object is connected to Earth.



Why does using identically charged paint drops help produce an evenly distributed spray of paint?

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(1)

Explain why the positive paint drops are attracted to the metal object.

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(3)

Why does the coat of paint become very patchy if the Earth connection is accidentally broken?

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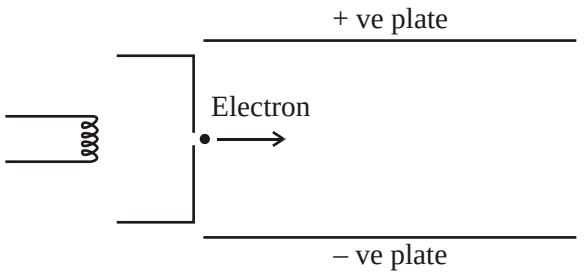
(2)

(Total 6 marks)

11. The diagram below illustrates an experiment with electrons. A beam of electrons is created using an electron gun, and deflected using an electric field.



Explain how the electron gun creates a beam of electrons. Add to the diagram if that will help your explanation.

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(4)

The electrons are accelerated from rest through a potential difference of 340 V. Calculate their speed as they leave the gun.

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Speed = ...

(3)

Explain what is meant by the term **electric field.**

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(1)

The electric field which deflects the beam is created by applying a potential difference of 2500 V across plates 9.0 cm apart. Show that the vertical acceleration of the electrons due to this field is about 5×10^{15} m s^{-2}.

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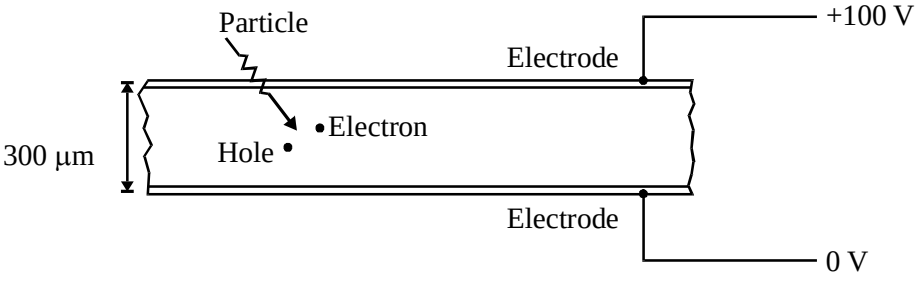
(4)

(Total 12 marks)

12. One type of particle detector at CERN consists of a thin wafer of silicon. On both sides of the wafer are aluminium electrodes, with a voltage of 100 V across them. The electrodes are 300 μm apart. When a particle enters the wafer, it creates an electron/hole pair as shown (a hole acts like a positive electron).



Electric field = ...

(2)

Calculate the force due to this field on an electron in the wafer.

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Force = ...

(2)

Indicate on the diagram the direction of this force on the free electron shown. Explain why the force has this direction.

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(2)

The hole can move in the direction of the electric field, provided that it can gain enough energy from the field to move it from one atom to the next. The distance between atoms is 2.8×10^{-10} m. Calculate how much energy the hole gains in moving this distance in the direction of the field.

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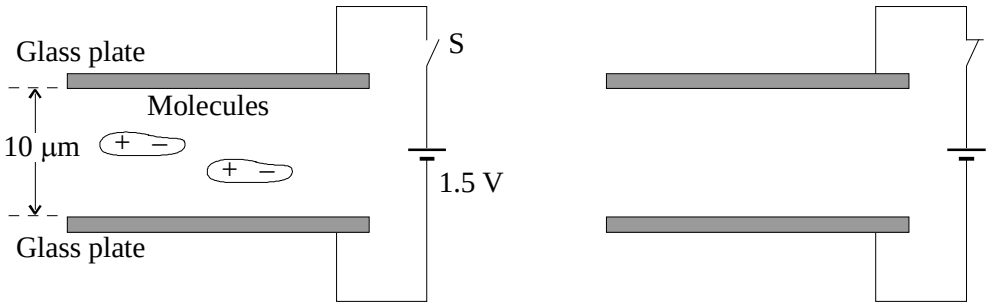
Energy = ...

(2)

(Total 8 marks)

13. Liquid crystal (LC) displays are found in digital watches and calculators. The display is made from two parallel pieces of glass separated by 1.0×10^{-5}m with liquid crystal molecules between them. The glass is coated with conducting material.

The LC molecules have a permanent dipole - that is, they are positive at one end of the molecule and negative at the other. The normal state of these molecules is to be aligned parallel with the glass surfaces as in diagram A. If a voltage of 1.5 V is applied as shown, the molecules align with the electric field.



A B

On diagram A, show the forces acting on the molecule as the switch S is closed.

(1)

Explain why the molecules align with the field.

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(2)

On diagram B, draw field lines to represent the electric field in the central region of the plates.

(2)

Calculate the strength of the electric field.

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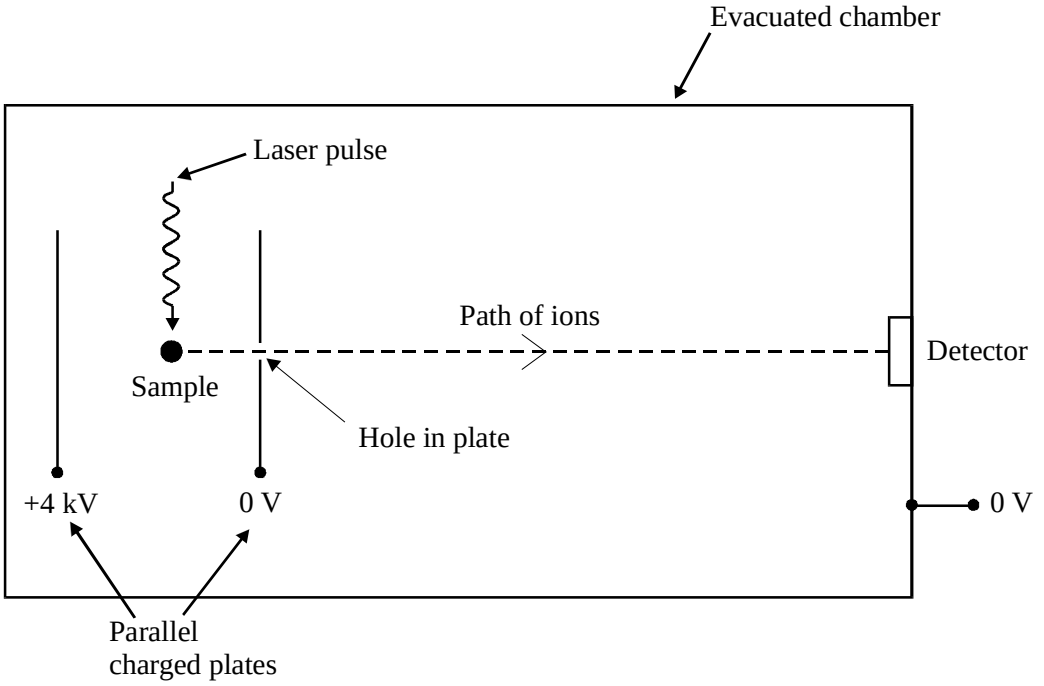
Field strength = ……

(2)
(Total 7 marks)

14. A mass spectrometer is used to determine the relative amounts of ions of different masses in a sample of material.

A diagram of a new type of mass spectrometer is shown below. In this mass spectrometer, a very short pulse of laser light is directed at the sample of material, which becomes ionised. Each ion has a charge of $+1.6 \times 10^{-19}$ C. This happens **mid-way** between a pair of parallel charged plates.

The time the ion takes to reach the detector depends on its mass. Thus the material in the original sample can be analysed.



Describe the movement of an ion from the sample to the detector. Hence explain why the time an ion takes to reach the detector depends on its mass. You should include relevant equations.

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(Total 7 marks)