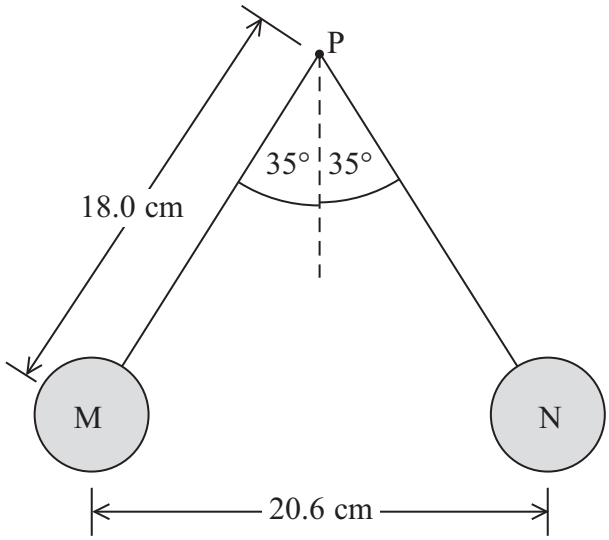
1 Two identical table tennis balls, M and N, are attached to non-conducting threads and suspended from a point P. The balls are each given the same positive charge and they hang as shown in the diagram. The mass of each ball is 2.7 g.



(a) Draw a free-body force diagram for ball M, label your diagram with the names of the forces.

(2)

(b) (i) Show that the tension in one of the threads is about 3×10^{2} N.

(3)

(ii) Show that the electrostatic force between the balls is about 2×10^{2} N.

(2)

(iii) Calculate the charge on each ball.

(3)

Charge .....

(c) State and explain what would have happened if the charge given to ball M was greater than the charge given to ball N.

(2)

(Total for Question 12 marks)

2 (a) Explain what is meant by a uniform electric field.

(2)

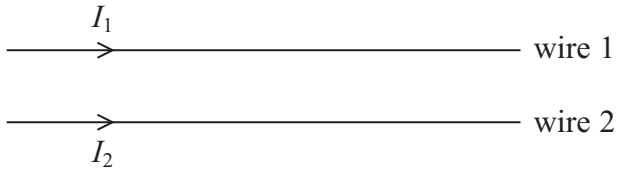
(b) Describe how a uniform electric field can be demonstrated in a laboratory.

(3)

(Total for Question 5 marks)

***3** In 1820 Hans Oersted did an experiment with an electric current in a wire. He noticed that whenever the current was on, it affected a compass needle lying near the wire.

A few years later, André Ampere observed that two parallel wires attract each other if they are carrying current in the same direction.

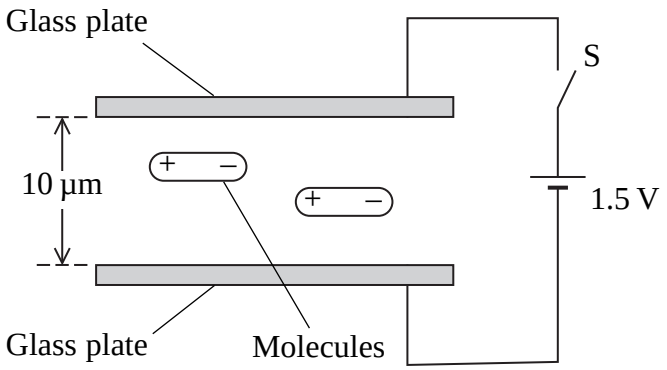


Explain André Ampere's observation. You may wish to add to the diagram.

(5)

(Total for Question 5 marks)

4 Liquid crystal displays (LCDs) are made from two parallel glass plates, 10 μm apart, with liquid crystal molecules between them. The glass is coated with a conducting material.



The molecules are positive at one end and negative at the other. They are normally aligned parallel with the glass plates as shown.

The switch S is closed and 1.5 V is applied across the glass plates.

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

(2)

Electric field strength =

(b) Explain what happens to the liquid crystal molecules.

(3)

(Total for Question = 5 marks)

5 The diagram represents a proton.

(a) Draw lines to represent its electric field.

(3)

(b) Calculate the electrostatic force on the electron in a hydrogen atom.

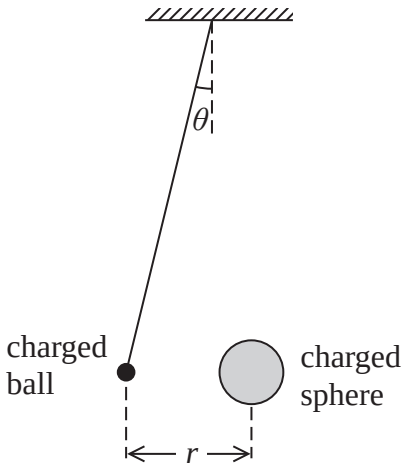
Average distance between proton and electron = 5.4×10^{-11} m

(3)

Force =

(Total for Question = 6 marks)

6 A student carries out an experiment to investigate the force acting between two charged objects. A lightweight negatively-charged ball is freely suspended from the ceiling by an insulating thread. The ball is repelled by a negatively-charged sphere that is placed near it on an insulated support.
The angle of deflection is θ and r is the distance between the centres of the ball and the sphere.



(a) (i) Draw a free-body force diagram for the suspended ball.

(2)

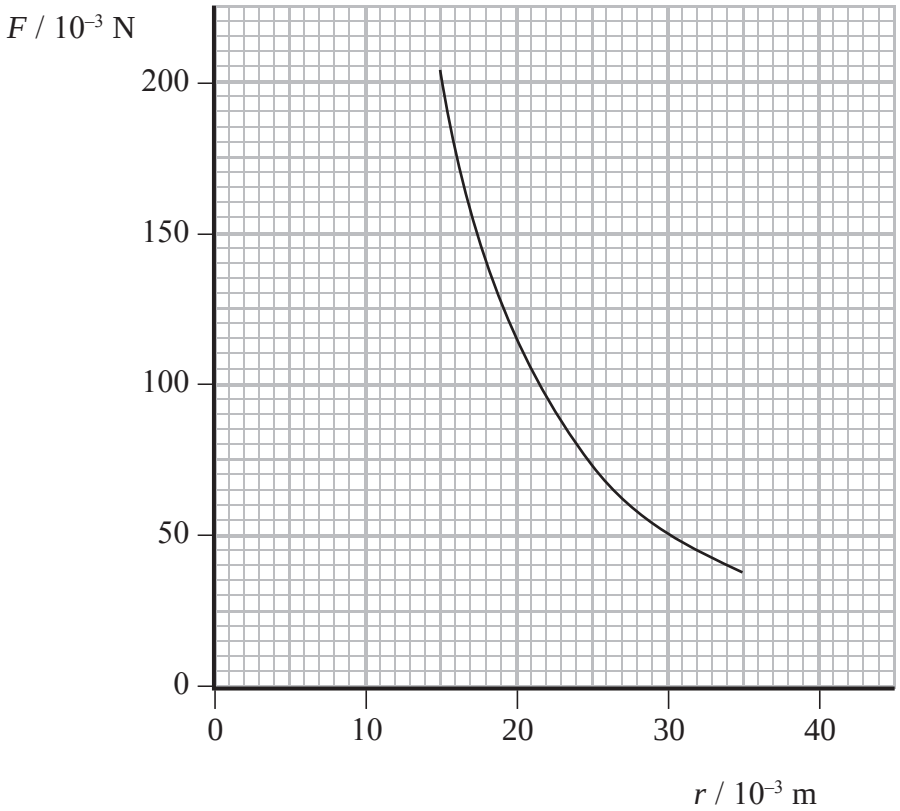
(ii) The weight of the suspended ball is W.

Show that the force of repulsion F on the suspended ball is given by

$$F = W \tan \theta$$

(2)

(b) (i) The student can increase the magnitude of the force by moving the sphere towards the suspended ball.
She takes pairs of measurements of r and θ and calculates the magnitude of the force F. She then plots a graph of F against r.



Use readings from the graph to demonstrate that the relationship between F and r obeys an inverse square law.

(4)

(ii) The charge on the sphere is 100 times greater than the charge on the ball.

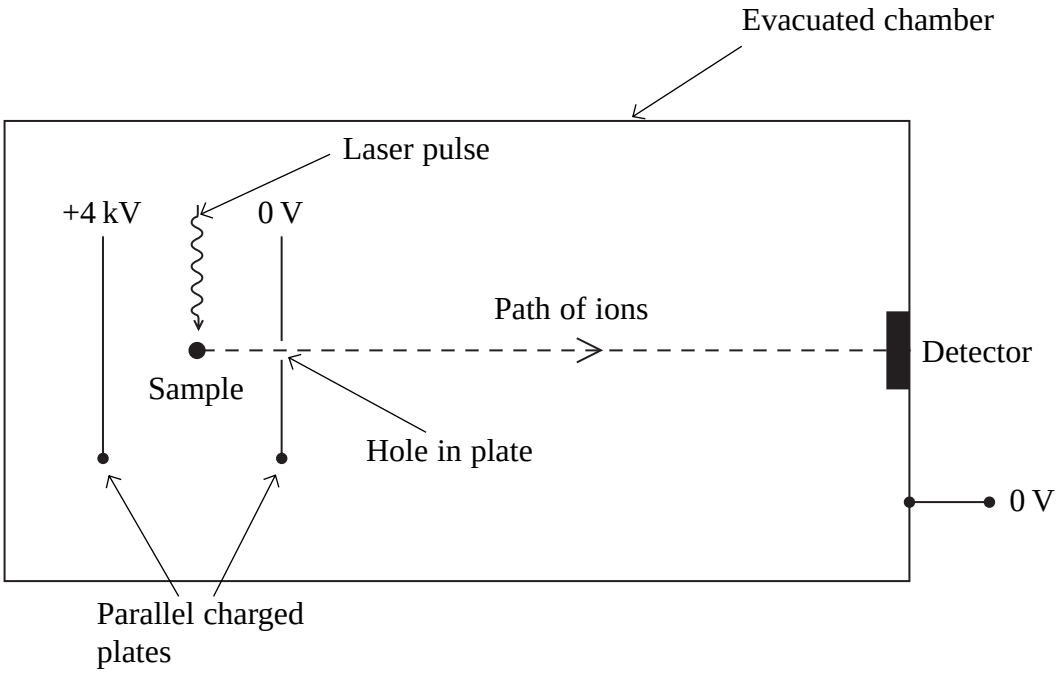
Calculate the charge on the ball.

(3)

Charge =

(Total for Question = 11 marks)

7 Time-of-flight mass spectroscopy uses the arrangement below to measure the mass of molecules. A laser pulse knocks an electron out of a molecule in a sample leaving it as a positively charged ion.



(a) Add to the diagram to show the electric field lines between the two plates.

(3)

(b) The sample is midway between the charged plates. Show that the speed, v, of an ion as it reaches the hole in the plate is given by

$$v = \sqrt{\frac{6.4\times10^{-16}\ \text{joule}}{m}}$$

where m is the mass of the molecule in kg.

(3)

(c) The distance between the hole in the plate and the detector is 1.5 m. The time taken for a molecule to cover this distance is 23 μs.

Calculate the mass of this molecule.

(3)

Mass =

(d) There is some uncertainty in the time a molecule with a particular mass will take to cover this distance.

Suggest **two** reasons for this.

(2)

1

2

(Total for Question = 11 marks)