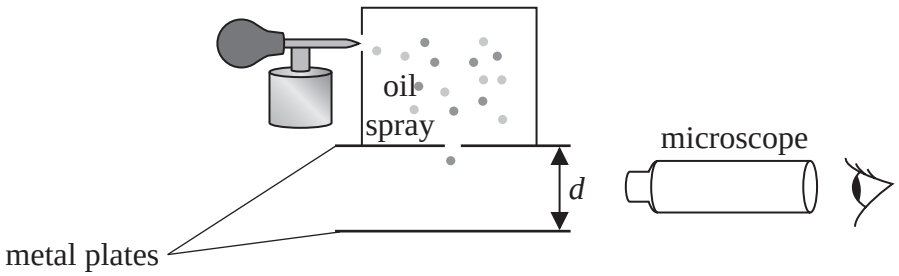
1 The diagram shows a simplified version of the apparatus used in an experiment to determine the charge on an electron.



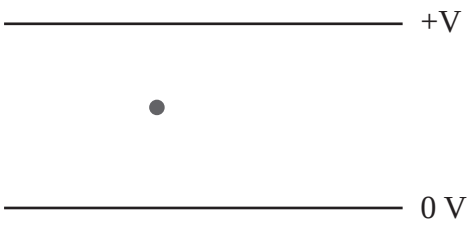
Negatively charged oil drops are sprayed into a region above two parallel metal plates. The plates are separated by a distance *d*. The oil drops are allowed to enter the region between the two plates.

A potential difference *V* is applied which causes an electric field to be set up between the plates.

(a) The diagram shows one oil drop falling between the plates.

Add lines to the diagram to show the electric field between the plates.

(2)



(b) *V* is gradually increased. At a particular value of *V*, the oil drop stops falling and remains stationary between the plates.

Explain this observation.

(2)

(c) The oil drop has mass m and charge Q and stops falling when $V = 5000$ V.

Show that $\frac{Q}{m}$ for this oil drop is about 50 μC kg^{-1}.

(3)

$d = 2.5$ cm

(d) The oil drop is close to another oil drop that has the same charge and mass. The oil drops can be considered to act as point charges 2.2 mm apart.

Calculate the electrostatic force between the two drops.

mass of each drop = 1.0×10^{-13} kg

(3)

Force between oil drops =

(e) With reference to the forces acting on the drops, explain what would happen to the oil drops if V is increased above 5000 V.

(3)

(Total for Question = 13 marks)

2 (a) Coulomb's law for the force F between point charges Q_1 and Q_2, which are a distance r apart, is given by

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Express the unit of ε_0 in base units.

(3)

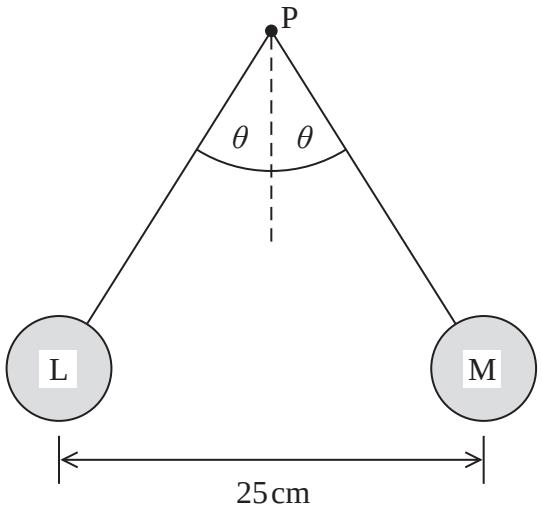
(b) Electric fields are caused by both point charges and by parallel plates with a potential difference across them.

Describe the difference between the electric field caused by a point charge and the electric field between parallel plates. Your answer should include a diagram of each type of field and reference to electric field strength.

(5)

(c) Two small spheres L and M are attached to non-conducting threads and suspended from a point P. Each sphere is given an equal positive charge of 4.0×10^{-7} C. The spheres hang in equilibrium as shown in the diagram.

The mass of each sphere is 2.7 g.



By considering the forces acting on one of the spheres, calculate the tension in the thread and the angle θ.

(6)

Tension =

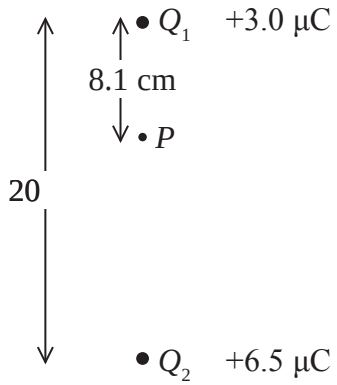
θ =

(Total for Question = 14 marks)

3 (a) Explain what is meant by the term electric field strength.

(2)

(b) (i) Two point charges Q_1 and Q_2 are placed 20 cm apart. Q_1 has a charge of +3.0 μC and Q_2 has a charge of +6.5 μC.



At point P, a distance 8.1 cm from Q_1, the electric field strength is approximately zero.

Demonstrate by calculation that this statement is correct.

(3)

(ii) A charge of +4.5 μC is placed at point *P*.
State the magnitude of the force acting on this charge.

(1)

(iii) The + 4.5 μC charge is moved from point *P* to a point half way between Q_1 and Q_2.

Explain qualitatively why energy would be needed for this movement.

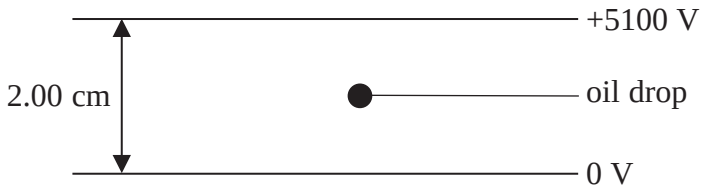
(2)

(Total for Question = 8 marks)

4 The charge on an electron was originally measured in an experiment called the Millikan Oil Drop experiment.

In a simplified version of this experiment, an oil drop with a small electric charge is placed between two horizontal, parallel plates with a large potential difference (p.d.) across them. The p.d. is adjusted until the oil drop is stationary.

For a particular experiment, a p.d. of 5100 V was required to hold a drop of mass 1.20×10^{-14} kg stationary.



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

(3)

(b) State whether the charge on the oil drop is positive or negative.

(1)

(c) Complete the free-body force diagram to show the forces acting on the oil drop. You should ignore upthrust.

(2)

(d) (i) Calculate the magnitude of the charge on the oil drop.

(4)

Charge =

(ii) Calculate the number of electrons that would have to be removed or added to a neutral oil drop for it to acquire this charge.

(2)

Number of electrons =

(Total for Question = 12 marks)

5 The positively charged particles in the solar wind are accelerating away from the Sun. Some scientists have therefore concluded that the Sun is positively charged.

(a) Explain this conclusion.

(2)

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(b) The circle below represents the Sun.

Complete the diagram to show the electric field produced by a positively-charged Sun.

(2)

(Total for Question 4 marks)

6 The London Eye consists of a large vertical circle with 32 equally-spaced passenger cabins attached to it. The wheel rotates so that each cabin has a constant speed of 0.26 m s ^{1} and moves around a circle of radius 61 m.

(a) Calculate the time taken for each cabin to make one complete revolution.

(2)

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.....

Time .....

(b) Calculate the centripetal force acting on each cabin.

mass of cabin 9.7×10^3 kg

(2)

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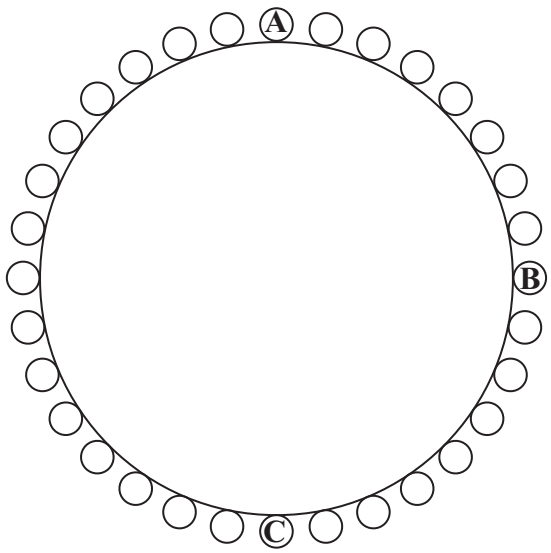
.....

.....

Centripetal force .....

(c) (i) The diagram shows just the circle and the cabins.
Draw arrows to show the direction of the centripetal force acting on a person in a cabin when the person is at each of positions **A**, **B** and **C**.

(1)



***(ii)** As the person in a cabin moves around the circle, the normal contact force between the person and the cabin varies.

State the position at which this force will be a maximum and the position at which it will be a minimum. Explain your answers.

(4)

(Total for Question 9 marks)