IB · SL · Physics

2 hours 16 questions

Structured Questions

Electric & Magnetic Fields

Electric Charge / Milikan's Oil Drop Experiment / Static Electricity / Coulomb's Law / Electric Field Strength / Electric Field Lines / Magnetic Fields

Easy (6 questions)	/64
Medium (5 questions)	/48
Hard (5 questions)	/37
Total Marks	**/149**

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Easy Questions

1 (a) Sketch a diagram to show the electric field that acts between the two charges.

(4 marks)

(b) Indicate, by drawing a circle around an area on your diagram from part (a) where the field lines are more dense and explain why they look like this.

(2 marks)

(c) Sketch a diagram to show the electric field that acts between the two charges.


(3 marks)

(d) Identify the differences between the central area of the diagrams you draw in (a) and (c).

(2 marks)

2 (a) Complete the sentence stating Coulomb's Law by using words from the text box.

directly	**electrostatic force**	**inversely**
sum	**product**	**separation**

The attractive or repulsive ..... between two point charges is ..... proportional to the ..... of the charges and ..... proportional to the square of their ..... .

(3 marks)

(b) Coulomb's Law is represented by the equation

$$F = k\frac{q_1 q_2}{r^2}$$

Define each of the terms used in this equation and state the units.

(4 marks)

3 (a) When calculating the electrostatic force between two charged bodies, a constant *k* called Coulomb's constant is taken into account.

State the relationship, name and the factor that affects the magnitude of k.

(3 marks)

(b) An electron experiences a force of 0.3 N in an electric field.

Calculate the field strength of the field.

(3 marks)

(c) In a vacuum, an alpha particle approaches an aluminium nucleus.

State:

- The charge on the nucleus
- The charge on the alpha particle
- The nature of the force between them

(3 marks)

(d) Calculate the magnitude of the electrostatic force acting on each of the charges from part (c).

- $q_1 = 3.2 \times 10^{-19}$ C
- $q_2 = 2.08 \times 10^{-18}$ C
- $r = 2.0 \times 10^{-3}$ m
- $k = 8.99 \times 10^{9}$ N m^2 C^{-2}

(4 marks)

4 (a) Define the term electrostatic field.

.....

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(2 marks)

(b) The equation to describe field strength is:

$$field\ strength = \frac{X}{Y}$$

Define X and Y for an electric field.

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(2 marks)

(c) Based on your answer to part (b), define the terms in the following equation:

$$E = \frac{F}{Q}$$

.....

(1 mark)

(d) The following text is about uniform electrostatic fields.

Complete the following sentences by circling the correct words:

An electric field is a region of space in which objects with **mass / charge** will experience a force.

The electric field strength is a vector quantity, it is always directed **away from / towards** a positive charge and **away from / towards** a negative charge.

Opposite charges (positive and negative) **repel / attract** each other and like charges (positive-positive or negative-negative) **repel / attract** each other.

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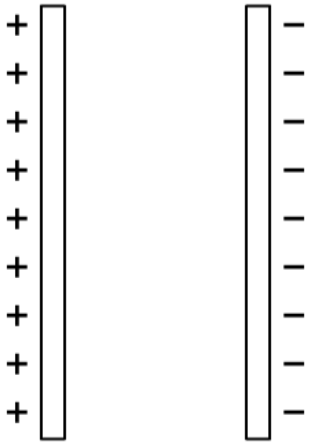
(3 marks)

5 (a) Draw the electric field lines around the positive and negative point charges below.

(3 marks)

(b) The diagram shows two parallel plates of opposite charge.



Draw the electric field lines between the two plates.

(3 marks)

(c) Electrostatic fields can be radial or uniform.

State the defining features of the equipotentials for:

(i) A radial field

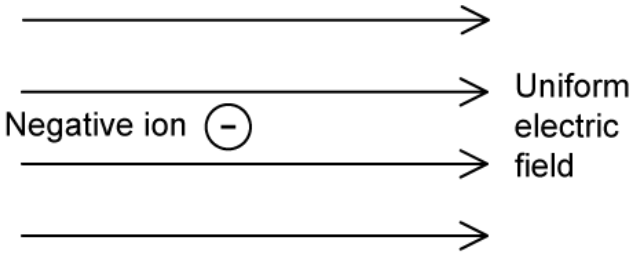
[2]

(ii) A uniform field

[3]

(5 marks)

6 (a) The diagram shows a negative ion which is free to move in a uniform electric field.



For the negative ion:

(i) State the direction of the electrostatic force acting on it.

[1]

(ii) Explain your answer with reference to the electric field lines in the diagram.

[2]

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(3 marks)

(b) 4.0×10^{-16} J of work is done on the ion to accelerate it through the field a distance of 63 mm in a line parallel to the field lines.

Calculate the magnitude of the electrostatic force acting on the negative ion.

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(5 marks)

(c) Complete the sentences to describe similarities between electrostatic and gravitational fields.

The magnitude of the gravitational and electrostatic force between two point masses or charges follows the ..... relationship with the separation distance between the point masses or charges.

Field lines around a point mass and negative point charge are both ..... and point ..... the mass or charge.

The field lines in uniform gravitational and electrostatic fields are both ..... and ..... .

(3 marks)

(d) Complete the sentences, using words or phrases, to describe the differences between electrostatic and gravitational fields.

The gravitational force acts on particles with ..... whilst the electrostatic force acts on particles with ..... .

The gravitational force is always ..... whilst the electrostatic force can be ..... .

The gravitational potential is always ..... whilst the electric potential can be either ..... .

(3 marks)

Medium Questions

1 (a) Electric fields exist in the space around charged particles. The strength of an electric field depends on the position occupied within that space.

Define what is meant by the strength of an electric field.

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(2 marks)

(b) An electron e^- and a positron e^+ occupy two positions in space.

Sketch on the image the resultant electric field in the region between the electron and the positron.

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(2 marks)

(c) The distance between the electron and the positron is 150 cm.

(i) Calculate the magnitude of the electrostatic force between the electron and the positron.

[2]

(ii) State the direction of the electrostatic force on the electron.

[1]

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(3 marks)

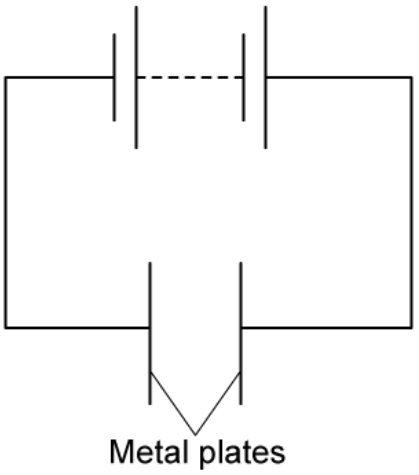
(d) A positive test charge is placed exactly midway between the electron and the positron.

Outline the subsequent motion of the positive test charge.

(2 marks)

2 (a) A parallel-plate capacitor is an electrical component that stores electric charge.

It is set up by connecting two metal plates to a power supply.



Label:

(i) the positively charged metal plate with the letter **A**

[1]

(ii) the negatively charged metal plate with the letter **B**

[1]

(iii) the electric field lines between the plates.

[2]

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(4 marks)

(b) State, for each of the scenarios below, whether the electric field strength between the metal plates increases, decreases, or stays constant:

(i) a positive test charge moving from one plate to the other.

[1]

(ii) a positive test charge moving between the plates along a line parallel to each other.

[1]

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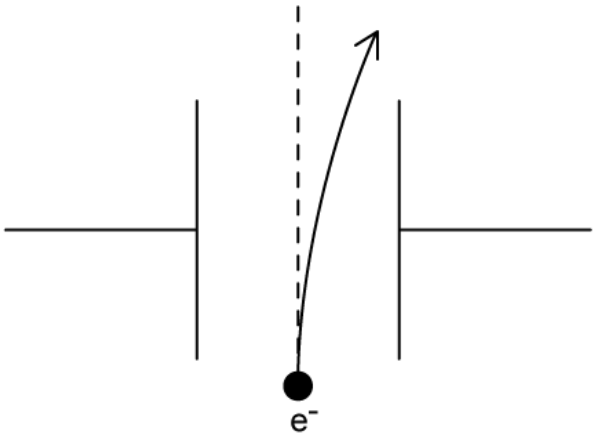
(2 marks)

(c) A free electron finds itself incident in the space between the metal plates and is deflected as it moves between them.



The magnitude of the electric field strength is 200 N C^{-1}. Calculate the magnitude of the electron's acceleration in the space between the plates.

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(3 marks)

(d) Explain the shape of the path shown in part (c).

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(3 marks)

3 (a) State Coulomb's law in words.

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(2 marks)

(b) In simple models of the hydrogen atom, an electron is in a circular orbit around the proton.

The magnitude of the force between the proton and the electron is 5.8×10^{-9} N.

Calculate:

(i) the orbital radius of the electron.

[2]

(ii) the magnitude of the electric field strength due to the proton at any point in the electron's orbit.

[2]

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(4 marks)

(c) The gravitational field strength *g* due to the proton at any point in the electron's orbit is given by the equation:

$$g = G\frac{m_p}{r^2}$$

where m_p is the proton mass, *r* is the orbital radius and *G* is the gravitational constant.

Show that the ratio of the gravitational field strength to the electric field strength due to the proton at any point in the electron's orbit is of the order 10^{-28}.

(4 marks)

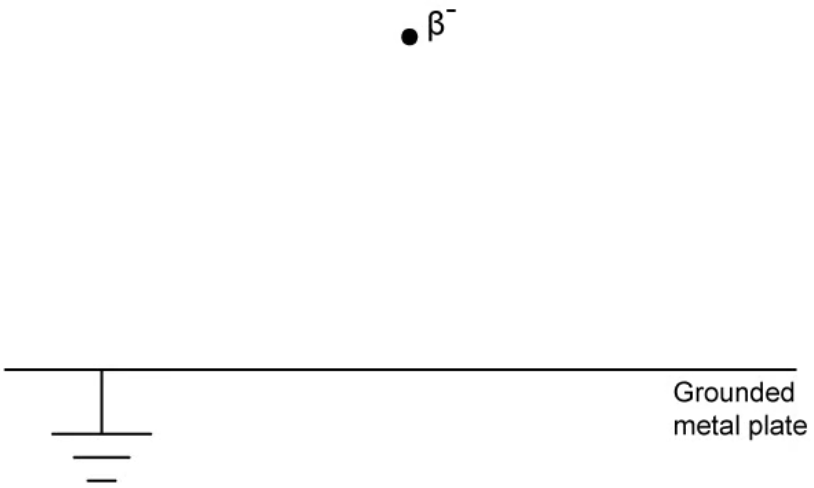
(d) Ionisation is the process of removing an outer shell electron from an atom, so it is transferred from its orbit to a point where the potential is zero.

The potential difference between the electron's orbit in a hydrogen atom and this point is about 3.4 V.

Calculate the gain in potential energy of an orbiting electron in a hydrogen atom if it is ionised.

(2 marks)

4 (a) A β^- particle is placed above a grounded metal plate.



Sketch the electric field lines between the β^- particle and the metal plate.

(3 marks)

(b) The β^- particle is replaced with an α particle at the same position above the grounded metal surface.

Outline the similarities and differences between the electric field now created to that in part (a).

(3 marks)

(c) The grounded metal surface is removed in order to analyse the combined electric field created between the α particle and the β^- particle.

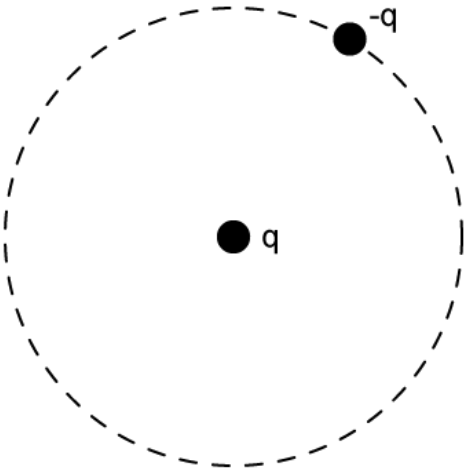
Sketch the electric field produced between an α particle and a β^- particle.

(3 marks)

(d) Discuss whether there is a point of zero electric field for the diagram in part (c).

(2 marks)

5 (a) A charge $-q$ with mass m orbits a stationary charge q with a constant orbital radius r.



Draw the electrostatic force on $-q$ due to the electric field created by q.

(2 marks)

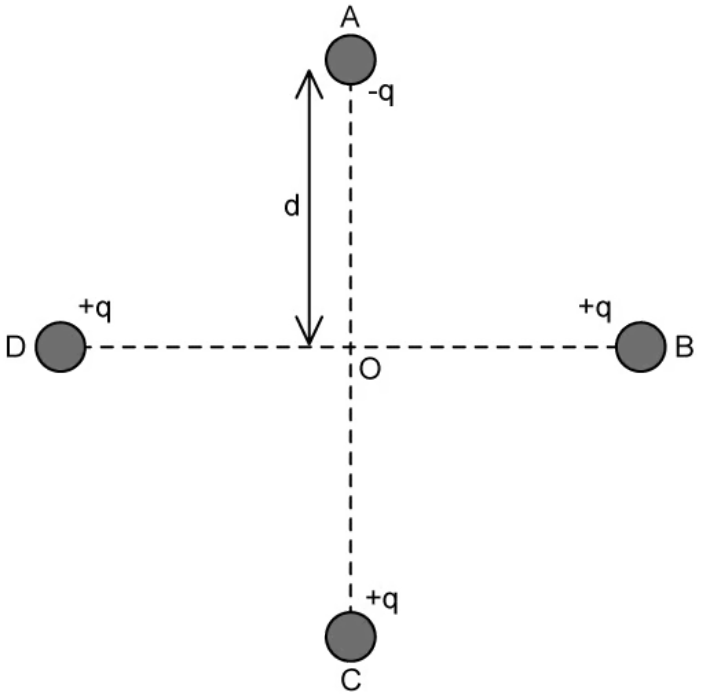
(b) Show that the orbital speed of v is given by:

$$v = \sqrt{\frac{1}{4\pi\varepsilon_0 mr}}\, q$$

(2 marks)

Hard Questions

1 (a) Four point charges A, B, C and D are each placed at a distance *d* from O as shown. Charges B, C and D each have a charge of +*q* and A has a charge –*q*.



(i) Derive an expression for the magnitude of the resultant electric field strength at O.

[1]

(ii) Determine the direction of the resultant electric field at O.

[1]

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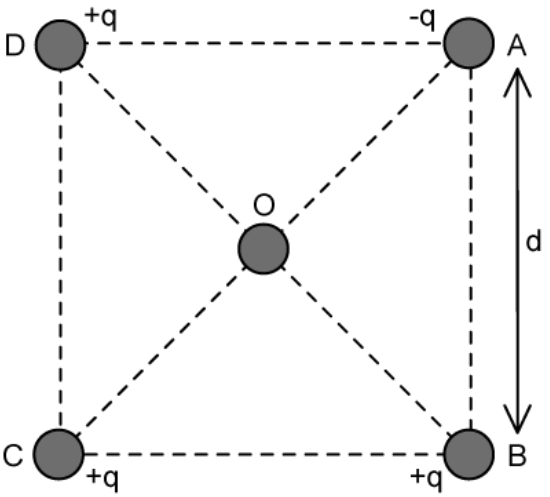
(2 marks)

(b) The arrangement of the charges is changed to the grid shown. Each charge is now the corner of a square of side *d*.



Calculate the magnitude of the resultant electric field strength at point O.

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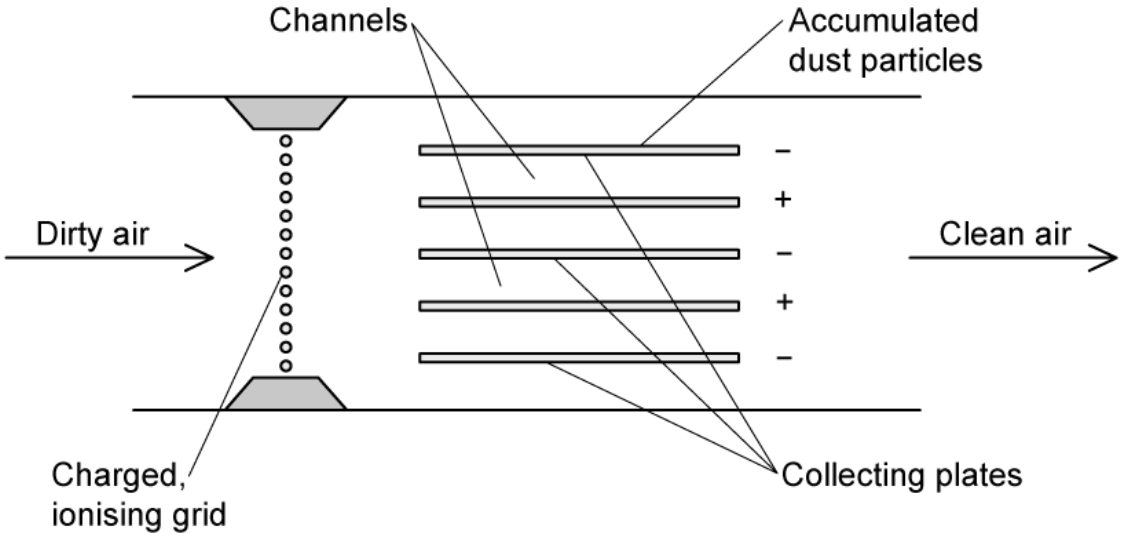
(2 marks)

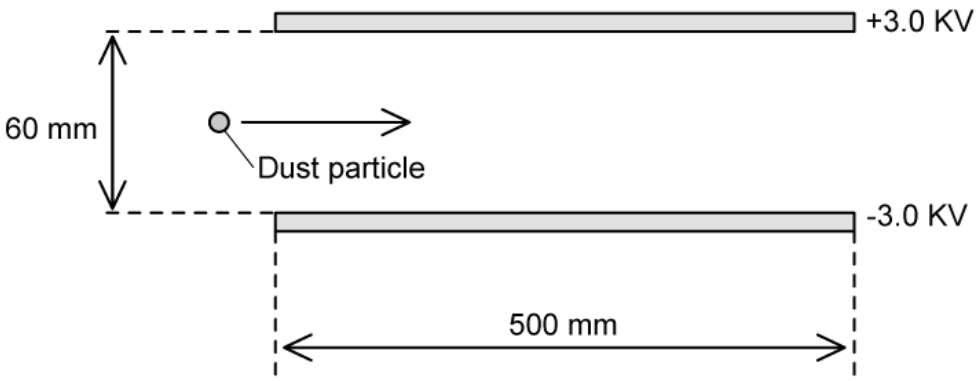
2 (a) The diagram shows an air filter which uses charged collecting plates to remove dust from the air of a workshop.

The air intake passes through a charged, ionising grid which attracts dust particles, cleaning the air which is then returned back into the workshop.



A dust particle of mass 6.7×10^{-15} kg enters the region between the collecting plates travelling horizontally with an initial velocity of 11 m s^{-1}. The particle carries a charge of 2.6×10^{-18} C.

Assume that the dust particles move horizontally between the plates.



Determine the electrostatic force acting on the particle.

(3 marks)

(b) Some particles are not caught by the air filter, but pass straight through. Others are caught by the filter. The particles are identical in mass and charge, and they all travel parallel to the plane of the plates. The plates are initially completely clean. Assume the particles are evenly vertically distributed.

Deduce the percentage of dust particles which will be 'trapped' by the negatively charged plate. Ignore the effect of gravity.

(4 marks)

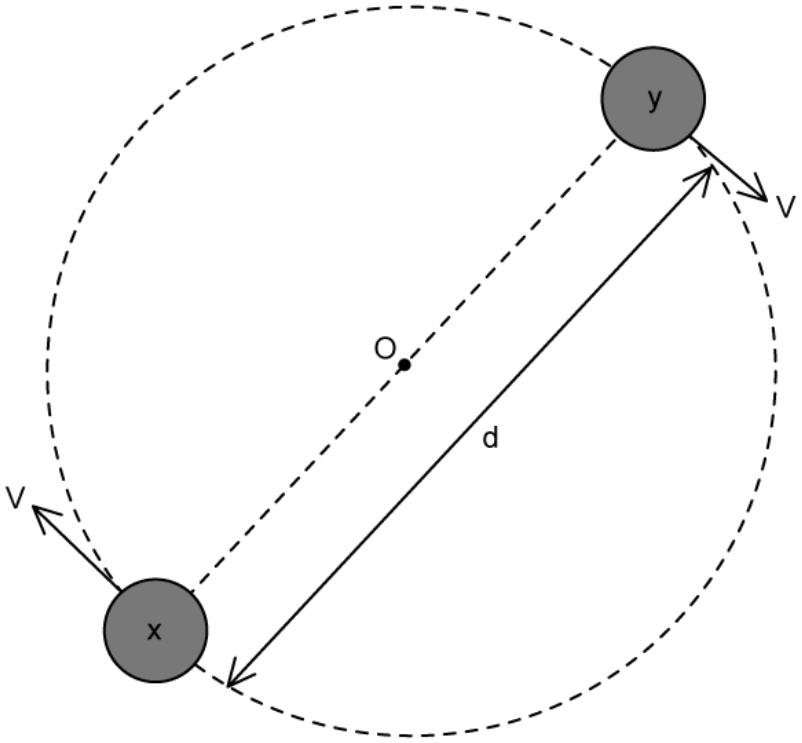
(c) As the air filter operates, there is a build up of particles on the negative plates. The gap between the plates therefore becomes narrower, by up to 10% of its initial height.

Discuss whether this narrowing makes the filter more or less effective at removing dust particles.

(3 marks)

3 (a) Two charged objects X and Y are made to circle a point O. X and Y are at a distance, d = 1.8×10^{-8} m and they have equal masses, where $m = 1.7 \times 10^{-9}$ kg.

The objects carry an equal but opposite charge, where the magnitude $q = 3.2 \times 10^{-19}$ C.



For this motion calculate

(i) The acceleration of X and Y.

[3]

(ii) Hence, the time to make one complete orbit.

[2]

(5 marks)

(b) The particles **X** and **Y** in part (a) are replaced with a gold nucleus $^{197}_{79}Au$, and an alpha particle.

Calculate the field strength at the surface of

(i) A gold nucleus with a radius of 7.0 fm.

[1]

(ii) An alpha particle with a radius of 1.7 fm.

[1]

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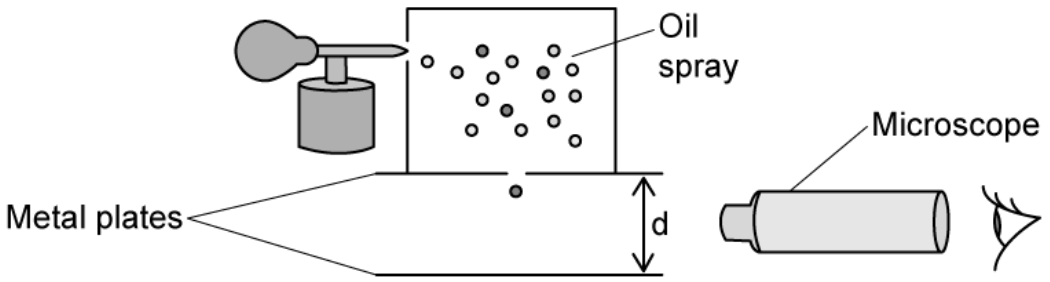
(2 marks)

4 (a) An experiment to determine the charge on an electron is shown.

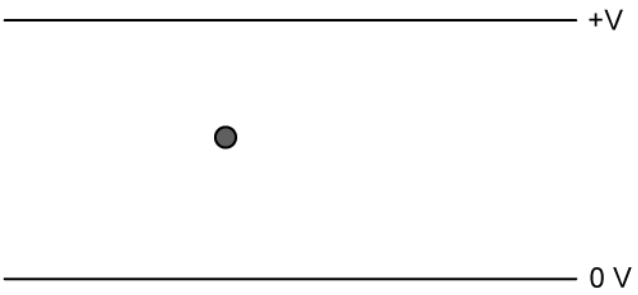


Negatively charged oil drops are sprayed into a region above two parallel metal plates which are separated by a distance, *d*. The oil drops enter the region between the plates.

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

(i) Using the sketch below, which shows one oil drop falling between the plates, show the electric field between the plates.

[1]



(ii) Hence or otherwise explain why the oil drop stops falling when *V* is increased.

[2]

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(3 marks)

(b) The oil drop has mass = m and charge = q. The distance between the plates = 2.5 cm.

The oil drop stops falling when potential difference, V = 5000 V

Determine the charge to mass ratio of the oil drop.

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(2 marks)

(c) Two oil drops are suspended between the plates at the same time. The oil drops can be considered as identical point charges with mass 1×10^{-13} kg which are spaced 2.2 mm apart.

Calculate the electrostatic force between the drops.

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(2 marks)

(d) For the oil drops in part (c)

Describe and explain the expected observations as the potential difference increases above 5000 V, using a mathematical expression to justify your answer.

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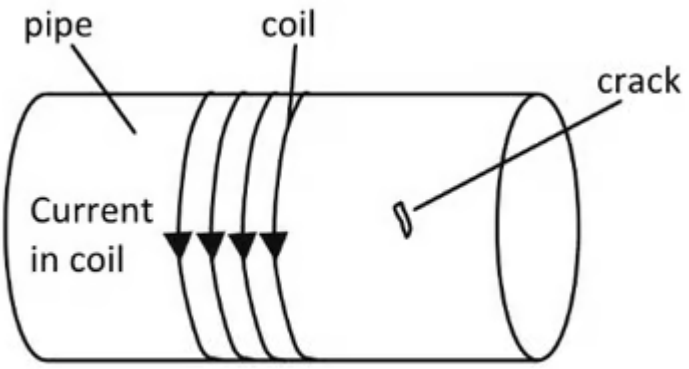
(2 marks)

5 (a) Very small cracks in some metals can be detected by a method which includes the use of magnetism. In a particular method for steel pipes, a coil of wire is wrapped around it, and a current passed through the coil. This magnetises the pipe and cracks in the direction shown in the image can be found by sprinkling iron filings on the pipe.



Cracks along or parallel to the length of the pipe do not show up.

Deduce why this method cannot be used for copper pipes.

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(2 marks)

(b) Explain why iron filings cluster around the crack shown in the image in part (a).

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(2 marks)

(c) The crack only shows up if it is across the direction of the field.

Describe and explain how the coil in the image in part (a) should be arranged so that the magnetic field it produces will show cracks cracks that are along the pipe.

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(3 marks)