PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

# PHYSICS



## EXAM QUESTION PACK

TOPIC 7: ELECTRIC AND MAGNETIC FIELDS

### ELECTRIC FIELDS

| SCORE | PERCENTAGE |
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STEMUP

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Q1.

What is the acceleration of an electron at a point in an electric field where the electric field strength is $2.0 \times 10^{4}$ N $C^{-1}$?

☒ **A** $2.8 \times 10^{-16}$ m $s^{-2}$

☒ **B** $3.2 \times 10^{-15}$ m $s^{-2}$

☒ **C** $1.8 \times 10^{11}$ m $s^{-2}$

☒ **D** $3.5 \times 10^{15}$ m $s^{-2}$

**(Total for question = 1 mark)**

Q2.

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.

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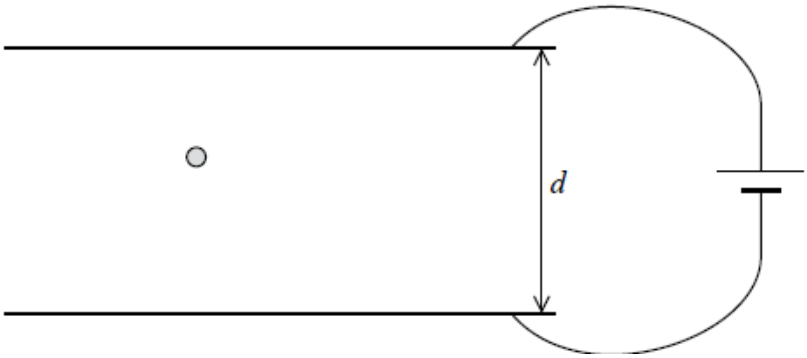
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Q3.

In an experiment to determine the charge on an electron, negatively charged oil drops are allowed to fall between two parallel metal plates separated by a distance *d*.

A potential difference (p.d.) is applied across the plates. The diagram shows one oil drop between the plates.




When the p.d. is 0 V the oil drop accelerates to terminal velocity. The p.d. is increased. It is observed that at a particular p.d. *V* the oil drop stops falling and remains stationary between the plates.

* Explain the motion of the oil drop in terms of the forces acting on it as the p.d. is increased from 0 to *V*.

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**(Total for question = 6 marks)**

Q4.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

State what is meant by an electric field.

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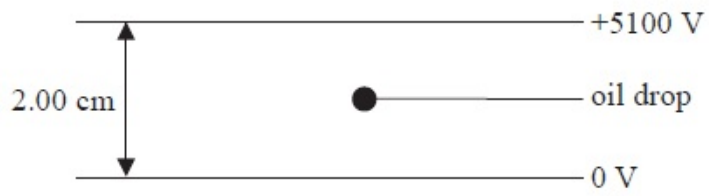
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**(Total for question = 1 mark)**

Q5. 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 $1.20 \times 10^{-14}$ 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)**

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(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)**

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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.

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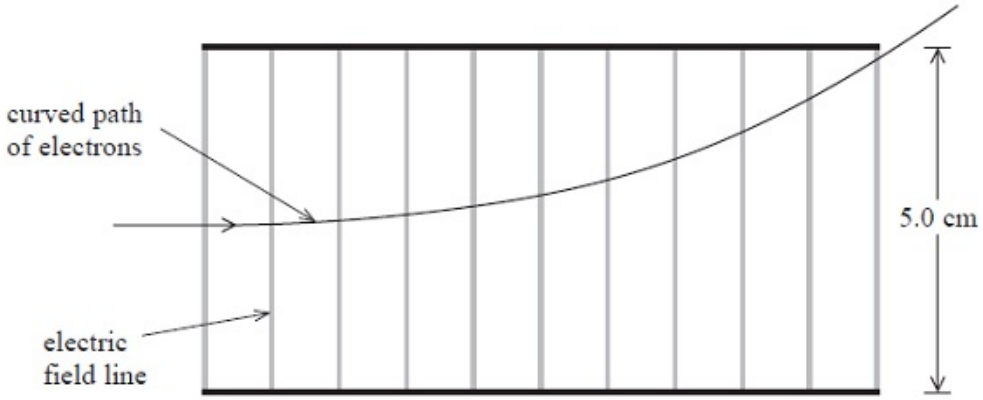
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Number of electrons = .....

**(Total for Question = 12 marks)**

Q6. A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.




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

**(1)**

(b) The conducting plates are 5.0 cm apart and have a potential difference of 160 V across them.

Calculate the force on the electron due to the electric field.

**(3)**

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Force = .....

(c) Explain why the path of the electron is curved between the plates and straight when it has left the plates.

**(3)**

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(d) The electron was initially released from a metal by thermionic emission and then accelerated

through a potential difference before entering the region of the electric field.

(i) State what is meant by thermionic emission.

**(1)**

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(ii) In order to be able to just leave the plates as shown, the electron must enter the electric field between the plates with a speed of $1.2 \times 10^7$ m $s^{-1}$.

Calculate the potential difference required to accelerate an electron from rest to this speed.

**(3)**

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Potential difference = .....

**(Total for Question = 11 marks)**

Q7.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

A potential difference is applied across two parallel plates. A particle carrying a charge of +0.1 C is placed between the plates and experiences a force *F*.

The distance between the plates is halved. The potential difference remains constant.

Which of the following is now equal to the electric field strength between the plates?

☒ **A** 5*F*

☒ **B** 10*F*

☒ **C** 20*F*

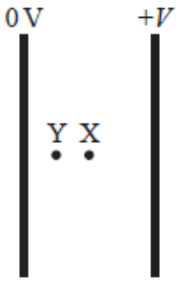
☒ **D** 40*F*

**(Total for question = 1 mark)**

Q8.

**Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).**

A potential difference *V* is applied across two parallel plates. An electron midway between the two plates at point X experiences an electric force *F*.




The electron moves to point Y which is halfway between point X and the left-hand plate.

Which of the following is the electric force experienced by the electron at Y?

☒ **A** $2F$

☒ **B** $F$

☒ **C** $\frac{F}{2}$

☒ **D** $\frac{F}{4}$

**(Total for question = 1 mark)**

Q9.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

A bee has short hairs which are thought to carry charge.

State how the bee might use this to detect the electric field of a flower.

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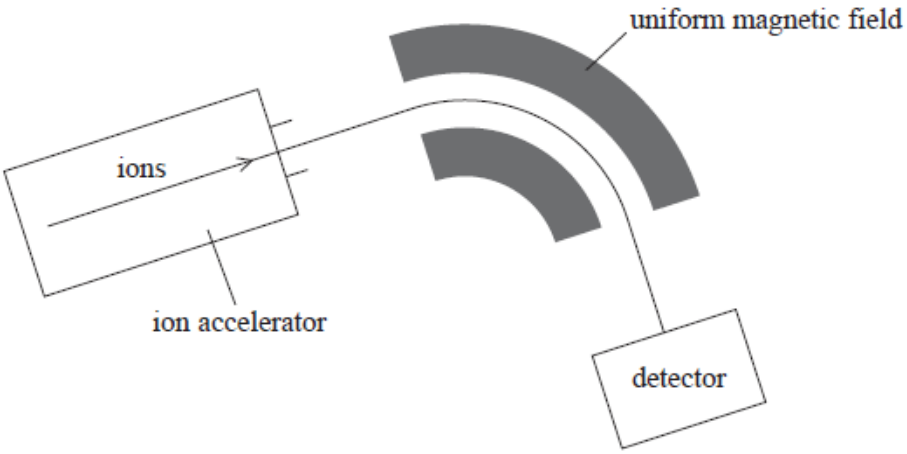
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Q10.

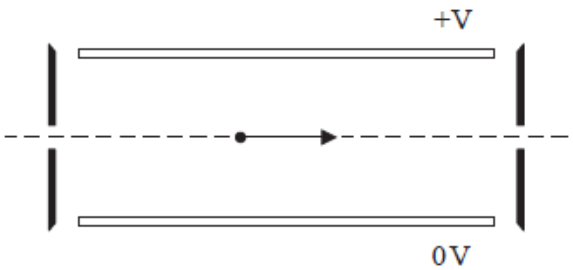
Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam.
This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.




Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

In most mass spectrometers the ions are passed through a velocity selector, after being accelerated, to produce a beam of ions of a particular velocity.
The velocity selector consists of a pair of parallel plates, across which a potential difference (p.d.) is applied to create an electric field.



In one mass spectrometer the plates are 2.5 cm apart and a p.d. of 135 V is applied.

A magnetic field is also applied to produce a force on the ions in the opposite direction to the force from the electric field. For one particular speed the ions travel in a straight line and emerge from the selector.

(i) Add to the diagram to indicate the directions of the electric field and the magnetic field.

**(2)**

(ii) The magnetic flux density applied to the velocity selector is 24.5 mT.

Deduce whether this magnetic flux density is suitable to produce a beam of chlorine-35 ions of speed $2.2 \times 10^5$ m $s^{-1}$.

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**(Total for question = 6 marks)**

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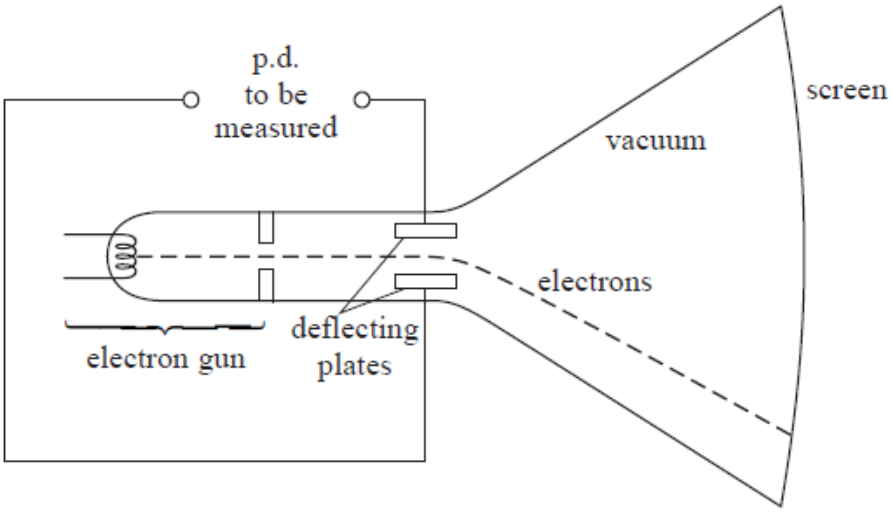
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Cathode ray tubes are used in oscilloscopes.



The diagram shows a simplified cathode ray tube that can be used to determine the magnitude and polarity of a potential difference (p.d.).

The cathode ray tube consists of an electron gun, a pair of deflecting plates and a fluorescent screen.



(a) The electron gun includes a filament. When this filament is heated, electrons are released and are accelerated by a p.d. of 1.5 kV to form an electron beam.

(i) Name the process by which electrons are released from the heated filament.

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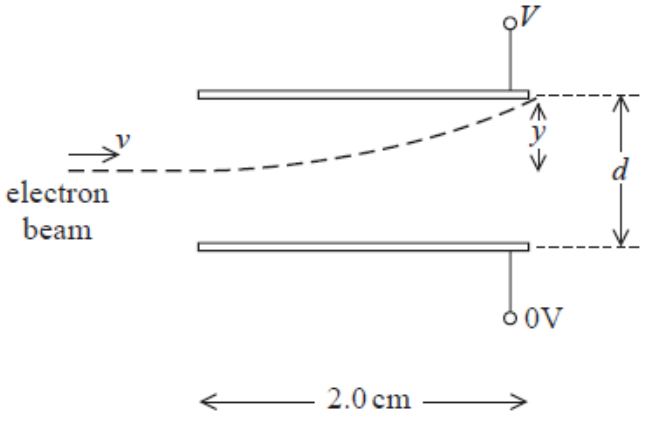
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(b) The electron beam then enters a uniform electric field between the two parallel horizontal deflecting plates. The magnitude and direction of the deflection is determined by the p.d. *V* that is applied across the plates.

The diagram shows one possible path of the electron beam as it passes between the plates.




(i) Show that the acceleration of an electron, of mass *m* and charge *Q*, is given by

$$\frac{VQ}{dm}$$

**(2)**

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(ii) Calculate the magnitude of the vertical deflection y of the beam as it leaves the plates.

$V$ = 50 V
$d$ = 0.01 m

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$y$ = .....

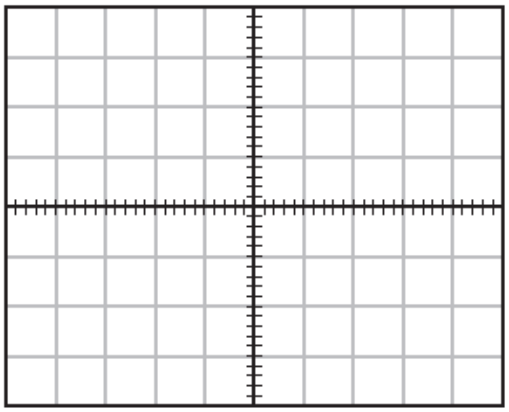
(c) A laboratory oscilloscope with the time base turned off operates in the same way as this simplified cathode ray tube. A student uses an oscilloscope in this way to monitor an alternating p.d. of 53 $V_{rms}$

On the grid, draw the trace that would be seen on the screen.

**(4)**

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1 square = 25 V

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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.

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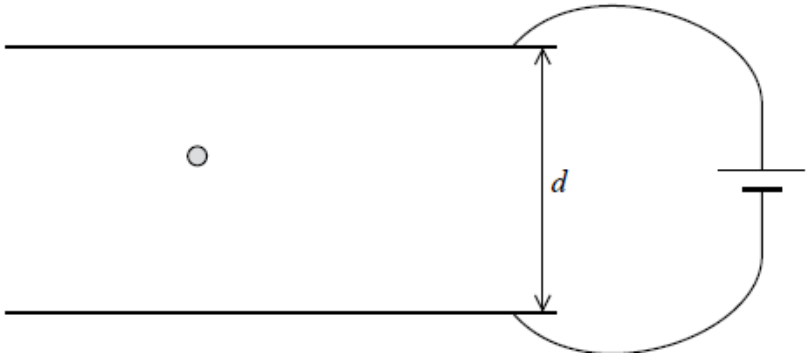
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A potential difference (p.d.) is applied across the plates. The diagram shows one oil drop between the plates.




When the p.d. is 0 V the oil drop accelerates to terminal velocity. The p.d. is increased. It is observed that at a particular p.d. *V* the oil drop stops falling and remains stationary between the plates.

(a) The oil drop has a mass *m*. Show that the charge *q* on the oil drop is given by

$$q = \frac{mgd}{V}$$

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(b) Explain what would happen to the oil drop if the p.d. is increased further.

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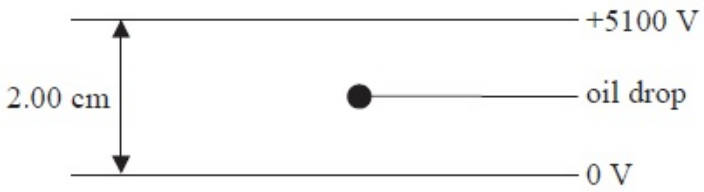
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Q5. The charge on an electron was originally measured in an experiment called the Millikan Oil Drop experiment.

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For a particular experiment, a p.d. of 5100 V was required to hold a drop of mass $1.20 \times 10^{-14}$ 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)**

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(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)**

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Charge = .....

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**(2)**

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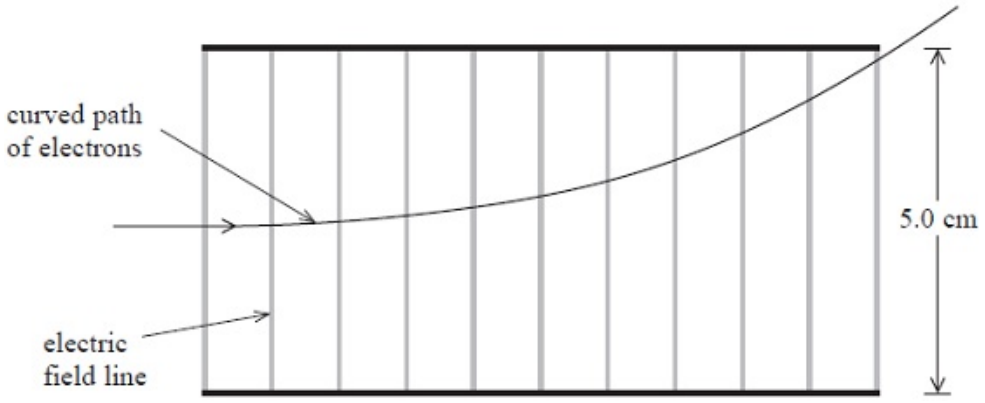
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Number of electrons = .....

**(Total for Question = 12 marks)**

Q6. A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.




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

**(1)**

(b) The conducting plates are 5.0 cm apart and have a potential difference of 160 V across them.

Calculate the force on the electron due to the electric field.

**(3)**

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Force = .....

(c) Explain why the path of the electron is curved between the plates and straight when it has left the plates.

**(3)**

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(d) The electron was initially released from a metal by thermionic emission and then accelerated through a potential difference before entering the region of the electric field.

(i) State what is meant by thermionic emission.

**(1)**

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(ii) In order to be able to just leave the plates as shown, the electron must enter the electric field between the plates with a speed of $1.2 \times 10^7$ m $s^{-1}$.

Calculate the potential difference required to accelerate an electron from rest to this speed.

**(3)**

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Potential difference = .....

**(Total for Question = 11 marks)**

Q7.

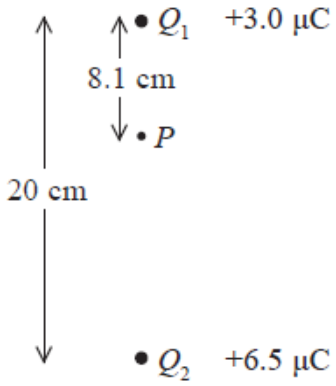
(a) Explain what is meant by the term electric field strength.

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(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.

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

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(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.

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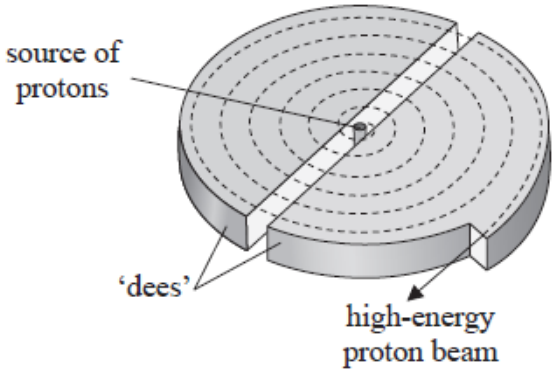
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**(Total for question = 8 marks)**

Q8.

Proton beam therapy is being introduced in the UK as a new cancer treatment.

A beam of protons is accelerated by a cyclotron to an energy of 23 MeV and is then focused onto a tumour.




* Explain how the cyclotron produces the high-energy proton beam.

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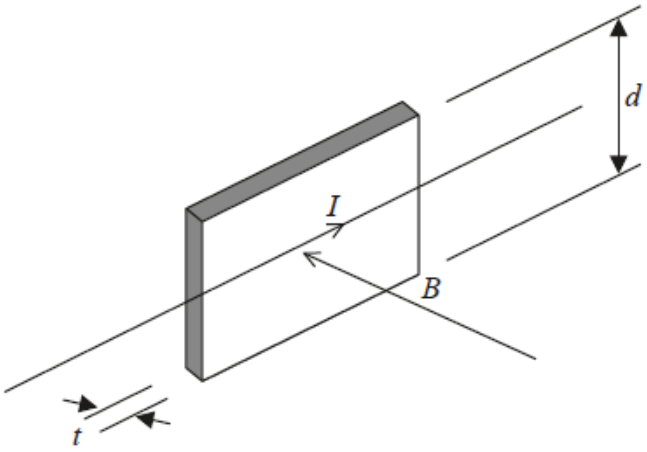
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**(Total for question = 6 marks)**

Q9.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current *I* and a magnetic field of flux density *B* are applied to a slice of semiconductor as shown. The slice has thickness *t* and depth *d*.




Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage $V_{HALL}$ develops.

Electrons continue to collect at the top edge of the slice, until the force on a moving electron due to the magnetic field is equal to the force on the electron due to the electric field.

Derive the following equation for $V_{HALL}$:

$$V_{HALL} = \frac{BI}{nte}$$

where *n* is the number of charge carriers per unit volume of the semiconductor.

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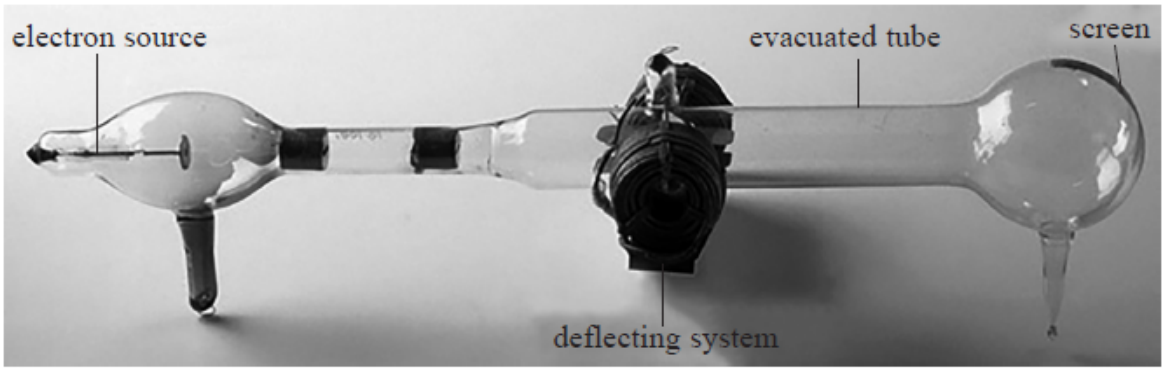
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**(Total for question = 4 marks)**

Q10.

At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.




© Science Museum London

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

In a modern version of Thompson's experiment, a uniform electric field of electric field strength $E$ is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

(i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where $B$ is the magnetic flux density of the magnetic field.

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(ii) The beam is produced by accelerating electrons through a potential difference of 250 V.

The electric field strength is $1.4 \times 10^4\,\text{V m}^{-1}$. The magnetic flux density is $1.5 \times 10^{-3}\,\text{T}$.

Calculate the value of the specific charge $e/m$ for the electron using this data.

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$e/m$ = .....

**(Total for question = 5 marks)**

Q1.

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☒ **A** $2.8 \times 10^{-16}$ m $s^{-2}$

☒ **B** $3.2 \times 10^{-15}$ m $s^{-2}$

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**(Total for question = 1 mark)**

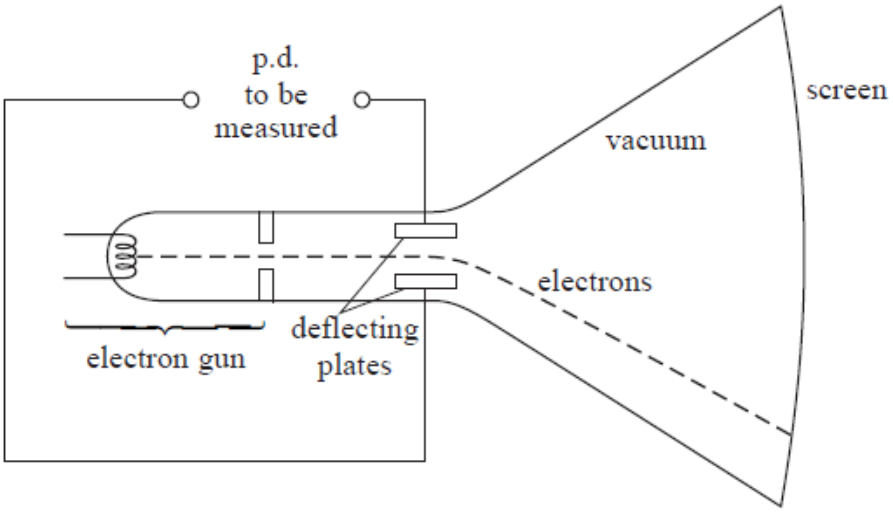
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Cathode ray tubes are used in oscilloscopes.



The diagram shows a simplified cathode ray tube that can be used to determine the magnitude and polarity of a potential difference (p.d.).

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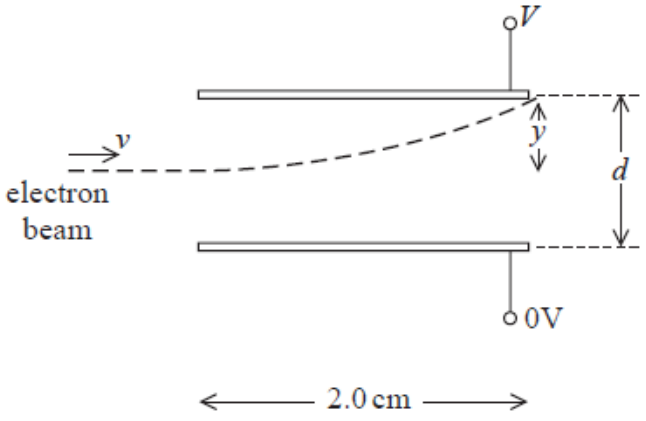
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$$\frac{VQ}{dm}$$

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$V$ = 50 V
$d$ = 0.01 m

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$y$ = .....

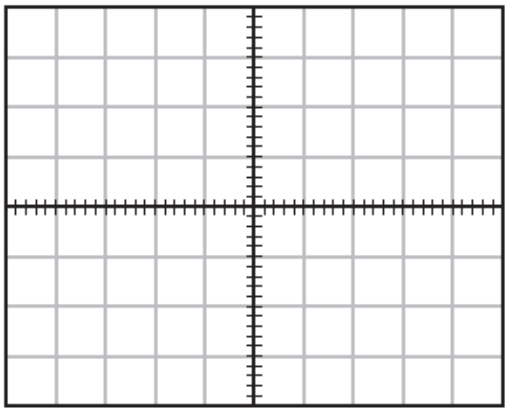
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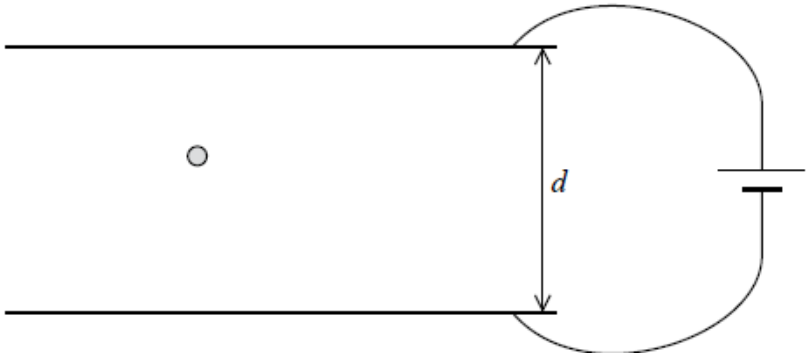
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In an experiment to determine the charge on an electron, negatively charged oil drops are allowed to fall between two parallel metal plates separated by a distance *d*.

A potential difference (p.d.) is applied across the plates. The diagram shows one oil drop between the plates.




When the p.d. is 0 V the oil drop accelerates to terminal velocity. The p.d. is increased. It is observed that at a particular p.d. *V* the oil drop stops falling and remains stationary between the plates.

(a) The oil drop has a mass *m*. Show that the charge *q* on the oil drop is given by

$$q = \frac{mgd}{V}$$

**(2)**

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(b) Explain what would happen to the oil drop if the p.d. is increased further.

**(2)**

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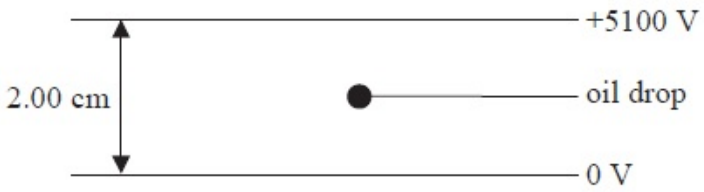
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**(Total for question = 4 marks)**

Q5. 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 $1.20 \times 10^{-14}$ 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)**

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(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)**

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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)**

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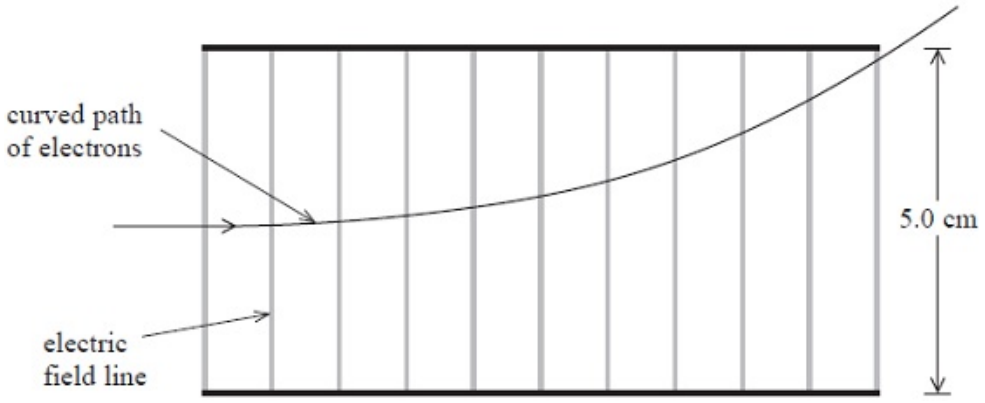
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Number of electrons = .....

**(Total for Question = 12 marks)**

Q6. A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.




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

**(1)**

(b) The conducting plates are 5.0 cm apart and have a potential difference of 160 V across them.

Calculate the force on the electron due to the electric field.

**(3)**

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Force = .....

(c) Explain why the path of the electron is curved between the plates and straight when it has left the plates.

**(3)**

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(d) The electron was initially released from a metal by thermionic emission and then accelerated through a potential difference before entering the region of the electric field.

(i) State what is meant by thermionic emission.

**(1)**

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(ii) In order to be able to just leave the plates as shown, the electron must enter the electric field between the plates with a speed of $1.2 \times 10^7$ m $s^{-1}$.

Calculate the potential difference required to accelerate an electron from rest to this speed.

**(3)**

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Potential difference = .....

**(Total for Question = 11 marks)**

Q7.

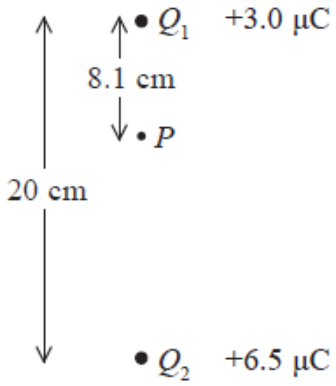
(a) Explain what is meant by the term electric field strength.

**(2)**

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(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)**

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

**(1)**

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(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)**

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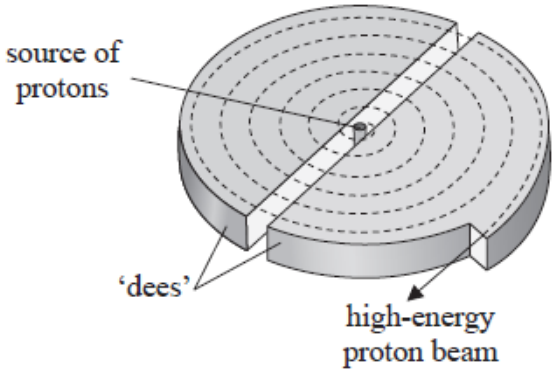
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**(Total for question = 8 marks)**

Q8.

Proton beam therapy is being introduced in the UK as a new cancer treatment.

A beam of protons is accelerated by a cyclotron to an energy of 23 MeV and is then focused onto a tumour.




* Explain how the cyclotron produces the high-energy proton beam.

**(6)**

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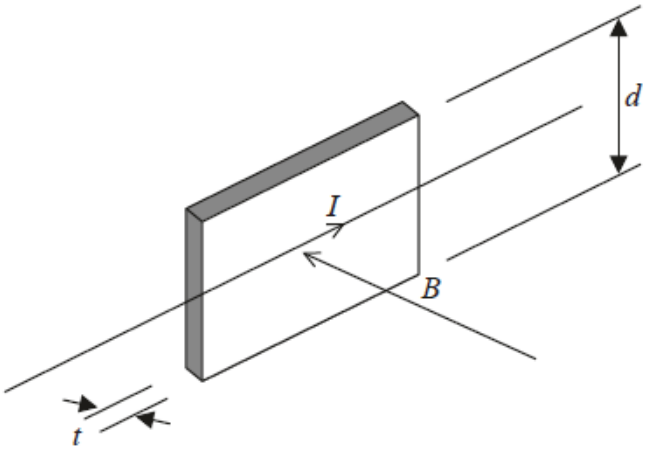
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**(Total for question = 6 marks)**

Q9.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current *I* and a magnetic field of flux density *B* are applied to a slice of semiconductor as shown. The slice has thickness *t* and depth *d*.




Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage $V_{HALL}$ develops.

Electrons continue to collect at the top edge of the slice, until the force on a moving electron due to the magnetic field is equal to the force on the electron due to the electric field.

Derive the following equation for $V_{HALL}$:

$$V_{HALL} = \frac{BI}{nte}$$

where *n* is the number of charge carriers per unit volume of the semiconductor.

**(4)**

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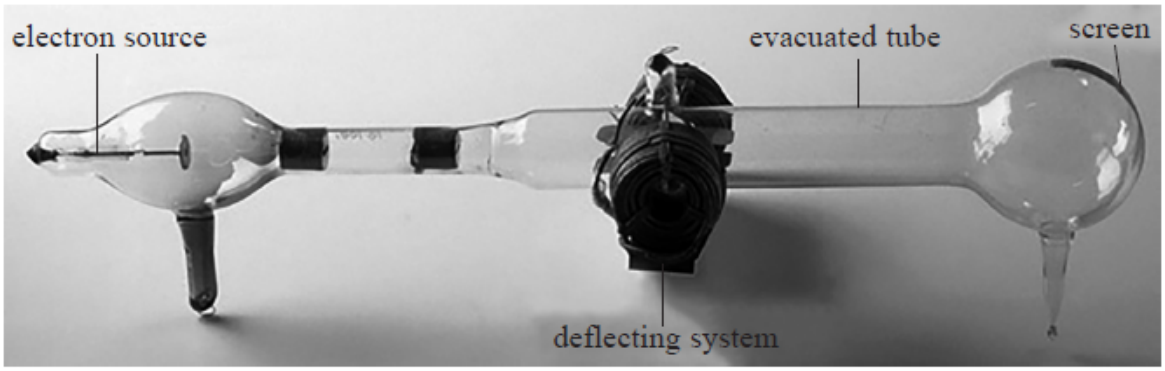
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**(Total for question = 4 marks)**

Q10.

At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.




© Science Museum London

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

In a modern version of Thompson's experiment, a uniform electric field of electric field strength $E$ is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

(i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where $B$ is the magnetic flux density of the magnetic field.

**(2)**

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(ii) The beam is produced by accelerating electrons through a potential difference of 250 V.

The electric field strength is $1.4 \times 10^4\,\text{V m}^{-1}$. The magnetic flux density is $1.5 \times 10^{-3}\,\text{T}$.

Calculate the value of the specific charge $e/m$ for the electron using this data.

**(3)**

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$e/m$ = .....

**(Total for question = 5 marks)**

Q1. Two protons, separated by a distance $x$, experience a repulsive force $F$.

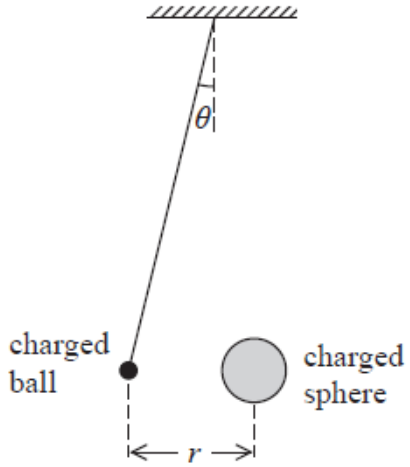
If the separation is reduced to $x/3$ the force between the protons will be

- **A** $F/9$
- **B** $F/3$
- **C** $3F$
- **D** $9F$

**(Total for Question = 1 mark)**

Q2.

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 $\theta$ 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)**

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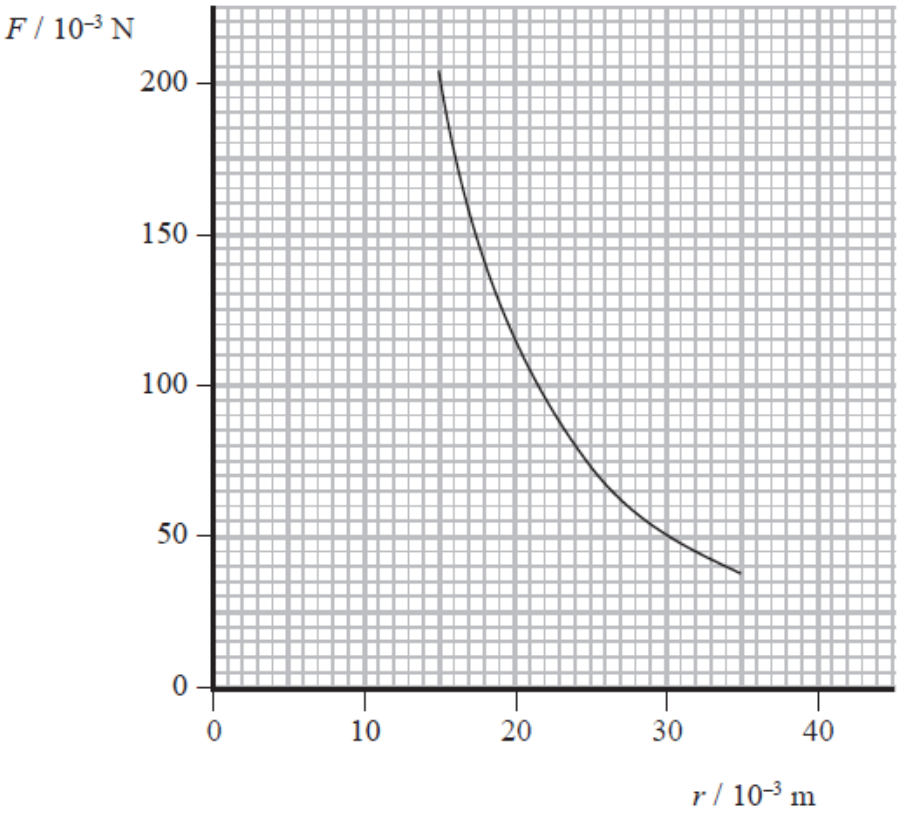
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(b) (i) The student can increase the magnitude of the force by moving the sphere towards the suspended ball.
She takes pairs of measurements of $r$ and $\theta$ and calculates the magnitude of the force $F$. She then plots a graph of $F$ against $r$.




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

**(4)**

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

Calculate the charge on the ball.

**(3)**

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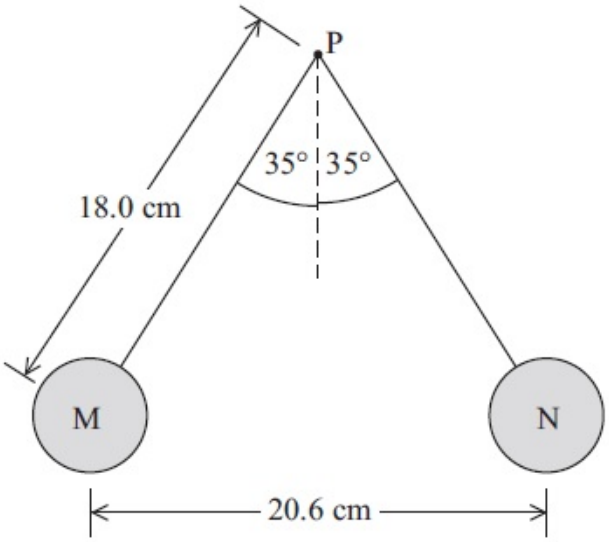
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Charge = .....

**(Total for question = 11 marks)**

Q3.

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 $3 \times 10^{-2}$ N.

**(3)**

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(ii) Show that the electrostatic force between the balls is about $2 \times 10^{-2}$ N.

**(2)**

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(iii) Calculate the charge on each ball.

**(3)**

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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.

Calculate the charge on each ball.

**(2)**

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**(Total for question = 12 marks)**

Q4. In an experiment to investigate the structure of the atom, α-particles are fired at a thin metal foil, which causes the α-particles to scatter.

(a) (i) State the direction in which the number of α-particles detected will be a maximum.

**(1)**

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(ii) State what this suggests about the structure of the atoms in the metal foil.

**(1)**

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(b) Some α-particles are scattered through 180°.

State what this suggests about the structure of the atoms in the metal foil.

**(2)**

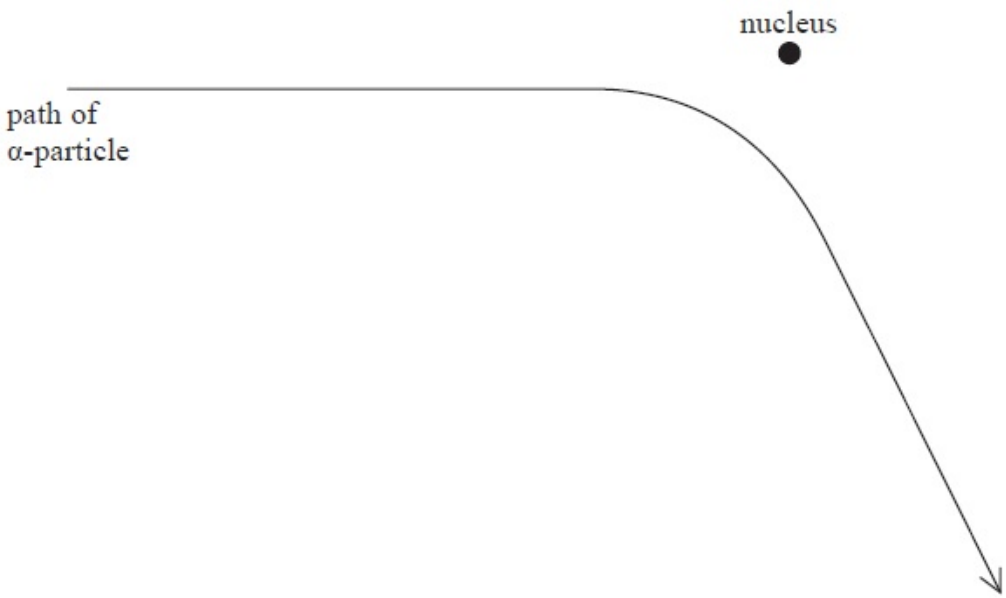
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(c) The diagram shows the path of an α-particle passing near to a single nucleus in the metal foil.




(i) Name the force that causes the deflection of the α-particle.

**(1)**

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(ii) On the diagram, draw an arrow to show the direction of the force acting on the α-particle at the point where the force is a maximum. Label the force F.

**(2)**

(iii) The foil is replaced by a metal of greater proton number.

Draw the path of an α-particle that has the same initial starting point and velocity as the one

drawn in the diagram.

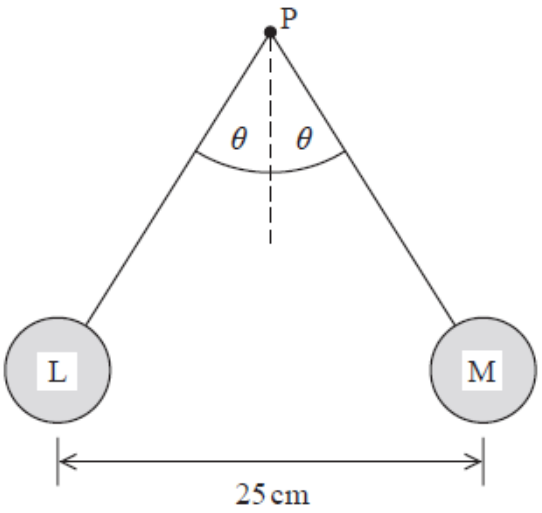
**(2)**

**(Total for Question = 9 marks)**

Q5.

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 $4.0 \times 10^{-7}$ 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 $\theta$.

**(6)**

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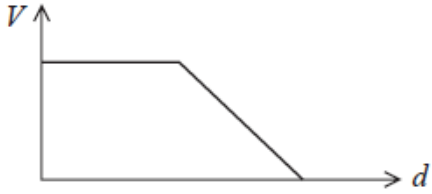
Tension = .....

$\theta$ = .....

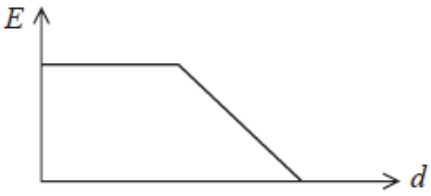
Q1.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

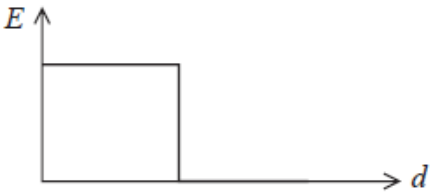
The graph shows how the potential $V$ varies with distance $d$ in an electric field.



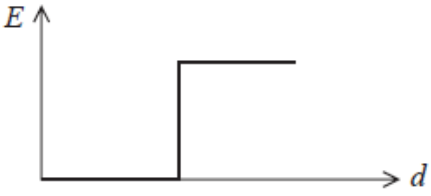

Which of the following shows the corresponding variation in electric field strength $E$?



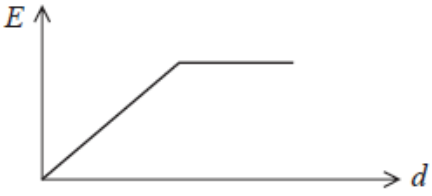

☒ **A**




☒ **B**




☒ **C**



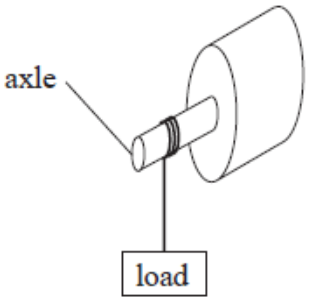

☒ **D**

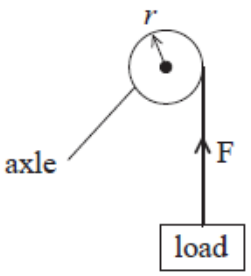
**(Total for question = 1 mark)**

Q2.

Motors usually have a rotating component which can do work $W$.

(a) A motor lifts a load in a time $t$. The axle of the motor has a radius $r$ and exerts a force $F$.




The power produced by a motor can be calculated by using the following word equation.

**Power = moment of the force exerted by the rotating axle × angular velocity**

Derive this equation, starting with power $P = \frac{W}{t}$.

**(4)**

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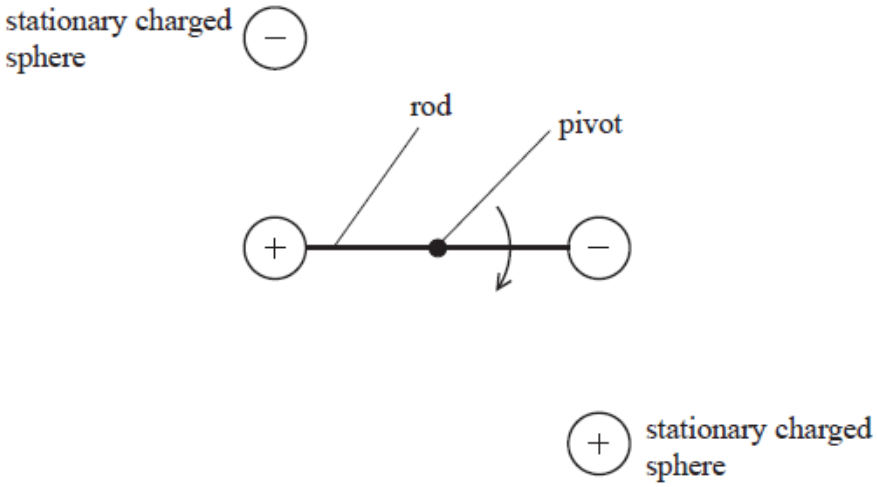
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(b) An electrostatic motor was first demonstrated by Benjamin Franklin in 1750.

The diagram shows a simplified version of part of this motor.

This consists of a rod, with an oppositely charged sphere at either end, which rotates around a fixed pivot. Two stationary charged spheres apply a force on the spheres at either end of the rod.

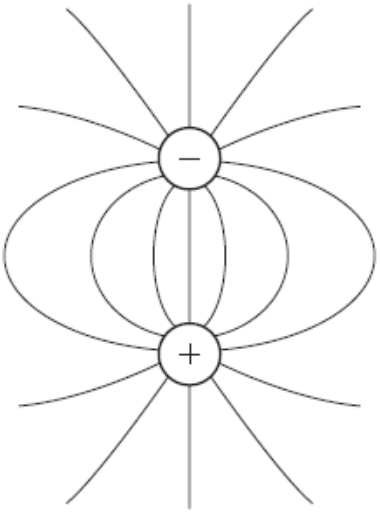



(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

- the directions of the field lines
- the lines of equipotential.

**(3)**




(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere = 0.10 μC

**(2)**

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(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

| | Power / W | Angular velocity / rad $s^{-1}$ |
|---|---|---|
| Electric car | $2.0 \times 10^4$ | 300 |
| Vacuum cleaner | $1.4 \times 10^3$ | 1000 |
| Small pond pump | 0.5 | 200 |

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

**(4)**

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**(Total for question = 13 marks)**

Q3.

A magician did a trick which he claimed was the most dangerous ever. He positioned himself midway between two charged spheres which were separated by a distance of about two metres. Each sphere was charged to a potential that would cause ionisation at a distance of one metre. He wore a protective suit of chain mail and a helmet consisting of a metal cage. The protective suit and helmet were earthed to a potential of 0 V.



A scientist said "there is no danger in this and I would happily do it tomorrow".

Explain whether this statement is justified.

**(3)**

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**(Total for question = 3 marks)**

Q4.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

When the bee is collecting nectar from the plant, the electric field strength decreases.
It is thought that this warns other bees that the nectar supply is low.

State the effect of a decreased electric field strength on the equipotential lines.

**(1)**

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**(Total for question = 1 mark)**

Q5.

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

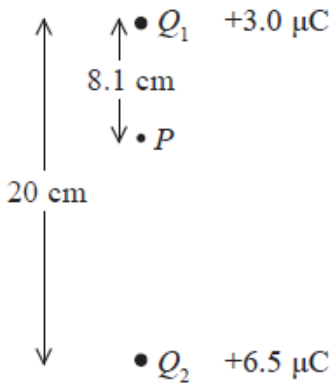
**(2)**

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(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)**

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

**(1)**

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(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)**

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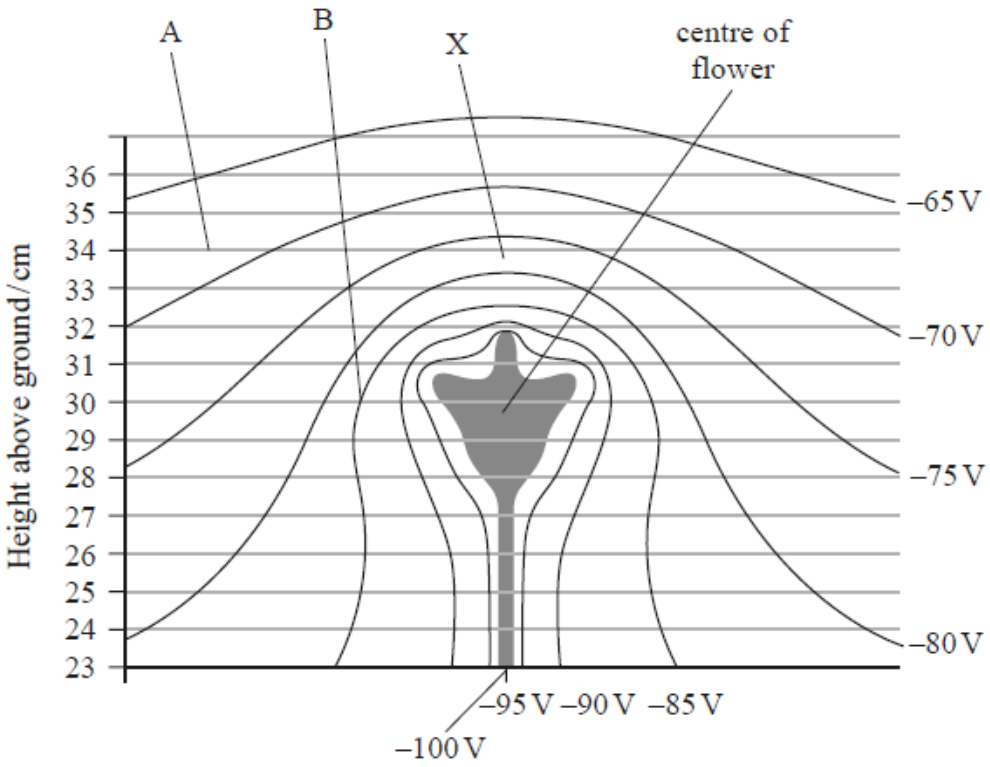
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**(Total for question = 8 marks)**

Q6.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

The diagram shows lines of equipotential surrounding a flower.




(i) Determine the electric field strength at X.

**(3)**

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Electric field strength at X = .....

(ii) Draw the electric field line between point A and point B on the diagram.

**(2)**

(iii) An equation for electric potential $V$ is

$$V = \frac{Q}{4_{\epsilon}{}^{\pi}{}_{0}r}$$

This applies to a radial field.

Deduce whether the electric field in the region directly above the flower is radial.
You should take values from the diagram. A graphical method is not required.

**(3)**

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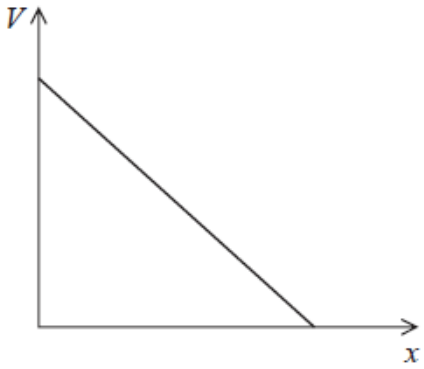
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**(Total for question = 8 marks)**

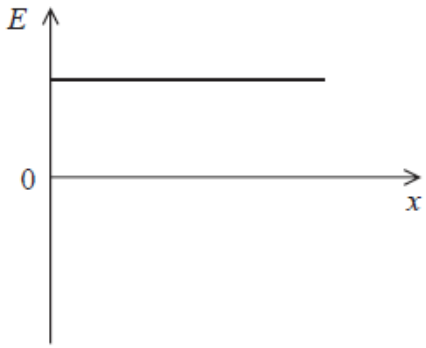
Q7.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

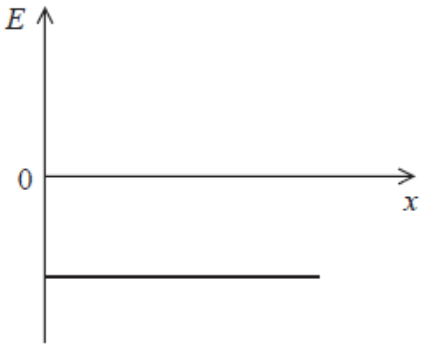
The graph shows how an electric potential $V$ varies with distance $x$.



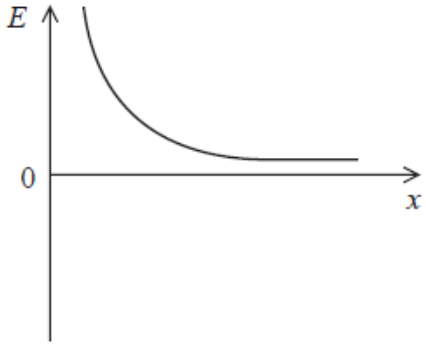

Which of the following shows the corresponding variation of electric field strength $E$ with $x$?



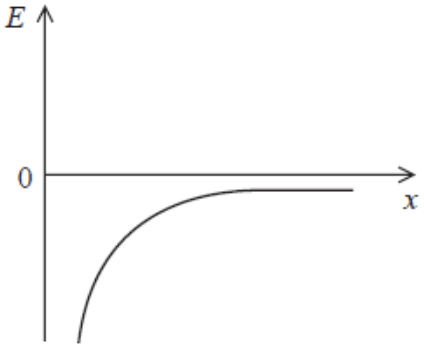

☒ **A**




☐ **B**




☒ **C**

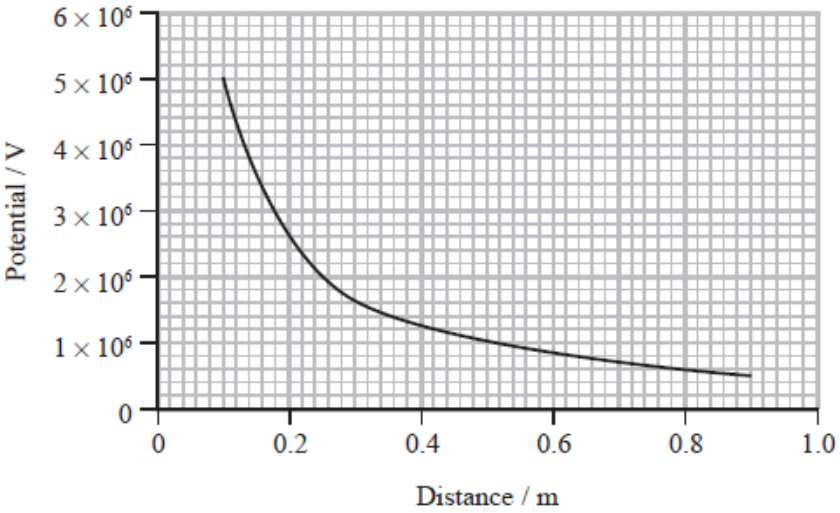



☐ **D**

**(Total for question = 1 mark)**

Q8.

The graph shows how potential varies with distance from the centre of a charged sphere.




Air molecules will be ionised if the electric field strength exceeds $3 \times 10^6$ V $m^{-1}$.

Deduce whether air molecules will be ionised at a distance of 30 cm from the centre of this sphere.

**(4)**

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**(Total for question = 4 marks)**

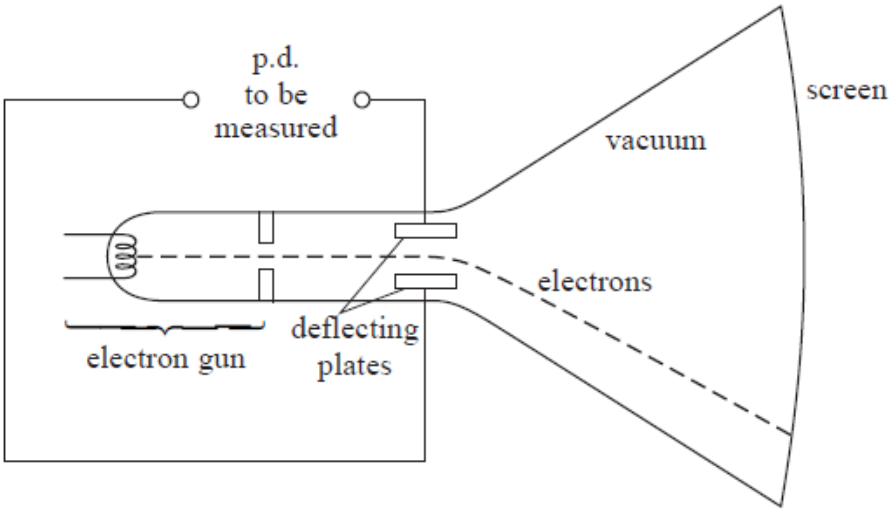
Q1.

Cathode ray tubes are used in oscilloscopes.



The diagram shows a simplified cathode ray tube that can be used to determine the magnitude and polarity of a potential difference (p.d.).

The cathode ray tube consists of an electron gun, a pair of deflecting plates and a fluorescent screen.




(a) The electron gun includes a filament. When this filament is heated, electrons are released and are accelerated by a p.d. of 1.5 kV to form an electron beam.

(i) Name the process by which electrons are released from the heated filament.

**(1)**

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(ii) Show that the maximum velocity of the electrons is about $2 \times 10^7$ m $s^{-1}$.

**(2)**

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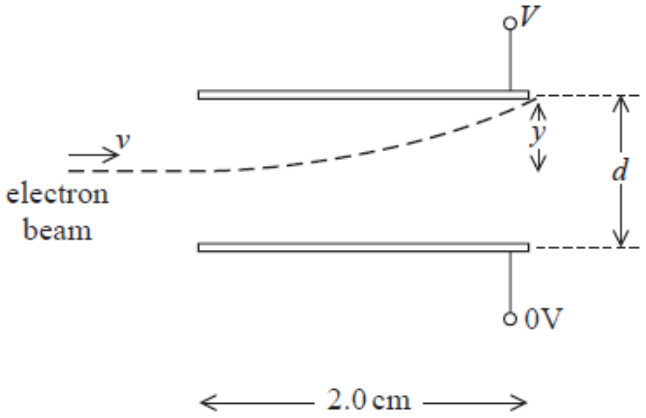
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(b) The electron beam then enters a uniform electric field between the two parallel horizontal deflecting plates. The magnitude and direction of the deflection is determined by the p.d. *V* that

is applied across the plates.

The diagram shows one possible path of the electron beam as it passes between the plates.




(i) Show that the acceleration of an electron, of mass $m$ and charge $Q$, is given by

$$\frac{VQ}{dm}$$

**(2)**

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(ii) Calculate the magnitude of the vertical deflection y of the beam as it leaves the plates.

$V = 50$ V
$d = 0.01$ m

**(5)**

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*y* = .....

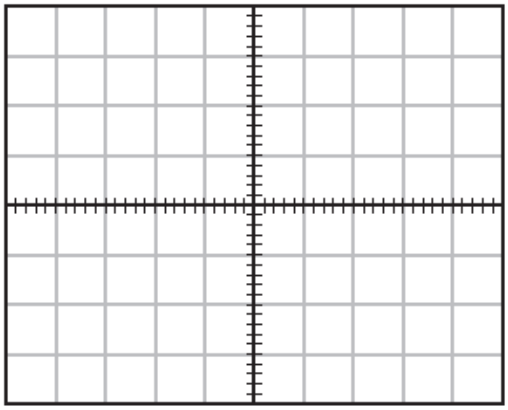
(c) A laboratory oscilloscope with the time base turned off operates in the same way as this simplified cathode ray tube. A student uses an oscilloscope in this way to monitor an alternating p.d. of 53 $V_{rms}$

On the grid, draw the trace that would be seen on the screen.

**(4)**

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1 square = 25 V

**(Total for question = 14 marks)**

Q2.

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)**

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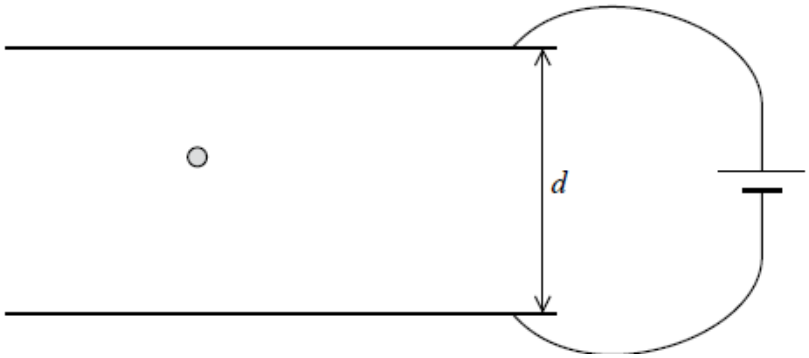
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Q3.

In an experiment to determine the charge on an electron, negatively charged oil drops are allowed to fall between two parallel metal plates separated by a distance *d*.

A potential difference (p.d.) is applied across the plates. The diagram shows one oil drop between the plates.




When the p.d. is 0 V the oil drop accelerates to terminal velocity. The p.d. is increased. It is observed that at a particular p.d. *V* the oil drop stops falling and remains stationary between the plates.

(a) The oil drop has a mass *m*. Show that the charge *q* on the oil drop is given by

$$q = \frac{mgd}{V}$$

**(2)**

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(b) Explain what would happen to the oil drop if the p.d. is increased further.

**(2)**

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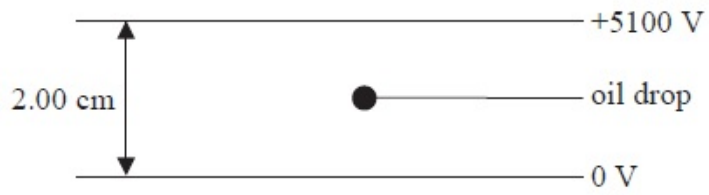
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**(Total for question = 4 marks)**

Q4. 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 $1.20 \times 10^{-14}$ 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)**

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(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)**

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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)**

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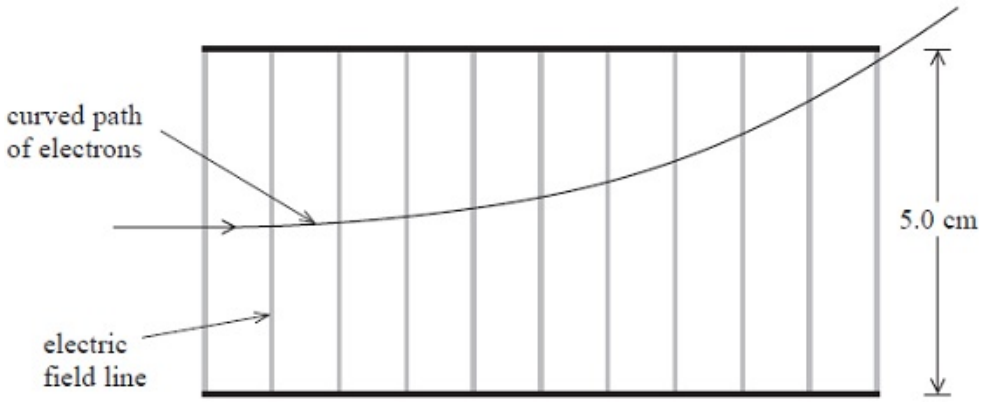
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Number of electrons = .....

**(Total for Question = 12 marks)**

Q5. A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.




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

**(1)**

(b) The conducting plates are 5.0 cm apart and have a potential difference of 160 V across them.

Calculate the force on the electron due to the electric field.

**(3)**

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Force = .....

(c) Explain why the path of the electron is curved between the plates and straight when it has left the plates.

**(3)**

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(d) The electron was initially released from a metal by thermionic emission and then accelerated through a potential difference before entering the region of the electric field.

(i) State what is meant by thermionic emission.

**(1)**

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(ii) In order to be able to just leave the plates as shown, the electron must enter the electric field between the plates with a speed of $1.2 \times 10^7$ m $s^{-1}$.

Calculate the potential difference required to accelerate an electron from rest to this speed.

**(3)**

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Potential difference = .....

**(Total for Question = 11 marks)**

Q6.

A potential difference of 50 V is applied between two identical parallel aluminium plates. The plates are separated by a distance of 10 mm.

Which combination of potential difference and separation would double the electric field strength?

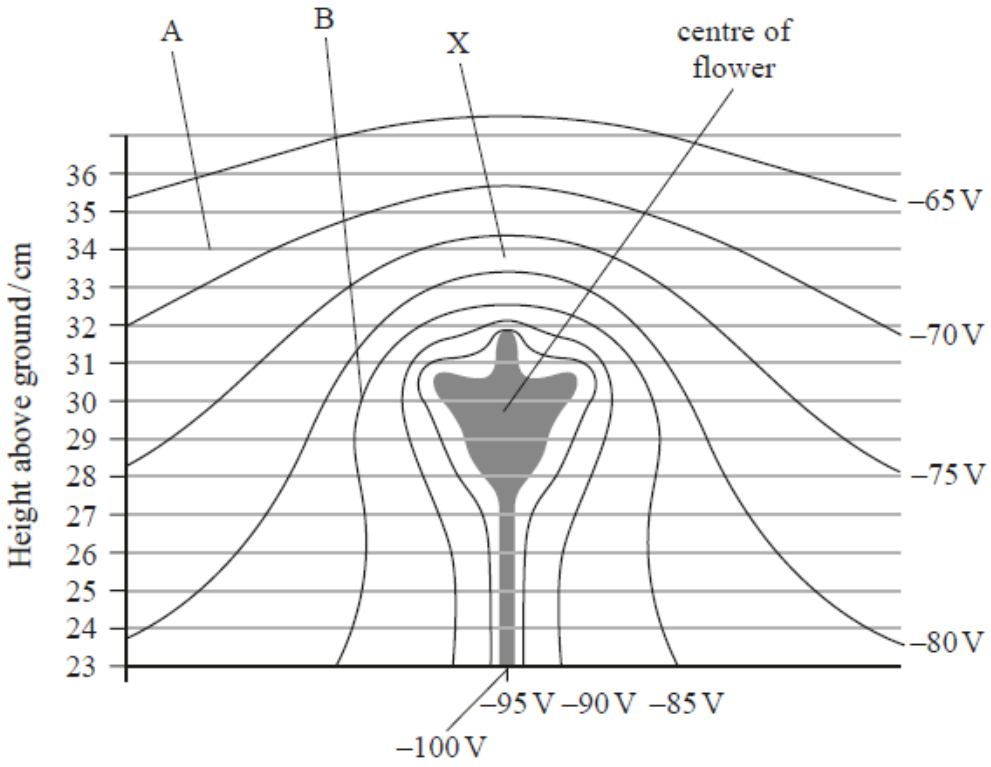
| | Separation/mm | Potential difference/ V |
|---|---|---|
| ☐ A | 20 | 100 |
| ☐ B | 20 | 25 |
| ☐ C | 10 | 100 |
| ☐ D | 10 | 25 |

**(Total for question = 1 mark)**

Q7.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

The diagram shows lines of equipotential surrounding a flower.




(i) Determine the electric field strength at X.

**(3)**

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Electric field strength at X = .....

(ii) Draw the electric field line between point A and point B on the diagram.

**(2)**

(iii) An equation for electric potential $V$ is

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

This applies to a radial field.

Deduce whether the electric field in the region directly above the flower is radial.
You should take values from the diagram. A graphical method is not required.

**(3)**

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**(Total for question = 8 marks)**

Q8.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

A potential difference is applied across two parallel plates. A particle carrying a charge of +0.1 C is placed between the plates and experiences a force *F*.

The distance between the plates is halved. The potential difference remains constant.

Which of the following is now equal to the electric field strength between the plates?

☒ **A** 5*F*

☒ **B** 10*F*

☒ **C** 20*F*

☒ **D** 40*F*

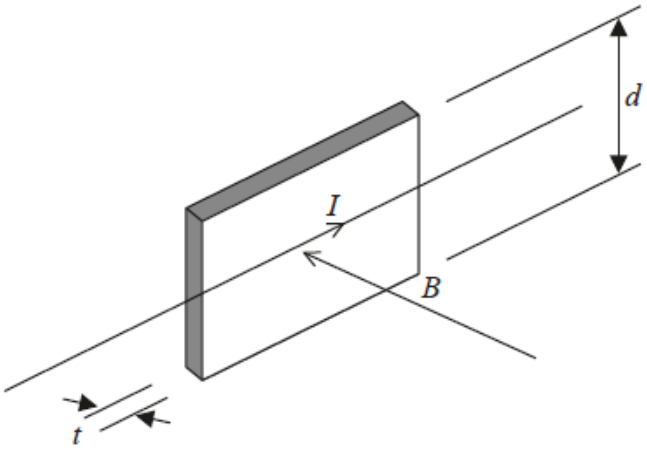
**(Total for question = 1 mark)**

Q9.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's

surface by measuring the Earth's magnetic flux density.

A current $I$ and a magnetic field of flux density $B$ are applied to a slice of semiconductor as shown. The slice has thickness $t$ and depth $d$.




Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage $V_{HALL}$ develops.

Electrons continue to collect at the top edge of the slice, until the force on a moving electron due to the magnetic field is equal to the force on the electron due to the electric field.

Derive the following equation for $V_{HALL}$:

$$V_{HALL} = \frac{BI}{nte}$$

where $n$ is the number of charge carriers per unit volume of the semiconductor.

**(4)**

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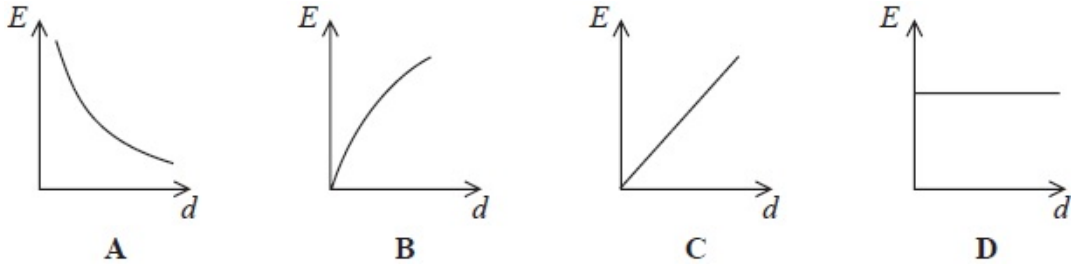
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**(Total for question = 4 marks)**

Q10. Two parallel, conducting plates are connected to a battery. One plate is connected to the positive terminal and the other plate to the negative terminal. The plate separation *d* is gradually increased while the plates stay connected to the battery.

Select the graph that shows how the electric field strength *E* between the plates varies with separation *d*.




☒ **A**

☒ **B**

☒ **C**

☒ **D**

**(Total for Question = 1 mark)**

Q1.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

Alpha particle scattering investigations were first carried out in the early part of the 20th century.

An alpha particle with initial kinetic energy $8.8 \times 10^{-13}$J approaches a nucleus of a gold $\left({}^{197}_{79}\mathrm{Au}\right)$ atom.

Which of the following is an equation for the closest distance *r*, in metres, between the alpha particle and the nucleus?

☒ **A** $r = 8.99 \times 10^{9} \left( \dfrac{2 \times 1.6 \times 10^{-19} \times 79 \times 1.6 \times 10^{-19}}{8.8 \times 10^{-13}} \right)$

☒ **B** $r = \dfrac{2 \times 1.6 \times 10^{-19} \times 197 \times 1.6 \times 10^{-19}}{8.99 \times 10^{9} \times 8.8 \times 10^{-13}}$

☒ **C** $r = 8.99 \times 10^{9} \left( \dfrac{8.8 \times 10^{-13}}{4 \times 1.6 \times 10^{-19} \times 79 \times 1.6 \times 10^{-19}} \right)$

☒ **D** $r = 8.99 \times 10^{9} \left( \dfrac{2 \times 79}{8.8 \times 10^{-13}} \right)$

**(Total for question = 1 mark)**

Q2.

Our understanding of the atom has developed over time, from early models in which atoms were considered to be hard incompressible spheres, through to the nuclear model of the atom and the ladder model in which electrons exist in a discrete number of allowed energy states.

The nuclear model of the atom was established following a series of experiments in which alpha particles were directed at thin gold foil.

(i) An alpha particle approaching a gold nucleus, ${}^{197}_{79}\mathrm{Au}$, head-on will be brought to rest and returned along its original path.

Calculate the minimum distance between the alpha particle and the nucleus for alpha particles of energy of 5.5 MeV.

**(4)**

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Minimum distance = .....

(ii) It is observed that electrons, with energy of 5.5 keV, are diffracted as they pass through the thin gold foil.

Explain a conclusion about the electrons that can be made from this observation.

**(3)**

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**(Total for question = 7 marks)**

Q3.

At the beginning of the 20th century, Rutherford carried out large-angle alpha particle scattering experiments using gold ($^{197}_{79}$Au) foil.

The vast majority of the alpha particles went straight through the foil whilst a few were deflected straight back.

In one experiment the alpha particles had an initial energy of 7.7 MeV.

Calculate the distance of closest approach of the alpha particles to the nucleus of a gold atom. Assume that the gold nucleus remains at rest.

**(4)**

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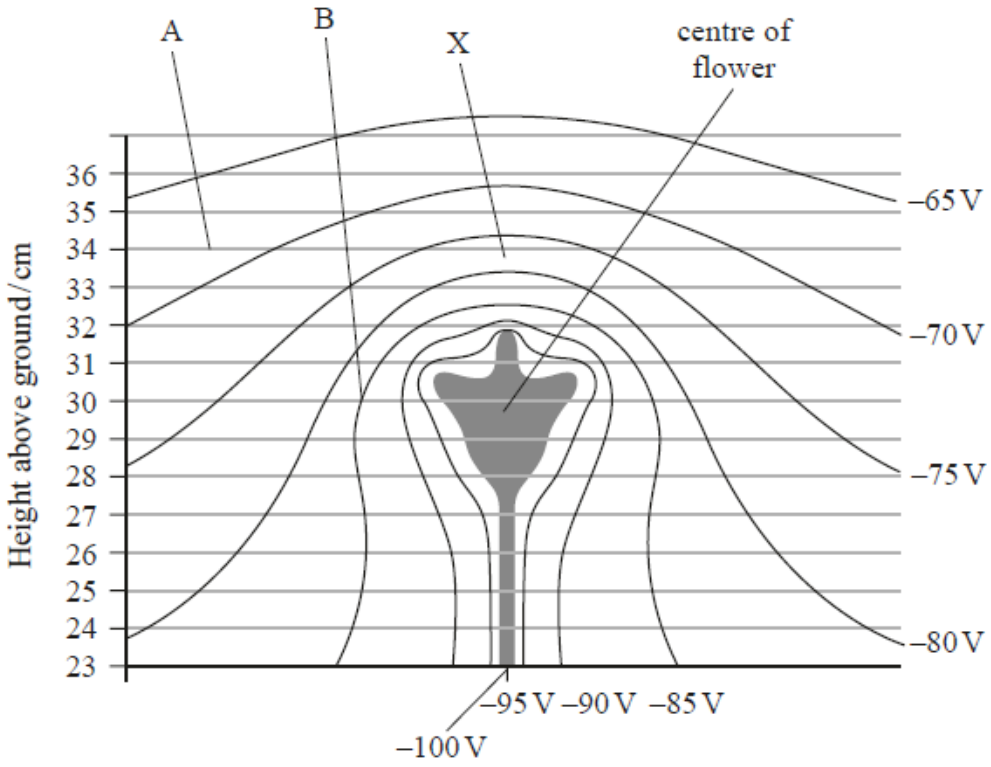
Distance of closest approach = .....

**(Total for question = 4 marks)**

Q4.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

The diagram shows lines of equipotential surrounding a flower.




(i) Determine the electric field strength at X.

**(3)**

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Electric field strength at X = .....

(ii) Draw the electric field line between point A and point B on the diagram.

**(2)**

(iii) An equation for electric potential $V$ is

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

This applies to a radial field.

Deduce whether the electric field in the region directly above the flower is radial.
You should take values from the diagram. A graphical method is not required.

**(3)**

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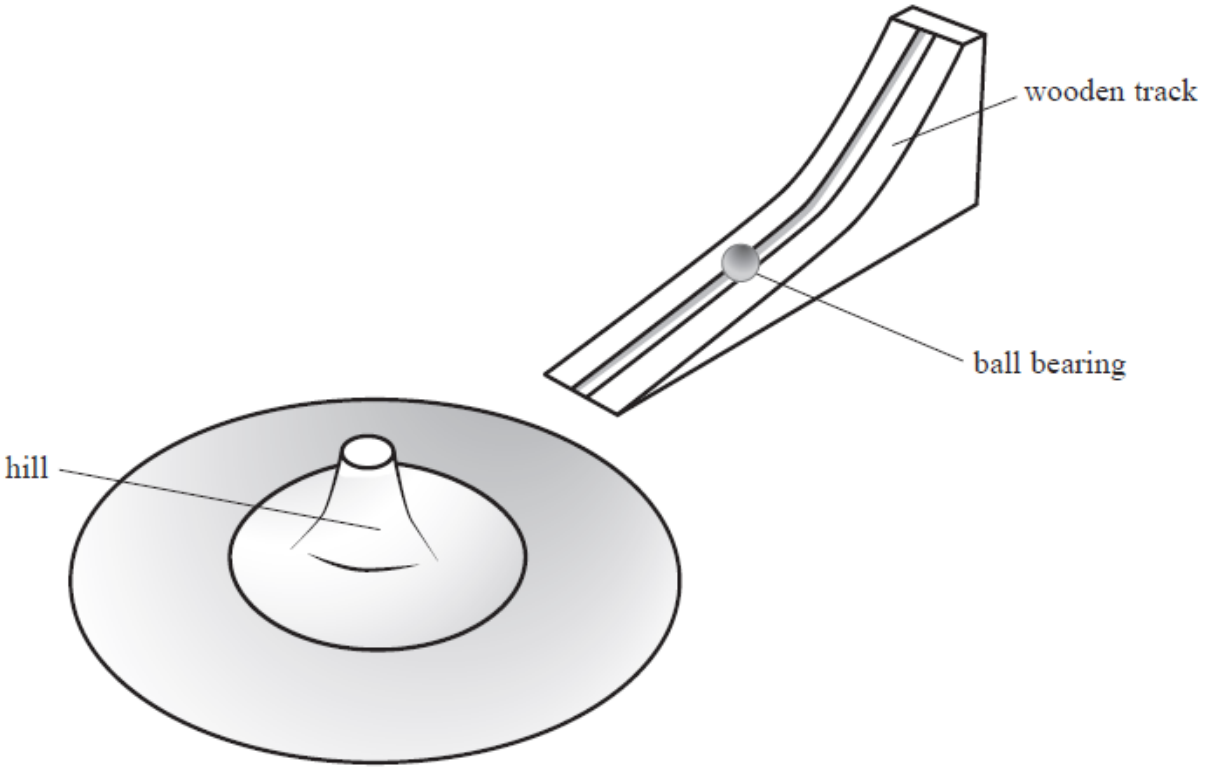
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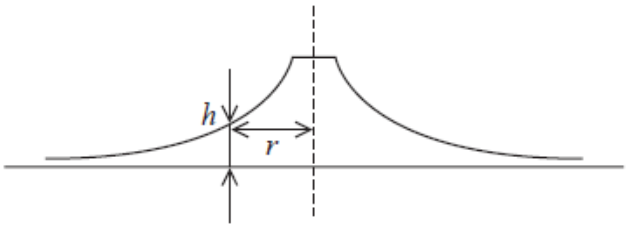
**(Total for question = 8 marks)**

Q5.

The diagram shows a model used to demonstrate alpha particle scattering. A ball bearing is set rolling on a wooden track. The track is positioned so that the ball bearing rolls onto a metal sheet with a curved surface known as a 'hill'.




The diagram shows a vertical cross-section through the hill. The surface is curved so that the height of a point *h* on the curved surface is inversely proportional to the distance *r* from the centre of the hill.




Explain why the hill is suitable as a model for the electric field surrounding the nucleus of an atom.

**(3)**

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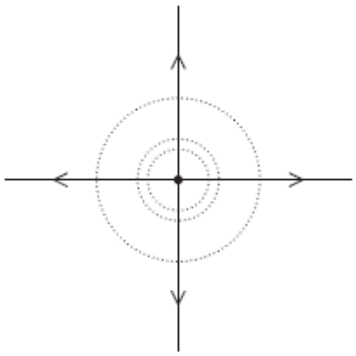
**(Total for question = 3 marks)**

Q1.

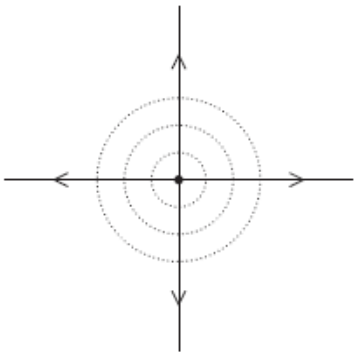
**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

A point object has a charge +Q.

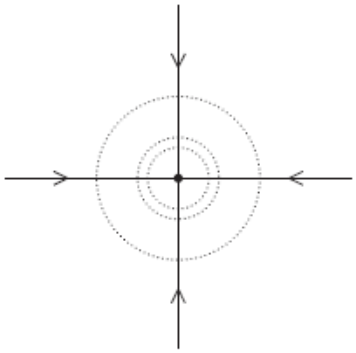
Which of the following diagrams shows equipotential lines differing by a constant potential difference, and electric field lines around the object?



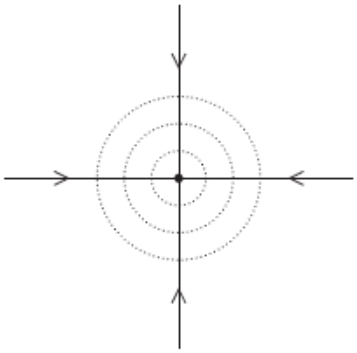
☒ **A**



☐ **B**



☒ **C**



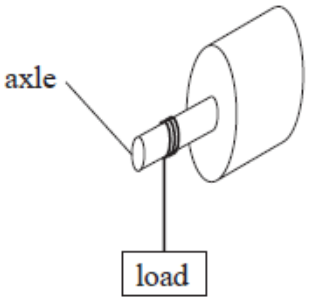
☐ **D**

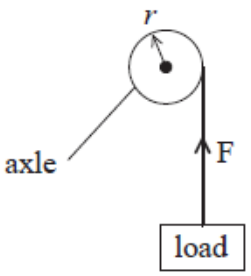
**(Total for question = 1 mark)**

Q2.

Motors usually have a rotating component which can do work *W*.

(a) A motor lifts a load in a time *t*. The axle of the motor has a radius *r* and exerts a force *F*.




The power produced by a motor can be calculated by using the following word equation.

**Power = moment of the force exerted by the rotating axle × angular velocity**

Derive this equation, starting with power $P = \frac{W}{t}$.

**(4)**

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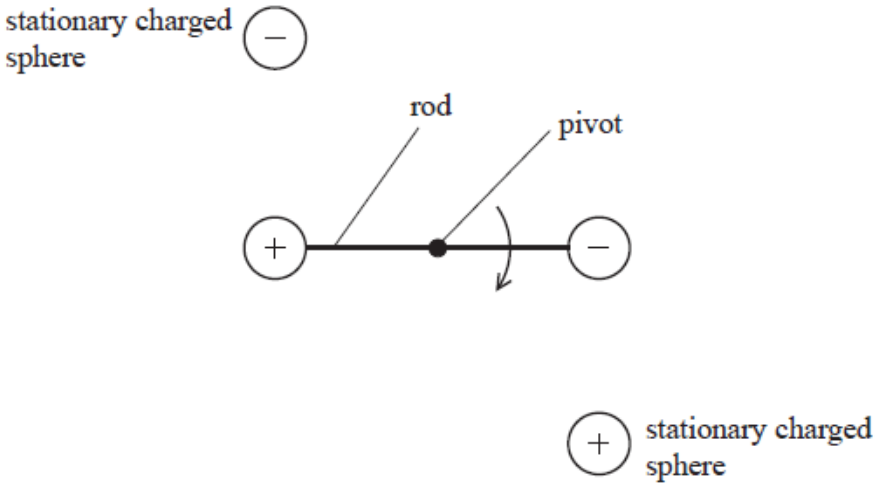
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(b) An electrostatic motor was first demonstrated by Benjamin Franklin in 1750.

The diagram shows a simplified version of part of this motor.

This consists of a rod, with an oppositely charged sphere at either end, which rotates around a fixed pivot. Two stationary charged spheres apply a force on the spheres at either end of the rod.

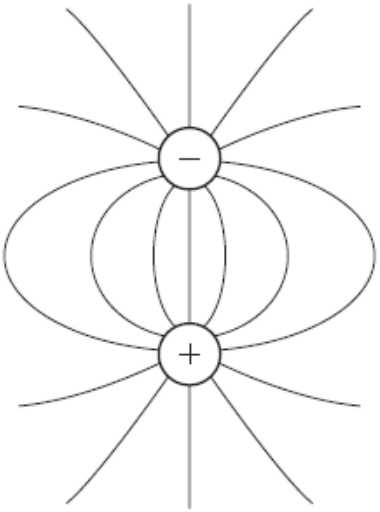



(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

- the directions of the field lines
- the lines of equipotential.

**(3)**




(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere = 0.10 μC

**(2)**

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(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

| | Power / W | Angular velocity / rad $s^{-1}$ |
|---|---|---|
| Electric car | $2.0 \times 10^4$ | 300 |
| Vacuum cleaner | $1.4 \times 10^3$ | 1000 |
| Small pond pump | 0.5 | 200 |

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

**(4)**

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**(Total for question = 13 marks)**

Q3.

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)**

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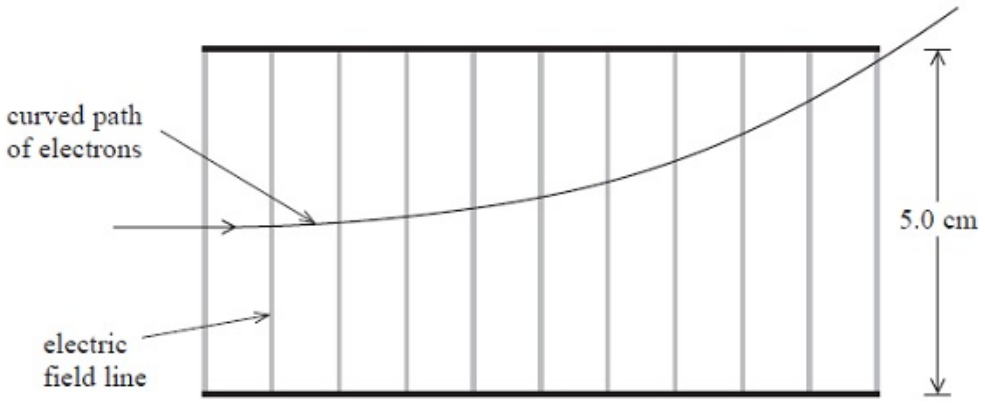
Q4.

Sketch the electric field around a positive point charge.

**(3)**

**(Total for question = 3 marks)**

Q5. A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.




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

**(1)**

(b) The conducting plates are 5.0 cm apart and have a potential difference of 160 V across them.

Calculate the force on the electron due to the electric field.

**(3)**

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Force = .....

(c) Explain why the path of the electron is curved between the plates and straight when it has left the plates.

**(3)**

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(d) The electron was initially released from a metal by thermionic emission and then accelerated through a potential difference before entering the region of the electric field.

(i) State what is meant by thermionic emission.

**(1)**

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(ii) In order to be able to just leave the plates as shown, the electron must enter the electric field between the plates with a speed of $1.2 \times 10^7$ m $s^{-1}$.

Calculate the potential difference required to accelerate an electron from rest to this speed.

**(3)**

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Potential difference = .....

**(Total for Question = 11 marks)**

Q6.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

When the bee is collecting nectar from the plant, the electric field strength decreases.
It is thought that this warns other bees that the nectar supply is low.

State the effect of a decreased electric field strength on the equipotential lines.

**(1)**

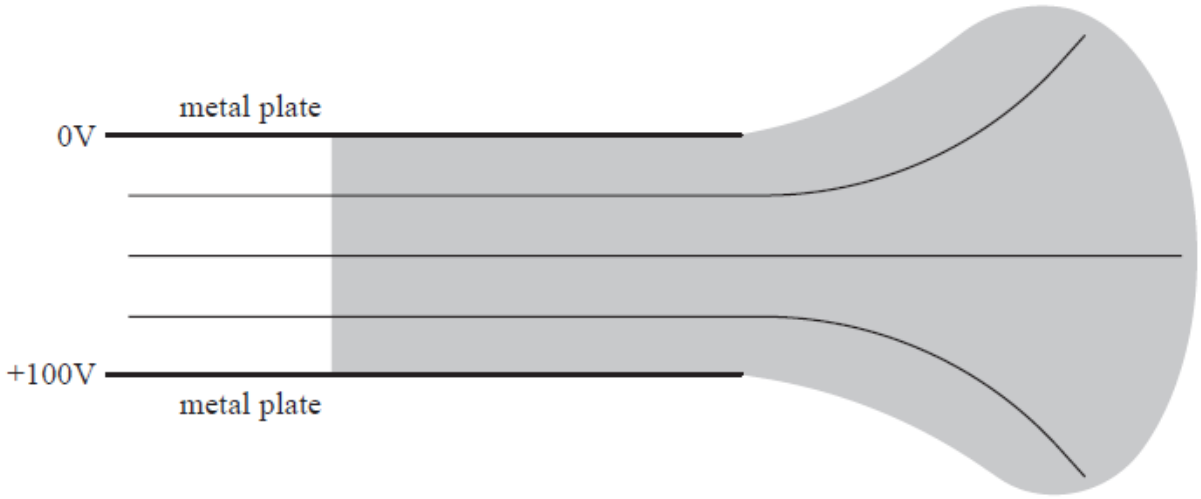
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**(Total for question = 1 mark)**

Q7.

13 The diagram shows two parallel metal plates with a potential difference (p.d.) of 100 V across them. Three equipotential lines are shown.



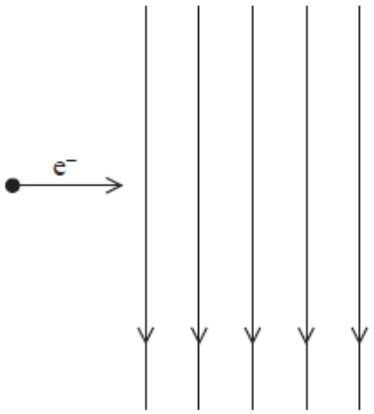

Draw lines to represent the electric field in the shaded area.

**(4)**

**(Total for question = 4 marks)**

Q8.

An electron travelling horizontally enters a uniform electric field which acts vertically downwards as shown in the diagram.




Which of the following statements is **incorrect**?

☒ **A** The electron follows a parabolic path.

☒ **B** The electron accelerates while in the field.

☒ **C** The electric force on the electron acts downwards.

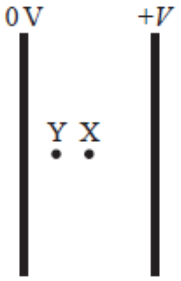
☒ **D** The speed of the electron increases.

**(Total for question = 1 mark)**

Q9.

**Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).**

A potential difference *V* is applied across two parallel plates. An electron midway between the two plates at point X experiences an electric force *F*.




The electron moves to point Y which is halfway between point X and the left-hand plate.

Which of the following is the electric force experienced by the electron at Y?

☒ **A** 2*F*

☒ **B** *F*

☒ **C** $\frac{F}{2}$

☒ **D** $\frac{F}{4}$

**(Total for question = 1 mark)**

Q10.

Protons interact with particles in the upper atmosphere and create new particles. Pions can be produced from high energy proton collisions.

(i) State why the following reaction is not possible.

$$p + p \rightarrow p + p + \pi^{-}$$

**(1)**

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(ii) State one similarity and one difference between the electric field of a proton and the electric field of a $\pi^{-}$.

**(2)**

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