PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 7: ELECTRIC AND MAGNETIC FIELDS

ELECTRIC FIELDS

SCORE	PERCENTAGE
/390	%

STEMUP

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Mark Scheme

Q1.

Question Number	Answer	Mark
	D	1

Q2.

Question Number	Answer	Mark
(b)	**Diagram mark for parallel plate**: a minimum of 3 parallel equispaced lines touching plates (ignore edge effect) (1) **Diagram mark for point charge**: minimum of 4 equispaced radial lines touching charged point (1) Direction of fields correct for both diagrams consistent with charges labelled (1) Parallel plate - field strength same at all points (1) Point charge - field strength decreases with (increasing)distance from point (1) **Or** obeys inverse square law	5

Q3.

Question number	Acceptable answers	Additional guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5–4 / 3 3–2 / 2 1 / 1 0 / 0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	

Question number	Acceptable answers	Additional guidance	Mark
* (continued)	The following table shows how the marks should be awarded for structure and lines of reasoning.		

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Question number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • At terminal velocity the forces on the drop are balanced **OR** weight = drag • The p.d. creates an electrostatic force acting upwards on the drop • The electrostatic force increases as p.d. increases • The net upward force causes the drop to have a negative acceleration • As speed decreases the drag decreases • The drop remains stationary when the forces are balanced **OR** until the drop remains stationary when weight = electrostatic force		**6**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• A region where a charged particle experiences a force/acceleration **(1)**		**(1)**

Q5.

Question Number	Answer		Mark
(a)	At least three vertical lines spread over symmetrically over more than half of the plate length and touching both plates. (ignore edge ones that might curve) All equispaced and parallel [don't allow gaping to avoid oil drop] Arrow pointing downwards	**(1)** **(1)** **(1)**	**3**
(b)	Negative / - / -ve (negative and/or positive does not get the mark)	**(1)**	**1**
(c)	Upward force labelled: Electric (force) **Or** Electrostatic (force) **Or** force due to electric field **Or** electromagnetic (force) [do not accept repulsive/attractive force. If EQ used, the symbols must be defined] Downward force labelled: mg, weight, W, gravitational force (for both marks the lines must touch the drop and be pointing away from it. Ignore upthrust if drawn but one mark lost for each extra force added)	**(1)** **(1)**	**2**
(d)(i)	E = 5100 V/ 2 cm Conversion of cm to m Use of $QE = mg$ (1.18×10^{-13} kg) $Q = 4.6 \times 10^{-19}$ C (E = 255 000 (V m^{-1}) scores MP1 & 2. unit conversion missed → $Q = 4.62 \times 10^{-17}$ C scores MP1 & 3 if V is halved → $Q = 9.23 \times 10^{-19}$ C scores MP1 ,2 & 3) <u>Example of calculation</u> $E = V/d$ $F = EQ = mg$ $Q = mg / E = mgd/V$ Q = (1.20 × 10^{-14} kg × 9.81m s^{-2}× 0.02 m) / (5100 V) Q = 4.62 × 10^{-19} C	**(1)** **(1)** **(1)** **(1)**	**4**
(d)(ii)	Answer to (d)(i) divided by e 3 electrons **Or** sensible integer number less than 500 (answers with very large numbers of electrons can get MP1 only) <u>Example of calculation</u> Number of electrons = 4.62 × 10^{-19} C / 1.6 × 10^{-19} C Number = 2.9 i.e. 3 electrons.	**(1)** **(1)**	**2**
	Total for question		**12**

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Q6.

Question Number	Answer		Mark
(a)	Arrow(s) downwards	**(1)**	**1**
(b)	Use of $E = V/d$ Use of $F = EQ$ $F = 5.1 \times 10^{-16}$ N Example of calculation $F = (160\text{ V} \times 1.6 \times 10^{-19}\text{ C}) / 5.0 \times 10^{-2}\text{ m}$ $F = 5.12 \times 10^{-16}$ N	**(1)** **(1)** **(1)**	**3**
(c)	Between the plates there is an acceleration/force which is vertical/upwards Constant horizontal velocity Outside the plates no (electric) field /force acts **Or** Outside the plates speed so large that gravitational effect negligible	**(1)** **(1)** **(1)**	**3**
(d)(i)	Release of (surface) electrons due to heating	**(1)**	**1**
(d)(ii)	Use of $E_k = ½mv^2$ Use of $V = W/Q$ p.d. = 410 V Example of calculation $E_k = 9.11 \times 10^{-31}\text{ kg} \times (1.2 \times 10^{7}\text{ m s}^{-1})^2/2$ $E_k = 6.56 \times 10^{-17}$ J p.d. $= (6.56 \times 10^{-17}\text{ J})/(1.6 \times 10^{-19}\text{ C})$ p.d. = 410V	**(1)** **(1)** **(1)**	**3**
	Total for question		**11**

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A is not correct as $E_{initial} = F/Q = 10F$, if d halved then $E_{after} = 20F$ B is not correct as $E_{initial} = F/Q = 10F$, if d halved then $E_{after} = 20F$ D is not correct as $E_{initial} = F/Q = 10F$, if d halved then $E_{after} = 20F$		**1**

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B A *is not correct because this is a uniform field so F constant* C *is not correct because this is a uniform field so F constant* D *is not correct because this is a uniform field so F constant*	*F*	**1**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• Charged particle/hair attracts/repels **(1)** **Or** charged/hair experiences a force		**(1)**

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Electric field vertically downwards (from top plate to bottom plate) **(1)** • Magnetic field into paper **(1)**		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• Use of $E = \frac{V}{d}$ **(1)** • Use of $F_E = EQ$ **(1)** • Use of $F_M = BQv$ **(1)** • Show that these forces are equal (if v is 2.2×10^5 m s^{-1}) and hence state that B is suitable **(1)**	Do not award MP4 if incorrect ion charge used Example of calculation: $E = \frac{V}{d} = \frac{135\,\text{V}}{2.5\times10^{-2}\,\text{m}} = 5400\,\text{V m}^{-1}$ $F = EQ = 5400\,\text{V m}^{-1} \times 1.6\times10^{-19}\,\text{C} = 8.6\times10^{-16}\,\text{N}$ $F = BQv = 24.5\times10^{-3}\,\text{T} \times 1.6\times10^{-19}\,\text{C} \times 2.2\times10^{5}\,\text{m s}^{-1}$ $= 8.6\times10^{-16}\,\text{N}$	**4**

Mark Scheme

Q1.

Question Number	Answer	Mark
	D	1

Q2.

Question Number	Answer	Additional guidance	Mark
(a)(i)	thermionic emission		**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• equate $\frac{1}{2}mv^2$ and VQ (1) • $v = 2.3 \times 10^7$ m s^{-1} (1)	Example of calculation: $E = 1500\text{ V} \times 1.6 \times 10^{-19}\text{ C} = 2.4 \times 10^{-16}\text{ J}$ $v = \sqrt{\frac{2 \times 2.4 \times 10^{-16}\text{ J}}{9.11 \times 10^{-31}\text{ kg}}} = 2.3 \times 10^7\text{ m s}^{-1}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(i)	• use of $F = EQ$ and $E = \frac{V}{d}$ (1) OR see $F = \frac{VQ}{d}$ • equate $F = ma$ and $F = EQ$ (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• use of speed = distance/time (1) • $t = 8.7 \times 10^{-10}$ (s) (1) • use of a = $\frac{VQ}{dm}$ (1) • use of $s = ut + \frac{1}{2}at^2$ (1) with $u = 0$ and vertical acceleration to find s • $s = 3.3 \times 10^{-4}$ m (1)	Example of calculation: $t = \frac{0.02\text{ m}}{2.3 \times 10^7\text{ m s}^{-1}} = 8.7 \times 10^{-10}\text{ s}$ $s = \frac{1}{2} \times \left(\frac{50\text{ V} \times 1.6 \times 10^{-19}\text{ C}}{0.01\text{ m} \times 9.11 \times 10^{-31}\text{ kg}} \right) \times (8.7 \times 10^{-10}\text{ s})^2$ $s = 3.3 \times 10^{-4}\text{ m}$	**(6)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	• use of $V = V_0/\sqrt{2}$ (1) • vertical line (1) • positive and negative deflection shown (1) • maximum deflection 75 V (1)	Example of calculation: $V_0 = 53\text{ V} \times \sqrt{2} = 75\text{ V}$	**(4)**

Q3.

Question Number	Answer	Mark
(b)	**Diagram mark for parallel plate**: a minimum of 3 parallel equispaced lines touching plates (ignore edge effect) (1) **Diagram mark for point charge**: minimum of 4 equispaced radial lines touching charged point (1) Direction of fields correct for both diagrams consistent with charges labelled (1) Parallel plate - field strength same at all points (1) Point charge - field strength decreases with (increasing)distance from point (1) **Or** obeys inverse square law	5

Q4.

Question number	Acceptable answers	Additional guidance	Mark
(b)	• Equate the electric force and the gravitational force **(1)** • Use of E=V/d to obtain $q = mgd/V$ **(1)**	$qE = mg$ $q(V/d) = mg$ $q = mgd/V$	**2**
(c)	An explanation that makes reference to: • Electrostatic/upward force (on drop) would be greater than the weight/downward force **(1)** • So drop would <u>accelerate</u> upwards **(1)**	Indication of which force is greater, unbalanced is insufficient.	**2**

Q5.

Question Number	Answer		Mark
(a)	At least three vertical lines spread over symmetrically over more than half of the plate length and touching both plates. (ignore edge ones that might curve) All equispaced and parallel [don't allow gaping to avoid oil drop] Arrow pointing downwards	**(1)** **(1)** **(1)**	**3**
(b)	Negative / - / -ve (negative and/or positive does not get the mark)	**(1)**	**1**
(c)	Upward force labelled: Electric (force) **Or** Electrostatic (force) **Or** force due to electric field **Or** electromagnetic (force) [do not accept repulsive/attractive force. If EQ used, the symbols must be defined] Downward force labelled: mg, weight, W, gravitational force (for both marks the lines must touch the drop and be pointing away from it. Ignore upthrust if drawn but one mark lost for each extra force added)	**(1)** **(1)**	**2**
(d)(i)	E = 5100 V/ 2 cm Conversion of cm to m Use of $QE = mg$ (1.18×10^{-13} kg) $Q = 4.6 \times 10^{-19}$ C (E = 255 000 (V m^{-1}) scores MP1 & 2. unit conversion missed → $Q = 4.62 \times 10^{-17}$ C scores MP1 & 3 if V is halved → $Q = 9.23 \times 10^{-19}$ C scores MP1 ,2 & 3) <u>Example of calculation</u> $E = V/d$ $F = EQ = mg$ $Q = mg / E = mgd/V$ Q = (1.20×10^{-14} kg × 9.81m s^{-2}× 0.02 m) / (5100 V) Q = 4.62×10^{-19} C	**(1)** **(1)** **(1)** **(1)**	**4**
(d)(ii)	Answer to (d)(i) divided by e 3 electrons **Or** sensible integer number less than 500 (answers with very large numbers of electrons can get MP1 only) <u>Example of calculation</u> Number of electrons = 4.62×10^{-19} C / 1.6×10^{-19} C Number = 2.9 i.e. 3 electrons.	**(1)** **(1)**	**2**
	Total for question		**12**

Q6.

Question Number	Answer		Mark
(a)	Arrow(s) downwards	**(1)**	**1**
(b)	Use of $E = V/d$ Use of $F = EQ$ $F = 5.1 \times 10^{-16}$ N Example of calculation $F = (160\ \text{V} \times 1.6 \times 10^{-19}\ \text{C}) / 5.0 \times 10^{-2}\ \text{m}$ $F = 5.12 \times 10^{-16}$ N	**(1)** **(1)** **(1)**	**3**
(c)	Between the plates there is an acceleration/force which is vertical/upwards Constant horizontal velocity Outside the plates no (electric) field /force acts **Or** Outside the plates speed so large that gravitational effect negligible	**(1)** **(1)** **(1)**	**3**
(d)(i)	Release of (surface) electrons due to heating	**(1)**	**1**
(d)(ii)	Use of $E_k = \frac{1}{2}mv^2$ Use of $V = W/Q$ p.d. = 410 V Example of calculation $E_k = 9.11 \times 10^{-31}\ \text{kg} \times (1.2 \times 10^{7}\ \text{m s}^{-1})^2/2$ $E_k = 6.56 \times 10^{-17}$ J p.d. $= (6.56 \times 10^{-17}\ \text{J})/(1.6 \times 10^{-19}\ \text{C})$ p.d. = 410V	**(1)** **(1)** **(1)**	**3**
	Total for question		**11**

Q7.

Question Number	Answer		Mark
(a)	(Electric field strength (at a point in a field) is) the force per unit charge (accept force per coulomb of charge) Acting on a (small) positive charge.	**(1)** **(1)**	**2**
(b)(i)	Use of $E = kQ/r^2$ Electric field due to $Q_1 = 4.1(1) \times 10^6$ (N C^{-1}) Use of 11.9 cm to find field due to Q_2 **Or** Use of $E = kQ/r^2$ Use of $E1/E2 = Q1\ r22/\ Q2\ r12$ $E_1/E_2 = 1$ Example of calculation Electric field due to Q_1 $= (8.99 \times 10^9$ N m^2 $C^{-2}) \times (3 \times 10^{-6}$ C) / $(8.1 \times 10^{-2})^2$ $= 4.11 \times 10^6$ N C^{-1} Electric field due to Q_2 $= (8.99 \times 10^9$ N m^2 $C^{-2}) \times (6.5 \times 10^{-6}$ C) / $(11.9 \times$ $10^{-2})^2 = 4.13 \times 10^6$ N C^{-1}	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
(b)(ii)	(Force on charge is) zero/negligible/approx zero (Allow values less than 0.1 N)	**(1)**	**1**
(b)(iii)	At midpoint repulsive force due to Q_2 > repulsive force due to Q_1 **Or** the resultant field/force is repulsive Work must be done against the repulsive force/field to move the charge to this position.	**(1)** **(1)**	**2**
	Total for question		**8**

Q8.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>
This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative points seen in answer</th><th>Number of marks awarded for indicative points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Indicative content

There is an alternating p.d./E-field
P.d./E-field accelerates protons between dees
Magnetic field perpendicular to plane of dees
Proton path curved by magnetic field
As velocity of protons increases radius of path in dees increases
The time for which a proton is in a dee remains constant
Or the frequency of p.d./E-field is constant

</td>
<td>
Guidance on how the mark scheme should be applied: The mark for The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure and lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table>
<table>
<tr><th>Number of IC points</th><th>Possible linkage marks</th></tr>
<tr><td>0, 1</td><td>0</td></tr>
<tr><td>2, 3</td><td>1</td></tr>
<tr><td>4, 5, 6</td><td>2</td></tr>
</table>
IC2 accept 'in the gap' for between dees. Accept increases E_k for accelerates

IC3 accept vertical or upwards for perpendicular to plane.

IC5 accept reference to $r = p/BQ$
</td>
<td>6</td>
</tr>
</table>

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equates $F=Bev$ and $F=eE$ **(1)** • Substitutes $E = V/d$ **(1)** **Or** $F = eV / d$ seen • Replaces v with I / neA **(1)** • Substitute $A = d \times t$ and leads to given equation **(1)** Alternative: • Equates $F = BIl$ and $F = QE$ with Q identified as total charge **(1)** • Substitutes $E = V/d$ **Or** $F = QV / d$ seen • Substitutes $Q = neAl$ and cancels l • Substitute $A = d \times t$ and leads to given equation	Example of derivation: $Bev = eE$ $Bev = eV/d$ $\frac{BI}{neA} = \frac{V_H}{d}$ $V_H = \frac{BI}{net}$ Alternative: $BIl = QE$ Total charge $Q = neAl$ $BIl = neAlE$ $BI = neAV_H / d$ $V_H = BI / net$	**(4)**

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $F = BQv$ and $F = EQ$ **(1)** • Algebra to show $v = \frac{E}{B}$ **(1)**		**2**
(ii)	• Use of $W = QV$ *and* $E_k = \frac{1}{2}mv^2$ **(1)** • Use of $v = \frac{E}{B}$ **(1)** • $\frac{e}{m} = 1.7 \times 10^{11}$ C kg^{-1} **(1)**	Example of calculation: $v = \frac{E}{B} = \frac{1.4 \times 10^4 \text{ V m}^{-1}}{1.5 \times 10^{-3} \text{ T}}$ $\frac{e}{m} = \frac{v^2}{2V}$ $\frac{e}{m} = \frac{\left(9.33 \times 10^6 \text{ m s}^{-1}{}^2\right)}{2 \times 250 \text{ V}} = 1.74 \times 10^{11}$ C kg^{-1}	**3**

Mark Scheme

Q1.

Question Number	Answer	Mark
	D	1

Q2.

Question Number	Answer	Additional guidance	Mark
(a)(i)	thermionic emission		**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• equate $\frac{1}{2}mv^2$ and VQ (1) • $v = 2.3 \times 10^7$ m s^{-1} (1)	Example of calculation: $E = 1500\text{ V} \times 1.6 \times 10^{-19}\text{ C} = 2.4 \times 10^{-16}\text{ J}$ $v = \sqrt{\frac{2 \times 2.4 \times 10^{-16}\text{ J}}{9.11 \times 10^{-31}\text{ kg}}} = 2.3 \times 10^7\text{ m s}^{-1}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(i)	• use of $F = EQ$ and $E = \frac{V}{d}$ (1) OR see $F = \frac{VQ}{d}$ • equate $F = ma$ and $F = EQ$ (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• use of speed = distance/time (1) • $t = 8.7 \times 10^{-10}$ (s) (1) • use of a = $\frac{VQ}{dm}$ (1) • use of $s = ut + \frac{1}{2}at^2$ (1) with $u = 0$ and vertical acceleration to find s • $s = 3.3 \times 10^{-4}$ m (1)	Example of calculation: $t = \frac{0.02\text{ m}}{2.3 \times 10^7\text{ m s}^{-1}} = 8.7 \times 10^{-10}\text{ s}$ $s = \frac{1}{2} \times \left(\frac{50\text{ V} \times 1.6 \times 10^{-19}\text{ C}}{0.01\text{ m} \times 9.11 \times 10^{-31}\text{ kg}} \right) \times (8.7 \times 10^{-10}\text{ s})^2$ $s = 3.3 \times 10^{-4}\text{ m}$	**(6)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	• use of $V = V_0/\sqrt{2}$ (1) • vertical line (1) • positive and negative deflection shown (1) • maximum deflection 75 V (1)	Example of calculation: $V_0 = 53\text{ V} \times \sqrt{2} = 75\text{ V}$	**(4)**

Q3.

Question Number	Answer	Mark
(b)	**Diagram mark for parallel plate**: a minimum of 3 parallel equispaced lines touching plates (ignore edge effect) (1) **Diagram mark for point charge**: minimum of 4 equispaced radial lines touching charged point (1) Direction of fields correct for both diagrams consistent with charges labelled (1) Parallel plate - field strength same at all points (1) Point charge - field strength decreases with (increasing)distance from point (1) **Or** obeys inverse square law	5

Q4.

Question number	Acceptable answers	Additional guidance	Mark
(b)	• Equate the electric force and the gravitational force **(1)** • Use of E=V/d to obtain $q = mgd/V$ **(1)**	$qE = mg$ $q(V/d) = mg$ $q = mgd/V$	**2**
(c)	An explanation that makes reference to: • Electrostatic/upward force (on drop) would be greater than the weight/downward force **(1)** • So drop would <u>accelerate</u> upwards **(1)**	Indication of which force is greater, unbalanced is insufficient.	**2**

Q5.

Question Number	Answer		Mark
(a)	At least three vertical lines spread over symmetrically over more than half of the plate length and touching both plates. (ignore edge ones that might curve) All equispaced and parallel [don't allow gaping to avoid oil drop] Arrow pointing downwards	**(1)** **(1)** **(1)**	**3**
(b)	Negative / - / -ve (negative and/or positive does not get the mark)	**(1)**	**1**
(c)	Upward force labelled: Electric (force) **Or** Electrostatic (force) **Or** force due to electric field **Or** electromagnetic (force) [do not accept repulsive/attractive force. If EQ used, the symbols must be defined] Downward force labelled: mg, weight, W, gravitational force (for both marks the lines must touch the drop and be pointing away from it. Ignore upthrust if drawn but one mark lost for each extra force added)	**(1)** **(1)**	**2**
(d)(i)	E = 5100 V/ 2 cm Conversion of cm to m Use of $QE = mg$ (1.18×10^{-13} kg) $Q = 4.6 \times 10^{-19}$ C (E = 255 000 (V m^{-1}) scores MP1 & 2. unit conversion missed → $Q = 4.62 \times 10^{-17}$ C scores MP1 & 3 if V is halved → $Q = 9.23 \times 10^{-19}$ C scores MP1 ,2 & 3) <u>Example of calculation</u> $E = V/d$ $F = EQ = mg$ $Q = mg / E = mgd/V$ Q = (1.20×10^{-14} kg × 9.81m s^{-2}× 0.02 m) / (5100 V) Q = 4.62×10^{-19} C	**(1)** **(1)** **(1)** **(1)**	**4**
(d)(ii)	Answer to (d)(i) divided by e 3 electrons **Or** sensible integer number less than 500 (answers with very large numbers of electrons can get MP1 only) <u>Example of calculation</u> Number of electrons = 4.62×10^{-19} C / 1.6×10^{-19} C Number = 2.9 i.e. 3 electrons.	**(1)** **(1)**	**2**
	Total for question		**12**

Q6.

Question Number	Answer		Mark
(a)	Arrow(s) downwards	**(1)**	**1**
(b)	Use of $E = V/d$ Use of $F = EQ$ $F = 5.1 \times 10^{-16}$ N Example of calculation $F = (160\ \text{V} \times 1.6 \times 10^{-19}\ \text{C}) / 5.0 \times 10^{-2}\ \text{m}$ $F = 5.12 \times 10^{-16}$ N	**(1)** **(1)** **(1)**	**3**
(c)	Between the plates there is an acceleration/force which is vertical/upwards Constant horizontal velocity Outside the plates no (electric) field /force acts **Or** Outside the plates speed so large that gravitational effect negligible	**(1)** **(1)** **(1)**	**3**
(d)(i)	Release of (surface) electrons due to heating	**(1)**	**1**
(d)(ii)	Use of $E_k = \frac{1}{2}mv^2$ Use of $V = W/Q$ p.d. = 410 V Example of calculation $E_k = 9.11 \times 10^{-31}\ \text{kg} \times (1.2 \times 10^{7}\ \text{m s}^{-1})^2/2$ $E_k = 6.56 \times 10^{-17}$ J p.d. $= (6.56 \times 10^{-17}\ \text{J})/(1.6 \times 10^{-19}\ \text{C})$ p.d. = 410V	**(1)** **(1)** **(1)**	**3**
	Total for question		**11**

Q7.

Question Number	Answer		Mark
(a)	(Electric field strength (at a point in a field) is) the force per unit charge (accept force per coulomb of charge) Acting on a (small) positive charge.	**(1)** **(1)**	**2**
(b)(i)	Use of $E = kQ/r^2$ Electric field due to $Q_1 = 4.1(1) \times 10^6$ (N C^{-1}) Use of 11.9 cm to find field due to Q_2 **Or** Use of $E = kQ/r^2$ Use of $E1/E2 = Q1\ r22/\ Q2\ r12$ $E_1/E_2 = 1$ Example of calculation Electric field due to Q_1 $= (8.99 \times 10^9$ N m^2 $C^{-2}) \times (3 \times 10^{-6}$ C) / $(8.1 \times 10^{-2})^2$ $= 4.11 \times 10^6$ N C^{-1} Electric field due to Q_2 $= (8.99 \times 10^9$ N m^2 $C^{-2}) \times (6.5 \times 10^{-6}$ C) / $(11.9 \times$ $10^{-2})^2 = 4.13 \times 10^6$ N C^{-1}	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
(b)(ii)	(Force on charge is) zero/negligible/approx zero (Allow values less than 0.1 N)	**(1)**	**1**
(b)(iii)	At midpoint repulsive force due to Q_2 > repulsive force due to Q_1 **Or** the resultant field/force is repulsive Work must be done against the repulsive force/field to move the charge to this position.	**(1)** **(1)**	**2**
	Total for question		**8**

Q8.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>
This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative points seen in answer</th><th>Number of marks awarded for indicative points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Indicative content

There is an alternating p.d./E-field
P.d./E-field accelerates protons between dees
Magnetic field perpendicular to plane of dees
Proton path curved by magnetic field
As velocity of protons increases radius of path in dees increases
The time for which a proton is in a dee remains constant
Or the frequency of p.d./E-field is constant

</td>
<td>
Guidance on how the mark scheme should be applied: The mark for The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure and lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table>
<table>
<tr><th>Number of IC points</th><th>Possible linkage marks</th></tr>
<tr><td>0, 1</td><td>0</td></tr>
<tr><td>2, 3</td><td>1</td></tr>
<tr><td>4, 5, 6</td><td>2</td></tr>
</table>
IC2 accept 'in the gap' for between dees. Accept increases E_k for accelerates

IC3 accept vertical or upwards for perpendicular to plane.

IC5 accept reference to $r = p/BQ$
</td>
<td>6</td>
</tr>
</table>

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equates $F=Bev$ and $F=eE$ **(1)** • Substitutes $E = V/d$ **(1)** **Or** $F = eV / d$ seen • Replaces v with I / neA **(1)** • Substitute $A = d \times t$ and leads to given equation **(1)** Alternative: • Equates $F = BIl$ and $F = QE$ with Q identified as total charge **(1)** • Substitutes $E = V/d$ **Or** $F = QV / d$ seen • Substitutes $Q = neAl$ and cancels l • Substitute $A = d \times t$ and leads to given equation	Example of derivation: $Bev = eE$ $Bev = eV/d$ $\frac{BI}{neA} = \frac{V_H}{d}$ $V_H = \frac{BI}{net}$ Alternative: $BIl = QE$ Total charge $Q = neAl$ $BIl = neAlE$ $BI = neAV_H / d$ $V_H = BI / net$	**(4)**

Q10.

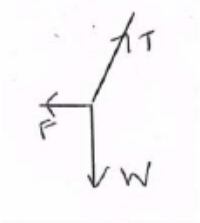
Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $F = BQv$ and $F = EQ$ **(1)** • Algebra to show $v = \frac{E}{B}$ **(1)**		**2**
(ii)	• Use of $W = QV$ *and* $E_k = \frac{1}{2}mv^2$ **(1)** • Use of $v = \frac{E}{B}$ **(1)** • $\frac{e}{m} = 1.7 \times 10^{11}$ C kg^{-1} **(1)**	Example of calculation: $v = \frac{E}{B} = \frac{1.4 \times 10^4 \text{ V m}^{-1}}{1.5 \times 10^{-3} \text{ T}}$ $\frac{e}{m} = \frac{v^2}{2V}$ $\frac{e}{m} = \frac{\left(9.33 \times 10^6 \text{ m s}^{-1}{}^2\right)}{2 \times 250 \text{ V}} = 1.74 \times 10^{11}$ C kg^{-1}	**3**

Mark Scheme

Q1.

Question Number	Answer	Mark
	D	**1**

Q2.

Question Number	Answer		Mark
(a)(i)	*W*/*mg* and *T* correct *F*/*E*/ electric force correct Example of diagram  	(1) (1)	2
(a)(ii)	See $T\cos\theta = W$ See $T\sin\theta = F$ **Or** Draws a correct triangle of forces Correctly labels θ (if a triangle is drawn it must be a closed polygon with correctly orientated direction of arrows)	(1) (1) (1) (1)	2
(b)(i)	Records 1pair of values from graph Records 2nd pair of values from graph Use of $F\,r^2$ Shows that $F_1r_1^2 = F_2r_2^2$ (accept answers with or without the powers of ten included) Example of answer Ignoring powers of 10 115 N × 20^2 m^2 = 46000 51 N × 30^2 m^2 = 45900	(1) (1) (1) (1)	4
(b)(ii)	Uses constant from (b) ignoring powers of ten errors **Or** uses a pair of values from graph Use of $F = kQ_1\,Q_2\,/r^2$ with 1.6 × 10^{-19} C Q = 7.2 × 10^{-9} C Example of answer 100 Q^2 = 46000 × 10^{-9} N m^2 / 8.99 × 10^9 N m^2 C^{-2} Q^2 = 5.12 × 10^{-17} C^2 Q = 7.2 × 10^{-9} C	(1) (1) (1)	3
	Total for question		**11**

Q3.

Question Number	Answer		Mark
(a)	Weight/W/mg vertically down Tension/T parallel to thread and pointing away Electrical (force) horizontal to left Accept electrostatic (force), repulsive (force), coulomb (force) repelling (force). Do **not** accept just F or drag All three correct 2 marks Any two correct 1 mark The lines must start on the ball and have arrow heads to indicate direction. Minus 1 mark for each extra force line. (Candidates who draw forces on M correctly but also include forces on N score 1)		**2**
(b)(i)	Use of $T \cos 35° = mg$ **Or** $T \sin 55° = mg$ g to kg and × 9.81 Tension = 3.2×10^{-2} (N) Example of calculation $T \cos 35° = mg$ $T = (2.7 \times 10^{-3}\ \text{kg} \times 9.81\ \text{N kg}^{-1}) / \cos 35°$ $T = 0.0323$ N	**(1)** **(1)** **(1)**	**3**
(b)(ii)	Equates electric force to $T \sin 35°$ **Or** $T \cos 55°$ **Or** $W \tan 35°$ **Or** use of pythagoras $F_E = 0.018$ **Or** 0.019 (N) ($F_E = 0.017$ N if show that value used. ecf T from (i) Example of calculation $F_E = 0.032 \times \sin 35°$ $F_E = 0.018$ N	**(1)** **(1)**	**2**
(b)(iii)	Use of $F = Q^2/4\pi\varepsilon_0 r^2$ **Or** $F = kQ^2/r^2$ (ecf value of F from (ii) conversion cm to m $Q = (2.9 - 3.1) \times 10^{-7}$ C (candidates who half the value of r can score the first 2 marks) Example of calculation $Q^2 = Fr^2/k$ $Q^2 = (0.020\ \text{N}) \times (20.6 \times 10^{-2}\ \text{m})^2/(8.99 \times 10^9\ \text{N m}^2\ \text{C}^{-2})$ $Q = 3.07 \times 10^{-7}$ C	**(1)** **(1)** **(1)**	**3**
(c)	Both balls would move through the same angle/distance **Or** the balls are suspended at equal angles (to the vertical) (Because) the force on both balls is the same	**(1)** **(1)**	**2**

Q4.

Question Number	Answer		Mark
(a)(i)	Straight through, zero deflection, direction fired in. (Do not accept 'through' or 'directly behind' on its own)	**(1)**	**1**
(a)(ii)	(Atom consists) mainly/mostly of <u>empty space</u> **Or** Volume of atom very much greater than volume of nucleus. (do not credit if part of a list)	**(1)**	**1**
(b)	Most of the mass is in the nucleus/centre [it is not enough to say that the nucleus is dense/concentrated. Looking for idea that nearly all of the atom's mass is in the nucleus] Nucleus/centre is <u>charged</u> [ignore references to the charge being positive. Just saying the nucleus is positive does not get the mark.]	**(1)** **(1)**	**2**
(c)(i) E	Electrostatic/electromagnetic/electric/coulomb	**(1)**	**1**
(c)(ii)	Arrow starting on the path at closest point to the nucleus Arrow pointing radially away from nucleus (correct direction starting on the nucleus scores 2nd mark only)	**(1)** **(1)**	**2**
(c)(iii)	Deflection starts earlier Final deflection is greater (paths should diverge)	**(1)** **(1)**	**2**
	Total for question		**9**

Q5.

Question Number	Answer		Mark
	Use of $F_E = kQ_1Q_2/r^2$	(1)	
	Use of $W = mg$	(1)	
	Resolve vertically $T\cos\theta = mg$ **and** Resolve horizontally $T\sin\theta = F_E$	(1)	
	Attempt to combine components to give tan θ (tan $\theta = F_E/mg$)	(1)	
	$\theta = 41°$ to 42°	(1)	
	$T = 0.035$ N	(1)	
	Or		
	Use of $F_E = kQ_1Q_2/r^2$	(1)	
	Use of $W = mg$	(1)	
	Use of Pythagoras to find tension force	(1)	
	Tan $\theta = F_E/mg$ **Or** $\cos\theta = mg/T$ **Or** $\sin\theta = F_E/T$	(1)	
	$\theta = 41°$ to 42°	(1)	
	$T = 0.035$ N	(1)	**6**
	(if they halve the separation or halve the electric force they can still get MP1 and so could score MP1,2, 3 & 4)		
	Example of calculation		
	Weight of sphere = 0.0027 kg × 9.81 N kg^{-1} = 0.026 N		
	Electric force $F_E = kQ_1Q_2/r^2$		
	= 8.99 ×10^{9}N m^2 C^{-2} × (4.0 × 10^{-7} C)^2 / 0.25^2 m^2 = 0.023 N		
	Vertically $T\cos\theta = mg$		
	Horizontally $T\sin\theta = F_E$		
	Tan $\theta = F_E$/mg = 0.023 N/ 0.026 N		
	$\theta = 41°$		
	sub into vertical equation		
	$T = mg/\cos\theta$ = 0.026 N /cos 41		
	$T = 0.034$ N		

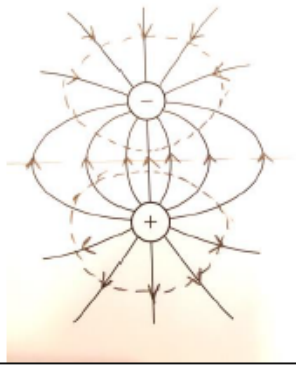
Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C		**1**
	A is not correct because the E is equal to − gradient of the graph of V against r *B is not correct because the E is equal to − gradient of the graph of V against r* *D is not correct because the E is equal to − gradient of the graph of V against r*		

Q2.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Replace Work W by force × distance • Replace distance ÷ time by velocity v • Use $v = r \times$ Angular velocity • Recognise $F \times r$ is the moment of F	**(1)** **(1)** **(1)** **(1)**	Alternative method: Consider one revolution of axle , Load rises $2\pi r$ Work done = $2\pi rF$ Time taken = $2\pi \div \omega$ Power = Work ÷ time= $2\pi rF \div 2\pi/\omega$ to give reqd eq	**4**

Question Number	Acceptable answers		Additional guidance	Mark
(b)(i)	• Arrow away from + charge **Or** arrow towards − charge • At least 3 Equipotential lines, perpendicular to field lines • Symmetrical about vertical/horizontal axis **and** not touching/crossing	**(1)** **(1)** **(1)**	MP3 dependent on lines being perpendicular in MP2 	**3**

Question Number	Acceptable answers		Additional guidance	Mark
(b)(ii)	• Use of $F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$ • $F = 0.036$ (N)	**(1)** **(1)**	Example of calculation: $F = 8.99\times10^{9}\,\text{Nm}^2\text{C}^{-2}\,\dfrac{(0.1\times10^{-6}\,\text{C})^2}{(0.05\text{m})^2}$ $F = 0.036\text{N}$	**2**

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of moment = $F x$	(1)	Show that value gives 3.2×10^{-3} Nm and 0.64 W	4
	• Expression for correct moment	(1)	Example of calculation: Moment $= 0.036\text{N} \times 0.04\text{m} \times 2 = 2.89 \times 10^{-3}\text{ Nm}$	
	• Use of power = moment of force x angular velocity	(1)		
	• Only realistic possibility is pond pump and $P = 0.6$W (calculated answer could also be force and then comparison with b(i))	(1)	$\text{Power} = 2.89 \times 10^{-3}\text{ N m} \times 200\text{s}^{-1} = 0.58\text{W}$	

Q3.

Question Number	Acceptable Answers		Additional guidance	Mark
	Maximum 3 marks			3max
	• There cannot be a p.d. across his body	(1)		
	• Electric field strength inside cage is zero	(1)	Accept reference to Faraday cage for MP2	
	• As no potential gradient	(1)		
	• Current/electrons/charge would conduct through suit **Or** the current would not pass through body	(1)		

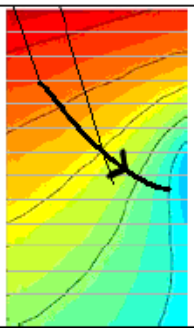
Q4.

Question Number	Acceptable answers		Additional guidance	Mark
	• Equipotential lines would be further apart	(1)		(1)

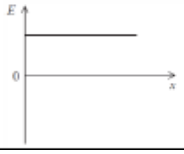
Q5.

Question Number	Answer		Mark
(a)	(Electric field strength (at a point in a field) is) the force per unit charge (accept force per coulomb of charge) Acting on a (small) positive charge.	**(1)** **(1)**	**2**
(b)(i)	Use of $E = kQ/r^2$ Electric field due to $Q_1 = 4.1(1) \times 10^6$ (N C^{-1}) Use of 11.9 cm to find field due to Q_2 **Or** Use of $E = kQ/r^2$ Use of $E1/E2 = Q1\ r22/\ Q2\ r12$ $E_1/E_2 = 1$ <u>Example of calculation</u> Electric field due to Q_1 $= (8.99 \times 10^9$ N m^2 $C^{-2}) \times (3 \times 10^{-6}$ C) / $(8.1 \times 10^{-2})^2$ $= 4.11 \times 10^6$ N C^{-1} Electric field due to Q_2 $= (8.99 \times 10^9$ N m^2 $C^{-2}) \times (6.5 \times 10^{-6}$ C) / $(11.9 \times 10^{-2})^2$ $= 4.13 \times 10^6$ N C^{-1}	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
(b)(ii)	(Force on charge is) zero/negligible/approx zero (Allow values less than 0.1 N)	**(1)**	**1**
(b)(iii)	At midpoint repulsive force due to Q_2 > repulsive force due to Q_1 **Or** the <u>resultant</u> field/force is repulsive <u>Work</u> must be done against the repulsive force/field to move the charge to this position.	**(1)** **(1)**	**2**
	Total for question		**8**

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• States a value of ΔV	(1)	Example of calculation: $E = \frac{(80-75)\text{V}}{0.009\text{m}} = 556\ \text{V m}^{-1}$ (Alt: 5.6 V cm^{-1})	(3)
	• Uses $\Delta V/\Delta d$ with a difference in distance	(1)		
	• $E = 560\ \text{V m}^{-1}$ allow range 500-560 V m^{-1}	(1)		
(ii)	• Line perpendicular to a least 2 equipotential lines	(1)		(2)
	• Arrow pointing towards flower	(1)		
(iii)	• States $V \times r$ = constant	(1)	Example of calculation: Using $V = 95$ and $r = 2.0 - 2.2$: $Vr = 190 - 209$ $V = 90$ and $r = 2.1 - 2.5$: $Vr = 189 - 225$ $V = 85$ and $r = 2.5 - 2.8$: $Vr = 212 - 238$ $V = 80$ and $r = 3.5 - 3.8$: $Vr = 280 - 304$ $V = 75$ and $r = 4.3 - 4.7$: $Vr = 323 - 353$ $V = 70$ and $r = 5.8 - 6.2$: $Vr = 406 - 434$ Using $r = 3$ and $V = 82-83$: $Vr = 246-249$ $r = 4$ and $V = 77-78$: $Vr = 308-312$ $r = 5$ and $V = 72-73$: $Vr = 360-365$	(3)
	• One corresponding pair of values of V and r	(1)		
	• At least two pairs of values used to show that the product is not constant therefore not radial (MP3 dependent on MP2)	(1)		

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A 	B,C and D are not the negative potential gradient	1

Q8.

Question Number	Acceptable Answers	Additional guidance	Mark
	• tangent at correct point (1) • triangle with base at least 0.4 m (1) • 5.3×10^6 (Vm^{-1}) (range 4.9×10^6 to 6.1×10^6) (1) • So would ionise as value greater than 3×10^6 (1) Alternative: • Correct value of V at 30 cm (1) • Use of $E = k\frac{Q}{r^2}$ and $V = k\frac{Q}{r}$ (1) • 5.3×10^6 (Vm^{-1}) (1) • So would ionise as value greater than 3×10^6 (1)	Example of calculation: Gradient = 3200000 / 0.6 $E = 5.3 \times 10^6$ V m^{-1} MP4 to be consistent with calculated value $V = 1.6 \times 10^6$ V m^{-1}	4

Mark Scheme

Q1.

Question Number	Answer	Additional guidance	Mark
(a)(i)	thermionic emission		**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• equate $\frac{1}{2}mv^2$ and VQ (1) • $v = 2.3 \times 10^7$ m s^{-1} (1)	Example of calculation: $E = 1500\text{ V} \times 1.6 \times 10^{-19}\text{ C} = 2.4 \times 10^{-16}\text{ J}$ $v = \sqrt{\frac{2 \times 2.4 \times 10^{-16}\text{ J}}{9.11 \times 10^{-31}\text{ kg}}} = 2.3 \times 10^7\text{ m s}^{-1}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(i)	• use of $F = EQ$ and $E = \frac{V}{d}$ (1) OR see $F = \frac{VQ}{d}$ • equate $F = ma$ and $F = EQ$ (1)		**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• use of speed = distance/time (1) • $t = 8.7 \times 10^{-10}$ (s) (1) • use of a = $\frac{VQ}{dm}$ (1) • use of $s = ut + \frac{1}{2}at^2$ (1) with $u = 0$ and vertical acceleration to find s • $s = 3.3 \times 10^{-4}$ m (1)	Example of calculation: $t = \frac{0.02\text{ m}}{2.3 \times 10^7\text{ m s}^{-1}} = 8.7 \times 10^{-10}\text{ s}$ $s = \frac{1}{2} \times \left(\frac{50\text{ V} \times 1.6 \times 10^{-19}\text{ C}}{0.01\text{ m} \times 9.11 \times 10^{-31}\text{ kg}} \right) \times (8.7 \times 10^{-10}\text{ s})^2$ $s = 3.3 \times 10^{-4}\text{ m}$	**(6)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	• use of $V = V_0/\sqrt{2}$ (1) • vertical line (1) • positive and negative deflection shown (1) • maximum deflection 75 V (1)	Example of calculation: $V_0 = 53\text{ V} \times \sqrt{2} = 75\text{ V}$	**(4)**

Q2.

Question Number	Answer	Mark
(b)	**Diagram mark for parallel plate**: a minimum of 3 parallel equispaced lines touching plates (ignore edge effect) (1) **Diagram mark for point charge**: minimum of 4 equispaced radial lines touching charged point (1) Direction of fields correct for both diagrams consistent with charges labelled (1) Parallel plate - field strength same at all points (1) Point charge - field strength decreases with (increasing)distance from point **Or** obeys inverse square law (1)	5

Q3.

Question number	Acceptable answers	Additional guidance	Mark
(b)	• Equate the electric force and the gravitational force **(1)** • Use of E=V/d to obtain $q = mgd/V$ **(1)**	$qE = mg$ $q(V/d) = mg$ $q = mgd/V$	**2**
(c)	An explanation that makes reference to: • Electrostatic/upward force (on drop) would be greater than the weight/downward force **(1)** • So drop would <u>accelerate</u> upwards **(1)**	Indication of which force is greater, unbalanced is insufficient.	**2**

Q4.

Question Number	Answer		Mark
(a)	At least three vertical lines spread over symmetrically over more than half of the plate length and touching both plates. (ignore edge ones that might curve) All equispaced and parallel [don't allow gaping to avoid oil drop] Arrow pointing downwards	**(1)** **(1)** **(1)**	**3**
(b)	Negative / - / -ve (negative and/or positive does not get the mark)	**(1)**	**1**
(c)	Upward force labelled: Electric (force) **Or** Electrostatic (force) **Or** force due to electric field **Or** electromagnetic (force) [do not accept repulsive/attractive force. If EQ used, the symbols must be defined] Downward force labelled: mg, weight, W, gravitational force (for both marks the lines must touch the drop and be pointing away from it. Ignore upthrust if drawn but one mark lost for each extra force added)	**(1)** **(1)**	**2**
(d)(i)	E = 5100 V/ 2 cm Conversion of cm to m Use of $QE = mg$ (1.18×10^{-13} kg) $Q = 4.6 \times 10^{-19}$ C (E = 255 000 (V m^{-1}) scores MP1 & 2. unit conversion missed → $Q = 4.62 \times 10^{-17}$ C scores MP1 & 3 if V is halved → $Q = 9.23 \times 10^{-19}$ C scores MP1 ,2 & 3) <u>Example of calculation</u> $E = V/d$ $F = EQ = mg$ $Q = mg / E = mgd/V$ Q = (1.20×10^{-14} kg × 9.81m s^{-2}× 0.02 m) / (5100 V) Q = 4.62×10^{-19} C	**(1)** **(1)** **(1)** **(1)**	**4**
(d)(ii)	Answer to (d)(i) divided by e 3 electrons **Or** sensible integer number less than 500 (answers with very large numbers of electrons can get MP1 only) <u>Example of calculation</u> Number of electrons = 4.62×10^{-19} C / 1.6×10^{-19} C Number = 2.9 i.e. 3 electrons.	**(1)** **(1)**	**2**
	Total for question		**12**

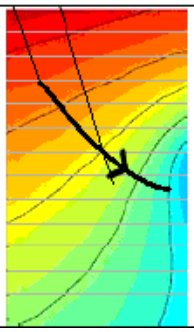
Q5.

Question Number	Answer		Mark
(a)	Arrow(s) downwards	**(1)**	**1**
(b)	Use of $E = V/d$ Use of $F = EQ$ $F = 5.1 \times 10^{-16}$ N Example of calculation $F = (160\ \text{V} \times 1.6 \times 10^{-19}\ \text{C}) / 5.0 \times 10^{-2}\ \text{m}$ $F = 5.12 \times 10^{-16}$ N	**(1)** **(1)** **(1)**	**3**
(c)	Between the plates there is an acceleration/force which is vertical/upwards Constant horizontal velocity Outside the plates no (electric) field /force acts **Or** Outside the plates speed so large that gravitational effect negligible	**(1)** **(1)** **(1)**	**3**
(d)(i)	Release of (surface) electrons due to heating	**(1)**	**1**
(d)(ii)	Use of $E_k = ½mv^2$ Use of $V = W/Q$ p.d. = 410 V Example of calculation $E_k = 9.11 \times 10^{-31}\ \text{kg} \times (1.2 \times 10^{7}\ \text{m s}^{-1})^2/2$ $E_k = 6.56 \times 10^{-17}$ J p.d. $= (6.56 \times 10^{-17}\ \text{J})/(1.6 \times 10^{-19}\ \text{C})$ p.d. = 410V	**(1)** **(1)** **(1)**	**3**
	Total for question		**11**

Q6.

Question Number	Answer	Mark
	C	**1**

Q7.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• States a value of ΔV	(1)		(3)
	• Uses $\Delta V/\Delta d$ with a difference in distance	(1)		
	• $E = 560$ V m^{-1} allow range 500-560 V m^{-1}	(1)	Example of calculation: $E = \frac{(80-75)\text{V}}{0.009\text{m}} = 556$ V m^{-1} (Alt: 5.6 V cm^{-1})	
(ii)	• Line perpendicular to a least 2 equipotential lines	(1)		(2)
	• Arrow pointing towards flower	(1)		
(iii)	• States $V \times r$ = constant	(1)	Example of calculation: Using $V = 95$ and $r =$ 2.0 – 2.2: $Vr = 190 - 209$ $V = 90$ and $r = 2.1 - 2.5$: $Vr = 189 - 225$ $V = 85$ and $r = 2.5 - 2.8$: $Vr = 212 - 238$ $V = 80$ and $r = 3.5 - 3.8$: $Vr = 280 - 304$ $V = 75$ and $r =$ 4.3 – 4.7: $Vr = 323 - 353$ $V = 70$ and $r = 5.8 - 6.2$: $Vr = 406 - 434$ Using $r = 3$ and $V = 82-83$: $Vr = 246-249$ $r = 4$ and $V = 77-78$: $Vr = 308-312$ $r = 5$ and $V = 72-73$: $Vr = 360-365$	(3)
	• One corresponding pair of values of V and r	(1)		
	• At least two pairs of values used to show that the product is not constant therefore not radial (MP3 dependent on MP2)	(1)		

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A is not correct as $E_{initial} = F/Q = 10F$, if d halved then $E_{after} = 20F$ B is not correct as $E_{initial} = F/Q = 10F$, if d halved then $E_{after} = 20F$ D is not correct as $E_{initial} = F/Q = 10F$, if d halved then $E_{after} = 20F$		**1**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equates $F=Bev$ and $F=eE$ **(1)** • Substitutes $E = V/d$ **(1)** **Or** $F = eV / d$ seen • Replaces v with I / neA **(1)** • Substitute $A = d \times t$ and leads to given equation **(1)** Alternative: • Equates $F = BIl$ and $F = QE$ with Q identified as total charge **(1)** • Substitutes $E = V/d$ **Or** $F = QV / d$ seen • Substitutes $Q = neAl$ and cancels l • Substitute $A = d \times t$ and leads to given equation	Example of derivation: $Bev = eE$ $Bev = eV/d$ $\frac{BI}{neA} = \frac{V_H}{d}$ $V_H = \frac{BI}{net}$ Alternative: $BIl = QE$ Total charge $Q = neAl$ $BIl = neAlE$ $BI = neAV_H / d$ $V_H = BI / net$	**(4)**

Q10.

Question Number	Answer	Mark
	A	**1**

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A *B is not correct because the charge on an Au nucleus is 79 $\times 1.6\times10^{-19}$C* *C is not correct because the charge on an alpha particle is 2 $\times 1.6\times10^{-19}$C* *D is not correct because the charges have not been converted to C*		**1**

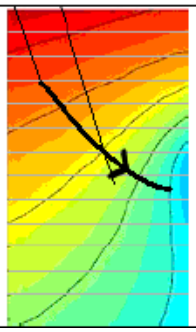
Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Conversion of MeV to J (1) • See $Q_1 = 79 \times 1.6 \times 10^{-19}$ and $Q_2 = 2 \times 1.6 \times 10^{-19}$ (1) • Use of $V = \frac{Q}{4\pi\varepsilon_0 r}$ and $W = QV$ (1) • $r = 4.1\times10^{-14}$ m (1)	Example of calculation $E_\alpha = 5.5\times10^{6}\text{eV}\times1.6\times10^{-19}\text{J eV}^{-1} = 8.8\times10^{-13}\text{J}$ $8.8\times10^{-13}\text{J} = \frac{79\times1.6\times10^{-19}\text{C}\times2\times1.6\times10^{-19}\text{C}}{4\pi\times8.85\times10^{-12}\text{ F m}^{-1}\, r}$ $r = \frac{3.64\times10^{-26}\text{ N m}^2}{8.8\times10^{-13}\text{ J}} = 4.1\times10^{-14}\text{ m}$	4
(ii)	• Electrons are behaving like waves (1) • wavelength $= \frac{h}{\text{momentum}}$ (1) • Electron wavelength must be similar to the atomic spacing in the foil (1)	MP3: Accept electron wavelength must be similar to the distance between (adjacent) nuclei	3

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $V = Q/4\pi\varepsilon_0 r$ (1) • Conversion MeV to J (1) • Use of $V = W/Q$ (1) • $r = 3.0 \times 10^{-14}$m (1)	allow for $Q = 2$ or 79, accept $V = kQ/r$ Must use $e = 1.6\times10^{-19}$ C to convert atomic number to C Example of calculation: $7.7 \times 10^{6}\text{eV} \times 1.6 \times 10^{-19}\text{J eV}^{-1} = 8.99 \times 10^{9}\text{N m}^2\text{C}^{-2} \times 2 \times 79 \times (1.6 \times 10^{-19}\text{ C})^2 \div r$ $r = 2.27 \times 10^{-7} \div 7.7 \times 10^{6}$ $r = 2.95 \times 10^{-14}$ m	4

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• States a value of ΔV	(1)	Example of calculation: $E = \frac{(80-75)V}{0.009m} = 556$ V m^{-1} (Alt: 5.6 V cm^{-1})	(3)
	• Uses $\Delta V/\Delta d$ with a difference in distance	(1)		
	• $E = 560$ V m^{-1} allow range 500-560 V m^{-1}	(1)		
(ii)	• Line perpendicular to a least 2 equipotential lines	(1)		(2)
	• Arrow pointing towards flower	(1)		
(iii)	• States $V \times r$ = constant	(1)	Example of calculation: Using $V = 95$ and $r =$ 2.0 – 2.2: $Vr = 190 - 209$ $V = 90$ and $r = 2.1 - 2.5$: $Vr = 189 - 225$ $V = 85$ and $r = 2.5 - 2.8$: $Vr = 212 - 238$ $V = 80$ and $r = 3.5 - 3.8$: $Vr = 280 - 304$ $V = 75$ and $r =$ 4.3 – 4.7: $Vr = 323 - 353$ $V = 70$ and $r = 5.8 - 6.2$: $Vr = 406 - 434$ Using $r = 3$ and $V = 82-83$: $Vr = 246-249$ $r = 4$ and $V = 77-78$: $Vr = 308-312$ $r = 5$ and $V = 72-73$: $Vr = 360-365$	(3)
	• One corresponding pair of values of V and r	(1)		
	• At least two pairs of values used to show that the product is not constant therefore not radial (MP3 dependent on MP2)	(1)		

Q5.

Question Number	Acceptable answers		Additional guidance	Mark
	• The curved surface is (analogous to) a radial field	(1)		3
	• (as $h \propto 1/r$ then) potential (energy) $\propto 1/r$	(1)		
	• compares with $V \propto 1/r$ around a point charge	(1)		

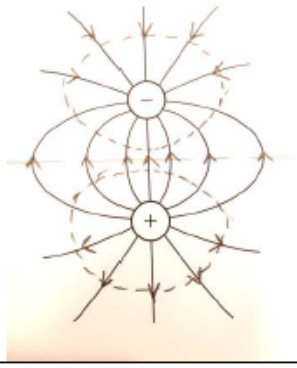
Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A *B is not correct because field direction is correct but equipotential lines will become further apart as distance increases as $V \propto 1/r$* *C is not correct because field direction is incorrect* *D is not correct because field direction is incorrect*		**1**

Q2.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Replace Work W by force × distance • Replace distance ÷ time by velocity v • Use $v = r \times$ Angular velocity • Recognise $F \times r$ is the moment of F	**(1)** **(1)** **(1)** **(1)**	Alternative method: Consider one revolution of axle , Load rises $2\pi r$ Work done = $2\pi rF$ Time taken = $2\pi \div \omega$ Power = Work ÷ time= $2\pi rF \div 2\pi/\omega$ to give reqd eq	**4**

Question Number	Acceptable answers		Additional guidance	Mark
(b)(i)	• Arrow away from + charge **Or** arrow towards − charge • At least 3 Equipotential lines, perpendicular to field lines • Symmetrical about vertical/horizontal axis **and** not touching/crossing	**(1)** **(1)** **(1)**	MP3 dependent on lines being perpendicular in MP2 	**3**

Question Number	Acceptable answers		Additional guidance	Mark
(b)(ii)	• Use of $F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$ • $F = 0.036$ (N)	**(1)** **(1)**	Example of calculation: $F = 8.99\times10^9\,\text{Nm}^2\text{C}^{-2}\,\dfrac{(0.1\times10^{-6}\text{C})^2}{(0.05\text{m})^2}$ $F = 0.036\text{N}$	**2**

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of moment = $F x$	(1)	Show that value gives 3.2×10^{-3} Nm and 0.64 W	4
	• Expression for correct moment	(1)	Example of calculation: Moment $= 0.036\text{N} \times 0.04\text{m} \times 2 = 2.89 \times 10^{-3}\text{ Nm}$	
	• Use of power = moment of force x angular velocity	(1)		
	• Only realistic possibility is pond pump and $P = 0.6$W (calculated answer could also be force and then comparison with b(i))	(1)	Power $= 2.89 \times 10^{-3}\text{ N m} \times 200\text{s}^{-1} = 0.58\text{W}$	

Q3.

Question Number	Answer		Mark
(b)	**Diagram mark for parallel plate**: a minimum of 3 parallel equispaced lines touching plates (ignore edge effect)	(1)	5
	Diagram mark for point charge: minimum of 4 equispaced radial lines touching charged point	(1)	
	Direction of fields correct for both diagrams consistent with charges labelled	(1)	
	Parallel plate - field strength same at all points	(1)	
	Point charge - field strength decreases with (increasing)distance from point **Or** obeys inverse square law	(1)	

Q4.

Question number	Acceptable Answers		Additional guidance	Mark
	• At least 4 radial lines	(1)	Ignore dotted lines	3
	• arrow pointing outwards	(1)		
	• straight, symmetrical and equally distributed	(1)		

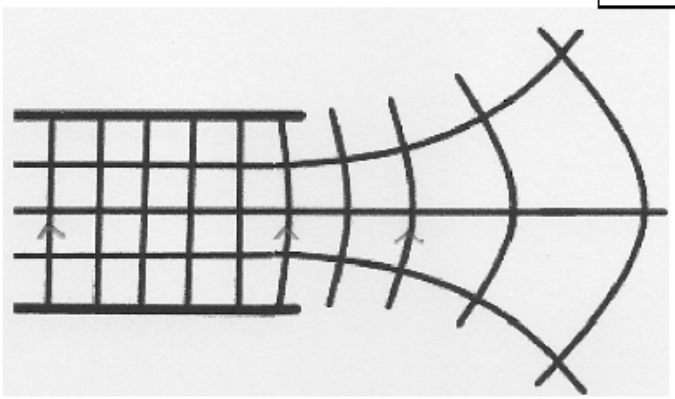
Q5.

Question Number	Answer		Mark
(a)	Arrow(s) downwards	**(1)**	**1**
(b)	Use of $E = V/d$ Use of $F = EQ$ $F = 5.1 \times 10^{-16}$ N Example of calculation $F = (160\text{ V} \times 1.6 \times 10^{-19}\text{ C}) / 5.0 \times 10^{-2}\text{ m}$ $F = 5.12 \times 10^{-16}$ N	**(1)** **(1)** **(1)**	**3**
(c)	Between the plates there is an acceleration/force which is vertical/upwards Constant horizontal velocity Outside the plates no (electric) field /force acts **Or** Outside the plates speed so large that gravitational effect negligible	**(1)** **(1)** **(1)**	**3**
(d)(i)	Release of (surface) electrons due to heating	**(1)**	**1**
(d)(ii)	Use of $E_k = \frac{1}{2}mv^2$ Use of $V = W/Q$ p.d. = 410 V Example of calculation $E_k = 9.11 \times 10^{-31}\text{ kg} \times (1.2 \times 10^{7}\text{ m s}^{-1})^2/2$ $E_k = 6.56 \times 10^{-17}$ J p.d. $= (6.56 \times 10^{-17}\text{ J})/(1.6 \times 10^{-19}\text{ C})$ p.d. = 410V	**(1)** **(1)** **(1)**	**3**
	Total for question		**11**

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equipotential lines would be further apart **(1)**		**(1)**

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• Arrow upwards on at least one line. (1) Uniform section: • at least 3 parallel, perpendicular straight lines, equispaced (1) Non-uniform: • at least 2 lines perpendicular to equipotentials (1) • spacing getting larger (1)		4

Q8.

Question Number	Answer	Mark
	C	1

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B A *is not correct because this is a uniform field so F constant* C *is not correct because this is a uniform field so F constant* D *is not correct because this is a uniform field so F constant*	*F*	1

Q10.

Question Number	Acceptable Answer	Additional guidance	Mark
(i)	charge not conserved		**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(ii)	• both radial fields OR (1) the magnitude of the fields is the same (at a given distance) • different directions (1)		**(2)**