

Mark Scheme

Q1.

Question Number	Answer	Mark
	C	1

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	Equipotential lines would be further apart		

Q3.

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

Q4.

Question Number	Answer	Mark
	C	1

Q5.

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

Q6.

Question Number	Answer	Mark
	A	1

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	So that the lightning makes contact with the conductor rather than the statue (1)		1

Q8.

Question Number	Answer	Mark
	D	1

Q9.

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

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

Q10.

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

Q11.

Question Number	Acceptable Answers	Additional guidance	Mark
	- tangent at correct point (1) - triangle with base at least 0.4 m (1) $5.3 \times 10^6 \text{ (Vm}^{-1}\text{)}$ (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) $5.3 \times 10^6 \text{ (Vm}^{-1}\text{)}$ (1) - So would ionise as value greater than 3×10^6 (1)	Example of calculation: Gradient = $3200000 / 0.6$ $E = 5.3 \times 10^6 \text{ V m}^{-1}$ MP4 to be consistent with calculated value $V = 1.6 \times 10^6 \text{ V m}^{-1}$	4

Q12.

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 $E = V/d$ (1) - 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)

Q13.

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

Q14.

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

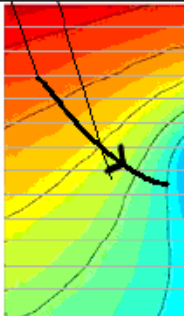
Q15.

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

Q16.

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

Q17.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	- States a value of ΔV (1) - Uses $\Delta V/\Delta d$ with a difference in distance (1) $E = 560 \text{ V m}^{-1}$ (1) allow range 500-560 V m^{-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)
(ii)	- Line perpendicular to a least 2 equipotential lines (1) - Arrow pointing towards flower (1)		(2)

(iii)	- States $V \times r = \text{constant}$ (1) - 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 (1) (MP3 dependent on MP2)	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)
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Q18.

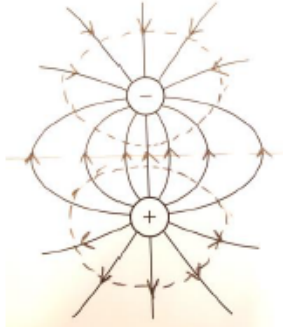
Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	- Conversion of MeV to J (1) - See $Q_1 = 79 \times 1.6 \times 10^{-19}$ and $Q_2 = 2 \times 1.6 \times 10^{-19}$ (1) - Use of $V = \frac{Q}{4\pi\epsilon_0 r}$ and $W = QV$ (1) $r = 4.1 \times 10^{-14} \text{ m}$ (1)	<u>Example of calculation</u> $E_\alpha = 5.5 \times 10^6 \text{ eV} \times 1.6 \times 10^{-19} \text{ J eV}^{-1} = 8.8 \times 10^{-13} \text{ J}$ $8.8 \times 10^{-13} \text{ J} = \frac{79 \times 1.6 \times 10^{-19} \text{ C} \times 2 \times 1.6 \times 10^{-19} \text{ C}}{4\pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} r}$ $r = \frac{3.64 \times 10^{-26} \text{ N m}^2}{8.8 \times 10^{-13} \text{ J}} = 4.1 \times 10^{-14} \text{ m}$	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

Q19.

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

Q20.

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

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

Question Number	Acceptable answers	Additional guidance	Mark
(b)(ii)	- Use of $F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$ (1) $F = 0.036$ (N) (1)	<u>Example of calculation:</u> $F = 8.99 \times 10^9 \text{ Nm}^2\text{C}^{-2} \frac{(0.1 \times 10^{-6} \text{ C})^2}{(0.05 \text{ m})^2}$ $F = 0.036 \text{ N}$	2

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

Q21.

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) $v = 2.3 \times 10^7 \text{ m s}^{-1}$ (1)	<u>Example of calculation:</u> $E = 1500 \text{ V} \times 1.6 \times 10^{-19} \text{ C} = 2.4 \times 10^{-16} \text{ J}$ $v = \sqrt{\frac{2 \times 2.4 \times 10^{-16} \text{ J}}{9.11 \times 10^{-31} \text{ kg}}} = 2.3 \times 10^7 \text{ m s}^{-1}$	(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) $t = 8.7 \times 10^{-10} \text{ (s)}$ (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 $s = 3.3 \times 10^{-4} \text{ m}$ (1)	<u>Example of calculation:</u> $t = \frac{0.02 \text{ m}}{2.3 \times 10^7 \text{ m s}^{-1}} = 8.7 \times 10^{-10} \text{ s}$ $s = \frac{1}{2} \times \left(\frac{50 \text{ V} \times 1.6 \times 10^{-19} \text{ C}}{0.01 \text{ m} \times 9.11 \times 10^{-31} \text{ kg}} \right) \times (8.7 \times 10^{-10} \text{ s})^2$ $s = 3.3 \times 10^{-4} \text{ m}$	(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)	<u>Example of calculation:</u> $V_0 = 53 \text{ V} \times \sqrt{2} = 75 \text{ V}$	(4)

Q22.

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

Q23.

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 $E = kQ/r^2$ (1) Electric field due to $Q_1 = 4.1(1) \times 10^6 \text{ (N C}^{-1}\text{)}$ (1) Use of 11.9 cm to find field due to Q_2 (1) Or Use of $E = kQ/r^2$ (1) Use of $E_1/E_2 = Q_1/r_1^2 / Q_2/r_2^2$ (1) $E_1/E_2 = 1$ (1) <u>Example of calculation</u> Electric field due to Q_1 $= (8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \times (3 \times 10^{-6} \text{ C}) / (8.1 \times 10^{-2})^2$ $= 4.11 \times 10^6 \text{ N C}^{-1}$ Electric field due to Q_2 $= (8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \times (6.5 \times 10^{-6} \text{ C}) / (11.9 \times 10^{-2})^2 = 4.13 \times 10^6 \text{ N C}^{-1}$	(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