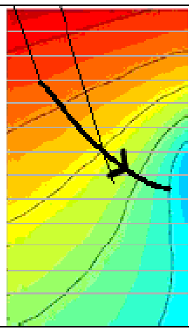
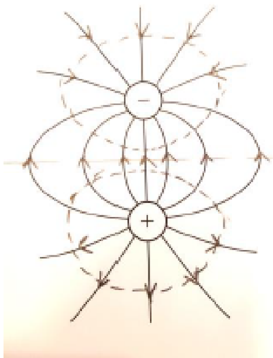
Q1.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• States a value of ΔV • Uses $\Delta V/\Delta d$ with a difference in distance • $E = 560\ \text{V m}^{-1}$ allow range 500-560 V m^{-1}	(1) (1) (1)	Example of calculation: $E = \frac{(80-75)\text{V}}{0.009\text{m}} = 556\ \text{V m}^{-1}$ (Alt: $5.6\ \text{V cm}^{-1}$)	(3)
(ii)	• Line perpendicular to a least 2 equipotential lines • Arrow pointing towards flower	(1) (1)		(2)
(iii)	• States $V \times r$ = constant • One corresponding pair of values of V and r • At least two pairs of values used to show that the product is not constant therefore not radial (MP3 dependent on MP2)	(1) (1) (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)

Q2.

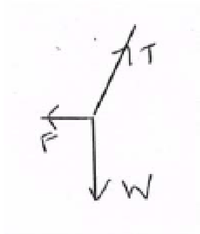
Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Replace Work W by force × distance • Replace distance ÷ time by velocity v • Use $v = r \times$ Angular velocity • Recognise $F \times r$ is the moment of F	(1) (1) (1) (1)	Alternative method: Consider one revolution of axle , Load rises $2\pi r$ 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 **(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 $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ **(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 = $F x$ **(1)** • Expression for correct moment **(1)** • Use of power = moment of force x 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 3.2×10^{-3} Nm and 0.64 W <u>Example of calculation:</u> Moment $= 0.036\text{N} \times 0.04\text{m} \times 2 = 2.89 \times 10^{-3}\text{Nm}$ $\text{Power} = 2.89 \times 10^{-3}\text{N m} \times 200\text{s}^{-1} = 0.58\text{W}$	4

Q3.

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 $F_1 r_1^2 = F_2 r_2^2$ (accept answers with or without the powers of ten included) Example of answer Ignoring powers of 10 $115\text{ N} \times 20^2\text{ m}^2 = 46000$ $51\text{ N} \times 30^2\text{ m}^2 = 45900$	(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 $Q = 7.2 \times 10^{-9}$ C Example of answer $100\,Q^2 = 46000 \times 10^{-9}\text{ N m}^2 / 8.99 \times 10^9\text{ N m}^2\text{ C}^{-2}$ $Q^2 = 5.12 \times 10^{-17}\text{ C}^2$ $Q = 7.2 \times 10^{-9}$ C	 (1) (1) (1)	**3**
	Total for question		**11**

Q4
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(a) *V* is inversely proportional to *r* [**or** $V \propto (-)1/r$] ✓
(*V* has negative values) because charge is negative
[**or** because force is attractive on + charge placed near it
or because electric potential is + for + charge and − for − charge] ✓
potential is defined to be zero at infinity ✓

Allow V × r = constant for 1st mark.

max 2

(b) (i) $Q(= 4\pi\varepsilon_0 rV) = 4\pi\varepsilon_0 \times 0.125 \times 2000$
OR *gradient = $Q / 4\pi\varepsilon_0$ = 2000 / 8 ✓*

(for example, using any pair of values from graph) ✓
= 28 (27.8) (± 1) (nC) ✓

(gives Q = 28 (27.8) ±1 (nC) ✓

2

(ii) at *r* = 0.20m *V* = −1250V and at *r* = 0.50m *V* = −500V
so pd Δ*V* = −500 − (−1250) = 750 (V) ✓
work done Δ*W* (= *Q*Δ*V*) = $60 \times 10^{-9} \times 750$
= $4.5(0) \times 10^{-5}$ (J) (45 μJ) ✓

(final answer could be between 3.9 and 5.1×10^{-5})
Allow tolerance of ± 50V on graph readings.
[Alternative for 1st mark:

$\Delta V = \frac{27.8 \times 10^{-9}}{4\pi\varepsilon_0} \times \left(\frac{1}{0.2} - \frac{1}{0.5}\right)$ *(**or** similar substitution using 60 nC*

instead of 27.8 nC:
use of 60 nC gives ΔV = 1620V)]

2

(iii) $E\left(= \frac{Q}{4\pi\varepsilon_0 r^2}\right) = \frac{27.8 \times 10^{-9}}{4\pi\varepsilon_0 \times 0.40^2}$ ✓ = 1600 (1560) (V m^{-1}) ✓

[or deduce $E = \frac{V}{r}$ by combining $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ with $V = \frac{Q}{4\pi\varepsilon_0 r}$ ✓

from graph $E = \frac{625 \pm 50}{0.40}$ = 1600 (1560 ± 130) (V m^{-1}) ✓]

Use of Q = 30 nC gives 1690 (V m^{-1}).
Allow ecf from Q value in (i).
If Q = 60 nC is used here, no marks to be awarded.

2

[10]

Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
5(a)	$F_g = \frac{6.67\times10^{-11}\times9.11\times10^{-31}\times9.11\times10^{-31}}{R^2}$ $F_e = \frac{8.98\times10^{9}\times1.60\times10^{-19}\times1.60\times10^{-19}}{R^2}$ $\frac{F_g}{F_e} = 2.40\times10^{-43}$	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	Two in parallel (capacitor and inductor), one in series (resistor). Evidence: Finite current at a zero and high frequency implies resistor in series. Can't have the capacitor in series (at low frequency – current would be zero). Can't have inductor in series (at high frequency – current would be zero). Zero current at finite frequency implies infinite impedance – this can happen with parallel branch containing an inductor and a capacitor.			

<table>
<tr><th>Question</th><th>Evidence</th><th>1-4 marks</th><th>5-6 marks</th><th>7-8 marks</th></tr>
<tr><td>6(a)</td><td>The values of angular momentum for the hydrogen electron are discrete, which means that the electron can only have discrete values of position or energy. When electrons transition from one energy level value to another, they do not go through all the values in between, which means that the accelerating electron in its orbit does not radiate electromagnetic energy. When the electron transitions from one energy level to another, it either emits or absorbs electromagnetic radiation of a frequency that depends on the size of the energy jump. This means that there will be emission and absorption spectra from the H atom.</td><td rowspan="4">Shows some understanding of the underlying physics.

AND / OR

(Partially) correct mathematical solution to given problem.</td><td rowspan="4">A reasonable understanding of the underlying physics.

AND

(Partially) correct mathematical solution to given problem.</td><td rowspan="4">Thorough understanding of the underlying physics.

AND

Correct mathematical solution to the given problem.</td></tr>
<tr><td>(b)</td><td>The attraction is due to the magnetic fields, caused by the movement of electrons in the wires. And currents in wires do not change the charge within the wire (effectively Kirchhoff's current law) – the moving electrons do not increase (or decrease) the number of charges within the wire.</td></tr>
<tr><td>(c)</td><td>The charged rod attracts opposite charges within the metal sphere, and repels like charges. The attracted charges are closer to the original charge than are the repelled charges, and so the attracted charges experience a larger force than the repelled charges, meaning that there is an overall (net) force of attraction. If the sphere is earthed, the repelled charges will leak away to earth (or be neutralised by charge flow from the Earth), while the attracted charges are locked in place by the rod. The net force of attraction is now increased because there is no longer a repulsion component.</td></tr>
<tr><td>(d)</td><td>Needs $\varepsilon_0 = 8.854 \times 10^{-12}$

Take 1 square meter of capacitor.

$C = \varepsilon_0 \dfrac{A}{d} = 8.8954 \times 10^{-9}$ F

$Q = CV = 8.8954 \times 10^{-6}$ C
Number of electrons in this amount of charge = 5.560×10^{13}
In 1 sq m this number of electrons will each occupy an area of $\dfrac{1}{5.560 \times 10^{13}} = 1.80 \times 10^{-14}$ m^2
The distance between each electron will be approximately $\sqrt{\text{Area}} = 1.34 \times 10^{-7}$ m
This separation is independent of the area of the capacitor.</td></tr>
</table>

Question			Answer	Marks	Guidance
7	**(a)**		$eV = ½mv^2$ so $v^2 = 2eV/m$ $ma = eE$ so $a = eE/m$ $x = vt$ $d = ½at^2 = ½a(x/v)^2$ $d = (eE/2m).x^2.(m/2eV) = Ex^2/4V$ $x^2 = 4(d/E)V$	**B1** **B1** **B1** **B1** **B1** **A0**	four equations are needed and some sensible substitution, etc. shown for the fifth mark
	(b)	**(i)**	22.1 ± 0.9	**B1**	value plus uncertainty both required for the mark allow ± 1.0
		(ii)	two points plotted correctly, including error bars; line of best fit worst acceptable straight line.	**B1** **B1**	**ecf** value and error bar of first point **allow ecf** from points plotted incorrectly steepest or shallowest possible line that passes through <u>all</u> the error bars; should pass from top of top error bar to bottom of bottom error bar **or** bottom of top error bar to top of bottom error bar
			gradient (= 4d/E) = 2.4 ± 0.4; $E = 4 \times 2.0 \times 10^{-2} / 2.4 \times 10^{-6} = 3.3 \times 10^4$ $(3.3) \pm 0.6 \times 10^4$ $V\ m^{-1}$ or $N\ C^{-1}$	**B1** **B1** **B1** **B1**	**allow** 2.4 ± 0.5 0.1/4 + 0.4/2.4 = 0.192 x 3.3 = 0.63 0.1/4 + 0.5/2.4 = 0.233 x 3.3 = 0.77 **allow** $3.3 \pm 0.8 \times 10^4$
			Total	**12**	