

7	B is the correct answer because $r = \frac{mv}{BQ}$	1
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9	The only correct answer is B (The area under the graph from 0.5 m to infinity.) A is not correct because area under the graph is incorrect C is not correct because the gradient does not give electric potential D is not correct because E at 0.5m divided by 0.5m does not give electric potential	1
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2	D is the correct answer , as this is a description of thermionic emission	1
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10	The only correct answer is A B is not correct because the length of the magnet is the length of wire perpendicular to the field C is not correct because the force is into the page D is not correct because the force is into the page	1
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8	The only correct answer is C because there is insufficient evidence to draw this conclusion A is not correct because this is a valid conclusion B is not correct because this is a valid conclusion D is not correct because this is a valid conclusion	1
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3	A is the only correct answer because the force is down the page using FLHR B is not correct because it does not show the force down the page C is not correct because it does not show the force down the page D is not correct because it does not show the force down the page	1
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3	The only correct answer is A $\left(\sqrt{\frac{1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times 0.77}} \right)$ B is not correct because the charge is squared C is not correct because quantity is not rooted D is not correct because the quantity is not rooted, and the charge is squared	1
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6	D is the correct answer A is not correct because we do not know the sign of the charge on each particle B is not correct because we do not know the direction of the magnetic field C is not correct because we do not know the direction of the magnetic field	1
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17(a)	At least 4 radial straight lines, from surface of sphere	(1)	3
	Equal spacing	(1)	
	Arrows outward	(1)	

17(b)(i)	Use of $V = \frac{Q}{4\pi\epsilon_0 r}$	(1)	2
	$Q = 1.1 \times 10^{-8}$ (C)	(1)	
	<u>Example of calculation</u> $5000 \text{ V} = 8.99 \times 10^9 \text{ Nm}^2\text{C}^{-2} \times \frac{Q}{0.02 \text{ m}}$ $Q = 1.1 \times 10^{-8} \text{ C}$		

17(b)(ii)	Use of $E = V/d$	(1)	3
	Use of $F = EQ$	(1)	
	$F = 5.2 \times 10^{-4} \text{ N}$ (e.c.f from (b)(i))	(1)	
	<u>Example of calculation</u> $E = 5000 \text{ V} \div 0.105 \text{ m} = 47\,600 \text{ V m}^{-1}$ $F = 47\,600 \text{ V m}^{-1} \times 1.1 \times 10^{-8} \text{ C}$ $F = 5.24 \times 10^{-4} \text{ N}$		

17(b)(iii)	Use of $W = mg$	(1)	3
	Use of suitable trigonometry, such as $\tan \theta = F/W$	(1)	
	$\theta = 1.1^\circ$ (e.c.f from (b)(i) and (b)(ii))	(1)	
	<u>Example of calculation</u> $W = 0.0027 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 0.0265 \text{ N}$ $\tan \theta = 5.24 \times 10^{-4} \text{ N} / 0.0265 \text{ N} = 0.0198$ $\theta = 1.13^\circ$		

17(c)	Use of $F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$	(1)	3
	with $Q_1 = Q_2 = 1.2 \times 10^{-8} \text{ C}$	(1)	
	$r = 0.051 \text{ m}$	(1)	
	<u>Example of calculation</u> $5.0 \times 10^{-4} \text{ N}$ $= \frac{8.99 \times 10^9 \text{ Nm}^2\text{C}^{-2} \times 1.2 \times 10^{-8} \text{ C} \times 1.2 \times 10^{-8} \text{ C}}{r^2}$ $r = 0.051 \text{ m}$		

16(a)	At least three equi-spaced vertical parallel lines touching the wires	(1)	2
	Arrows towards bottom plate [Ignore curved lines at edges of plates]	(1)	
	<u>Example of diagram</u> 		

16(b)	Use of $\rho = \frac{m}{V}$	(1)	5
	Use of $w = mg$	(1)	
	Use of $E = \frac{V}{d}$	(1)	
	Use of $E = \frac{F}{Q}$	(1)	
	$Q = 5e$, so the charge on the oil drop was a whole number multiple of the electronic charge.	(1)	
<u>Example of calculation</u>			
$m = \rho V = 920 \text{ kg m}^{-3} \times 5.00 \times 10^{-19} \text{ m}^3 = 4.60 \times 10^{-16} \text{ kg}$			
$w = mg = 4.60 \times 10^{-16} \text{ kg} \times 9.81 \text{ N kg}^{-1} = 4.51 \times 10^{-15} \text{ N}$			
$E = \frac{V}{d} = \frac{85 \text{ V}}{1.5 \times 10^{-2} \text{ m}} = 5.67 \times 10^3 \text{ V m}^{-1}$			
$Q = \frac{F}{E} = \frac{4.51 \times 10^{-15} \text{ N}}{5.67 \times 10^3 \text{ N C}^{-1}} = 7.96 \times 10^{-19} \text{ C}$			
$N = \frac{7.96 \times 10^{-19} \text{ C}}{1.6 \times 10^{-19} \text{ C}} = 4.97$			

16(a)	Use of GeV to J conversion	(1)	3
	Use of $E_k = \frac{1}{2} mv^2$	(1)	
	$v = 1.5 \times 10^{11} \text{ m s}^{-1}$ which is greater than the speed of light (so particle speed relativistic)	(1)	
<u>Example of calculation</u>			
$(60 \times 10^9 \text{ eV} \times 1.6 \times 10^{-19} \text{ V}) = 9.6 \times 10^{-9} \text{ J}$			
$9.6 \times 10^{-9} \text{ J} = \frac{1}{2} \times 9.11 \times 10^{-31} \text{ kg} \times v^2$			
$v = 1.5 \times 10^{11} \text{ m s}^{-1}$ which is greater than the speed of light, which is impossible, so they must be travelling at relativistic speeds			

***16(b)**

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.

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

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

Indicative content

IC1 The electrons are accelerated by an electric field between the drift tubes

IC2 The (a.c) polarity changes (when the electrons are in the tubes) so the (electric) field is in the same direction when the particle is in the gaps

Or The (a.c.) polarity changes so it is always accelerating the particles

IC3 The a.c. frequency is constant

IC4 The length of the drift tubes increases (along the Linac) so the electrons spend the same time in the tubes / gaps

Or The length of the gaps increases (along the Linac) so the electrons spend the same time in the tubes / gaps

IC5 The tubes have constant length at the end

IC6 As the electrons approach (but do not achieve) the speed of light their speed no longer increases

6

16(c)

(High energy particles have) large momentum

(1)

(So) the (de Broglie) wavelength is small

Or to make (de Broglie) wavelength the size of proton

(1)

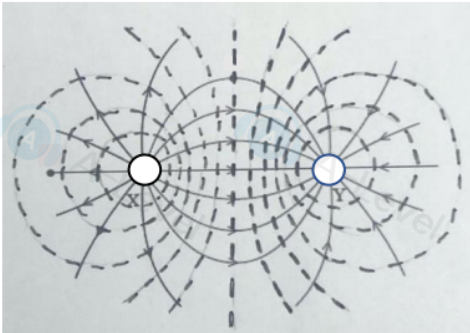
(This produces) better resolution (for small objects)

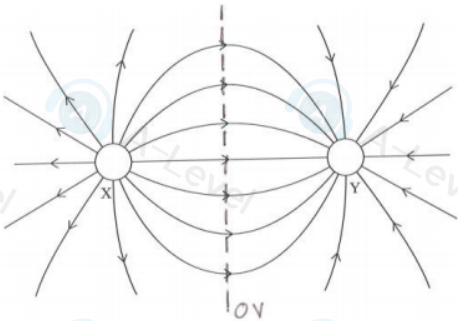
Or (This results in) more detailed observations

Or allows the electrons to penetrate the protons

(1)

3

<p>17(a)(i)</p>	<p>Central straight line equidistant from spacecraft and satellite and at least one of the diverging lines between spacecraft and the central line and at least one of the diverging lines between the central line and satellite (1)</p> <p>At least one line looping spacecraft and one line looping satellite (1)</p> <p>Line spacing between spacecraft and satellite smaller than line spacing to the left of spacecraft and to the right of satellite (1)</p> <p><u>Example of diagram</u></p> 	<p>3</p>
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<p>17(a)(ii)</p>	<p>Straight line equidistant from spacecraft and satellite and labelled 0 V. (1)</p> <p><u>Example of diagram</u></p> 	<p>1</p>
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<p>17(b)(i)</p>	<p>Use of $V = Q / 4\pi\epsilon_0 r$ Or Use of $V = kQ / r$ (1)</p> <p>Use of $W = QV$ (1)</p> <p>Minimum energy = 1.7×10^{-15} (J) (1)</p> <p><u>Example of calculation</u></p> <p>$V_{\text{spacecraft}} (= V_{\text{satellite}}) = 1.5 \times 10^{-6} \text{ C} / 4 \times \pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} \times 2.5 \text{ m}$ $= 5400 \text{ V}$ $W = 2 \times 5400 \text{ V} \times 1.6 \times 10^{-19} \text{ J} = 1.7 \times 10^{-15} \text{ J}$</p>	<p>3</p>
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17(b)(ii)	Use of $F = Q_1 Q_2 / 4\pi\epsilon_0 r^2$ Or Use of $F = k Q_1 Q_2 / r^2$	(1)	4
	Use of $F = ma$ Or Use of $Fs = \frac{1}{2} mv^2$	(1)	
	Use of suitable <i>suvat</i> equation(s), e.g. $s = ut + \frac{1}{2} at^2$	(1)	
	Correct value for s (270 km) or t (62.5 days), comparison and consistent conclusion	(1)	
	<u>Example of calculation</u> $F = 1.5 \times 10^{-6} \text{ C} \times 1.5 \times 10^{-6} \text{ C} / 4 \times \pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} \times (20 \text{ m})^2$ $= 5.1 \times 10^{-5} \text{ N}$ $a = 5.1 \times 10^{-5} \text{ N} / 2500 \text{ kg} = 2.0 \times 10^{-8} \text{ m s}^{-2}$ $300\,000 \text{ m} = \frac{1}{2} \times 2.0 \times 10^{-8} \text{ m s}^{-2} \times t^2$ $t = 5.4 \times 10^6 \text{ s}$ $t = 5.4 \times 10^6 \text{ s} / (24 \times 60 \times 60 \text{ s})$ $t = 62.5 \text{ days}$ is approximately 60 days, so the estimate is correct		

17(c)	A reasonable suggestion, such as		1
	• Some of the electrons / beam misses	(1)	
	• Some of the electrons are deflected	(1)	
	• The spacecraft is already charged from use on a previous satellite	(1)	
	• The spacecraft emits further electrons in another direction as a fine control on the electrostatic force	(1)	
	• UV (from Sun) leads to photoelectric emission	(1)	