1)

Question			Answer	Marks	Guidance
	(a)		A region in which a charged particle experiences a force / acceleration	B1	**Allow**: Where a charge experiences a force **Allow**: Force per (unit positive) charge **Note**: Must have reference to charge and force/acceleration for the mark
	(b)		Difference: Any one from • gravitational field / force is attractive (AW) • electric field / force can be either attractive or repulsive (AW)	B1	**Allow**: Gravitational force is in the direction of the field / towards the mass **Note**: For the second bullet point, must have reference to both attractive and repulsive or 'towards charge' and 'away from charge'
			Similarity: Any one from: • Force / field (strength) inversely proportional to distance squared • Radial fields	B1	**Allow**: (Both) obey the inverse-square law (with distance) or (Both) have $F \propto 1/r^2$ or $g \propto 1/r^2$ and $E \propto 1/r^2$ **Allow**: 'radius or separation' for 'distance'
	(c)		Any three from: • The electron is repelled by **B** / attracted by **A** / experience a force to the left • (Initially the) electron decelerates / slows down • It does not reach plate **B** / It reverses direction • When it returns to **A** it has 4 eV (of KE) • It stops 2/3 of the distance across the plates (AW)	B1 × 3	
	(d)	(i)	$E = 60\times10^{3} \div 0.25$ / $E = 2.4 \times 10^{5}$ (V m^{-1}) $F = 2.4 \times 10^{5} \times 1.5 \times 10^{-13}$ force = 3.6×10^{-8} (N)	C1 A1	**Allow**: $F = [1.5 \times 10^{-13} \times 60 \times 10^{3}]/0.25$ for the first C1 mark **Allow**: 1 mark for 7.2×10^{-8} (N); d = 12.5 cm used

Question			Answer	Marks	Guidance
		(ii)	t = 1.8/1.2 (= 1.5 s) **or** $a = \frac{3.6\times10^{-8}}{8.0\times10^{-7}}$ (= 4.5×10^{-2} m s^{-2}) ($s = ut + \frac{1}{2}at^2$ and u = 0)	C1	Possible ecf from **(d)(i)**
			$s = \frac{1}{2} \times 4.5 \times 10^{-2} \times 1.5^2$	C1	**Note**: No ecf within calculation if $t \neq$ 1.8/1.2
			displacement = 5.1×10^{-2} (m)	A1	**Note**: Answer to 3 sf is 5.06×10^{-2} (m)
			Total	**11**	

2)

Question			Answers	Marks	Guidance
	(a)		Correct direction of the electric field. A minimum of 5 field lines shown. Correct shape of field lines.	B1 B1	 Expect a minimum of 3 field lines to be normal (by eye) to the plate - ignore the angles made by the field lines at the sphere. Also there must not be any field lines within the sphere.
	(b)	(i)	($E \propto Q/r^2$ and the magnitude of E is the same due to each charge **A** and **B** at **X**. Therefore) **B** has a greater charge because **X** is further away from **B**.	B1	
		(ii)	Curve showing E = 0 at position of **X**. Curve showing E is positive between **A** and **X** and negative between **X** and **B** (or vice versa). The magnitude of E is small close to **A** and large close to **B**.	B1 M1 A1	**Allow** any graph, including a straight line. Tolerance for E = 0: ± ½ large square about **X**. **Note**: The curve must be continuous and pass through position of **X**. Ignore any curve to the right of **B** and to the left of **A**. **Note**: This mark can only be scored if the previous M1 has been awarded.
	(c)		Both E and g vary with 1/distance^2. (Hence the ratio is independent of the distance.)	B1	**Allow**: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ and $g = \frac{GM}{r^2}$ **or** $E \propto \frac{1}{r^2}$ and $g \propto \frac{1}{r^2}$ **Allow** 'both are inverse square laws'.
			Total	**7**	

3)

Question			Answer	Marks	Guidance
	(a)		number = $\frac{2.8\times10^{-9}}{1.6\times10^{-19}}$ number = 1.75×10^{10} or 1.8×10^{10}	 B1	 Ignore a negative sign
	(b)		$F=\frac{Qq}{4\pi\varepsilon_0 r^2}$ $F=\frac{2.8\times10^{-9}\times2.8\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(2.0\times10^{-2})^2}$ force = 1.76×10^{-4} (N) or 1.8×10^{-4} (N)	 C1 A1	 **Note**: No credit for using charge equal to *e*
	(c)	(i)	Tension and weight	B1	**Allow**: force provided by the string / force in the string instead of tension **Not**: 'gravity' for weight **Allow**: force due to gravity **Allow**: gravitational (force)
		(ii)	(weight =) $6.5\times10^{-5}\times g$ $\tan\theta = 1.76\times10^{-4}/6.38\times10^{-4}$ $\theta = 15°$ Or Scale drawing of triangle of force θ in the range 13° to 18° θ in the range 14° to 16°	C1 C1 A1 C1 A1 A1	Deduct 1 mark for the use of 10 (m s^{-2}) followed by ecf **Note** that getting to this stage scores both C1 marks Possible ecf from **(b)** **Note**: No marks if mass is used instead of the weight
			Total	**7**	

4)

Question			Answer	Marks	Guidance
	(a)		Arrow to the left	B1	
	(b)	(i)	1500 (eV)	B1	**Note**: 2.4×10^{-16} (J) on the answer line scores zero
		(ii)	(KE =) $1500\times1.6\times10^{-19}$ (= 2.4×10^{-16} J) $2.4\times10^{-16}=\frac{1}{2}\times9.11\times10^{-31}\times v^2$ (Allow any subject) $v = 2.3\times10^{7}$ (m s^{-1})	C1 C1 A1	Possible ecf from **(b)(i)** **Allow**: 2 marks for 5.3×10^{14} (answer not square-rooted) **Note**: $v=\sqrt{\frac{2\times1500}{9.11\times10^{-31}}}=5.74\times10^{16}$ (m s^{-1}) does not score

5)

Question			Expected Answer	Mark	Additional Guidance
	(a)	(i)	$E = \frac{V}{d} = \frac{2400}{9.4\times10^{-3}}$ $E = 2.55 \times 10^{5}$ (V m^{-1}) force = $E \times Q = 2.55 \times 10^{5} \times 1.60 \times 10^{-19}$ force = 4.09×10^{-14} (N)	C1 A1	**Allow** 1 mark for 4.1×10^{-n}, $n \neq 14$ **Allow** 2sf answer of 4.1×10^{-14} (N) Alternative: $F = \frac{Ve}{d} = \frac{2400\times1.60\times10^{-19}}{9.4\times10^{-3}}$ C1 force = $4.08(5) \times 10^{-14}$ (N) A1 [Allow: 4.08×10^{-14} (N)]
		(ii)	KE = $e \times V$ or KE = $F \times d$ KE = $1.6 \times 10^{-19} \times 2400$ or KE = $4.09 \times 10^{-14} \times 9.4 \times 10^{-3}$ KE = 3.84×10^{-16} (J)	C1 A1	**Allow** 2 sf answer Possible ecf if answer from **(a)(i)** is used
		(iii)	KE = $\frac{1}{2}mv^2$ $v = \sqrt{\frac{2\times3.84\times10^{-16}}{9.11\times10^{-31}}}$ speed = $2.9(0) \times 10^{7}$ (m s^{-1})	B1	Possible ecf if answer from **(a)(ii)** is used
	(b)		There is no change (to the gain in KE) work done or KE = Fd, F or E is halved and d is doubled or work done or KE = VQ and V is the same or work done or KE = VQ and this does not depend on distance	M1 A1	
			Total	7	

6)

Question			Answers	Marks	Guidance
	(a)		electric field strength = force per unit (positive) charge	B1	**Allow**: force/charge **Not**: F/Q
	(b)	(i)	$E = V / d$ $3.0\times10^{6} = V / 1.3\times10^{-3}$ V = 3900 (V)	C1 A1	**Note**: This mark is for correct substitution **Allow**: 1 mark if answer is 3.9×10^{n} (V), n ≠3 – POT error
		(ii)1	$Q = It$ $Q = 2.7 \times 10^{-9} \times 4.0 \times 10^{-2}$ charge = 1.1×10^{-10} (C) or 1.08×10^{-10} (C)	 C1 A1	 **Note**: This mark is for correct substitution
		(ii)2	number = $1.08 \times 10^{-10} / 1.6 \times 10^{-19}$ number = 6.8×10^{8} or 6.75×10^{8}	 B1	 Possible ecf from **(b)(ii)1**
		(iii)	energy = VQ energy = $3900 \times 1.08\times 10^{-10}$ energy = 4.2×10^{-7} (J)	 C1 A1	**Note**: No credit for using ½ QV Possible ecf from **(b)(ii)1**
			Total	**8**	

7)

Question			Answer	Marks	Guidance
	(a)		Any two from: 1. There is a repulsive (electrical) force (between the gold nucleus and the alpha particle) 2. Momentum is conserved (because there are no external forces) / initial momentum of alpha particle = final momentum of gold nucleus (because there are no external forces) 3. KE of alpha particle transformed into (electrical) PE	B1×2	**Allow**: (The gold nucleus and alpha particle experience) forces in opposite directions
	(b)		Correct directions of field shown on lines from **A** and **B** Correct curved field lines from **A** and **B**	B1 B1	
	(c)		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ $Q = 79e$ and $q = 2e$ force = $\frac{79\times2\times(1.60\times10^{-19})^2}{4\pi\times8.85\times10^{-12}\times(6.0\times10^{-14})^2}$ force = 10.1 (N)	C1 C1 C1 A0	**All** values must be substituted for this mark
	(d)		Correctly shaped curve with F decreasing as r increases Value of F is between 2 to 3 (N) at $r = 12 \times 10^{-14}$ m	M1 A1	**Note**: $F \propto 1/r^2$, hence F should be about 2.5 (N)
			Total	**9**	

8)

Question			Expected Answers	Marks	Additional guidance
	(a)		(Electric field strength is the) force per (unit positive) charge	B1	**Allow:** $E = F/Q$, F is the force on a (positive) charge Q
	(b)		Parallel and equally spaced lines at right angles to plates Correct upward direction of field shown on at least one field line	B1 B1	
	(c)	**(i)**	An arrow vertically downwards at **P**	B1	
		(ii)	$E = \frac{3400}{0.050}$ or $E = 6.8 \times 10^4$ (V m^{-1}) $a = \frac{EQ}{m}$ $a = \frac{6.8\times10^4\times1.6\times10^{-19}}{9.11\times10^{-31}}$ or $a = \frac{1.09\times10^{-14}}{9.11\times10^{-31}}$ acceleration = 1.19×10^{16} (m s^{-2}) or 1.2×10^{16} (m s^{-2})	C1 C1 A0	**Vital:** Candidates using separation of 0.050 cm must be awarded full credit for the analysis shown below $E = \frac{3400}{0.050\times10^{-2}}$ or $E = 6.8 \times 10^6$ (V m^{-1}) C1 $a = \frac{EQ}{m}$ $a = \frac{6.8\times10^6\times1.6\times10^{-19}}{9.11\times10^{-31}}$ C1 acceleration = 1.19×10^{18} (m s^{-2}) A0
		(iii)	$t = \frac{0.04}{4.0\times10^7}$ time = 1.0×10^{-9} (s)	B1	**Allow:** 1×10^{-9} (s) or 10^{-9} (s)
		(iv)	initial vertical velocity = 0, final vertical velocity = at vertical velocity = $1.2 \times 10^{16} \times 1.0 \times 10^{-9}$ (**Allow:** $1 \times 10^{16} \times 1.0 \times 10^{-9}$) vertical velocity = 1.2×10^7 (m s^{-1})	M1 A0	**Vital:** Candidates using separation of 0.050 cm must be awarded full credit for the analysis shown below vertical velocity = $1.2 \times 10^{18} \times 1.0 \times 10^{-9}$ M1 vertical velocity = 1.2×10^9 (m s^{-1}) A0

Question		Expected Answers	Marks	Additional guidance
	(v)	$v^2 = (4.0\times10^7)^2 + (1.2\times10^7)^2$ velocity = 4.2×10^7 (m s^{-1}) Or $v^2 = (4.0\times10^7)^2 + (1\times10^7)^2$ velocity = 4.1×10^7 (m s^{-1})	C1 A1 C1 A1	Possible ecf from **(iv)**
	(vi)	KE = ½ mv^2 KE = $0.5 \times 9.11 \times 10^{-31} \times (4.2 \times 10^7)^2$ kinetic energy = 8.04×10^{-16} (J) or 8.0×10^{-16} (J)	C1 A1	Possible ecf from **(v)** **Allow:** 1 sf answer if the answer comes out as 8.0×10^{-16} (J)
	(vii)	Graph starts at non-zero value for E_k Between 0 and 0.08 (m) the graph has increasing gradient Horizontal line after 0.080 (m)	B1 B1 B1	 **Note:** The E_k value for the horizontal line > E_k value at x = 0
		Total	**15**	

9)

Question		Expected Answers	Marks	Additional guidance
	(a)	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ $\frac{(-)4.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$ and $\frac{5.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$ $E_B = 1.17 \times 10^5$ (N C^{-1}) and $E_A = 1.47 \times 10^5$ (N C^{-1}) field strength = (1.17 + 1.47) $\times 10^5$ (N C^{-1}) field strength = 2.64×10^5 (N C^{-1}) or 2.6×10^5 (N C^{-1}) direction = to the left / towards B	C1 C1 A1 B1	 Ignore signs **Allow:** 2 marks for $2.9(4) \times 10^4$ (N C^{-1}) when the fields are subtracted **Allow:** 2 marks for 6.6×10^4 (N C^{-1}) for using 3.5×10^{-2} m
	(b)	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ force = $\frac{4.0\times10^{-9}\times5.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(3.5\times10^{-2})^2}$ force = 1.47×10^{-4} (N)	C1 C1 A0	 Ignore signs **Allow:** ε_0 in the equation
	(c)	(weight =) $4.5 \times 10^{-5} \times 9.81$ or (weight =) $4.4(1) \times 10^{-4}$ (N) $\tan\theta = \frac{1.5\times10^{-4}}{4.41\times10^{-4}}$ angle = 18.8 (°) or 19 (°) (**Allow**: Full credit when angle is determined using a scale diagram)	C1 C1 A1	**Allow:** weight = $4.5 \times 10^{-5} \times g$ **Note:** Using force = 1.47×10^{-4} (N) gives an angle of 18.4°; hence allow 18° **Allow:** 2 marks for θ = 71°; this is the complementary angle **Allow:** 1 mark for '$\tan\theta = \frac{1.5\times10^{-4}}{4.5\times10^{-5}}, \theta = 73^0$' when mass is used instead of weight.
		Total	**9**	

10)

Question			Expected Answers	Marks	Additional Guidance
	a	(i)	uniformly spaced, vertical parallel lines must begin and end on the plates with a minimum of three lines arrow in the correct direction down	B1 B1	ignore any edge effects
		(ii)	$E = V / d$ $E = 60 / 5 \times 10^{-3}$ $= 12000$ (V m^{-1})	A1	
	b	(i)	Use of energy qV and kinetic energy = ½ mv^2 $v = [(2qV)/m]^{1/2}$ $v = [(2 \times 3.2 \times 10^{-19} \times 400)/6.6 \times 10^{-27}]^{1/2}$ $v = 1.97 \times 10^5$ (m s^{-1})	M1 M1 A0	
		(ii)	$a = F / m$ $a = Eq / m$ $a = (12000 \times 3.2 \times 10^{-19}) / 6.6 \times 10^{-27}$) $= 5.82 \times 10^{11}$ (m s^{-2})	C1 A1	Both required for the mark
		(iii)	1 $t = \underline{(16 \times 10^{-3}) / 2 \times 10^5}$ $= 8 \times 10^{-8}$ (s) 2 $s = ½ a \times t^2 = ½ [5.82 \times 10^{11} \times (8 \times 10^{-8})^2]$ $= 1.86 \times 10^{-3}$ (m)	M1 A0 C1 A1	Answer will depend on number of sf used by candidate. Using $u = 2 \times 10^5$ scores 0/2 Allow slight variation in answers that follow from the candidates working

11)

Question			Expected Answers	Marks	Additional Guidance
	a		$F = Q_1Q_2 / 4\pi\varepsilon_0 r^2$ $= (1.6 \times 10^{-19} \times 1.6 \times 10^{-19}) / 4\pi\varepsilon_0 (2 \times 10^{-15})^2$ $= 57.5$ (N)	C1 A1	Allow use of 9×10^9 instead of $1 / 4\pi\varepsilon_0$ (using this gives 57.6) Allow ≥ 2sf (58) If correct formula quoted and then AE (e.g. not squaring r or not squaring Q) then allow ecf in final answer for 2/3
	b		attractive strong (nuclear force)	B1	Do not it holds them together
	c		as the proton travels towards the stationary proton it experiences a repulsive force that slows it down. (It needs a high velocity) to get close enough (to the proton) / for the (attractive) short range force to have any effect	B1 B1	
			Total	**[5]**	

12)

Question			Answer	Marks	Guidance
	(a)		force per unit (positive) charge	B1	**Allow**: $E = \frac{F}{Q}$, where F = force on (a positive) charge Q
	(b)	(i)	The direction is different (AW)	B1	
		(ii)	$E \propto 1/r^2$ or distance is doubled ∴ E decreases by a factor of 4	C1	**Not**: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ on its own
			electric field strength = 2.0×10^5 (N C^{-1})	A1	**Allow** 1 sf answer
	(c)	(i)	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$	C1	
			$F_E = \frac{1.6\times10^{-19}\times1.6\times10^{-19}}{4\pi\varepsilon_0\times(5.0\times10^{-11})^2}$	C1	
			$F_E = 9.2 \times 10^{-8}$ (N)	A1	**Allow**: 1 mark if $Q = q = 1$ giving an answer of 3.6×10^{30} (N)
		(ii)	$F_G = \frac{6.67\times10^{-11}\times1.67\times10^{-27}\times9.11\times10^{-31}}{(5.0\times10^{-11})^2}$	C1	
			$F_G = 4.06 \times 10^{-47}$ (N)		**Note**: Deduct 1 mark if mass of two electrons or two protons is used, then ecf
			ratio = $9.2 \times 10^{-8}/4.06 \times 10^{-47}$		
			ratio = 2.3×10^{39}	A1	Possible ecf from **(c)(i)**
		(iii)1	wavelength = 2.0×10^{-10} (m)	C1	
			$\lambda = h/mv$		
			$p = \frac{6.63\times10^{-34}}{2.0\times10^{-10}}$	C1	Possible ecf for incorrect wavelength
			$p = 3.3 \times 10^{-24}$ (kg m s^{-1})	A1	**Note**: Answer to 3 sf is 3.32×10^{-24} (kg m s^{-1}) **Allow**: 1 sf answer

Question			Answer	Marks	Guidance
		(iii)2			Possible ecf from **(iii)1**
			$v = \frac{3.32\times10^{-24}}{9.11\times10^{-31}}$ (= 3.64×10^6 m s^{-1})	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			$E_k = ½ \times 9.11 \times 10^{-31} \times (3.64 \times 10^6)^2$	C1	
			$E_k = 6.0 \times 10^{-18}$ (J)	A1	**Note**: Answer to 3 sf is 6.05×10^{-18} (J) **Allow**: 1 sf answer
			or		
			$E_k = ½ p^2/m$	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			$E_k = ½ \times (3.32 \times 10^{-24})^2/9.11 \times 10^{-31}$	C1	
			$E_k = 6.0 \times 10^{-18}$ (J)	A1	
			Total	**15**	