Answers – Electric Fields 3

1.

(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

	(v)	$v^2 = (4.0 \times 10^7)^2 + (1.2 \times 10^7)^2$ velocity = 4.2×10^7 (m s^{-1}) Or $v^2 = (4.0 \times 10^7)^2 + (1 \times 10^7)^2$ 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 $x = 0$

2.

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

c		Eq = Bqv B = E / v = $12000 / 2 \times 10^5$ = 0.060 (T)	C1 C1 A1	 Allow one sf unless answer is 0.061 when using v =1.97×10^5
d		velocity (produced by p.d / 400 V) is less force due the magnetic field is reduced / Bqv is less / force due to the electric field is unchanged hence beam deflects <u>down</u>	B1 B1	 Allow the resultant force is downward Allow towards the lower plate

3.

a		six or more equally spaced horizontal lines from plate to plate	**1**	
		arrows towards -36 V plate	**1**	**2**
b	**i**	$E = V/d = 36/ 8 \times 10^{-3} = 4500$ (N C^{-1})	**1**	
	ii	$F = eE = 1.6 \times 10^{-19} \times 4500 = 7.2 \times 10^{-16}$ (N)	**1**	
	iii	$\Delta\varepsilon = eV$ or $Fd = 1.6 \times 10^{-19} \times 36$ or $7.2 \times 10^{-16} \times 8 \times 10^{-3} = 5.76 \times 10^{-18}$ (J)	**1**	
	iv	$1/2mv^2 = 1/2mu^2 \pm \Delta\varepsilon$ or $v^2 = u^2 \pm 2Fd/m$	**1**	
		$v^2 = 16 \times 10^{12} - 11.5 \times 10^{-18}/9.1 \times 10^{-31} = 3.4 \times 10^{12}$ *ecf b(ii) or (iii)*	**1**	
		$\Delta v = u - v = 4.0 \times 10^6 - 1.8 \times 10^6 = 2.2 \times 10^6$ (m s^{-1})	**1**	**6**
c	**i**	F is / from P to Q/downwards/towards -36 V plate	**1**	
	ii	magnetic force (Bev) is in the opposite direction to the electric force (eE)	**1**	
		these can be made equal and opposite (by adjusting B)	**1**	
		(so that the electrons are undeviated by Newton 1)		
	iii	Bev = eE; $B = E/v = 4500/4 \times 10^6$; $= 1.125 \times 10^{-3}$; T or 1.125 mT	**4**	**7**

4.

a	**i**	appropriate shape; lines perpendicular to and touching plate and sphere;	**2**	
		arrows towards negative charge	**1**	**3**
b	**i**	$E = V/d = 50000/0.04$; $=1.25 \times 10^6$ (N C^{-1})	**2**	
	ii	$F = QE = 5 \times 10^{-9} \times 1.25 \times 10^6$; $= 6.25 \times 10^{-3}$ (N) *ecf b(i)*	**2**	**4**
c	**i**	$F = Q^2 / 4\pi\varepsilon_o r^2$; $= 9 \times 10^9 \times 25 \times 10^{-18} / 16 \times 10^{-4}$; $= 1.406 \times 10^{-4}$ (N)	**3**	
	ii	$\Delta m = 1.4 \times 10^{-5}$ kg or 0.014 g ; giving new reading as 8.219 g	**2**	**5**

5.

a		Positive as E-field is downwards/top plate is positive/like charges repel/AW	**1**	**1**
b	**i**	k.e. $= QV$; $= 300 \times 1.6 \times 10^{-19} = (4.8 \times 10^{-17}$ J)	**2**	
	ii	$1/2mv^2 = 4.8 \times 10^{-17}$; $= 0.5 \times 2.3 \times 10^{-26} \times v^2$ so $v^2 = 4.17 \times 10^9$; (giving $v = 6.46 \times 10^4$ m s^{-1})	**2**	**4**
c		$E = V/d$; so $d = V/E = 600/4 \times 10^4 = 0.015$ m	**2**	**2**
d	**i**	semicircle to right of hole *ecf(a); (a) and d(i) to be consistent*	**1**	
	ii	mv^2/r; $= BQv$;	**2**	
		giving $r = mv/BQ = 2.3 \times 10^{-26} \times 6.5 \times 10^4/(0.17 \times 1.6 \times 10^{-19})$;	**1**	
		$r = 55$ mm ;so distance $= 2r = 0.11$ m	**2**	**6**