Mark Scheme Electric Fields Past Paper Questions
Jan 2002—Jan 2010 (old spec)

4(a)(i) (force) to the right ✓

(ii) electrons accelerate or speed increases ✓ (*2*)

Q4 Jan 2002

(b)(i) sketch to show path <u>curving</u> upwards in the field (must not become vertical) ✓

(ii) horizontal component of velocity is unchanged ✓
vertical or upwards acceleration (or force) ✓
parabolic path described (or named) ✓ max (*3*)

(*5*)

3(a)(i) $E\ (= \frac{Q}{4\pi\varepsilon_o r^2}) = \frac{29 \times 1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times (1..15 \times 10^{-10})^2}$ ✓

$= 3.15 \times 10^{12}$ V m^{-1} (or N C^{-1}) ✓

Q3 Jan 2003

(a)(ii) $V(= -\frac{GM}{r}) = (-)\ \frac{6.67 \times 10^{-11} \times 63 \times 1.66 \times 10^{-27}}{1.15 \times 10^{-10}}$ ✓

$= (-)\ 6.07 \times 10^{-26}$ ✓ – sign and J kg^{-1} ✓ (5)

(b) arrow pointing to the right ✓ (*1*)

(*6*)

2

(a)

Q2 Jan 2004

quantity	SI unit	
(gravitational potential)	J kg^{-1} or N m kg^{-1}	scalar
(electric field strength)	N C^{-1} or V m^{-1}	vector
(magnetic flux density	T or Wb m^{-2} or N A^{-1} m^{-1}	vector

6 entries correct ✓✓✓
4 or 5 entries correct ✓✓
2 or 3 entries correct ✓ (*3*)

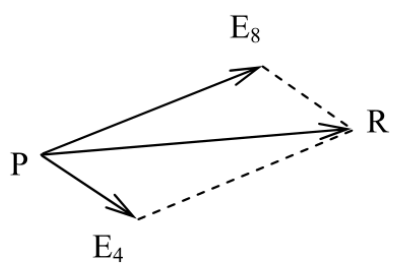
(b)(i) $mg = EQ$ ✓

$E\left(= \frac{mg}{Q} = \frac{4.3 \times 10^{-9} \times 9.81}{3.2 \times 10^{-12}}\right) = 1.32 \times 10^4\ (\text{V m}^{-1})$ ✓

(ii) positive ✓ (*3*)

(*6*)

Question 5		
(a) (i)	$E\left(=\frac{V}{d}\right)=\frac{1400}{15\times10^{-3}}$ ✓ (= 9.3×10^{4} V m^{-1}) **Q5 Jan 2006**	
(ii)	$t\left(=\frac{l}{v}\right)=\frac{30\times10^{-3}}{3.2\times10^{7}}$ = 9.38×10^{-10} s ✓	**5**
(iii)	$ma_{y}=Ee$ ✓ $a_{y}=\frac{9.3\times10^{4}\times1.60\times10^{-19}}{9.11\times10^{-31}}$ ✓ (= 1.64×10^{16} m s^{-2}) acceleration is upwards [or towards + plate]✓	
(b)	v_{y} (= $a_{y}t$) = $1.64\times10^{16}\times9.38\times10^{-10}$ ✓ (= 1.54×10^{7} m s^{-1}) $v=\sqrt{(1.54\times10^{7})^{2}+(3.2\times10^{7})^{2}}$ = 3.55×10^{7} m s^{-1} ✓ at $\tan^{-1}\left(\frac{1.54}{3.2}\right)=26^{\circ}$ above the horizontal ✓	**3**
	Total	**8**

Question 3		
(a) (i)	force per unit charge ✓ acting on a positive charge ✓ **Q3 Jun 2006**	**3**
(ii)	vector ✓	
(b) (i)	$F\left(=\frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}\right)=\frac{4.0\times10^{-9}\times8.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(80\times10^{-3})^2}$ ✓ $=4.5(0)\times10^{-5}$ N ✓	**4**
(ii)	(use of $V=\frac{Q}{4\pi\varepsilon_0 r}$ gives) $0=\left(\frac{4.0\times10^{-9}}{4\pi\varepsilon_0 x}\right)-\left(\frac{8.0\times10^{-9}}{4\pi\varepsilon_0(80\times10^{-3}-x)}\right)$ or $\frac{4}{x}=\frac{8}{80-x}$ ✓ $x=26.7$ mm ✓	
(c)	 correct directions for E_4 and E_8 ✓ E_8 approx twice as long as E_4 ✓ correct direction of resultant R shown ✓	**3**
	Total	**10**

Question 4			
(a)	(i)	$E\left(=\dfrac{Q}{4\pi\varepsilon_0 r^2}\right)=\dfrac{79\times1.6\times10^{-19}}{4\pi\times8.85\times10^{12}\times(3.0\times10^{-14})^2}$ ✓ **Q4 Jun 2007**	5
		(gives E = 1.3 × 10^{20} V m^{-1} (1.26 × 10^{20}))	
	(ii)	$F\,(=EQ')$ = 1.26 × 10^{20} × 2 × 1.60 × 10^{-19} ✓	
		= 40 N (40.3) ✓	
	(iii)	$V\left(=\dfrac{Q}{4\pi\varepsilon_0 r}\right)=\dfrac{79\times1.6\times10^{-19}}{4\pi\times8.85\times10^{-12}\times3.0\times10^{-14}}$ ✓	
		gives V = 3.8 × 10^{6} V (or J C^{-1}) (3.79 × 10^{6}) ✓	
(b)	(i)	kinetic energy → electric potential energy → kinetic energy ✓	4
	(ii)	initial kinetic energy = potential energy at point P ✓	
		$= (2\,e)\,V$ ✓	
		= 2 ×1.60 × 10^{-19} × 3.79 × 10^{6} = 1.21 × 10^{-12} (J) ✓	
		Total	**9**

Question 3			
(a)	(i)	force is perpendicular to initial velocity **or** acts in opposite direction to direction of electric field ✓	max 5
		initial velocity component is maintained ✓ **Q3 Jan 2008**	
		electron is accelerated in perpendicular direction ✓	
		parabolic path ✓	
	(ii)	force is in opposite direction to initial velocity ✓	
		electron decelerated ✓	
		direction of motion may eventually be reversed ✓	

(b)	(i)	$E\left(\dfrac{V}{d}\right) = \dfrac{110}{44\times10^{-3}}$ = 2500 V m^{-1} (or N C^{-1}) ✓	4
	(ii)	F (= EQ) 2500 × 1.6 × 10^{-19} = 4.0 × 10^{-16} N ✓	
	(iii)	E_k gained (= E_p lost) = eV ✓	
		= 1.6 × 10^{-19} × 110 = 1.7(6) × 10^{-17} (J) ✓	
		[**or** E_k gained = Fd ✓	
		= 4.0 × 10^{-16} × 44 × 10^{-3} = 1.7(6) × 10^{-17} (J) ✓]	
		[**or** use of $F = ma$ and $v^2 = u^2 + 2as$ gives	
		a = 4.39 × 10^{14} (m s^{-2}) and v^2 = 3.86 × 10^{13} (m^2 s^{-2}) ✓	
		E_k gained = ½ mv^2 = ½ × 9.11 × 10^{-31} × 3.86 × 10^{13}	
		= 1.7(6) × 10^{-13} J ✓]	
		Total	**9**

Question 4		
(a) (i)	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$ and $E_p = eV$ ✓ **Q4 Jan 2008** gives $E_p \left(\dfrac{e^2}{4\pi\varepsilon_0 r}\right) = \dfrac{(1.6\times10^{-19})^2}{4\pi\times8.85\times10^{-12}\times2.0\times10^{-15}}$ ✓ (= 1.15×10^{-13} J)	**5**
(ii)	$2 \times ½\, mv^2 = 1.15 \times 10^{-13}$ ✓ gives $v^2 = \dfrac{1.15\times10^{-13}}{2\times1.67\times10^{-27}}$ ✓ $\therefore\ v = 5.8(7) \times 10^6\ \text{m s}^{-1}$ ✓	
(b) (i)	$\Delta m = 2 \times (2.01355) - (3.01550 + 1.00728)$ ✓ (= 4.32×10^{-3} u) $E = 4.32 \times 10^{-3} \times 931.3 = 4.02$ (MeV) ✓ $= 4.02 \times 10^6 \times 1.6 \times 10^{-19} = 6.4(4) \times 10^{-13}$ J ✓	**4**
(ii)	energy per unit mass = $\dfrac{6.44\times10^{-13}}{4\times1.67\times10^{-27}}$ $= 9.6(4) \times 10^{13}$ (J kg^{-1}) ✓ [denominator may be $2 \times 2.014 \times 1.66 \times 10^{-27}$]	
(c)	supply of fuel is almost unlimited (deuterium from sea water) ✓ fewer waste or radioactivity or environmental problems ✓ energy released per unit mass is (generally) greater ✓	**max 2**
	Total	**11**

Question 4		
(a) (i)	radial straight lines ✓ **Q4 Jun 2009** symmetrical in all directions ✓ directed inwards towards charge ✓ (marks could be taken from diagram)	**4**
(ii)	line, labelled **L**, which is a circular arc (or a complete circle) centred on charge ✓	
(b) (i)	$E\left(=\dfrac{Q}{4\pi\varepsilon_0 r^2}\right) = \dfrac{0.80\times10^{-9}}{4\pi\times8.85\times10^{-12}\times\left(40\times10^{-3}\right)^2}$ ✓ $= 4.50 \times 10^3$ (V m^{-1}) ✓	**5**
(ii)	point marked at (40, 4.5) ✓ curve of decreasing gradient ✓ correct $E \propto (1/r^2)$ relationship shown by line drawn ✓	
	Total	**9**

Question 2		
(a)	graph B ✓	**1**
(b)	for graph A, $V \propto \frac{1}{r}$ ✓ **Q2 Jan 2010** for graph B, $E \propto \frac{1}{r^2}$ ✓ [if candidate correctly quotes equations for V and E only, with no further explanation in words, allow ✓ only] [**alternatively** allow a fully correct reference to the – and + gradients of graphs A and B respectively in regions R for ✓✓]	**2**
(c)	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ and $V = \frac{Q}{4\pi\varepsilon_0 r}$ give $E = \frac{V}{r}$ ✓ [no credit for using just $E = \frac{V}{d}$] ∴ potential of the point $V = E\,r = 3.6 \times 10^4 \times 40 \times 10^{-3} = 1.4 \times 10^3$ V ✓ (1440) (allow $\mathrm{J\,C^{-1}}$)	**2**
	Total	**5**