

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 curving 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)

$$3(a)(i) \quad E \left(= \frac{Q}{4\pi\epsilon_0 r^2} \right) = \frac{29 \times 1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times (1.15 \times 10^{-10})^2} \quad \checkmark$$

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

Q3 Jan 2003

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

$$= (-) 6.07 \times 10^{-26} \quad \checkmark \quad \text{– sign and J kg}^{-1} \quad \checkmark$$

(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) $mg = EQ$ ✓

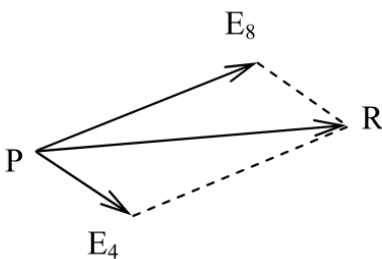
$$E \left(= \frac{mg}{Q} = \frac{4.3 \times 10^{-9} \times 9.81}{3.2 \times 10^{-12}} \right) = 1.32 \times 10^4 \text{ (V m}^{-1}\text{)} \quad \checkmark$$

(ii) positive ✓

(3)

(6)

Question 5			
(a)	(i)	$E\left(=\frac{V}{d}\right)=\frac{1400}{15\times 10^{-3}}\checkmark (=9.3\times 10^4\text{ V m}^{-1})$	Q5 Jan 2006
	(ii)	$t\left(=\frac{l}{v}\right)=\frac{30\times 10^{-3}}{3.2\times 10^7}=9.38\times 10^{-10}\text{ s}\checkmark$	
	(iii)	$ma_y = Ee\checkmark$ $a_y = \frac{9.3\times 10^4 \times 1.60\times 10^{-19}}{9.11\times 10^{-31}}\checkmark (=1.64\times 10^{16}\text{ m s}^{-2})$ acceleration is upwards [or towards + plate]✓	
(b)		$v_y (= a_y t) = 1.64\times 10^{16} \times 9.38\times 10^{-10}\checkmark (=1.54\times 10^7\text{ m s}^{-1})$ $v = \sqrt{(1.54\times 10^7)^2 + (3.2\times 10^7)^2} = 3.55\times 10^7\text{ m s}^{-1}\checkmark$ at $\tan^{-1}\left(\frac{1.54}{3.2}\right) = 26^\circ$ above the horizontal ✓	5
Total			8

Question 3			
(a)	(i)	force per unit charge ✓ acting on a positive charge ✓	Q3 Jun 2006
	(ii)	vector ✓	
(b)	(i)	$F\left(=\frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}\right)=\frac{4.0\times 10^{-9} \times 8.0\times 10^{-9}}{4\pi \times 8.85\times 10^{-12} \times (80\times 10^{-3})^2}\checkmark$ $=4.5(0)\times 10^{-5}\text{ N}\checkmark$	4
	(ii)	(use of $V = \frac{Q}{4\pi\epsilon_0 r}$ gives) $0 = \left(\frac{4.0\times 10^{-9}}{4\pi\epsilon_0 x}\right) - \left(\frac{8.0\times 10^{-9}}{4\pi\epsilon_0 (80\times 10^{-3} - x)}\right)$ or $\frac{4}{x} = \frac{8}{80 - x}\checkmark$ $x = 26.7\text{ mm}\checkmark$	
(c)			correct directions for E_4 and E_8 ✓ E_8 approx twice as long as E_4 ✓ correct direction of resultant R shown ✓
Total			10

Question 4			
(a)	(i)	$E \left(= \frac{Q}{4\pi\epsilon_0 r^2} \right) = \frac{79 \times 1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{12} \times (3.0 \times 10^{-14})^2} \checkmark$ <p style="text-align: center;">(gives $E = 1.3 \times 10^{20} \text{ V m}^{-1}$ (1.26×10^{20}))</p>	Q4 Jun 2007
	(ii)	$F (= EQ') = 1.26 \times 10^{20} \times 2 \times 1.60 \times 10^{-19} \checkmark$ $= 40 \text{ N (40.3)} \checkmark$	5
	(iii)	$V \left(= \frac{Q}{4\pi\epsilon_0 r} \right) = \frac{79 \times 1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times 3.0 \times 10^{-14}} \checkmark$ <p>gives $V = 3.8 \times 10^6 \text{ V (or J C}^{-1}\text{)}$ (3.79×10^6) \checkmark</p>	
(b)	(i)	kinetic energy \rightarrow electric potential energy \rightarrow kinetic energy \checkmark	
	(ii)	initial kinetic energy = potential energy at point P \checkmark $= (2e)V \checkmark$ $= 2 \times 1.60 \times 10^{-19} \times 3.79 \times 10^6 = 1.21 \times 10^{-12} \text{ (J)} \checkmark$	
Total			9

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

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

Question 4				
(a)	(i)	$V = \frac{Q}{4\pi\epsilon_0 r} \text{ and } E_p = eV \checkmark$ $\text{gives } E_p \left(\frac{e^2}{4\pi\epsilon_0 r} \right) = \frac{(1.6 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times 2.0 \times 10^{-15}} \checkmark$ $= 1.15 \times 10^{-13} \text{ J}$	Q4 Jan 2008	5
	(ii)	$2 \times \frac{1}{2} mv^2 = 1.15 \times 10^{-13} \checkmark$ $\text{gives } v^2 = \frac{1.15 \times 10^{-13}}{2 \times 1.67 \times 10^{-27}} \checkmark \therefore v = 5.8(7) \times 10^6 \text{ ms}^{-1} \checkmark$		
(b)	(i)	$\Delta m = 2 \times (2.01355) - (3.01550 + 1.00728) \checkmark (= 4.32 \times 10^{-3} \text{ u})$ $E = 4.32 \times 10^{-3} \times 931.3 = 4.02 \text{ (MeV)} \checkmark$ $= 4.02 \times 10^6 \times 1.6 \times 10^{-19} = 6.4(4) \times 10^{-13} \text{ J} \checkmark$		4
	(ii)	$\text{energy per unit mass} = \frac{6.44 \times 10^{-13}}{4 \times 1.67 \times 10^{-27}}$ $= 9.6(4) \times 10^{13} \text{ (J kg}^{-1}\text{)} \checkmark$ <p style="text-align: center;">[denominator may be $2 \times 2.014 \times 1.66 \times 10^{-27}$]</p>		
(c)		supply of fuel is almost unlimited (deuterium from sea water) \checkmark fewer waste or radioactivity or environmental problems \checkmark energy released per unit mass is (generally) greater \checkmark		max 2
			Total	11

Question 4				
(a)	(i)	radial straight lines \checkmark symmetrical in all directions \checkmark directed inwards towards charge \checkmark (marks could be taken from diagram)	Q4 Jun 2009	4
	(ii)	line, labelled L , which is a circular arc (or a complete circle) centred on charge \checkmark		
(b)	(i)	$E \left(= \frac{Q}{4\pi\epsilon_0 r^2} \right) = \frac{0.80 \times 10^{-9}}{4\pi \times 8.85 \times 10^{-12} \times (40 \times 10^{-3})^2} \checkmark$ $= 4.50 \times 10^3 \text{ (V m}^{-1}\text{)} \checkmark$		5
	(ii)	point marked at (40, 4.5) \checkmark curve of decreasing gradient \checkmark correct $E \propto (1/r^2)$ relationship shown by line drawn \checkmark		
			Total	9

Question 2		
(a)	graph B ✓	1
(b)	<p style="text-align: right;">Q2 Jan 2010</p> for graph A, $V \propto \frac{1}{r}$ ✓ 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)	$E = \frac{Q}{4\pi\epsilon_0 r^2}$ and $V = \frac{Q}{4\pi\epsilon_0 r}$ give $E = \frac{V}{r}$ ✓ [no credit for using just $E = \frac{V}{d}$] \therefore potential of the point $V = E r = 3.6 \times 10^4 \times 40 \times 10^{-3} = 1.4 \times 10^3 \text{ V}$ ✓ (1440) (allow J C^{-1})	2
	Total	5