PRESTON MANOR

A Level Physics Exam Packs

Electric fields

Name:

Form:

Question	Mark

3 **(a)** Fig. 3.1 shows two charged horizontal plates.

Fig. 3.1

The potential difference across the plates is 60 V. The separation of the plates is 5.0 mm.

(i) On Fig. 3.1 draw the electric field pattern between the plates. **[2]**

(ii) Calculate the electric field strength between the plates.

electric field strength = ... $V\,m^{-1}$ **[1]**

(b) Positive ions are accelerated from rest in the horizontal direction through a potential difference of 400 V. The charged plates in **(a)** are then used to deflect the ions in the vertical direction. Fig. 3.2 shows the path of these ions.

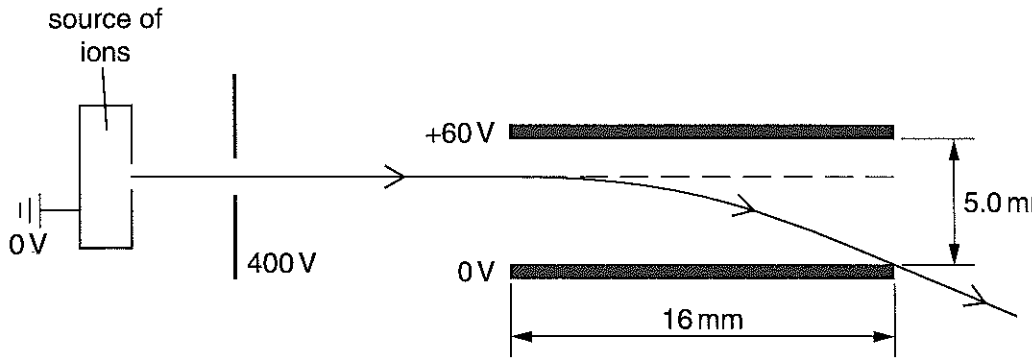


Fig. 3.2

Each ion has a mass of 6.6×10^{-27} kg and a charge of 3.2×10^{-19} C.

(i) Show that the horizontal velocity of an ion after the acceleration by the 400 V potential difference is $2.0 \times 10^5\,\mathrm{m\,s^{-1}}$.

[2]

(ii) The ions enter at right angles to the uniform electric field between the plates. Calculate the vertical acceleration of an ion due to this electric field.

acceleration = ... $\mathrm{m\,s^{-2}}$ **[2]**

(iii) The length of each of the charged plates is 16 mm.

1 Show that an ion takes about 8.0×10^{-8} s to travel through the plates.

[1]

2 Calculate the vertical deflection of an ion as it travels through the plates.

deflection = ... m **[2]**

(c) A uniform magnetic field is applied in the region between the plates in Fig. 3.2. The magnetic field is perpendicular to both the path of the ions and the electric field between the plates.

Calculate the magnitude of the magnetic flux density of field needed to make the ions travel horizontally through the plates.

magnetic flux density = ... T **[3]**

(d) Ions of the same charge but greater mass are accelerated by the potential difference of 400 V described in **(b)**. Describe and explain the effect on the deflection of the ions after they have travelled between the plates using the same electric and magnetic fields of **(c)**.

....

....

....

.... **[2]**

[Total: 15]

Question			Expected Answers	Marks	Additional Guidance
3	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 = $\frac{1}{2} mv^2$ $v = [(2qV)/m]^{1/2}$ $v = [(2 \times 3.2 \times 10^{-19} \times 400)/6.6 \times 10^{-27}]^{1/2}$ $v = 1.97 \times 10^5$ ($m\ s^{-1}$)	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 $s = \frac{1}{2} a \times t^2 = \frac{1}{2} [5.82 \times 10^{11} \times (8 \times 10^{-8})^2]$ $= 1.86 \times 10^{-3}$ (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	C1	
			B = E / v = 12000 / 2 x 10^5	C1	
			= 0.060 (T)	A1	Allow one sf unless answer is 0.061 when using v =1.97 x 10^5
	d		velocity (produced by p.d / 400 V) is less	B1	
			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	Allow the resultant force is downward Allow towards the lower plate
			Total	**[15]**	

3 **(a)** Define *electric field strength*.

....

.... **[1]**

(b) Fig. 3.1 shows two horizontal, parallel metal plates **A** and **B**.

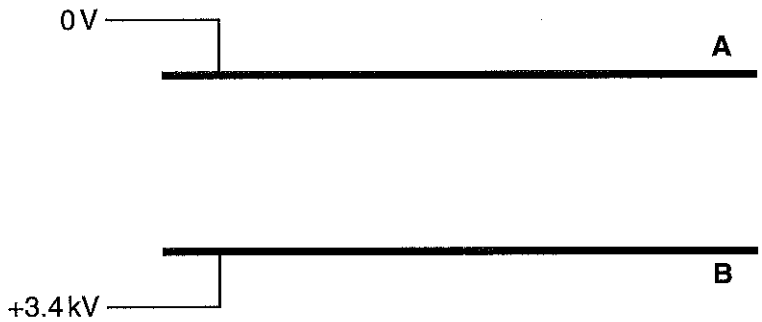


Fig. 3.1

The potential difference across the plates is 3.4 kV and the arrangement provides a uniform electric field between the plates.

On Fig. 3.1 draw at least six lines to represent the electric field between the plates. **[2]**

(c) A beam of electrons enters between the plates at right angles to the electric field. The horizontal velocity of the electrons is $4.0 \times 10^7\,\mathrm{m\,s^{-1}}$. The path of the electrons is shown on Fig. 3.2. The horizontal length of each plate is 0.080 m and the separation of the plates is 0.050 cm. **P** is a point 0.040 m from where the beam enters the plates.

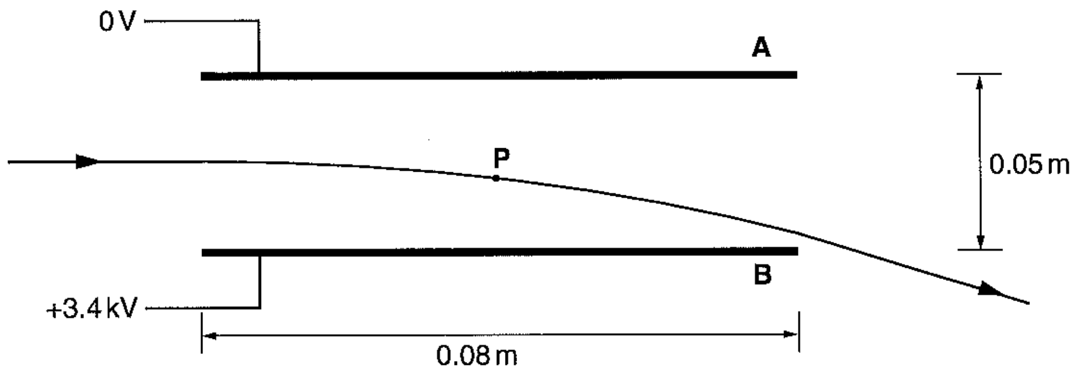


Fig. 3.2

(i) Draw an arrow on Fig. 3.2 to show the direction of the acceleration of an electron at **P**. **[1]**

(ii) Show that the acceleration of an electron between the plates is about $1 \times 10^{16}\,\mathrm{m\,s^{-2}}$.

[2]

(iii) Calculate the time taken for an electron on entering the plates to reach **P**.

time = ... s **[1]**

(iv) Show that the vertical velocity of the electron at **P** is $1.2 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

[1]

(v) Calculate the magnitude of the resultant velocity of the electron at **P**.

magnitude of the velocity = ... $\mathrm{m\,s^{-1}}$ **[2]**

(vi) Calculate the kinetic energy of the electron at **P**.

kinetic energy = ... J **[2]**

(vii) On Fig. 3.3 sketch the variation of kinetic energy E_k of the electron with the horizontal distance x it travels through the electric field and beyond. No calculations are required.

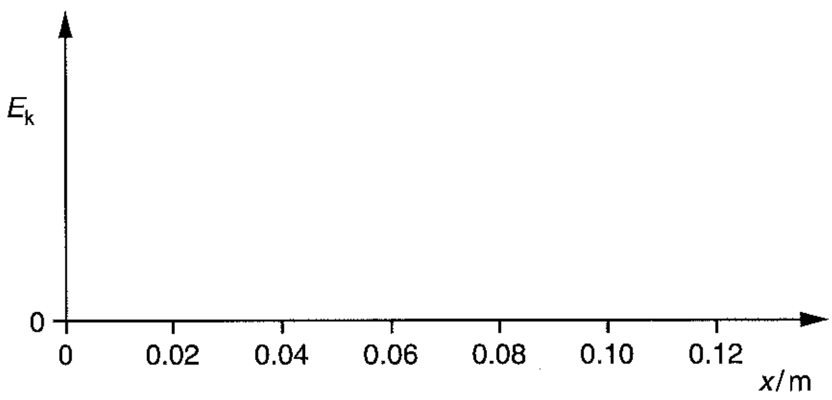


Fig. 3.3

[3]

[Total: 15]

Question			Expected Answers	Marks	Additional guidance
3	(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}) $a = \frac{EQ}{m}$ $a = \frac{6.8 \times 10^4 \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}$ or $a = \frac{1.09 \times 10^{-14}}{9.11 \times 10^{-31}}$ 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 $E = \frac{3400}{0.050 \times 10^{-2}}$ or $E = 6.8 \times 10^6$ (V m^{-1}) C1 $a = \frac{EQ}{m}$ $a = \frac{6.8 \times 10^6 \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}$ C1 acceleration = 1.19×10^{18} (m s^{-2}) A0
		(iii)	$t = \frac{0.04}{4.0 \times 10^7}$ 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 = $\frac{1}{2} mv^2$ 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**	

4 A small, charged metal sphere **A** is hung from an insulating string. The charge on **A** is +5.0 nC. Fig. 4.1 shows the effect on **A** when a charged sphere **B** on an insulated rod is positioned close to it. The string makes an angle θ with the vertical.

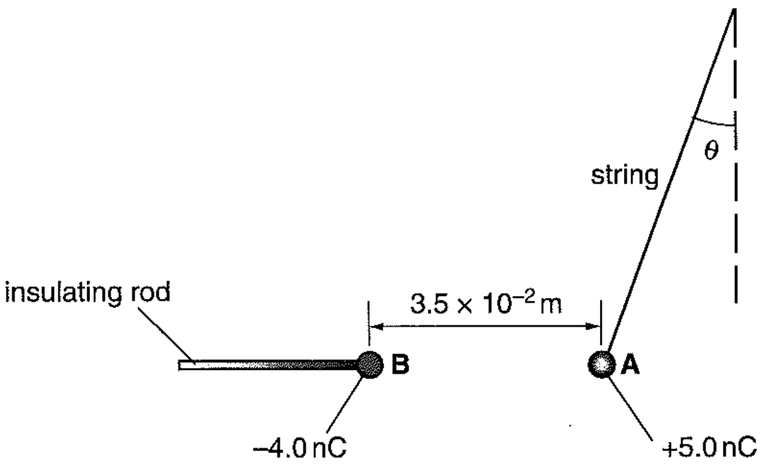


Fig. 4.1

The charge on **B** is –4.0 nC. The separation between the centres of the two spheres is 3.5×10^{-2} m.

(a) Determine the magnitude and direction of the electric field strength at the **midpoint** between the two charged spheres.

electric field strength = ... NC^{-1}

direction = ...

[4]

(b) Show that the electric force on **A** is 1.5×10^{-4} N.

[2]

(c) The mass of sphere **A** is 4.5×10^{-5} kg. Use the method of resolving vectors or a vector triangle to determine the angle θ made by the string with the vertical.

θ = ... ° **[3]**

[Total: 9]

Question			Expected Answers	Marks	Additional guidance
4	(a)		$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$	C1	
			$\dfrac{(-)4.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$ and $\dfrac{5.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$	C1	Ignore signs
			$E_B = 1.17\times10^5$ (N C^{-1}) and $E_A = 1.47\times10^5$ (N C^{-1})		
			field strength = $(1.17 + 1.47)\times10^5$ (N C^{-1})		
			field strength = 2.64×10^5 (N C^{-1}) or 2.6×10^5 (N C^{-1})	A1	**Allow:** 2 marks for $2.9(4)\times10^4$ (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
			direction = to the left / towards B	B1	
	(b)		$F = \dfrac{Qq}{4\pi\varepsilon_0 r^2}$	C1	
			force = $\dfrac{4.0\times10^{-9}\times5.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(3.5\times10^{-2})^2}$	C1	Ignore signs **Allow:** ε_0 in the equation
			force = 1.47×10^{-4} (N)	A0	
	(c)		(weight =) $4.5\times10^{-5}\times9.81$ or (weight =) $4.4(1)\times10^{-4}$ (N)	C1	**Allow:** weight = $4.5\times10^{-5}\times g$
			$\tan\theta = \dfrac{1.5\times10^{-4}}{4.41\times10^{-4}}$	C1	
			angle = 18.8 (°) or 19 (°) (**Allow:** Full credit when angle is determined using a scale diagram)	A1	**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 '$\tan\theta = \dfrac{1.5\times10^{-4}}{4.5\times10^{-5}}, \theta = 73^0$' when mass is used instead of weight.
			Total	**9**	

Answer **all** the questions.

1 Fig. 1.1 shows a close up of the two electrodes of a spark plug.

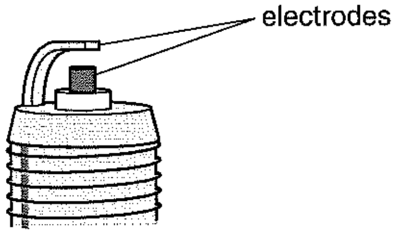


Fig. 1.1

The electrodes may be considered as two parallel plates. The electric field strength between the electrodes is almost uniform.

(a) Define *electric field strength*.

....

.... **[1]**

(b) The separation between the electrodes is 1.3 mm. An electric spark is produced when the electric field strength is $3.0 \times 10^{6}\,\mathrm{V\,m^{-1}}$.

(i) Estimate the potential difference V between the electrodes when the spark is produced.

$V =$ .... V **[2]**

(ii) The electric spark lasts for 4.0×10^{-2} s and produces an average current of 2.7×10^{-9} A.

1 Calculate the charge transferred between the electrodes.

charge = ...C **[2]**

2 Calculate the number of electrons transferred between the electrodes.

number = ... **[1]**

(iii) Estimate the total energy transferred by the electrons in **(ii)**.

energy = ... J **[2]**

[Total: 8]

Question			Answers	Marks	Guidance
1	(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), $n \neq 3$ – 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**	

4 An alpha particle is fired at high speed directly towards a stationary nucleus of a gold atom. At its distance of closest approach to the gold nucleus, the alpha particle stops and the gold nucleus has a small velocity, see Fig. 4.1. The alpha particle and the gold nucleus both have positive charges.

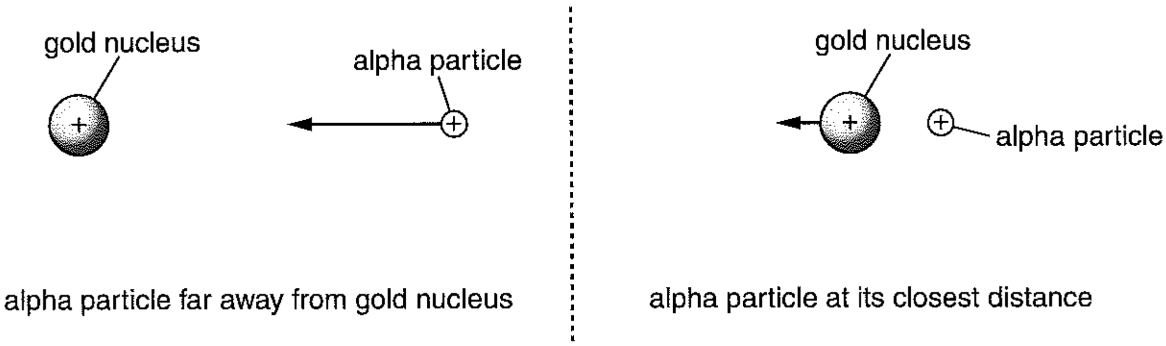


Fig. 4.1

(a) Explain why, at this distance of closest approach, the gold nucleus has a velocity and the alpha particle does not.

....

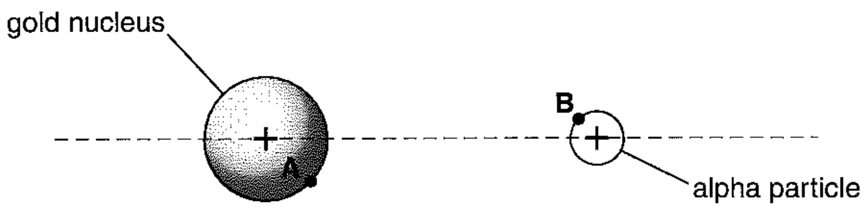
....

....

....

.... **[2]**

(b) Fig. 4.2, shows the alpha particle at its closest distance to the gold nucleus. Draw one electric field line from point **A** and one from point **B**. For each field line, show the direction of the field.



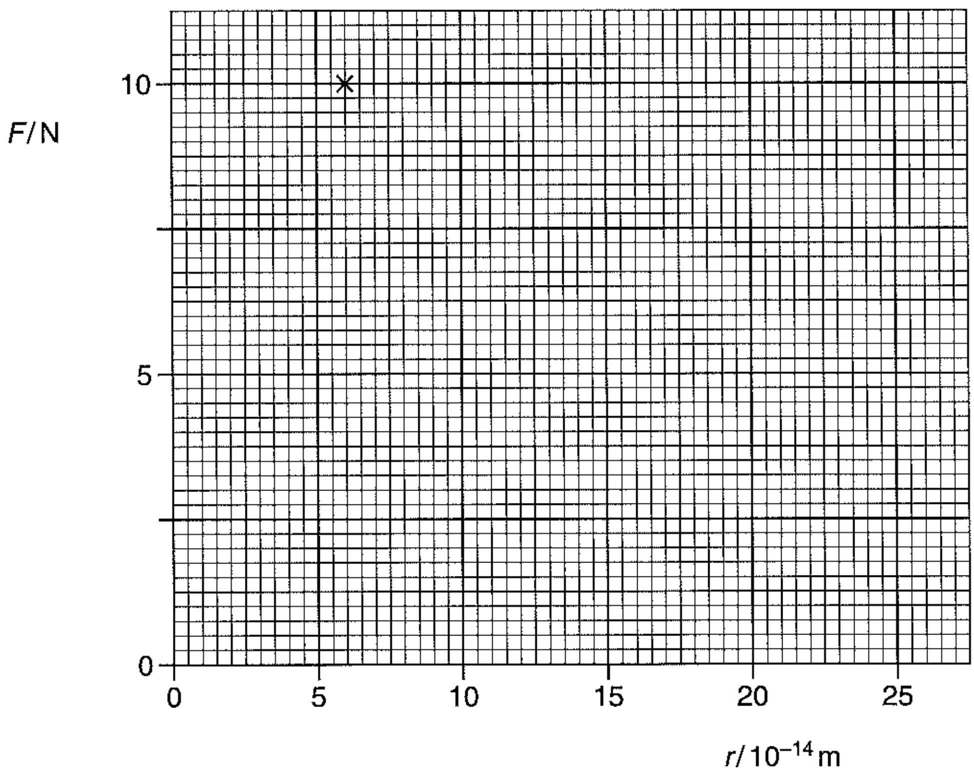
[2]

Fig. 4.2

(c) Show that the electrical force experienced by the alpha particle at its closest distance of 6.0×10^{-14} m to the gold nucleus is about 10 N. The gold nucleus has 79 protons and the alpha particle has 2 protons.

[3]

(d) On Fig. 4.3, sketch a graph to show the variation of the electrical force F on the alpha particle with distance r from the centre of the gold nucleus. The value of F at the distance of closest approach has been marked on the graph.



[2]

Fig. 4.3

[Total: 9]

Question			Answer	Marks	Guidance
4	(a)		Any <u>two</u> 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)		$F = \dfrac{Qq}{4\pi\varepsilon_0 r^2}$ Q = 79e and q = 2e force = $\dfrac{79 \times 2 \times (1.60 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times (6.0 \times 10^{-14})^2}$ 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**	

2 **(a)** Define *electric field strength* at a point in space.

....

.... **[1]**

(b) Fig. 2.1 shows an evenly spaced grid.

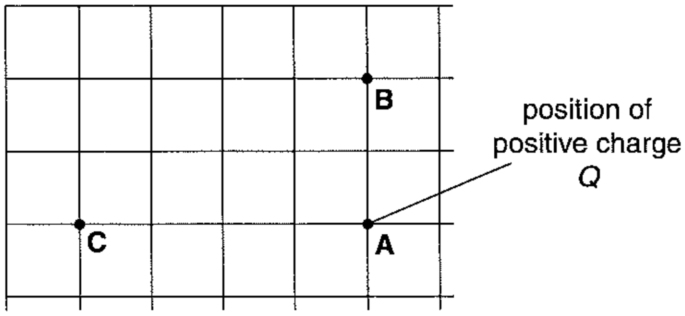


Fig. 2.1

A, **B** and **C** are points on the grid. A positive charge Q is placed on the grid at point **A**. The magnitude of the electric field strength at point **B** due to the charge Q is $8.0 \times 10^5\,\mathrm{N\,C^{-1}}$.

(i) Apart from the magnitudes of the electric field strength, state another difference between the electric field at points **B** and **C**.

....

.... **[1]**

(ii) Determine the magnitude of the electric field strength at point **C**.

electric field strength = ... $\mathrm{N\,C^{-1}}$ **[2]**

(c) The simplest atom is that of hydrogen with one proton and one electron, see Fig. 2.2.

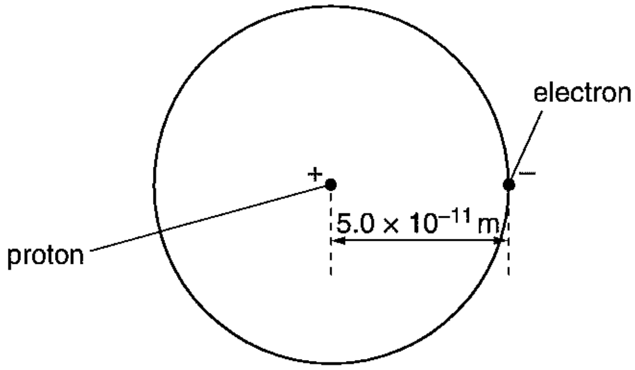


Fig. 2.2

The mean separation between the proton and the electron is shown in Fig. 2.2.

(i) Calculate the magnitude of the electrical force F_E acting on the electron.

F_E = ...N **[3]**

(ii) The gravitational force F_G acting on the electron due to the proton is very small compared with the electrical force F_E it experiences.

Calculate the ratio $\frac{F_E}{F_G}$.

ratio = ... **[2]**

(iii) A simplified model of the hydrogen atom suggests that the de Broglie wavelength of the electron is four times the mean separation between the proton and the electron shown in Fig. 2.2.

Estimate

1 the momentum p of the electron

p = ... kg m s^{-1} **[3]**

2 the kinetic energy E_k of the electron.

E_k = ... J **[3]**

[Total: 15]

Question			Answer	Marks	Guidance
2	(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 electric field strength = 2.0×10^5 (N C^{-1})	C1 A1	**Not**: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ on its own **Allow** 1 sf answer
	(c)	(i)	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ $F_E = \frac{1.6\times10^{-19}\times1.6\times10^{-19}}{4\pi\varepsilon_0\times(5.0\times10^{-11})^2}$ $F_E = 9.2 \times 10^{-8}$ (N)	C1 C1 A1	 **Allow**: 1 mark if Q = q = 1 giving an answer of 3.6×10^{30} (N)
		(ii)	$F_G = \frac{6.67\times10^{-11}\times1.67\times10^{-27}\times9.11\times10^{-31}}{(5.0\times10^{-11})^2}$ $F_G = 4.06 \times 10^{-47}$ (N) ratio = $9.2 \times 10^{-8}/4.06 \times 10^{-47}$ ratio = 2.3×10^{39}	C1 A1	**Note**: Deduct 1 mark if mass of two electrons or two protons is used, then ecf Possible ecf from **(c)(i)**
		(iii)1	wavelength = 2.0×10^{-10} (m) $\lambda = h/mv$ $p = \frac{6.63\times10^{-34}}{2.0\times10^{-10}}$ $p = 3.3 \times 10^{-24}$ (kg m s^{-1})	C1 C1 A1	 Possible ecf for incorrect wavelength **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**
			$v = \dfrac{3.32\times10^{-24}}{9.11\times10^{-31}}$ (= 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**	

2 Fig. 2.1 shows two identical negatively charged conducting spheres.

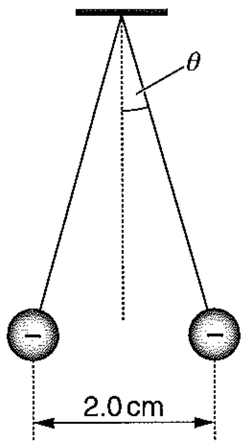


Fig. 2.1

The spheres are tiny and each is suspended from a nylon thread. Each sphere has mass 6.5×10^{-5} kg and charge -2.8×10^{-9} C. The separation between the centres of the spheres is 2.0 cm.

(a) Calculate the number of excess electrons on the surface of each sphere.

number = ... **[1]**

(b) Calculate the repulsive electrical force acting on each sphere.

force = ...N **[2]**

(c) **(i)** Each sphere is in equilibrium and experiences three forces. One of the forces acting on each sphere is the electrical force. State the other **two** forces acting on each sphere.

....

.... **[1]**

(ii) Use your knowledge of vectors to determine the angle θ made by each thread with the vertical.

θ = ... ° **[3]**

[Total: 7]

Question			Answer	Marks	Guidance
2	(a)		number = $\frac{2.8 \times 10^{-9}}{1.6 \times 10^{-19}}$ number = 1.75×10^{10} or 1.8×10^{10}	B1	Ignore a negative sign
	(b)		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ $F = \frac{2.8 \times 10^{-9} \times 2.8 \times 10^{-9}}{4\pi \times 8.85 \times 10^{-12} \times (2.0 \times 10^{-2})^2}$ 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 <u>and</u> weight	B1	**Allow**: force provided by the <u>string</u> / force in the <u>string</u> instead of tension **Not**: 'gravity' for weight **Allow**: force due to gravity **Allow**: gravitational (force)
		(ii)	(weight =) $6.5 \times 10^{-5} \times g$ $\tan\theta = 1.76 \times 10^{-4}/6.38 \times 10^{-4}$ $\theta = 15°$ 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**	

Answer **all** the questions.

1 **(a)** Fig. 1.1 shows a negatively charged metal sphere close to a positively charged metal plate.

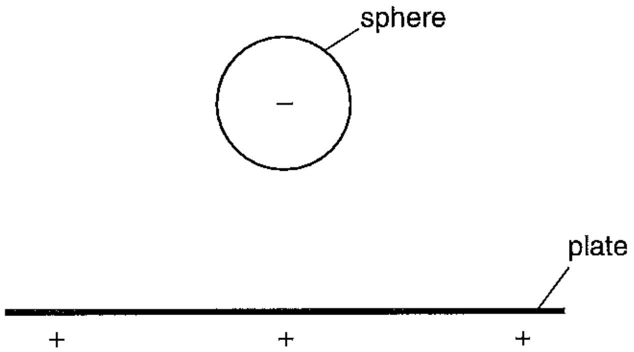


Fig. 1.1

On Fig. 1.1, draw a minimum of five field lines to show the electric field pattern between the plate and the sphere. **[2]**

(b) Fig. 1.2 shows two positively charged particles **A** and **B**.

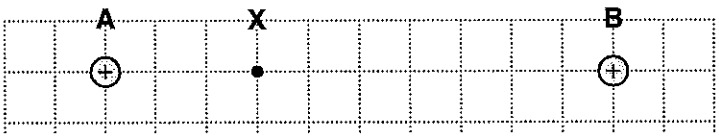


Fig. 1.2

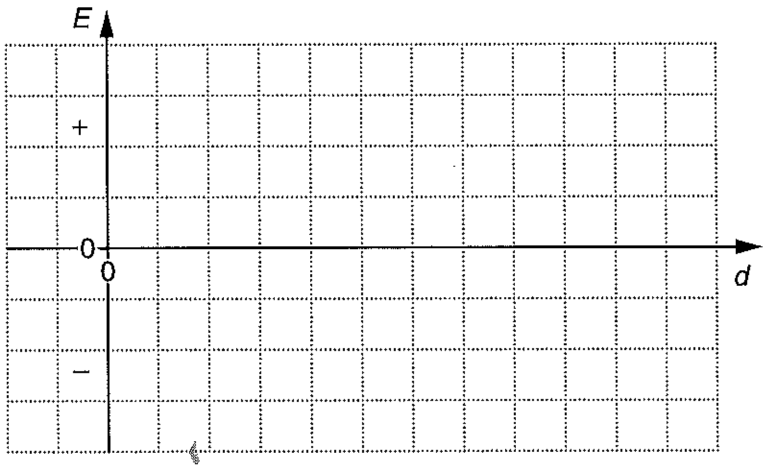


Fig. 1.3

At point **X**, the magnitude of the **resultant** electric field strength due to the particles **A** and **B** is zero.

(i) State, with a reason, which of the two particles has a charge of greater magnitude.

....

....

.... **[1]**

(ii) On Fig. 1.3 sketch the variation of the resultant electric field strength E with distance d from the particle **A**. **[3]**

(c) Fig. 1.4 shows a stationary positively charged particle.

$\oplus$

Fig. 1.4

This particle creates both electric and gravitational fields in the space around it. Explain why the **ratio** of the electric field strength E to the gravitational field strength g at any point around this charge is independent of its distance from the particle.

....

....

....

.... **[1]**

[Total: 7]

Question			Answers	Marks	Guidance
1	(a)		Correct direction of the electric field.	B1	
			A minimum of 5 field lines shown. Correct shape of field lines.	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**.	B1	**Allow** any graph, including a straight line. Tolerance for $E = 0$: $\pm$ ½ large square about **X**.
			Curve showing E is positive between **A** and **X** and negative between **X** and **B** (or vice versa).	M1	**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**.
			The magnitude of E is small close to **A** and large close to **B**.	A1	**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**	

Answer **all** the questions.

1 **(a)** An electric field always exists around a charged particle.

Explain what is meant by an *electric field*.

....

.... [1]

(b) State **one** difference and **one** similarity between the electric field of a point charge and the gravitational field of a point mass.

difference ....

....

similarity ....

.... [2]

(c) Fig. 1.1 shows the uniform electric field between two vertical parallel plates **A** and **B**.

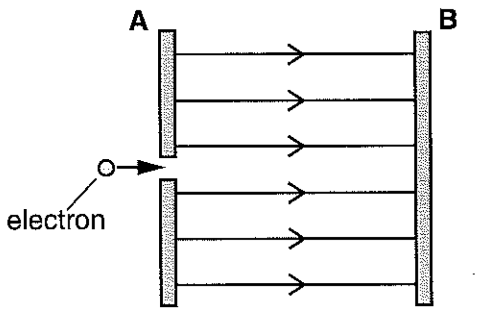


Fig. 1.1

The potential difference between the plates is 6V. An electron of kinetic energy 4eV is fired in a direction parallel to the electric field through a tiny hole in plate **A**.

Describe and explain the subsequent motion of the electron in the space between **A** and **B**. The weight of the electron has negligible effect on its motion between the plates.

....

....

....

....

....

....

.... [3]

(d) Two different minerals acquire opposite charges when they are crushed into tiny particles. These oppositely charged mineral particles fall from a conveyor belt through the uniform electric field between two vertical parallel plates, as shown in Fig. 1.2.

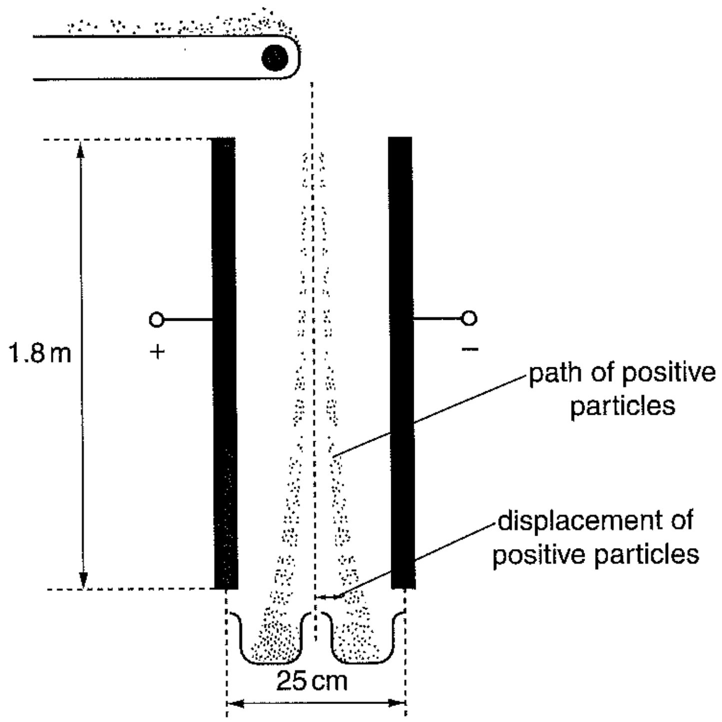


Fig. 1.2

The potential difference across the plates is 60 kV. The separation between the plates is 25 cm and each plate has length 1.8 m. The mineral particles fall through the air between the plates with a terminal velocity of $1.2\,\mathrm{m\,s^{-1}}$. Each mineral particle has a charge of magnitude 1.5×10^{-13} C and a mass of 8.0×10^{-7} kg.

(i) Calculate the horizontal electric force experienced by a positively charged mineral particle as it falls between the plates.

force = ... N **[2]**

(ii) Calculate the horizontal displacement of a positively charged mineral particle after a 1.8 m fall through the electric field of the plates. Ignore any horizontal drag forces due to air.

displacement = ... m **[3]**

Question			Answer	Marks	Guidance
1	(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)	$E = 60 \times 10^3 \div 0.25$ / $E = 2.4 \times 10^5$ (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)**
			$s = \frac{1}{2}\times4.5\times10^{-2}\times1.5^2$	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**	