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OCR A LEVEL PHYSICS A (H556): QUESTIONS BY TOPIC

Electric fields (6.2)

A Level Physics A (H556) · Module 6: Particles and medical physics

18 questions · 81 marks · Mark schemes included

OCR A Level Physics A (H556), June 2017 – June 2025

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HOW TO USE THIS BOOKLET

Questions run from the lowest mark tariff to the highest, so similar questions sit together.

Click any row below to jump straight to that question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION	SOURCE	MARKS	PAGE
1. Q9 <i>also 6.1</i>	H556/02 Exploring physics June 2017	1	4
2. Q13 <i>also 3.2 & 6.3</i>	H556/02 Exploring physics June 2017	1	5
3. Q13 <i>also 3.3</i>	H556/02 Exploring physics June 2018	1	6
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13. Q20 <i>also 3.2</i>	H556/02 Exploring physics June 2017	8	20
14. Q6 <i>also 3.2 & 6.3</i>	H556/03 Unified physics June 2024	10	23
15. Q5 <i>also 3.1 & 4.4 & 5.3</i>	H556/03 Unified physics November 2020	12	26
16. Q6 <i>also 3.5 & 3.3</i>	H556/03 Unified physics November 2020	13	30
17. Q22 <i>also 6.1</i>	H556/02 Exploring physics June 2024	13	33
18. Q1 <i>also 3.5 & 3.3 & 3.1 & 4.1 & 6.3</i>	H556/03 Unified physics June 2025	13	35



QUESTIONS

18 questions · 81 marks · lowest tariff first

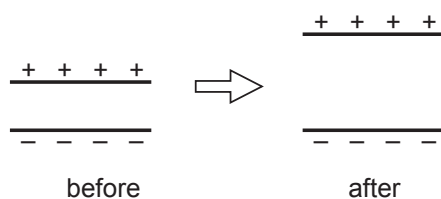


MULTIPLE-CHOICE QUESTIONS

12 questions in this booklet



- 9 Two isolated parallel capacitor plates have an equal and opposite charge. The separation between the plates is doubled. The charge on each plate remains the same but the potential difference between the plates doubles.



Which statement is correct?

- A The capacitance of the capacitor doubles.
- B The energy stored by the capacitor is halved.
- C The permittivity of free space doubles.
- D The electric field strength between the plates remains the same.

Your answer

[1]

- 13 A beam of charged particles is not deflected when it passes through a region where both electric and magnetic fields are present.

Which statement is **not** correct?

- A All the particles have the same speed.
- B The resultant force on each particle is zero.
- C The magnetic force is equal to the electric force on each particle.
- D The magnetic field and the electric field are in the same direction.

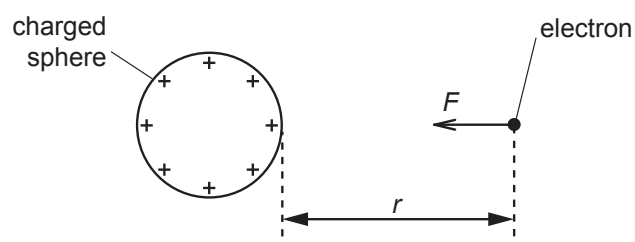
Your answer

[1]

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- 13 An electron is released at a distance r from the surface of a positively charged sphere. It is attracted towards the centre of the sphere and moves until it touches the surface.



Which of the following statements is/are correct?

- 1 The area under the F against r graph is equal to work done on the electron.
- 2 The electric field strength E at distance r is equal to $\frac{F}{1.6 \times 10^{-19}}$.
- 3 The work done on the electron is equal to $F \times r$.

- A** Only 1
- B** Only 1 and 2
- C** Only 1 and 3
- D** 1, 2 and 3

Your answer

[1]

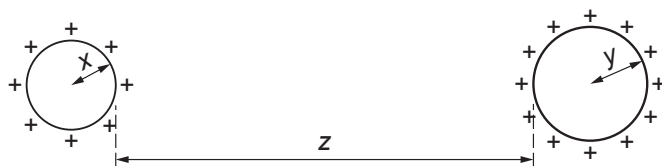
- 1 Which law indicates that charge is conserved?
- A Lenz's law
 - B Coulomb's law
 - C Kirchhoff's first law
 - D Faraday's law of electromagnetic induction

Your answer

[1]



- 2 The diagram below shows two uniformly charged spheres separated by a large distance z .



The radius of the small sphere is x and the radius of the large sphere is y .

Which is the correct distance to use when determining the electric force between the charged spheres?

- A z
- B $x + z$
- C $y + z$
- D $x + y + z$

Your answer

[1]

- 8 The electric field strength at a distance of $2.0 \times 10^{-8} \text{ m}$ from a nucleus is $3.3 \times 10^8 \text{ NC}^{-1}$.

What is the charge on the nucleus?

A $1.6 \times 10^{-19} \text{ C}$

B $1.5 \times 10^{-17} \text{ C}$

C $7.3 \times 10^{-10} \text{ C}$

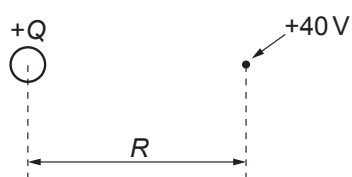
D $3.8 \times 10^{-9} \text{ C}$

Your answer

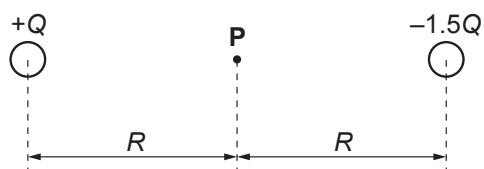
[1]



- 13 The electric potential at a distance R from the centre of a charge $+Q$ is $+40\text{ V}$.



What is the potential at the point **P** for the arrangement of the charges $+Q$ and $-1.5Q$ as shown below?



- A** -20 V
- B** -60 V
- C** $+80\text{ V}$
- D** $+100\text{ V}$

Your answer

[1]

- 4 The diagram below shows two oppositely charged spheres.



The magnitude of the charge on each sphere is the same.

The point **P** is on the line joining the centres of the spheres and is the same distance from the centre of each sphere.

Which statement is correct?

- A** A negatively charged particle at **P** will move to the right.
- B** The direction of the electric field at **P** is to the left.
- C** The electric potential at **P** is zero.
- D** The magnitude of the electric field strength at **P** is zero.

Your answer

[1]

- 15 An electron has both mass and charge. The electron has a gravitational field and an electric field around it.

Which statement is **not** correct?

- A Both field patterns look the same.
- B Both field patterns show parallel field lines around the electron.
- C Both field strengths obey an inverse square law with distance from the electron.
- D The direction of both fields is the same at any point around the electron.

Your answer

[1]

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SECTION B

Answer **all** the questions.



- 9 The centres of a positron and a helium nucleus are separated by 2 mm.

What is the electrostatic force between them?

- A** $1.15 \times 10^{-28} \text{ N}$
- B** $2.30 \times 10^{-25} \text{ N}$
- C** $5.75 \times 10^{-23} \text{ N}$
- D** $1.15 \times 10^{-22} \text{ N}$

Your answer

[1]



15 Which statement is Faraday's law?

- A** The direction of electric current induced by a changing magnetic field is such that the magnetic field created by the induced current opposes changes in the initial magnetic field.
- B** The magnitude of the electrostatic force between two point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the separation.
- C** The magnitude of induced EMF is proportional to the rate of change of the magnetic flux linkage.
- D** The total energy of an isolated system remains constant.

Your answer

[1]

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13 Some physical quantities are scalars and some are vectors.

Which row of the table is correct?

	Vector	Scalar
A	Current	Electric field strength
B	Power	Electric potential
C	Electric field strength	Current
D	Electric potential	Power

Your answer

[1]

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Turn over



8-MARK QUESTIONS

1 question in this booklet



- 20 (a) Fig. 20.1 shows a positively charged metal sphere and a negatively charged metal plate.

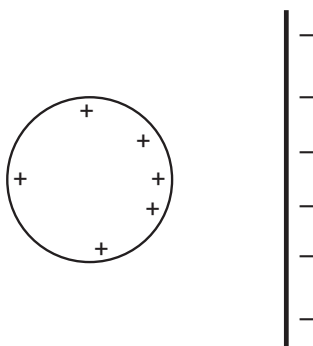


Fig. 20.1

On Fig. 20.1, draw a minimum of **five** electric field lines to show the field pattern between the sphere and the plate. [2]

- (b) Define *electric potential* at a point in space.

.....
 [1]

- (c) A metal sphere is given a positive charge by connecting its surface briefly to the positive terminal of a power supply. The electric potential at the surface of the sphere is + 5.0 kV. The sphere has radius 1.5 cm.

- (i) Show that the charge Q on the surface of the sphere is $8.3 \times 10^{-9} \text{ C}$.

[2]

- (ii) Fig. 20.2 shows the charged sphere from (i) suspended from a nylon thread and placed between two oppositely charged vertical plates.

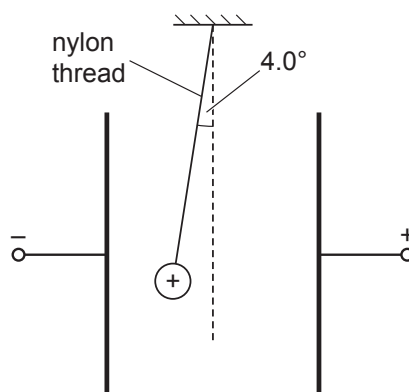


Fig. 20.2 (not to scale)

The weight of the sphere is $1.7 \times 10^{-2} \text{ N}$. The string makes an angle of 4.0° with the vertical.

1. Show that the electric force on the charged sphere is $1.2 \times 10^{-3} \text{ N}$.

[1]

2. Calculate the uniform electric field strength E between the parallel plates.

$$E = \dots\dots\dots \text{ NC}^{-1} \text{ [2]}$$

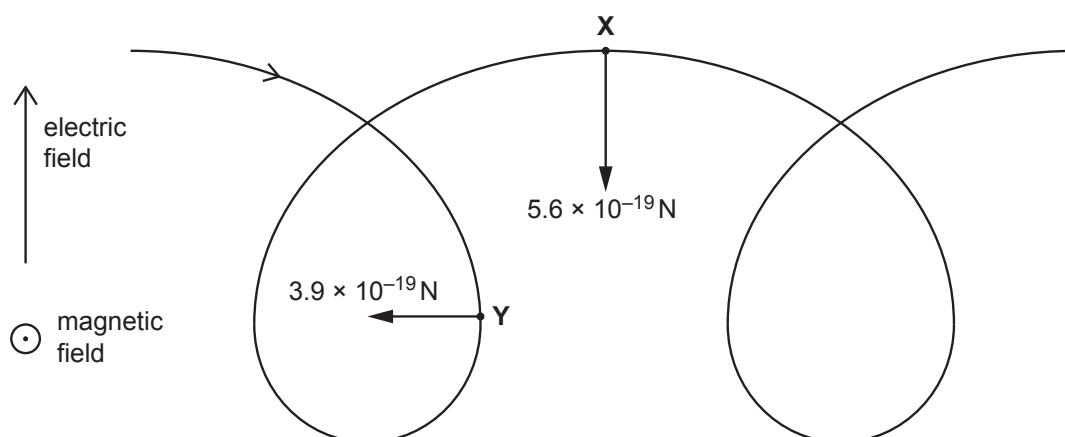
10-MARK QUESTIONS

1 question in this booklet



- 6 The figure below shows the path of a proton moving in a region occupied by both an electric field and a magnetic field.

The direction of the electric field lines is perpendicular to the direction of the magnetic field lines.



The uniform electric field is directed upwards, with electric field strength $E = 0.90 \text{ NC}^{-1}$.

The uniform magnetic field is directed out of the plane of the paper, with magnetic flux density $B = 5.0 \times 10^{-5} \text{ T}$.

At point **X** the proton is moving horizontally to the right. The magnitude of the **magnetic** force at **X** is $5.6 \times 10^{-19} \text{ N}$.

At point **Y** the proton is moving vertically downwards. The magnitude of the **magnetic** force at **Y** is $3.9 \times 10^{-19} \text{ N}$.

The **electric** forces acting on the proton at **X** and **Y** are **not** shown in the figure.

- (a) Show that the magnitude of the constant **electric** force acting on the proton is about 10^{-19} N .

[1]

(b)

- (i) Suggest why the **magnetic** force acting on the proton has a different magnitude at **X** than at **Y**.

.....

 [1]

- (ii) At **X**, the motion of the proton is instantaneously equivalent to motion in a circle at a constant speed.

Calculate the radius of this circular motion.

radius = ... m [4]

- (iii) 1 Calculate the magnitude of the resultant force on the proton at **Y**.

resultant force = ... N [2]

- 2 Explain why the motion of the proton at **Y** is **not** instantaneously equivalent to motion in a circle at a constant speed.

.....
.....
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..... [2]



12-MARK QUESTIONS

1 question in this booklet



- 5 This question is about investigations involving an electromagnetic wave.

A vertical transmitter aerial emits a **vertically polarised** electromagnetic wave which travels towards a vertical receiver aerial. The wavelength of the wave is 0.60 m.

Fig. 5.1 shows a short section of the oscillating electric field of the electromagnetic wave.

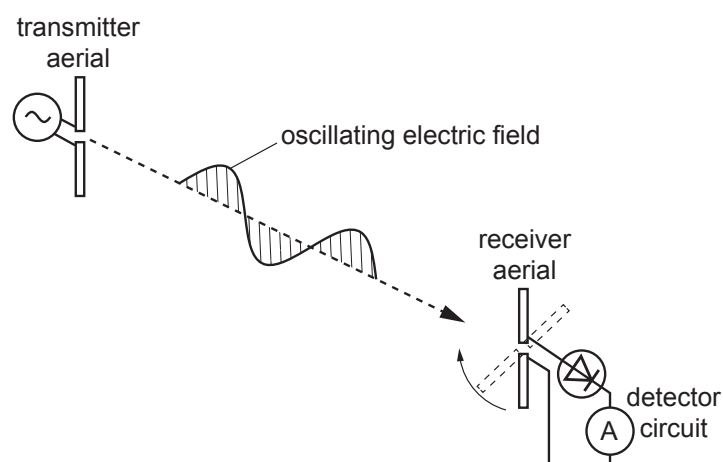


Fig. 5.1

- (a) Calculate the frequency f of the transmitted wave.

$$f = \dots\dots\dots \text{ Hz [2]}$$

- (b) The electromagnetic wave is caused by electrons oscillating in the transmitter aerial. Each electron oscillates with simple harmonic motion.

Calculate the maximum acceleration a_{max} of an electron which oscillates with an amplitude of $4.0 \times 10^{-6} \text{ m}$.

$$a_{\text{max}} = \dots\dots\dots \text{ ms}^{-2} [3]$$

- (c) Suggest why the diode in **Fig. 5.1** is necessary for an ammeter to detect a signal at the receiver aerial.

.....

 [1]

- *(d) A student carries out two investigations with these electromagnetic waves.

In **investigation 1**, the student rotates the receiver aerial about the horizontal axis joining the two aerals, as shown in **Fig. 5.1**.

In **investigation 2**, the student places a metal sheet behind the receiver aerial. The student moves the sheet backwards and forwards along the horizontal axis joining the two aerals, as shown in **Fig. 5.2**.

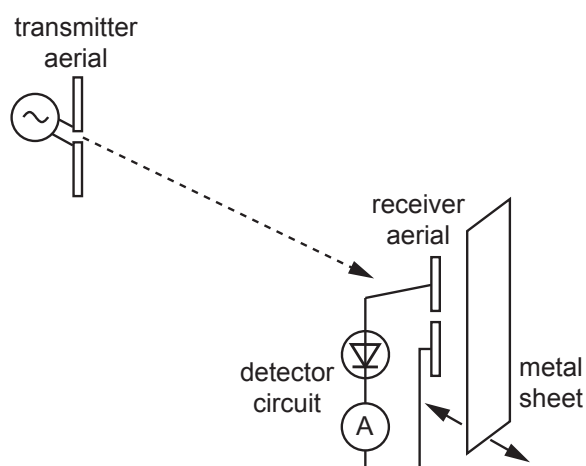


Fig. 5.2

For each of these two investigations:

- Explain why the ammeter sometimes gives a maximum reading and sometimes a zero (or near zero) reading.
- State the orientations of the receiver aerial in **investigation 1**, and the positions of the metal sheet in **investigation 2**, where these maximum and zero readings would occur.

[6]

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Additional answer space if required.

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13-MARK QUESTIONS

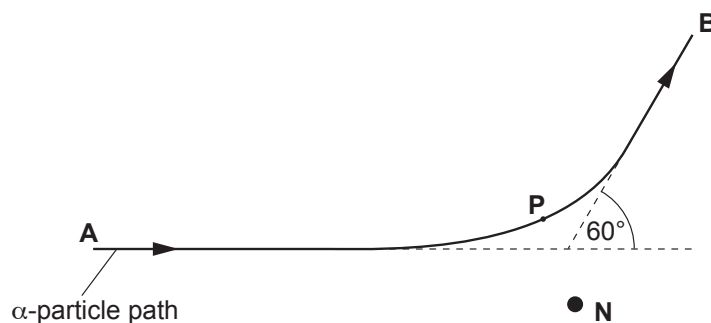
3 questions in this booklet



- 6 A beam of α -particles is incident on a thin gold foil. Most α -particles pass straight through the foil. A few are deflected by gold nuclei.

The diagram shows the path of one α -particle which passes close to a gold nucleus **N** in the foil. The α -particle is deflected through an angle of 60° as it travels from **A** to **B**.

P marks its position of closest approach to the gold nucleus.



- (a) Another α -particle in the beam is deflected by the same gold nucleus **N** through an angle of 30° .

Sketch its path onto the diagram above.

[2]

- (b) The distance between **P** and **N** is $6.8 \times 10^{-14} \text{ m}$.

Calculate the magnitude of the electrostatic force F between the α -particle (${}^4_2\text{He}$) and the gold nucleus (${}^{197}_{79}\text{Au}$) when the α -particle is at **P**.

$F = \dots\dots\dots \text{ N}$ [4]

Question 6 continues on page 18

- (c) The initial kinetic energy of each α -particle is 5.0 MeV.

Show that the magnitude of the initial momentum of each α -particle is about $10^{-19} \text{ kg ms}^{-1}$.
Take the mass of the α -particle to be $6.6 \times 10^{-27} \text{ kg}$.

[3]

- (d) The **magnitude** of the final momentum of the α -particle at **B** is equal to its initial value at **A**.

The gold nucleus **N** is initially at rest. During the passage of the α -particle from **A** to **B**, no other forces act on the two particles.

In the following questions label any relevant angles.

- (i) Draw two vectors in the spaces below to represent the initial momentum and the final momentum of the α -particle.

initial momentum at **A**

final momentum at **B**

[2]

- (ii) Draw a vector in the space below to represent the momentum of the nucleus **N** when the α -particle reaches **B**.

Explain how you determined this momentum.

.....
.....
..... [2]



22 This question is about lightning.

- (a)** Sheet lightning occurs when there is an electrical discharge between the upper and lower regions of a thunder cloud.

The upper regions are positive and the lower regions are negative.

The thunder cloud can be modelled as an ideal parallel plate capacitor with circular horizontal plates.

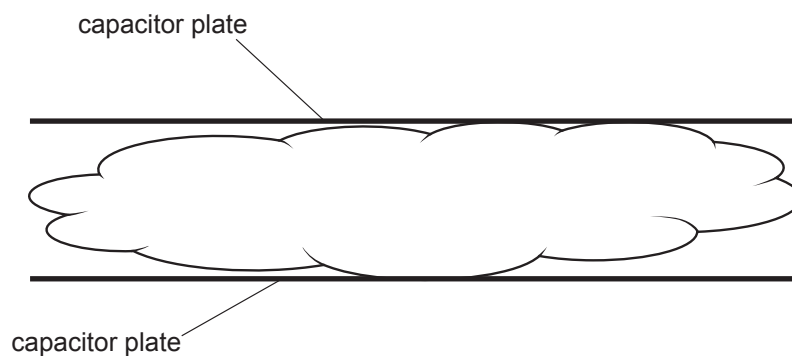
The data for the capacitor comes from the cloud.

Diameter of cloud	24 km
Distance between upper and lower regions	3.2 km
Electric field strength between the regions	$4.0 \times 10^5 \text{ V m}^{-1}$

- (i)** The diagram shows the plates of the model capacitor superimposed on the cloud.

Draw on the diagram to show the electric field lines between capacitor plates.

[2]



- (ii)** Suggest why the actual electric field lines of the cloud would differ from what you have drawn.

.....
 **[1]**

- (iii)** Show that the potential difference (p.d.) V between the plates is about $1 \times 10^9 \text{ V}$.

[1]

- (iv) Calculate the capacitance C of the model capacitor.

Assume the permittivity of the material of the cloud is the same as the permittivity of free space.

$$C = \dots\dots\dots \text{ F [2]}$$

- (v) Calculate the magnitude of the charge Q on one of the plates of the model capacitor.

$$Q = \dots\dots\dots \text{ C [2]}$$

- (b) Fork lightning is an electrical discharge that occurs between the bottom of the cloud and the surface of the Earth.

Another cloud has a charge of 155 C and is at a height of 2.0 km .

The surface of the Earth has an electrical potential V of 0 V .

- (i) Assume the cloud acts as a **point** charge.

Calculate the magnitude of the electrical potential V between the cloud and the surface of the Earth.

$$V = \dots\dots\dots \text{ V [2]}$$

- (ii) A fork lightning strike has a duration of 25 ms . The cloud discharges at a constant rate. The cloud is uncharged after the strike.

Calculate the number of electrons reaching the ground in 1.0 ms .

$$\text{number of electrons in } 1.0 \text{ ms} = \dots\dots\dots \text{ [3]}$$



- 1 The Earth's aurora is an atmospheric effect visible in the polar regions.

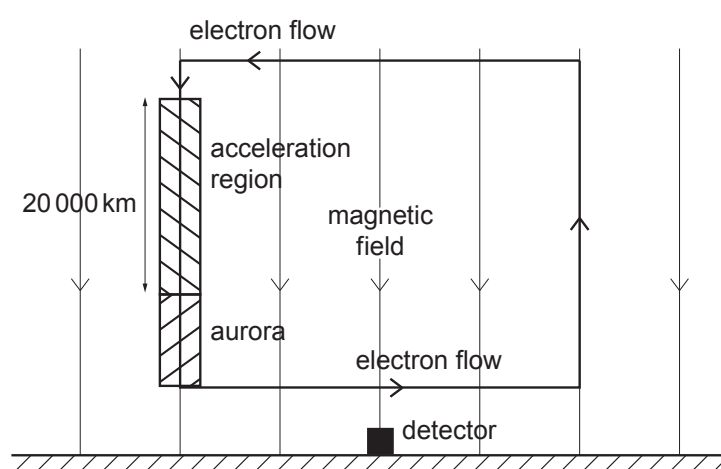
Electrons in the upper atmosphere initially move vertically downwards along one of the Earth's **magnetic** field lines. They are accelerated by an **electric** field.

These electrons collide with oxygen atoms causing atomic electrons to be excited to higher energy levels. The atomic electrons then return to lower energy levels, releasing photons of green light, red light and ultraviolet.

The accelerated electrons then travel horizontally through the atmosphere, before travelling vertically along a different magnetic field line, and then completing the circuit by travelling horizontally back to their starting point.

The situation is shown in **Fig. 1.1**.

Fig. 1.1



not to scale

- (a) The accelerated electrons are accelerated by electric fields parallel to the magnetic field lines.

The length of the acceleration region is 20 000 km and the electric field value is 0.2 mV/m . The electric field can be assumed to be uniform.

- (i) Calculate the kinetic energy gained by the electrons as they pass through the electric field, in joules.

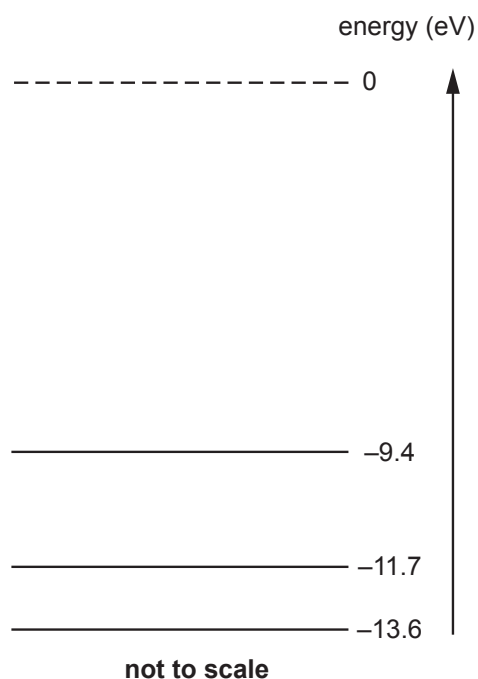
kinetic energy = ...J [3]

- (ii) State and explain the direction of the electric field required to accelerate the electrons **downwards**.

.....

 [2]

- (b) A simplified energy level diagram for atomic oxygen is shown below.



Determine the wavelength of the green light emitted.

Fully justify your answer.

wavelength = ... m [4]

- (c) The horizontal current closest to the Earth produces a magnetic field which can be detected at ground level.

With reference to **Fig. 1.1**, state and explain the direction of this magnetic field.

.....

.....

.....

..... [2]

- (d) Suggest **two** ways that the horizontal current may affect the atmosphere.

1

.....

2

..... [2]

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MARK SCHEMES

official OCR mark schemes



9	D	1	
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13	D		1	
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13	B		1	
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1	C	1	
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2	D	1	
---	---	---	--



8	B	1	
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13	A	1	
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4	C	1	
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15	B	1	
	Total	15	

8

SECTION B

General rule: For substitution into an equation, allow any subject - unless stated otherwise in the guidance

Question	Answer	Marks	Guidance
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9	D	1	
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15	C	1	
	Total	15	

9

SECTION B

General rule: For substitution into an equation, allow any subject - unless stated otherwise in the guidance

Question	Answer	Mark	Guidance
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13	C	1	
----	---	---	--



20	(a)		Correct pattern	B1	Note: At least five field lines must be drawn and of these, two must be perpendicular (by eye) to the surface of the sphere and plate
			Correct direction of the field	B1	Note: This may be shown on just one line
	(b)		(Electric potential) is the <u>work</u> done per (unit) charge in bringing a <u>positive</u> charge from infinity (to the point).	B1	Allow: <u>work</u> done / <u>energy</u> required to bring a unit <u>positive</u> charge from infinity (to the point)
	(c)	(i)	$V = Q/4\pi\epsilon_0 r$ (Allow any subject) $Q = 4\pi \times 8.85 \times 10^{-12} \times 0.015 \times 5000$ $Q = 8.3(4) \times 10^{-9} \text{ (C)}$	C1 A0	Note using $E = V/d$ with $E = Q/4\pi\epsilon_0 r^2$ is wrong physics and hence scores zero Note if the value of ϵ_0 is not given here, it could be implied in the correct 3sf answer Allow any subject here if the answer is given to more than 2sf Allow the use of $1/4\pi\epsilon_0 = 9 \times 10^9$
		(ii)1	(electric force =) $1.7 \times 10^{-2} \times \tan 4.0$ (Allow any subject) (electric force = $1.19 \times 10^{-3} \text{ N}$)	M1 (A0)	Not $1.7 \times 10^{-2} \sin 4$ or $1.7 \times 10^{-2} \cos 86$ Allow $1.7 \times 10^{-2} \times \sin 4 / \cos 4$
		(ii)2	$E = 1.2 \times 10^{-3} / 8.3(4) \times 10^{-9}$ $E = 1.4 \times 10^5 \text{ (N C}^{-1}\text{)}$	C1 A1	Allow 2 marks for $1.45 \times 10^5 \text{ (N C}^{-1}\text{)}$, 8.3×10^{-9} used Allow 2 marks for $1.43 \times 10^5 \text{ (N C}^{-1}\text{)}$, $1.19 \times 10^{-3} \text{ (N)}$ used
			Total	8	

6	(a)		$F (= EQ) = 0.90 \times 1.60 \times 10^{-19} = 1.4(4) \times 10^{-19} \text{ (N)}$	B1	Working and answer must both be shown Answer must be given to 2sf or more Unit need not be given but, if given, must be correct
	(b)	(i)	$(F = BQv \text{ but } B \text{ and } Q \text{ are constant, so})$ (the magnitude of) the velocity is different /changes	B1	Allow speed Ignore the direction is different
6	(b)	(ii)	$v = \left(\frac{F_{mag}}{BQ} \right) = \frac{5.6 \times 10^{-19}}{5.0 \times 10^{-5} \times 1.60 \times 10^{-19}}$	C1	$v = 7.0 \times 10^4 \text{ (m s}^{-1}\text{)}$ implies first C1



Question			Answer	Mark	Guidance
			resultant force $F_R = (5.6 - 1.4) \times 10^{-19}$	C1	Allow 10^{-19} for 1.4×10^{-19} (giving $F_R = 4.6 \times 10^{-19}$) $F_R = 4.2 \times 10^{-19}$ implies second C1 Do not credit if used as F_{mag} in $F_{mag} = BQv$
			$r = \left(\frac{mv^2}{F_R} \right) = \frac{1.673 \times 10^{-27} \times (7.0 \times 10^4)^2}{4.2 \times 10^{-19}}$	C1	Third C1 is for correct substitution into formula Allow $m_p = 1.67 \times 10^{-27}$ kg given to 3 s.f. Not $m_p = 1.661 \times 10^{-27}$ kg or $m_p = 1.675 \times 10^{-27}$ kg Allow ECF for incorrect v Use of $F_R = 5.6 \times 10^{-19}$ or $= 1.4 \times 10^{-19}$ is XP
			$r = 20$ (m)	A1	Allow $r = 19$ (m)
			Alternative all-in-one method:		
			$r = \frac{mF_{mag}^2}{F_R B^2 Q^2}$	(C1)	$F_R = 4.2 \times 10^{-19}$ (4.16×10^{-19} to 3sf) implies second C1 An incorrect value of F_R is XP from this point
			resultant force $F_R = (5.6 - 1.4) \times 10^{-19}$	(C1)	
			$r = \frac{1.673 \times 10^{-27} \times (5.6 \times 10^{-19})^2}{4.2 \times 10^{-19} \times (5.0 \times 10^{-5})^2 \times (1.60 \times 10^{-19})^2}$	(C1)	Third C1 is for correct substitution into formula
			$r = 20$ (m)	(A1)	Allow $r = 19$ (m)

6	(b)	(iii)1	$ \text{resultant force} = (\sqrt{3.9^2 + 1.4^2}) \times 10^{-19}$ $ \text{resultant force} = 4.1 \times 10^{-19} \text{ (N)}$	C1 A1	Ignore attempt to calculate weight of proton Allow $F_E = 10^{-19}$ Allow $ F = 4.0 \times 10^{-19} \text{ (N)}$ using $F_E = 1.0 \times 10^{-19}$ Allow $ F = 4.2 \times 10^{-19} \text{ (N)}$ using $F_E = 1.44 \times 10^{-19}$
		(iii)2	<u>resultant / net</u> force is not perpendicular to velocity work is done on proton (therefore kinetic energy changes so speed is not constant)	B1 B1	Allow direction of motion / path but not speed for velocity Allow acceleration / <u>resultant</u> force is not (always) towards centre (of circle) Allow electric force is not perpendicular to velocity / is in the same direction as velocity Ignore references to centripetal Ignore references to centripetal
			Total	10	

5	(a)	$c = f\lambda$ or $f = 3.0 \times 10^8 / 0.60$ $f = 5.0 \times 10^8$ (Hz)	C1	Allow $v = f\lambda$
			A1	Allow 5×10^8
	(b)	$a_{\max} = -\omega^2 A$ or $a_{\max} = -(2\pi f)^2 A$ $\omega = 2 \times \pi \times 5.0 \times 10^8 = 3.1(4) \times 10^9$ (rad s ⁻¹) or $10^9 \pi$ $a_{\max} (= \pi^2 \times 10^{18} \times 4.0 \times 10^{-6}) = 3.9 \times 10^{13}$ (m s ⁻²)	C1	Allow without the minus sign
			C1	ECF from (a)
			A1	Not $4.0 \times 10^{12} \pi^2$
	(c)	the current (induced in the aerial) is alternating (5×10^8 times per second) (so the meter would register zero) / AW or the diode (half-)rectifies the current / changes the current (from a.c.) to d.c. / AW	B1	Allow 'a diode only lets current pass through in one direction' AW
	(d)	see next page	B1 x 6	
		Total	12	

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Question			Answer	Marks	Guidance
5	(d)	*	Level 3 (5 - 6 marks) Response shows clear distinction between investigations; clear and correct reasoning is given for the situations which give maximum/minimum readings in <u>both</u> cases, including correct numerical values <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Response refers to both investigations; some reasoning is given for the situations which give maximum/minimum readings in <u>both</u> investigations, including some numerical values <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Limited reasons are given for the situations which give maximum/minimum readings in <u>either</u> investigation <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Indicative scientific points may include: explanation 1 - receiver aerial vertical – electrons are driven (maximum distance) up and down along the length of the aerial because the oscillations (of the electric field) are vertical, causing maximum (a.c.) current - receiver aerial horizontal – electrons are driven (minimum distance) across the aerial because the oscillations (of the electric field) are only in the vertical plane (no oscillation along the aerial to cause current), so zero / minimum current - rotation of receiver aerial by $\pm 90^\circ$ (or 90° and 270°) from vertical leads to zero current explanation 2 - reflected wave superposes with incident wave at receiver aerial - coherent waves as from same source - constructive interference/waves in phase gives max current - reflected wave has travelled $n\lambda$ further, $n = 0, 1$, etc - so max current when plate is at $\lambda/2$, $2\lambda/2$, etc from receiver aerial, i.e. 30, 60 cm - destructive interference/waves 180° (π rad) out of phase gives zero current - reflected wave has travelled $(2n + 1)\lambda/2$ further, $n = 0, 1$, etc - so zero current when plate is at $\lambda/4$, $3\lambda/4$, etc from receiver aerial, i.e. 15, 45 cm - reflected signal will be weaker the further it has to travel so no longer complete cancellation (ammeter reads close to zero) Note: Give full credit to candidates who take the 180° (π rad) phase change on reflection into account, which gives max current at 15, 45 cm etc and zero current at 30, 60 cm etc.



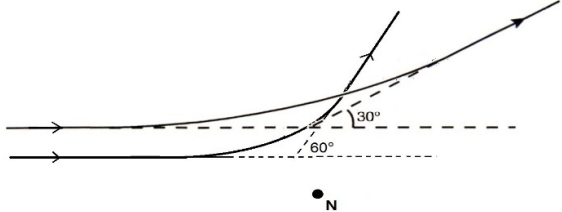
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Mark Scheme

November 2020

Question	Answer	Marks	Guidance
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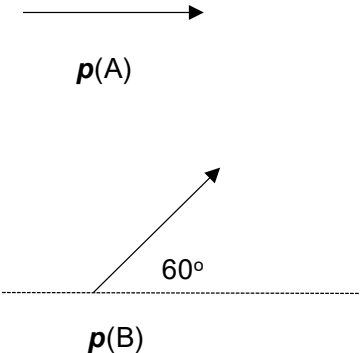
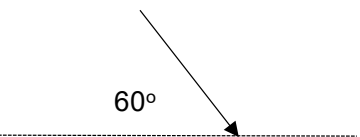


6	(a)		B1	Path is initially horizontal and further up the page than original
			B1	Path <u>ends</u> at 30° to horizontal (angle must be labelled) in the direction shown
	(b)	$Q = 79e$ and $q = 2e$ $F = (1/4\pi\epsilon_0)Qq/r^2$ $= 79 \times 2 \times (1.6 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (6.8 \times 10^{-14})^2]$ $= 7.9 \text{ (N)}$	C1 C1 C1 A1	Apply ECF for wrong charge(s), e.g. Q and/or $q = e$, or $Q = 79$ and/or $q = 2$, etc
6	(c)	(k.e. =) $E = 5.0 \times 10^6 \times 1.6 \times 10^{-19}$ $v = \sqrt{(2E/m)}$ or $= \sqrt{(2 \times 8.0 \times 10^{-13} / 6.6 \times 10^{-27})} = 1.6 \times 10^7 \text{ (ms}^{-1}\text{)}$ $p (= mv) = 6.6 \times 10^{-27} \times 1.6 \times 10^7$ giving $p = 1.1 \times 10^{-19} \text{ (kg m s}^{-1}\text{)}$	C1 C1 A1	$E = 8(.0) \times 10^{-13} \text{ J}$ or ($E = p^2/2m$ so) $p = \sqrt{(2mE)}$ Note: A value of $v = 1.6 \times 10^7 \text{ (ms}^{-1}\text{)}$ automatically scores both C1 marks even if the calculation for E is not shown or $p (= \sqrt{(2mE)}) = \sqrt{(2 \times 6.6 \times 10^{-27} \times 8.0 \times 10^{-13})}$ giving $p = 1.0 \times 10^{-19} \text{ (kg m s}^{-1}\text{)}$ Full substitution of values must be shown and answer (if calculated) must be correct

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6	(d)	(i)	Example (not to scale):  $p(A)$ 60° $p(B)$	B1	horizontal arrow (judge by eye), in the direction shown
				B1	arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown
		(ii)	Example (not to scale):  60° (Can apply principle of) conservation of momentum (since no external forces are acting)	B1	arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown
				B1	
			Total	13	



22	(a)	(i)	At least 4 equidistant parallel vertical (straight) lines With arrows pointing downwards	B1 B1	By eye Ignore field lines outside of plates At least one line must touch top and bottom plate At least one arrow, and all arrows given must be correct
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Question			Answer	Mark	Guidance
		(ii)	The top and the bottom of the clouds will not be parallel / will be uneven	B1	Allow uneven charge distribution / charge density Allow the field is non-uniform Allow the cloud is a non-uniform shape Ignore cloud has non uniform density
		(iii)	$(V = Ed) = 4.0 \times 10^5 \times 3.2 \times 10^3 = 1.3 \times 10^9 \text{ (V)}$	B1	Values of E , d with correct powers of 10 and correct evaluation must be seen to at least 2sf (1.28) Ignore unit
		(iv)	$C = \left(\frac{\epsilon_0 A}{d} \right) = \frac{8.85 \times 10^{-12} \times \pi \times (12 \times 10^3)^2}{3.2 \times 10^3}$ $C = 1.3 \times 10^{-6} \text{ (F)}$	C1 A1	All values (including ϵ_0) substituted correctly Correct evaluation to at least 2sf (1.25×10^{-6}) Note: use of $C = 4\pi\epsilon_0 R$ (leading to 1.3×10^{-6} is XP)
		(v)	$Q (= CV) = 1.25 \times 10^{-6} \times 1.28 \times 10^9$ $Q = 1600 \text{ (C)}$	C1 A1	Ecf from (a)(iii) and (a)(iv) Correct evaluation to at least 2sf Allow 2sf answer of 1700 C for 2sf values used in calculation Allow answer of 1250C for p.d. value of 1×10^9
	(b)	(i)	$V = \frac{Q}{4\pi\epsilon_0 r}$ $V = \frac{155}{(4\pi \times 8.85 \times 10^{-12} \times 2 \times 10^3)}$	C1	All values substituted correctly



Question			Answer	Mark	Guidance
			$= 7.0 \times 10^8 \text{ (V)}$	A1	Correct answer to at least 2sf (6.97)
		(ii)	Either $(I =) 155 / 25 \times 10^{-3} = (6200 \text{ A})$ $n = 6200 / 1.6 \times 10^{-19} = 3.88 \times 10^{22}$ $n \text{ (in 1ms)} = 3.88 \times 10^{22} \times 10^{-3} = 3.9 \times 10^{19}$ Or $(\text{Charge flow}) = 155/25 = (6.2 \text{ C ms}^{-1})$ $n = 6.2 / 1.6 \times 10^{-19}$ $n = 3.9 \times 10^{19}$	C1 C1 A1 (C1) (C1) (A1)	Ignore units throughout although penalise any unit on answer line Correct evaluation to at least 2sf (3.88) Correct evaluation to at least 2sf (3.88)

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1	(a)	(i)	$V (= Ed) = 0.2 \times 10^{-3} \times 20,000 \times 10^3$ or $V = 4000 \text{ (V)}$ $W (= QV) = 1.6 \times 10^{-19} \times 4000$ $6.4 \times 10^{-16} \text{ (J)}$	C1 C1 A1	Allow $F (= QE) = 1.6 \times 10^{-19} \times 0.2 \times 10^{-3}$ or $F = 3.2 \times 10^{-23} \text{ (N)}$ Allow $W (= Fd) = 3.2 \times 10^{-23} \times 20,000 \times 10^3$
1	(a)	(ii)	electrons move in opposite direction to (electric) field/conventional current (so electric field is) upwards	M1 A1	Allow electrons are negatively charged
1	(b)		$11.7 - 9.4 (= 2.3 \text{ eV})$ $\lambda = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{2.3 \times 1.6 \times 10^{-19}}$ $5.4 \times 10^{-7} \text{ (m)}$ Correct reasoning to select 540 nm - the middle wavelength (from red, green, UV) - the middle frequency - the middle photon energy - the middle-sized electron transition	C1 C1 A1 B1	Allow $13.6 - 11.7 (= 1.9 \text{ eV})$ or $13.6 - 9.4 (= 4.2 \text{ eV})$ Allow a <u>full</u> substitution with an energy level change of 9.4, 11.7 or 13.6 eV for this C1 mark only Allow an answer consistent with 1.9 eV or 4.2 eV (i.e. 296 nm or 654 nm gains 3 marks) Allow up to 4 marks for working backwards from stating wavelength of green light is ~550 nm i.e. $E = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{550 \times 10^{-9} \times 1.6 \times 10^{-19}}$ $E = 2.3 \text{ eV}$ $11.7 - 9.4 (= 2.3 \text{ eV})$

Question			Answer	Mark	Guidance
1	(c)		(conventional) current opposite to electron flow or (right) to left (magnetic field) out of the page	B1 B1	Allow annotation of figure to show circular magnetic field lines around current or arrow labelled current towards left on Fig 1.1
1	(d)		heating effect ionisation of atoms / lightning strikes	B1 B1	 Allow (ionisation causes) horizontal force / acceleration of gas (due to $F = BIL$ / motor effect)
			Total	13	