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

Electromagnetism (6.3)

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

32 questions · 160 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.

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QUESTIONS

32 questions · 160 marks · lowest tariff first



MULTIPLE-CHOICE QUESTIONS

18 questions in this booklet



- 11 An electron moves in a circle of radius 2.0 cm in a uniform magnetic field of flux density 170 mT.

What is the momentum of this electron?

- A** $3.4 \times 10^{-3} \text{ kg ms}^{-1}$
B $5.4 \times 10^{-17} \text{ kg ms}^{-1}$
C $1.4 \times 10^{-18} \text{ kg ms}^{-1}$
D $5.4 \times 10^{-22} \text{ kg ms}^{-1}$

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.

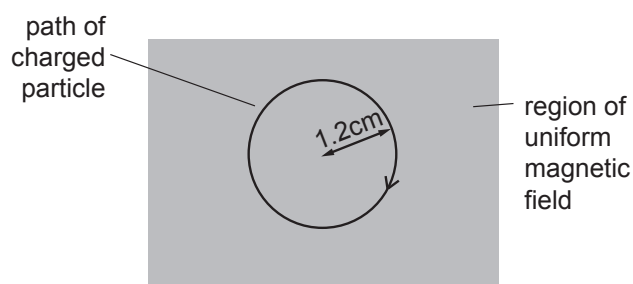
Your answer

[1]

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- 10 A charged particle moves in a circular path of radius 1.2 cm in a uniform magnetic field.



The direction of the magnetic field is perpendicular to the plane of the paper.

The particle has mass m , charge $+Q$ and speed v .

Another particle of mass $3m$, charge $+2Q$ and speed v moves in a circular path of radius R in the same magnetic field.

What is the value of R ?

- A 0.8 cm
- B 1.2 cm
- C 1.8 cm
- D 7.2 cm

Your answer

[1]

14 Which lepton is emitted in the decay of an up quark and is affected by a magnetic field?

- A** neutrino
- B** electron
- C** positron
- D** antineutrino

Your answer

[1]

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1 Which law indicates that charge is conserved?

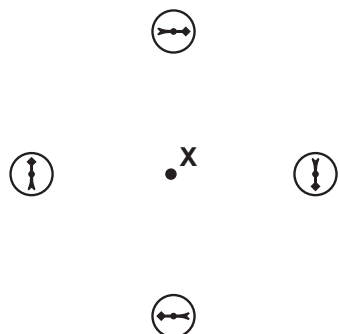
- A Lenz's law
- B Coulomb's law
- C Kirchhoff's first law
- D Faraday's law of electromagnetic induction

Your answer

[1]



- 9 The diagram shows four magnetic compasses placed at the same distance from point **X**.



Which of the following is most likely to be at point **X**?

- A** permanent magnet
- B** current-carrying solenoid
- C** current-carrying flat coil
- D** straight current-carrying wire

Your answer

[1]

- 10 A coil with 500 turns is placed in a uniform magnetic field.
The average cross-sectional area of the coil is $3.0 \times 10^{-4} \text{ m}^2$.
The magnetic flux through the plane of the coil is reduced from $1.8 \times 10^{-4} \text{ Wb}$ to zero in a time t .
The average electromotive force (e.m.f.) induced across the ends of the coil is 0.75 V .

What is the value of t ?

- A $3.6 \times 10^{-5} \text{ s}$
B $2.4 \times 10^{-4} \text{ s}$
C 0.12 s
D 8.3 s

Your answer

[1]

11. The magnetic flux through the plane of a coil is reduced from $1.8 \times 10^{-4} \text{ Wb}$ to zero in a time t . The average electromotive force (e.m.f.) induced across the ends of the coil is 0.75 V .

- 15 The number of turns on the coils of four ideal iron-cored transformers **A**, **B**, **C** and **D** are shown in the table below.

Transformer	Number of turns on the secondary coil	Number of turns on the primary coil
A	100	100
B	50	200
C	200	50
D	500	100

Each transformer is connected in turn to an alternating 240 V supply.

Which transformer will give the largest output current?

Your answer

[1]

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Turn over

SECTION B

Answer **all** the questions.



- 4 A student is doing an experiment on the magnetic force experienced by a current-carrying wire in a uniform magnetic field. The magnetic flux density B can be varied.

For a particular flux density, the current in the wire is 2.0A. The length of the wire in the field is 0.12m. The angle between the current and the magnetic field is 30° . The force experienced by the wire is $7.7 \times 10^{-2}\text{N}$.

The student calculates B and records the results in a table.

Which row shows the correct table heading for B and the correct value for B ?

	Table heading for B	Value for B
A	B/T	0.37
B	B/T	0.64
C	B/Wb	0.37
D	B/Wb	0.64

Your answer

[1]

- 1 Faraday's law of electromagnetic induction is written below with **two** terms missing.

The induced in a circuit is directly proportional to the rate of change of magnetic flux

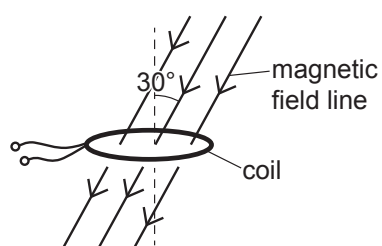
What are the **two** missing terms?

- A current, density
- B current, linkage
- C electromotive force, density
- D electromotive force, linkage

Your answer

[1]

- 12 A flat coil has 200 turns and a cross-sectional area of $1.20 \times 10^{-4} \text{ m}^2$.



The coil is placed horizontally in a uniform magnetic field. The magnetic flux density is 0.050 T . The magnetic field is at an angle of 30.0° to the vertical.

What is the magnetic flux linkage for this coil?

- A $3.00 \times 10^{-6} \text{ Wb}$
- B $5.20 \times 10^{-6} \text{ Wb}$
- C $6.00 \times 10^{-4} \text{ Wb}$
- D $1.04 \times 10^{-3} \text{ Wb}$

Your answer

[1]

- 7 A particle is moving at right angles to a uniform magnetic field of flux density B . The particle has mass m , charge q and moves in a circular arc of radius r in the region of the magnetic field.

What quantities are required to determine the momentum of this particle?

- A B , q and r
- B B , q and m
- C B , q , r and m
- D q , r and m

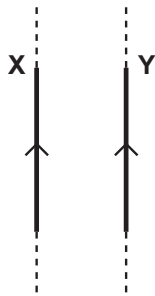
Your answer

[1]

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8 The diagram below shows two long current-carrying conductors **X** and **Y**.



The conductors are parallel to each other.
Y experiences a force because it is in the magnetic field of **X**.

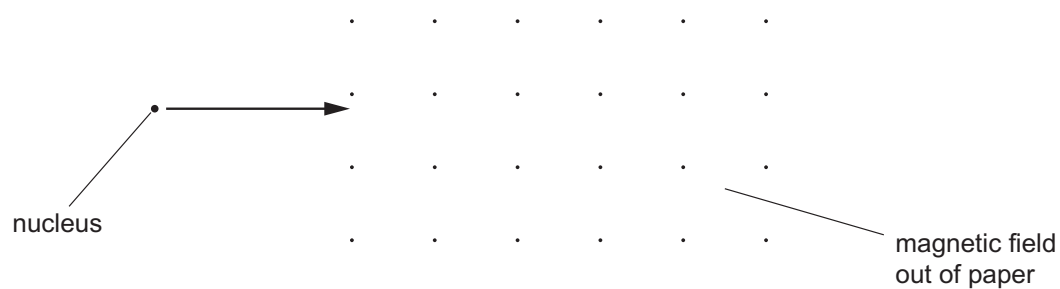
Which row gives the correct direction of the magnetic field at **Y** due to **X**, and the direction of the force experienced by **Y** due to this field?

	Direction of magnetic field	Direction of force
A	Down into the plane of paper	To the right
B	Up from the plane of paper	To the right
C	Down into the plane of paper	To the left
D	Up from the plane of paper	To the left

Your answer

[1]

- 5 The diagram shows the path of a nucleus entering a magnetic field.



In which direction does the force on the nucleus act as it enters the magnetic field?

- A down the page
- B into the page
- C out of the page
- D up the page

Your answer

[1]

- 14** A step-down transformer has an input potential difference of 200 V. There are 250 turns on the primary coil and 50 turns on the secondary coil. The secondary coil is connected to a $1.0\text{ k}\Omega$ resistor.

What is the current through the resistor?

- A** $2 \times 10^{-4}\text{ A}$
- B** 0.04 A
- C** 1 A
- D** 40 A

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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11 At the Earth's equator the magnetic flux density B is approximately $25\mu\text{T}$.

What is the magnitude of the force on an electron with velocity $v = 100\text{ km s}^{-1}$ as it is moving perpendicular to the Earth's magnetic field at the equator?

A $4.0 \times 10^{-25}\text{ N}$

B $4.0 \times 10^{-22}\text{ N}$

C $4.0 \times 10^{-19}\text{ N}$

D $4.0 \times 10^{-16}\text{ N}$

Your answer

[1]

- 11 A proton with kinetic energy $1.6 \times 10^{-17} \text{ J}$ is travelling at right angles to a magnetic field. The magnetic flux density is 0.050 T .

What is the magnitude of the force on the proton?

A $8.0 \times 10^{-19} \text{ N}$

B $1.1 \times 10^{-15} \text{ N}$

C $2.8 \times 10^{-6} \text{ N}$

D 6900 N

Your answer

[1]

12 The diagram shows a coil of wire connected to a power supply. The coil is placed in a uniform magnetic field.

6-MARK QUESTIONS

2 questions in this booklet



21 Fig. 21.1 shows a coil of a simple generator rotating in a uniform magnetic field.

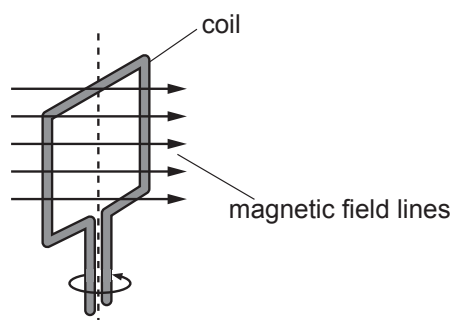


Fig. 21.1

The coil has 85 turns of insulated wire. The cross-sectional area of the coil is 14 cm^2 .

Fig. 21.2 shows the variation of magnetic flux density B through the plane of the coil with time t as it rotates.

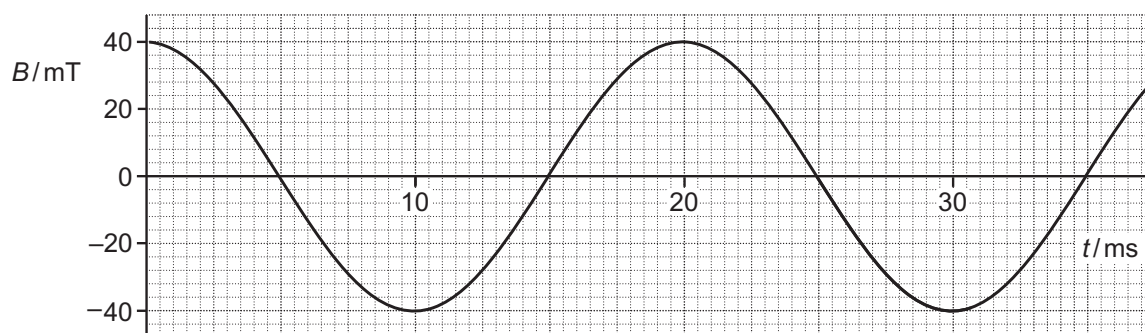


Fig. 21.2

- (a) (i) Explain why the electromotive force (e.m.f.) induced across the ends of the coil is a **maximum** at the times when $B = 0$.

.....

 [1]

- (ii) Draw a tangent to the curve in Fig. 21.2 when $B = 0$, and hence determine the **maximum** e.m.f. induced across the ends of the coil.

maximum e.m.f. = ... V [3]

- (b) Fig. 21.3 shows the variation of the e.m.f. induced across the ends of the coil with time t .

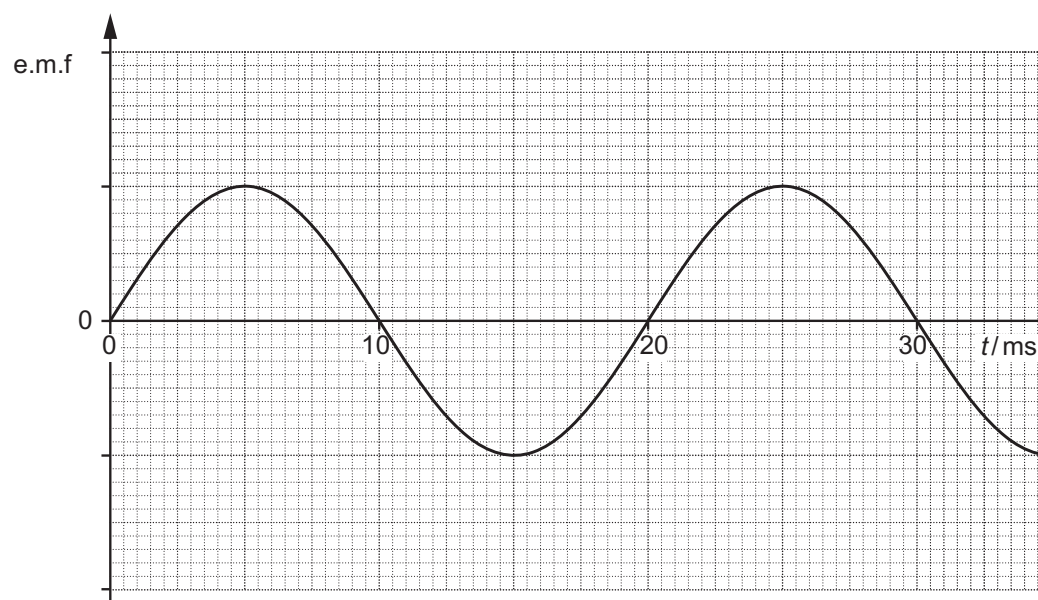
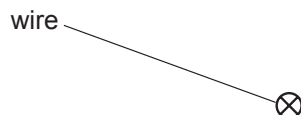


Fig. 21.3

The magnitude of the magnetic flux density of the uniform field is now halved and the coil is rotated at twice its previous frequency.

On Fig. 21.3 sketch the new variation of the e.m.f. induced with time t . [2]

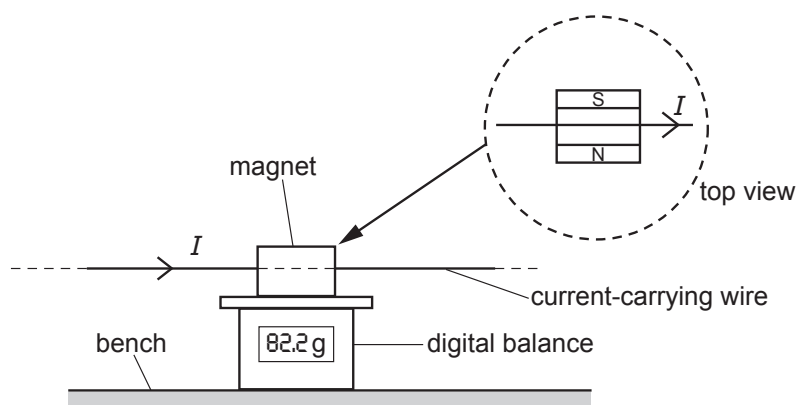
- 19 (a) The diagram below shows the top-view of a long current-carrying wire.



The direction of the current in the wire is into the plane of the paper.

Draw at least **three** field lines to indicate the magnetic field pattern around this wire. [2]

- (b) The arrangement shown in the diagram below is used to determine the magnetic flux density between the poles of a permanent magnet.



The magnet is placed on the digital balance. The current-carrying wire is horizontal and at right angles to the magnetic field between the poles of the magnet. The wire is fixed.

The following results are collected.

- length of the wire in the uniform field of the magnet = 6.0 ± 0.2 cm
- balance reading with no current in wire = 80.0 g
- balance reading with current in wire = 82.2 g
- current in wire = 5.0 ± 0.1 A

Calculate the magnetic flux density B , including the absolute uncertainty.
Ignore the absolute uncertainty in the balance readings.
Write your value for B to **2** significant figures and the absolute uncertainty to **1** significant figure.

$B = \dots\dots\dots \pm \dots\dots\dots \text{ T [4]}$

7-MARK QUESTIONS

2 questions in this booklet



20 Fig. 20 illustrates a device used to determine the relative abundance of charged rubidium ions.

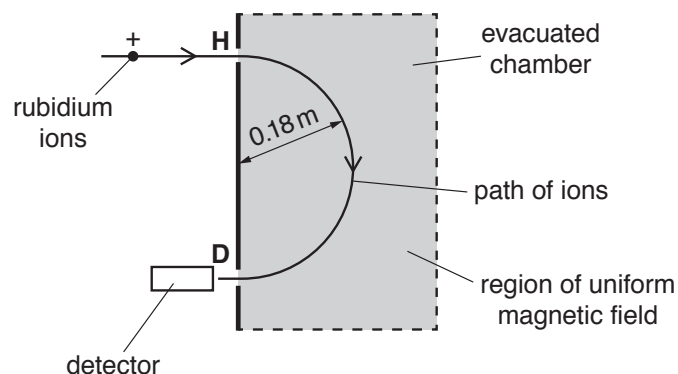


Fig. 20

A uniform magnetic field is applied to an evacuated chamber. The direction of the magnetic field is perpendicular to the plane of the paper.

A beam of positive rubidium ions enters the chamber through a hole at **H**. The ions travel in a semi-circular path in the magnetic field. The ions are detected at point **D**.

- (a) Each rubidium ion has charge $+1.6 \times 10^{-19} \text{ C}$ and speed $4.8 \times 10^4 \text{ ms}^{-1}$.
 The radius of the semi-circular path of the ions is 0.18 m .
 The mass of a rubidium ion is $1.4 \times 10^{-25} \text{ kg}$.

Calculate the magnitude of the magnetic flux density B of the magnetic field.

$B = \dots\dots\dots \text{ T [3]}$

- (b) The chemical composition of ancient rocks found on the Earth can be used to estimate the age of the Earth.

Nuclei of rubidium-87 ($^{87}_{37}\text{Rb}$) decay spontaneously into nuclei of strontium-87 ($^{87}_{38}\text{Sr}$).

The half-life of rubidium-87 is 49 billion years.

- (i) Name the two leptons emitted in the decay of a rubidium-87 nucleus.

1.

2.

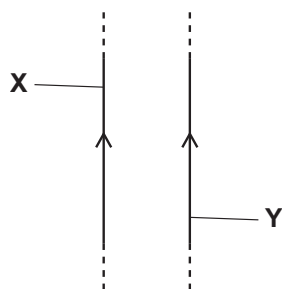
[1]

- (ii) The percentage of rubidium **left** in a sample of an ancient rock is 95%.

Estimate the age of the Earth in billion years.

age = ... billion years [3]

22 (a) The diagram below shows two long vertical current-carrying wires **X** and **Y**.



The direction of the current in each wire is the same.

Explain why wire **Y** experiences a force and deduce the direction of this force.

.....

.....

.....

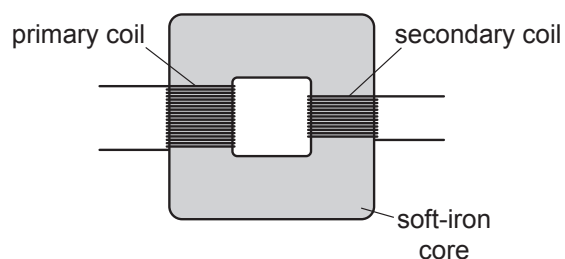
.....

..... [3]

(b) (i) State **Faraday's law of electromagnetic induction**.

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

(ii) The diagram below shows a simple transformer constructed by a student.



Describe how the student can do an experiment in the laboratory to show that the maximum electromotive force (e.m.f.) E induced in the secondary coil is directly proportional to the number of turns N on the secondary coil.

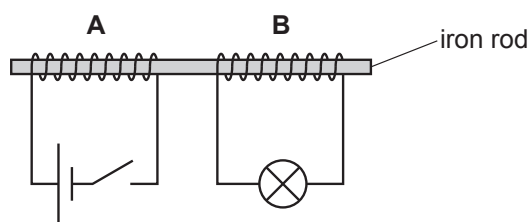
.....
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.....
.....
.....
..... [3]

10-MARK QUESTIONS

3 questions in this booklet



- 21 (a) The diagram below shows two insulated-copper coils **A** and **B** connected in circuits.



Both coils are individually wrapped around the same iron rod.

Coil **A** is connected to a cell and a switch. Coil **B** is connected to a filament lamp.

The switch is initially closed and the lamp is off.

The switch is then opened. The lamp flashes on for a brief time, and then remains off.

Explain these observations in terms of magnetic flux.

.....

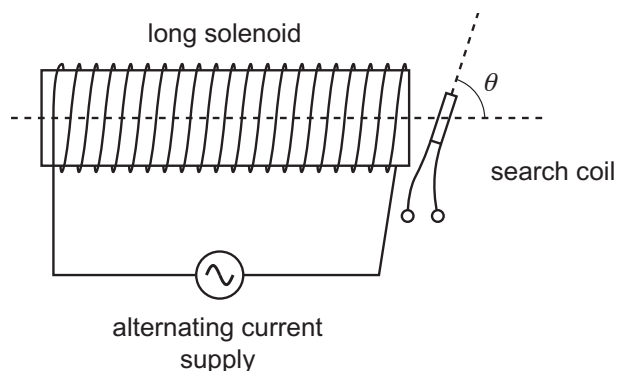
.....

.....

.....

..... [3]

- (b) A student is carrying out an experiment using a search coil.



A long solenoid is connected to an alternating current supply.

The search coil is placed at one end of the solenoid. The plane of the search coil is tilted such that it makes an angle θ with the central axis of the solenoid. The maximum alternating induced electromotive force (e.m.f.) across the ends of the search coil is E_0 .

- (i) Name an instrument that can be used to determine E_0 .

..... [1]

(ii) The equation for E_0 is:

$$E_0 = KI_0 ANf \sin \theta$$

where I_0 = maximum current in the solenoid, A = cross-sectional area of the search coil, N = number of turns of the search coil, f = frequency of the alternating current in the solenoid and $K = 4.0 \times 10^{-3} \text{ VA}^{-1} \text{ m}^{-2} \text{ s}$.

The magnitude of the induced e.m.f. in the search coil can be determined using Faraday's law of electromagnetic induction:

e.m.f. = rate of change of magnetic flux linkage

In the experiment, angle θ is changed and E_0 measured.

Suggest the quantity, or quantities, in the equation $E_0 = KI_0 ANf \sin \theta$ linked to

1 the 'rate' part of the law

..... [1]

2 the 'change of magnetic flux linkage' part of the law.

..... [1]

(iii) The student plots a straight-line graph of E_0 against $\sin \theta$.

Determine f , including the absolute uncertainty. Write your value of f to **2** significant figures.

$$I_0 = (8.0 \pm 0.2) \text{ A}$$

$$A = (7.8 \pm 0.1) \times 10^{-5} \text{ m}^2$$

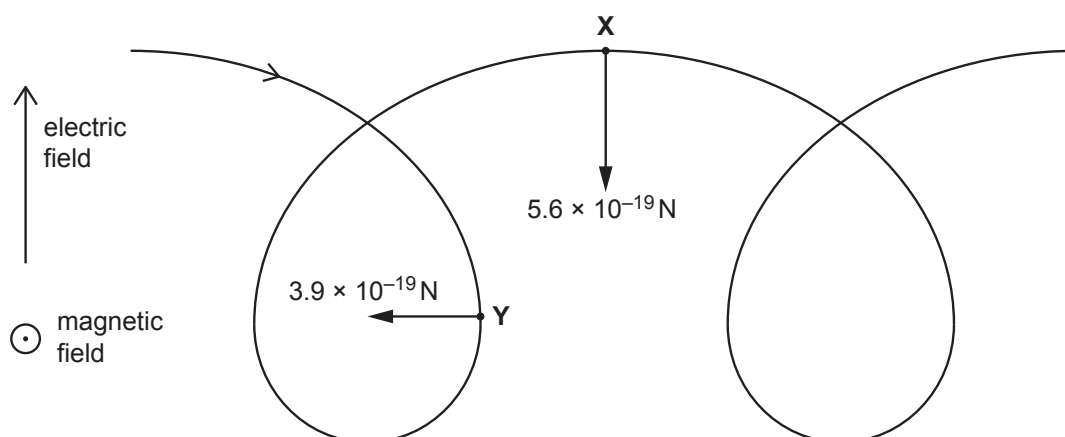
$$N = 5000$$

$$\text{gradient of line} = KI_0 ANf = (0.62 \pm 0.03) \text{ V}$$

$$f = \dots \pm \dots \text{ Hz [4]}$$

- 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**.

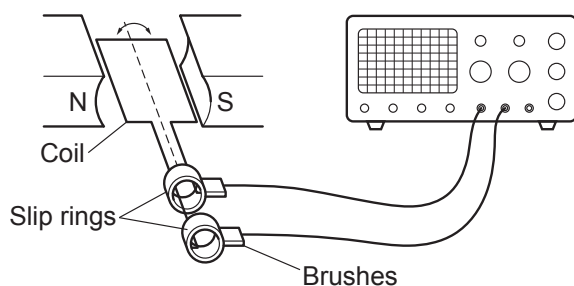
resultant force = ... N [2]

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

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

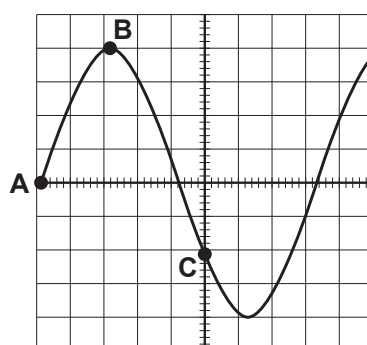


- 21 The diagram shows a simple a.c. generator connected to an oscilloscope (CRO).

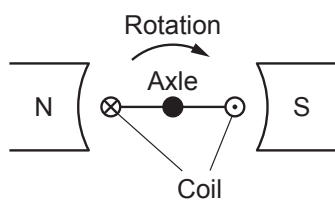


Students turn the coil at a steady rate and an a.c. signal is displayed on the oscilloscope screen, as shown in **Fig. 21.1**.

Fig. 21.1



- (a) Which position on the signal, **A**, **B** or **C**, corresponds to the generator position shown below?



view from end of coil

Tick **one** box.

A	☐
B	☐
C	☐

[1]

- (b) Draw on **Fig. 21.1** to show how the signal would change if the coil is rotated at a steady, faster rate.

[2]

- (c) The coil is rotated 45° clockwise from the position shown in (a) in a time of 0.13 s.
 The magnetic field between the poles of the magnet is uniform and is 25 mT.
 The coil has 120 turns.
 The coil is 8.0×10^{-2} m long and 4.0×10^{-2} m wide.

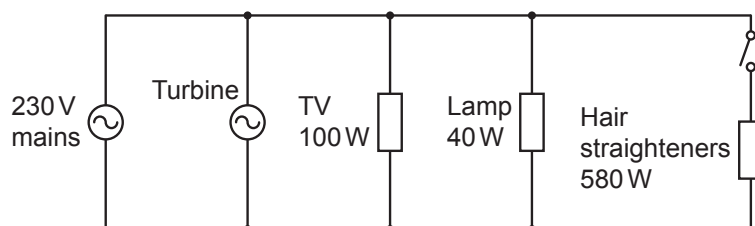
- (i) Calculate the change in flux linkage.

Change in flux linkage = ... Wb [2]

- (ii) Calculate the average induced electromotive force (e.m.f.) $\mathcal{E}$ across the contacts of the coil.

$\mathcal{E}$ = ... V [2]

- (d) A larger generator is used in a wind turbine to supply electricity to a house. The house is also connected to the 230 V mains supply.



The TV and lamp are switched on.

When the turbine is providing a steady 400 W, the hair straighteners are switched on.

Calculate the current, I , drawn from the mains supply.

I = ... A [2]

- (e) State the unit used to measure the electrical energy supplied to homes in the UK.

..... [1]

11-MARK QUESTIONS

1 question in this booklet



24 (a) Fig. 24 shows two horizontal metal plates in a vacuum.

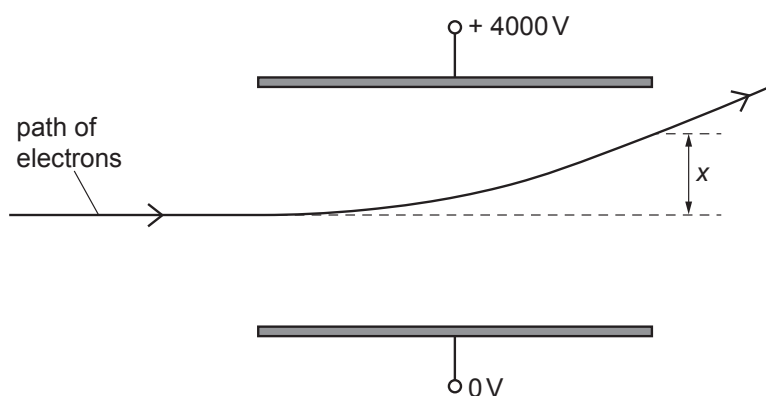


Fig. 24

The diagram is **not** drawn to scale.

Electrons travelling horizontally enter the space between the charged plates and are deflected vertically.

The potential difference between the plates is 4000 V.

The distance between the plates is 0.08 m.

The initial speed of the electrons is $6.0 \times 10^7 \text{ m s}^{-1}$.

The vertical deflection of the electrons at the far end of the plates is x .

(i) Show that the vertical acceleration a of an electron between the plates is $8.8 \times 10^{15} \text{ m s}^{-2}$.

[3]

(ii) The length of each plate is 0.12 m.

Show that the time t taken by the electron to travel this length is $2.0 \times 10^{-9} \text{ s}$.

[1]

(iii) Calculate the vertical deflection x of the electron.

$x = \dots\dots\dots$ m [2]

(b) The arrangement shown in **Fig. 24** is now used to investigate positrons emitted from a radioactive source.

The speed of the positrons is also $6.0 \times 10^7 \text{ ms}^{-1}$.

The initial path of the positrons is the same as that of the electrons in **Fig. 24**.

On **Fig. 24**, sketch the path of the positrons between the plates. [2]

(c) Beta-minus particles (electrons) emitted from a radioactive source have a range of speeds.

Describe and explain how a uniform magnetic field can be applied in the space between the charged plates to select beta-minus particles with a specific speed. No calculations are required.

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..... [3]

12-MARK QUESTIONS

3 questions in this booklet



- 2 A small thin rectangular slice of semiconducting material has width a and thickness b and carries a current I . The current is due to the movement of electrons. Each electron has charge $-e$ and mean drift velocity v . A uniform magnetic field of flux density B is perpendicular to the direction of the current and the top face of the slice as shown in Fig. 2.1.

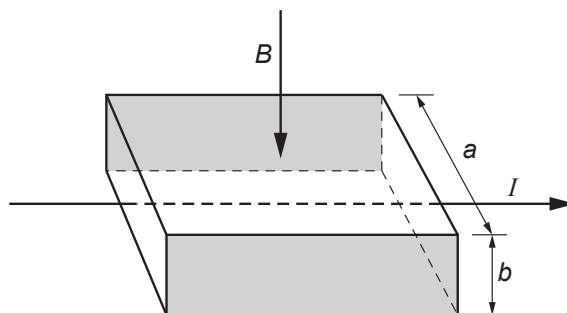


Fig. 2.1

- (a) As soon as the current is switched on, the moving electrons in the current are forced towards the shaded rear face of the slice where they are stored. This causes the shaded faces to act like charged parallel plates. Each electron in the current now experiences both electric and magnetic forces. The resultant force on each electron is now zero.

Write the expressions for the electric and magnetic forces acting on each electron and use these to show that the magnitude of the potential difference V between the shaded faces is given by

$$V = Bva.$$

[3]

(b) Here are some data for the slice in a particular experiment.

number of conducting electrons per cubic metre, $n = 1.2 \times 10^{23} \text{ m}^{-3}$

$a = 5.0 \text{ mm}$

$b = 0.20 \text{ mm}$

$I = 60 \text{ mA}$

$B = 0.080 \text{ T}$

Use this data to calculate

(i) the mean drift velocity v of electrons within the semiconductor

$v = \dots\dots\dots \text{ ms}^{-1}$ **[3]**

(ii) the potential difference V between the shaded faces of the slice.

$V = \dots\dots\dots \text{ V}$ **[1]**

- (c) The slice is mounted and used as a measuring instrument called a Hall probe. A cell is connected to provide the current in the slice. The potential difference across the slice is measured by a separate voltmeter.

A student wants to measure the magnetic flux density between the poles of two magnets mounted on a steel yoke as shown in Fig. 2.2. The magnitude of the flux density is between 0.02 T and 0.04 T.

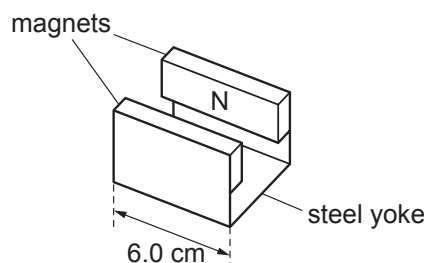


Fig. 2.2

- (i) Suggest **one** reason why this Hall probe is **not** a suitable instrument to measure the magnetic flux density for the arrangement shown in Fig. 2.2.

.....

 [1]

- (ii) Another method of measuring the magnetic flux density for the arrangement shown in Fig. 2.2 is to insert a current-carrying wire between the poles of the magnet. Explain how the magnetic flux density can be determined using this method and discuss which measurement in the experiment leads to the greatest uncertainty in the value for the magnetic flux density.

.....

 [4]

- 4 This question is about an electric cooker, which consists of an oven and an electromagnetic induction hob.

*(a) The oven is not sealed, so the air inside remains at atmospheric pressure of $1.0 \times 10^5 \text{ Pa}$. The volume of the oven is 0.065 m^3 . The air inside the oven behaves as an ideal gas.

The temperature of the oven increases from room temperature to 200°C .

Show that the internal energy of the air in the oven is the same at **all** temperatures of the oven. Support your answer with an explanation of the motion of the air molecules in terms of kinetic theory. [6]

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Additional answer space if required

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Question 4 continues on page 12

(b) The electromagnetic induction hob is shown in **Fig. 4.1**.

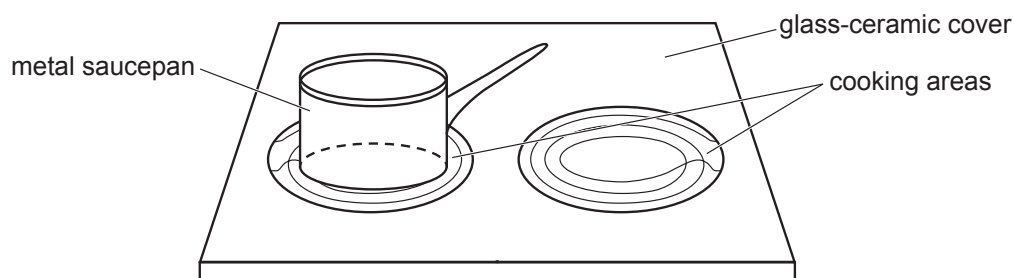


Fig. 4.1

Each cooking area has a coil below the glass-ceramic cover. When switched on, the coils carry a high-frequency **alternating** current.

A metal saucepan is placed above one of the coils. A large alternating current is induced in the saucepan base, and this causes the saucepan to heat up.

(i) **Fig. 4.2** shows one of the coils at a time when the current is in the direction indicated by the arrows.

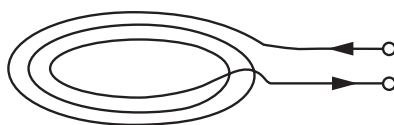


Fig. 4.2

On **Fig. 4.2**, sketch the magnetic field pattern for the current-carrying coil.

[2]

- (ii) Fig. 4.3 shows the path of the large alternating current induced in the metal base of the saucepan.

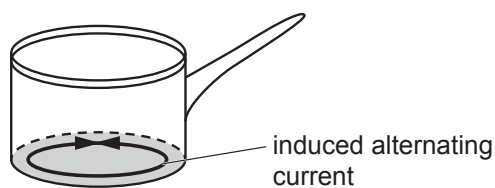


Fig. 4.3

Explain the origin of this large current.

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..... [2]

- (iii) Explain why it would be safe for a person to place a hand on the cooking area before the saucepan is put onto it.

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3 This question is about comparing two methods for storing energy.

(a) A proposed method for storing energy uses trucks powered by electric motors.

The trucks carry sand up a mountain, storing surplus energy as gravitational potential energy.

When the energy needs to be released, they carry the sand back down the mountain, converting the gravitational potential energy into chemical energy stored in a battery.

Explain how an electrical generator in the truck could use **electromagnetic induction** to convert gravitational potential energy into chemical energy stored in a battery.

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..... [3]

(b) A second proposed method for storing energy uses a tank of wax.

The wax is heated using an electrical heater, storing surplus energy as internal energy of the wax. The wax increases in temperature and melts as it is heated.

When the energy needs to be released, the wax is allowed to cool, converting the internal energy of the wax into thermal energy.

Explain, in terms of the particles in the wax, how energy is stored when it is heated.

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..... [3]

(c)* A gravitational potential energy storage system, as described in (a), is proposed as follows:

- height of mountain = 1 km
- overall efficiency = 70 %

A thermal energy storage system, as described in (b), is proposed as follows:

- lower operating temperature = 18 °C
- melting point of wax = 51 °C
- upper operating temperature = 70 °C
- specific heat capacity of solid wax = $2.6 \text{ kJ kg}^{-1} \text{ K}^{-1}$

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- specific heat capacity of liquid wax = $3.0 \text{ kJ kg}^{-1} \text{ K}^{-1}$
- specific latent heat of fusion of wax = 160 kJ kg^{-1}
- overall efficiency = 95 %

Estimate the energy that can be stored by each system using 1 kg of sand or wax.

Discuss which system would be more appropriate for storing surplus electrical energy. Your answer should include an estimate of the energy that can be stored in each system using 1 kg of sand or wax.

Ignore any financial factors.

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Additional answer space if required

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13-MARK QUESTIONS

3 questions in this booklet



- 22 (a)*** A student conducts an experiment to confirm that the uniform magnetic flux density B between the poles of a magnet is 30 mT.

A current-carrying wire of length 5.0 cm is placed perpendicular to the magnetic field.

The current I in the wire is changed and the force F experienced by the wire is measured. Fig. 22.1 shows the graph plotted by the student.

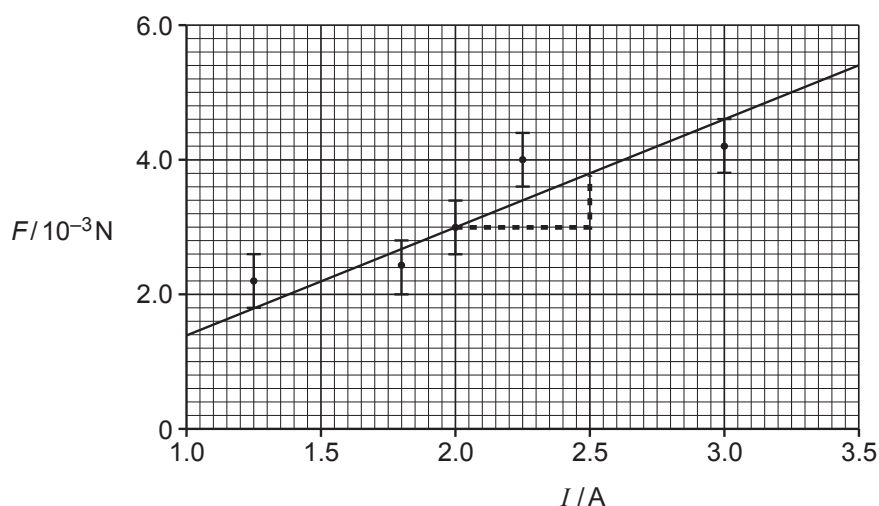


Fig. 22.1

The student's analysis is shown on the graph of Fig. 22.1 and in the space below.

$$F = BIL$$

$$\text{gradient} = BL = \frac{(3.8 - 3.0) \times 10^{-3}}{2.5 - 2.0} = 0.0016$$

$$B = \frac{0.0016}{0.05} = 0.032 \text{ T} = 32 \text{ mT}$$

This is just 2 mT out from the 30 mT value given by the manufacturer, so the experiment is very accurate.

Evaluate the information from Fig. 22.1 and the analysis of the data from the experiment. No further calculations are necessary.

[6]

[6]

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Turn over



(b) Fig. 22.2 shows a transformer circuit.

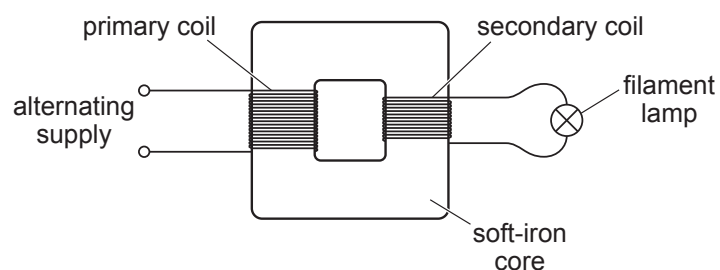


Fig. 22.2

The primary coil is connected to an alternating voltage supply. A filament lamp is connected to the output of the secondary coil.

(i) Use Faraday's law of electromagnetic induction to explain why the filament lamp is lit.

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..... [3]

- (ii) The primary coil has 400 turns and the secondary coil has 20 turns. The potential difference across the lamp is 12 V and it dissipates 24 W. The transformer is 100% efficient.

1. Calculate the current in the primary coil.

current = ... A [2]

2. The alternating voltage supply is replaced by a battery and an open switch in series. The switch is closed. The lamp is lit for a short period of time and then remains off. Explain this observation.

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..... [2]

18*

- (a) Describe how an experiment can be conducted to determine how the output current of a step-up transformer depends on the number of turns on the secondary coil.

Explain how the data collected can be analysed to establish the relationship between the output current and the number of turns on the secondary coil.

You are provided with wire and a suitable core on which to wind the wire, as well as any other normal laboratory equipment.

Use the space below to draw a labelled circuit diagram.

[6]

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Additional space if required

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- (b) A simple laminated iron-core transformer takes mains voltage 230 V, 50 Hz into the primary coil. The output voltage from the secondary coil is 5.0 V. The primary coil has 920 turns.

- (i) State *Faraday's law*.

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..... [1]

- (ii) Show that the number of turns on the secondary coil is 20.

[2]

- (iii) At one particular instant, the output voltage from the transformer is 3.4 V.

Calculate the change in magnetic flux experienced by the secondary coil in a short time interval of 1.2 ms and state its unit.

Assume that the output voltage from the transformer remains constant at 3.4 V over this time interval.

$\Delta\Phi =$ unit [4]



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

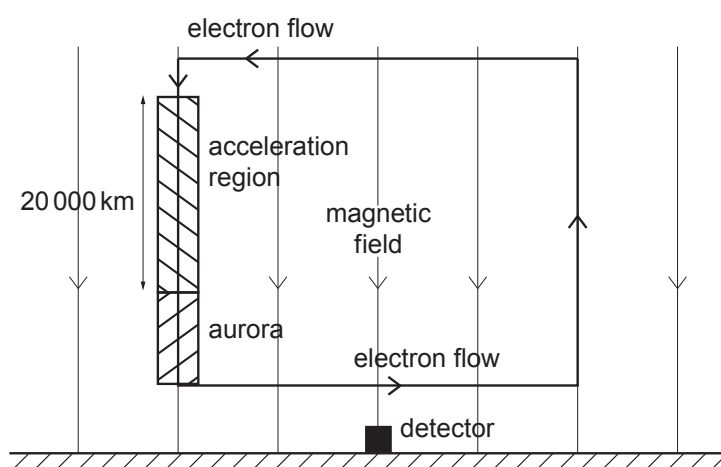
Electrons in the upper atmosphere initially move vertically downwards along one of the Earth's **magnetic** field lines. They are accelerated by an **electric** field.

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.

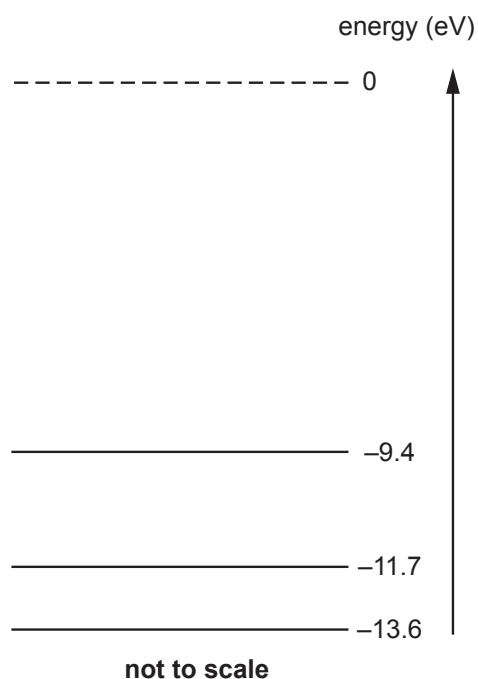
kinetic energy = ...J [3]

- (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.

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..... [2]

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

1

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2

..... [2]

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MARK SCHEMES

official OCR mark schemes



11	D	1	
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13	D	1	
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10	C		1	
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14	C		1	
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1	C	1	
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9	D	1	
---	---	---	--



10	C	1	
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15	B	1	
	Total	15	

4

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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4	B	1	
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1	D	1	
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12	D	1	
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7	A		1	
---	---	--	---	--



8	C		1	
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5	A	1	
---	---	---	--



14	B	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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11	C	1	
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11	B	1	
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21	(a)	(i)	The gradient is maximum / maximum rate of change of B / maximum rate of change of flux (linkage)	B1	Allow slope instead of gradient
		(ii)	Tangent drawn to curve at $B = 0$ gradient = 12.5 (maximum e.m.f. = $12.5 \times 14 \times 10^{-4} \times 85$) maximum e.m.f. = 1.5 (V)	C1 C1 A1	Allow 11.70 to 13.30; no need to check calculation Allow fraction if calculated value is within the range Allow ECF from the gradient value if value is outside the range Alternative: $E = BAN\omega$ $E = 40 \times 10^{-3} \times 14 \times 10^{-4} \times 85 \times 2\pi \times 50$ maximum e.m.f. = 1.5 (V) C1 C1 A1
	(b)		Sinusoidal curve with the same peak e.m.f. Sinusoidal curve with half period	B1 B1	Note curve must show at least half a period Allow ± 1 small square for e.m.f. Ignore phase Note graph must show at least half a period Allow ± 1 small square for t
			Total	6	

Question	Answer	Marks	Guidance
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19	(a)	Direction of field shown as clockwise <u>Three</u> field lines shown as concentric circles and distance between adjacent field lines increasing as distance from wire increases	B1 B1	Expect at least one field line with an arrow Allow more than three lines, but distance between adjacent field lines increasing distance from wire must increase for all
	(b)	(force =) $2.2 \times 10^{-3} \times 9.81$ $2.2 \times 10^{-3} \times 9.81 = B \times 5.0 \times 0.060 (= 0.072 \text{ T})$ (absolute uncertainty =) $\frac{0.2}{6.0} + \frac{0.1}{5.0} \quad (\times 0.072 = 0.0038 \text{ T})$ $B = 0.072 \pm 0.004$	C1 C1 C1 A1	Allow calculation of percentage uncertainty = 5.3% Allow calculation of max B (=0.0759 T) and min B (=0.0683 T) Note B must be given to 2 SF and the uncertainty given to 1 SF. Special case: allow follow through from incorrect B calculation.
		Total	6	

20	(a)		$F = BQv$ and $F = mv^2/r$ or $B = mv/Qr$ (Any subject) $(B =) \frac{1.4 \times 10^{-25} \times 4.8 \times 10^4}{1.6 \times 10^{-19} \times 0.18}$ $B = 0.23$ (T)	C1 C1 A1	Allow e
	(b)	(i)	Electron and (electron) antineutrino	B1	Allow beta-minus (particle) / β^- ; $\bar{\nu}_{(e)}$ Allow anti electron neutrino
		(ii)	$\lambda = \ln 2/49$ or $\lambda = 0.0141$ (billion y^{-1}) $0.95 = e^{-0.0141t}$ or $0.95 = e^{-4.48 \times 10^{-19}t}$ (age = $-\ln(0.95)/0.0141$) age = 3.6 (billion years)	C1 C1 A1	Allow $\frac{\ln 2}{49 \times 10^9 \times 3.16 \times 10^7}$ or $4.48 \times 10^{-19} \text{ (s}^{-1}\text{)}$ Allow both C1 marks for $\ln(0.95) = \ln(0.5) \times t/49$ Allow $0.05/0.0141 \approx t$ (this gives 3.5.. for the final mark) Note age in seconds is 1.15×10^{17} (s); this will score 2 marks
			Total	7	

22	(a)		Magnetic <u>field</u> (around current-carrying wire) (Fleming's) left-hand rule mentioned (Magnetic) field into page, (current is up the page) and force is to the left / towards X	B1 B1 B1	Not magnetic force Allow 'field into page and wires attract' Note the field direction and force direction can be shown on the figure
	(b)	(i)	(induced) e.m.f. is (directly) proportional / equal to the rate of change of (magnetic) flux linkage	B1	Not current Allow 'rate of cutting' for 'rate of change'
		(ii)	Connect the primary (coil) to an alternating voltage / current Oscilloscope connected across secondary coil / to measure E A graph of E against N will be a straight line through the origin.	B1 B1 B1	Allow AC (can be on the figure) Not changing / variable for alternating Allow voltmeter (can be on the figure) Allow p.d. / voltage for e.m.f. / E throughout Ignore any component (e.g. lamp or resistor) connected across the secondary coil Allow $(E \div N) = \text{constant}$
			Total	7	

21	(a)		When switch is opened, there is (rate of) change in (magnetic) flux (linkage) which induces an emf / current as the (magnetic) flux links to B which causes the lamp to light (Lamp off) at start / end there is constant flux / no change in (magnetic) flux (linkage for coil B)	B1 B1 B1	Not just a statement of Faraday's law Allow flux is cut by B
	(b)	(i)	Oscilloscope / CRO	B1	Allow a.c. voltmeter Ignore datalogger / multimeter
		(ii)1	f	B1	Not any other symbol. Only mark quantity letters – ignore any words, but allow frequency.
		(ii)2	θ or $\sin \theta$	B1	Allow θ or $\sin \theta$ with any or all of K , I_0 , A , N . Only mark quantity letters – ignore any words.
		(iii)	$f = \frac{0.62}{5000 \times 4.0 \times 10^{-3} \times 8.0 \times 7.8 \times 10^{-5}} \quad / \quad f = 49.67 \dots \text{ (Hz)}$ $\frac{0.2}{8.0} \quad / \quad \frac{0.1}{7.8} \quad / \quad \frac{0.03}{0.62}$ $\text{abs uncertainty} = \left(\frac{0.2}{8.0} + \frac{0.1}{7.8} + \frac{0.03}{0.62} \right) \times 49.67 \dots \quad / \quad 4.28 \dots \text{ (Hz)}$ $f = 50 \pm 4 \text{ (Hz)}$	C1 C1 C1 A1	Any individual raw uncertainty Max value = 54.11 (Hz) and min value = 45.54 (Hz) for f Allow 8.6% as evidence of this calculation For min / max method: difference / 2 = 4.29 (Hz) Allow ecf on abs uncertainty from incorrect f Any ecf on f must be given to 2sf and uncertainty sf consistent. Not the paper SF penalty
			Total	10	

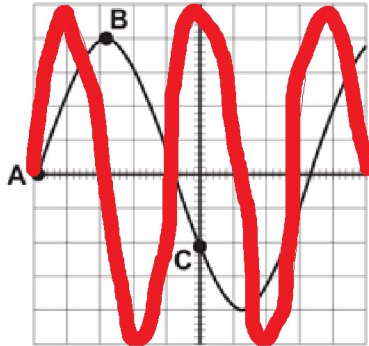


6	(a)		$F (= EQ) = 0.90 \times 1.60 \times 10^{-19} = 1.4(4) \times 10^{-19} \text{ (N)}$	B1	Working and answer must both be shown Answer must be given to 2sf or more Unit need not be given but, if given, must be correct
	(b)	(i)	$(F = BQv \text{ but } B \text{ and } Q \text{ are constant, so})$ (the 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	

21	(a)	B	A1	
21	(b)	Amplitude drawn is larger Time period drawn is smaller	B1 B1	At least one complete cycle needs to be drawn for any credit Consider all cycles drawn. All peaks must be greater than amplitude of given wave and consistent within $\frac{1}{2}$ square of each other For T, only mark first complete cycle – do not insist on symmetry but such that the end of the first cycle is less than or equal to 8 squares e.g. 

Question	Answer	Mark	Guidance
21	(c) (i)	$\Phi = BA \cos \theta = 25 \times 10^{-3} \times (8.0 \times 10^{-2} \times 4.0 \times 10^{-2}) \times \cos 45 (= 5.66 \times 10^{-5} \text{ Wb})$ Change in flux linkage = $N \Phi = 120 \times 5.66 \times 10^{-5}$ $= 6.8 \times 10^{-3} \text{ (Wb)}$	C1 A1 Correct to at least 2 significant figures (6.79×10^{-3}) IGNORE sign
21	(c) (ii)	Induced emf ($E = - \Delta \Phi / \Delta t$) = (-) 0.0068 / 0.13 $\mathcal{E} = (-) 0.052 \text{ (V)}$	C1 A1 Correct to at least 2 significant figures IGNORE sign
21	(d)	Total power requirement = $580 + 40 + 100 = 720 \text{ W}$ Power required from mains = $720 - 400 = 320 \text{ (W)}$ Mains current drawn = $(P / V) = 320 / 230$ $= 1.4 \text{ (A)}$	C1 A1 ALLOW other methods e.g. total current required = $(40 + 100 + 580) / 230 = 3.13 \text{ (A)}$ Current supplied by mains = current required - current from turbine = $3.13 - (400/230) = 1.4 \text{ (A)}$ Correct to at least 2 significant figures

Question		Answer	Mark	Guidance
21	(e)	kWh or kilowatt-hour	B1	IGNORE case of letters

24	(a)	(i)	$(E =) \frac{4000}{0.080}$ $(F =) \frac{4000}{0.080} \times 1.6 \times 10^{-19}$ $(a =) \frac{8.0 \times 10^{-15}}{9.11 \times 10^{-31}} \quad \text{or} \quad 8.78 \times 10^{15}$ $a = 8.8 \times 10^{15}$	C1 C1 C1 A0	$E = 5.0 \times 10^4 \text{ (V m}^{-1}\text{)}$ $F = 8.0 \times 10^{-15} \text{ (N)}$ Allow this mark if the working is shown. If only value is given, then the answer must be 3SF or more
		(ii)	$(t =) \frac{0.12}{6.0 \times 10^7}$ $(t = 2.0 \times 10^{-9} \text{ s})$	M1 A0	
		(iii)	$(x =) \frac{1}{2} \times 8.78 \times 10^{15} \times (2.0 \times 10^{-9})^2$ $x = 1.8 \times 10^{-2} \text{ (m)}$	C1 A1	Allow $a = 8.8 \times 10^{15}$
	(b)		Downward curved path Same x	B1 B1	Ignore any line outside of the plates Expect same x by eye
	(c)		Apply a magnetic field at right angles to electric field electric force = magnetic force No resultant vertical force, so only beta-particles with a specific speed will travel horizontally	B1 B1 B1	Note this mark is for the idea that E and B are <u>perpendicular</u> even if direction of B is incorrect Allow 'apply horizontal magnetic field' Allow $Eq = Bqv$ Allow $v = E/B$ in this arrangement
			Total	11	

Question	Answer	Mark	Guidance
2	() F = Bev and F = eE E = V/a or F = (eE) = eV/a Bev = eV/a giving V = Bva	B1 B1 B1	allow Q or q for e
	(b) (i) $I = nAev$; $v = 60 \times 10^{-3} / 1.2 \times 10^{23} \times 1.6 \times 10^{-19} \times 5.0 \times 0.2 \times 10^{-6}$ $v = 3.1 \text{ (m s}^{-1}\text{)}$	C1 C1 A1	allow any subject
	(ii) $V = 80 \times 10^{-3} \times 3.1 \times 5.0 \times 10^{-3} = 1.2 \times 10^{-3} \text{ (V)}$	A1	ecf (b)(i); allow 1.2 mV; $1.3 \times 10^{-3} \text{ (V)}$
	(c) (i) Hall probe only compares B-fields/AW or V will be too small/less than 1 mV so not easy to measure	B1	allow any sensible comment, e.g. how do you convert the measured V into a B value
	(ii) find B using $F = BIl$; F is measured by weighing magnets (e.g. placed on top pan balance assuming wire is fixed); graph of F against I to find B(I) from gradient/AW; greatest uncertainty: measurement of I in B-field sensible reason/justification for choosing I or small masses	B1 B1 B1 B1 B1	max 4 of the 5 marking points alt measure F by adding small masses to wire to return it to zero current position or use readings of F at several I to find average F/I, etc. or measurement of small masses in alt. method, etc quantitative suggestion about % error i.e. I small (1 mm in 60) leading to large % uncertainty or difficulty in determining edge/end of B-field
	Total	12	

H556/03

Mark Scheme

June 2017

Question	Answer	Marks	Guidance
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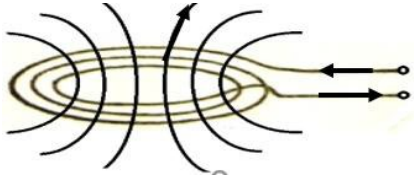


4	(a)	*	Level 3 (5 - 6 marks) Clear explanation using kinetic theory ideas and either a clear proof using formulae or a correct calculation <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) A partial explanation using kinetic theory ideas and either a partial proof using formulae or a partial calculation <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) An attempt at either explanation or proof or calculation <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 Indicative scientific points may include: Explanation using kinetic theory • pressure = force/area • force is caused by air molecules colliding with oven walls • Newton's 2nd Law states force = rate of momentum change • increased temperature means each molecule has greater KE • hence greater velocity and hence greater momentum • and more collisions with walls per second • hence greater rate of momentum change on hitting walls. • This would lead to greater pressure if N remained constant • so number of molecules in oven must decrease (air escapes) • so fewer but 'harder' collisions at higher temperatures giving constant pressure. • Rms velocity c increases with temperature but number N decreases and so effects balance out to keep total KE ($\frac{1}{2}Nmc^2$) constant Proof using formulae • equate $pV = NkT$ and $E = \frac{3}{2}NkT$ to show $E = \frac{3}{2}pV$ • in an ideal gas, all internal energy E is kinetic energy • so E is independent of temperature Calculation • Internal energy = $\frac{3}{2}pV = 1.5 \times 0.065 \times 1.0 \times 10^5 = 9.8 \text{ kJ}$ • At $T = 293\text{K}$, $N = pV/kT = 1.6 \times 10^{24}$ and $n = 2.7$ moles • At $T = 473\text{K}$, $N = 1.0 \times 10^{24}$ and $n = 1.7$ moles • so we can show that NT (and/or nT) remain constant
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H556/03

Mark Scheme

October 2021

Question			Answer	Marks	Guidance
4	(b)	(i)		B1	One correct line (or dot and cross) drawn Line must go through centre of coil Allow an incomplete line or a complete circle round the coil Ignore direction of arrow
				B1	More than one line drawn All lines drawn must go through centre of coil and follow correct shape and <u>direction</u> of field Ignore spacing of lines Ignore any lines to the right of the coil
		(ii)	• (the magnetic) flux (of the coil) links the <u>base</u> / <u>saucepan</u> • (the size/direction of) the flux linkage (constantly) <u>changes/alternates</u> (causing an alternating induced e.m.f.) • (induced) <u>current</u> is large because metal/base/ saucepan has low resistance	B1 x 2	2 out of 3 possible marking points Allow (the magnetic) field lines cut the (base of the) <u>saucepan</u> Allow the (magnetic) field constantly changes/alternates Allow a bald statement of Faraday's Law
		(iii)	The resistance of glass-ceramic/the (cook's) hand is (very) large So (induced) <u>current</u> (or heating effect of <u>current</u>) is zero/negligible	M1 A1	Allow glass-ceramic/hand is an insulator/not a (good) conductor Do not allow the induced <u>e.m.f.</u> is (very) small
Total				12	

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H556/03

Mark Scheme

October 2021

Question	Answer	Marks	Guidance
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3	(a)	(motion of truck) moves/spins coil/wire in magnetic field (rate of) change in flux linkage (causes induced e.m.f. driving a current through the battery) Any one from: • <u>work done</u> by gravity / weight (reduces GPE) • <u>work done</u> on charge by magnetic field (transfer to electric energy) • <u>work done</u> by charge passing through battery (transfer to chemical energy)	B1 B1 B1	Allow (motion of truck) moves/spins magnet in coil of wire or description of relative motion between coil and magnet/magnetic field Allow lines of flux are cut (inducing an emf)
3	(b)	Any 3 from: • (internal energy is) sum of kinetic and potential energy of particles (in the wax) • increase in temperature in solid wax corresponds to particles increasing their kinetic energy (but potential energy remains constant) • change of state corresponds to particles increasing their potential energy • increase in temperature in liquid wax corresponds to particles increasing their kinetic energy (but potential energy remains constant)	B1x3	Accept KE for kinetic energy and PE for potential energy throughout Allow $KE \propto \text{temperature}$ Allow during change of state work is being done against intermolecular attractive forces Note only award KE mark once unless one comment is clearly for solid wax and the other for liquid wax i.e. before and after melting

3	(c)	Level 3 (5–6 marks) Clear correct calculations, including efficiency, for both sand and wax and clear quantitative discussion comparing the two methods or limited quantitative discussion and discussion of pros/cons of both methods <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) Some correct calculations for both sand and wax including a specific heat capacity calculation OR Limited calculation(s) for sand and/or wax and some discussion of pros/cons <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 calculation(s) OR Limited discussion <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>	6 × B1	Use level of response annotations in RM Assessor No ticks Indicative scientific points may include: Calculations • $\Delta GPE = mg\Delta h \approx 1 \times 9.81 \times 1000 = 9.8 \text{ kJ}$ • $\text{useful} = 0.7 \times 10 \text{ kJ} = 6.9 \text{ kJ}$ • $\Delta E = mc\Delta\theta = 1 \times 2.6 \times (51-18) = 86 \text{ kJ}$ • $\Delta E = mL = 1 \times 160 = 160 \text{ kJ}$ • $\Delta E = mc\Delta\theta = 1 \times 3.0 \times (70-51) = 57 \text{ kJ}$ • Total E for wax = 300 kJ • useful for wax = $0.95 \times 300 \approx 290 \text{ kJ}$ Discussion • Thermal system stores ~40 times as much energy per kg of material • GPE pros: readily available material; no new infrastructure required; energy stored in batteries can be directly released to the grid; energy can be stored indefinitely • GPE cons: requires mountainous terrain; slow response time • Thermal pros: high energy density; easily scaled up or automated; can be built in any location • Thermal cons: energy stored cannot readily be converted to electrical energy for the grid; limited storage time as wax cools
		Total	12	



22	(a)*	Level 3 (5–6 marks) Clear evaluation of Fig. 22.1 and clear analysis <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) Some evaluation of Fig. 22.1 and some analysis <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 evaluation of Fig. 22.1 or limited analysis <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>	B1×6 Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Ignore incorrect references to the terms precision and accuracy Indicative scientific points may include: Evaluation of Fig. 22.1 • Comment on the line • The straight line misses one error bar / anomalous point ringed or indicated • Too few data points plotted • The triangle used to calculate the gradient is (too) small • Some plots should have been repeated / checked • No error bars for current • 'Not regular intervals' (for current) • No origin shown (AW) Evaluation of analysis • The value of B is close to the accepted value • The difference of only 7% • No absolute or percentage uncertainty in B shown (AW) • Worst-fit line or maximum / minimum gradient line could have been used to determine the (absolute or percentage) uncertainty in B • F against I graph should be a straight line or • $BL = \text{gradient (any subject)}$
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Question			Answer	Marks	Guidance
	(b)	(i)	There is a changing / fluctuating (magnetic) field / flux (linkage) (magnetic) field / flux (linkage) in <u>core</u> and <u>secondary</u> (coil) Statement of Faraday's law: e.m.f. (induced) $\propto$ <u>rate</u> of change of (magnetic) flux <u>linkage</u>	M1 A1 B1	Note: This changing flux can be anywhere Allow 'the direction of the field oscillates' Allow 'the core helps to link the flux to the secondary coil' Allow 'equal to / =' Ignore 'cutting of flux' Not just $E = (-)\Delta(N\phi)/\Delta t$
		(ii)1	$(I_S \Rightarrow) 24/12$ or 2.0 (A) $(I_P \Rightarrow) \frac{20}{400} \times 2.0$ (current in primary $\Rightarrow$) 0.10 (A) or $(V_P \Rightarrow) 12 \times 20$ or 240 (V) $(I_P \Rightarrow) \frac{24}{240}$ (current in primary $\Rightarrow$) 0.10 (A)	C1 A1 C1 A1	 Allow 1 sf answer Allow 1 sf answer
		(ii)2	Idea of changing / increasing (magnetic) field / flux / current (in primary) at the start Eventually <u>current</u> and <u>flux</u> (linkage) are constant, therefore no <u>e.m.f.</u>	B1 B1	Note: Any labels used must be clearly defined
			Total	13	

18	(a)	Level 3 (5–6 marks) Clear description and clear analysis <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) Clear description or clear analysis or some description and some analysis	B1 x 6	Use level of response annotations in RM Assessor Indicative scientific points may include: Expect to see use of ac for clear description Description • labelled circuit diagram • smaller number of turns on primary • a.c. supply on primary
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13



Question			Answer	Mark	Guidance
			<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 description or limited analysis <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 No response or no response worthy of credit.		- load resistor on output - a.c. ammeter to measure current - measurement of number of turns on secondary - keep number of turns on primary constant - keep input ac voltage constant - increase number of turns on secondary each time Analysis - algebra to get to $N_s \propto 1/I_s$ - graph drawn $1/I_s$ against N_s / I_s against $1/N_s$ - expect straight line through origin or $\lg I_s$ against $\lg N_s$ - expect straight line to show gradient = -1 - therefore $N_s \propto 1/I_s$ or – if load resistor in circuit only - use of Ohm's law applied to load resistor to explain why presence of load resistor increases primary current - plotting graph drawn I_s against N_s - expect straight line through origin
	(b)(i)		The (magnitude of the induced) e.m.f. is (directly) proportional/equal to the rate of change of (magnetic) flux linkage	B1	Allow electromotive force for e.m.f Do not allow electromagnetic force for e.m.f. Allow change per unit time for rate of change Allow cutting flux for change of flux linkage Do not allow flux density for flux linkage

Question		Answer	Mark	Guidance
	(b)(ii)	Use of $N_s / N_p = V_s / V_p$	C1	Expect to see attempt at substitution following the equation
		$N_s / 920 = 5.0 / 230$ so $N_s = 20$	A1	Correct substitution and correct algebra into any arrangement
	(b)(iii)	Use of $N = 20$	C1	Expect to see factor of 20 correctly used
		$3.4 = 20 \times \Delta\phi / 1.2 \times 10^{-3}$	C1	
		$\Delta\phi = 2.0 \times 10^{-4}$	A1	Correctly calculated to 2sf (2.04)
		Unit: Wb / weber(s)	B1	Special cases: for two marks from the calculation Use of $N = 1$ gives 4.08×10^{-3} correct to 2sf Use of $N = 920$ gives 4.43×10^{-6} correct to 2sf Allow T m ² Ignore V s Allow correct base unit (kg m ² s ⁻² A ⁻¹)

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	