Oxford Cambridge and RSA

Thursday 22 May 2025 – Morning

GCSE (9–1) Physics B (Twenty First Century Science)

J259/03 Breadth in physics (Higher Tier)

Time allowed: 1 hour 45 minutes

You must have:
- a ruler (cm/mm)
- the Equation Sheet for GCSE (9–1) Physics B (inside this document)

You can use:
- a scientific or graphical calculator
- an HB pencil

H

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **90**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **28** pages.

ADVICE
- Read each question carefully before you start your answer.

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1 A boat makes a journey along a canal.

Fig. 1.1 shows part of the canal **drawn to scale**.

The boat travels from **A** to **C** via **B**.

Fig. 1.1

(a) The distance travelled from **A** to **C** is 5000 m.

(i) Find the distance from **A** to **B**.

Use:
- **Fig. 1.1**
- a ruler.

Distance from **A** to **B** = ... m **[2]**

(ii) When the boat leaves **A**, the time is 09:23.
When the boat reaches **B**, the time is 09:53.

Calculate the average speed of the boat for its journey from **A** to **B**.

Use the Equation Sheet.

Give your answer in **m/s**.

Average speed = ... m/s **[3]**

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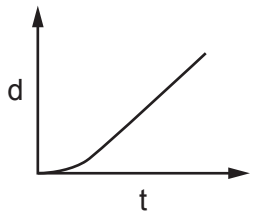
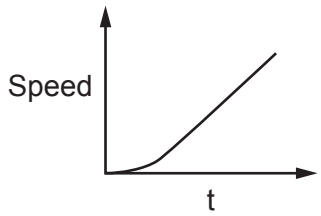
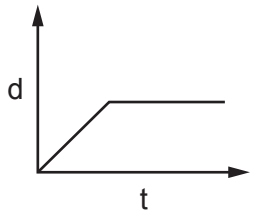
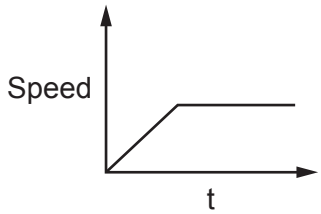
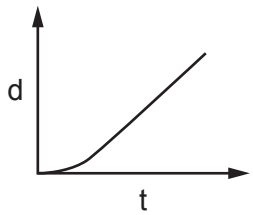
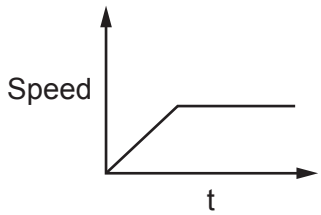
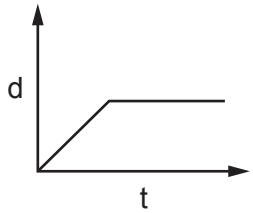
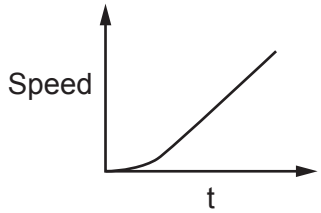
(b) The boat sets off from **A** at constant acceleration and then reaches a constant speed.

Which row in the table shows the correct distance-time graph **and** speed-time graph for the motion of the boat from **A**?

Tick (✓) **one** box.

Distance-time	Speed-time	
		☐
		☐
		☐
		☐

[1]

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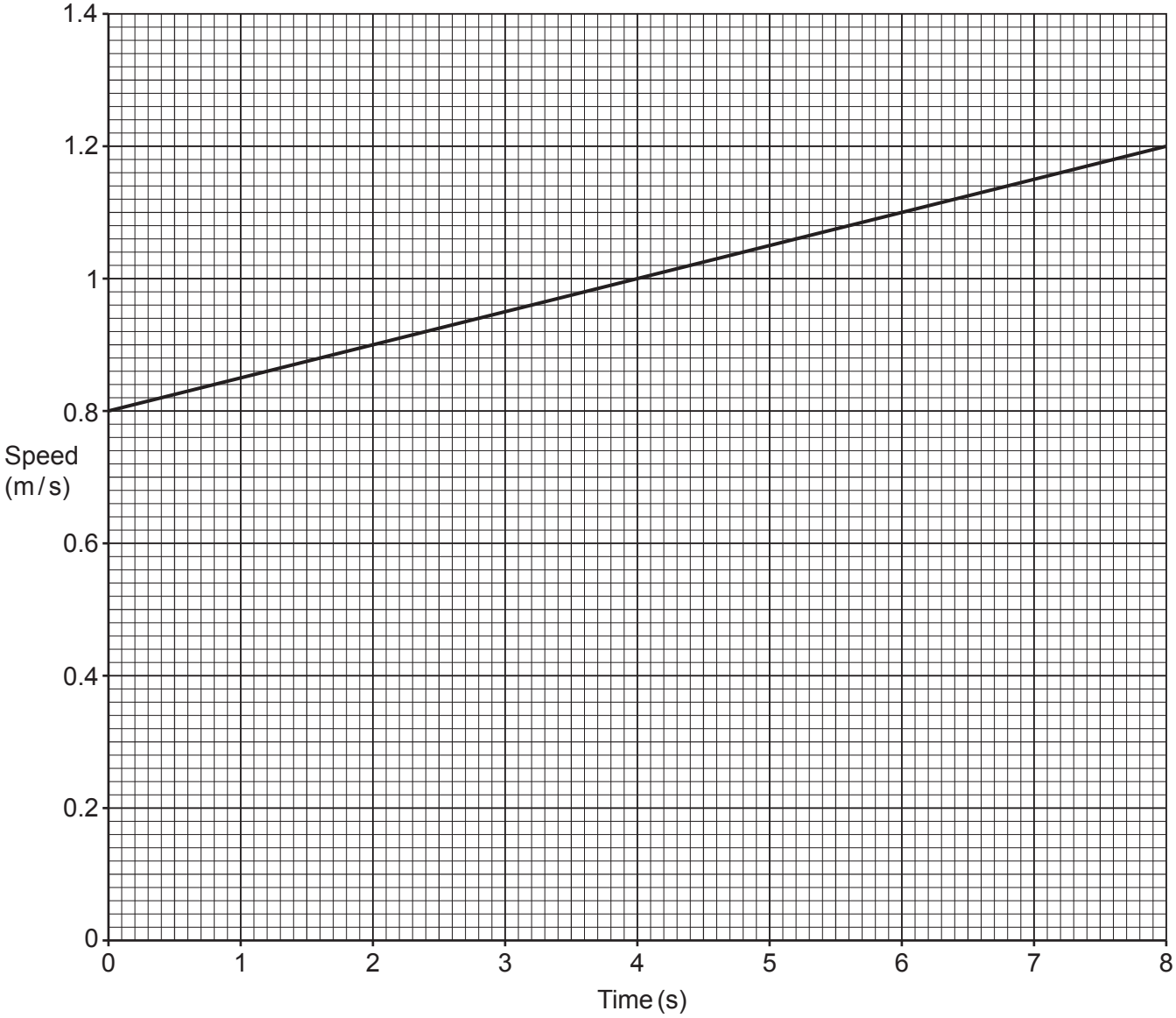
(c) **Fig. 1.2** shows the speed–time graph for the boat for a short period.

Fig. 1.2



Calculate the acceleration of the boat.

Use **Fig. 1.2**.

Acceleration = ... m/s^2 **[3]**

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(d) The boat has a force acting on it from the wind.

Which of these is a typical value for the speed of wind?

Tick (✓) **one** box.

0.12 m/s ☐

12 m/s ☐

1200 m/s ☐

120 000 m/s ☐

[1]

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2 In the 1930s, scientists experimented with elements and split their nuclei.

(a) Complete the sentences about splitting the nucleus.

Use words from the list.

fission	**fusion**	**negative**
power	**stable**	**unstable**

The nuclei of certain elements can be split into two smaller nuclei because they

are ..... .

The process is called nuclear ..... .

[2]

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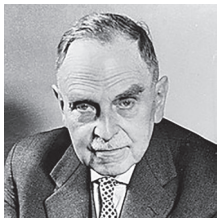
(b) The discovery that nuclei could be split developed over several years in the 1930s.

The table shows a timeline of some of the scientists involved and what they did.

Year	Scientist	What they did
1934	Enrico Fermi	Fired neutrons at uranium nuclei which were captured by the uranium nuclei and made different elements. Fermi thought he created elements **heavier** than uranium.
1934	Ida Noddack © shethoughtit.ilcml.com, She Thought It. Item remove	Published a paper suggesting that Fermi's elements might be **lighter** than uranium. Her paper was ignored as she had no experimental data or theory.
1939	Otto Hahn 	Repeated Fermi's experiment and identified one of the elements that was made as the lighter element **barium**.
1939	Lise Meitner	Calculated the energy changes for Hahn's data and confirmed that energy is **conserved** when splitting a uranium nucleus into a barium nucleus and another nucleus.

(i) Suggest why Enrico Fermi's hypothesis was believed in 1934.

.....

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

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(ii) Explain why, by 1940, more scientists had confidence in the theory that nuclei can be split.

Use information from the table to support your answer.

.....

.....

.....

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

(c) When uranium nuclei split, neutrons are released and a chain reaction happens.

Which statement correctly explains how a chain reaction happens?

Tick (✓) **one** box.

The neutrons released are absorbed by other uranium nuclei. ☐

The neutrons released contaminate the surroundings. ☐

The neutrons released link to form a chain. ☐

[1]

(d) Which **two** statements describe how the energy is released when uranium nuclei split?

Tick (✓) **two** boxes.

As kinetic energy of the new particles. ☐

As kinetic energy of the uranium nuclei. ☐

As potential energy of the new particles. ☐

By emission of infrared radiation. ☐

By emission of ionising radiation. ☐

[2]

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3 A force is applied to a spring.

There is a linear relationship between the force and the extension of the spring.

(a) Complete the sentence to describe a linear force-extension relationship.

In a linear system, for each 1 N of force added, ...

.....

.....

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

(b) A spring has a spring constant of 15 N / m.

Calculate the energy stored when its extension is 0.01 m.

Use the Equation Sheet.

Give your answer in **standard form**.

Energy stored = ... J **[4]**

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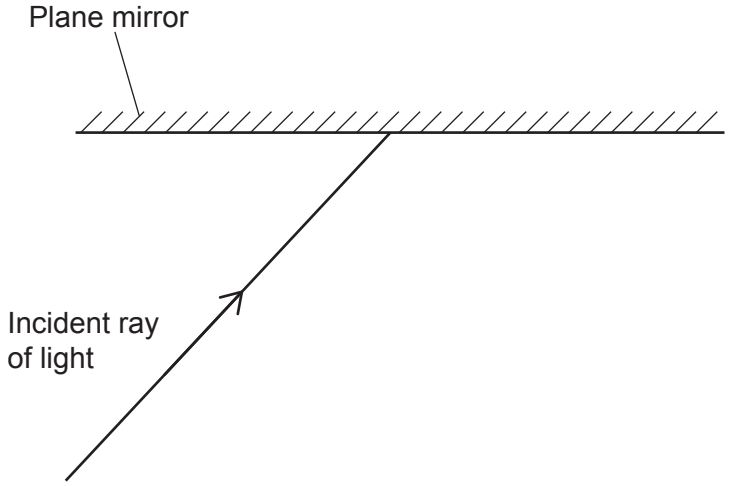
4 Light and sound both travel as waves.

The diagram shows a ray of white light directed at a plane mirror.



(a) Draw on the diagram:

- the reflected ray of light
- the normal, labelled **N**
- the angle of incidence, labelled **i**
- the angle of reflection, labelled **r**.

[3]

(b) Which **two** of these words can be used to describe light waves?

Tick (✓) **two** boxes.

Compression	☐
Electromagnetic	☐
Longitudinal	☐
Radioactive	☐
Seismic	☐
Transverse	☐

[2]

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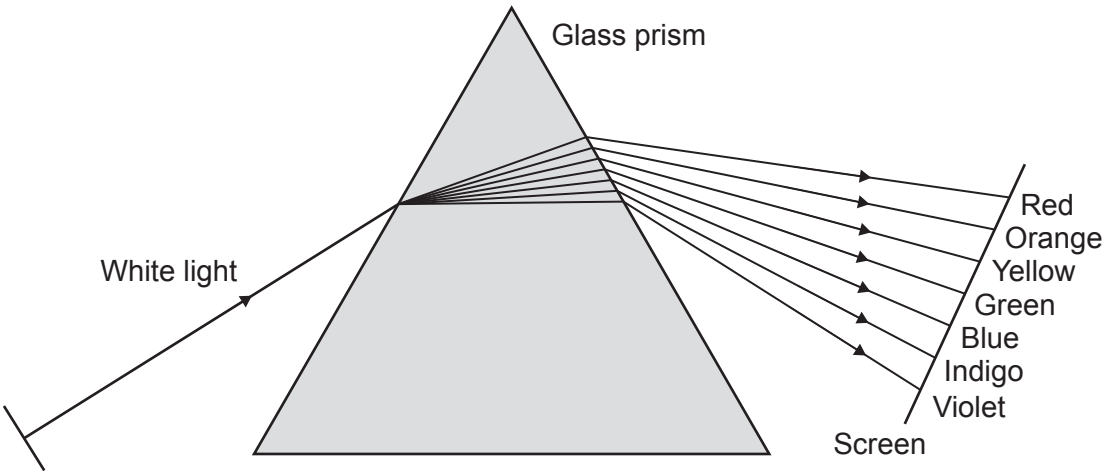
(c) The diagram shows a ray of white light passing through a glass prism.

The white light is split into the spectrum of different colours.



Explain why the prism splits the white light into the spectrum of different colours.

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.....

.....

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

(d) An orange light wave has a frequency of 5.0×10^{14} Hz.

Its wavelength in the glass prism is 400×10^{-9} m.

Calculate the speed of the wave in the glass prism.

Use the Equation Sheet.

Speed of the wave = ... m/s **[3]**

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(e) Draw lines to connect each **medium** a sound wave is travelling in with its correct **speed**.

Medium	**Speed of sound wave**
Air	0 m / s
Steel	330 m / s
Vacuum	1500 m / s
Water	5000 m / s

[3]

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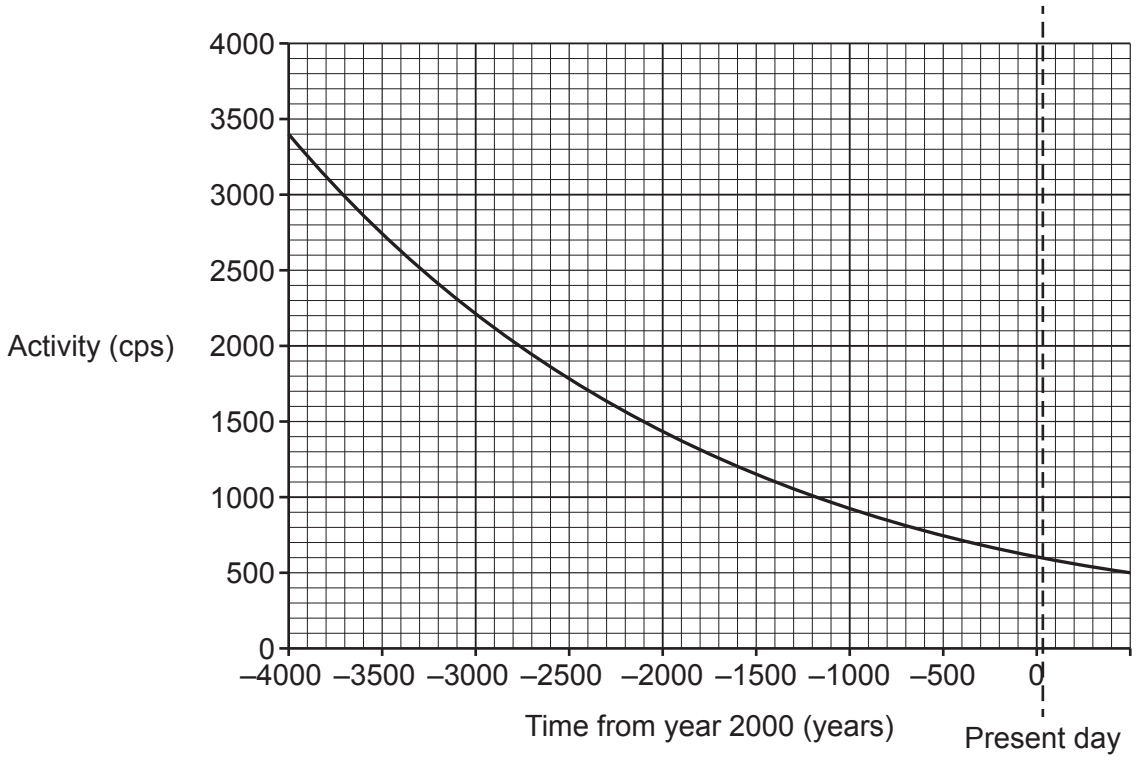
5 Marie Curie discovered radioactive elements by extracting them from their ores.
Her notebook became contaminated with radium and is still radioactive today.

The graph shows the activity of a sample of radium from approximately 4000 years ago until now.



(a) Find the half-life of radium.

Use the graph.

Half-life = ... years **[3]**

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(b) The radium that remains on Marie Curie's notebook has an activity today of around 600 cps.

(i) The activity of the radium that remains on the notebook will decrease in the future.

Calculate the activity of the radium that remains on the notebook after 3 further half-lives.

Activity = ... cps **[2]**

(ii) Calculate the fraction of the number of nuclei that will decay in 3 half-lives.

Fraction = ... **[1]**

(c) Handling the notebook is hazardous to health.

Compare how hazardous handling the notebook was 100 years ago to how hazardous it is today.

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

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6 A permanent magnet and a coil of wire are used in a speaker as shown in **Fig. 6.1**.

Fig. 6.1

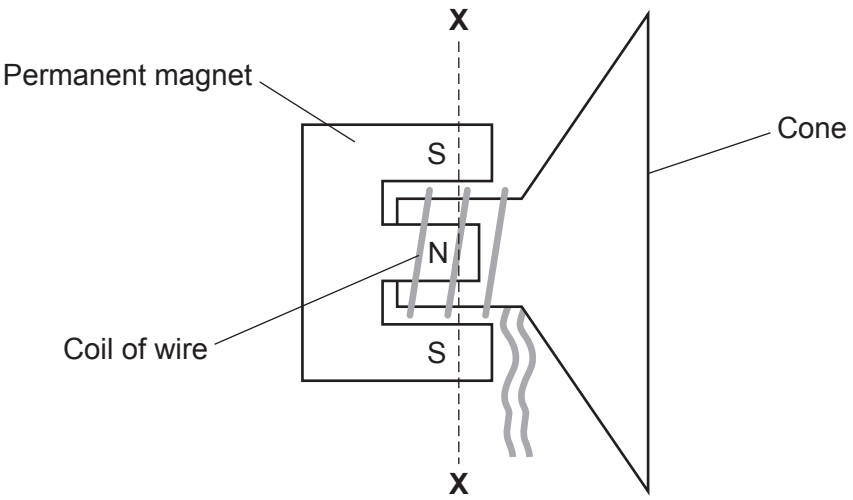
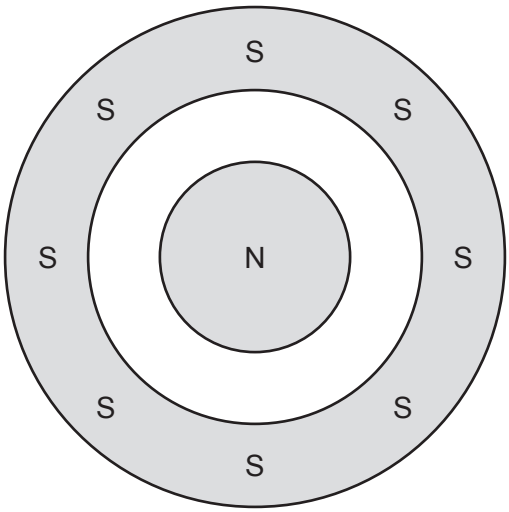


Fig. 6.2 shows a cross-section view of the permanent magnet along X–X.

Fig. 6.2



(a) Draw **four** lines to show the magnetic field of the permanent magnet on **Fig. 6.2**.

Include arrows to show the direction of the magnetic field of the permanent magnet.

[2]

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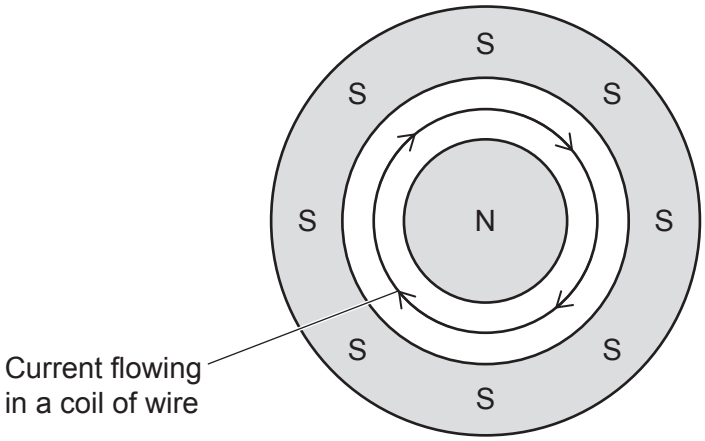
(b) **Fig. 6.3** shows **one** coil of wire around the centre of the permanent magnet.

Fig. 6.3



When an alternating current flows in the coil of wire, the wire experiences a force.

(i) Explain why there is a force on the coil of wire.

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

(ii) Explain how the force on the coil of wire produces sound from the speaker with the same frequency as the alternating current.

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

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(iii) Calculate the force on the **one** coil of wire.

- The magnetic flux density is 1.2 T.
- The current is 0.3 A.
- The circumference of the coil of wire is 5 cm.

Use the Equation Sheet.

Force = ... N **[4]**

(iv) Suggest **three** ways to increase the size of force on the coil of wire in the speaker.

1 .....

.....

2 .....

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3 .....

.....

[3]

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7 An exercise bike is connected to a magnet which turns when the wheels go round.

When the exercise bike is ridden, the magnet turns inside a coil of wire.
This induces a potential difference in a circuit.

(a) What must the coil of wire be connected to so that a direct current is produced in the circuit?

Tick (✓) **one** box.

An ammeter ☐

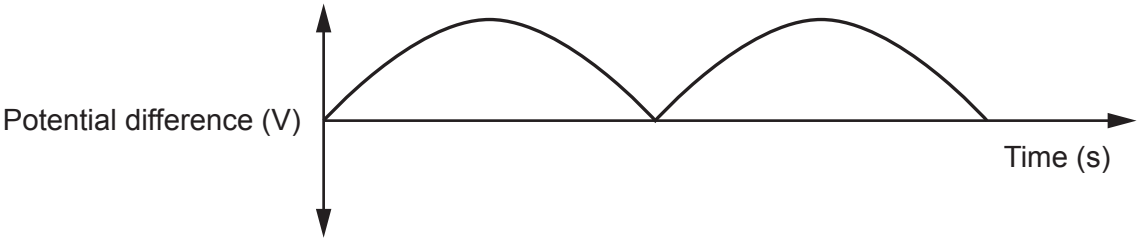
A slip ring ☐

A split ring commutator ☐

A switch ☐

[1]

(b) The graph shows the potential difference-time graph for the exercise bike.



Which feature of the potential difference-time graph shows that a direct current is produced?

Tick (✓) **one** box.

The potential difference always has the same maximum value. ☐

The potential difference is always a positive value. ☐

The potential difference is zero each cycle. ☐

The potential difference varies with time. ☐

[1]

(c)
(i) Define a renewable energy resource.

.....

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

(ii) Explain whether the electricity produced by riding the bike has come from a renewable or non-renewable source.

.....

.....

.....

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

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8 Emperor penguins dive very deep in the sea.

(a) Explain why the pressure on an object increases as its depth in the sea increases.

Use ideas about forces in your answer.

.....

.....

.....

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

(b) An emperor penguin dives to a depth of 400 m.

(i) Calculate the pressure on the penguin.

- The approximate density of seawater is 1020 kg / m^3.
- The gravitational field strength is 10 N / kg.

Use the Equation Sheet.

Give your answer in **kPa**.

Pressure = ... kPa **[4]**

(ii) Colder water has a higher density.

Explain the effect on your answer to **(b)(i)** if the penguin still dives to 400 m but the water is colder.

.....

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

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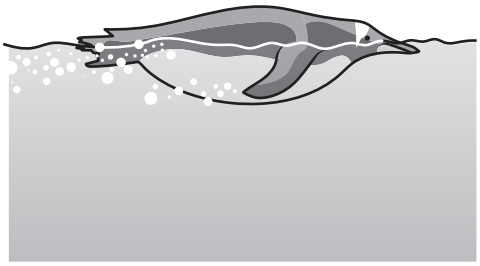
(c) **Fig. 8.1** shows an emperor penguin partially submerged on the surface of the water.

Fig. 8.1



Explain why the water exerts a net force upwards on the penguin.

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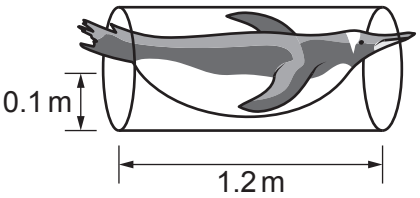
..... **[2]**

(d) **Fig. 8.2** shows how the volume of a penguin can be modelled as a cylinder.

Fig. 8.2



Calculate the density of the penguin when it is modelled as a cylinder as shown in **Fig. 8.2**.

The mass of the penguin is 25 kg.

Use:
- the equation: volume of a cylinder = $\pi r^2 l$, where r is the radius and l is the length of the cylinder
- the Equation Sheet.

Density = ... kg / m^3 **[3]**

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(e) When an emperor penguin dives deeper into the sea, air sacs in its body compress.

The table shows the body volume and body density for an emperor penguin at increasing depths.

Depth (cm)	Body volume of penguin (m^3)	Body density of penguin (kg/m^3)
72	0.028	893
84	0.027	925
96	0.023	1087
108	0.022	1136
120	0.021	1190

(i) Explain the trends in the data shown in the table.

.....

.....

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.....

.....

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

(ii) Explain why the penguin will sink at a depth of 100 cm if it is **not** swimming.

Use the data in the table.

The approximate density of seawater is 1020 kg/m^3.

.....

.....

.....

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

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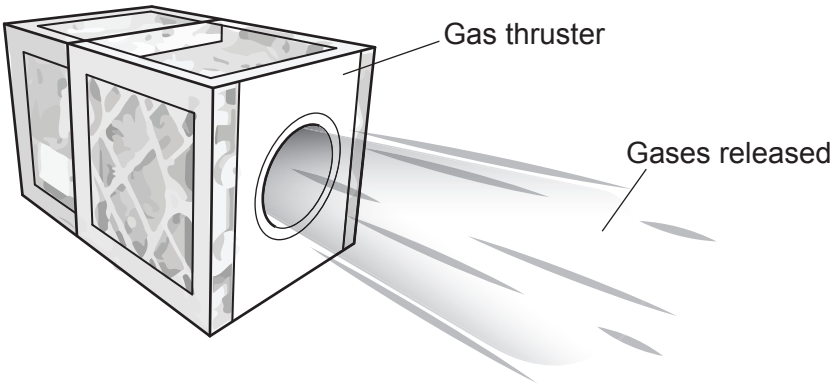
9 The diagram shows a gas thruster.

The gas thruster releases a gas to change the orbit of a satellite.



(a) The satellite is in a stable circular orbit at a height of about 500 km above the Earth.
The gas thruster moves the satellite about 3 km further away from Earth.
The gas thruster is turned off and the satellite settles into a new stable circular orbit.

(i) Compare the force of gravity at the two orbits.

.....

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

(ii) Explain the difference in the speed of the satellite in its new orbit compared to its speed in the original orbit.

.....

.....

.....

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

(iii) Explain why the satellite is accelerating when it is in a stable circular orbit.

.....

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.....

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

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(b) When the satellite moves to its new orbit its momentum is 9 144 000 kgm / s.

Calculate the velocity of the satellite in its new orbit.

The mass of the satellite is 1200 kg.

Use the Equation Sheet.

Velocity = ... m / s **[3]**

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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