Oxford Cambridge and RSA

Wednesday 20 October 2021 – Morning

A Level Physics A

H556/03 Unified physics

Time allowed: 1 hour 30 minutes

You must have:
- The Data, Formulae and Relationships Booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

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 **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

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

Answer **all** the questions.

1 **Fig. 1** shows a high-speed electric train.

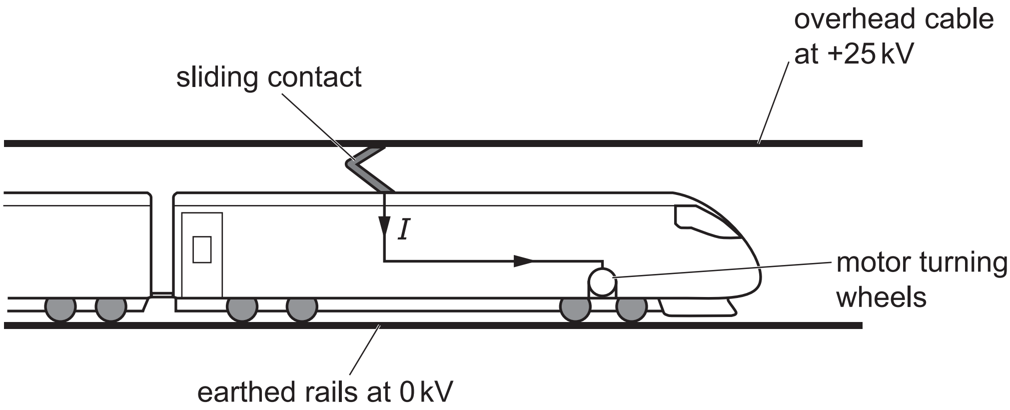


Fig. 1

The potential difference between the overhead cable and the rails on the ground is 25 kV.
The sliding contact on the top of the train constantly touches the overhead cable.
The overhead cable supplies a current I to the electric motor of the train.
The motor turns the wheels. The train experiences a **resultant** forward force F.

The total mass of the train is 2.1×10^5 kg.

(a) The train accelerates from rest. The value of F is 190 kN for speeds less than $6.0\,\text{m}\,\text{s}^{-1}$.

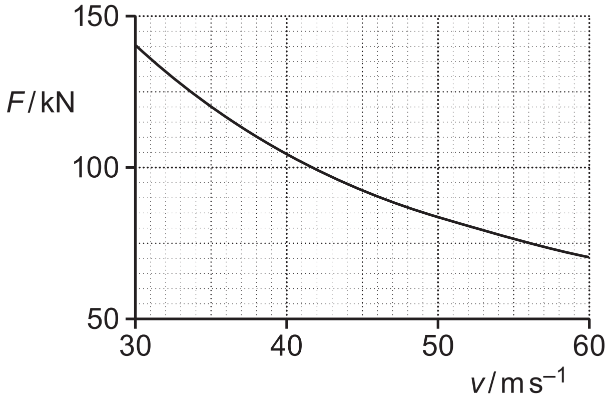
(i) Show that the train's acceleration is about $1\,\text{m}\,\text{s}^{-2}$.

[1]

(ii) Calculate the distance s that the train travels to reach a speed of $6.0\,\text{m}\,\text{s}^{-1}$.

s = ... m **[2]**

(iii) The speed of the train is v.
During one period of its journey, the train accelerates from $v = 30\,\text{m}\,\text{s}^{-1}$ to $v = 60\,\text{m}\,\text{s}^{-1}$.
The graph of F against v for this period is shown below.



1. Use the graph to show that output power of the electric motor during this period is constant at about 4 MW.

[3]

2. Calculate the current I in the electric motor when the train is travelling at $50\,\text{m}\,\text{s}^{-1}$.

I = ... A **[2]**

Question 1 is continued on page 4

(b) The overhead cable in **Fig. 1** must be tensioned.
It is constructed from several equal lengths of wire.

Some data for one length of this wire are shown below.

- length = 1500 m
- area of cross-section = 1.1×10^{-4} m^2
- resistivity = 1.8×10^{-8} Ω m
- the Young modulus = 1.2×10^{10} Pa
- strain = 1.3%

(i) Calculate the resistance *R* of one length of wire.

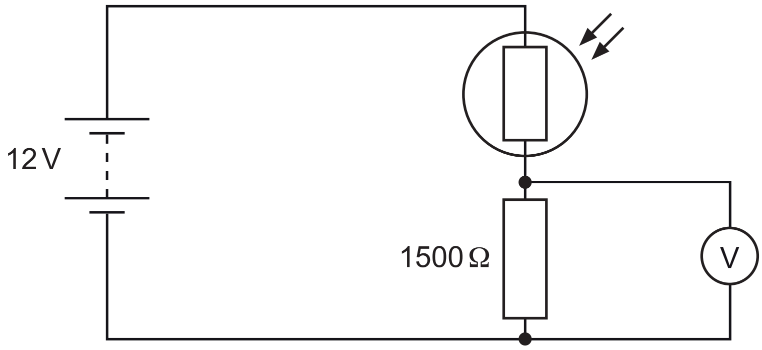
R = ... Ω **[2]**

(ii) Calculate the tension *T* in one length of wire.

T = ... N **[3]**

2 This question is about a light-dependent resistor (LDR).

(a) A student connects a potential divider circuit as shown below. It contains an LDR.



The fixed resistor has resistance 1500 Ω.
The battery has electromotive force (e.m.f.) 12 V and negligible internal resistance.
The voltmeter has extremely high resistance.

(i) When the LDR is covered, its resistance is 3000 Ω.

Calculate the voltmeter reading.

voltmeter reading = ... V **[2]**

(ii) When fully illuminated, the resistance of the LDR is 100 Ω.
Show that the voltmeter reading **changes** by more than 7 V.

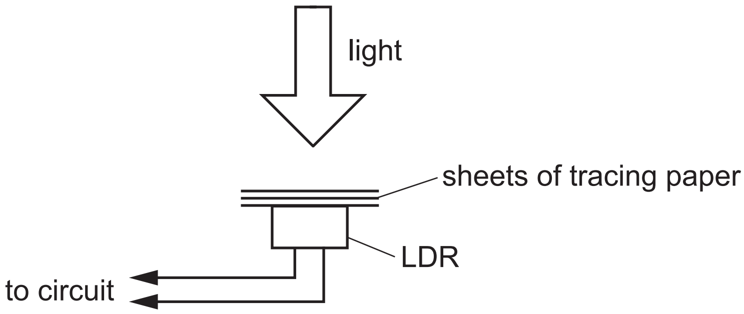
[1]

Question 2 is continued on page 6

***(b)** The current in an LDR depends on the intensity of light incident on it.

A student decides to alter the intensity of light incident on an LDR by using sheets of tracing paper and a light source.

The diagram below shows **part** of an arrangement suggested by the student.



It is suggested that the current I in the LDR is given by the expression

$I = ke^{-nx}$

where x is the **total** thickness of the sheets of tracing paper, and k and n are constants.

Describe how the student could carry out an experiment to verify the validity of this expression and determine k and n. Include in your answer

- a circuit diagram
- a possible table for the results, including the headings
- the graph plotted to determine k and n
- any precautions taken to improve the quality of the results. **[6]**

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Additional answer space if required

3 This question is about a space probe which is in orbit around the Sun.

(a) Define **gravitational potential energy** of an object at a point in a gravitational field.

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.... **[1]**

(b) The space probe has mass 810 kg. The orbital radius of the space probe is 1.5×10^{11} m. The orbital period of the space probe around the Sun is 3.16×10^{7} s.
The mass of the Sun is 2.0×10^{30} kg.

(i) Show that the magnitude of the gravitational potential energy of the space probe is about 7×10^{11} J.

[2]

(ii) Show that the kinetic energy of the space probe is half the value of your answer to **(b)(i)**.

[3]

(iii) Calculate the total energy of the space probe.

total energy = ... J **[1]**

(c) The power source for the instrumentation on board the space probe is plutonium-238, which provides 470 W initially.

Plutonium-238 decays by α-particle emission with a half-life of 88 years.
The kinetic energy of each α-particle is 8.8×10^{-13} J.

(i) Calculate the number *N* of plutonium-238 nuclei needed to provide the power of 470 W.

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

(ii) Calculate the power *P* still available from the plutonium-238 source 100 years later.

P = ... W **[3]**

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 1.0×10^5 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

Turn over

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

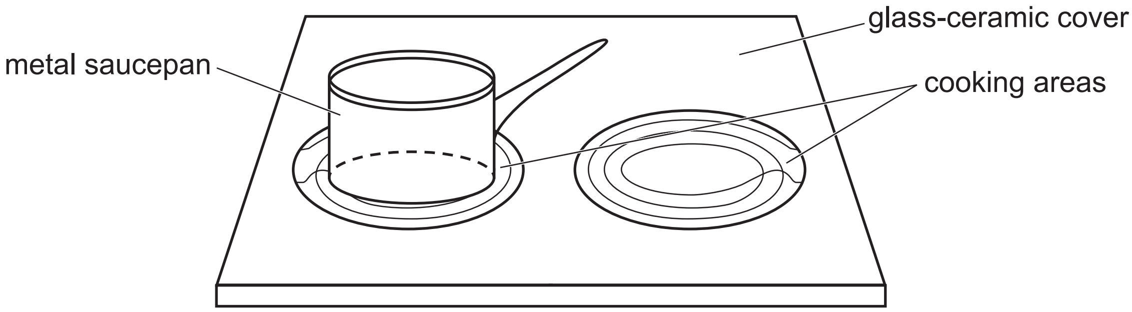

Fig. 4.1

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.

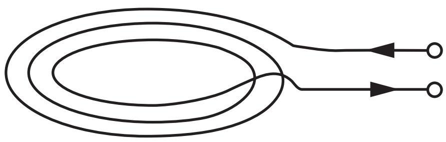

Fig. 4.2

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.

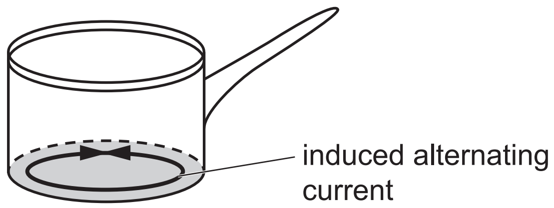

Fig. 4.3

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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.... **[2]**

5 A student is investigating stationary waves in the air column inside a tube, using the apparatus shown in **Fig. 5.1**.

The loudspeaker emits sound of frequency *f* and wavelength λ. The tube is initially fully immersed in the water. The student then slowly raises the tube until the oscilloscope trace shows its first maximum. A stationary wave of fundamental frequency *f* is produced in the air column. When this occurs, the student measures the length l of the tube above the water level.

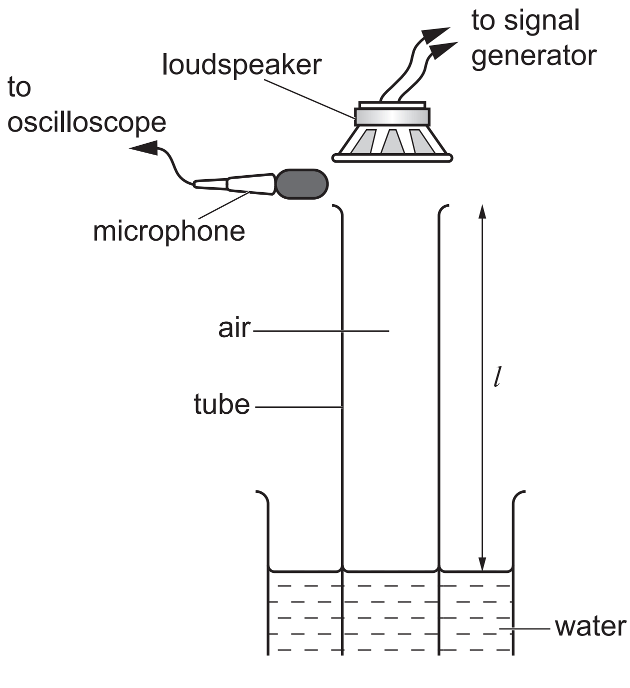

Fig. 5.1

(a) Explain how a stationary wave of fundamental frequency is produced and state the relationship between l and λ.

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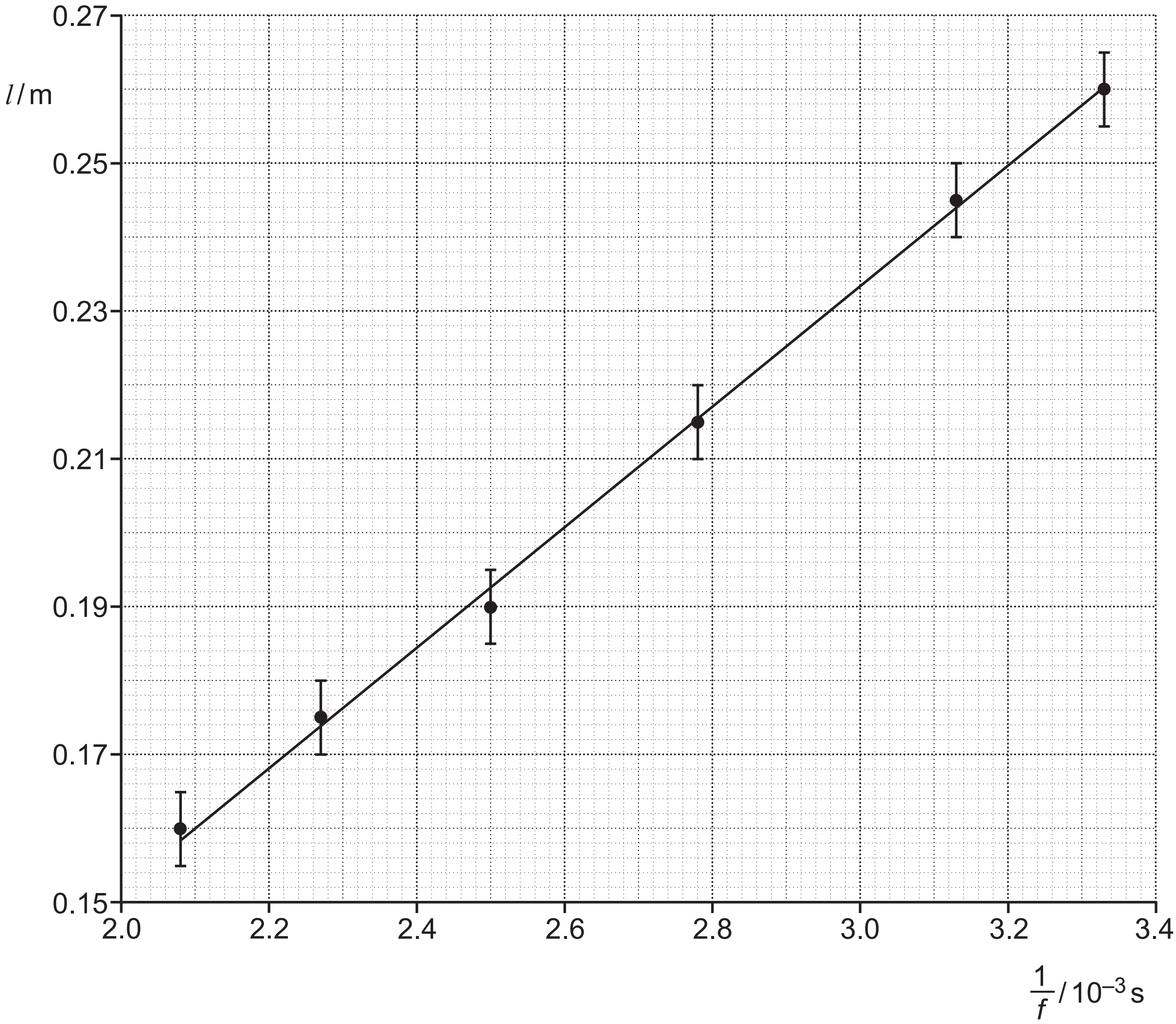
.... **[4]**

(b) Theory suggests that f and l are related by the equation $4(l + k) = \frac{v}{f}$, where v is the speed of sound in air and k is a constant.

The student measures corresponding values of l and f and plots a graph of l against $\frac{1}{f}$.

The data points, error bars and the line of best fit drawn by the student are shown in the graph below.



(i) Show that the line of best fit has gradient = $\frac{v}{4}$ and y-intercept = $-k$.

[2]

(ii) Calculate v from the gradient of the line of best fit.

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

Question 5 is continued on page 16

(c) The experiment is repeated using the same tube and an unlabelled tuning fork, as shown in **Fig. 5.2**. The distance l is measured as 22 cm.

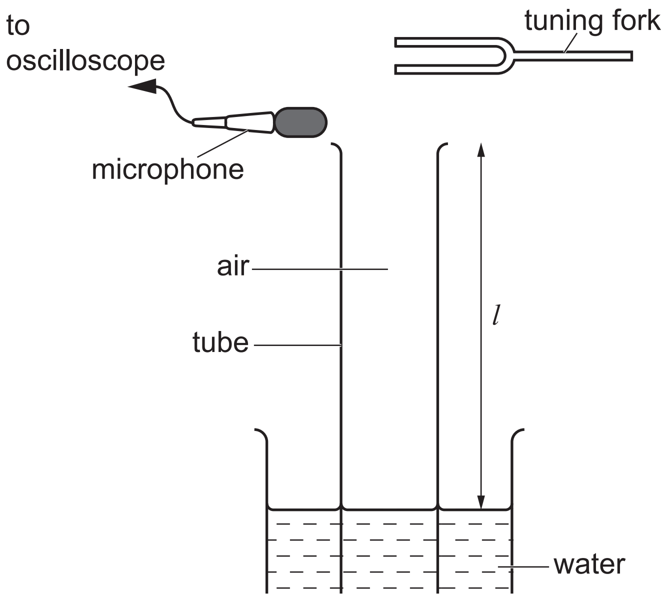


Fig. 5.2

The frequency of the vibrating tuning fork is F.

(i) Use the line of best fit on the graph to estimate F.

F = ... Hz **[2]**

(ii) The percentage uncertainty in the value of F can be written as $100\,\frac{\Delta F}{F}$ where ΔF is the absolute uncertainty in F.

Use the rules for combining uncertainties to write an expression for the percentage uncertainty in the value of F in terms of v and its absolute uncertainty Δv, l and its absolute uncertainty Δl, and k and its absolute uncertainty Δk.

[2]

6 The London Eye, shown rotating anticlockwise in **Fig. 6.1**, is a giant wheel which rotates slowly at a constant speed.

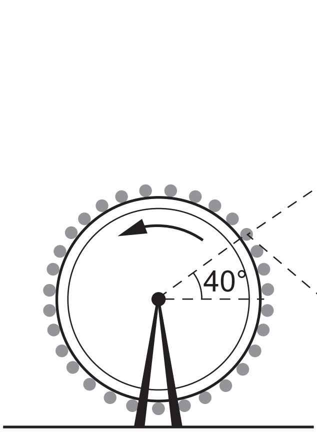


Fig. 6.1

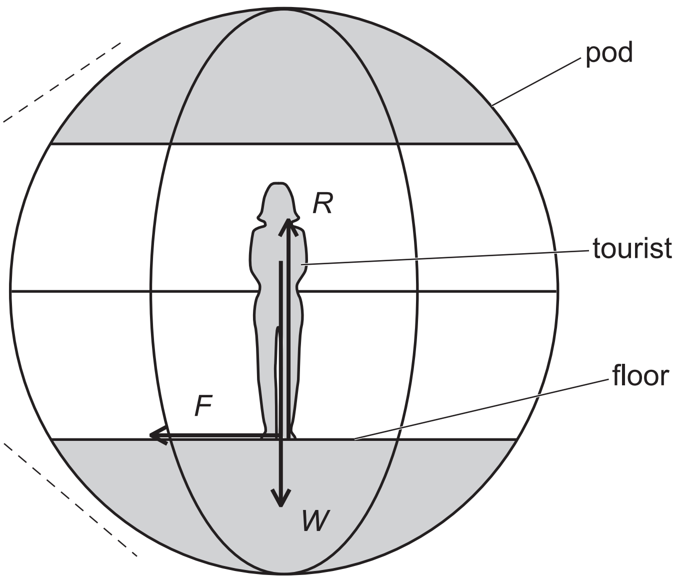


Fig. 6.2

Tourists stand in pods around the circumference of the wheel.
The floor remains horizontal at all times.
At time t = 0, a tourist who has a weight W of 650 N enters a pod at the bottom of the wheel.
Fig. 6.2 shows the forces acting on the tourist at a later time, when the angle between the pod's position and the centre of the wheel is 40° above the horizontal. R is the normal contact force and F is friction.

(a) The resultant upward force ($R - W$) on the tourist changes during the 30 minutes of the rotation of the London Eye as shown in **Fig. 6.3**.

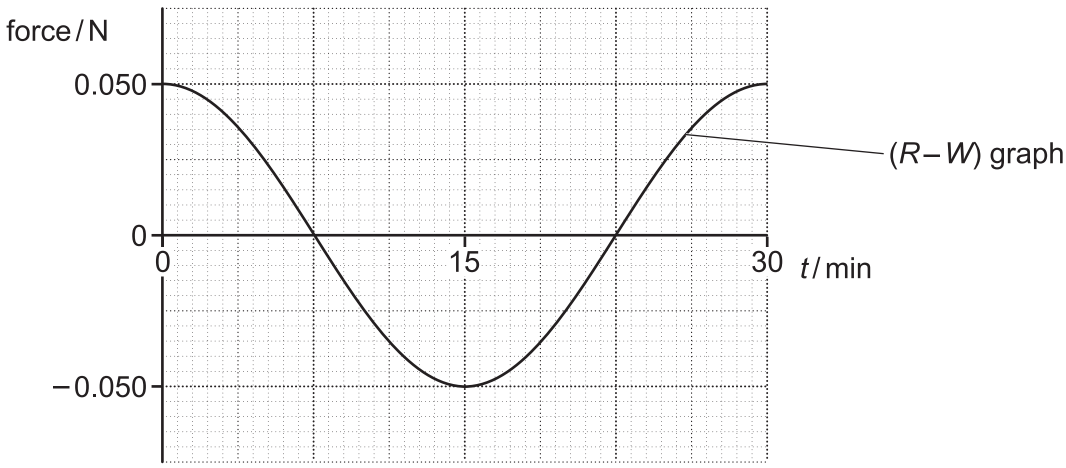


Fig. 6.3

Explain how the graph in **Fig. 6.3** shows that the magnitude of the centripetal force on the tourist during the rotation is 0.050 N.

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.... **[1]**

(b) **(i)** Explain why the horizontal force *F* between the floor and the tourist is necessary.

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.... **[2]**

(ii) Draw on **Fig. 6.3** the variation of the horizontal force *F* during the 30 minutes of the anticlockwise rotation of the London Eye. Take forces to the right to be positive. **[2]**

(iii) Calculate the magnitude of force *F* when the pod is at the position shown in **Fig. 6.2**, at 40° above the horizontal.

F = ... N **[2]**

(c) Calculate the distance *d* of the centre of mass of the tourist from the centre of rotation of the London Eye.

d = ... m **[3]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

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OCR
Oxford Cambridge and RSA

Thursday 16 June 2022 – Morning

A Level Physics A

H556/03 Unified physics

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* 9 1 1 5 0 7 7 9 6 4 *

* H 5 5 6 0 3 *

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1 The table shows some data on the planet Venus.

Mass / kg	4.87×10^{24}
Radius / km	6050
Density of atmosphere at surface / kg m^{-3}	65
Period of rotation about its axis / hours	5830

(a) Calculate the magnitude of the gravitational field strength *g* at the surface of Venus.

Give your answer to **3** significant figures.

g = ... N kg^{-1} **[3]**

(b) Two identical space probes, **A** and **B**, land on a flat surface on Venus.

Probe **A** lands at the north pole. Probe **B** lands on the equator.

Each probe has mass 760 kg and volume 1.7 m^3.

(i) Calculate the centripetal acceleration *a* of probe **B** at the equator due to the rotation of Venus about its axis.

a = ... m s^{-2} **[3]**

(ii) The atmosphere exerts the same upthrust on each probe.

Using your answer to **(a)**, calculate the upthrust acting on each probe.

upthrust = ... N **[3]**

(iii) Explain which probe will experience the greater normal contact force from the surface of Venus.

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.... **[3]**

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2 A student investigates the oscillations of a uniform rod of length *L* which is pivoted at the top, as shown in **Fig. 2.1**.

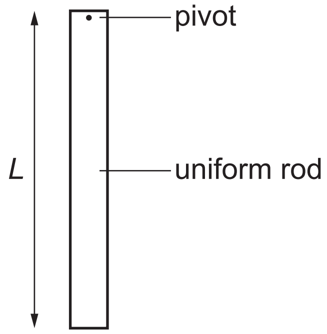

Fig. 2.1

(a) Describe how to determine accurately the period *T* of oscillations of this rod.

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.... **[2]**

(b) The relationship between the frequency f of the oscillations of the rod and its length L is

$$f = \frac{1}{2\pi}\sqrt{\frac{3g}{2L}},$$

where g is the acceleration of free fall.

The student varies the length L of the rod and determines the period T for each length.

The student plots a graph of T^2 against L, shown in **Fig. 2.2**. A line of best fit has already been drawn.

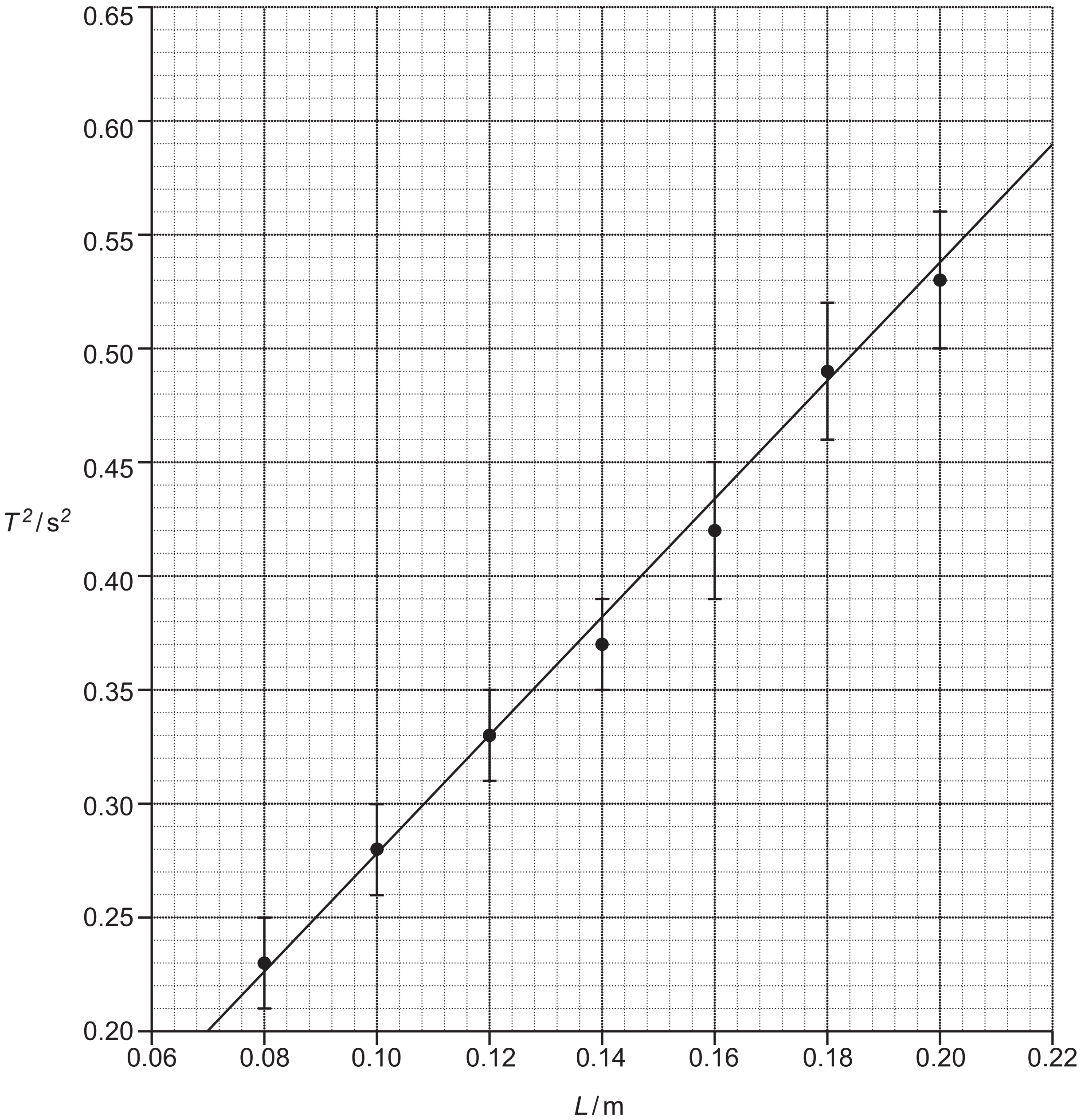

Fig. 2.2

(i) Show that the gradient of the graph is given by the equation

gradient = $\frac{8\pi^2}{3g}$

[2]

(ii) The gradient of the line of best fit on **Fig. 2.2** is 2.64 $s^2 m^{-1}$.

Use this value to determine *g*.

g = ... $m s^{-2}$ **[2]**

(iii) Draw a line of worst fit on **Fig. 2.2**. **[1]**

(iv) Use your line of worst fit to calculate the percentage uncertainty in *g*.

percentage uncertainty = ... % **[3]**

(v) Use the true value of *g* (9.81 $m s^{-2}$) to evaluate the accuracy of the student's value of *g* from this experiment. Include a calculation in your answer.

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.... **[2]**

3 **(a)** In beta-plus decay, a proton decays into three other particles.

Write a nuclear equation for this process.

[2]

(b)* A student, supervised by their teacher, carries out an experiment with three unlabelled radioactive sources.

The student is told that each source emits only one type of radiation. One emits gamma rays, one emits beta-minus particles and one emits beta-plus particles.

The student has the following equipment:

- a selection of materials with different thicknesses
- a strong magnet
- a radiation counter (GM tube and counter).

Explain how the student can use this equipment to determine safely which radiation each source emits.

You may use the space below to draw a diagram. **[6]**

Additional answer space if required

4 Astronomers can detect microwave background radiation coming from space in every direction.

The temperature of this microwave radiation is 2.7 K and its **total** intensity is about 3×10^{-6} W m^{-2}.

(a) Describe the origin of the microwave background radiation.

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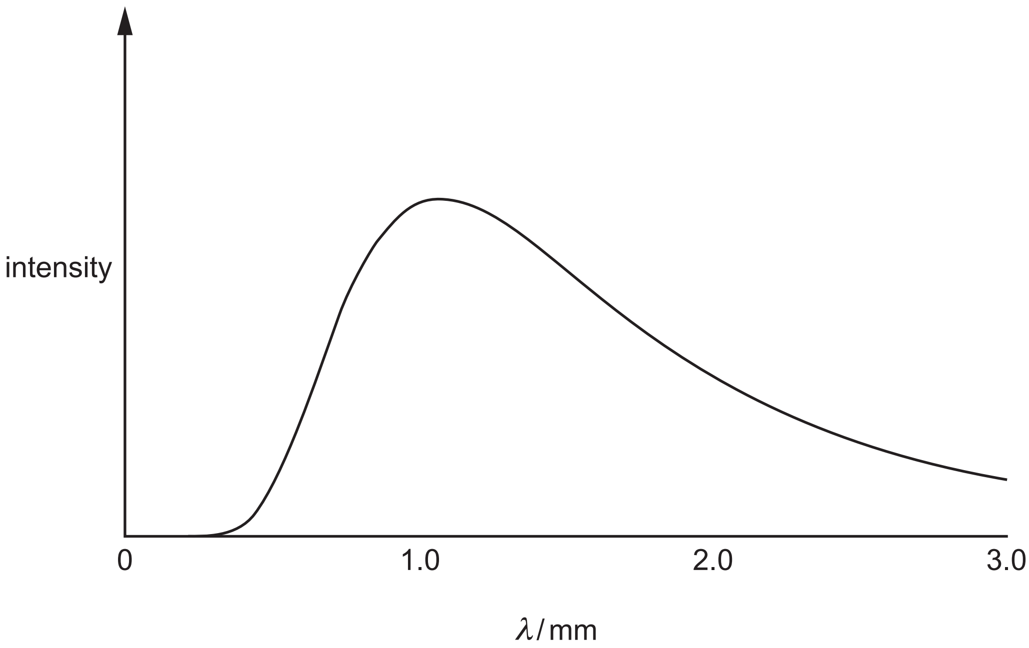
.... **[2]**

(b) The figure below shows how the intensity of the microwave background radiation varies with its wavelength λ.

The **peak** intensity is at a wavelength of 1.1 mm.



This spectrum of microwave background radiation changes with temperature according to Wien's displacement law.

(i) Suggest and explain how the spectrum might have looked in the distant past. You may draw on the figure to support your answer.

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.... **[2]**

(ii) Calculate the energy of a photon which has a wavelength of 1.1 mm.

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

(iii) Estimate the number of photons of microwave background radiation incident per second on the back of your hand.

Assume that all emitted photons have the energy calculated in **(ii)**, and that the back of your hand has a surface area of 150 cm^2.

number of photons per second = ... s^{-1} **[2]**

(iv) A scientist suggests that the microwave background radiation could be used as an energy source.

The scientist proposes using large tanks of water to absorb the microwave radiation.

Estimate the maximum rise in temperature that could be produced per second for a large cylindrical tank of depth 5.0 m. Assume that all microwave radiation incident on the top of the tank is absorbed.

density of water = 1000 $kg\,m^{-3}$
specific heat capacity of water = 4200 $J\,kg^{-1}\,K^{-1}$

maximum rise in temperature per second = ... $°C\,s^{-1}$ **[3]**

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5 A student experiments with microwaves emitted from a transmitter. The frequency f of the microwaves from the transmitter can be adjusted.

(a) The microwaves are produced by an alternating current in the transmitter.

In one experiment, f is 11 GHz. In a wire in the transmitter, the magnitude of the **maximum** alternating current is 20 mA. The wire has cross-sectional area $1.4 \times 10^{-8}\,\text{m}^2$ and is made of a metal with free electron number density $8.0 \times 10^{28}\,\text{m}^{-3}$.

(i) Show that the maximum drift velocity of each free electron in the wire is about $0.1\,\text{mm}\,\text{s}^{-1}$.

[3]

(ii) The student models the average motion of the free electrons in the wire as simple harmonic motion.

Use your answer to **(i)** to calculate the amplitude A of this motion.

A = ... m **[3]**

(iii) Without further calculation, explain how the maximum acceleration of a free electron varies as the frequency f is adjusted, provided that the maximum alternating current remains constant.

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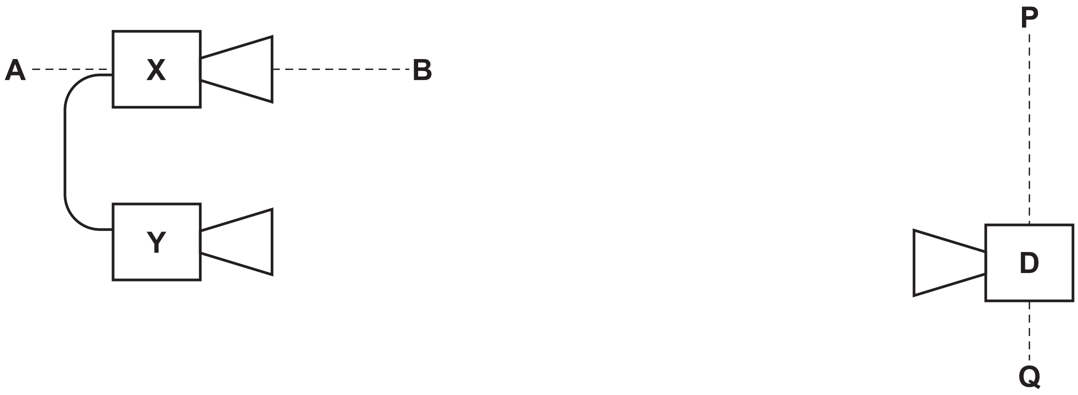
.... **[2]**

(b) The student connects two microwave transmitters **X** and **Y**, and places them in front of a microwave detector **D**, as shown in the diagram below.



The transmitters **X** and **Y** produce **coherent** vertically polarised microwaves with the same frequency f.

The detector **D** is sensitive to vertically polarised microwaves only.

When the detector **D** is moved along the line **PQ**, a pattern of maximum and minimum intensity is observed. Adjacent maxima are separated by a distance x.

(i)* Explain:

- why this pattern of intensity occurs
- the expected relationship between the frequency f and the distance x
- how to verify this relationship experimentally. **[6]**

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(ii) Transmitter **X** is rotated about the line **AB** and the experiment is repeated at different orientations until it has been rotated by 180°.

Describe and explain the observed patterns of maximum and minimum intensity.

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.... **[3]**

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6 **(a)** Define the **time constant** of a circuit containing a capacitor of capacitance *C* and a resistor of resistance *R*.

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.... **[1]**

(b) The capacitor circuit shown in **Fig. 6.1** can be used to smooth oscillating electrical signals.

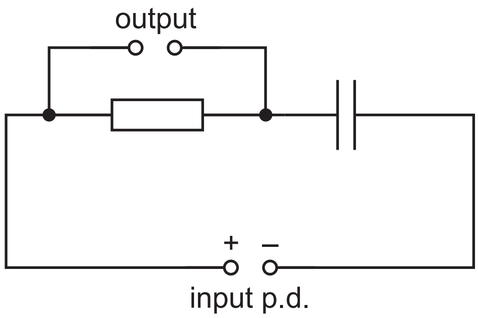

Fig. 6.1

(i) **Fig. 6.2** shows the input signal of potential difference (p.d.) *V* against time *t*.

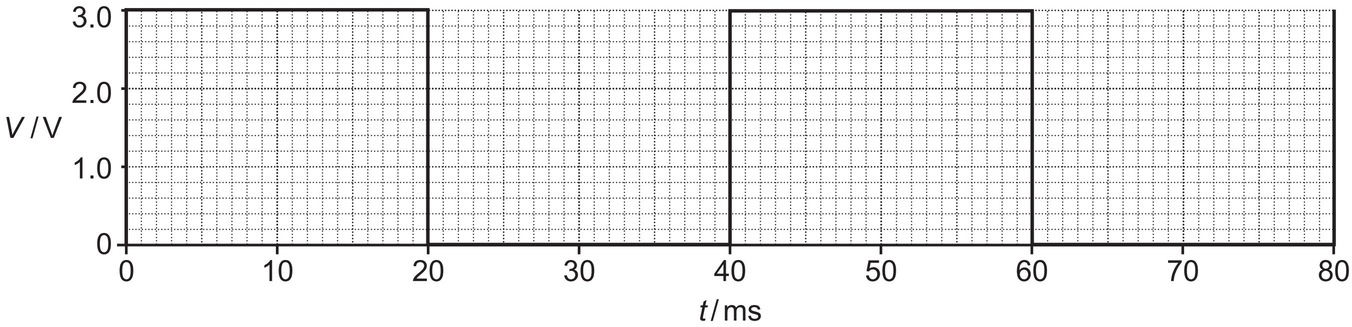

Fig. 6.2

Calculate the frequency *f* of this input signal.

f = ... Hz **[2]**

(ii) **Fig. 6.3** shows the variation of the charge Q on the positive plate of the capacitor with time t.

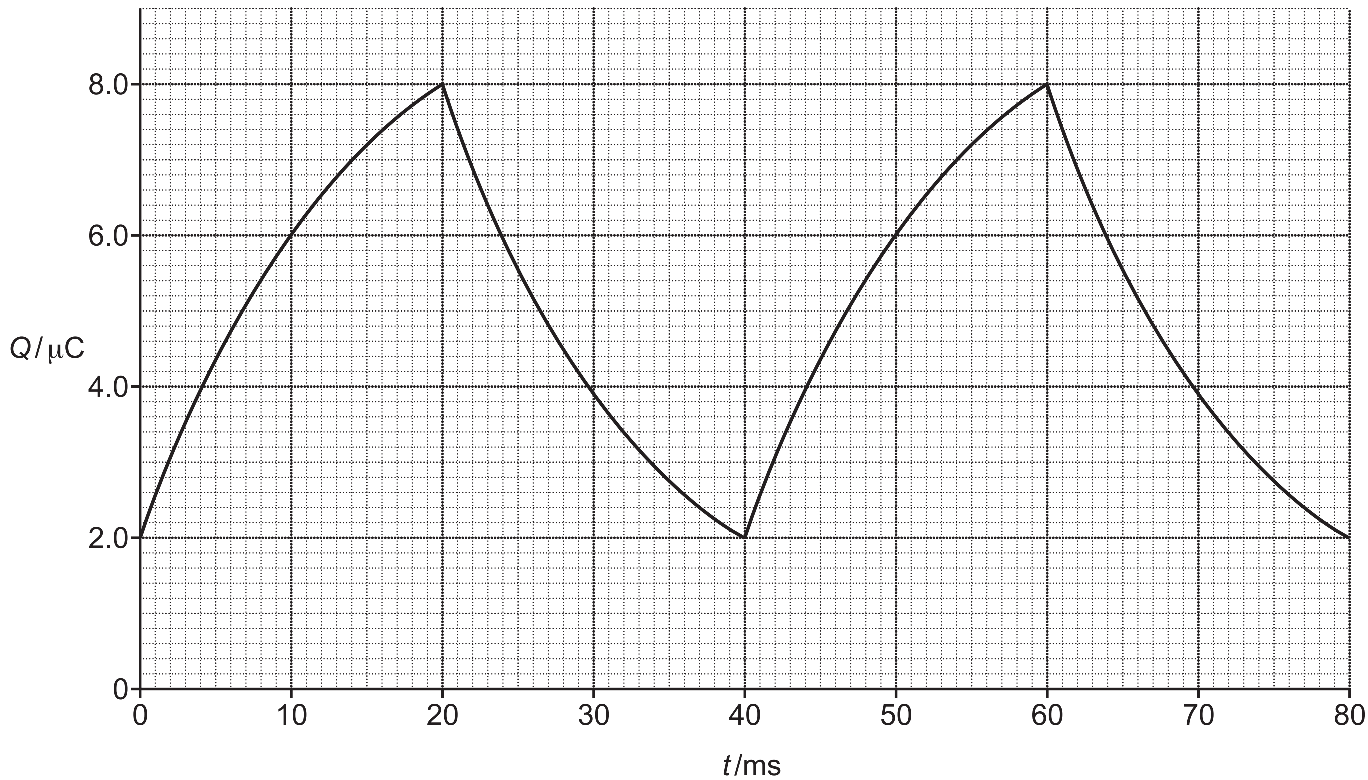

Fig. 6.3

Use a discharging section of the graph in **Fig. 6.3** to determine the time constant of the circuit. Give your answer in ms.

time constant = ... ms **[2]**

(iii) By drawing a suitable tangent to the graph in **Fig. 6.3**, calculate the maximum current in the resistor.

maximum current = ... A **[2]**

(iv) **On Fig. 6.4** below, sketch the variation of the current I in the resistor with time t. Include an appropriate label and scale on the vertical axis.

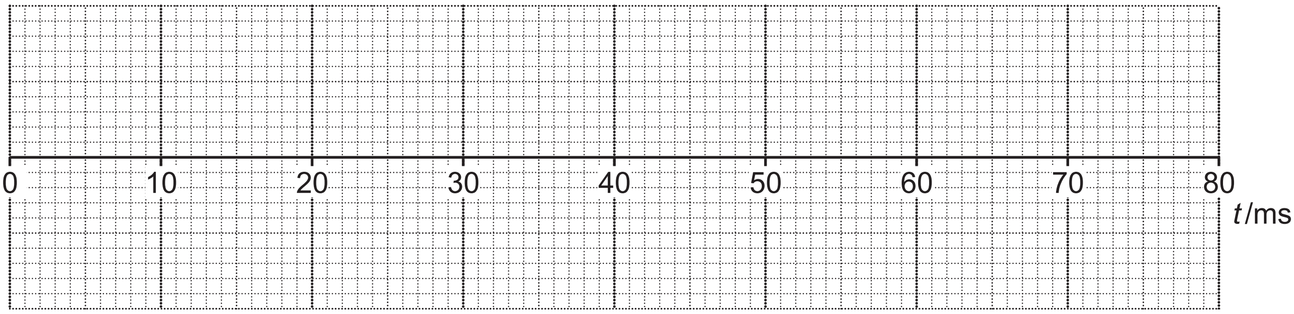

Fig. 6.4

[3]

END OF QUESTION PAPER

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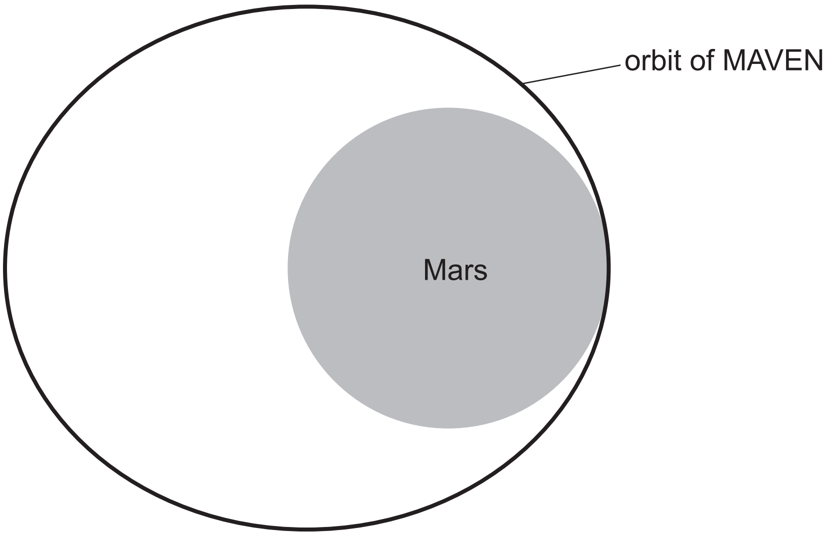
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks might be given for a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **24** pages.

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

1 The MAVEN spacecraft orbits Mars and studies its upper atmosphere.

(a) The diagram below shows the orbit of MAVEN around Mars.



(i) Mark an **X** on the diagram to show the point in the orbit where MAVEN has maximum acceleration. **[1]**

(ii) Explain how Kepler's 1st law applies to MAVEN's orbit around Mars.

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.... **[2]**

(b) The table shows data for four orbits around Mars.

Phobos and Deimos are moons of Mars.

An areostationary orbit for Mars is the equivalent of a geostationary orbit for Earth.

Orbit	Time period / hours	Average distance from centre of Mars / km
MAVEN	4.5	6500
Phobos	7.7	9400
Deimos	30	23000
Areostationary	25	20000

(i) Show that Kepler's 3rd law applies to this data.

[2]

(ii) Suggest **two** reasons why MAVEN was **not** placed in an areostationary orbit.

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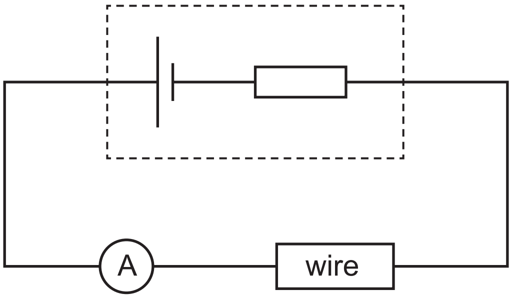
[2]

2 A student uses the circuit below to investigate the resistivity of a wire.



The cell has e.m.f. ε and internal resistance r. The wire has resistivity ρ and diameter d.

(a) The student takes five measurements of the diameter of the wire, which are shown in the table below.

Diameter / mm	0.460	0.450	0.455	0.495	0.455

(i) Suggest how the student made these measurements.

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.... **[2]**

(ii) The student calculates the value of the diameter as $d = 0.455 \pm 0.005$ mm.

Explain how the student calculated the value of the diameter, and its uncertainty, from the data in the table above.

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.... **[3]**

(b) The student varies the length L of the wire in the circuit and records the current I using the ammeter.

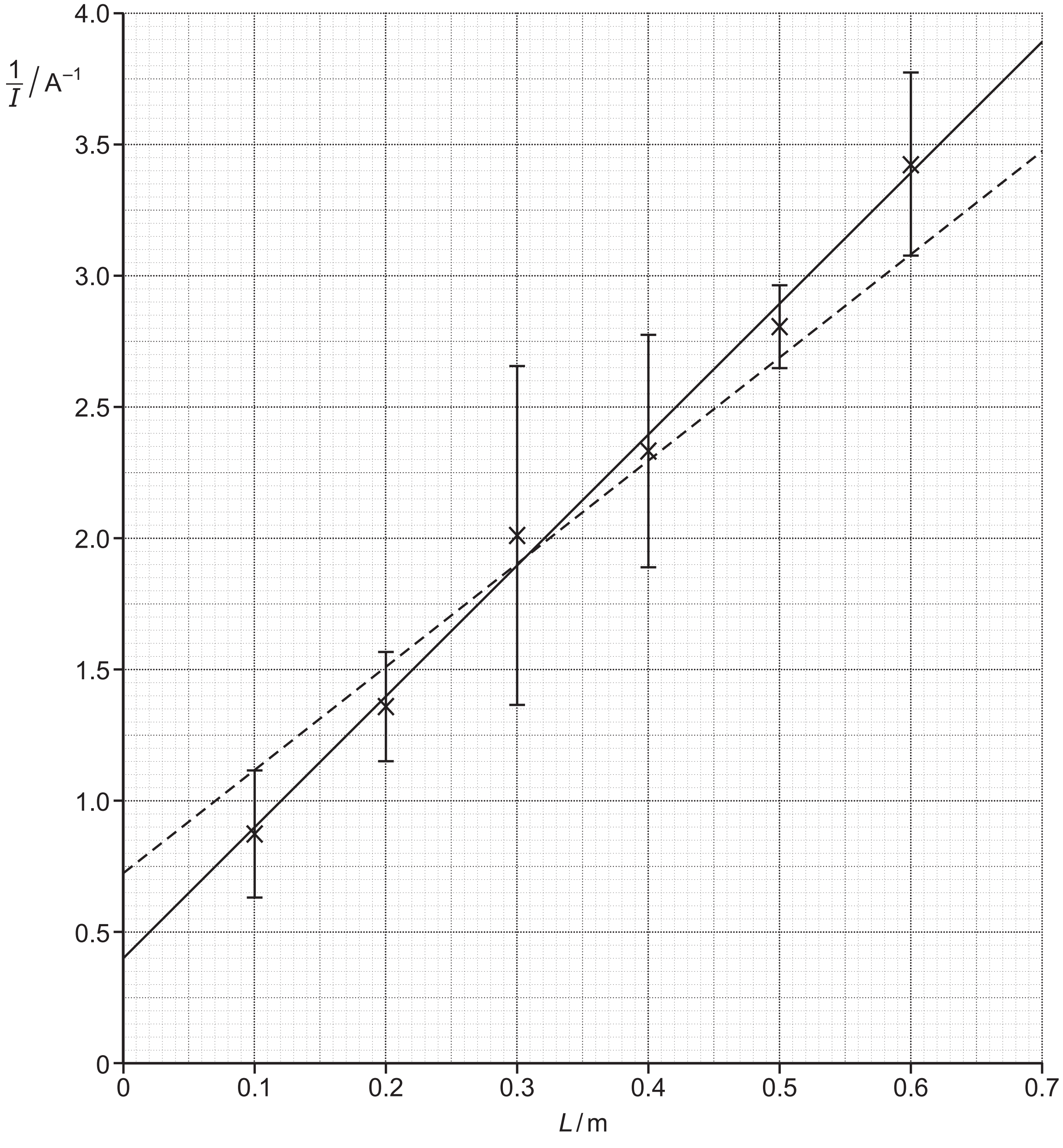
(i) Show that

$$\frac{1}{I} = \left(\frac{4\rho}{\pi\varepsilon d^2}\right)L + \frac{r}{\varepsilon}$$

[3]

Question 2 continues on page 6

(ii) The student plots a graph of $\frac{1}{I}$ against L. The data points, error bars, line of best fit and a line of worst fit are shown in the graph below.



The cell has e.m.f. $\varepsilon = 1.45 \pm 0.05\,\text{V}$

The wire has diameter $d = 0.455 \pm 0.005\,\text{mm}$

1 Calculate the gradient of the best fit line and use this to determine a value for the resistivity ρ of the wire.

You are **not** required to determine an uncertainty.

ρ = ... Ω m **[2]**

2 Determine a value for the internal resistance r of the cell **and** its absolute uncertainty.

r = ... ± .... Ω **[4]**

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3 A pulsar is a rapidly rotating neutron star that emits radio waves.

(a) **(i)** Describe the formation of a neutron star.

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.... **[2]**

(ii) State **one** characteristic of a neutron star.

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.... **[1]**

(b) A typical neutron star can be modelled as a sphere with mass ≈ 2×10^{30} kg and radius ≈ 10 km.

Show that the average density of a neutron star is similar to the average density of an atomic nucleus.

- radius of a nucleon ≈ 1 fm

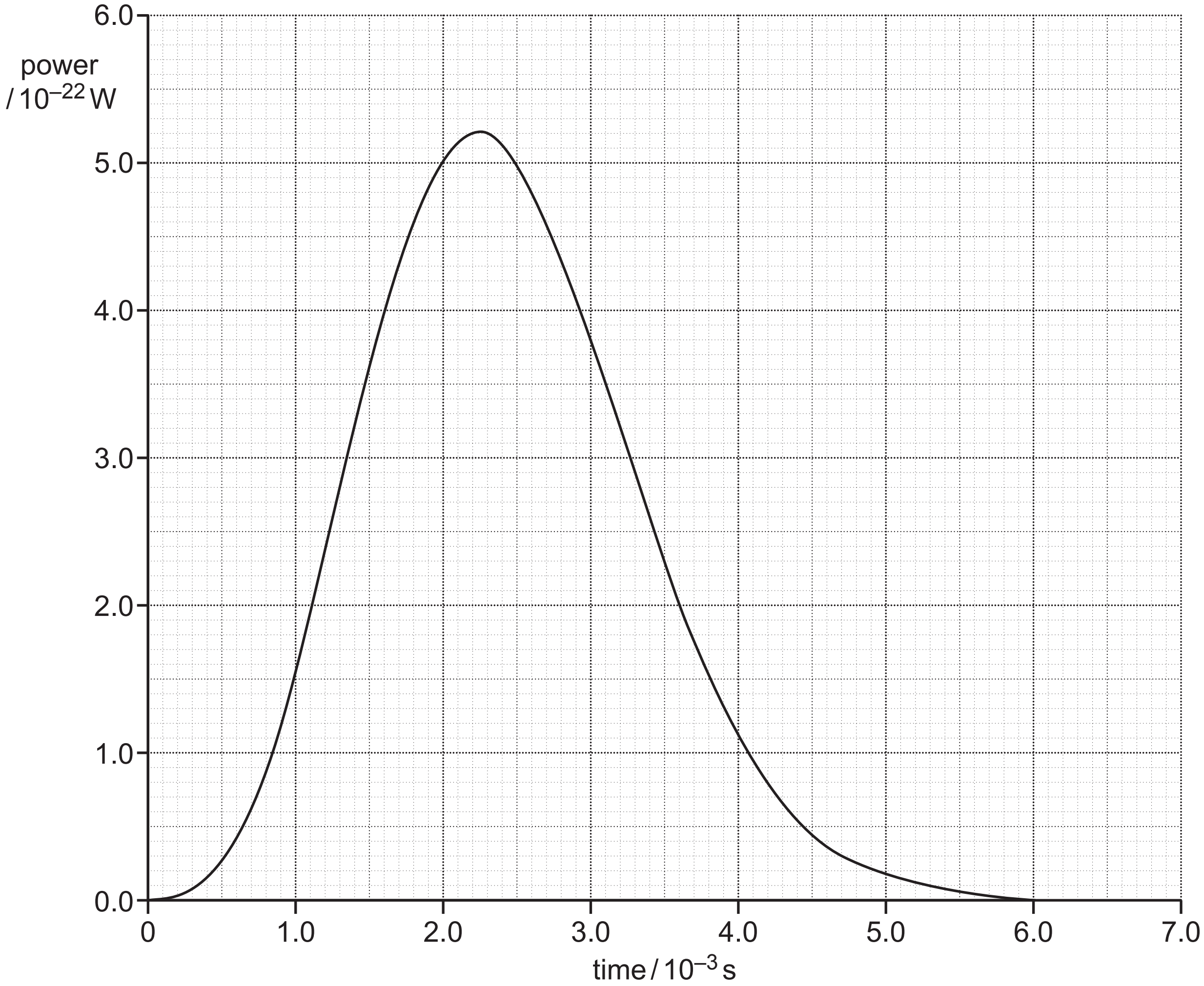
[3]

Question 3 continues on page 10

Turn over

(c) An astronomer uses a radio telescope to observe a pulsar.

The graph below shows the power that the telescope receives due to the radio waves from one full rotation of a pulsar.



(i) By calculating the area between the curve and the horizontal axis, estimate the total energy received by the telescope in one full rotation of the pulsar.

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

(ii) The surface area of the telescope is about 3000 m^2.

The distance to the pulsar is about 300 pc.

By assuming that the radiation from the pulsar is emitted equally in all directions, estimate the total energy emitted in one full rotation.

energy emitted = ... J **[3]**

4 A cloud is made up of droplets of water falling at terminal velocity.

(a) Describe and explain the motion of an object falling at terminal velocity.

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.... **[3]**

(b) **(i)** The terminal velocity v of a small sphere of density ρ_s and radius r falling through a fluid of density ρ_f is given by the formula:

$$v = \frac{2gr^2(\rho_s - \rho_f)}{9\eta}$$

where η is a constant for the fluid and g is the acceleration of free fall.

Water droplets of rain fall to the ground whereas water droplets in mist appear to float.

Use the formula above to suggest why.

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.... **[2]**

***(ii)** A student models water droplets falling through air using small solid spheres in a liquid.

The table shows properties of the materials available to the student.

Material	**Solid density, ρ_s / kg m^{-3}**	**Liquid density, ρ_f / kg m^{-3}**	**Approximate value of η / 10^{-3} kg m^{-1} s^{-1}**
Water (liquid)		1000	1
Sunflower oil (liquid)		920	50
Steel (solid sphere)	7800		
Lead (solid sphere)	11300		

Describe an experiment to verify the expression given in **(i)** as accurately as possible. As part of your answer, estimate the **lowest** terminal velocity if the student uses a solid sphere of diameter = 1 mm.

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.... **[6]**

Additional answer space if required

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5 Large power stations generate an electrical power of about 1 GW.

Current methods of energy production that use nuclear fusion are unable to produce enough energy for large-scale energy production. A proposed method of controlling nuclear fusion is inertial confinement fusion (ICF). ICF uses a large number of powerful lasers to create the high temperatures required for nuclear fusion to occur.

One ICF experiment uses a network of capacitors to store the energy needed to power the lasers. When the network is fully charged:

- potential difference across the network = 24 kV
- total energy stored in the network = 400 MJ

(a) **(i)** Calculate the total capacitance, *C*, of the network.

C = ... F **[2]**

(ii) Explain why the individual capacitors in the network should be connected in parallel in order to produce this total capacitance.

....

.... **[1]**

(b) The total stored energy must be released in a time of less than 1 millisecond.

Explain, using a calculation, why the lasers are powered by the network of capacitors instead of being connected directly to the mains electricity supply.

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.... **[2]**

(c) The fusion reaction in the ICF experiment is

deuterium + tritium $\rightarrow$ alpha particle + neutron

Calculate the number of fusion reactions that must occur for the energy released by fusion to be equal to the electrical energy stored in the network of capacitors.

- mass of deuterium = 2.014102 u
- mass of tritium = 3.016049 u
- mass of alpha particle = 4.002603 u
- mass of neutron = 1.008665 u

number of fusion reactions = ... **[4]**

6 A 3D printer can manufacture small objects.

Some 3D printers use polylactic acid (PLA). PLA is supplied in the form of long filaments. The 3D printer melts the PLA and builds up the shape of the desired object in layers.

The electrical supply to the heater in the printer has an e.m.f., ε, of 12 V. The power of the heater is 40 W.

(a) Calculate the resistance, *R*, of the heater.

R = ... Ω **[2]**

(b) The specific latent heat of fusion of PLA is $9.4 \times 10^4\ \mathrm{J\,kg^{-1}}$ and its melting point is 160 °C.

(i) Define **specific latent heat of fusion**.

....

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.... **[1]**

(ii) Calculate the **maximum** mass *m* of PLA that the heater could melt in one minute.

m = ... kg **[2]**

(iii) Explain why the printing process is slower in practice than your answer to **(ii)** suggests.

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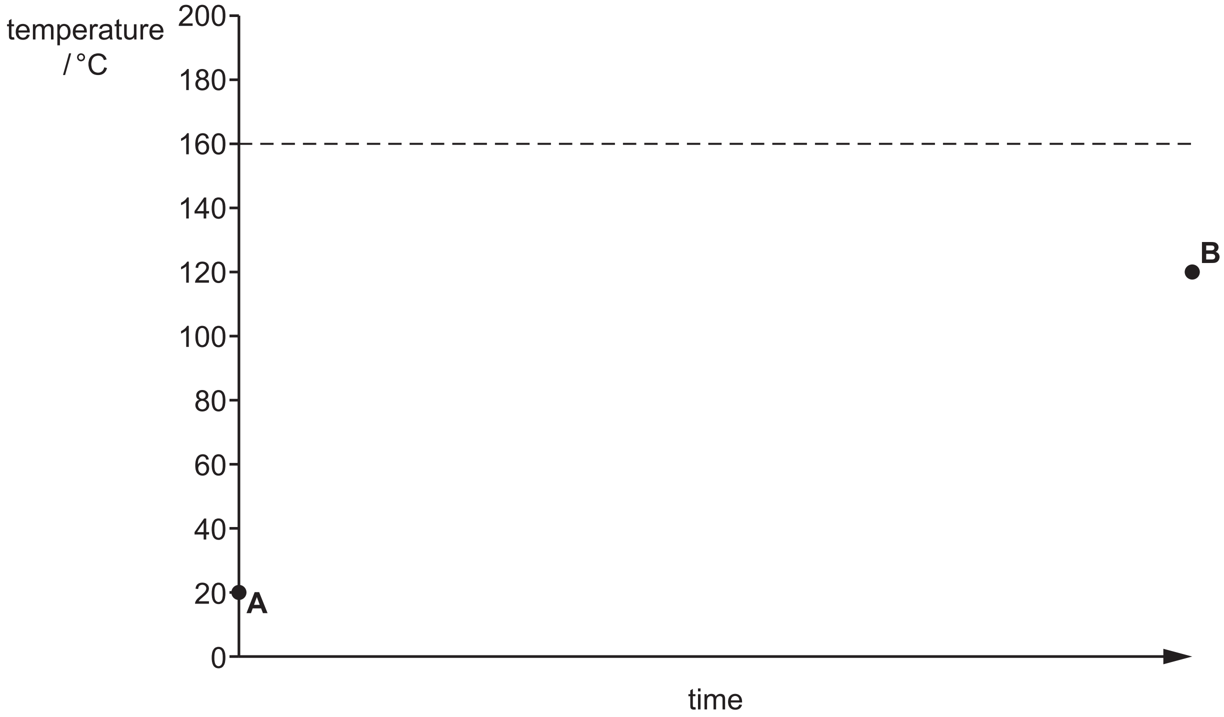
.... **[2]**

(iv) **Fig. 6.1** shows the initial and final temperature of the PLA during the printing process.

Initially (point **A**), the solid PLA is at 20 °C and is just entering the heater. Later (point **B**), the PLA has been added to the object and is solid again.

Fig. 6.1



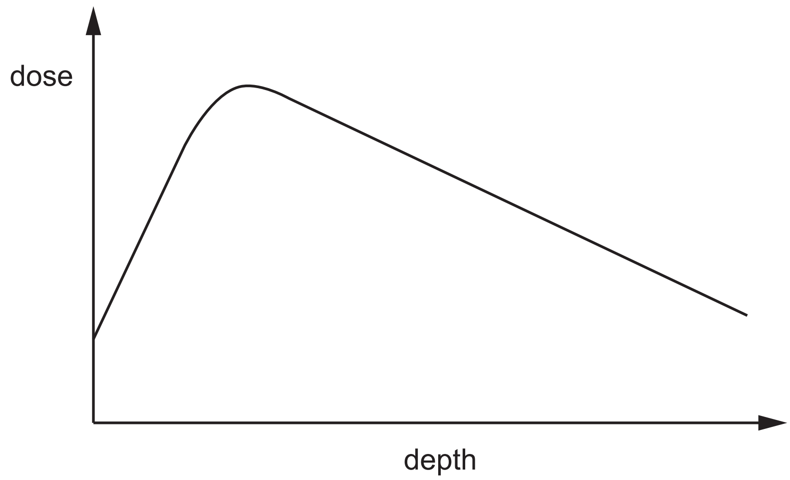
Complete **Fig. 6.1** to show how the temperature of the PLA changes between **A** and **B**. You are **not** required to label the time axis. **[3]**

(c) High-energy X-ray photons can destroy living cells. In radiotherapy, these photons are targeted at cancer cells.

The radiation **dose** is the amount of energy that a patient's body absorbs from the high-energy X-ray photons.

Fig. 6.2 shows how this dose changes with depth below the surface of the skin.

Fig. 6.2



The dose initially rises with depth because the high-energy X-ray photons produce electrons and positrons as they pass through the body. These electrons and positrons are quickly absorbed, increasing the dose.

(i) Explain why high-energy X-ray photons produce electrons **and** positrons as they pass through the body.

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.... **[2]**

***(ii)** A 3D object called a **bolus** is used in radiotherapy for patients with skin cancer. A bolus targets the maximum radiation dose near the surface of the skin. So using a bolus makes the radiotherapy more effective.

A bolus can be made from PLA using a 3D printer. The bolus must fit the shape of the patient's body exactly. This shape is found beforehand by giving the patient either a CAT scan or a PET scan.

- Explain how CAT scans and PET scans work.
- Discuss the advantages and disadvantages of having a scan to produce a bolus for radiotherapy.

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Additional answer space if required

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END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR

Oxford Cambridge and RSA

Monday 17 June 2024 – Morning

A Level Physics A

H556/03 Unified physics

Time allowed: 1 hour 30 minutes

You must have:
- the Data, Formulae and Relationships Booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

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 page at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
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INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

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

Answer **all** the questions.

1 A flute is a musical instrument made from a long tube that is open at both ends.

A stationary sound wave in the tube produces a musical note.

The lowest frequency note that a standard flute produces in air is 262 Hz.

The speed of sound in air at a temperature of 20 °C is $340\,\text{m}\,\text{s}^{-1}$.

(a) Show that a standard flute has an approximate length of 0.65 m.

[3]

(b) In an ideal gas, the speed v of sound is given by

$$v = \left(\frac{\gamma RT}{M}\right)^{1/2}$$

where

γ is a dimensionless constant that depends on the gas

R is the molar gas constant

T is the absolute temperature

M is the molar mass of the gas.

The table below shows values of γ and M for both air and helium.

Gas	**γ**	**M / g mol^{-1}**
Air	1.40	29.0
Helium	1.67	4.00

(i) The kinetic model of an ideal gas assumes that there are a large number of particles in rapid, random motion.

State **two** further assumptions for the kinetic model of an ideal gas.

1 ....

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2 ....

.... **[2]**

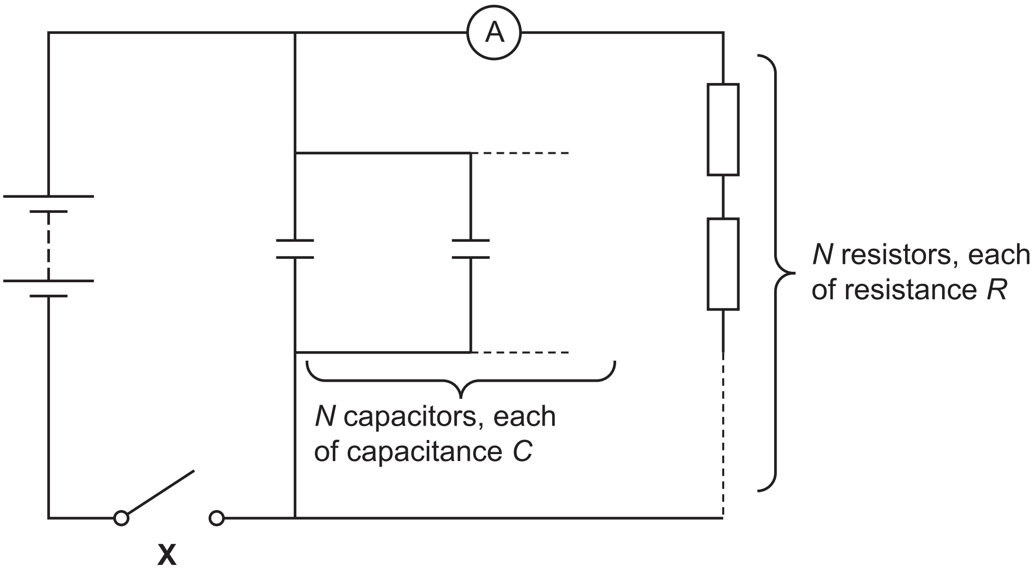
(ii) A standard flute is placed inside a sealed chamber.

The chamber is filled with helium at a temperature of –10 °C.

Calculate the lowest frequency that the flute could produce inside the chamber.

frequency = ... Hz **[4]**

2 A group of students investigate the circuit shown in the figure below.



There are N capacitors, each of capacitance C, connected in parallel.

There are N resistors, each of resistance R, connected in series.

Initially, the students close the switch **X**. They then note the reading on the ammeter.

The students then open the switch. They record the time T for the reading on the ammeter to fall to half of its initial value.

The table below shows the students' results.

N	***T* / s**			
	1	**2**	**3**	**Mean**
1	14.7	14.1	14.3	....
2	50.3	49.6	50.1	....
3	126.6	126.3	125.2	126.0
4	224.4	224.3	225.9	224.9
5	356.1	354.3	345.6	352.0
6	500.4	512.7	499.5	504.2

(a) Show that $T = (\ln 2)N^2RC$.

[2]

(b) The students write in their lab books, "Our data is precise".

Evaluate this statement.

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.... **[2]**

Question 2 continues on page 6

(c) The results table is repeated below.

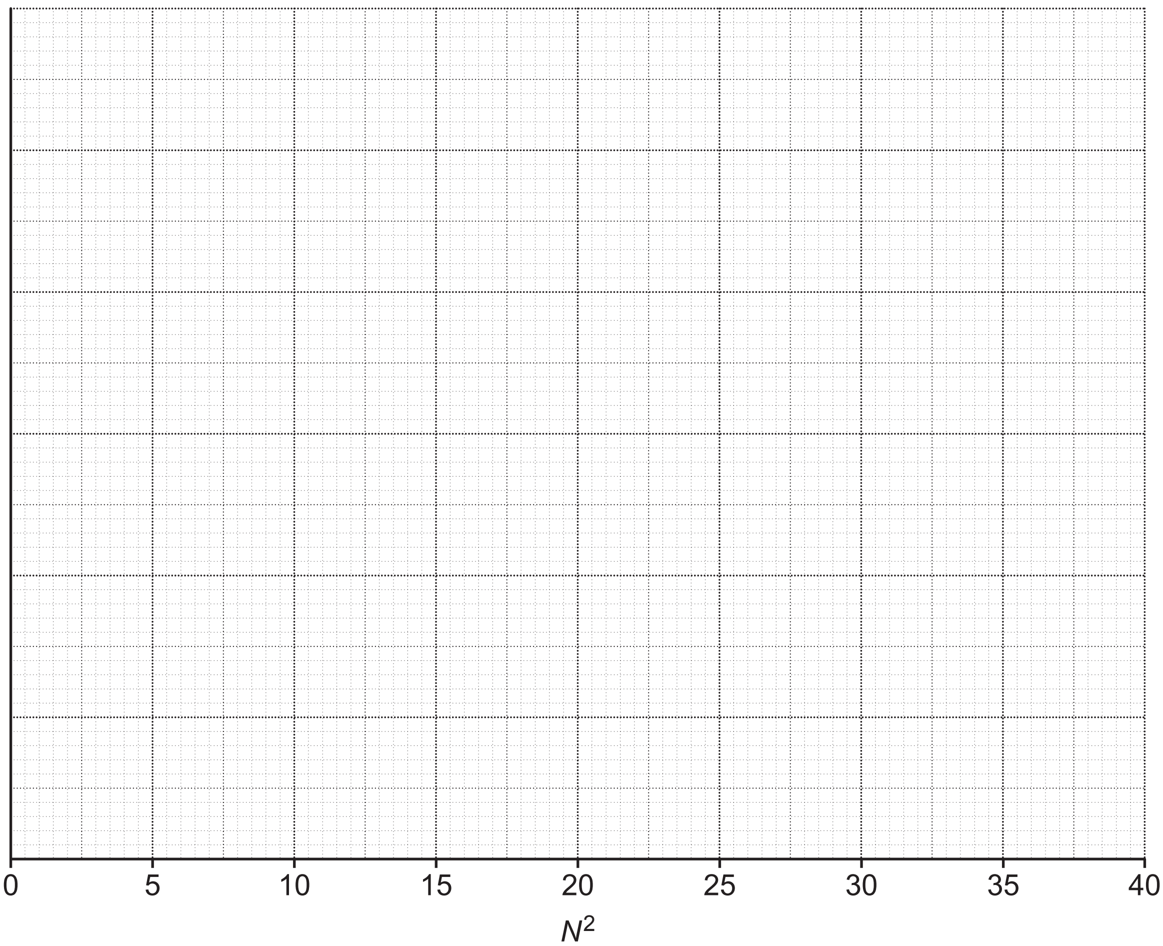
Complete the last column for $N = 1$ and $N = 2$ in the table below.

N	T / s			
	1	**2**	**3**	**Mean**
1	14.7	14.1	14.3	....
2	50.3	49.6	50.1	....
3	126.6	126.3	125.2	126.0
4	224.4	224.3	225.9	224.9
5	356.1	354.3	345.6	352.0
6	500.4	512.7	499.5	504.2

[1]

(d) The students begin to plot a graph of T (y-axis) against N^2 (x-axis).

(i) Complete the graph below and plot the 6 results from the table. You are **not** expected to include error bars. **[4]**



(ii) Draw a straight line of best fit on the graph. **[1]**

(iii) Calculate the gradient of the straight line of best fit.

gradient = ... s **[2]**

(iv) The value of *C* is known to be 1000 μF ± 5%.

Use your gradient value from **(iii)** to find a value for *R*, in units of kΩ, including an **absolute** uncertainty.

R = ... ± .... kΩ **[2]**

(e) Following the investigation, the students discovered that the sixth 1000 μF capacitor connected to the circuit was actually two 470 μF capacitors connected in parallel.

(i) State the type of error caused by this mistake.

.... **[1]**

(ii) Explain the effect that this error would have had on the calculated value of *R*.

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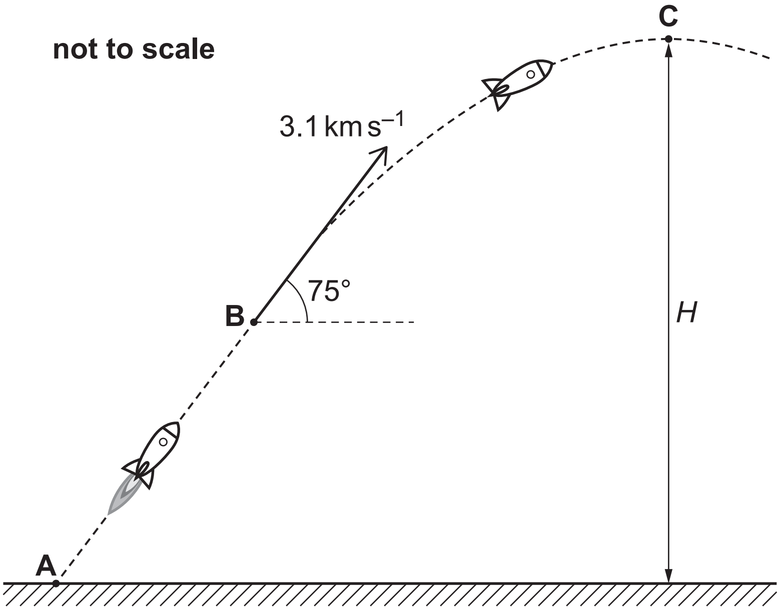
.... **[1]**

3 A scientist uses a rocket to study the Earth's atmosphere.

The scientist launches the rocket from rest at the point **A** at t = 0 seconds. The force produced by the rocket's engine causes it to accelerate.

At t = 50 seconds, the rocket's engine no longer produce an accelerating force as all of the fuel has been used. The rocket has reached point **B**. Its velocity is now 3.1 km s^{-1} at an angle of 75° to the horizontal.



(a) The rocket engine works by expelling hot gas backwards.

Explain, using Newton's laws of motion, how the engine causes the rocket to accelerate between t = 0 and t = 50 s.

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.... **[3]**

***(b)** The rocket reaches its maximum height at point **C**.

- Estimate the vertical displacement H between **A** and **C**. Assume that $g = 9.81\,\mathrm{m\,s^{-2}}$ throughout.
- Clearly state any other assumptions required at each stage in your calculations.
- Evaluate the assumption that $g = 9.81\,\mathrm{m\,s^{-2}}$ between **A** and **C**, supporting your discussion with a calculation. Assume that the radius of the Earth ≈ 6400 km.

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Additional answer space if required

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.... **[6]**

4 The length of an unloaded spring is approximately 4 cm.

The force constant k of the spring is $0.62\,\text{N}\,\text{cm}^{-1}$.

(a) Describe how you could determine k using an appropriate experiment.

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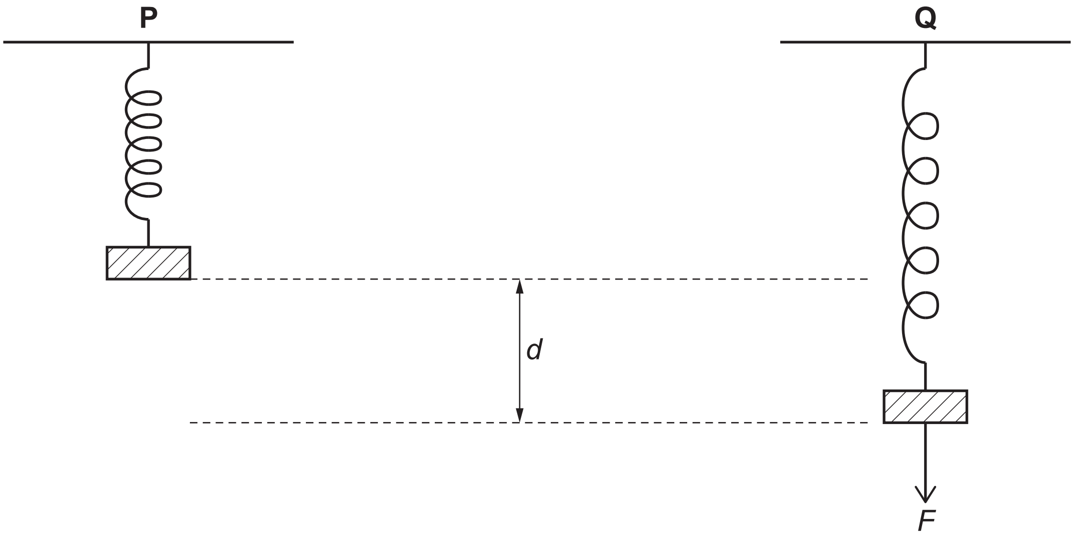
.... **[3]**

(b) The figure below shows a block of mass 0.20 kg attached to one end of the spring. The other end of the spring is attached to a fixed support vertically above the block.

In position **P** the block rests in equilibrium. The extension of the spring is 3.2 cm.

In position **Q** a downwards force F has been applied to the block, so that it now rests a distance d below its position at **P**. The extension of the spring is now 8.5 cm.



The force F is removed.

(i) Calculate the magnitude of the block's initial acceleration at the instant that the force F is removed.

Assume that the spring is not extended beyond its limit of proportionality.

acceleration = ... $m\,s^{-2}$ **[3]**

(ii) The block now moves with simple harmonic motion.

Calculate the frequency of this motion.

frequency = ... Hz **[3]**

(c) The block is replaced by a strong magnet **L** of slightly greater mass.

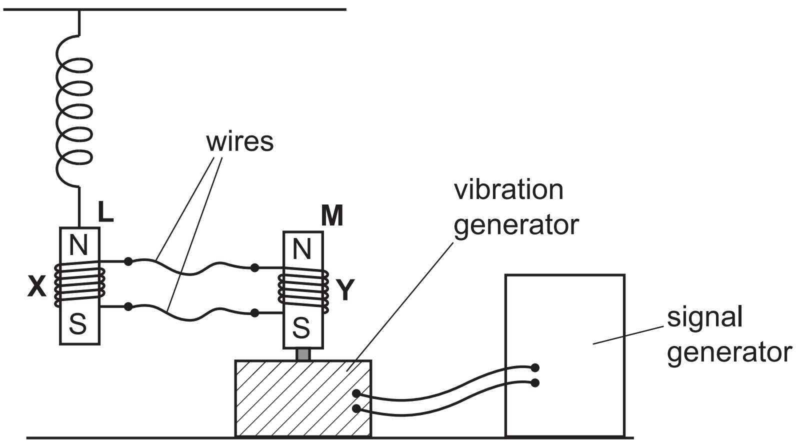
The oscillation frequency of this new arrangement is 2.5 Hz.

The magnet **L** is placed inside a coil **X** of insulated copper wire.

The coil **X** is connected with long wires to a second, identical coil **Y**.

A second strong magnet **M** is placed inside **Y** and attached to a vibration generator.

The vibration generator is then forced to oscillate with a frequency of approximately 2.5 Hz by adjusting the signal generator.



(i) As magnet **M** oscillates, it moves in and out of coil **Y**.

The magnet **L** also begins to oscillate.

Explain why **L** oscillates.

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.... **[3]**

(ii) The frequency of the vibration generator is now varied between 0.5 Hz and 5.0 Hz.

Suggest how the amplitude and frequency of the oscillations of **L** will change as the frequency of the generator is varied.

You may draw a diagram to support your answer.

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.... **[3]**

5

(a) Explain what is meant by

(i) internal resistance of a cell

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.... **[1]**

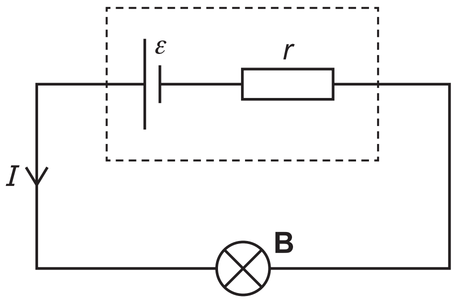
(ii) e.m.f. of a cell.

....

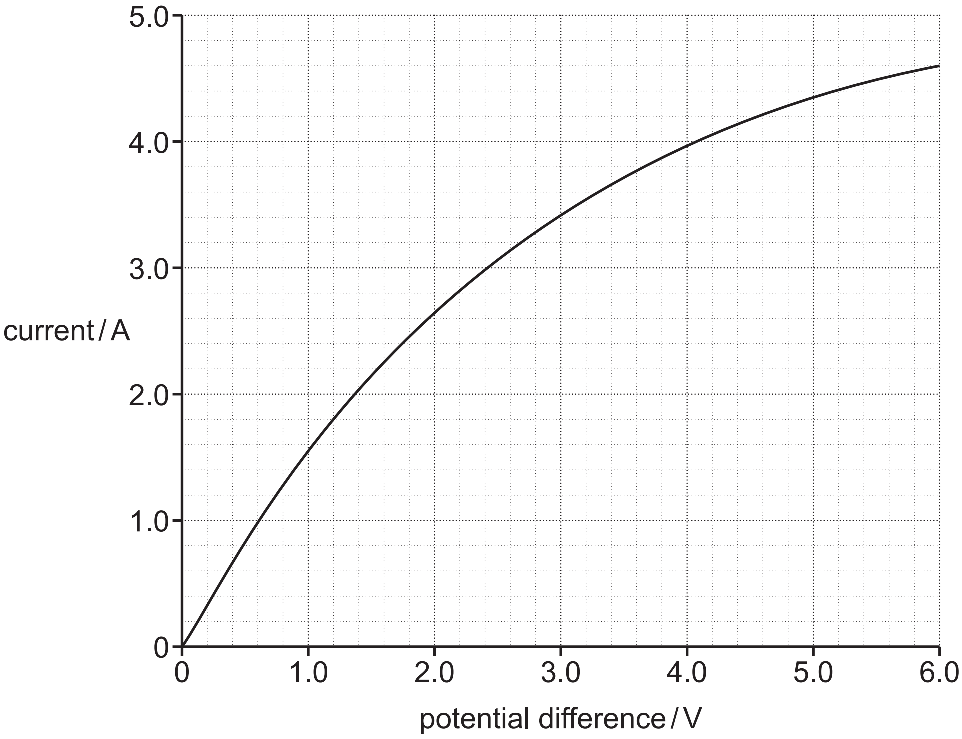
.... **[1]**

(b) A cell has internal resistance $r = 1.2\,\Omega$ and e.m.f. $\varepsilon = 5.6\,V$.

When the cell is connected to a filament lamp **B**, as shown in the circuit diagram below, the current in the circuit is I.



The I-V characteristic for **B** is shown in the figure below.



Determine the current I in the circuit.

current = ... A **[3]**

Question 5 continues on page 16

***(c)** A student wants to determine the internal resistance *r* and the e.m.f. ε of a different cell.

The student knows that the internal resistance is approximately 0.1 Ω.

The only other **electrical** equipment available is as follows:

- one voltmeter
- one ammeter
- one sensitive thermistor, known to have resistance of approximately 0.1 Ω at 20 °C
- several connecting wires and crocodile clips.

Describe how the student can determine *r* and ε for the cell.

Include how the student should:

- collect and analyse the data
- determine the uncertainties in the values of *r* and ε.

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Additional answer space if required

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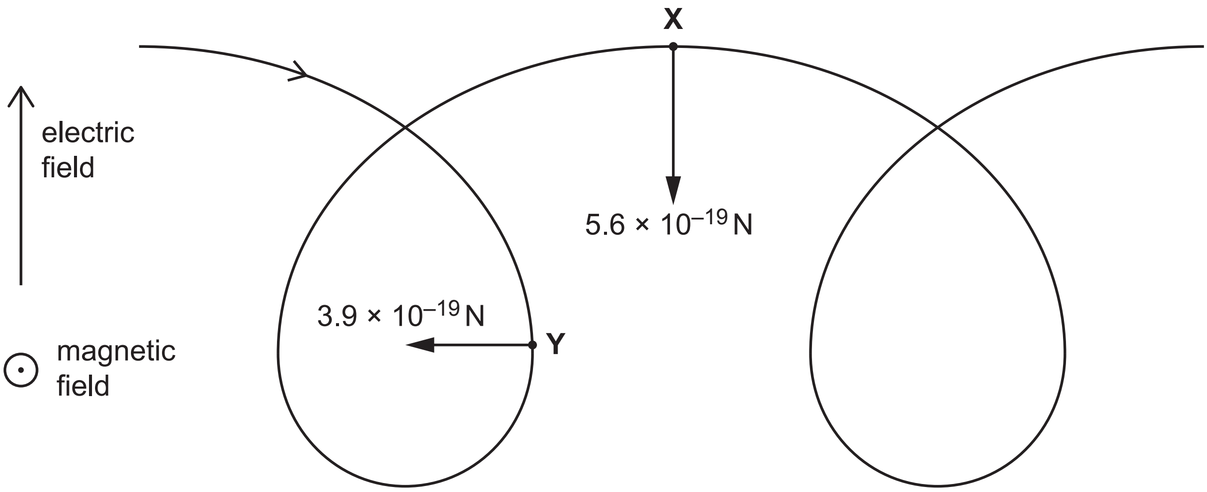
.... **[6]**

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 $E = 0.90\,\mathrm{N\,C^{-1}}$.

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

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

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

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 $10^{-19}\,\mathrm{N}$.

[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]**

END OF QUESTION PAPER

EXTRA ANSWER SPACE

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