OXFORD AQA
INTERNATIONAL QUALIFICATIONS

Please write clearly in block capitals.

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Forename(s) ____________________

Candidate signature ____________________
I declare this is my own work.

INTERNATIONAL A-LEVEL
PHYSICS

Unit 4 Energy and Energy resources

Tuesday 10 June 2025   07:00 GMT   Time allowed: 2 hours

Materials
For this paper you must have:
- a Data and Formulae Booklet as a loose insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate
- a protractor.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7–21	
TOTAL	

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Section A

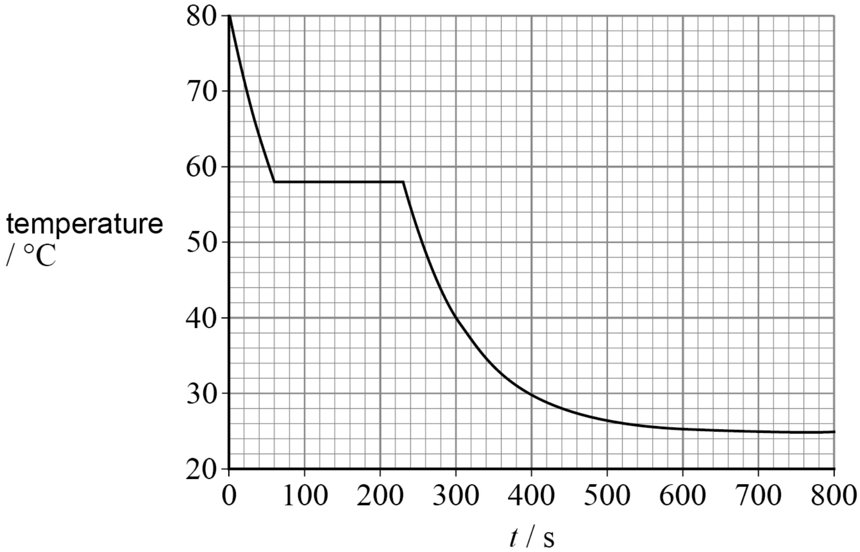
Answer **all** questions in this section.

0 1 A test tube contains a sample **S** of a liquid at $80.0\ ^\circ\mathrm{C}$.

A student records the temperature of **S** using a temperature sensor and data logger. At time $t = 0$, **S** starts to cool down. It turns into a solid before cooling to room temperature.

Figure 1 shows the variation of the temperature of **S** with t.

Figure 1



0 1 . 1 Suggest why the student uses a temperature sensor and data logger rather than a thermometer and stopclock when recording the temperature in this experiment.

[1 mark]

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0 1 . 2 Explain, in terms of energy transfer, why the temperature of **S** does not change between $t = 60$ s and $t = 230$ s.

[2 marks]

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Table 1 shows some of the properties of **S**.

Table 1

mass / kg	6.60×10^{-2}
specific heat capacity of liquid / $J\ kg^{-1}\ K^{-1}$	2.80×10^{3}
specific latent heat of fusion / $J\ kg^{-1}$	2.64×10^{5}
specific heat capacity of solid / $J\ kg^{-1}\ K^{-1}$	2.10×10^{3}

0 1 . 3 Calculate the total energy transferred from **S** during the time shown in **Figure 1**.

[4 marks]

energy transferred = ____________________ J

0 1 . 4 Determine, using **Figure 1**, the rate of temperature decrease of **S** when $t = 300$ s.

[2 marks]

rate = ____________________ $K\ s^{-1}$

Question 1 continues on the next page

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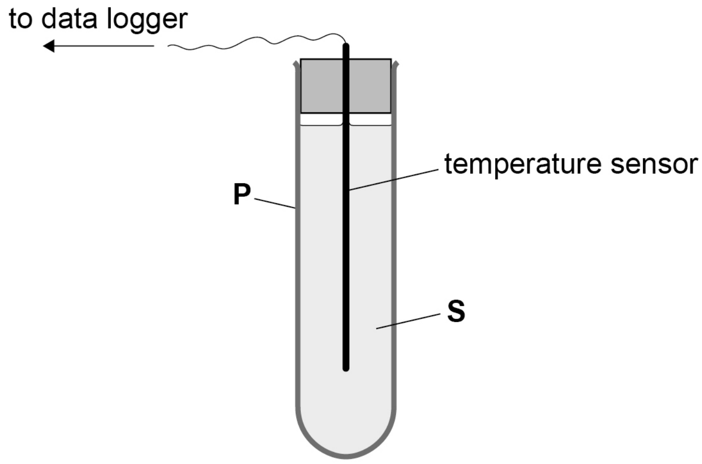
0 1 . 5 **Figure 2** shows **S** in the test tube.

Figure 2



P is a point on the **outside** of the test tube as shown in **Figure 2**.

The test tube is made from glass of thickness $1.2\ \text{mm}$.
The thermal conductivity of the glass is $1.14\ \text{W m}^{-1}\ \text{K}^{-1}$.

Energy is transferred by conduction from **S** through an area of $8.0 \times 10^{-3}\ \text{m}^2$ of the glass. Assume that all the energy transferred from **S** is by conduction through this area.

When $t = 400\ \text{s}$ the rate of temperature decrease of **S** is $0.055\ \text{K s}^{-1}$.

Determine the temperature of **P** when $t = 400\ \text{s}$.

[3 marks]

temperature of **P** = ____________________ °C

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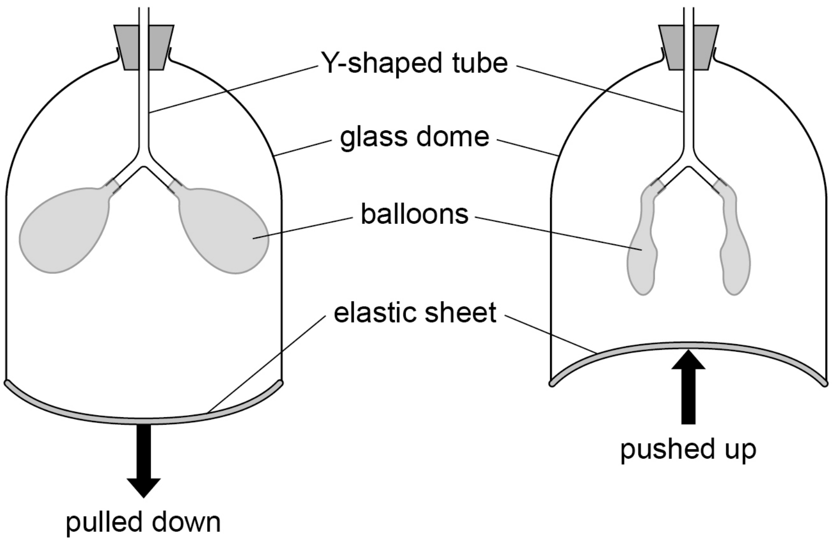
0 2 **Figures 3a** and **3b** show a simple model of the human breathing system.
The model consists of a glass dome that contains two balloons.
The balloons are connected by a Y-shaped tube that is open to the atmosphere at one end.
Air can be made to enter or leave the balloons by moving an elastic sheet that covers the bottom of the dome.

Figure 3a **Figure 3b**



The air is heated as it travels through the Y-shaped tube. The heater is not shown.
The air that enters the balloons is at a temperature of 32 °C.

0 2 . 1 The temperature of the air before it enters the Y-shaped tube is 15 °C.

Calculate the change in the average molecular kinetic energy of air when its temperature is increased from 15 °C to 32 °C.

[2 marks]

change in average molecular kinetic energy = ____________________ J

Question 2 continues on the next page

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The elastic sheet is pulled down as shown in **Figure 3a** and then pushed up as shown in **Figure 3b**.

Air moves in and out of the balloons so that the air inside the balloons is always at atmospheric pressure.

Table 2 shows data for the air in one balloon.

Table 2

	Figure 3a	**Figure 3b**
volume / 10^2 cm^3	3.1	0.35
temperature / °C	32	32

Atmospheric pressure is 1.10×10^5 Pa.
Assume that the air behaves as an ideal gas.

0 2 . 2 Calculate the work done on the air as it leaves **one** balloon.

[2 marks]

work done = ______________________ J

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0 2 . 3 Calculate the number of particles of air that leave **one** balloon when the elastic sheet is pushed up.

[3 marks]

number of particles = ____________________

0 2 . 4 The model is taken to the top of a mountain.
The air in the balloons is now at a much smaller atmospheric pressure.
The air entering the Y-shaped tube is also at a much lower temperature.

The air is now heated to a temperature of $32\ ^\circ\mathrm{C}$ as it travels through the tube, as in Question **02.1**.

Discuss, without calculation, how taking the model to the top of the mountain affects the energy required to:

- move the same volume of air as in Question **02.2**
- heat the same number of air particles to the same temperature as in Question **02.3**
- move the same number of particles out of **one** balloon as calculated in Question **02.3**.

[3 marks]

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0 3 Experiments are done to determine the nuclear radius of an iron isotope **X** and of an iron isotope **Y**.

A nucleus of **X** contains 26 protons and 28 neutrons.

0 3 . 1 The radius of a nucleus of **X** is measured as 4.30×10^{-15} m using electron diffraction.

Determine the density of this nucleus.

[3 marks]

density = ____________________ $\mathrm{kg\ m^{-3}}$

0 3 . 2 The radius of a nucleus of **Y** is measured as 4.40×10^{-15} m using electron diffraction.

Determine the number of neutrons in the nucleus of **Y**.

[3 marks]

number of neutrons = ____________________

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The nuclear radius of **X** and the nuclear radius of **Y** are estimated using the closest approach of an alpha particle.

0 3 . 3 The upper limit for the radius of a nucleus of **X** is estimated to be 5.0×10^{-14} m.

Calculate the initial speed of an alpha particle that gives this estimate.
Assume that the nucleus remains at rest during the interaction.

[4 marks]

initial speed = ____________________ m s^{-1}

0 3 . 4 The upper limit for the radius of a nucleus of **Y** is estimated using an alpha particle with the same initial speed as in Question **03.3**.

Suggest a value for this estimate.
Explain your answer.

[1 mark]

estimate of upper limit for radius = ____________________ m

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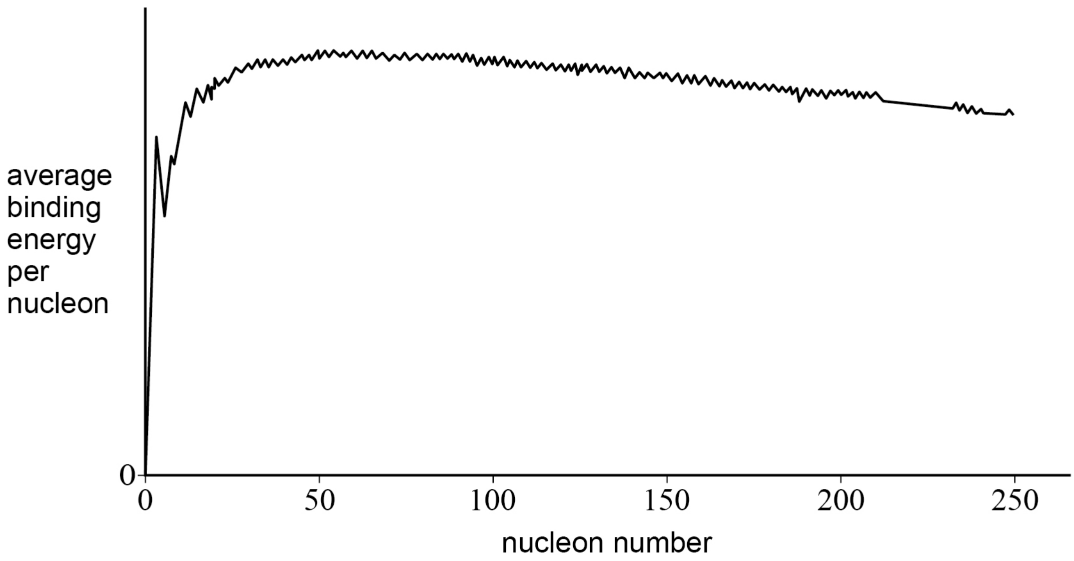
0 4 **Figure 4** is a plot of average binding energy per nucleon against nucleon number for common nuclides.

Figure 4



0 4 . 1 Explain how:

- the fission of a nucleus and the fusion of nuclei can release energy
- the fission of a nucleus can release a greater amount of energy than the fusion of two nuclei.

Refer to relevant regions of **Figure 4** in your answer.

[4 marks]

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0 4 . 2 The reaction below occurs in a nuclear reactor.

$$^{236}_{92}\text{U} \rightarrow {}^{146}_{57}\text{La} + {}^{87}_{35}\text{Br} + 3\,^{1}_{0}\text{n}$$

Table 3 gives data for the nuclides in this reaction.

Table 3

Nuclide	**Binding energy per nucleon / MeV**
$^{236}_{92}\text{U}$	7.5865
$^{146}_{57}\text{La}$	8.2400
$^{87}_{35}\text{Br}$	8.6059

Calculate, in J, the energy released in the reaction.

[3 marks]

energy = ____________________ J

Question 4 continues on the next page

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0 4 . 3 An iron $\left({}^{56}_{26}\mathrm{Fe}\right)$ nucleus has a mass of $55.935\ \mathrm{u}$.

Calculate, in MeV, the binding energy of this nucleus.

[3 marks]

binding energy = ____________________ MeV

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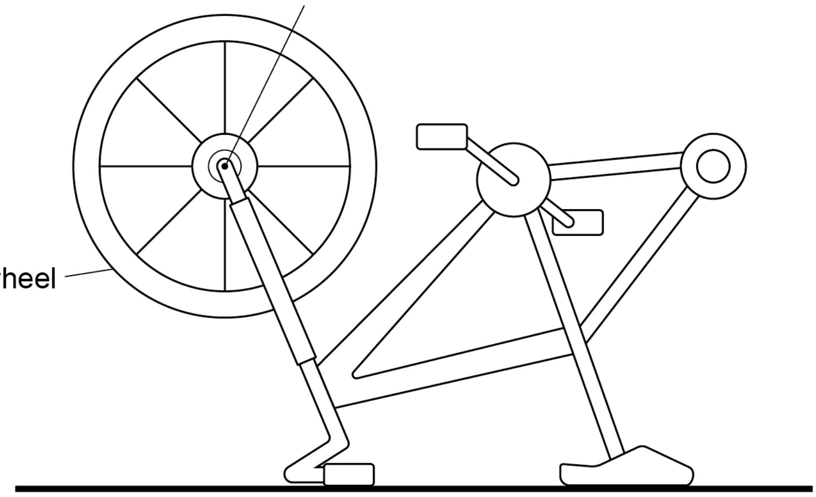
0 5 A student investigates the frictional torque on the wheel of a bicycle.

Figure 5 shows a bicycle that has been turned upside down and placed on level ground. The back wheel is removed. The front wheel is not connected to the pedals. The axis of rotation **Q** of the front wheel is horizontal.

Figure 5



0 5 . 1 The wheel has an initial angular speed of $21\ \text{rad s}^{-1}$.

A frictional torque of $3.6 \times 10^{-3}\ \text{N m}$ acts on the wheel.
The wheel takes 481 revolutions to come to rest.

Calculate the moment of inertia of the wheel.

[3 marks]

moment of inertia = ____________________ kg m^2

Question 5 continues on the next page

Turn over ►

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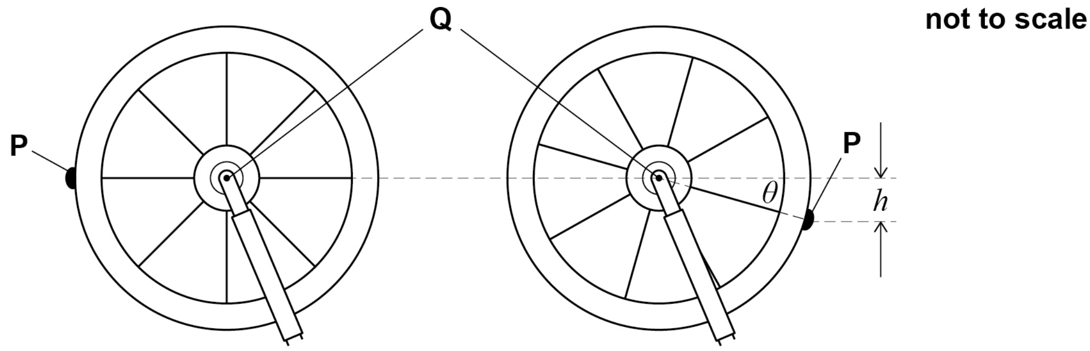
The student then reduces the frictional torque on the wheel and attaches a mass **P** to the outside of the wheel.

The mass of **P** is $0.017\ \text{kg}$.

The edge of the wheel is held with **P** at the same height above the ground as **Q**, as shown in **Figure 6a**. The edge is then released and the wheel begins to rotate.

Figure 6b shows the wheel when it comes to rest for the first time. The angle θ between the horizontal and the line from **Q** through the centre of mass of **P** is measured.
The vertical distance h from the centre of mass of **P** to its starting position is also measured.

Figure 6a **Figure 6b**



position when the wheel is released **position when the wheel comes to rest for the first time**

The work done by the frictional torque is equal to the change in the gravitational potential energy of **P**.

0 5 . 2 The student obtains the following readings:
$\theta = 5°$
$h = 4.8\ \text{cm}$

Calculate the new frictional torque.

[4 marks]

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new frictional torque = ______________ N m

0 5 . 3 The student now repeats the investigation.

Describe how repeated measurements can be used to determine the absolute uncertainty in the value of the frictional torque.

Assume that the uncertainty in the mass of **P** is negligible.

[4 marks]

11

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0 6 A wind farm is being designed to provide power to a small town.

0 6 . 1 Explain the factors that affect the design of the wind farm and its location.

In your answer you should consider:
- the factors that affect the maximum power that is available from a wind turbine
- the factors that determine the number and arrangement of the turbines
- the environmental factors involved in the use of wind turbines.

[6 marks]

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Question 6 continues on the next page

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A solar farm is suggested as an alternative to the wind farm.

The solar farm consists of an array of solar panels. Each panel is angled so that the average intensity of the sunlight on the panels is at a maximum.
Each panel has an area of $1.0\ \text{m}^2$.

The power per square metre from the Sun at a distance equal to the orbital radius of the Earth is $1.34\ \text{kW m}^{-2}$.

0 6 . 2 Calculate the power output of the Sun.

radius of Earth's orbit = $150\ \text{Gm}$

[2 marks]

power output = ____________________ W

0 6 . 3 The maximum output of a $1.0\ \text{m}^2$ solar panel is typically about $250\ \text{W}$ in bright conditions.

Discuss why this is significantly smaller than $1.34\ \text{kW}$.

[3 marks]

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11

END OF SECTION A

Section B

Each of the questions in this section is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

Only **one** answer per question is allowed.
For each question, completely fill in the circle alongside the appropriate answer.

CORRECT METHOD WRONG METHODS

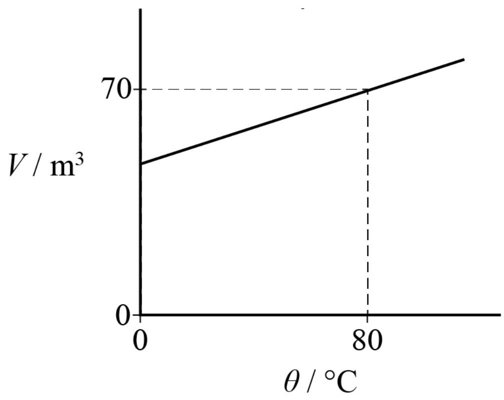
If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional pages for this working.

0 7 The graph shows the variation of volume V with temperature θ for a fixed mass of an ideal gas at constant pressure.

not to scale



What is the gradient of the line?

[1 mark]

A 0.20

B 0.26

C 0.58

D 0.88

Turn over ►

0 8 An efficient moderator in a thermal nuclear reactor must

[1 mark]

A contain atoms that are good at absorbing neutrons.

B be a good thermal conductor.

C be a liquid at its operating temperature.

D contain atoms with a small nucleon number.

0 9 What is the main purpose of lowering control rods into the core of a thermal nuclear reactor?

[1 mark]

A to decrease the number of thermal neutrons

B to increase the number of thermal neutrons

C to decrease the average kinetic energy of the thermal neutrons

D to increase the average kinetic energy of the thermal neutrons

1 0 A nuclear fission power station is designed to provide $45\ \text{MW}$ of electrical power.

The energy output of the power station is 11% of the energy obtained by converting mass into energy.

What is the rate of conversion of mass into energy in the power station?

[1 mark]

A $4.5 \times 10^{-15}\ \text{kg s}^{-1}$

B $5.5 \times 10^{-11}\ \text{kg s}^{-1}$

C $5.0 \times 10^{-10}\ \text{kg s}^{-1}$

D $4.5 \times 10^{-9}\ \text{kg s}^{-1}$

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1 1 An equation that arises from the kinetic theory model is

$$pV = \frac{1}{3} N m (c_{\text{rms}})^2$$

Which assumption is required in the derivation of this equation?

[1 mark]

A The particles all move with the same speed. ⬭

B The mass of an individual particle is negligible. ⬭

C The sides of the container all have the same area. ⬭

D The volume of an individual particle is negligible. ⬭

1 2 An isolated system initially has an internal energy U_0.

An amount of energy Q is removed from the system by cooling.
The internal energy increases to U_1.

What is the work done on the system?

[1 mark]

A $U_0 + U_1 - Q$ ⬭

B $U_1 + Q - U_0$ ⬭

C $U_0 + Q - U_1$ ⬭

D $U_0 - U_1 - Q$ ⬭

Turn over for the next question

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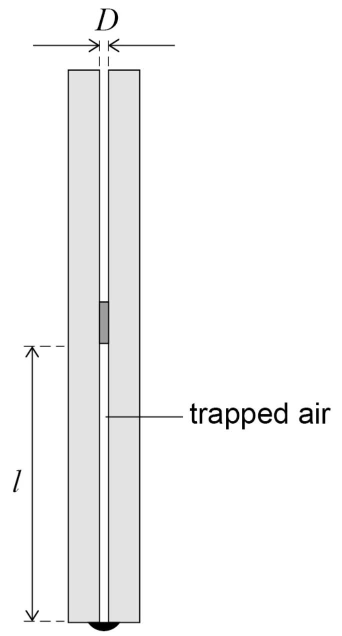
1 3 A student does a Charles's law experiment. The student uses measurements of the length of air trapped in a tube to estimate a value for absolute zero.



The initial length of the trapped air is l and the diameter of the tube is D.

The behaviour of the liquid trapping the air does not depend on the diameter of the tube.

Which row shows the changes to l and D that could lead to an improvement in the accuracy of the student's value?

[1 mark]

	l	D	
A	decrease	increase	⬭
B	increase	decrease	⬭
C	decrease	decrease	⬭
D	increase	increase	⬭

Do not write outside the box

1 4 What are the fundamental (base) units of U-value?

[1 mark]

A $\mathrm{kg\ m^2\ s^{-3}\ K^{-1}}$ ⬭

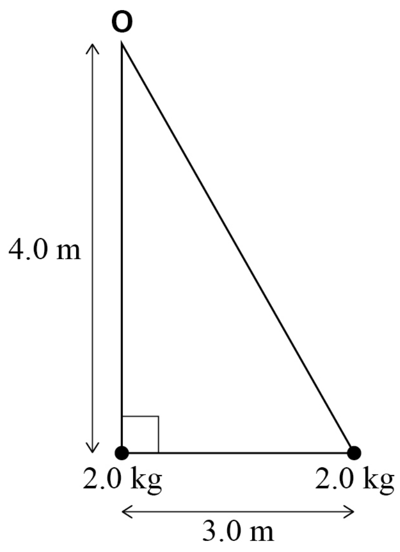
B $\mathrm{kg\ s^{-2}\ K^{-1}}$ ⬭

C $\mathrm{kg\ s^{-3}\ K^{-1}}$ ⬭

D $\mathrm{kg\ m^{-1}\ s^{-3}\ K^{-1}}$ ⬭

1 5 The diagram shows a light triangular card with point masses of $2.0\ \mathrm{kg}$ attached at two corners.

not to scale



The system is completed by adding a third point mass of $2.0\ \mathrm{kg}$ at a distance of $1.0\ \mathrm{m}$ from **O**.

What is the moment of inertia of the system about **O**?

[1 mark]

A $16\ \mathrm{kg\ m^2}$ ⬭

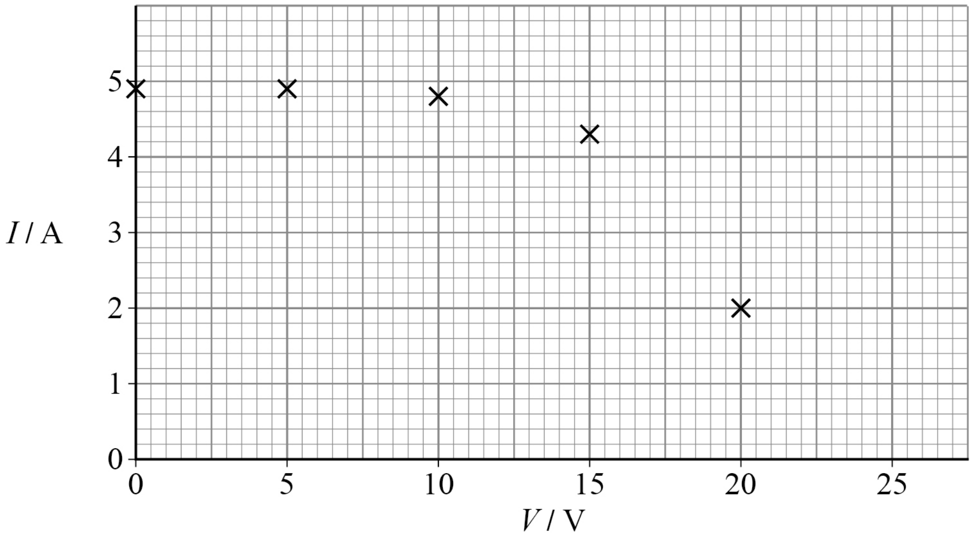
B $20\ \mathrm{kg\ m^2}$ ⬭

C $82\ \mathrm{kg\ m^2}$ ⬭

D $84\ \mathrm{kg\ m^2}$ ⬭

Turn over ►

1 6 A student takes measurements to obtain an I–V characteristic for an array of solar panels. The diagram shows the student's results.



The student decides to take more readings to obtain an accurate value for the maximum power output.

What range of voltages should the student investigate?

[1 mark]

A 0 to 6 V ☐

B 6 V to 12 V ☐

C 12 V to 18 V ☐

D 18 V to 24 V ☐

1 7 The energy storage capacity of a pumped storage station is 9.1×10^6 kW h.
At peak output, the rate of flow of water through the generators is $390\ \mathrm{m^3\ s^{-1}}$.
The generators are 110 m below the upper reservoir.
The density of water is $1000\ \mathrm{kg\ m^{-3}}$.

What is the maximum possible length of time for which the station can provide peak output?

[1 mark]

A 1.3×10^3 s ☐

B 2.2×10^4 s ☐

C 7.8×10^4 s ☐

D 7.6×10^5 s ☐

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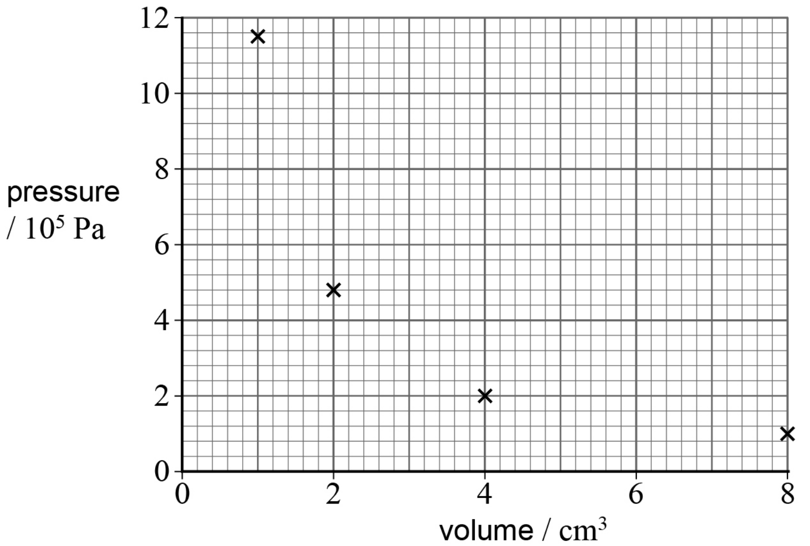
Questions **18** and **19** relate to the data shown below.

The pressure on a fixed mass of ideal gas is increased.
The graph shows the values of pressure and volume for the gas.



The temperature of the gas is $35\ °C$ when its volume is $8\ cm^3$.

1 8 What is the number of moles of molecules in the gas?

[1 mark]

A 3.1×10^{-4}

B 2.8×10^{-3}

C 3.1×10^{-3}

D 2.8×10^{-2}

1 9 Which volume is the smallest at which the temperature of the gas remains at $35\ °C$?

[1 mark]

A $8\ cm^3$

B $4\ cm^3$

C $2\ cm^3$

D $1\ cm^3$

Turn over for the next question

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2 0 Which statement about power stations is always correct?

[1 mark]

A Back-up power stations are more efficient than base-power stations.

B Back-up power stations do not release carbon dioxide.

C The power output of base-power stations can be changed quickly.

D Back-up power stations can be started up quickly.

2 1 A disc is rotating.

At time $t = 0$ the disc has an angular displacement of zero and an angular velocity of 8.0 rad s^{-1} anticlockwise.

The disc accelerates uniformly to an angular velocity of 12.0 rad s^{-1} clockwise. As a result of the acceleration, the final angular displacement of the disc is 80 rad clockwise.

What is the angular acceleration?

[1 mark]

A 0.50 rad s^{-2} clockwise

B 0.50 rad s^{-2} anticlockwise

C 0.90 rad s^{-2} clockwise

D 0.90 rad s^{-2} anticlockwise

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END OF QUESTIONS

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