OXFORD AQA
INTERNATIONAL QUALIFICATIONS

Please write clearly in block capitals.

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Candidate signature	

I declare this is my own work.

INTERNATIONAL A-LEVEL
PHYSICS

Unit 4 Energy and Energy resources

Tuesday 11 June 2024 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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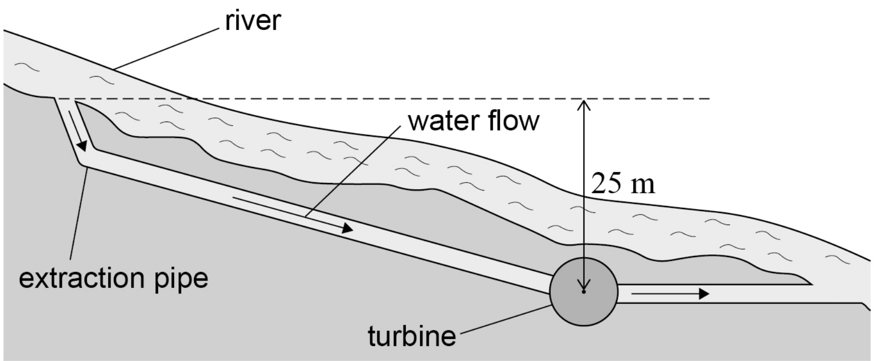
Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows part of a small hydroelectric power (HEP) station. Some of the river water enters the extraction pipe. This water flows through a turbine before it re-enters the river.
The flow in the river can vary, depending on the weather.

Figure 1



For this HEP station:

- the water falls a vertical distance of $25\ \text{m}$
- the mean electrical power output is $79\ \text{kW}$
- the efficiency is 86%.

0 1 . 1 Calculate the mean mass of water entering the extraction pipe every second.

[3 marks]

mean mass = ____________________ kg

Do not write outside the box

0 1 . 2 The HEP station has an alternating output of voltage $69\ \mathrm{kV}$ rms.

Calculate the peak current output from the HEP station.

[2 marks]

peak current = ____________________ A

A second type of HEP station uses a dam and a reservoir to store water.

0 1 . 3 Suggest **one** environmental benefit of the station shown in **Figure 1** compared with one that uses a dam and a reservoir.

[1 mark]

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0 1 . 4 State what is meant by a base-power station.
Go on to discuss whether either type of HEP station can operate as a base-power station.

[3 marks]

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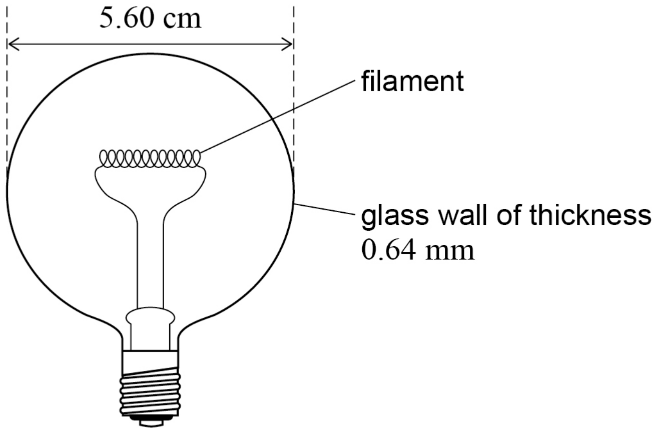
0 2 **Figure 2** shows a filament lamp with a total power output of 60.0 W. The glass wall of the lamp has a uniform thickness of 0.64 mm.

Figure 2



Assume the lamp to be a glass sphere of external diameter 5.60 cm.

The lamp is turned on and reaches thermal equilibrium.

The temperature difference across the glass wall is now 1.2 K.

0 2 . 1 Calculate the percentage of the power output of the lamp that transfers through the glass by conduction.

thermal conductivity of glass = $1.10\ \mathrm{W\ m^{-1}\ K^{-1}}$

[3 marks]

percentage of power output = ______________________

Do not write outside the box

0 2 . 2 At equilibrium, the mean temperature of the glass wall is $131\ °C$.

Calculate the energy needed to increase the temperature of the glass from $20\ °C$ to $131\ °C$.

density of glass = $2.5 \times 10^{3}\ kg\ m^{-3}$
specific heat capacity of glass = $0.84\ kJ\ kg^{-1}\ K^{-1}$

[3 marks]

energy = ____________________ J

6

Turn over for the next question

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0 3 A deuterium $\left({}^{2}_{1}\mathrm{H}\right)$ nucleus with an initial kinetic energy of 1.6×10^{-14} J approaches a second deuterium nucleus head-on. The second nucleus is initially stationary.

When the nuclei have reached a minimum separation d, each nucleus has a kinetic energy of 4.0×10^{-15} J.

0 3 . 1 Calculate d.

[3 marks]

$d =$ ____________________ m

0 3 . 2 On another occasion, two deuterium $\left({}^{2}_{1}\mathrm{H}\right)$ nuclei have initial kinetic energies of 1.6×10^{-14} J each.

On this occasion, their minimum separation is different from the value of d in Question **03.1**.

Suggest, without calculation, how this minimum separation differs from the value of d in Question **03.1**.

[3 marks]

Do not write outside the box

03.3 The minimum distances in Question **03.1** and Question **03.2** are both too large for the two nuclei to fuse.

Deuterium nuclei can fuse in a plasma in which the mean kinetic energy of nuclei is 1.6×10^{-14} J.

Suggest why some deuterium nuclei can fuse in this plasma.

[1 mark]

03.4 Explain **two** reasons why the kinetic theory of gases can model the behaviour of an ideal gas but cannot model the behaviour of a plasma.

[2 marks]

1

2

03.5 An ideal gas has particles with a mean kinetic energy of 1.6×10^{-14} J.

Calculate the absolute temperature of the gas.

[2 marks]

absolute temperature = ____________ K

11

Turn over ►

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0 4 The solar fusion cycle has three stages.
The equation for the reaction in the third stage of the cycle is:

$$^{3}_{2}\mathrm{He} + ^{3}_{2}\mathrm{He} \rightarrow ^{4}_{2}\mathrm{He} + 2\,^{1}_{1}\mathrm{p}$$

Table 1 shows the mass of each particle involved.

Table 1

Particle	Mass / u
$^{3}_{2}\mathrm{He}$	3.016029
$^{4}_{2}\mathrm{He}$	4.002603
$^{1}_{1}\mathrm{p}$	1.007823

0 4 . 1 Show that the energy equivalent of a mass of 1 u is approximately 930 MeV.

$1\ \mathrm{u} = 1.661 \times 10^{-27}\ \mathrm{kg}$

[2 marks]

0 4 . 2 Calculate, in MeV, the energy released in one reaction in the third stage of the solar fusion cycle.

[2 marks]

energy = ______________________ MeV

Do not write outside the box

The equation for a reaction in the second stage of the solar fusion cycle is:

$$ {}^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{p} \rightarrow {}^{3}_{2}\mathrm{He} + \gamma $$

Table 2 shows the binding energy of each particle involved.

Table 2

Particle	Binding energy / pJ
${}^{2}_{1}\mathrm{H}$	0.35593
${}^{1}_{1}\mathrm{p}$	0
${}^{3}_{2}\mathrm{He}$	1.23489
γ	0

0 4 . 3 Explain how the second stage contributes approximately 1.8×10^{-12} J of the energy released in one complete cycle.
Support your explanation with a calculation.

[2 marks]

0 4 . 4 Write the equation for the reaction in the first stage of the solar fusion cycle.

[2 marks]

Question 4 continues on the next page

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0 4 . 5 It is estimated that the Sun contains 2×10^{30} kg of hydrogen $\left({}^{1}_{1}\mathrm{H}\right)$ and emits energy at the rate of 4×10^{26} W.

Each solar fusion cycle produces 4.5×10^{-12} J of energy.

Estimate, in years, the maximum length of time for which the Sun can continue to emit energy at its current rate using only the solar fusion cycle.

mass of 1.0 mol of ${}^{1}_{1}\mathrm{H} = 1.0 \times 10^{-3}$ kg

[4 marks]

time = ______________________ years

0 4 . 6 The fusion of two helium nuclei in the core of a star leads to the formation of heavier elements.

Explain why helium fusion requires the plasma temperature to be greater than the temperature needed for hydrogen fusion.

[2 marks]

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0 5 A wind turbine has a rotor with a diameter of $135\ \mathrm{m}$.

0 5 . 1 Calculate, in MW, the maximum power available from the air to the turbine when the wind speed is $11.4\ \mathrm{m\ s^{-1}}$.

density of air = $1.2\ \mathrm{kg\ m^{-3}}$

[2 marks]

maximum power = ______________________ MW

0 5 . 2 State **two** reasons why the total kinetic energy of the wind passing through the turbine is **not** available to the turbine.

[2 marks]

1 ____

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2 ____

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The rotor accelerates from rest to its maximum angular speed of $1.41\ \mathrm{rad\ s^{-1}}$.

0 5 . 3 Calculate, in revolutions per minute, the maximum frequency of rotation of the rotor.

[1 mark]

frequency = ______________________ revolutions per minute

Turn over ►

The rotor is connected to an electric generator.
The wind exerts a constant torque on the rotor.

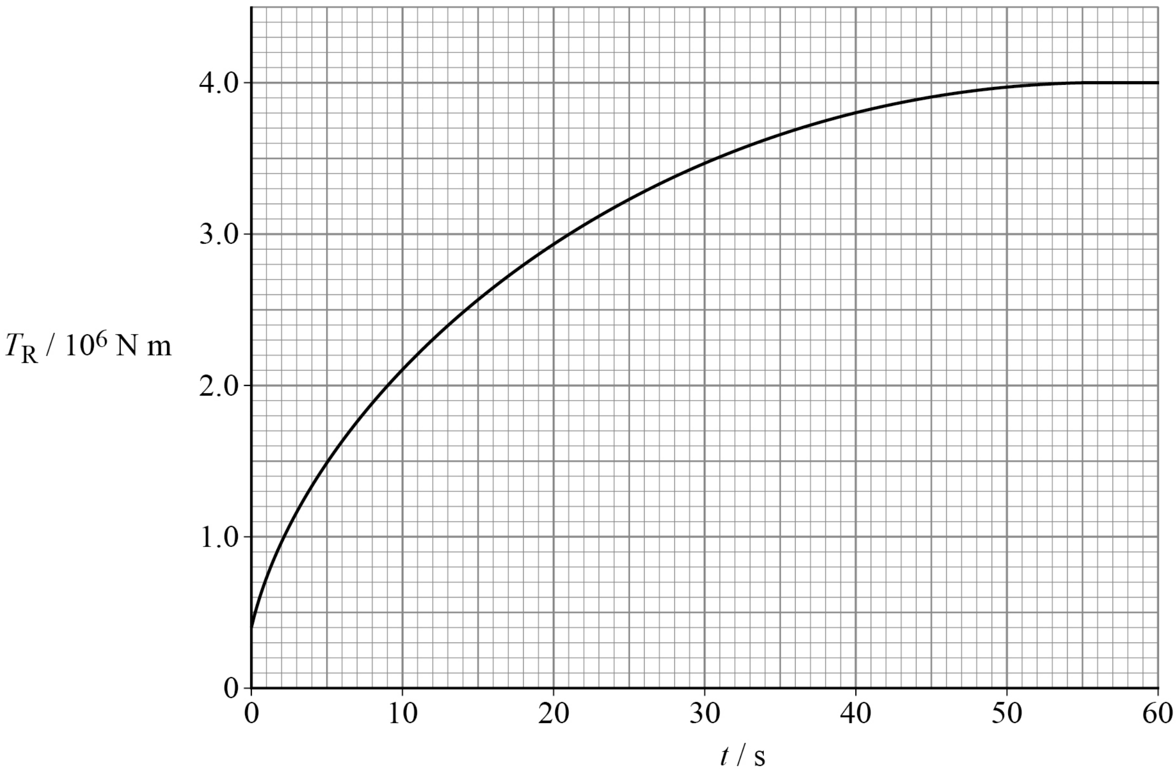
Two types of resistive torque are exerted on the rotor:

- a constant frictional resistive torque of 4.0×10^5 N m
- a varying resistive torque exerted by the generator.

The total resistive torque is T_R.

Figure 3 shows the variation of T_R with time t while the rotor is accelerating. The rotor achieves its maximum angular speed of 1.41 rad s^{-1} at $t = 55$ s.

Figure 3



0 5 . 4 Calculate, in MJ, the energy that the wind transfers to the turbine between $t = 55$ s and $t = 60$ s.
Use data from **Figure 3**.

[2 marks]

energy = ____________________ MJ

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The moment of inertia of the rotor is 7.1×10^7 kg m^2.

0 5 . 5 Calculate the initial angular acceleration of the rotor.

[2 marks]

angular acceleration = ______________________ rad s^{-2}

0 5 . 6 Calculate the maximum rotational kinetic energy of the rotor.

[2 marks]

maximum kinetic energy = ______________________ J

0 5 . 7 Explain why the angular acceleration of the rotor varies between $t = 0$ and $t = 55$ s.

[3 marks]

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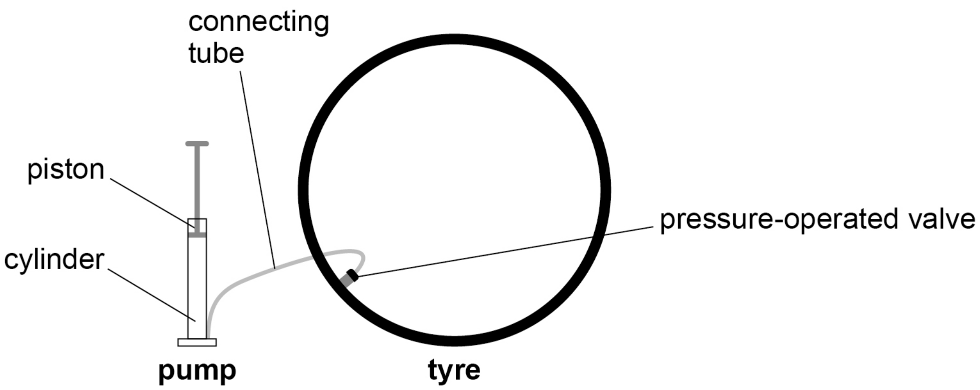
Turn over ►

0 6 **Figure 4** shows a pump connected to a bicycle tyre through a connecting tube and a pressure-operated valve.

Figure 4

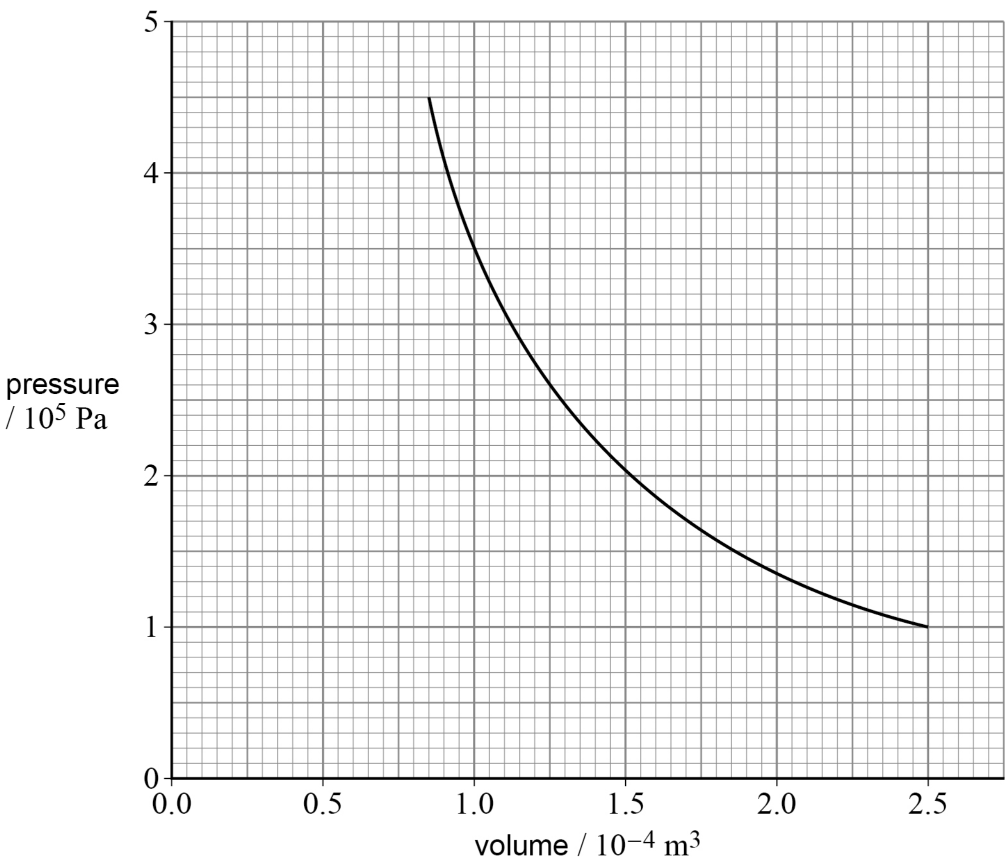


Initially, the piston is at the top of the cylinder as shown in **Figure 4**. The cylinder contains 2.5×10^{-4} m^3 of air at a pressure of 1.0×10^5 Pa and a temperature of 17 °C. The initial pressure of the air in the tyre is 4.5×10^5 Pa.

When the pump is operated for the first time, the piston is pushed down quickly. All the air remains in the cylinder until the cylinder pressure is 4.5×10^5 Pa. The valve opens when the cylinder pressure and the tyre pressure are equal. All the air in the cylinder then enters the tyre.

Figure 5 shows the variation of pressure with volume for the air in the cylinder.

Figure 5



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0 6 . 1 Determine the work done in compressing the air in the cylinder to a pressure of 4.5×10^5 Pa.

[3 marks]

work done = ______________________ J

0 6 . 2 Calculate, in K, the temperature of the air in the cylinder when the pressure has increased to 4.5×10^5 Pa.

[2 marks]

temperature = ______________________ K

Question 6 continues on the next page

Turn over ►

Do not write outside the box

0 6 . 3 The tyre needs an additional $0.27\ \text{mol}$ of air to be inflated to its correct pressure. The volumes of the connecting tube and the valve are negligible.

Calculate the number of times the pump has to be operated to inflate the tyre.

[3 marks]

number = ____________________

0 6 . 4 Explain, with reference to the first law of thermodynamics, why the temperature of the air in the cylinder increases when the piston is pushed down quickly.

[3 marks]

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11

END OF SECTION A

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Turn over for Section B

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ANSWER IN THE SPACES PROVIDED

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 A non-ideal gas has molecules that contain more than one atom.
Each molecule has a moment of inertia.

The internal energy of the gas is the sum of:

[1 mark]

A the translational kinetic energies of all of the molecules.

B the translational, rotational and vibrational kinetic energies of all of the molecules.

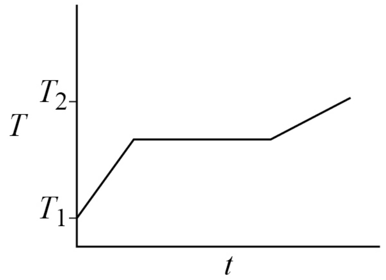
C the potential energies and the translational kinetic energies of all of the molecules.

D the potential energies and the translational, rotational and vibrational kinetic energies of all of the molecules.

0 8 A material is initially solid at a temperature of T_1.

The material is heated with a constant power of P. It melts and the temperature of the liquid increases to T_2.

The graph shows the variation of the temperature T with time t for the material.

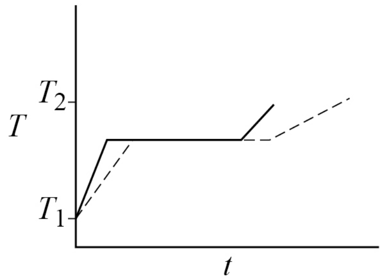


The same mass of the same material is now heated with a constant power of $2P$.

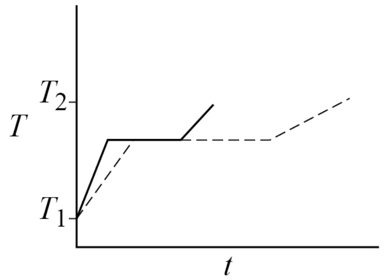
Which graph shows the new variation of T with t?
The dashed lines show the shape of the original graph.

[1 mark]

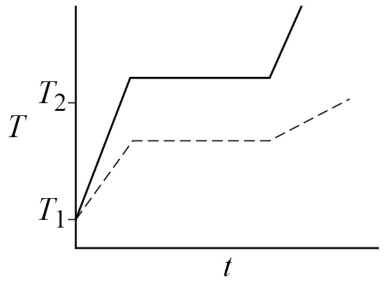
A



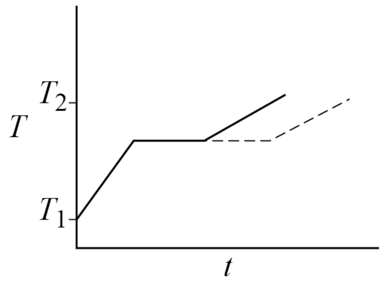
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

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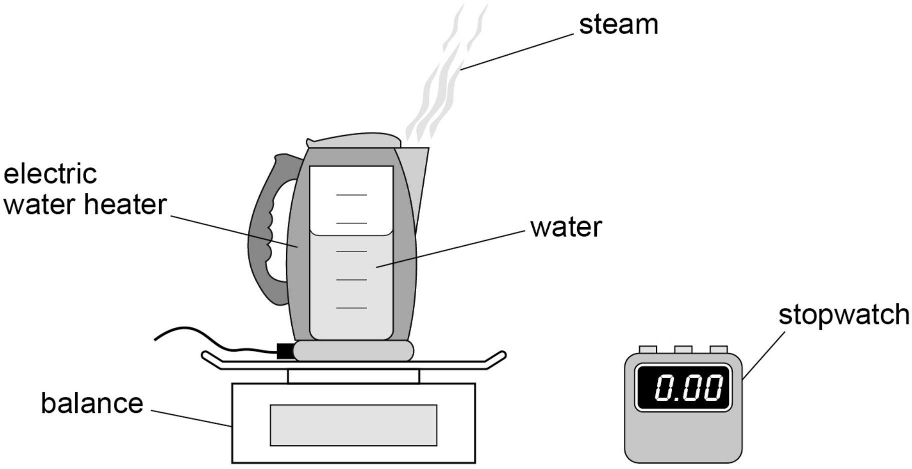
0 9 A student does an experiment to estimate the specific latent heat L of water.



An electric water heater is placed on a balance and switched on.
The water heater uses a constant power of P.
The student waits until the water is boiling. He then starts the stopwatch and measures the time t taken for the mass of water to decrease by m.

The student estimates L using:

$$mL = Pt$$

Which error would result in an overestimate of L?

[1 mark]

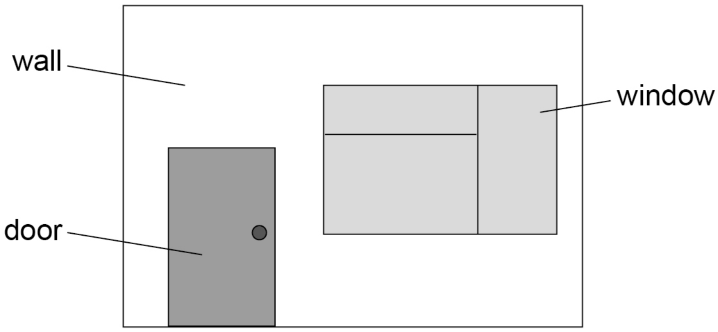
A underestimating t ⬭

B overestimating m ⬭

C ignoring energy losses from the water heater ⬭

D ignoring the mass of drops of water emitted with the steam ⬭

1 0 The front of a house has three parts: a wall, a window and a door.



The table shows the U-values and the areas for the three parts.

Part	U-value / $W\ m^{-2}\ K^{-1}$	Area / m^2
wall	1.0	8.0
window	1.5	2.3
door	2.2	1.6

Which row shows the parts in order from the smallest rate of heat transfer to the largest rate of heat transfer?

[1 mark]

A wall, window, door

B wall, door, window

C window, door, wall

D window, wall, door

Turn over for the next question

1 1 Atmospheric pressure is 100 kPa.

Sample **X** of an ideal gas has a volume of 2.0 m^3 and an initial pressure of 100 kPa above atmospheric pressure. It is compressed at constant temperature until its volume is V_X and its pressure is 300 kPa above atmospheric pressure.

Sample **Y** of an ideal gas has a volume of 2.0 m^3 and an initial temperature of 177 °C. It is heated at constant pressure until its temperature is 354 °C and its volume is V_Y.

What are V_X and V_Y?

[1 mark]

	V_X / m^3	V_Y / m^3	
A	1.0	2.8	⬭
B	1.0	4.0	⬭
C	0.67	2.8	⬭
D	0.67	4.0	⬭

1 2 A student uses a microscope to observe Brownian motion in some smoke.

Which statement is **not** true?

[1 mark]

A Randomly moving air molecules are in collision with smoke particles.

B Smoke particles are seen to move randomly.

C Air molecules are seen to move randomly.

D The random motion of smoke particles demonstrates the random motion of air molecules.

1 3 A hydrogen $\left({}^{1}_{1}\mathrm{H}\right)$ nucleus has a radius of approximately $1\ \mathrm{fm}$.

Which is the best estimate of the density of a helium-4 $\left({}^{4}_{2}\mathrm{He}\right)$ nucleus?

[1 mark]

A $2 \times 10^{17}\ \mathrm{kg\ m^{-3}}$

B $4 \times 10^{17}\ \mathrm{kg\ m^{-3}}$

C $1 \times 10^{18}\ \mathrm{kg\ m^{-3}}$

D $2 \times 10^{18}\ \mathrm{kg\ m^{-3}}$

Turn over for the next question

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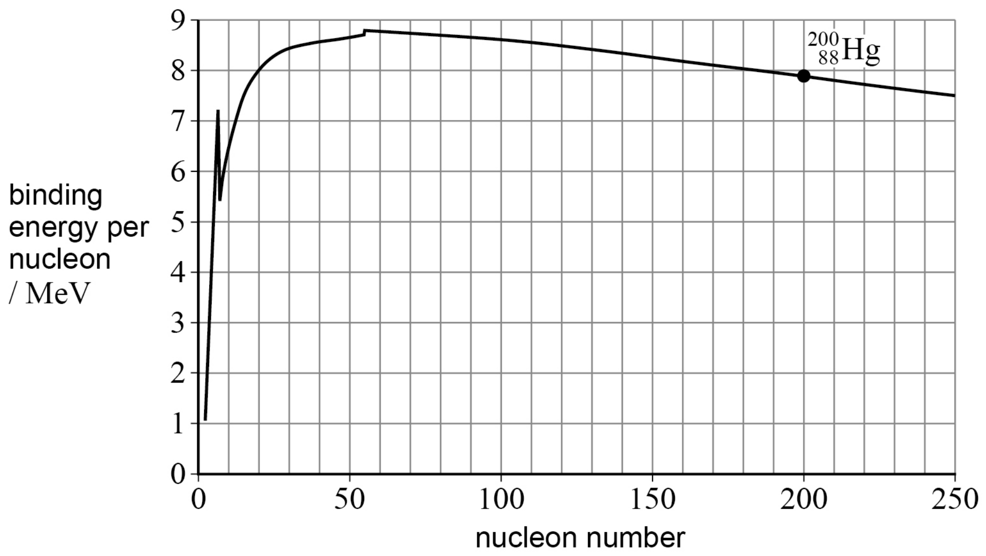
1 4 The graph shows the variation of binding energy per nucleon with nucleon number.

The position of $^{200}_{88}\mathrm{Hg}$ is shown.



What is the best estimate of the release of energy from the fission of a $^{200}_{88}\mathrm{Hg}$ nucleus?

[1 mark]

A 0.7 MeV

B 8 MeV

C 62 MeV

D 140 MeV

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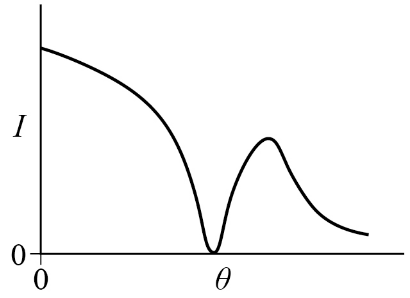
1 5 Which graph shows the variation of electron intensity I with diffraction angle θ for the diffraction of electrons by a nucleus?

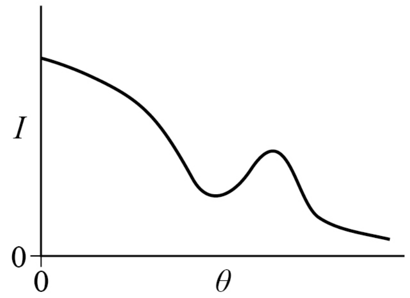
[1 mark]

A



○

B



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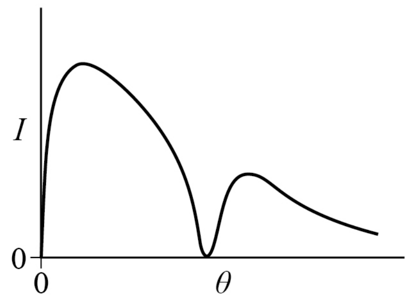
C



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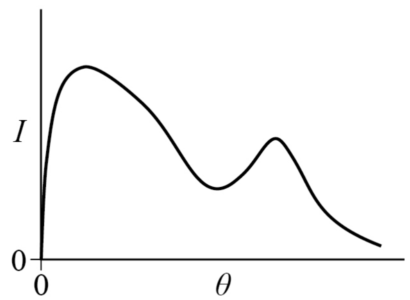
D



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Turn over for the next question

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1 6 Neutron absorption cross-section σ is measured in cm^2. Nuclei with a large value of σ are more likely to absorb neutrons.

The table gives nucleon numbers and approximate values of σ for four isotopes.

Which isotope would be most suitable as a moderator in a thermal fission reactor?

[1 mark]

	Nucleon number	σ / cm^2	
A	6	1000	⬭
B	7	0.0005	⬭
C	181	0.0005	⬭
D	177	1000	⬭

1 7 Used fuel rods from a nuclear reactor are stored in water for a long time. The water contains dissolved boron.

Possible reasons for this type of storage are:

1. to prevent overheating due to radioactive decay of nuclei in the used fuel

2. to shield against radiation from radioactive materials in the used fuel

3. to prevent the possibility of a chain reaction occurring in the remaining uranium in the used fuel.

Which of these reasons are correct?

[1 mark]

A **1** and **2** only ⬭

B **1** and **3** only ⬭

C **2** and **3** only ⬭

D **1** and **2** and **3** ⬭

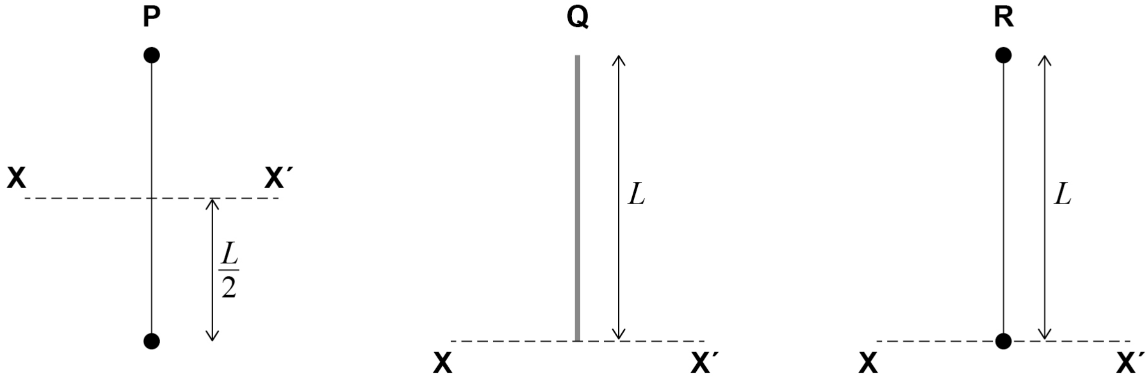
Do not write outside the box

1 8 **P**, **Q** and **R** are objects with the same mass m and the same length L.

P and **R** each consist of a light rod with a point mass of mass $\frac{m}{2}$ at each end.

Q is a uniform rod of mass m. **Q** has a moment of inertia of $\frac{1}{3}mL^2$.

X–**X**′ is the axis of rotation for each object.



Which shows the objects in order of increasing moment of inertia?

[1 mark]

A **P**, **Q**, **R** ⬭

B **P**, **R**, **Q** ⬭

C **R**, **P**, **Q** ⬭

D **R**, **Q**, **P** ⬭

Turn over for the next question

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1 9 A wheel has an initial angular velocity of $10\ \mathrm{rad\ s^{-1}}$.
The wheel experiences an angular acceleration of $-2.0\ \mathrm{rad\ s^{-2}}$ until its angular velocity is $-20\ \mathrm{rad\ s^{-1}}$.

How many revolutions does the wheel make during this change of angular velocity?

[1 mark]

A 12

B 20

C 75

D 125

2 0 A remote island has renewable sources that generate between 2300 kW and 2900 kW of electrical power.
The island needs a continuous power supply of 2500 kW.
The island also has a pumped storage system that stores an energy of 60 MW h.

The output of the renewable resources falls to its minimum value and remains at this minimum value.

The renewable sources together with the pumped storage system can only supply the island's needs for a time t.

What is t?

[1 mark]

A 300 h

B 150 h

C 30 h

D 15 h

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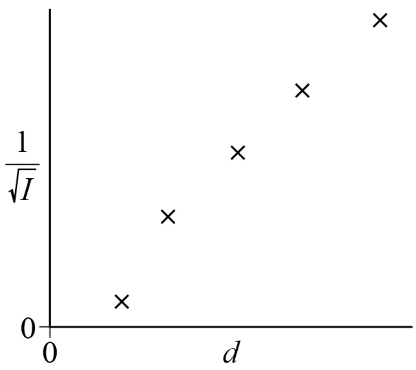
2 1 A student measures how light intensity I varies with distance d from a filament lamp.

The axes show the student's plot of $\frac{1}{\sqrt{I}}$ against d.



The points are not all on a straight line through the origin.

What could be a reason for this?

[1 mark]

A The lamp is not a point source of monochromatic light.

B A systematic error has occurred in the measurement of d.

C An additional light source was present for part of the time.

D White light does not obey the inverse-square law.

15

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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