OXFORD AQA

INTERNATIONAL QUALIFICATIONS

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

INTERNATIONAL A-LEVEL

PHYSICS

Unit 4 Energy and Energy resources

Thursday 15 January 2026 07:00 UK Time 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	
8–22	
TOTAL	

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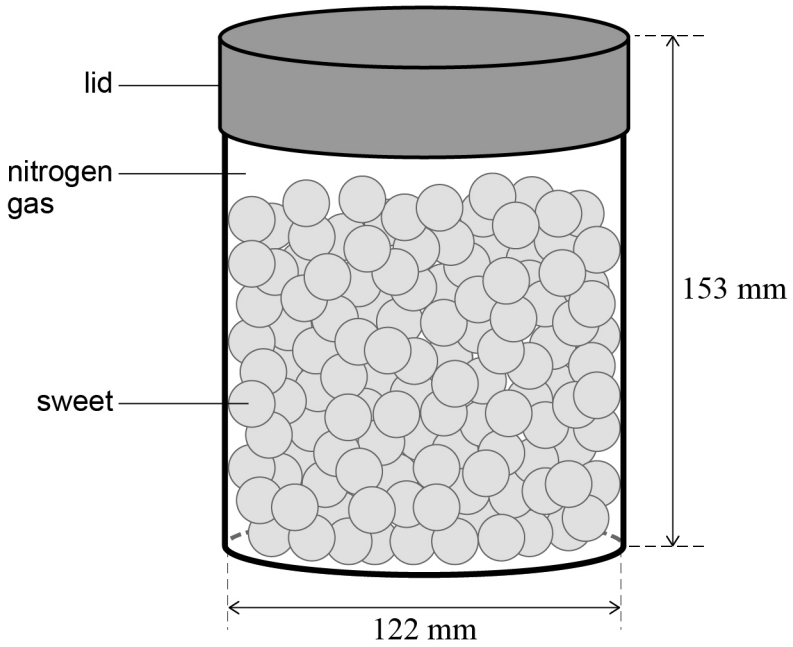
Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows a container in the shape of a cylinder. It contains identical spherical sweets and nitrogen gas. The lid seals the container so that gas cannot move in or out.

Figure 1



There is 1.15×10^{-3} m^3 of nitrogen in the container.

The container has an internal height of 153 mm and the base has an internal diameter of 122 mm.

There are 595 sweets in the container.
The density of the sweets is 1.18×10^{3} kg m^{-3}.

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0 1 . 1 Calculate the mass of one sweet.

[3 marks]

mass of one sweet = _____ kg

The nitrogen in the container is at a temperature of 291 K and a pressure of 1.1×10^5 Pa.

0 1 . 2 Calculate, in g, the mass of nitrogen in the container.

mass of 1.0 mol of nitrogen = 28 g

[2 marks]

mass = _____ g

Question 1 continues on the next page

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The container and its contents are now cooled to a temperature of –15 °C.
The volume of the sweets, container and lid do not change.

0 1 . 3 Calculate the new pressure of the nitrogen in the container.

[2 marks]

pressure = _____ Pa

0 1 . 4 The container is in a room that contains air at a temperature of 18 °C.

Explain why it is much harder to pull the lid from the container when the gas in the container is at –15 °C than when it is at 18 °C.
Refer to the movement of gas particles in your answer.

[3 marks]

10

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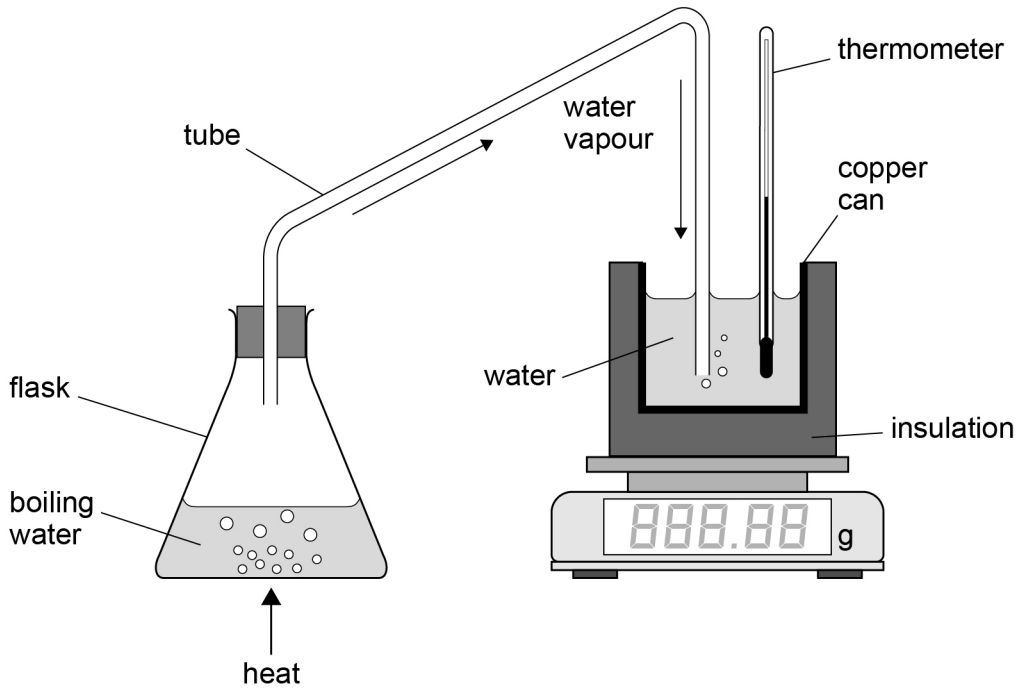
0 2 The boiling point of water is 100 °C.
Water is heated to its boiling point and then changes state to become water vapour.

0 2 . 1 Describe what happens to the kinetic energies and potential energies of the water particles during the change of state.

[2 marks]

Figure 2 shows the arrangement that a student uses to determine the specific latent heat of water.

Figure 2



Throughout the experiment the temperature of the copper can is equal to the temperature of the water in the can.

Just as the water in the flask begins to boil, the student measures the initial temperature of the water in the can and the initial mass of the water in the can.

There is no liquid water in the water vapour. Water vapour at 100 °C enters the water in the can. This causes the temperature of the water and can to increase. The liquid water formed from the water vapour and the water in the can reach the same temperature.

Question 2 continues on the next page

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The experiment is stopped when the water and the can reach a temperature of $45\ °C$.

The water vapour transfers a total of $36\ kJ$ of energy to the original water in the can and to the can.

The specific heat capacity of water is $4200\ J\ kg^{-1}\ K^{-1}$.

0 2 . 2 Determine the initial temperature of the water and can.

initial mass of water in can = $0.250\ kg$
mass of can = $0.350\ kg$
specific heat capacity of copper = $385\ J\ kg^{-1}\ K^{-1}$

[3 marks]

initial temperature = _____ °C

0 2 . 3 During the experiment the mass of water in the can increases by $0.015\ kg$.
This increase in mass is due to the water vapour changing state.

Determine the specific latent heat of this change of state.

[2 marks]

specific latent heat = _____ $J\ kg^{-1}$

Do not write outside the box

0 2 . 4 State and explain **two** changes to this experiment that would improve the accuracy of the value determined for the specific latent heat.

[2 marks]

1 _____

_____

_____

2 _____

_____

_____

9

Turn over for the next question

Do not write outside the box

0 3 **Table 1** gives the nuclear radius R for five different nuclides.

Table 1

Nuclide	R / fm		
$^{4}_{2}\mathrm{He}$	1.68		
$^{15}_{7}\mathrm{N}$	2.61		
$^{23}_{11}\mathrm{Na}$	2.99		
$^{32}_{18}\mathrm{Ar}$	3.35		
$^{72}_{36}\mathrm{Kr}$	4.41		

Theory suggests that R is related to the nucleon number A by

$$R = R_0 A^{\frac{1}{3}}$$

where R_0 is a constant.

0 3 . 1 Show that the data in **Table 1** are consistent with this equation.

Plot a straight-line graph on **Figure 3** as part of your answer. Use one or more of the blank columns in **Table 1** for any data that you wish to calculate.

Explain how your graph is consistent with the equation.

[5 marks]

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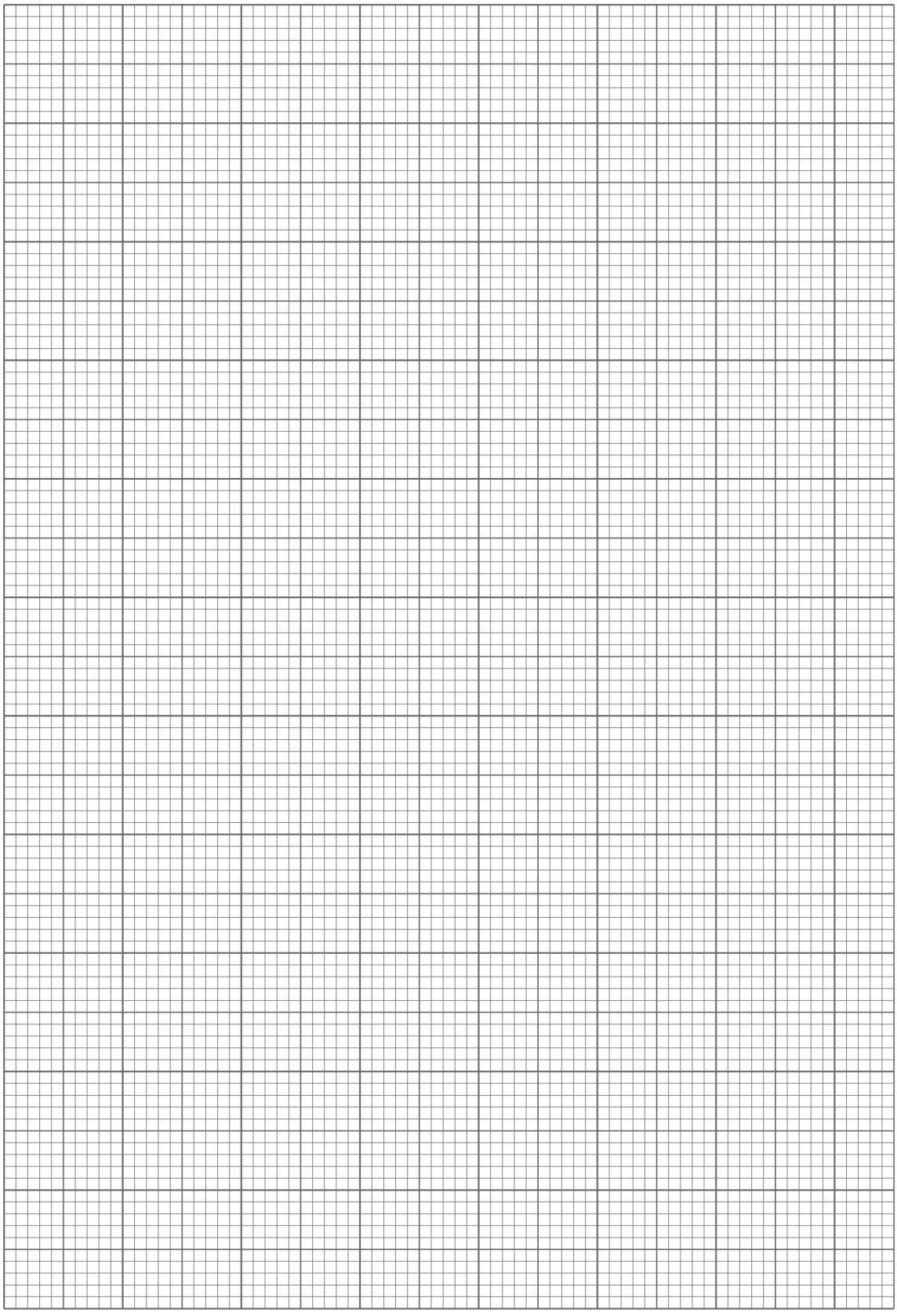
Figure 3



Question 3 continues on the next page

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0 3 . 2 The data in **Table 1** were obtained by electron diffraction.
Using the same method, the radius of a palladium nucleus was found to be 5.03 fm.

Determine, using your graph in **Figure 3**, the number of nucleons in this palladium nucleus.

[2 marks]

number of nucleons = _____

0 3 . 3 The Coulomb equation is used to estimate the closest approach of alpha particles to a sodium $^{23}_{11}\mathrm{Na}$ nucleus.

Calculate the maximum kinetic energy of an alpha particle that has the closest approach of 25 fm to the sodium nucleus.
Assume that the sodium nucleus does not recoil.

[3 marks]

maximum kinetic energy = _____ J

0 3 . 4 Explain why the radius of the sodium nucleus obtained by electron diffraction is different from the estimate obtained by the closest approach of alpha particles.

[1 mark]

_____

_____

11

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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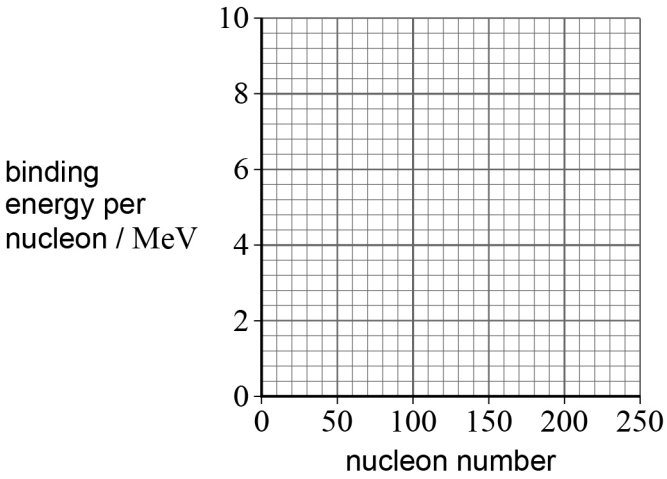
0 4 . 1 State what is meant by the binding energy of a nucleus.

[1 mark]

0 4 . 2 Sketch, on the axes in **Figure 4**, a plot of binding energy per nucleon against nucleon number.

[2 marks]

Figure 4



0 4 . 3 A large nucleus **X** undergoes a fission reaction to form two smaller nuclei **Y** and **Z**.

State how the binding energy per nucleon of **X** compares with the binding energy per nucleon of **Y** and of **Z**.

Explain your answer.

[2 marks]

Do not write outside the box

A fusion reaction that occurs in a star is

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

The binding energy per nucleon of $^{3}_{2}\mathrm{He} = 2.57\ \mathrm{MeV}$.

The binding energy per nucleon of $^{4}_{2}\mathrm{He} = 7.07\ \mathrm{MeV}$.

0 4 . 4 Explain why the binding energy per nucleon of $^{1}_{1}\mathrm{H}$ is zero.

[1 mark]

0 4 . 5 The reaction occurs 9.2×10^{37} times per second in the star.

Calculate the total power output from these reactions within the star.

[4 marks]

total power output = _____ W

10

Turn over ►

Do not write outside the box

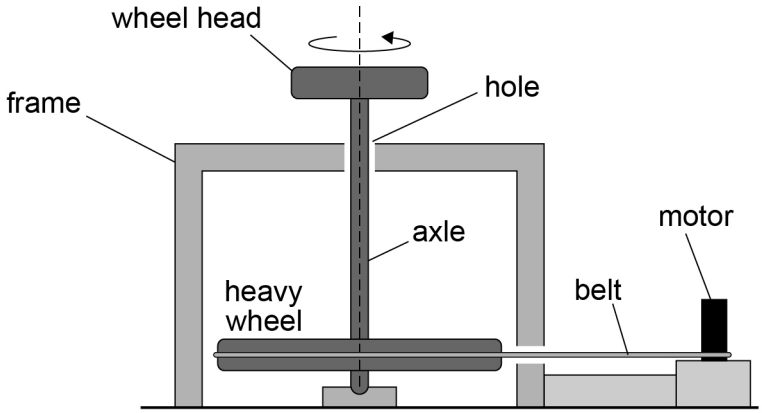
0 5 A potter is a person who forms pots from a material called clay.
The pots can then be hardened for use in cooking.

Figure 5 shows a rotating system used by the potter. The system is inside a stationary frame.

The system is made up of three parts that are connected together:
- a horizontal wheel head
- a vertical axle
- a horizontal heavy wheel.

The horizontal heavy wheel is attached to the wheel head by the vertical axle.
The axle passes through a hole in the frame.

Figure 5



A motor is used to turn the system. The motor is connected to the heavy wheel by a belt.

The moment of inertia of the system about the axle is $35.0\ \text{kg m}^2$.

0 5 . 1 At one instant, the force applied by the belt makes the system rotate at a constant angular speed. The rotational kinetic energy of the system is $933\ \text{J}$.

Calculate the time taken for the system to complete one revolution at this angular speed.

[2 marks]

time = _____ s

Do not write outside the box

0 5 . 2 The potter uses the motor to increase the speed of the system.
The belt applies a tangential force F to the heavy wheel at a distance of $0.68\ \text{m}$ from the centre of the axle.
As F is being applied, the system moves through an angle of $17°$ and increases its rotational kinetic energy from $933\ \text{J}$ to $947\ \text{J}$.

A constant frictional torque of $18\ \text{N m}$ acts on the system.

Calculate F.

[5 marks]

$F =$ _____ N

Question 5 continues on the next page

Turn over ►

Do not write outside the box

The motor accelerates the system to a constant angular speed of $7.6\ \text{rad s}^{-1}$.
The belt is then detached from the heavy wheel and the angular speed does not change.

The potter then drops a piece of clay vertically onto the centre of the wheel head.
The clay sticks to the centre of the wheel head.
The total moment of inertia of the system and the clay about the axle is $39.7\ \text{kg m}^2$.

0 5 . 3 Calculate the angular speed of the system immediately after the clay sticks to the wheel head.
Assume that there is no net external torque on the clay and system.

[2 marks]

angular speed = _____ rad s^{-1}

Do not write outside the box

0 5 . 4 The clay and system start to slow down due to the frictional torque.

At a time $t = 0$ the clay and system are rotating at 5.0 rad s^{-1}.

At time $t = t_1$ the clay and system come to rest. Between $t = 0$ and $t = t_1$ the system rotates through an angle θ.

The frictional torque on the system is 18 N m as it slows down.

Calculate
- t_1
- θ

[3 marks]

$t_1 =$ _____ s

$\theta =$ _____ rad

12

Turn over for the next question

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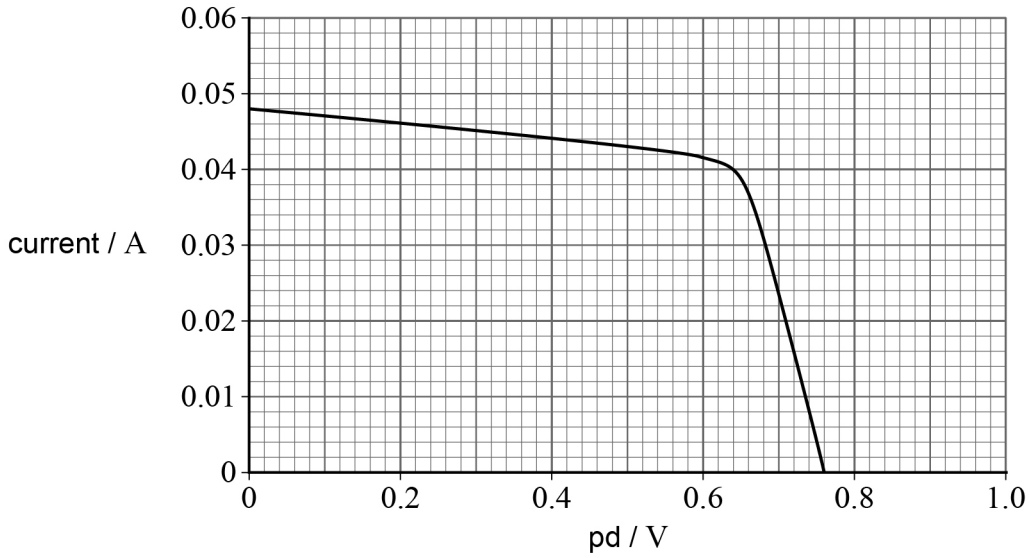
0 6 **Figure 6** shows the variation of current in a solar cell with potential difference (pd) across the cell.

Figure 6



0 6 . 1 Deduce the current and pd when the power output of the cell is at its maximum value.

[1 mark]

current = _____ A

pd = _____ V

The cell is one of many identical cells that form a solar array on a spacecraft that orbits the Sun.

The intensity of the Sun's power at the orbit of the spacecraft is $720\ \text{W m}^{-2}$.

0 6 . 2 Calculate the distance between the centre of the Sun and the spacecraft.

power output of Sun = 3.8×10^{26} W

[2 marks]

distance = _____ m

Do not write outside the box

0 6 . 3 The spacecraft requires a power of $650\ \text{W}$.

To prevent the spacecraft overheating, 75% of the energy from the Sun that is incident on the solar array is reflected back into space and not transferred to the solar array.

45% of the energy that is transferred to the solar array becomes electrical energy.

Each cell has an area of $20\ \text{cm}^2$.

Determine the number of solar cells needed to power the spacecraft.

[4 marks]

number of cells = _____

7

Turn over for the next question

Do not write outside the box

0 7 Discuss the use of a pumped storage system as part of a country's electrical power supply.

In your answer you should:

- describe the principles of operation of the pumped storage system
- explain why the pumped storage system is used
- state and explain the factors that determine the maximum power available from the system.

[6 marks]

6

END OF SECTION A

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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 8 A sample of gas is at a constant temperature.
The gas contains two isotopes **X** and **Y** of the same element.
X has fewer neutrons than **Y**.

Which statement is correct?

[1 mark]

A The rms speed of the molecules of **X** is greater than the rms speed of the molecules of **Y**. ⬭

B The rms speed of the molecules of **Y** is greater than the rms speed of the molecules of **X**. ⬭

C Molecules of **X** have a greater mean kinetic energy than molecules of **Y**. ⬭

D Molecules of **Y** have a greater mean kinetic energy than molecules of **X**. ⬭

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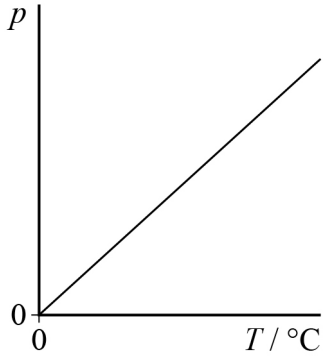
0 9 The volume of a fixed mass of an ideal gas remains constant.
The temperature of the gas is increased.

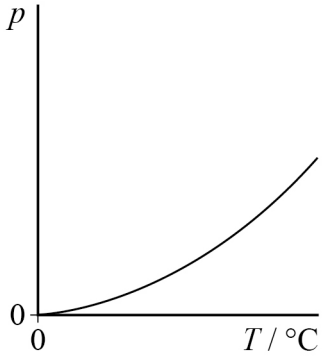
Which graph shows the variation of the pressure p with temperature T in °C?

[1 mark]

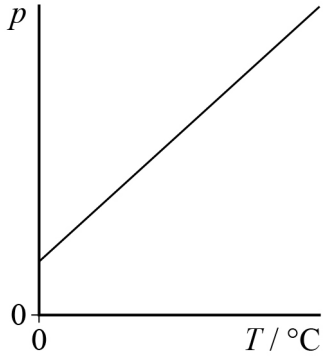
A



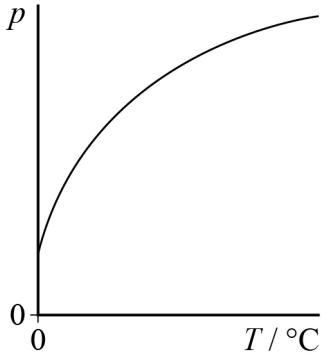
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

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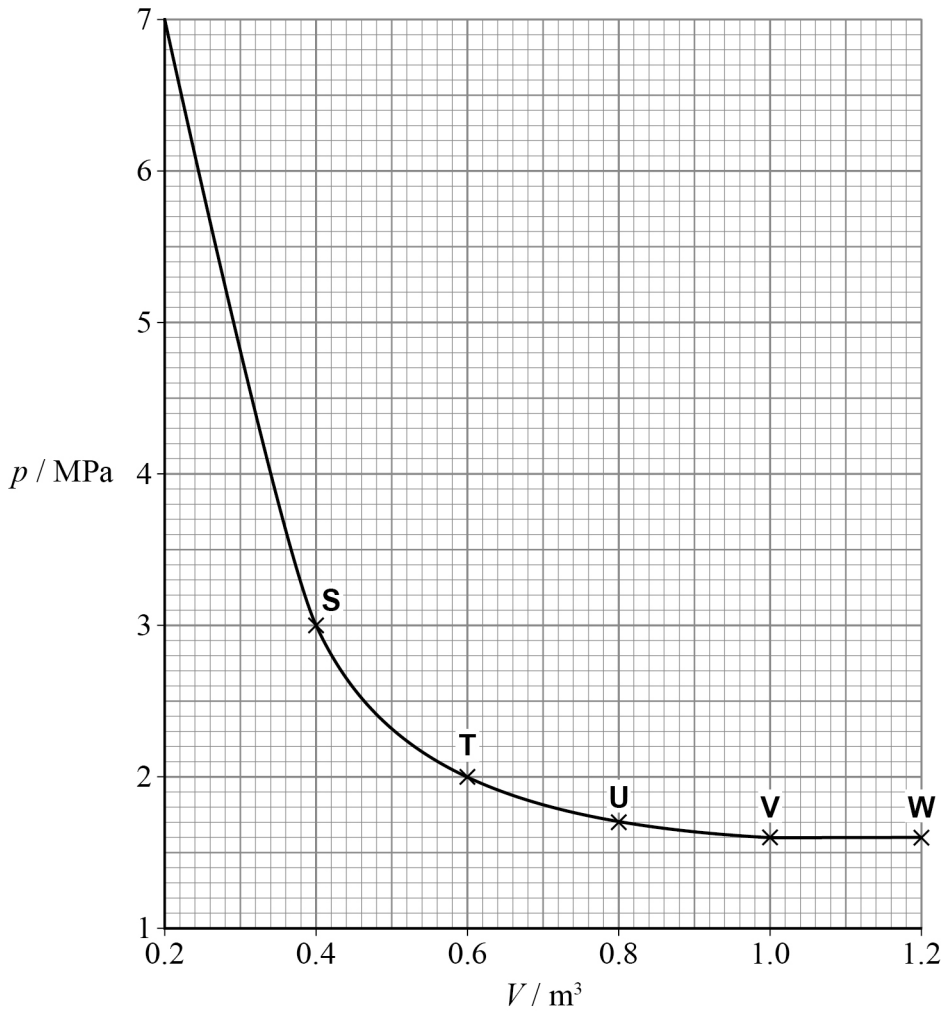
1 0 The graph shows the variation of pressure p with volume V for a fixed mass of an ideal gas.

S, **T**, **U**, **V** and **W** are points on the graph.



For which pair of points is the temperature of the gas the same?

[1 mark]

A **S** and **T** ⬭

B **T** and **U** ⬭

C **U** and **V** ⬭

D **V** and **W** ⬭

Turn over ►

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1 1 Four gas molecules are moving along the same straight line with velocities of $+250\ \text{m s}^{-1}$, $-25\ \text{m s}^{-1}$, $-100\ \text{m s}^{-1}$ and $-125\ \text{m s}^{-1}$.

What is the rms speed of the molecules?

[1 mark]

A 0 ⬭

B $74\ \text{m s}^{-1}$ ⬭

C $125\ \text{m s}^{-1}$ ⬭

D $149\ \text{m s}^{-1}$ ⬭

1 2 A system contains a fixed mass of an ideal gas.

Which combination of processes **always** produces a decrease in the internal energy of the system?

[1 mark]

	Work is done…	**Energy is transferred by heating…**	
A	by the system.	to the system.	⬭
B	by the system.	from the system.	⬭
C	on the system.	to the system.	⬭
D	on the system.	from the system.	⬭

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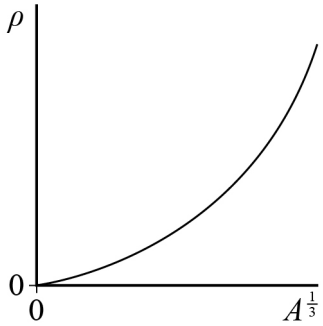
1 3 Nuclear density is ρ.
Nucleon number is A.

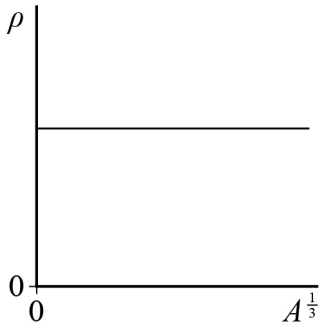
Which graph shows the variation of ρ with $A^{\frac{1}{3}}$?

[1 mark]

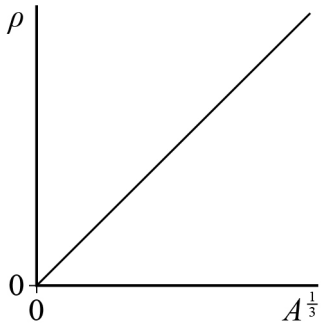
A



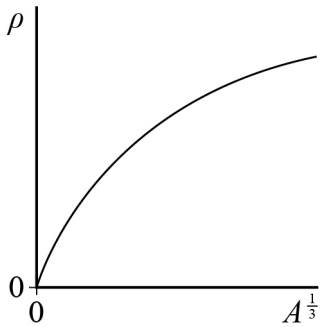
B



C



D



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Questions **14** and **15** are about four samples of different materials.

The table shows the properties of samples **A**, **B**, **C** and **D**.

Sample	U-value / $W\ m^{-2}\ K^{-1}$	Thickness / mm	Area / m^2
A	1.0	30	0.04
B	1.0	20	0.05
C	2.0	30	0.04
D	2.0	20	0.05

The temperature difference across each sample is the same.

1 4 Energy is transferred by conduction through each sample.

Which sample has the greatest rate of energy transfer by conduction?

[1 mark]

A ⬭

B ⬭

C ⬭

D ⬭

1 5 Which sample has the greatest thermal conductivity?

[1 mark]

A ⬭

B ⬭

C ⬭

D ⬭

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1 6 Two discs **X** and **Y** are rotating about an axis.

The table gives information about the mass and diameter of **X** and **Y**.

	Mass of disc	**Diameter of disc**
X	m	d
Y	$2m$	$0.5d$

For a disc of mass M and radius r, the moment of inertia about this axis is $\frac{1}{2}Mr^2$.

X and **Y** are rotating with the same angular momentum.

The rotational kinetic energy of **X** is E.

What is the rotational kinetic energy of **Y**?

[1 mark]

A $\frac{E}{2}$ ⬭

B E ⬭

C $2E$ ⬭

D $4E$ ⬭

Turn over for the next question

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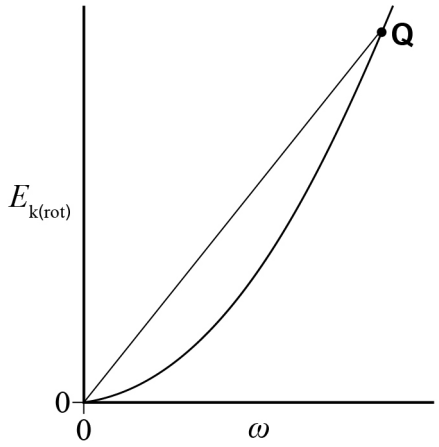
1 7 The graph shows the variation in rotational kinetic energy $E_{k(rot)}$ with angular speed ω for a rotating object.

The moment of inertia of the object is I and its angular momentum is P_A.



A straight line is drawn from the origin to point **Q** on the graph.

What does the gradient of this line represent?

[1 mark]

A $\frac{1}{2} P_A$ ⬭

B P_A ⬭

C $\frac{1}{2} I$ ⬭

D I ⬭

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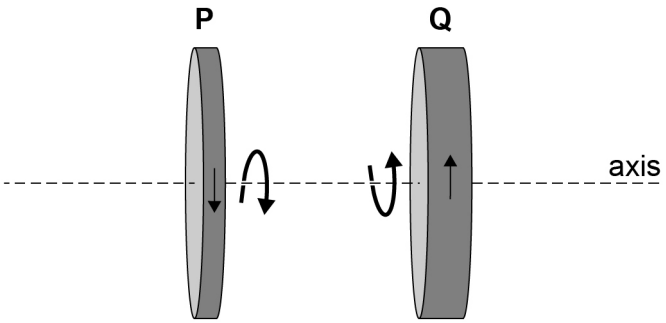
1 8 The diagram shows two discs **P** and **Q** rotating freely about a common axis.



P has a moment of inertia about its axis of $12\ \text{kg m}^2$ and an angular velocity of $8.0\ \text{rad s}^{-1}$ clockwise.

Q has a moment of inertia about its axis of $15\ \text{kg m}^2$ and an angular velocity of $6.0\ \text{rad s}^{-1}$ anticlockwise.

P and **Q** come into contact. They reach a new constant angular velocity. They stick together and do not slip.

Which row shows the new constant angular velocity?

[1 mark]

	Magnitude / rad s^{-1}	**Direction**	
A	0.22	clockwise	⬭
B	0.22	anticlockwise	⬭
C	6.9	clockwise	⬭
D	6.9	anticlockwise	⬭

Turn over for the next question

Do not write outside the box

1 9 **M** is a moderator in a thermal nuclear reactor.

Which row shows the ideal properties of a nucleus of **M**?

[1 mark]

	Probability of absorbing a neutron	Mass compared to mass of a neutron	
A	low	much greater	⬭
B	low	similar	⬭
C	high	much greater	⬭
D	high	similar	⬭

2 0 Fuel rods are removed from a nuclear fission reactor and stored in water for several months.

This is because the water:

[1 mark]

A stops the remaining fuel from undergoing fission in the fuel rods. ⬭

B cools the fuel rods that still generate heat. ⬭

C combines with the elements in the fuel and reduces their radioactivity. ⬭

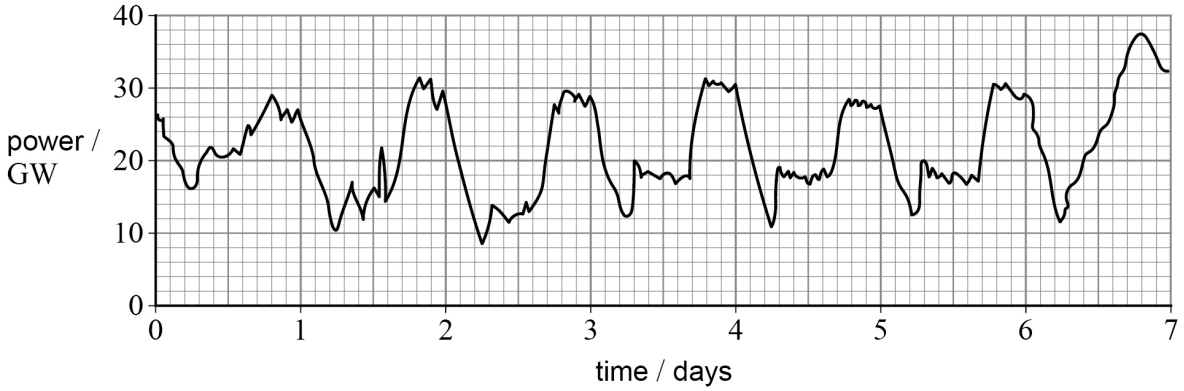
D dissolves the fuel which makes it easier to transport for reprocessing. ⬭

Do not write outside the box

Questions **21** and **22** refer to the graph below.

A country's electricity is generated partly by base-power stations and partly by back-up power stations.

The graph shows the total power provided by the power stations over a period of seven days.



2 1 Which statement is consistent with the graph?

[1 mark]

A Back-up power stations always provide less than half of the maximum output power. ⬭

B The base-power stations provide more than 20 GW of power. ⬭

C The daily variation is due to the supply from solar power. ⬭

D The back-up power stations can be brought on line quickly. ⬭

2 2 What is an order of magnitude estimate for the energy supplied during the seven-day period?

[1 mark]

A 10^{11} J ⬭

B 10^{13} J ⬭

C 10^{16} J ⬭

D 10^{19} J ⬭

15

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

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