OXFORD
INTERNATIONAL AQA EXAMINATIONS

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

Wednesday 19 January 2022   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	
8–22	
TOTAL	

Section A

Answer **all** questions in this section.

0 1 Helium gas particles are single atoms that behave as an ideal gas.
A container of helium gas is used to inflate an empty balloon.

Immediately after inflation, the gas in the balloon has:

- a pressure of $106\ \text{kPa}$
- a temperature of $288\ \text{K}$
- a volume of $1.40 \times 10^{-2}\ \text{m}^3$.

0 1 . 1 Show that the number of atoms in the balloon is approximately 3.7×10^{23}

[2 marks]

0 1 . 2 Each helium atom has a mass of $6.6 \times 10^{-27}\ \text{kg}$.

Calculate the density of the gas in the balloon.

[2 marks]

density = ____________________ kg m^{-3}

Do not write outside the box

0 1 . 3 The gas in the container has an initial temperature greater than 288 K.

Explain, with reference to the first law of thermodynamics, why the temperature of the gas decreases as the balloon is inflated.

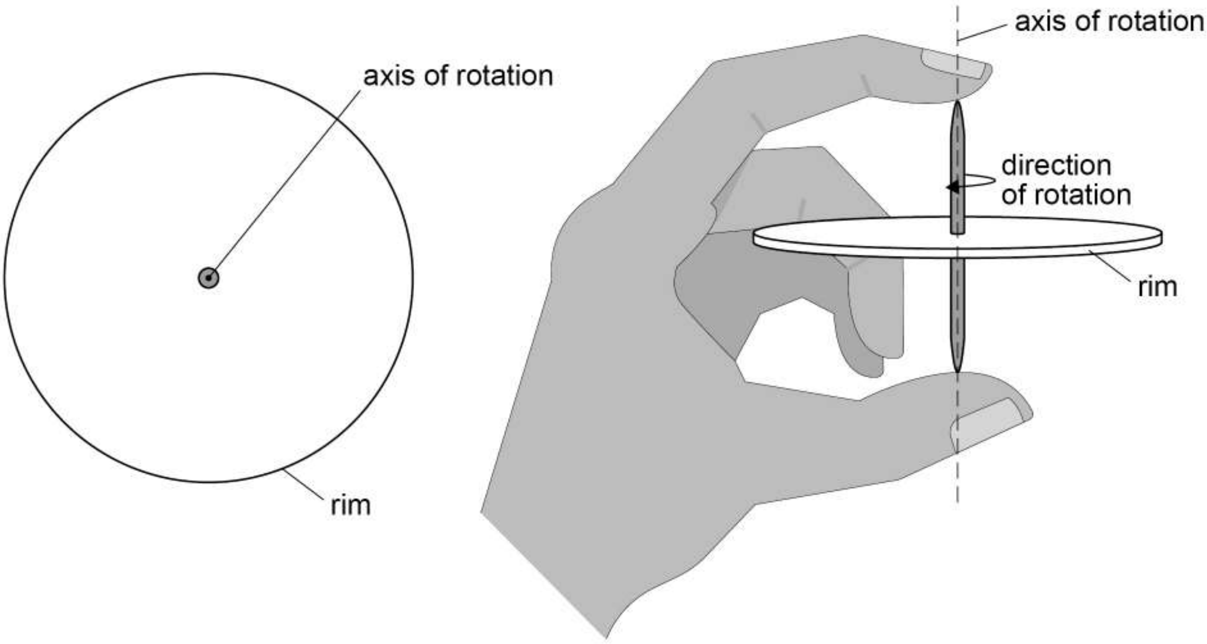
[4 marks]

8

Turn over for the next question

0 2 **Figure 1** shows a spinning toy rotating about its axis.

Figure 1



The moment of inertia of the toy about its axis of rotation is 3.5×10^{-5} kg m^2.

0 2 . 1 The toy is rotating with an initial angular speed of 19.4 rad s^{-1}.
A constant frictional torque of 2.7×10^{-4} N m acts on the toy.
The toy decelerates to rest.

Calculate the time taken for the toy to decelerate to rest.

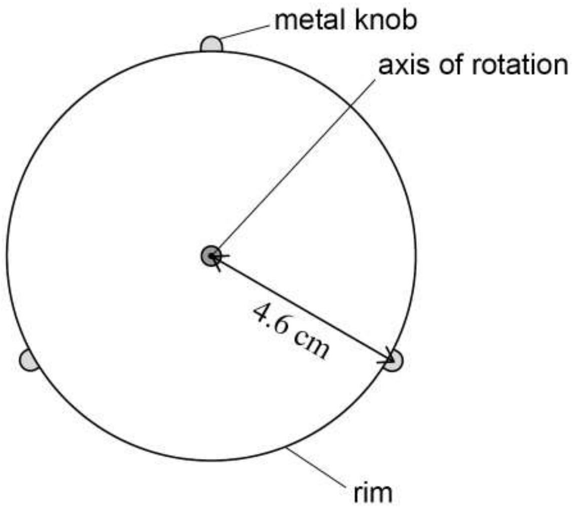
[2 marks]

time taken = ______________________ s

Three identical metal knobs are added to the rim of the toy as shown in **Figure 2**.

The centre of mass of each knob is $4.6\ \text{cm}$ from the axis of rotation.

Figure 2



The addition of the three knobs increases the moment of inertia of the toy to $8.1 \times 10^{-5}\ \text{kg m}^2$ about its axis of rotation.

0 2 . 2 Calculate the mass of one knob.

[3 marks]

mass of one knob = ____________________ kg

Question 2 continues on the next page

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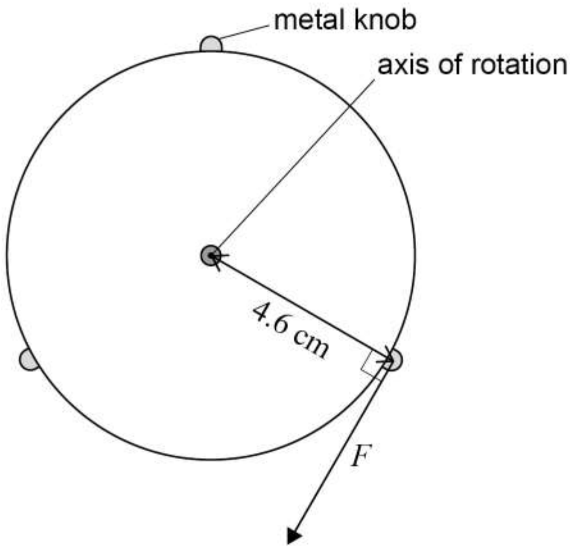
0 2 . 3 **Figure 3** shows a force F of constant magnitude acting on one of the knobs to make the toy rotate again.

Figure 3



F acts for a time of $0.12\ \text{s}$ in a direction tangential to the rim.

The toy gains an angular momentum of $2.1 \times 10^{-4}\ \text{kg m}^2\ \text{s}^{-1}$.

The frictional torque is still $2.7 \times 10^{-4}\ \text{N m}$.

Calculate the magnitude of F.

[4 marks]

magnitude of F = ______________________ N

9

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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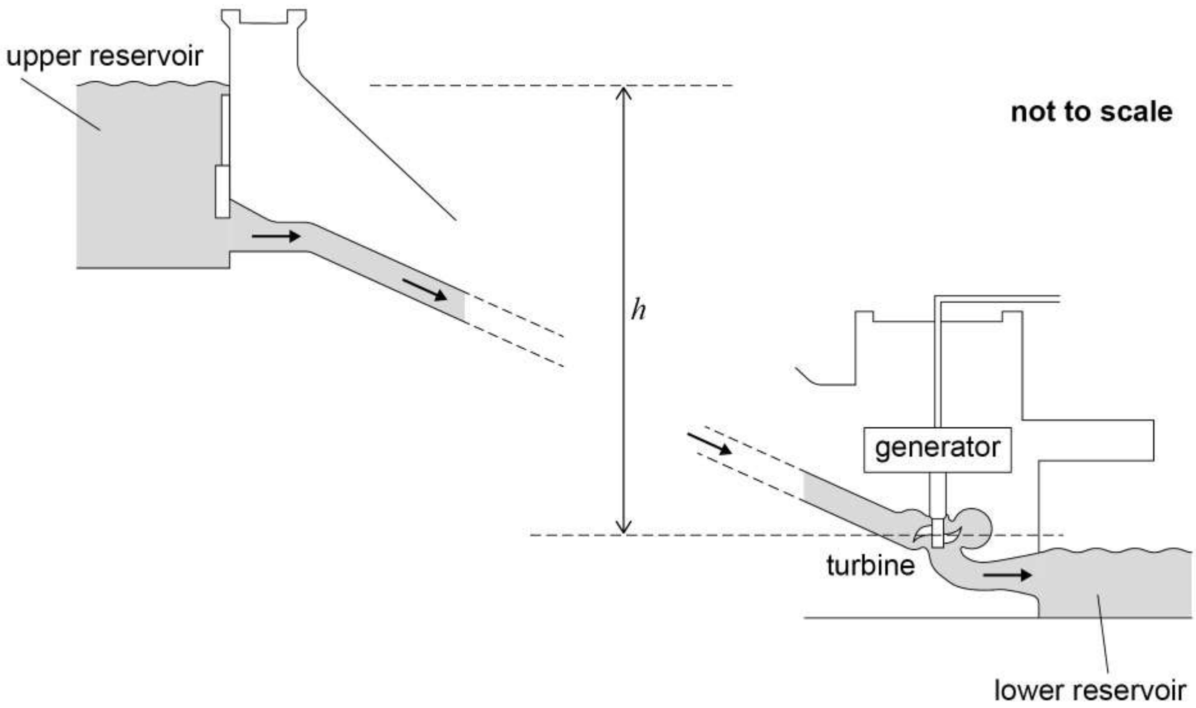
0 3 There are two stages to the operating cycle of a pumped storage system (PSS):

- a generating stage when water falls from the upper to the lower reservoir
- a pumping stage when water is returned to the upper reservoir.

Figure 4 shows a PSS being used to generate electrical power.
The water falls a vertical distance h from the upper reservoir to the turbine.

Figure 4



0 3 . 1 Show that the theoretical maximum power P_{max} available from the water during the generating stage is given by

$$P_{max} = \rho\, g\, h\, \frac{\Delta V}{\Delta t}$$

where:

- ρ is the density of the water
- $\frac{\Delta V}{\Delta t}$ is the volume of water flowing through the turbine per unit time.

[1 mark]

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In one PSS, h is $320\ \text{m}$ and P_{max} is $440\ \text{MW}$.

0 3 . 2 Calculate $\frac{\Delta V}{\Delta t}$.

$$\rho = 1.0 \times 10^3\ \text{kg m}^{-3}$$

[1 mark]

$\frac{\Delta V}{\Delta t}$ = ______________________ $\text{m}^3\ \text{s}^{-1}$

The PSS has an efficiency of 90% during the generating stage.

0 3 . 3 Suggest **two** sources of inefficiency in the PSS during the generating stage.

[2 marks]

1 ____

____

____

2 ____

____

____

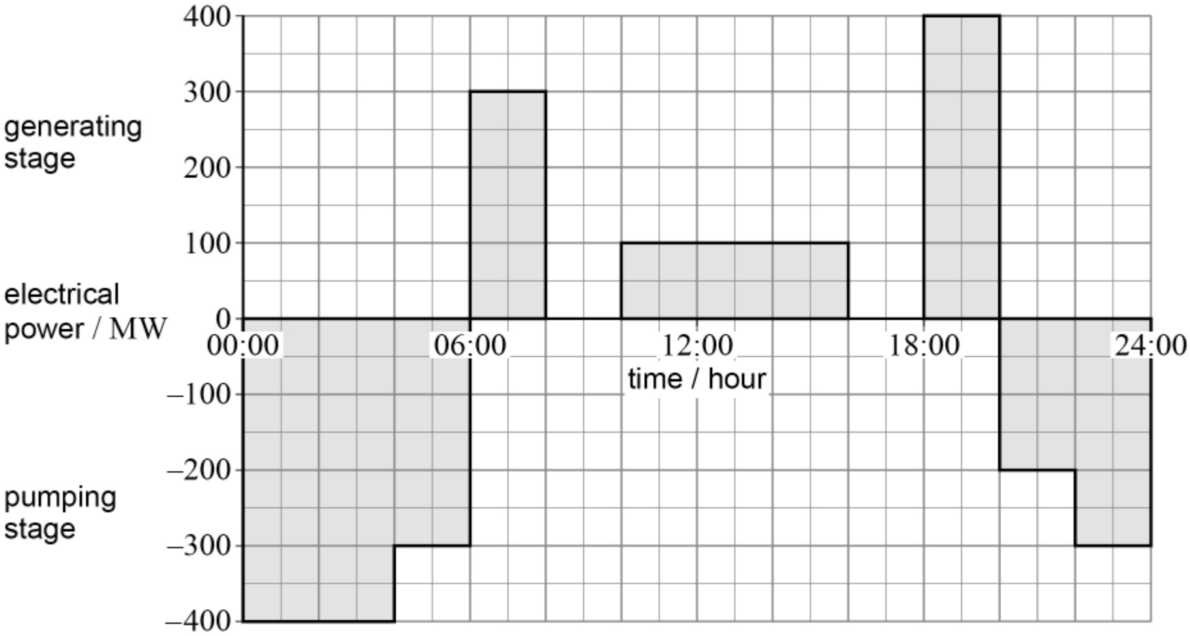
Question 3 continues on the next page

Do not write outside the box

Figure 5 shows the variation in the transfer of electrical power for the PSS with time during a 24-hour period.

In the generating stage, values of power are positive.
In the pumping stage, values of power are negative.

Figure 5



0 3 . 4 Determine, in J, the **net** electrical energy output of the PSS for the 24-hour period shown in **Figure 5**.

[3 marks]

net electrical energy output = ____________________ J

Do not write outside the box

0 3 . 5 Explain why the overall efficiency of the PSS, for the 24-hour period, is significantly less than the generating efficiency of 90%.

[1 mark]

0 3 . 6 Explain **two** reasons why pumped storage systems are useful.

[2 marks]

1

2

10

Turn over for the next question

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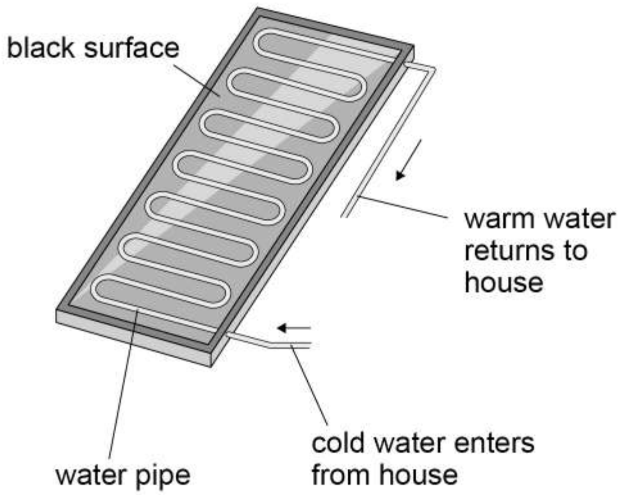
0 4 **Figure 6** shows a thermal solar panel to be used on the roof of a house.
Water is heated by solar radiation as it flows through a pipe in the solar panel.

Figure 6



0 4 . 1 Not all of the solar radiation incident on the Earth's upper atmosphere reaches the Earth's surface.
The proportion R of solar radiation incident on the Earth's surface is given by:

$$R = \frac{\text{solar power per m}^2\text{ incident on the Earth's surface}}{\text{solar power per m}^2\text{ incident on the Earth's upper atmosphere}}$$

Solar radiation is incident normally on the surface of the solar panel with a power of 2.2×10^3 W.

Calculate R.

total power output of Sun = 3.85×10^{26} W
distance between Earth and Sun = 1.50×10^{11} m
area of the upper surface of the panel = $5.5\ \text{m}^2$

[3 marks]

R = ______________________________

Do not write outside the box

0 4 . 2 The rate of flow of water through the panel is $45\ g\ s^{-1}$.
The water enters the panel at a temperature of $15\ °C$ and absorbs energy from the panel at a rate of $1.7\ kW$.

Calculate the temperature of the water as it leaves the panel.

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

[2 marks]

temperature = ______________________ °C

5

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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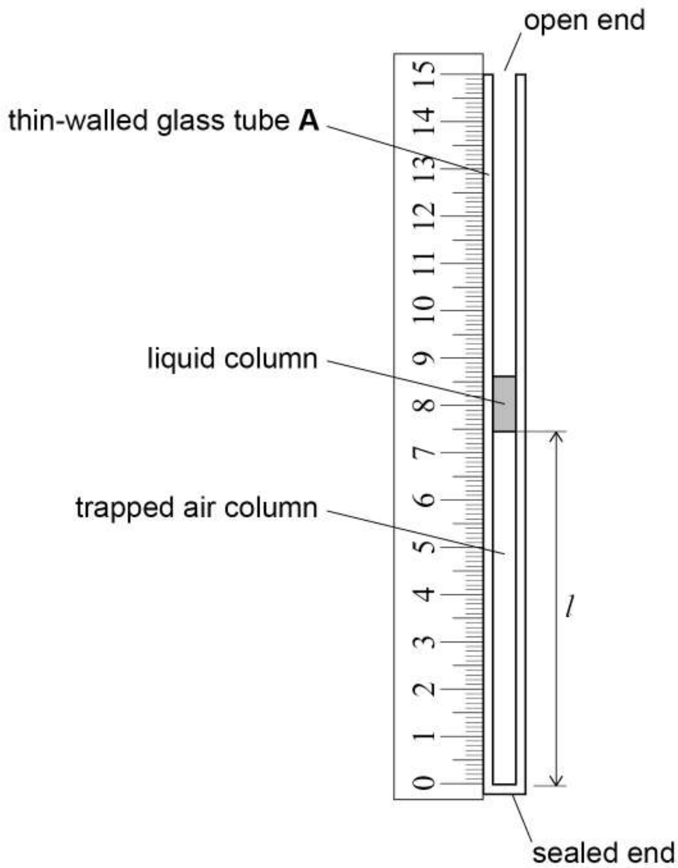
0 5 **Figure 7** shows apparatus used to estimate absolute zero in a school laboratory.

The apparatus consists of a thin-walled glass tube **A** attached to a ruler. The tube is sealed at one end and open at the other. The tube contains a fixed mass of dry air that is trapped by a short column of liquid. The pressure of the trapped air is constant. The trapped air column has a length l.

Figure 7



The apparatus is heated slowly in a water bath. l is measured for a range of temperatures T of the water bath.

0 5 . 1 Explain why l increases as T increases.

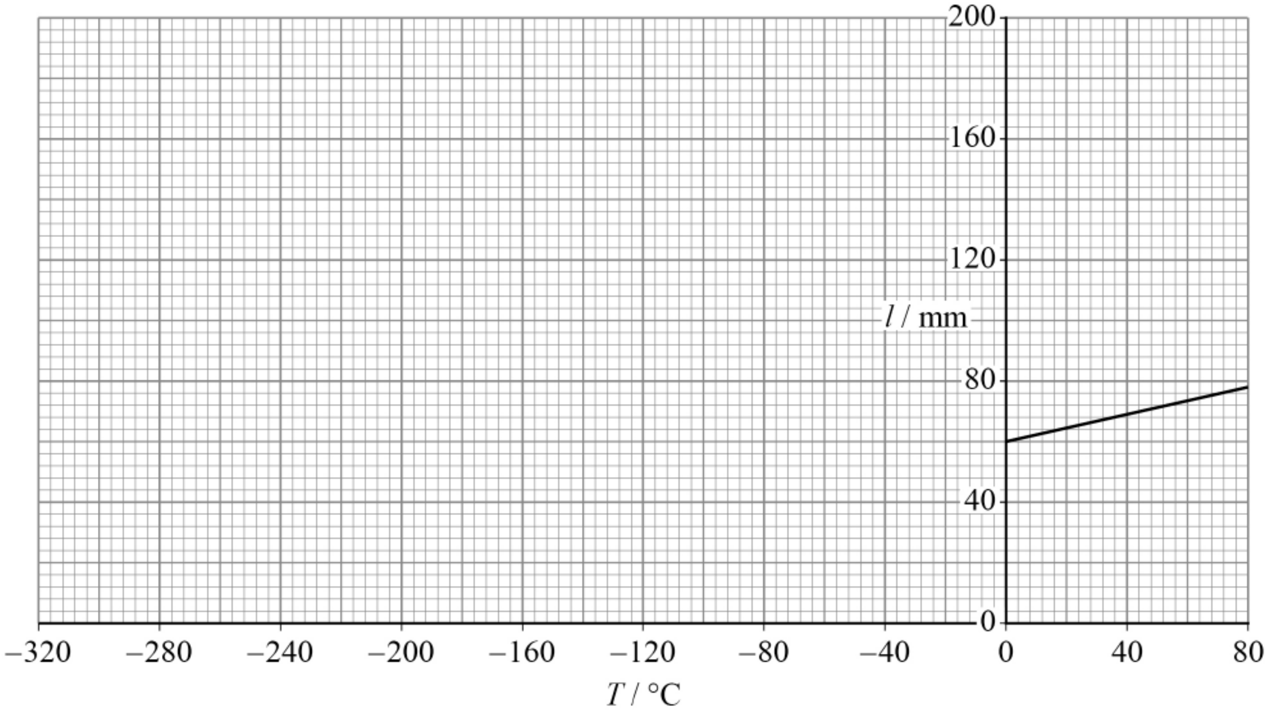
[2 marks]

Question 5 continues on the next page

Turn over ►

Figure 8 shows the variation of l with T.

Figure 8



0 5 . 2 Estimate, using **Figure 8**, absolute zero in °C.

[1 mark]

absolute zero = ______________________ °C

Do not write outside the box

The trapped air contains 2.06×10^{-6} mol of dry air at a pressure of 1.01×10^{5} Pa.

0 5 . 3 Calculate, in mm^2, the internal cross-sectional area of the glass tube.
Use your estimate of absolute zero from Question **05.2** in your calculation.

[4 marks]

internal cross-sectional area = ______________________ mm^2

0 5 . 4 Describe **two** features of the experiment that may lead to inaccuracy when determining a value of absolute zero.

[2 marks]

1 ____

____

____

2 ____

____

____

0 5 . 5 A student suggests repeating the same experiment with a glass tube **B**.

B has half the internal cross-sectional area of **A**.
B contains the same mass of trapped air as **A**.

Draw, on **Figure 8**, the variation of l with T for **B**.
Label this line **B**.

[2 marks]

11

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ANSWER IN THE SPACES PROVIDED

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0 6 . 1 Nuclear radii can be estimated using the closest approach of an alpha particle. Nuclear radii can be determined using electron diffraction.

Discuss the benefits of using electron diffraction rather than the closest approach of an alpha particle to evaluate nuclear radii.

[3 marks]

0 6 . 2 Show that the relationship between nuclear radius R and nucleon number A is given by

$$R = \left(\frac{3u}{4\pi\rho}\right)^{\frac{1}{3}} A^{\frac{1}{3}}$$

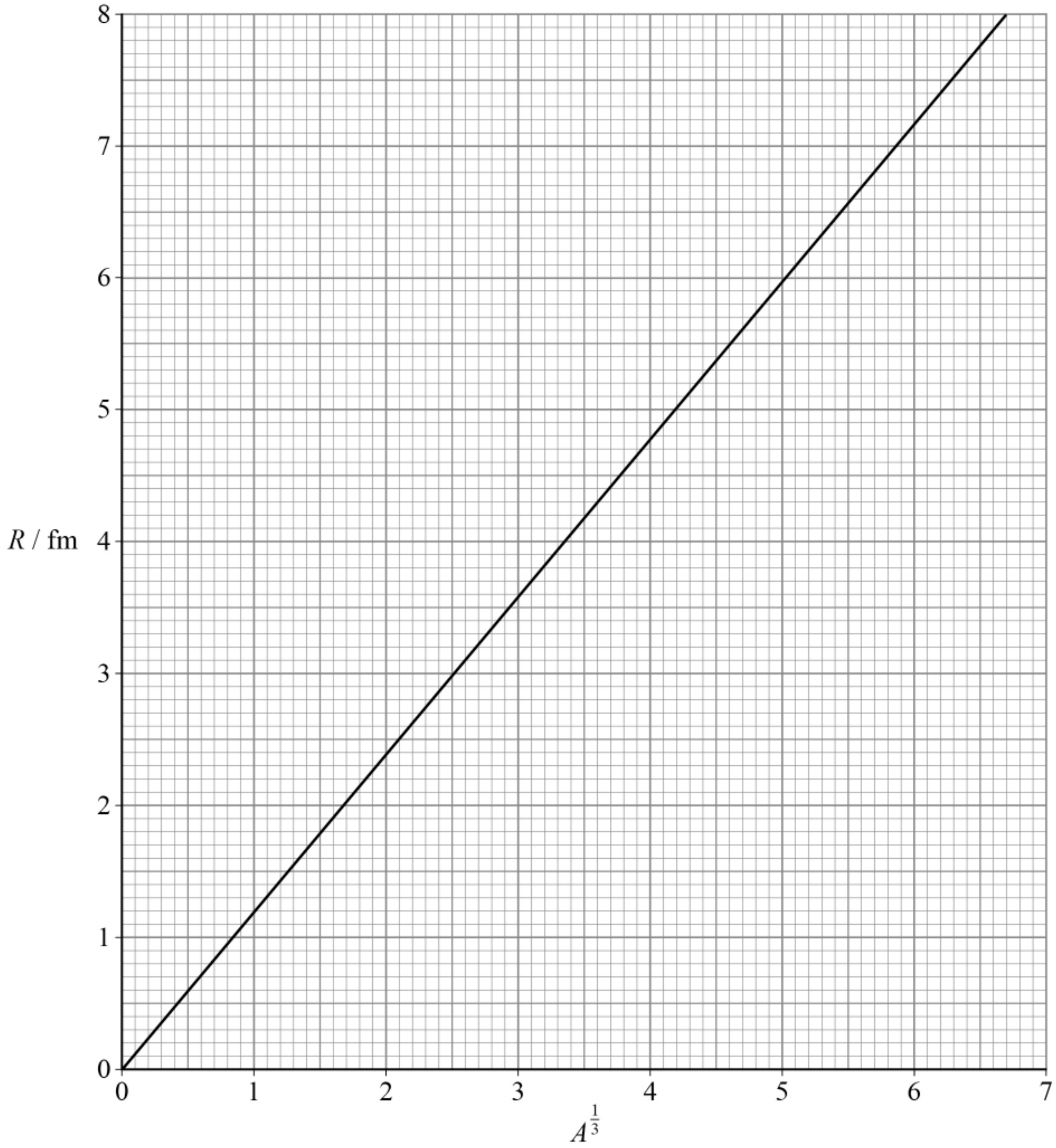
where ρ is the density of nuclear material.

[2 marks]

Question 6 continues on the next page

Figure 9 shows the variation of R with $A^{\frac{1}{3}}$.

Figure 9



Do not write outside the box

0 6 . 3 Show that ρ is approximately $2 \times 10^{17}\ \mathrm{kg\ m^{-3}}$.

[4 marks]

9

Turn over for the next question

Do not write outside the box

0 7 . 1 State what is meant by the binding energy of a nucleus.

[1 mark]

A possible fission of U-235 can be represented by:

$$^{235}_{92}\mathrm{U} + \mathrm{n} \rightarrow {}^{136}_{55}\mathrm{Cs} + {}^{97}_{37}\mathrm{Rb} + 3\mathrm{n}$$

Table 1 gives the binding energy per nucleon for each nuclide in the fission.

Table 1

Nuclide	**Binding energy per nucleon / MeV**
U-235	7.59094
Cs-136	8.38981
Rb-97	8.37460

0 7 . 2 Calculate, in J, the energy released in this reaction.

[3 marks]

energy released = ____________________ J

0 7 . 3 The average energy released by the fission of a U-235 nucleus in a reactor core is 3.2×10^{-11} J.

The fission of U-235 generates a power of 1.5 GW in the core.

Calculate the average mass of U-235 that undergoes fission in one second in this reactor core.

molar mass of U-235 = 235 g

[3 marks]

average mass = ______________________ kg

0 7 . 4 The thermal neutrons in the core can be modelled as the particles of an ideal gas. The effective temperature of this gas is 850 K.

Calculate c_{rms} for the thermal neutrons for this model.

[3 marks]

c_{rms} = ______________________ $m\ s^{-1}$

Question 7 continues on the next page

Turn over ►

0 7 . 5 Explain the role of control rods in ensuring a constant power output in a nuclear reactor core.

[3 marks]

____

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____

13

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 8 Which row shows a possible combination of changes as energy is added to a fixed mass of an ideal gas?

[1 mark]

	Work done on the gas ΔW	**Gain in internal energy of the gas ΔU**	**Change in pressure of the gas Δp**	
A	zero	positive	zero	○
B	zero	positive	positive	○
C	positive	zero	zero	○
D	positive	zero	negative	○

Do not write outside the box

0 9 What are the fundamental (base) units for thermal conductivity?

[1 mark]

A $kg\ m\ s^{-3}\ K^{-1}$ ☐

B $kg\ m\ s^{-2}\ K^{-1}$ ☐

C $J\ m^{-1}\ s^{-1}\ K^{-1}$ ☐

D $J\ m^{-1}\ K^{-1}$ ☐

1 0 Two hollow cubes **M** and **N** are made of the same material and are in the same room. They are filled with hot liquid at the same initial temperature.

M has sides of length x and walls of thickness t.

N has sides of length $2x$ and walls of thickness $2t$.

R is the initial rate of energy transfer by conduction from **M**.

What is the initial rate of energy transfer by conduction from **N**?

[1 mark]

A $8R$ ☐

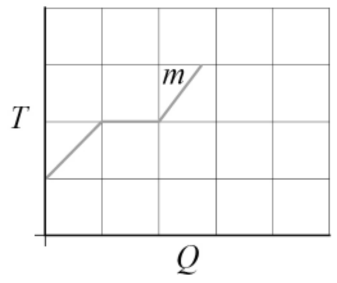
B $4R$ ☐

C $2R$ ☐

D R ☐

Do not write outside the box

1 1 Energy Q is transferred to a mass m of wax that is initially solid.
The graph shows the variation of the temperature T of the wax with Q.

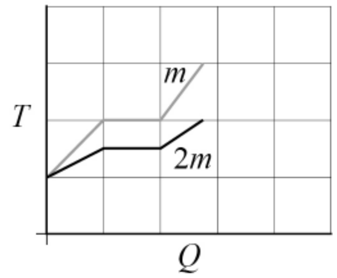


The process is repeated with wax of mass $2m$ at the same initial temperature.

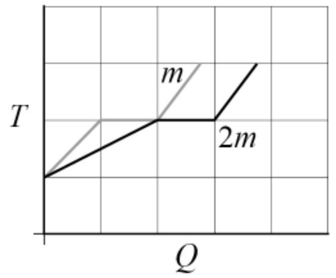
What is the variation of T with Q for this new mass?

[1 mark]

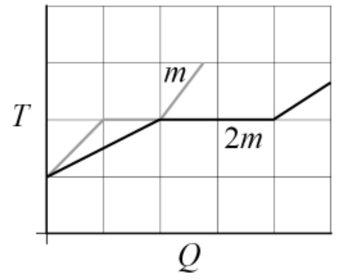
A



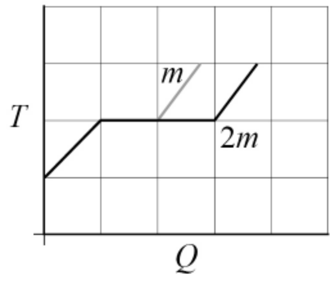
B



C



D



A ⬭

B ⬭

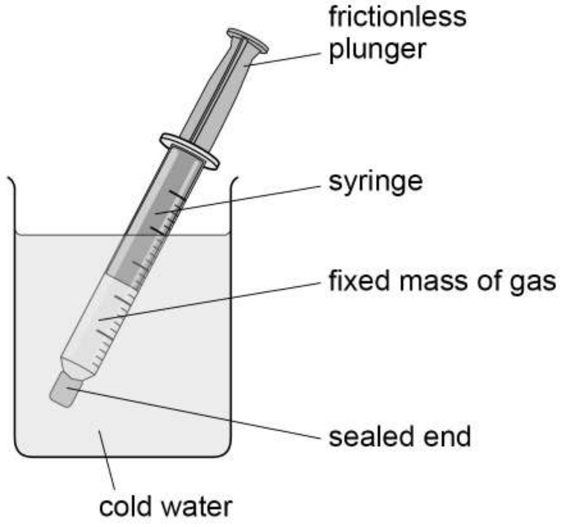
C ⬭

D ⬭

Turn over ►

1 2 A sealed syringe with a frictionless plunger contains a fixed mass of an ideal gas.

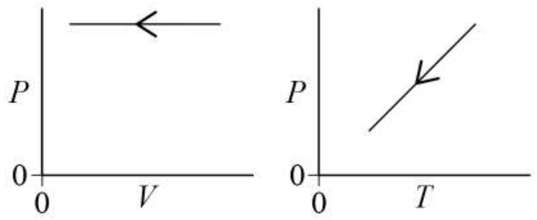
The syringe is placed into water that is colder than the initial temperature of the gas.



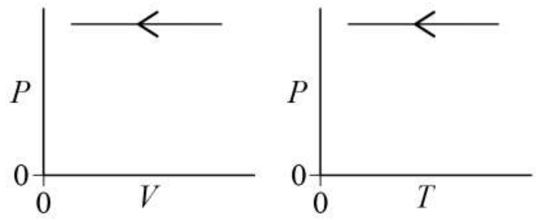
Which graphs show the variations of pressure P with volume V and with absolute temperature T for the fixed mass of gas in the syringe?

[1 mark]

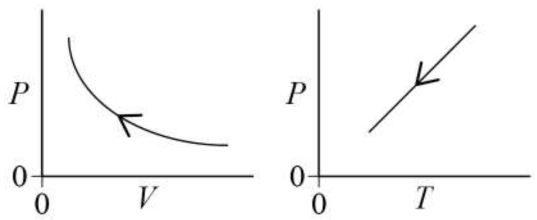
A



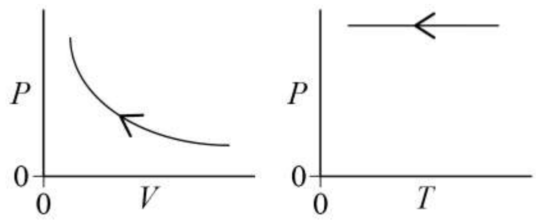
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

Do not write outside the box

1 3 The speeds of three gas particles are

$475\ \text{m s}^{-1}$ $455\ \text{m s}^{-1}$ $320\ \text{m s}^{-1}$

What is c_{rms} (root mean squared speed) for these gas particles?

[1 mark]

A $455\ \text{m s}^{-1}$

B $422\ \text{m s}^{-1}$

C $417\ \text{m s}^{-1}$

D $414\ \text{m s}^{-1}$

1 4 Which row shows desirable properties for a material chosen for the moderator in a thermal nuclear reactor?

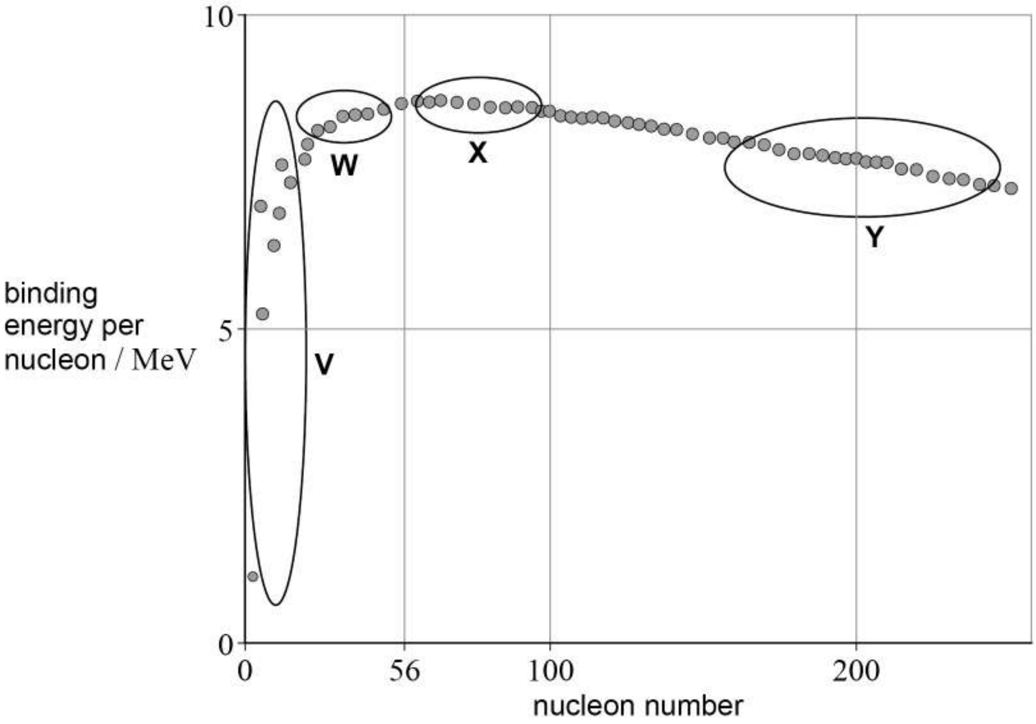
[1 mark]

A	small nucleon number	poor neutron absorber
B	small nucleon number	good neutron absorber
C	large nucleon number	poor neutron absorber
D	large nucleon number	good neutron absorber

Turn over for the next question

Do not write outside the box

1 5 The plot shows the variation of binding energy per nucleon with nucleon number.



Identify the regions on the plot where nuclei will release energy when undergoing fission or fusion.

[1 mark]

	Region(s) where fusion of nuclei releases energy	Region(s) where fission of nuclei releases energy	
A	**W** only	**Y** only	○
B	**V** and **W**	**Y** only	○
C	**V** only	**X** and **Y**	○
D	**V** and **W**	**X** and **Y**	○

1 6 The table shows the energy released in each reaction of the hydrogen cycle.

Reaction	**Energy released / MeV**
${}^{1}_{1}\text{p} + {}^{1}_{1}\text{p} \rightarrow {}^{2}_{1}\text{H} + \text{e}^{+} + \nu_{\text{e}}$	0.42
${}^{2}_{1}\text{H} + {}^{1}_{1}\text{p} \rightarrow {}^{3}_{2}\text{He} + \gamma$	5.49
${}^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \rightarrow {}^{4}_{2}\text{He} + 2\,{}^{1}_{1}\text{p}$	12.86

What is the energy released per proton when one ${}^{4}_{2}\text{He}$ nucleus is formed?

[1 mark]

A 3.12 MeV

B 4.11 MeV

C 4.69 MeV

D 6.17 MeV

1 7 Which is the most significant obstacle that must be overcome to produce a practical plasma fusion reactor?

[1 mark]

A safe disposal of the nuclear waste produced by the reactor

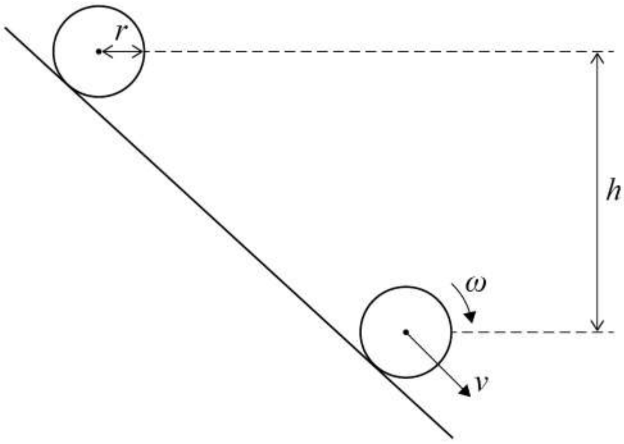
B obtaining the deuterium fuel for the reactor

C effective confinement of the plasma in the reactor

D effective emergency shut-down of the reactor

Do not write outside the box

1 8 A sphere of radius r, mass m and moment of inertia I is released from rest.
It rolls down the slope without slipping.



When the sphere has moved through a vertical distance of h it has a linear speed of v and an angular speed of ω.

What is ω?

[1 mark]

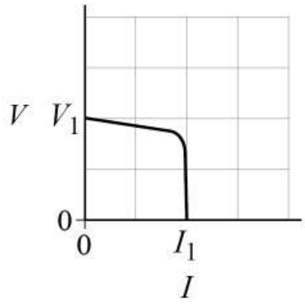
A $\sqrt{\dfrac{2gh}{I}}$ ⬭

B $\sqrt{\dfrac{2mgh}{I}}$ ⬭

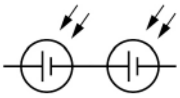
C $\sqrt{\dfrac{m(2gh - v^2)}{I}}$ ⬭

D $\sqrt{\dfrac{m(2gh + v^2)}{I}}$ ⬭

1 9 The diagrams show the V–I characteristic and the circuit symbol for a solar cell **P**.



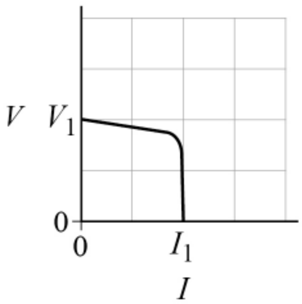
Two solar cells identical to **P** are connected in the same light conditions as **P** as shown below.



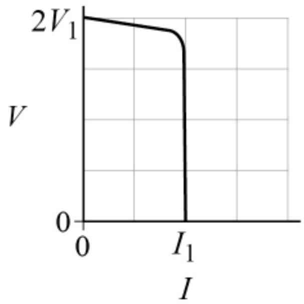
Which diagram shows the V–I characteristic for this series combination?

[1 mark]

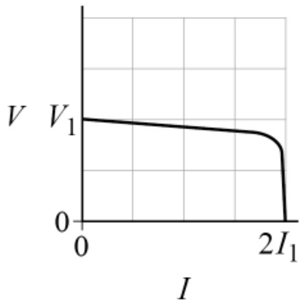
A



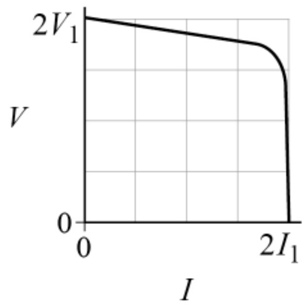
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

2 0 Which row gives an advantage and a disadvantage of the named method of electricity generation?

[1 mark]

	Method of electricity generation	Advantage	Disadvantage	
A	photovoltaic solar panels	greenhouse gases not emitted during power generation	toxic materials used in manufacture of panels	⬭
B	photovoltaic solar panels	suitable for base-power stations	slow response to changes in demand	⬭
C	wind turbines	not damaging to plant and animal habitats	unavailable in some weather conditions	⬭
D	wind turbines	continuous production of electricity is possible	few suitable sites are available	⬭

Questions 21 and 22 are about location X and location Y.

Location **X** is at sea level.
At **X**, the air has a pressure of $1.0 \times 10^5\ \mathrm{N\ m^{-2}}$ and a density of $1.2\ \mathrm{kg\ m^{-3}}$.

Location **Y** is on a mountain.
At **Y**, the air has a pressure of $0.90 \times 10^5\ \mathrm{N\ m^{-2}}$ and a density of $1.1\ \mathrm{kg\ m^{-3}}$.

Assume that the air is an ideal gas.

2 1 The air has a temperature of $300\ \mathrm{K}$ at **X**.

What is the temperature of the air at **Y**?

[1 mark]

A $248\ \mathrm{K}$ ⬭

B $270\ \mathrm{K}$ ⬭

C $275\ \mathrm{K}$ ⬭

D $295\ \mathrm{K}$ ⬭

2 2 The wind speed at **Y** is 50% greater than the wind speed at **X**.
P is the theoretical maximum power available to a wind turbine at **X**.

What is the theoretical maximum power available to an identical wind turbine at **Y**?

[1 mark]

A $3.7P$ ⬭

B $3.1P$ ⬭

C $1.6P$ ⬭

D $1.4P$ ⬭

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END OF QUESTIONS

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