OXFORD
INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

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I declare this is my own work.

INTERNATIONAL A-LEVEL
PHYSICS

Unit 4 Energy and Energy resources

Thursday 15 June 2023 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	

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Section A

Answer **all** questions in this section.

0 1 Brownian motion provides evidence that gas is made of particles.
Brownian motion is demonstrated in a school laboratory by observing the motion of smoke particles under a microscope.

Properties of the gas molecules are deduced from observations made during the demonstration.

Explain **two** properties of the gas molecules in terms of these observations.

[4 marks]

1 ____

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2 ____

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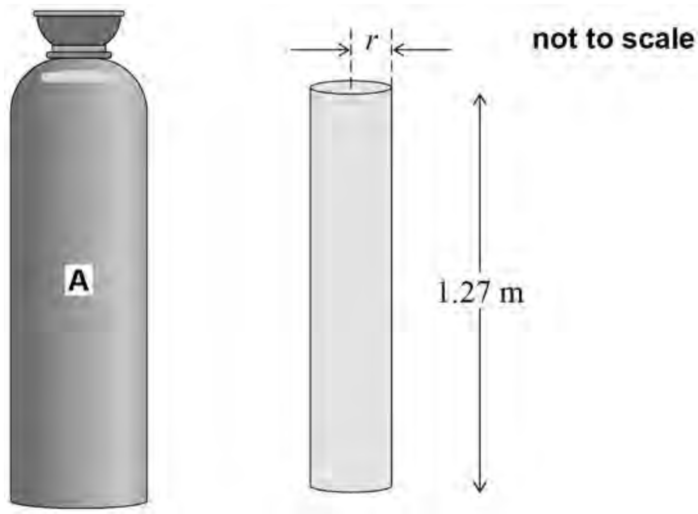
4

0 2 Gas bottles are used to store gases at high pressure.

Gas bottle **A** in **Figure 1** contains $25\ \mathrm{mol}$ of gas at a pressure of $1.0\ \mathrm{MPa}$.

Assume that the interior of **A** is a cylinder of length $1.27\ \mathrm{m}$ and radius r, as shown in **Figure 2**, and that the gas behaves as an ideal gas.

Figure 1 **Figure 2**



0 2 . 1 The temperature of the gas is $17\ °\mathrm{C}$.

Determine r.

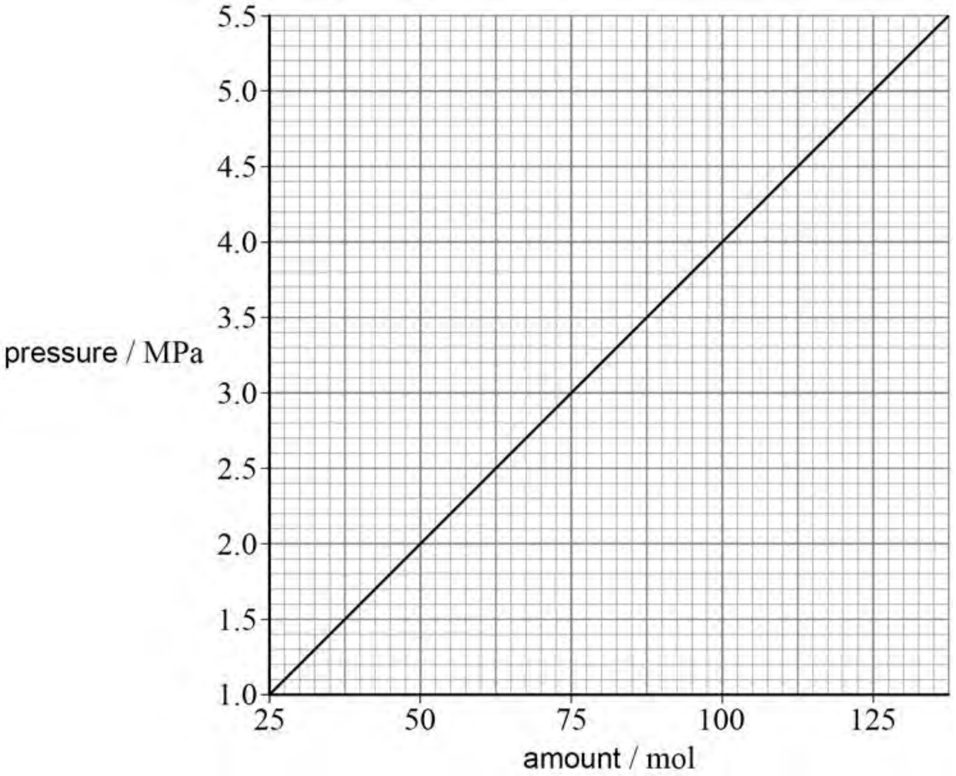
[3 marks]

r = ______________________ m

Question 2 continues on the next page

More of the gas is added to **A** and the pressure inside **A** increases.
The volume of **A** does not change.
The gas is put into **A** slowly so that the temperature of the gas remains constant at $17\ ^\circ\text{C}$.
Figure 3 shows the variation of pressure with amount of gas in the bottle.

Figure 3



0 2 . 2 Calculate, using **Figure 3**, the mass of gas added to **A** to increase the pressure inside from $1.0\ \text{MPa}$ to $3.8\ \text{MPa}$.

molar mass of the gas = $29\ \text{g mol}^{-1}$

[2 marks]

mass = ______________________ kg

0 2 . 3 Explain how **Figure 3** shows that the temperature of the gas is constant.

[3 marks]

0 2 . 4 Discuss the difference in the total internal energy of the ideal gas in **A** before and after the extra gas is added.

[4 marks]

0 2 . 5 Gas bottle **B** is identical to **A**.

B initially contains the same amount of gas as the initial amount in **A**.

The temperature of the gas in **B** is greater than $17\ ^\circ\mathrm{C}$.

More of the gas is added to bottle **B** without changing its temperature.

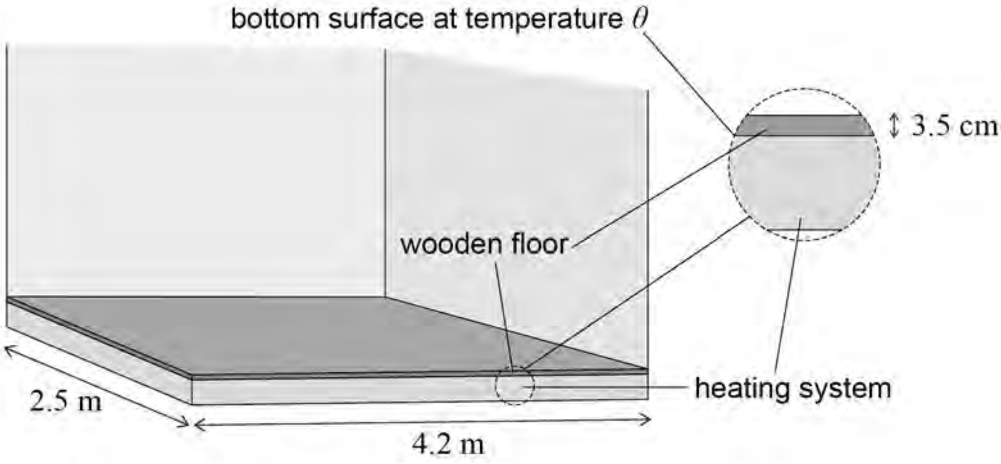
Draw a line on **Figure 3** to show how the pressure in **B** changes as more gas is added.

[2 marks]

14

0 3 A room is heated by a heating system under the floor.
The room has a wooden floor, as shown in **Figure 4**.
The floor is 2.5 m wide, 4.2 m long and 3.5 cm thick.

Figure 4



The heating system keeps all points on the bottom surface of the floor at temperature θ.
θ can be changed by adjusting the power output of the heating system.

0 3 . 1 Initially, θ is 45 °C and the temperature at the upper surface of the floor is 22 °C.
Energy is transferred by conduction through the floor at a rate of 1.2 kW.

Calculate the thermal conductivity of the wood used to make the floor.
State an appropriate SI unit for your answer.

[4 marks]

thermal conductivity = ____________________ unit = ____________________

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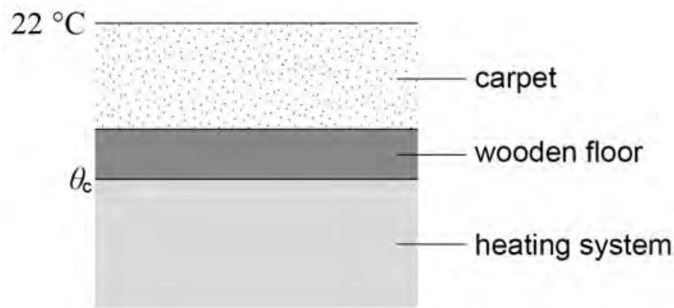
0 3 . 2 The whole of the floor is now covered with a carpet. The combined U-value of the floor and carpet is $2.1\ \mathrm{W\,m^{-2}\,K^{-1}}$.
The power output of the heating system is adjusted until the rate of energy transfer through the floor and carpet is $1.2\ \mathrm{kW}$.
The temperature of the top of the carpet is $22\ ^\circ\mathrm{C}$ as shown in the cross-sectional view of the floor in **Figure 5**.

Figure 5



Calculate θ_c, the new temperature of the bottom of the wooden floor.

[2 marks]

θ_c = ______________ °C

0 3 . 3 Some of the energy is wasted heating the ground underneath the heating system.

Suggest how the use of a carpet on the floor affects the wasted heat transfer from the heating system.

[2 marks]

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8

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0 4 . 1 Estimate the theoretical maximum value of the radius of a silicon nucleus using the closest approach of a $6.5\ \mathrm{MeV}$ alpha particle.

proton number of silicon $= 14$

[4 marks]

radius of silicon nucleus = ____________________ m

0 4 . 2 Explain why the value obtained in Question **04.1** is only an estimate of the theoretical maximum value of the radius.

[1 mark]

____

____

Table 1 contains data about two nuclides **X** and **Y**.

Table 1

Nuclide	Number of protons in nucleus	Number of neutrons in nucleus
X	16	24
Y	20	20

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0 4 . 3 The radius of the nucleus of each nuclide is estimated using the closest approach of alpha particles. The alpha particles all have the same initial kinetic energy.

Discuss how the radius estimated for **X** compares with the radius estimated for **Y**.

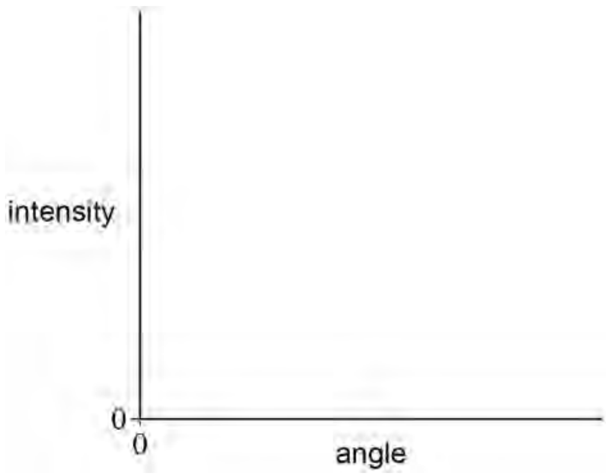
[3 marks]

Information about the radius R of a nucleus of nucleon number A is obtained from electron diffraction.

0 4 . 4 Sketch, on the axes in **Figure 6**, the variation of intensity with angle for electron diffraction by a nucleus.

[1 mark]

Figure 6



Question 4 continues on the next page

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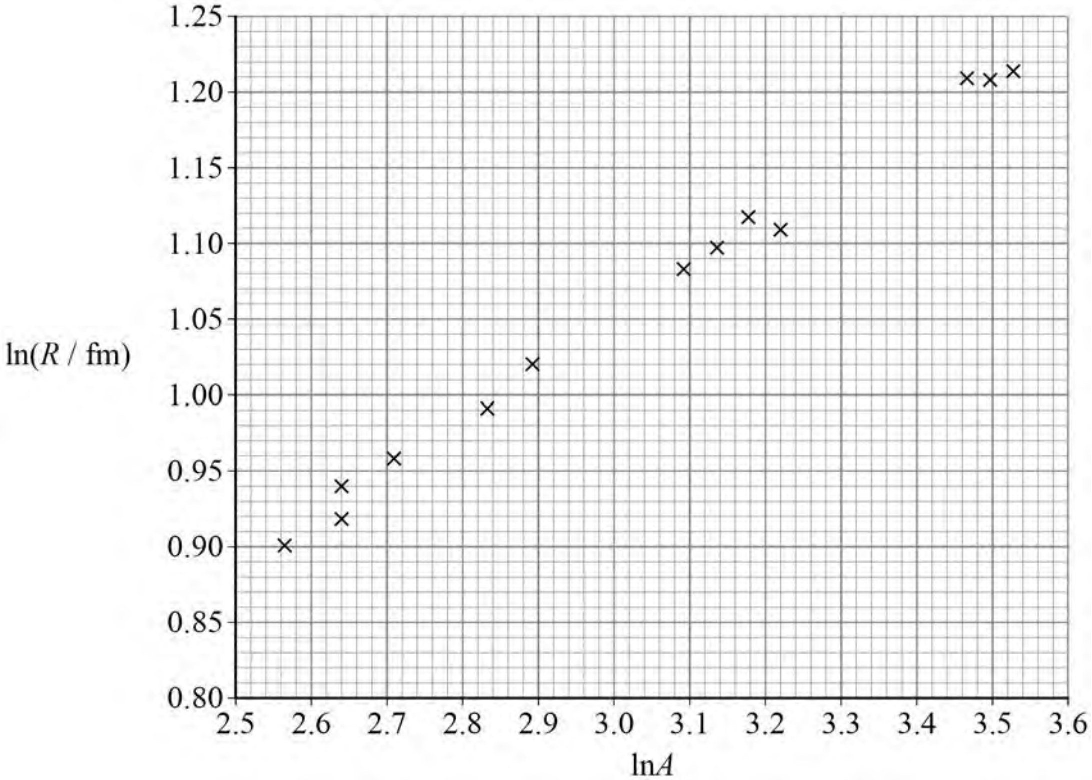
0 4 . 5 The radius of the nucleus of **X** and the radius of the nucleus of **Y** are determined using the electron-diffraction method.

Discuss how the radius determined for **X** compares with the radius determined for **Y**.

[2 marks]

Values of $\ln(R\ /\ \mathrm{fm})$ and $\ln A$ for several nuclides are plotted on the axes in **Figure 7**.

Figure 7



0 4 . 6 The experimental data used to plot **Figure 7** suggest that R is related to A by the equation

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

Determine, using **Figure 7**, a value for R_0.

[4 marks]

$R_0 =$ ____________________ fm

15

Turn over for the next question

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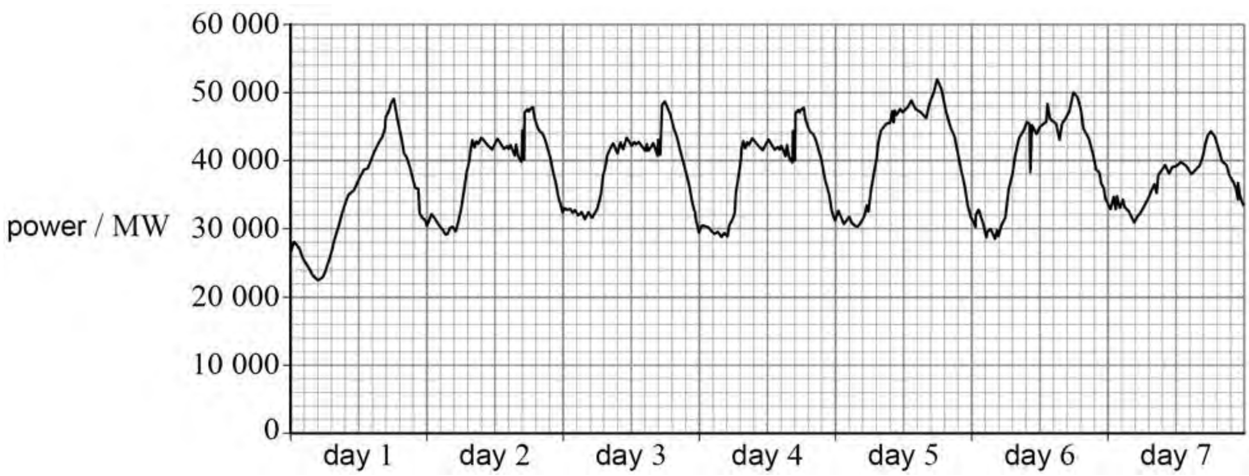
0 5 A network of power stations and other power sources provides electrical power to industrial and residential consumers.

Figure 8 shows the variation of total power provided by the power stations and other power sources over a period of seven days.

Figure 8



0 5 . 1 Estimate, in J, the energy provided during the seven days shown in **Figure 8**.
Give your answer to the nearest order of magnitude.

[3 marks]

order of magnitude of energy provided = ____________________ J

Some of the power was supplied from base-power stations and some was provided from back-up power stations. Power was also provided from other renewable sources.

0 5 . 2 Suggest a value for the power provided by base-power stations during the seven days shown in **Figure 8**.

[1 mark]

power = ____________________ W

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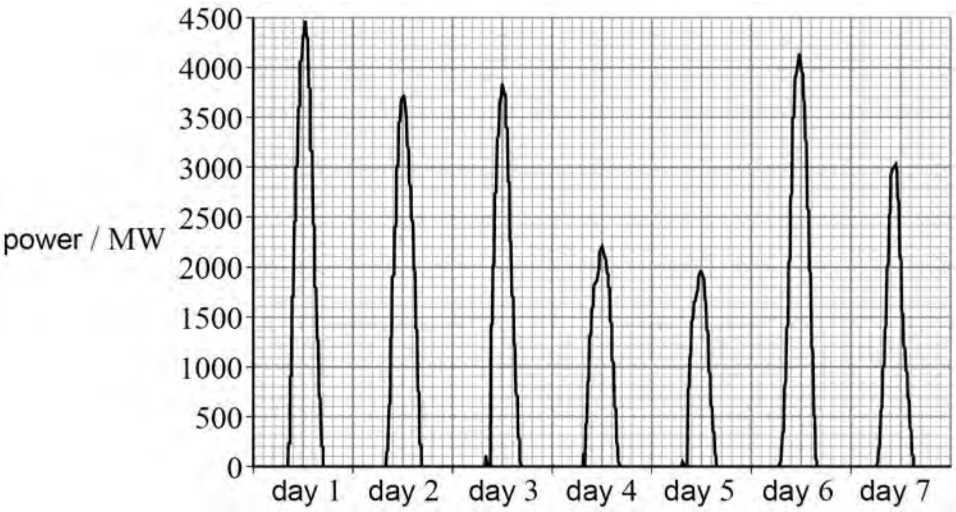
Figure 9 shows the contribution from solar power to the data in **Figure 8**.

Figure 9



0 5 . 3 Explain **one** similarity and **one** difference between the peaks in **Figure 9**.

[2 marks]

similarity ____

difference ____

0 5 . 4 The demands for power by consumers at noon on day 2 and day 4 were similar.

Explain how the contributions from solar power affected the power required from base-power stations and back-up power stations at these two times.

[3 marks]

base-power stations ____

back-up power stations ____

9

Turn over ►

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0 6 **Figure 10** shows a system made of two metal spheres attached by rigid rods to a frictionless hinge. The hinge is at the top of a vertical pole.

Figure 10

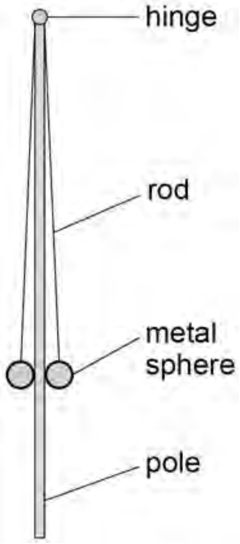

Figure 11

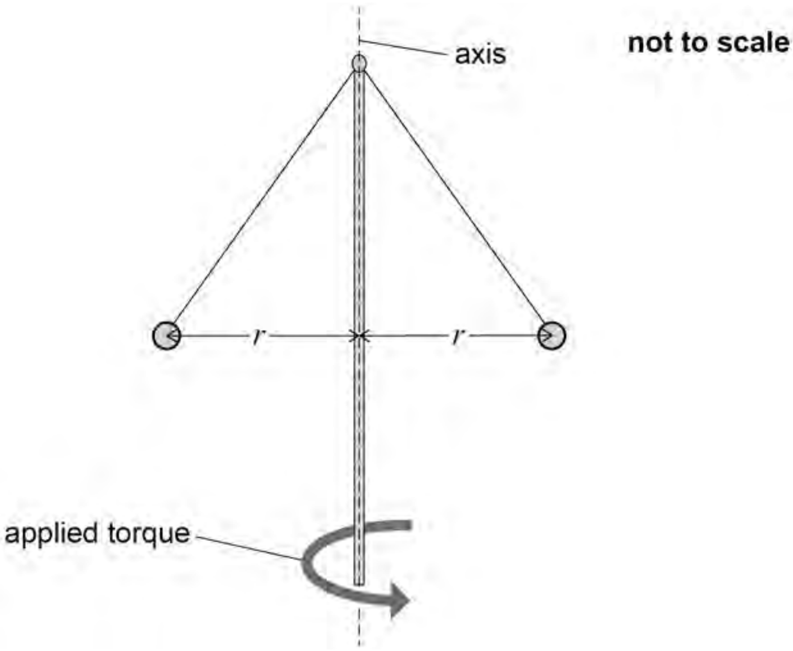

Figure 11 shows a torque being applied to the pole, making it rotate about its axis.

The torque is removed when the distance between the centre of mass of each sphere and the axis is r.

The mass of each sphere is $0.24\ \mathrm{kg}$. For the position shown in **Figure 11**, the rotating system has a moment of inertia of $2.2 \times 10^{-3}\ \mathrm{kg\ m^2}$ and rotational kinetic energy of $59\ \mathrm{mJ}$ about the axis.

Assume that the spheres behave as point masses. The pole, rods and hinge each have negligible mass.

0 6 . 1 Calculate r.

[2 marks]

$r =$ ____________________ m

Do not write outside the box

0 6 . 2 Calculate the angular velocity of the spheres.

[2 marks]

angular velocity = ______________________ rad s^{-1}

A constant frictional torque is now applied to the rotating pole. When the system has come to rest the arrangement returns to that shown in **Figure 10**.

0 6 . 3 Explain why the angular deceleration is **not** constant as the spheres come to rest.

[2 marks]

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0 6 . 4 Explain why the work done by the frictional torque is greater than $59\ \text{mJ}$.

[2 marks]

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0 7 A helium-3 $\left({}^{3}_{2}\mathrm{He}\right)$ nucleus has a binding energy of $7.72\ \mathrm{MeV}$ and a rest energy of $2810\ \mathrm{MeV}$.

0 7 . 1 Explain why the rest energy is much greater than the binding energy.

[1 mark]

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____

A fusion reaction between two nuclei of deuterium $\left({}^{2}_{1}\mathrm{H}\right)$ produces a helium-3 nucleus and a particle **X**.

The equation for this reaction is

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

$3.28\ \mathrm{MeV}$ of energy is released in this reaction.

0 7 . 2 Determine the rest energy of **X**.

[2 marks]

rest energy = ____________________ MeV

Do not write outside the box

0 7 . 3 Determine the binding energy of a deuterium nucleus.

[2 marks]

binding energy = ______________________ MeV

0 7 . 4 Many experimental fusion reactors use tritium $\left({}^{3}_{1}\mathrm{H}\right)$ and deuterium nuclei as fuel rather than two deuterium nuclei.

Discuss **two** factors that influence the choice of fuel in the design of a fusion reactor.

[2 marks]

1 ____

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2 ____

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7

END OF SECTION A

Turn over ►

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.

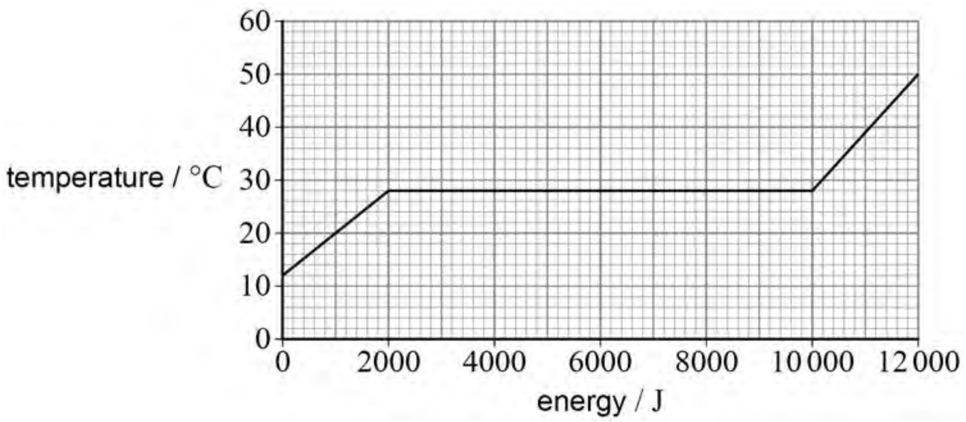
CORRECT METHOD WRONG METHODS

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 The graph shows how the temperature of $500\ \text{g}$ of a metal changes as energy is transferred to the metal.



What is the specific latent heat of the metal?

[1 mark]

A $0.16\ \text{kJ kg}^{-1}$ ⬭

B $12\ \text{kJ kg}^{-1}$ ⬭

C $16\ \text{kJ kg}^{-1}$ ⬭

D $24\ \text{kJ kg}^{-1}$ ⬭

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0 9 The first law of thermodynamics for a system can be written as:

$$\Delta U = Q + W$$

The energy input to a system by heating is $800\ \mathrm{J}$, and the system does $600\ \mathrm{J}$ of work.

What is ΔU?

[1 mark]

A $1400\ \mathrm{J}$ ⬭

B $200\ \mathrm{J}$ ⬭

C $-200\ \mathrm{J}$ ⬭

D $-1400\ \mathrm{J}$ ⬭

1 0 The ideal gas equation is

$$pV = NkT$$

Which row identifies N and k?

[1 mark]

	N	k	
A	the number of molecules in the gas	$\frac{R}{N_A}$	⬭
B	the number of molecules in the gas	$\frac{N_A}{R}$	⬭
C	the amount of gas, in mol	$\frac{N_A}{R}$	⬭
D	the amount of gas, in mol	$\frac{R}{N_A}$	⬭

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1 1 Which is **not** true for gas molecules in the kinetic theory of gases?

[1 mark]

A Collisions between the molecules and container walls are elastic. ⬭

B They have negligible mass. ⬭

C There are no intermolecular forces except during collisions. ⬭

D Their motion is random. ⬭

1 2 A fission reaction is

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

Nuclide	Binding energy per nucleon / MeV
$^{236}_{92}\mathrm{U}$	7.59
$^{146}_{57}\mathrm{La}$	8.24
$^{87}_{35}\mathrm{Br}$	8.61

What is the energy released in this reaction?

[1 mark]

A 9.3 MeV ⬭

B 73 MeV ⬭

C 88 MeV ⬭

D 161 MeV ⬭

Do not write outside the box

1 3 A stable nucleus has a mass M.

The nucleus contains Z protons and A nucleons.

rest mass of proton = m_p
rest mass of neutron = m_n

What is the mass defect of the nucleus?

[1 mark]

A $Am_n + Zm_p - M$ ⬭

B $M - Am_n - Z(m_p - m_n)$ ⬭

C $Am_n + Z(m_p - m_n) - M$ ⬭

D $M - Am_n + Zm_p$ ⬭

1 4 In a thermal nuclear reactor, the number of neutrons and the speeds of neutrons need to be controlled.

What material is used to control the number of neutrons and what material is used to control the speeds of neutrons?

[1 mark]

	Control the number of neutrons	**Control the speeds of neutrons**	
A	graphite	water	⬭
B	boron	graphite	⬭
C	graphite	boron	⬭
D	water	boron	⬭

Turn over ►

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1 5 A wind turbine has blades that sweep out a circular area of radius r.
The wind speed is v.
The maximum power available to a wind turbine is P.

Which combination of r and v produces the greatest value of P?

[1 mark]

	r / m	v / m s^{-1}	
A	7	15	⬭
B	8	12	⬭
C	9	9	⬭
D	10	6	⬭

1 6 A satellite is 4.5×10^{10} m from the Sun.
The solar cells on the satellite have an area of $0.5\ \text{m}^2$ and provide 240 W to power the satellite when the solar cells face the Sun.

What percentage of the total solar power incident on the solar cells is used to provide power to the satellite?

power output of the Sun = 3.8×10^{26} W

[1 mark]

A 0.4% ⬭

B 0.8% ⬭

C 1.6% ⬭

D 3.2% ⬭

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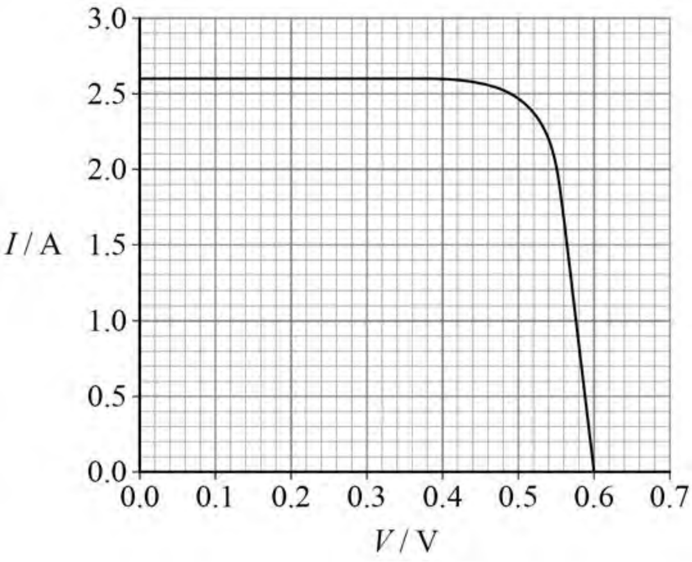
1 7 The graph shows the I–V characteristic for a solar cell.



What is the maximum power for the solar cell?

[1 mark]

A 1.04 W ⬭

B 1.20 W ⬭

C 1.23 W ⬭

D 1.56 W ⬭

1 8 A power station using a thermal nuclear reactor has an efficiency of 33%.

A fission reaction in the core results in a mass of 0.23 u being transferred into energy.

How many of these reactions per second are required to generate 750 MW of electrical power?

[1 mark]

A 1.7×10^{18} ⬭

B 7.3×10^{18} ⬭

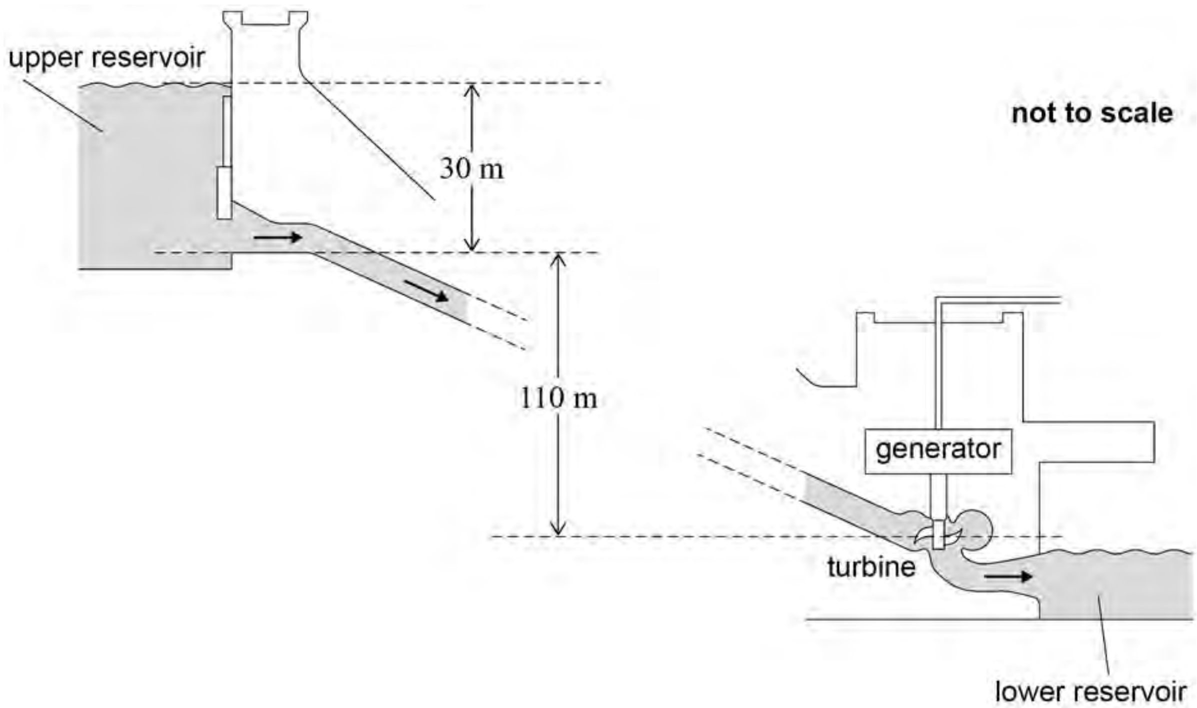
C 1.5×10^{19} ⬭

D 6.6×10^{19} ⬭

Turn over ►

Do not write outside the box

1 9 Water flows through the turbine of a hydroelectric power station at a rate of $250\ \mathrm{m^3\ s^{-1}}$.
The height of the outflow of the upper reservoir is $110\ \mathrm{m}$ above the turbine.
The depth of the water in the upper reservoir is $30\ \mathrm{m}$.
The density of water is $1000\ \mathrm{kg\ m^{-3}}$.



What is the maximum power available from the flow of water through the turbine?

[1 mark]

A 74 MW ⬭

B 270 MW ⬭

C 310 MW ⬭

D 340 MW ⬭

2 0 Which statement about the critical mass of fissile material is true?

[1 mark]

A For a critical mass of fuel, each fission reaction releases one neutron. ⬭

B The determination of the critical mass assumes that the fuel is spherical. ⬭

C A nuclear reactor must always contain less than the critical mass of fuel. ⬭

D Slowing neutrons from fission increases the amount of fuel needed to reach the critical mass. ⬭

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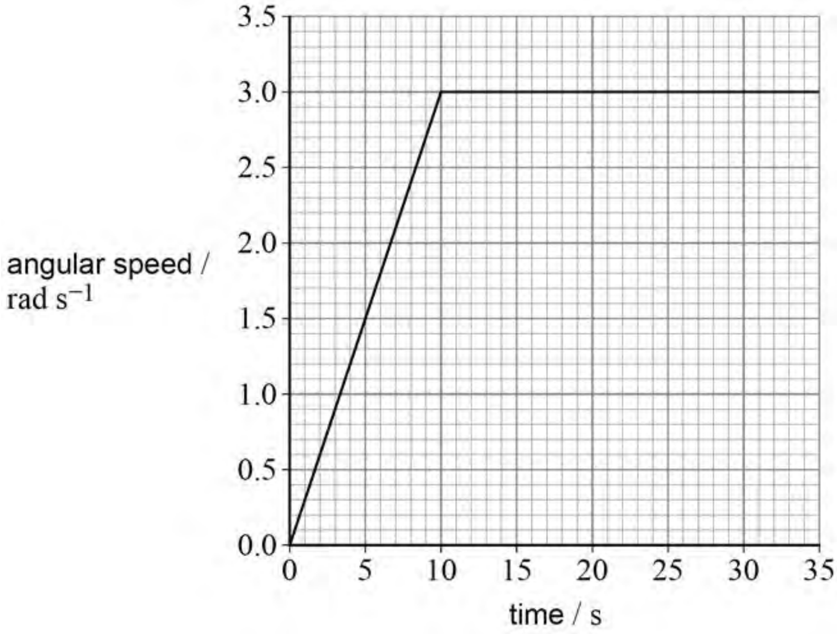
2 1 A flywheel is accelerated from rest.
The angular speed of the flywheel varies with time as shown.



What is the average angular speed of the flywheel over the 35 s?

[1 mark]

A $1.5\ \text{rad s}^{-1}$

B $2.0\ \text{rad s}^{-1}$

C $2.3\ \text{rad s}^{-1}$

D $2.6\ \text{rad s}^{-1}$

2 2 A flywheel is initially rotating at $5.0\ \text{rad s}^{-1}$. It comes to rest after a constant angular deceleration of $0.25\ \text{rad s}^{-2}$.

How many revolutions does the flywheel make as it decelerates to rest?

[1 mark]

A 8

B 16

C 20

D 50

15

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED**

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