OXFORD
INTERNATIONAL AQA EXAMINATIONS

Please write clearly in block capitals.

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

Surname ______________________________

Forename(s) ______________________________

Candidate signature ______________________________

INTERNATIONAL A-LEVEL

PHYSICS

Unit 4 Energy and Energy resources

Thursday 20 June 2019 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.

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	
6–35	
TOTAL	

Section A

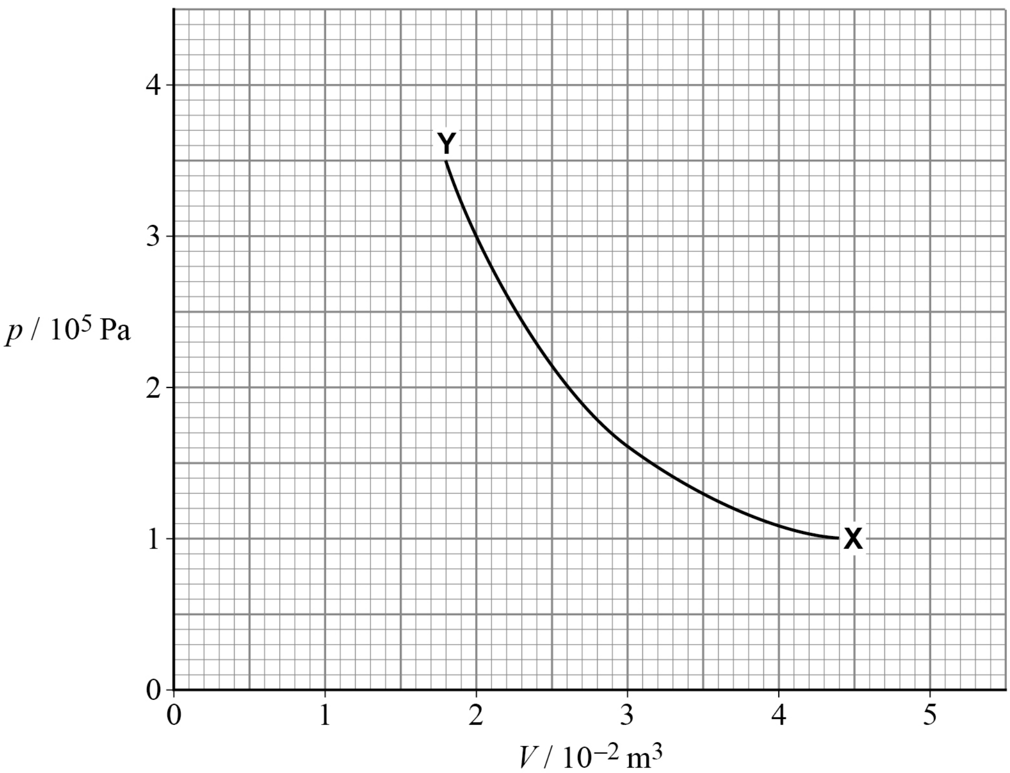
Answer **all** questions in this section.

0 1 . 1 Distinguish between the internal energy of an ideal gas and the internal energy of a solid.

[2 marks]

0 1 . 2 **Figure 1** shows the variation of pressure p with volume V for the air in a pump as the air is compressed rapidly.

Figure 1



The temperature of the air in the pump at point **X** on the graph is $23\ ^\circ\mathrm{C}$.

Calculate the number of air molecules in the pump.

[3 marks]

number of air molecules = ____________________

0 1 . 3 Determine the work done in compressing the air in the pump from **X** to **Y**.

[3 marks]

work done = ____________________ J

Question 1 continues on the next page

0 1 . 4 Deduce what happens to the temperature of the air in the pump as the air is compressed rapidly.
You should use the kinetic theory of gases and the first law of thermodynamics to answer this question.

[4 marks]

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Turn over for the next question

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0 2 **Table 1** shows the nucleon number A and the nuclear radii R for three nuclides.

Table 1

Nuclide	A	R / 10^{-15} m
Carbon	12	2.66
Iron	56	4.35
Lead	208	6.66

0 2 . 1 It is suggested that:

$$A = \frac{R^3}{k}$$

where k is a constant.

Use the data in **Table 1** to determine a reliable value for k.

[3 marks]

k = ____________________ m^3

0 2 . 2 Determine the percentage uncertainty in the value of k that you found in question **02.1**.

[1 mark]

percentage uncertainty in k = ____________________

0 2 . 3 The mass of a nucleon is 1.67×10^{-27} kg.

Show that the data in **Table 1** support the idea that nuclear material has a constant density.

[2 marks]

Question 2 continues on the next page

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0 2 . 4 This question is about Rutherford's scattering experiment.
The nuclear radius cannot be bigger than the distance of closest approach of an alpha particle.

Complete **Figure 2** to show the paths followed by each alpha particle.

The meaning of the symbols used in **Figure 2**:

⟶ indicates the initial direction of alpha particle

○ indicates target nucleus

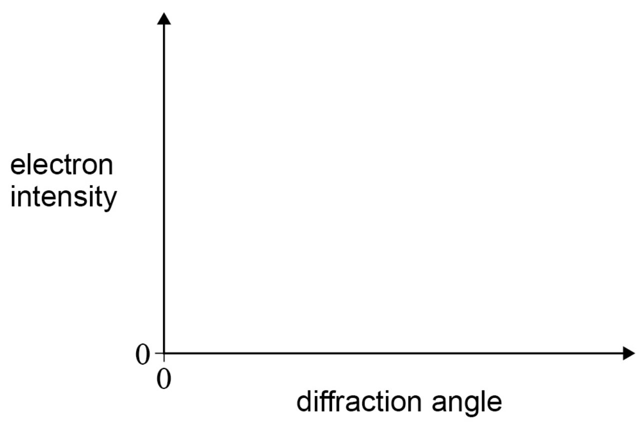
[3 marks]

Figure 2

0 2 . 5 Nuclear radii can be found using the diffraction of high-energy electrons.

Sketch, on the axes below, a graph showing the variation of electron intensity with diffraction angle.
Label the angle θ used in the calculation of nuclear radius.

[2 marks]



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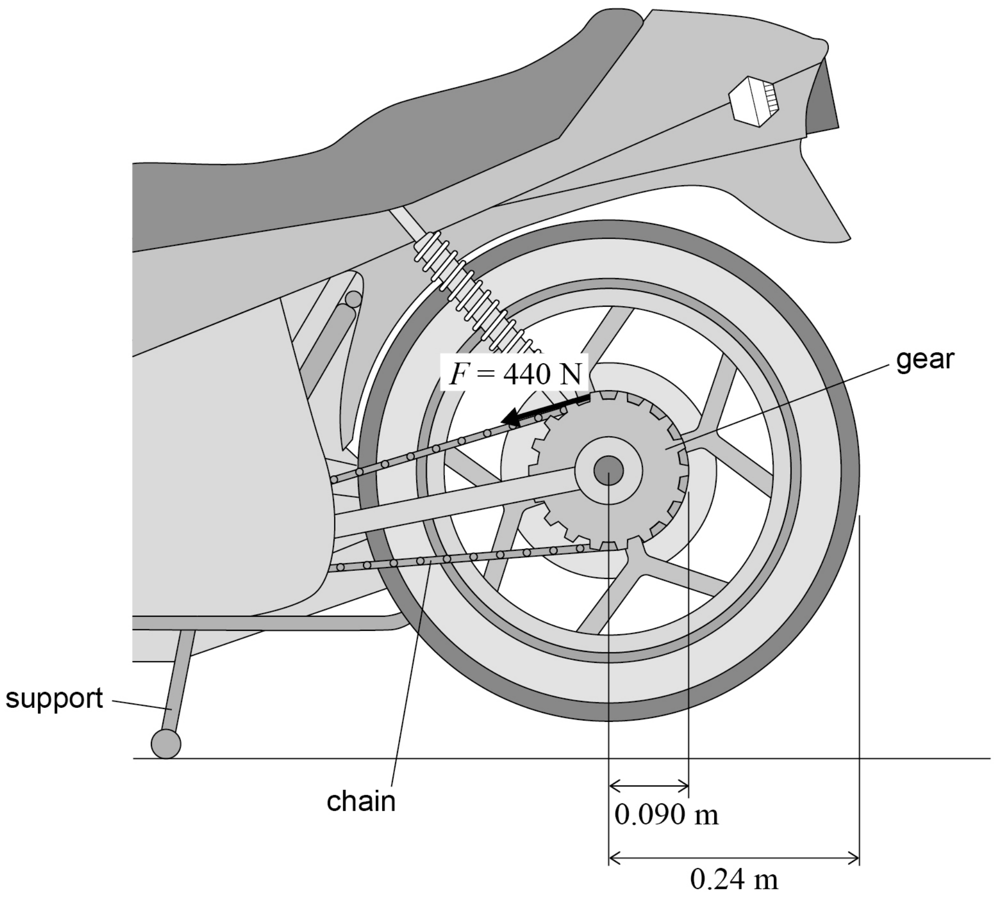
0 3 **Figure 3** shows the rear wheel of a motorcycle. The motorcycle is supported so that the wheel does not touch the ground. The chain pulls on a gear to rotate the wheel.

Figure 3



The radius of the gear is 0.090 m and the force F exerted by the chain is 440 N. The wheel has a mass of 12 kg, a moment of inertia of 0.69 kg m^2 and a radius of 0.24 m.

0 3 . 1 The wheel experiences a resistive torque of 4.0 N m.

Calculate the angular acceleration of the wheel.

[3 marks]

angular acceleration = ______________________ rad s^{-2}

Question 3 continues on the next page

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0 3 . 2 Calculate the angular speed of the wheel after $0.60\ \mathrm{s}$.

[1 mark]

angular speed = ____________________ $\mathrm{rad\ s^{-1}}$

0 3 . 3 The motorcycle is taken off its support so that both wheels are on the ground. The motorcycle accelerates from rest. The wheels do not slip.

Show that the angular speed of the wheel is approximately $120\ \mathrm{rad\ s^{-1}}$ when the motorcycle is travelling at $28\ \mathrm{m\ s^{-1}}$.

[1 mark]

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0 3 . 4 The total mass of the motorcycle and rider is $290\ \mathrm{kg}$. The front wheel has the same mass, dimensions and moment of inertia as the rear wheel.
The motorcycle travels at $28\ \mathrm{m\ s^{-1}}$.

Determine the rotational kinetic energy of the wheels as a percentage of the total kinetic energy of the motorcycle.

[4 marks]

percentage = ____________________

0 3 . 5 An engineer suggests that the wheels should be replaced with wheels that have the same dimensions but are made from a material that is less dense.

Discuss how the change would affect the ability of the motorcycle to accelerate and decelerate.

[3 marks]

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12

Turn over ►

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0 4 . 1 In an experimental nuclear fusion reactor, fusion happens in a plasma.

Explain how the properties of the plasma allow fusion reactions to happen.

[3 marks]

0 4 . 2 Two hydrogen nuclei fuse to produce deuterium as shown.

$$ {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + \beta^{+} + \nu_e $$

Determine, in J, the amount of energy released in this reaction.

mass of ${}^{1}_{1}\mathrm{H} =$ 1.6726×10^{-27} kg

mass of ${}^{2}_{1}\mathrm{H} =$ 3.3435×10^{-27} kg

mass of $\beta^{+} =$ 0.0009×10^{-27} kg

mass of ν_e is negligible

[3 marks]

energy released = ____________________ J

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0 4 . 3 The reaction described in question **04.2** is the first part of the solar fusion (hydrogen) cycle.

Outline the other **two** reactions that occur in the hydrogen cycle.

[2 marks]

First reaction

____

____

Second reaction

____

____

8

Turn over for the next question

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0 5 . 1 A solar panel with an area of $1.0\ \mathrm{m}^2$ is placed at the Earth's surface at an angle of $90°$ to the direction of the Sun's radiation. The output power of the Sun is $3.9 \times 10^{26}\ \mathrm{W}$. The radius of the Earth's orbit around the Sun is $1.5 \times 10^{11}\ \mathrm{m}$. The panel has an efficiency of 15%.

Show that the power output from the solar panel is approximately $200\ \mathrm{W}$.

[2 marks]

0 5 . 2 A nuclear fission power station has an output power of $1.2\ \mathrm{GW}$.

Calculate the number of solar panels, identical to the one in question **05.1**, required to produce the same output as the nuclear power station.

[1 mark]

number of panels = ____________________

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0 5 . 3 State how the power output of an array of solar panels can be maximised throughout the day.

[1 mark]

0 5 . 4 Compare the environmental effects of the use of solar panels with the environmental effects of a nuclear fission power station.

[3 marks]

7

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.

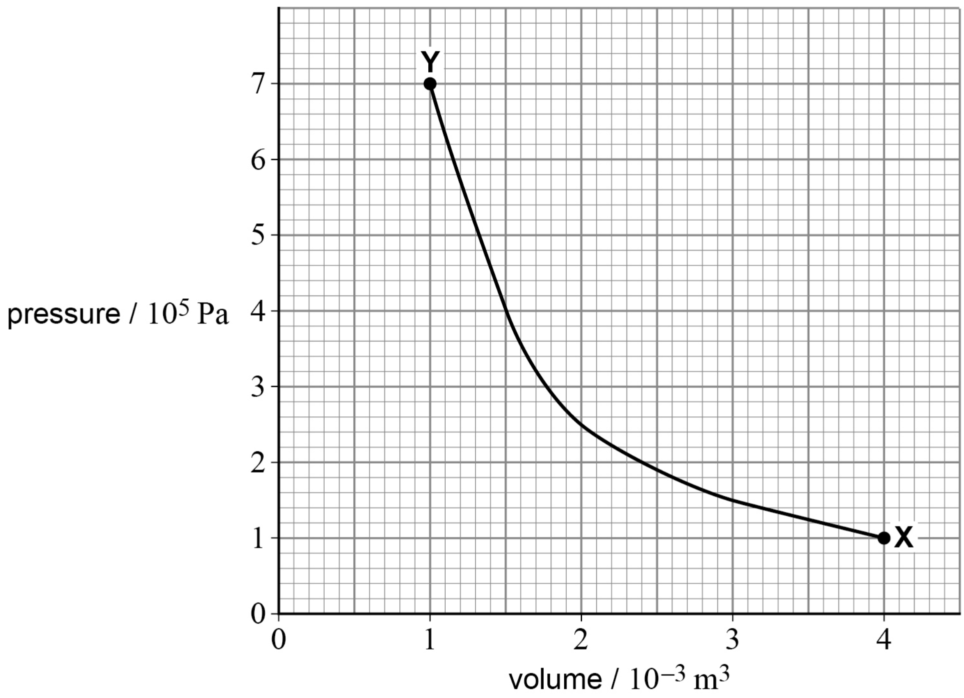
CORRECT METHOD   WRONG METHODS

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 sheets for this working.

0 6 The graph shows the variation of pressure with volume for a fixed mass of gas as it changes from state **X** to state **Y**.
T_X and T_Y are the temperatures of the gas at states **X** and **Y** respectively.
U_X and U_Y are the internal energies of the gas at states **X** and **Y** respectively.



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Which row describes the temperatures and internal energies at **X** and **Y**?

[1 mark]

	Temperatures	Internal energies	
A	$T_Y < T_X$	$U_Y = U_X$	⬭
B	$T_Y < T_X$	$U_Y < U_X$	⬭
C	$T_Y > T_X$	$U_Y = U_X$	⬭
D	$T_Y > T_X$	$U_Y > U_X$	⬭

0 7 The table shows the changes in internal energy of a system and the heating done to the system.

Which pair of changes requires work to be done by the system?

[1 mark]

	Change in internal energy of the system	Heating done to the system	
A	Increase by 40 J	+ 20 J	⬭
B	Increase by 40 J	− 20 J	⬭
C	Decrease by 20 J	− 40 J	⬭
D	Decrease by 20 J	+ 40 J	⬭

Turn over ►

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0 8 A liquid with specific heat capacity c is heated in a continuous flow system. The power input to the system is P.
In a second continuous flow system, the same rate of flow is used and the same temperature rise is observed.

What are possible features of the second system?

[1 mark]

	Specific heat capacity	Power input	
A	$0.5c$	$2P$	⬭
B	c	$4P$	⬭
C	$2c$	$2P$	⬭
D	$4c$	$0.5P$	⬭

0 9 0.50 kg of water initially at $20\ ^\circ\mathrm{C}$ is heated by a 3.0 kW heater for 2.0 minutes without energy losses.

specific heat capacity of water = $4.2\ \mathrm{kJ\ kg^{-1}\ K^{-1}}$
specific latent heat of vaporisation of water = $2260\ \mathrm{kJ\ kg^{-1}}$

The water reaches

[1 mark]

A a temperature below $100\ ^\circ\mathrm{C}$. ⬭

B $100\ ^\circ\mathrm{C}$ but no water is boiled away. ⬭

C $100\ ^\circ\mathrm{C}$ and some water is boiled away. ⬭

D $100\ ^\circ\mathrm{C}$ and all of the water is boiled away. ⬭

1 0 A manufacturer heats milk so that its temperature rises from 6 °C to 72 °C.
55 Mg of milk are processed over a 24 hour period. Energy losses are negligible.

specific heat capacity of milk = 3.9 kJ kg^{-1} K^{-1}

What is the average power needed to process the milk?

[1 mark]

A 16.4 kW ⬭

B 164 kW ⬭

C 1.64 MW ⬭

D 164 MW ⬭

1 1 Which is the equivalent of the internal energy of 1 mol of an ideal gas with a temperature T?

[1 mark]

A $\frac{2}{3}RT$ ⬭

B $\frac{3}{2}RT$ ⬭

C $\frac{2}{3}\frac{RT}{N_A}$ ⬭

D $\frac{3}{2}\frac{RT}{N_A}$ ⬭

Turn over for the next question

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1 2 Which row describes the potential and kinetic energies of particles in a solid material at a temperature of absolute zero?

[1 mark]

	Potential energy	Kinetic energy	
A	0	0	⬭
B	0	< 0	⬭
C	< 0	0	⬭
D	< 0	< 0	⬭

1 3 The table shows data for two ideal gases, **X** and **Y**.

X and **Y** each have the same mass and volume.

	X	**Y**
Pressure / kPa	100	200
Molecular mass	14	28
Temperature / °C	−23	

What is the temperature of gas **Y**?

[1 mark]

A 727 °C ⬭

B 227 °C ⬭

C −23 °C ⬭

D −148 °C ⬭

1 4 A student wants to do an experiment to verify Boyle's law.

Which quantities must be measured and which quantity must be kept constant?

[1 mark]

	Quantities to be measured	Quantity to be kept constant	
A	Pressure and temperature	Volume	⬭
B	Pressure and volume	Temperature	⬭
C	Volume and temperature	Pressure	⬭
D	Pressure, volume and temperature	None	⬭

1 5 Brownian motion demonstrates that

[1 mark]

A the pressure of a fixed mass of gas at constant volume depends on the absolute temperature. ⬭

B the average molecular kinetic energy of the molecules of a gas depends on the absolute temperature. ⬭

C gases are made up of randomly moving particles which have momentum. ⬭

D in ideal gases, the internal energy is the same as the kinetic energy of the particles. ⬭

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1 6 The average molecular kinetic energy of the molecules in a sample of gas is $\frac{1}{2}m\left(c_{\text{rms}}^2\right)$ where m is the mass of one molecule.

What is the magnitude of the average velocity of the molecules in the sample of gas?

[1 mark]

A $\sqrt{2}\times c_{\text{rms}}$ ⬭

B c_{rms} ⬭

C $\frac{c_{\text{rms}}}{\sqrt{2}}$ ⬭

D 0 ⬭

1 7 Two containers, **X** and **Y**, contain helium gas. The rms speed of the molecules in container **X** is c_{rms}.

	X	**Y**
Volume of container / m^3	3.0	2.0
Mass of gas / kg	0.50	1.50
Pressure in container / 10^5 Pa	1.0	6.0

What is the rms speed of the molecules in container **Y**?

[1 mark]

A $0.50c_{\text{rms}}$ ⬭

B $1.15c_{\text{rms}}$ ⬭

C $1.41c_{\text{rms}}$ ⬭

D $2.00c_{\text{rms}}$ ⬭

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1 8 The radius of a lead−208 nucleus is 6.7×10^{-15} m.

What is the radius of an oxygen−16 nucleus?

[1 mark]

A 3.0×10^{-18} m

B 5.1×10^{-16} m

C 1.9×10^{-15} m

D 2.8×10^{-15} m

1 9 An alpha particle of kinetic energy 4.0 MeV has a distance of closest approach r when directed at a nucleus of plutonium−241 ($^{241}_{94}Pu$).

What is the distance of closest approach of a 6.0 MeV alpha particle when directed at a nucleus of aluminium−27 ($^{27}_{13}Al$)?

[1 mark]

A $0.075r$

B $0.092r$

C $0.17r$

D $0.21r$

2 0 The radius of a hydrogen nucleus is of the order of

[1 mark]

A 10^{-10} m.

B 10^{-12} m.

C 10^{-15} m.

D 10^{-18} m.

Do not write outside the box

2 1 Cobalt−60 decays by β^- emission to form nickel−60.

What is true about the magnitude of the binding energy per nucleon of the nickel nuclide and the additional particle emitted in the decay?

[1 mark]

	Magnitude of the binding energy per nucleon of nickel−60	**Additional particle emitted in the decay**	
A	Less than the binding energy per nucleon of cobalt−60	Antineutrino	⬭
B	Less than the binding energy per nucleon of cobalt−60	Neutrino	⬭
C	Greater than the binding energy per nucleon of cobalt−60	Antineutrino	⬭
D	Greater than the binding energy per nucleon of cobalt−60	Neutrino	⬭

2 2 The binding energy of a nucleus is equivalent to

[1 mark]

A the energy released when the nucleus de-excites and emits a gamma ray. ⬭

B the sum of the kinetic energy of an emitted alpha particle and the recoil energy of the nucleus. ⬭

C the total energy required to assemble all of the particles in the nucleus. ⬭

D the total energy required to separate all of the particles in the nucleus. ⬭

Do not write outside the box

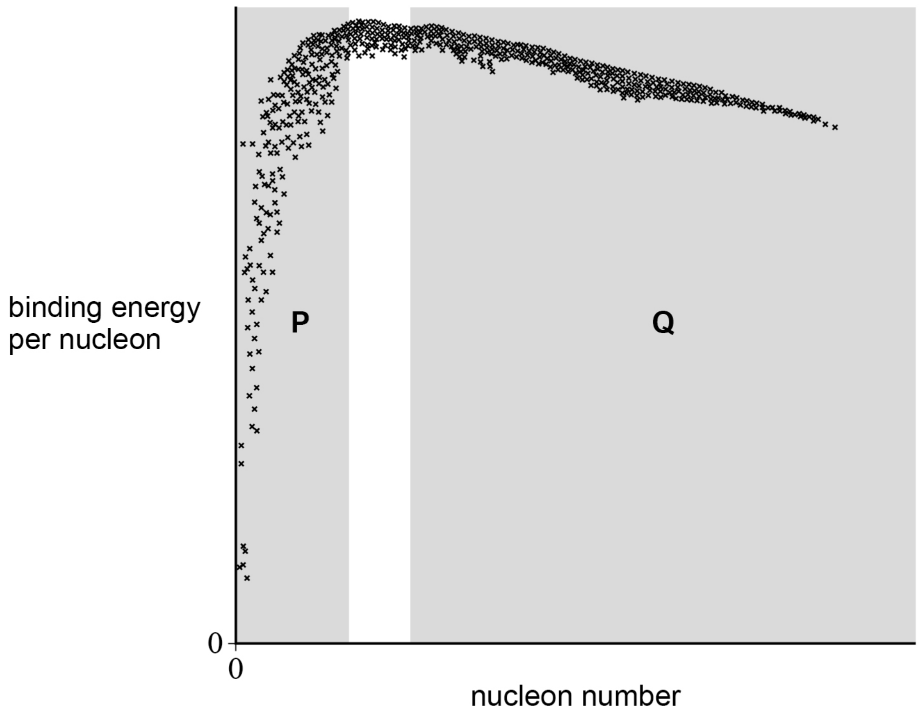
2 3 Which row gives the binding energy of an iron−56 nucleus and of a proton?

[1 mark]

	Binding energy of an iron−56 nucleus / MeV	Binding energy of a proton / MeV	
A	8.8	0	⬭
B	8.8	1	⬭
C	493	0	⬭
D	493	1	⬭

Turn over for the next question

2 4 The diagram shows a plot of binding energy per nucleon against nucleon number for the whole range of nuclides.



Which row shows regions of the plot in which nuclei can undergo fission and / or fusion accompanied by a net release of energy?

[1 mark]

	Fission	Fusion	
A	**P**	**Q**	⬭
B	**Q**	**P**	⬭
C	**P** and **Q**	**P**	⬭
D	**P** and **Q**	**P** and **Q**	⬭

2 5 The atomic mass unit u is defined as:

[1 mark]

A the rest mass of a free neutron. ⬭

B the rest mass of a free proton. ⬭

C $\frac{1}{12}$ of the mass of a carbon−12 atom. ⬭

D $\frac{1}{16}$ of the mass of an oxygen−16 atom. ⬭

2 6 The mass of an alpha particle is 6.644×10^{-27} kg.
A mass of 1.0×10^{-27} kg is equivalent to an energy of 561 MeV.

What is the binding energy of an alpha particle?

[1 mark]

A 27 MeV ⬭

B 29 MeV ⬭

C 84 MeV ⬭

D 3700 MeV ⬭

2 7 Which is a possible thermal fission reaction?

[1 mark]

A ${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 2$ neutrons ⬭

B ${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{137}_{52}\text{Te} + {}^{97}_{40}\text{Zr} + 3$ neutrons ⬭

C ${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{137}_{55}\text{Cs} + {}^{96}_{37}\text{Rb} + 3$ neutrons ⬭

D ${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{95}_{38}\text{Sr} + {}^{142}_{36}\text{Xe} + 1$ neutron ⬭

2 8 In a nuclear fission reactor, it is useful to have a moderator that slows the neutrons down with the smallest possible number of collisions.

Which material would slow neutrons with the smallest number of collisions?

[1 mark]

A Hydrogen ⬭

B Deuterium ⬭

C Helium ⬭

D Carbon ⬭

2 9 Which row shows an appropriate choice of materials for the moderator, control rods and coolant for a thermal nuclear reactor?

[1 mark]

	Moderator	**Control rods**	**Coolant**	
A	Graphite	Uranium	Carbon dioxide	⬭
B	Sodium	Boron	Carbon dioxide	⬭
C	Water	Boron	Water	⬭
D	Water	Uranium	Water	⬭

3 0 What is the order of magnitude of the temperature at the centre of the Sun?

[1 mark]

A 10^3 K ⬭

B 10^5 K ⬭

C 10^7 K ⬭

D 10^9 K ⬭

3 1 Which is **not** a problem with the containment and shielding of a nuclear fusion reactor?

[1 mark]

A The high temperature of the plasma would cause the shielding material to melt. ⬭

B Large amounts of radioactive beta emitters are produced in the fusion reactions. ⬭

C Contact with a containment vessel would reduce the temperature of the plasma. ⬭

D Large numbers of high-energy neutrons are produced in the fusion reactions. ⬭

3 2 A bicycle wheel has a rotational kinetic energy E when the bicycle is travelling at $8.0\ \mathrm{m\ s^{-1}}$. The speed of the bicycle changes to $12.0\ \mathrm{m\ s^{-1}}$.

What is the new rotational kinetic energy of the wheel?

[1 mark]

A $0.44E$ ⬭

B $1.22E$ ⬭

C $1.50E$ ⬭

D $2.25E$ ⬭

3 3 Which is an environmental benefit of using wind turbines for electricity generation?

[1 mark]

A Greenhouse gases are not produced during the manufacture of the wind turbines. ⬭

B Plant or animal habitats are not damaged by the use of wind turbines. ⬭

C Fossil fuels are not used by the wind turbines during electricity production. ⬭

D Wind turbines do not produce any noise pollution. ⬭

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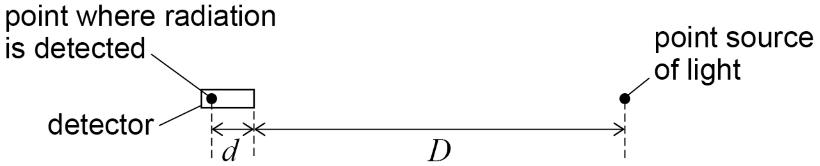
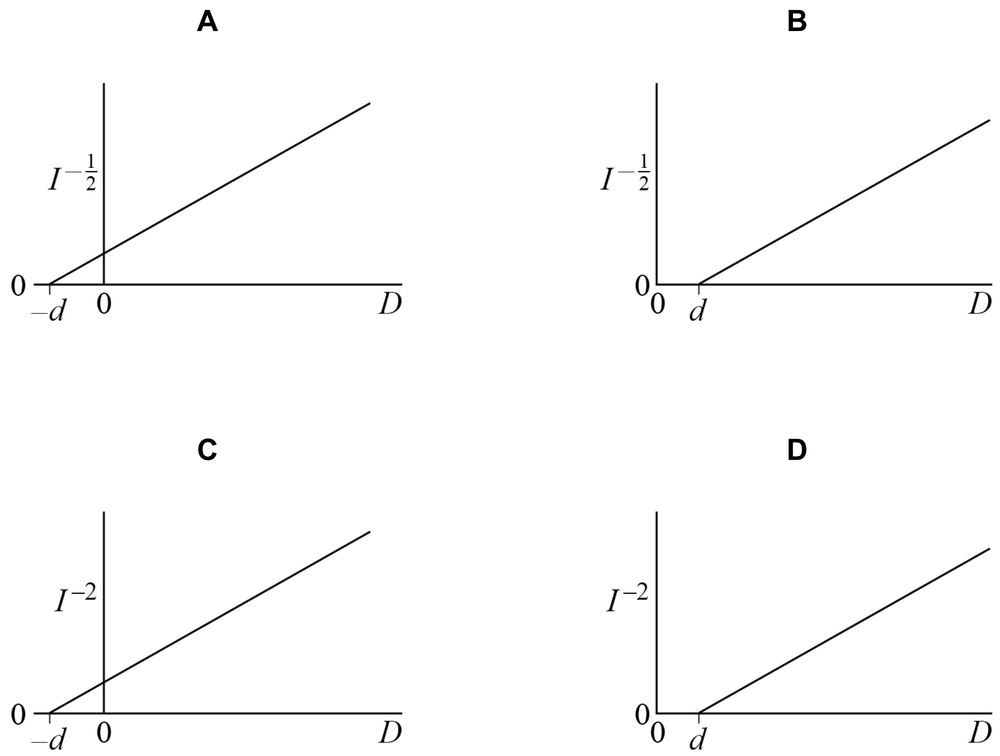
3 4 A student measures the intensity I of the radiation from a point source of light.
The point source is a distance D from the front of the detector. The radiation is detected at an additional distance d inside the detector.



Which graph shows the expected relationship between I and D?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

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3 5 Which row shows appropriate types of base-power stations and back-up power stations? **[1 mark]**

	Base-power	Back-up	
A	Fossil fuelled	Fossil fuelled	⬭
B	Fossil fuelled	Pump-storage	⬭
C	Pump-storage	Fossil fuelled	⬭
D	Pump-storage	Pump-storage	⬭

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END OF QUESTIONS

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