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

Wednesday 23 January 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.

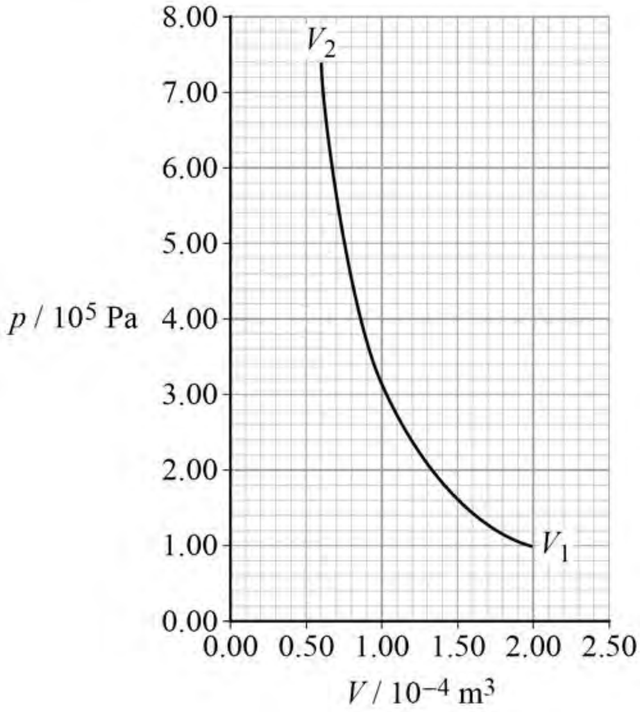
For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6–35	
TOTAL	

Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows the variation of pressure p with volume V of a fixed mass of gas as it is compressed from a volume of V_1 to a volume of V_2.
There is no transfer of heat energy between the gas and its surroundings during this compression.

Figure 1



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0 1 . 1 Estimate the work done on the gas during the compression from V_1 to V_2.

[3 marks]

work done = ________________________ J

0 1 . 2 The density of the gas is $0.179\ \mathrm{kg\ m^{-3}}$ when the volume is V_1.

Calculate the number of moles of gas present.

mass of $1\ \mathrm{mol}$ of the gas $= 4.00 \times 10^{-3}\ \mathrm{kg}$

[2 marks]

number of moles = ________________________ mol

Question 1 continues on the next page

Turn over ►

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0 1 . 3 Calculate the increase in temperature of the gas as a result of it being compressed from V_1 to V_2.

[3 marks]

increase in temperature = ____________________ K

0 1 . 4 Explain in terms of the movement of particles why the pressure of the gas increases when it is compressed from V_1 to V_2.

[4 marks]

12

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0 2 A plasma containing nuclei of two isotopes of hydrogen, ${}^{2}_{1}\mathrm{H}$ and ${}^{3}_{1}\mathrm{H}$, is considered to be a possible fuel for fusion reactors in the future. The plasma must be heated to a high temperature to provide the nuclei with the minimum kinetic energy to enable the fusion reaction to occur.

0 2 . 1 Explain why the nuclei in the plasma require a minimum kinetic energy for this fusion reaction to occur.

[3 marks]

0 2 . 2 The radius of a ${}^{2}_{1}\mathrm{H}$ nucleus is 1.51×10^{-15} m.

Show that the distance between the centre of a ${}^{2}_{1}\mathrm{H}$ nucleus and the centre of a ${}^{3}_{1}\mathrm{H}$ nucleus is about 3.2×10^{-15} m when they are just in contact.

[3 marks]

Question 2 continues on the next page

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0 2 . 3 Assume that the ${}^{2}_{1}\mathrm{H}$ and ${}^{3}_{1}\mathrm{H}$ nuclei fuse when they are just in contact.

Calculate the minimum total kinetic energy that would allow a ${}^{2}_{1}\mathrm{H}$ nucleus and a ${}^{3}_{1}\mathrm{H}$ nucleus to fuse.

[3 marks]

minimum total kinetic energy = ____________________ J

Do not write outside the box

0 2 . 4 The equation for this fusion reaction is

$${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + \text{energy}$$

Table 1 shows the mass of each particle involved.

Table 1

Particle	Mass / u
${}^{1}_{0}\mathrm{n}$	1.008665
${}^{2}_{1}\mathrm{H}$	2.013553
${}^{3}_{1}\mathrm{H}$	3.016049
${}^{4}_{2}\mathrm{He}$	4.002603

Calculate, in J, the energy released when this fusion reaction takes place.

[3 marks]

energy released = ____________________ J

Question 2 continues on the next page

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0 2 . 5 Plasmas are contained using magnetic fields.

Explain how magnetic containment can be made to be more energy-efficient.

[2 marks]

14

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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0 3 A stationary uranium-235 nucleus $\left({}^{235}_{92}\mathrm{U}\right)$ decays to a thorium-231 nucleus $\left({}^{231}_{90}\mathrm{Th}\right)$ by emitting an alpha particle $\left({}^{4}_{2}\mathrm{He}\right)$.

98% of the total energy released in the decay is transferred to the emitted alpha particle as kinetic energy.

0 3 . 1 Explain, in terms of the masses of the nuclei, why the total binding energy of the nuclei must increase as a result of this decay.

[3 marks]

Do not write outside the box

0 3 . 2 **Table 2** shows the binding energy per nucleon of nuclei involved in the decay.

Table 2

Nucleus	Binding energy per nucleon / pJ
$^{235}_{92}\mathrm{U}$	1.215
$^{231}_{90}\mathrm{Th}$	1.219
$^{4}_{2}\mathrm{He}$	1.132

Calculate the speed of the alpha particle just after it is emitted.

mass of alpha particle = 6.648×10^{-27} kg

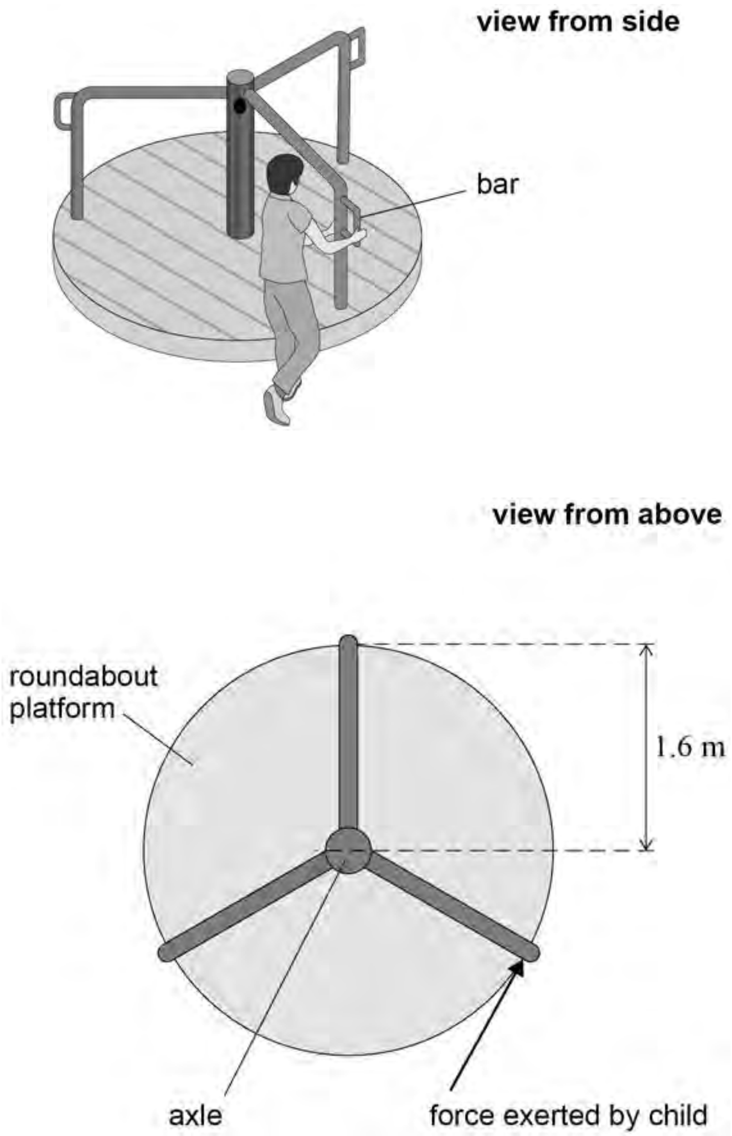
[4 marks]

speed of the alpha particle = ______________________ $\mathrm{m\,s^{-1}}$

7

0 4 **Figure 2** shows a playground roundabout that is being turned by a child pushing at $90°$ to one of the bars.

Figure 2



The moment of inertia of the roundabout about its axle is $320\ \mathrm{kg\ m^2}$.

There is a constant frictional torque of $45\ \mathrm{N\ m}$ acting on the roundabout when it is turning.

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0 4 . 1 The child pushes with a horizontal force F of constant magnitude at a distance of $1.6\ \mathrm{m}$ from the centre of the axle. The roundabout accelerates from rest to an angular velocity of $2.9\ \mathrm{rad\ s^{-1}}$ in $11\ \mathrm{s}$.

Calculate F.

[4 marks]

$F =$ ________________________ N

0 4 . 2 The child stops pushing and steps onto the roundabout platform at a point $1.3\ \mathrm{m}$ from the centre of the axle.
The mass of the child is $35\ \mathrm{kg}$.

Show that the combined moment of inertia of the child and roundabout about the centre of the axle is approximately $380\ \mathrm{kg\ m^2}$.

[1 mark]

Question 4 continues on the next page

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0 4 . 3 Show that the angular velocity of the roundabout changes from 2.9 rad s^{-1} to approximately 2.4 rad s^{-1} when the child steps onto the roundabout platform.

[2 marks]

0 4 . 4 The angular velocity of 2.4 rad s^{-1} decreases because of the constant frictional torque. The child remains on the roundabout until the angular velocity has decreased to 0.5 rad s^{-1}.

Calculate the number of rotations of the roundabout as it slows.

[4 marks]

number of rotations = ____________________

11

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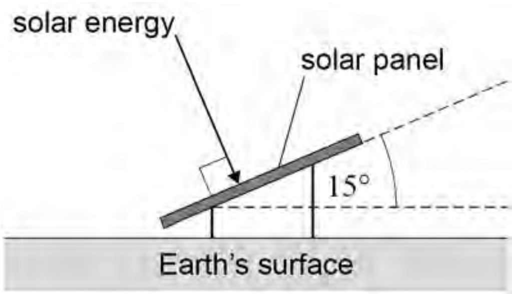
0 5 An array of solar panels is used to generate electrical power. Each panel has an area of $2.2\ \mathrm{m^2}$ and a constant efficiency of 18%.

At midday in midsummer, solar energy has an intensity of $630\ \mathrm{W\ m^{-2}}$ at the surface of the Earth.

Figure 3 shows a panel mounted in a fixed position at an angle of $15°$ to the Earth's surface so that at midday the solar energy arrives at $90°$ to the surface of the panel.

Figure 3



0 5 . 1 Calculate the number of panels needed to deliver a power output of $150\ \mathrm{kW}$ at midday in midsummer.

[3 marks]

number of panels = ____________________

Question 5 continues on the next page

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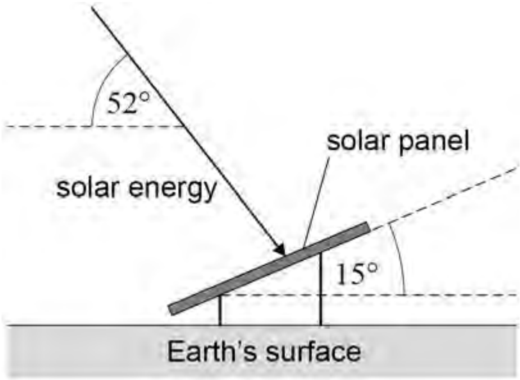
0 5 . 2 At midday in midwinter, solar energy has an intensity of $310\ \mathrm{W\ m^{-2}}$ at the Earth's surface, and arrives at $52°$ to the horizontal, as shown in **Figure 4**.

Figure 4



There are two possible ways of installing the panels.

- The panel is fixed and remains at $15°$ to the horizontal throughout the year.
- There is a tracking system that changes the angle of the panel so that solar energy always falls onto the panel at $90°$.

Calculate the additional power that can be generated by **one** panel at midday in midwinter using the tracking system instead of a fixed panel.

[3 marks]

additional power = ______________________ W

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 answer 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 Which row will always result in an increase in the internal energy of a system?

[1 mark]

	Energy input to the system by heating	Work done on the system	
A	Negative	Positive	○
B	Positive	Negative	○
C	Negative	Negative	○
D	Positive	Positive	○

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0 7 Which is **not** an assumption made when deriving the equation $pV = \frac{1}{3} Nm(c_{rms})^2$?

[1 mark]

A Molecules have negligible volume compared with the volume of the container. ⬭

B The forces between molecules can be ignored. ⬭

C The duration of collisions is very small compared with the time between collisions. ⬭

D Molecules undergo inelastic collisions with the walls of the container. ⬭

0 8 A fixed mass of a substance changes from a liquid to a gas at a constant temperature.

Which row indicates what happens to the sums of the kinetic energies and potential energies of the molecules of the substance?

[1 mark]

	Sum of kinetic energies	**Sum of potential energies**	
A	Remains constant	Increases	⬭
B	Remains constant	Remains constant	⬭
C	Increases	Increases	⬭
D	Increases	Decreases	⬭

Do not write outside the box

0 9 A $9.5\ \mathrm{kW}$ heater in an electric shower heats water from $15\ °\mathrm{C}$ to $50\ °\mathrm{C}$. Thermal energy transfer to the surroundings is negligible.

What volume of water can be heated by the shower in 1.0 minute when operating under these conditions?

specific heat capacity of water = $4.2 \times 10^3\ \mathrm{J\ kg^{-1}\ K^{-1}}$
density of water = $1000\ \mathrm{kg\ m^{-3}}$

[1 mark]

A $4.4 \times 10^{-4}\ \mathrm{m^3}$ ⬭

B $2.7 \times 10^{-3}\ \mathrm{m^3}$ ⬭

C $3.9 \times 10^{-3}\ \mathrm{m^3}$ ⬭

D $2.3 \times 10^{-1}\ \mathrm{m^3}$ ⬭

1 0 What is the unit of specific latent heat in fundamental (base) units?

[1 mark]

A $\mathrm{J\ kg^{-1}}$ ⬭

B $\mathrm{m^2\ s^{-2}\ K^{-1}}$ ⬭

C $\mathrm{m^2\ s^{-2}}$ ⬭

D $\mathrm{kg\ m^2\ s^{-2}}$ ⬭

1 1 Which is the correct unit for U-value?

[1 mark]

A $\mathrm{J\ m^{-2}\ K^{-1}}$ ⬭

B $\mathrm{J\ K^{-1}}$ ⬭

C $\mathrm{W\ m^{-2}\ K^{-1}}$ ⬭

D $\mathrm{W^2\ K^{-1}}$ ⬭

Turn over ►

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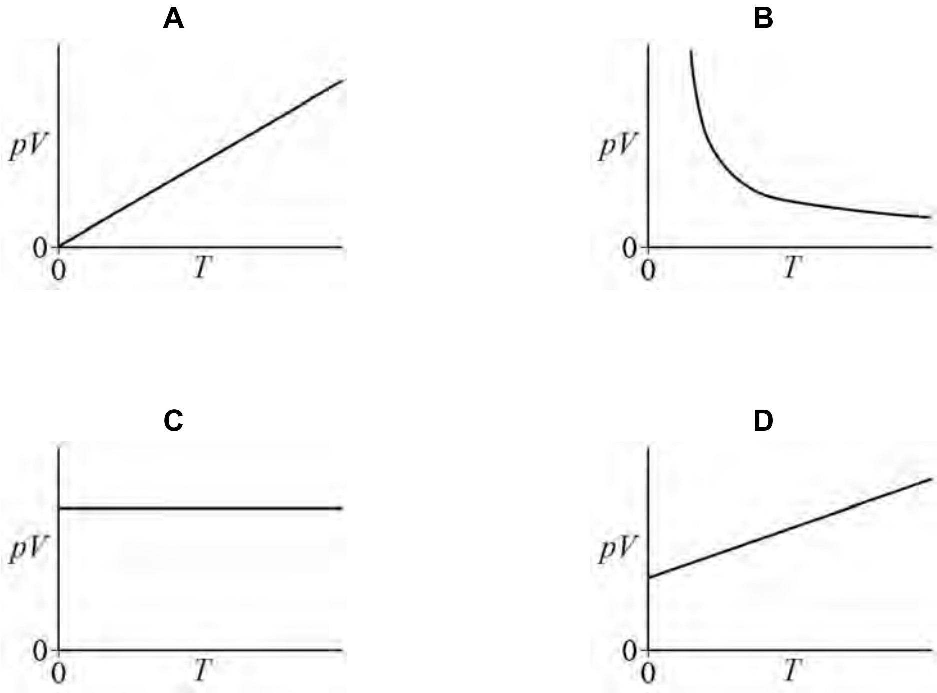
1 2 A fixed mass of an ideal gas has a pressure p and volume V.

Which graph shows the relationship between pV and the temperature T, in K, for the fixed mass of ideal gas?

[1 mark]



A ○

B ○

C ○

D ○

1 3 $2.0\ \text{mol}$ of an ideal gas has a pressure of $3.0\ \text{MPa}$ and a volume of $1.5 \times 10^{-3}\ \text{m}^3$.

What is the average kinetic energy of a molecule of this gas?

[1 mark]

A $5.6 \times 10^{-26}\ \text{J}$ ○

B $3.8 \times 10^{-21}\ \text{J}$ ○

C $5.6 \times 10^{-21}\ \text{J}$ ○

D $1.1 \times 10^{-20}\ \text{J}$ ○

Do not write outside the box

1 4 An ideal gas has a temperature of 100 °C. It is heated so that the root mean square speed (c_{rms}) of the molecules in the gas is doubled.

What is the new temperature of the gas?

[1 mark]

A 200 °C

B 400 °C

C 1200 °C

D 1500 °C

1 5 Two containers **X** and **Y** each contain an ideal gas at the same pressure.
The volume of **X** is twice the volume of **Y**.
The temperature of the gas in **X** is 150 K.
The temperature of the gas in **Y** is 300 K.
The number of molecules in **X** is N.

What is the number of molecules in **Y**?

[1 mark]

A $\frac{N}{4}$

B $\frac{N}{2}$

C N

D $2N$

Turn over ►

Do not write outside the box

1 6 Brownian motion can be studied using smoke in air.

What is observed through a microscope during this study?

[1 mark]

A Vibration of air molecules

B Random motion of smoke particles

C Vibration of smoke particles

D Random motion of air molecules

1 7 A $^{208}_{82}\mathrm{Pb}$ nucleus has a diameter of 1.26×10^{-14} m.

What is the density of a neutron in this nucleus?

[1 mark]

A $4.1 \times 10^{16}\ \mathrm{kg\ m^{-3}}$

B $1.3 \times 10^{17}\ \mathrm{kg\ m^{-3}}$

C $2.0 \times 10^{17}\ \mathrm{kg\ m^{-3}}$

D $3.3 \times 10^{17}\ \mathrm{kg\ m^{-3}}$

1 8 The most accurate determination of the radius of a nucleus is found from:

[1 mark]

A the diffraction of high-energy electrons by the nucleus.

B the distance of closest approach of low-energy alpha particles to the nucleus.

C the distance of closest approach of high-energy alpha particles to the nucleus.

D the diffraction of low-energy electrons by the nucleus.

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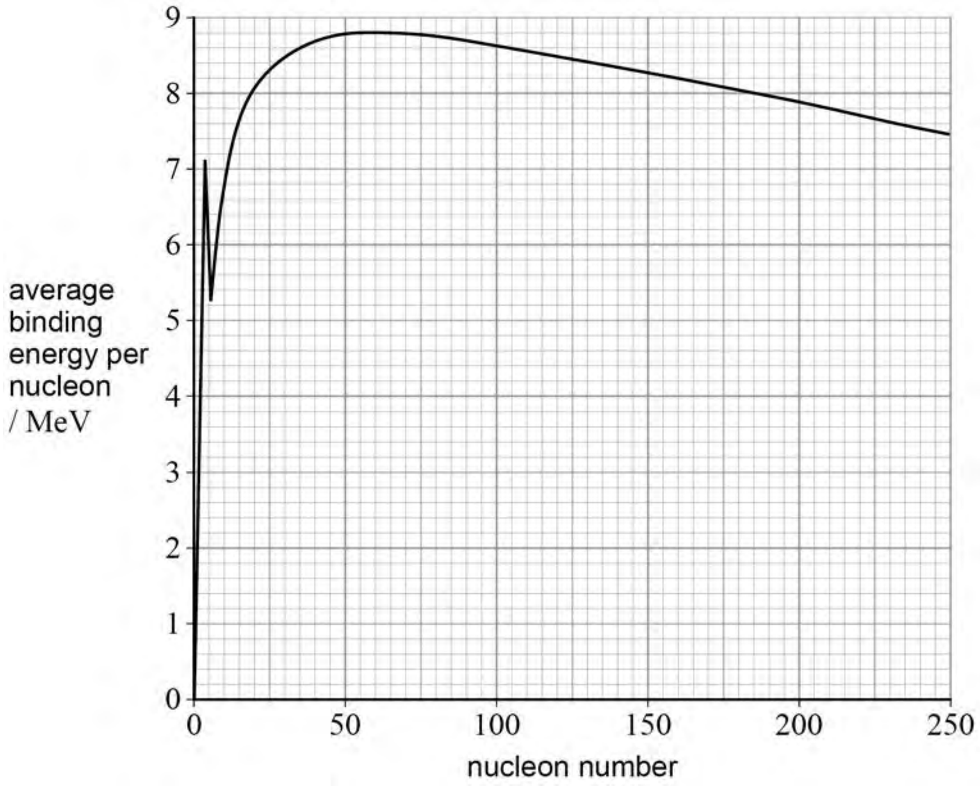
1 9 The graph shows the variation of average binding energy per nucleon with nucleon number.



What is the binding energy of a nucleus of $^{56}_{26}\mathrm{Fe}$?

[1 mark]

A 3.3×10^{-17} J

B 7.9×10^{-17} J

C 3.3×10^{-11} J

D 7.9×10^{-11} J

Do not write outside the box

2 0 An example of nuclear fission is:

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow \mathrm{X} + ^{91}_{36}\mathrm{Kr} + 3\,^{1}_{0}\mathrm{n}$$

What is the number of neutrons in nucleus **X**?

[1 mark]

A 85

B 86

C 106

D 142

2 1 Which combination of materials can be used for moderators and control rods in nuclear reactors?

[1 mark]

	Moderator	**Control rod**
A	Water	Graphite
B	Water	Boron
C	Cadmium	Boron
D	Cadmium	Graphite

2 2 A fissile material produces an average of 2.4 neutrons per fission.

For a critical mass of the material, how many neutrons per fission, on average, will **not** induce further fissions?

[1 mark]

A 2.4

B 1.4

C 1.2

D 0

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2 3 A pumped storage system has an upper reservoir at a vertical height of $75\ \mathrm{m}$ above the pumps. The pumps are supplied with a power of $1.7\ \mathrm{MW}$.
The density of water is $1000\ \mathrm{kg\ m^{-3}}$.

What is the maximum volume of water that the pumps can deliver every hour into the upper reservoir?

[1 mark]

A $2.3\ \mathrm{m^3}$ ○

B $2300\ \mathrm{m^3}$ ○

C $8300\ \mathrm{m^3}$ ○

D $8\ 300\ 000\ \mathrm{m^3}$ ○

2 4 Used fuel rods are stored in water for several months after they are removed from a nuclear reactor.

This is because used fuel rods:

[1 mark]

A emit gamma radiation which is completely absorbed by the water. ○

B continue to generate energy and are cooled by the water. ○

C undergo a chemical reaction with the water which reduces their radioactivity. ○

D can generate steam from the water to drive a turbine. ○

2 5 What does the equation $E = mc^2$ suggest?

[1 mark]

A The mass of a substance is increased when it is heated. ○

B The mass of a nucleus is greater than the mass of its constituent parts. ○

C The total mass of a nucleus is converted into kinetic energy when the nucleus decays. ○

D Energy is required to initiate proton–antiproton annihilation. ○

Do not write outside the box

2 6 Which equation summarises the hydrogen cycle in the Sun?

[1 mark]

A $6\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{1}_{1}\mathrm{H} + 2\beta^{+} + 2\gamma + 2\nu_{e}$ ⬭

B $6\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{1}_{1}\mathrm{H} + 2\beta^{+} + 2\gamma + 2\overline{\nu}_{e}$ ⬭

C $6\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{1}_{1}\mathrm{H} + 2\beta^{-} + 4\gamma + 2\nu_{e}$ ⬭

D $6\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{1}_{1}\mathrm{H} + 2\beta^{+} + 4\gamma + 2\overline{\nu}_{e}$ ⬭

2 7 Spheres **P** and **Q** of equal mass each rotate around an axis through their centres.

The moment of inertia of a sphere rotating about an axis through its centre is $\frac{2}{5}mr^2$

where m is the mass of the sphere and r is the radius of the sphere.

Q has twice the radius of **P**.
Q has twice the angular velocity of **P**.
P has rotational kinetic energy E.

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

[1 mark]

A $\frac{E}{16}$ ⬭

B E ⬭

C $4E$ ⬭

D $16E$ ⬭

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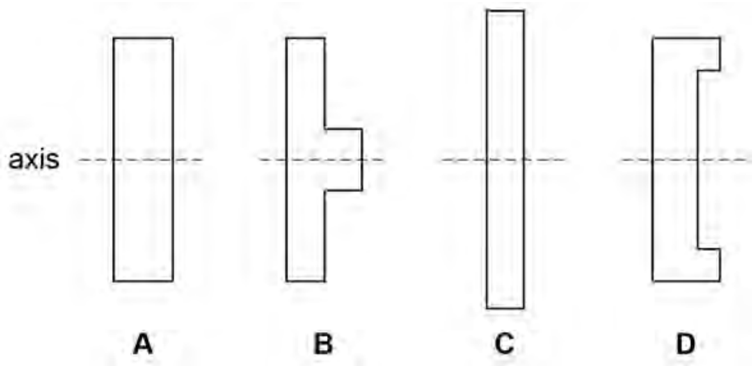
2 8 A flywheel is a rotating disc used to store rotational kinetic energy.
The diagram shows the cross-sections of four solid uniform flywheels. Each flywheel has the same mass. The diagrams are all drawn to the same scale.

Which flywheel has the smallest moment of inertia about the axis shown?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

Turn over for the next question

2 9 The table shows the masses of three planets and the radii of their orbits around the Sun.

Planet	Mass / $\times 10^{24}$ kg	Orbital radius / $\times 10^{12}$ m
Saturn	568	1.4
Uranus	87	2.9
Neptune	102	4.5

Which shows the planets arranged in order of decreasing moment of inertia around the Sun?

[1 mark]

A Saturn, Uranus, Neptune

B Saturn, Neptune, Uranus

C Neptune, Saturn, Uranus

D Neptune, Uranus, Saturn

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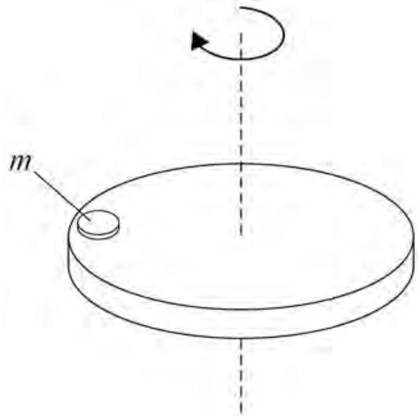
3 0 A turntable is rotating freely around the axis shown. A mass m is then placed onto the turntable and rotates with it.



Which row identifies whether or not rotational kinetic energy and angular momentum are conserved when m is placed onto the turntable?

[1 mark]

	Rotational kinetic energy	Angular momentum	
A	Not conserved	Conserved	⬭
B	Not conserved	Not conserved	⬭
C	Conserved	Conserved	⬭
D	Conserved	Not conserved	⬭

3 1 Wind turbine **P** has blades of length $5.0\ \mathrm{m}$. It produces an electrical power output of $15\ \mathrm{kW}$ when the wind speed is $30\ \mathrm{km\ hour^{-1}}$.
Wind turbine **Q** has blades of length $6.0\ \mathrm{m}$ and operates in a wind of speed $25\ \mathrm{km\ hour^{-1}}$.
Wind turbine **Q** has the same efficiency as wind turbine **P** under these conditions.

What is the electrical power output of wind turbine **Q**?

[1 mark]

A $6.0\ \mathrm{kW}$ ⬭

B $7.2\ \mathrm{kW}$ ⬭

C $10.4\ \mathrm{kW}$ ⬭

D $12.5\ \mathrm{kW}$ ⬭

Turn over ►

Do not write outside the box

3 2 The mean distance of Mars from the Sun is $\frac{3d}{2}$ where d is the mean distance of the Earth from the Sun. The radius of Mars is approximately half the radius of the Earth.

What is $\dfrac{\text{solar power incident on Mars}}{\text{solar power incident on Earth}}$?

[1 mark]

A $\frac{1}{9}$ ⬭

B $\frac{1}{6}$ ⬭

C $\frac{2}{9}$ ⬭

D $\frac{1}{3}$ ⬭

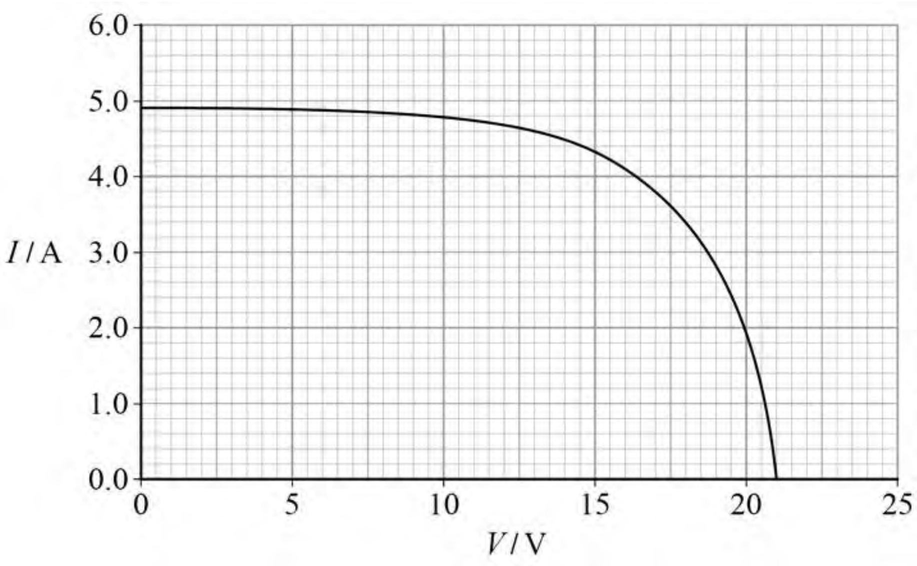
3 3 A solar panel generates 60 W of electrical power at a current of 5.0 A.
12 of these solar panels are connected in an array.

Which is **not** a possible output from this array?

[1 mark]

	Output voltage / V	**Output current / A**	
A	12	60	⬭
B	18	40	⬭
C	36	20	⬭
D	144	5.0	⬭

3 4 The graph shows the V–I characteristic for an array of solar panels.



Which row gives the correct emf and maximum power available for the array?

[1 mark]

	Emf / V	Maximum power available / W	
A	16	66	⬭
B	16	103	⬭
C	21	66	⬭
D	21	103	⬭

Turn over for the next question

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3 5 What is an advantage of pumped storage systems?

[1 mark]

A They have efficiencies greater than one because they use energy that would otherwise be wasted. ⬭

B Electricity can be generated rapidly by the system at times of peak demand. ⬭

C Sites for development of pumped storage systems are available in most geographical locations. ⬭

D Response times for starting and stopping production are similar to those of nuclear power stations. ⬭

30

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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