OXFORD
INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

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

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Forename(s) ____________________

Candidate signature ____________________
I declare this is my own work.

INTERNATIONAL A-LEVEL
PHYSICS

Unit 4 Energy and Energy resources

Wednesday 22 January 2020   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	

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Section A

Answer **all** questions in this section.

0 1 Balloons carry instruments into the upper atmosphere to help with weather forecasting. One balloon is inflated at ground level using $0.58\ \mathrm{kg}$ of helium. The inflated balloon is released and expands as it ascends. Eventually it bursts and the instruments return to the ground.

0 1 . 1 When it is inflated at ground level, the balloon experiences an upwards force of $29.3\ \mathrm{N}$.
The combined mass of the skin of the balloon and the instruments is $2.40\ \mathrm{kg}$.

Calculate the resultant force on the balloon as it is released at ground level.
[2 marks]

resultant force = ____________________ N

0 1 . 2 The speed of the balloon changes as it ascends.

Describe **two** factors that affect the speed of the balloon as it ascends.
[2 marks]

1 ____

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2 ____

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0 1 . 3 The temperature of the helium in the balloon changes from $25\ ^\circ\text{C}$ to $-50\ ^\circ\text{C}$ during the balloon's ascent.

Calculate the change in internal energy of the helium.

$1\ \text{mol}$ of helium has a mass of $4.0\ \text{g}$.

[3 marks]

change in internal energy = ______________________ J

0 1 . 4 The balloon expands as it ascends.
The temperature inside the balloon is always greater than the temperature outside the balloon.

Explain, using the first law of thermodynamics, how the internal energy of the helium changes during the ascent.

[3 marks]

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Question 1 continues on the next page

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0 1 . 5 During the ascent, the volume of the balloon increases by a factor of more than a hundred.

Explain why the rate of heat transfer through the skin of the balloon increases as it ascends.

[2 marks]

12

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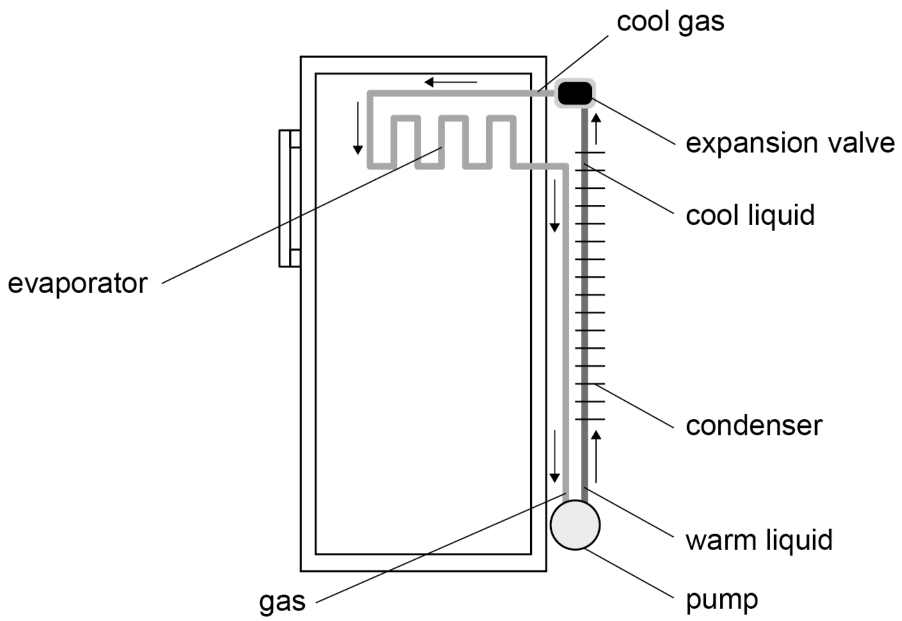
0 2 **Figure 1** shows the main parts of a refrigerator.
A fluid is pumped continuously around pipes inside and at the back of the refrigerator.
The fluid transfers energy from inside the refrigerator to the surroundings.

Figure 1



- The fluid is a liquid as it reaches the expansion valve. It enters the evaporator where it changes into a cool gas and expands.
- The cool gas absorbs energy from the refrigerator contents by thermal conduction through the walls of the pipe.
- The gas turns back into a warm liquid when it is pumped into the condenser.
- This liquid cools as it travels through the condenser and energy is transferred to the surroundings.

0 2 . 1 Explain why there is an energy transfer to the fluid as it changes state in the evaporator.

[3 marks]

Question 2 continues on the next page

Turn over ►

0 2 . 2 The temperature of the refrigerator's surroundings varies throughout the day. **Figure 2** shows the variation of temperature with time for the surroundings. The normal operating temperature inside the refrigerator is a constant 5.0 °C.

Figure 2

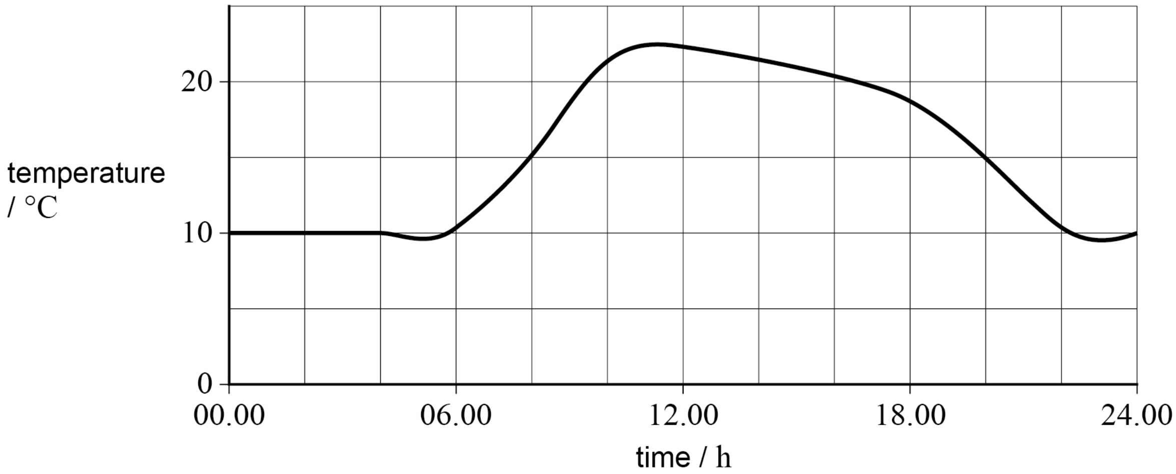
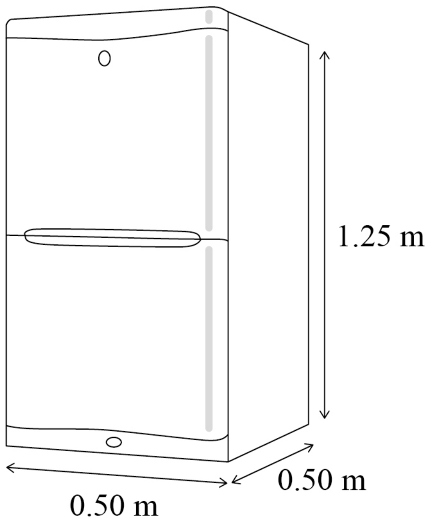


Figure 3 shows the dimensions of the refrigerator.

Figure 3



All faces of the refrigerator have a U-value of $0.66\ \mathrm{W\ m^{-2}\ K^{-1}}$.

Show that the average rate of energy conduction into the refrigerator from the surroundings is approximately $20\ \mathrm{W}$.

[3 marks]

0 2 . 3 $6.5\ \mathrm{kg}$ of food is put into the refrigerator.
The food is at an initial temperature of $21\ °\mathrm{C}$ and has an average specific heat capacity of $3900\ \mathrm{J\ kg^{-1}\ K^{-1}}$.
The temperature of the food decreases to $5.0\ °\mathrm{C}$ in $4.0\ \mathrm{h}$.

Calculate, in W, the average rate of heat transfer from the food.

[2 marks]

average rate of heat transfer = ____________________ W

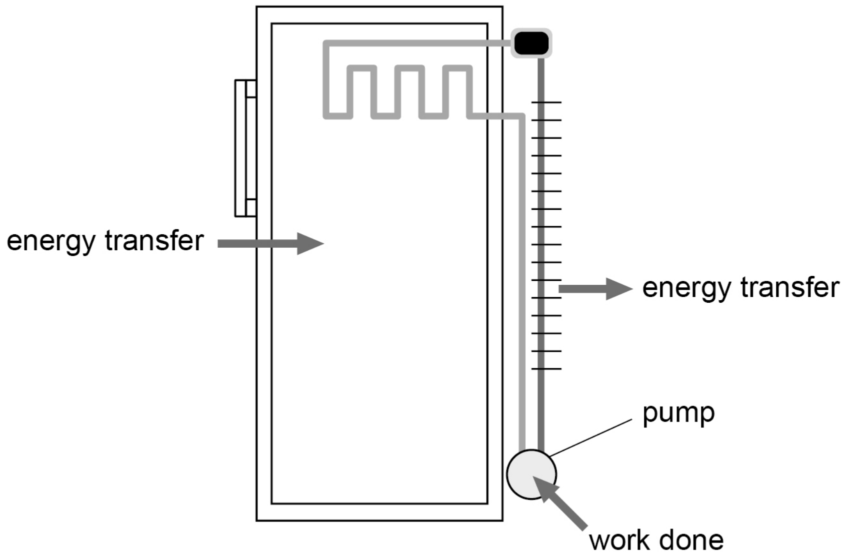
Question 2 continues on the next page

Do not write outside the box

0 2 . 4 **Figure 4** shows the refrigerator. The total internal energy of the refrigerator is affected in three ways:

- work is done by the pump on the fluid in the pipes at the rate of 60 W
- energy is transferred **into** the refrigerator through its walls
- energy is transferred **from** the refrigerator to the surroundings by the condenser.

Figure 4



Calculate the total rate of energy transfer from the condenser to the surroundings as the refrigerator is cooling the food to 5.0 °C.

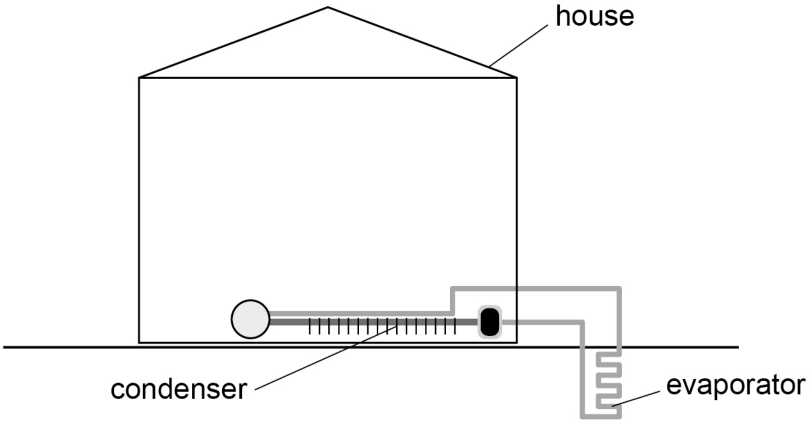
[2 marks]

rate of energy transfer = ____________________ W

Do not write outside the box

0 2 . 5 An engineer suggests heating a house using a reversed refrigerator system.
He suggests that the evaporator is in the ground outside the house and the condenser is inside the house as shown in **Figure 5**.

Figure 5



The engineer thinks that using this system will be more energy efficient than using normal electrical heating for the house.

Discuss whether the engineer is correct.

[2 marks]

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Turn over for the next question

0 3 Hydroelectric power is used for electricity generation. Energy for the process comes from the Sun.

0 3 . 1 Describe the energy transfers in this process, starting with energy transfers in the Sun.

[4 marks]

Do not write outside the box

0 3 . 2 Compare the environmental impacts of hydroelectric power with the environmental impacts of power generation using nuclear fission.

[3 marks]

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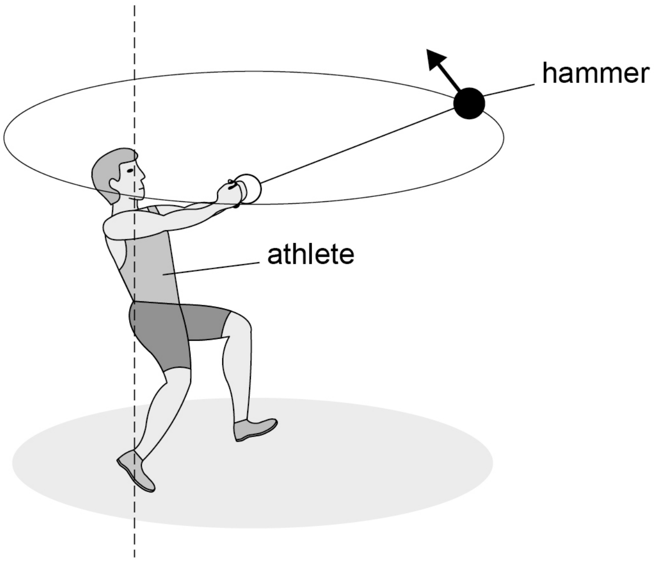
7

Do not write outside the box

0 4 In athletics, a hammer is a steel ball on a light chain. The athlete spins about a vertical axis through his body with increasing angular speed before releasing the hammer.

Figure 6 shows the athlete at the instant the hammer is released.

Figure 6



0 4 . 1 The athlete starts from rest and exerts a constant torque of $55\ \mathrm{N\ m}$ for $7.1\ \mathrm{s}$ before releasing the hammer.

The average combined moment of inertia of the athlete and hammer is $37\ \mathrm{kg\ m^2}$.

Show that the athlete's angular speed about the vertical axis at the instant of release is approximately $11\ \mathrm{rad\ s^{-1}}$.

[3 marks]

Do not write outside the box

0 4 . 2 Calculate the angular momentum of the athlete and hammer at the instant of release.

State an appropriate unit for your answer.

[2 marks]

angular momentum = ____________________

unit = ____________________

0 4 . 3 From the instant the hammer is released, the athlete no longer exerts any torque. Assume that there is no other external torque.

State and explain what happens to the angular speed of the athlete at the instant the hammer is released.

[3 marks]

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Do not write outside the box

0 5 The two stages of an induced fission reaction are shown below.

$$^{235}_{92}\mathrm{U} + \mathrm{n} \rightarrow \,^{\_\_\_}_{\_\_\_}\mathrm{U} \rightarrow \,^{144}_{55}\mathrm{Cs} + \,^{\_\_\_}_{\_\_\_}\mathrm{Rb} + 2\mathrm{n}$$

0 5 . 1 Complete the equation.

[2 marks]

0 5 . 2 **Table 1** shows the masses of the reactants and products of the reaction.

Table 1

	mass / 10^{-27} kg
$^{235}_{92}\mathrm{U}$	390.40797
n	1.67493
$^{144}_{55}\mathrm{Cs}$	239.07118
Rb	149.34849

Do not write outside the box

Calculate the energy released during this fission reaction.

[3 marks]

energy released = ____________________ J

0 5 . 3 A neutron produced in this fission reaction has a kinetic energy of 2.0 MeV.

Show that the speed of the neutron is approximately $2 \times 10^{7} \text{ m s}^{-1}$.

[2 marks]

Question 5 continues on the next page

Do not write outside the box

0 5 . 4 In one nuclear reactor, the moderator is heavy water that contains deuterium $\left({}^{2}_{1}\mathrm{H}\right)$ nuclei.

The neutron in Question **05.3** has a head-on collision with a stationary deuterium nucleus. After the collision, the deuterium nucleus has a speed of $1.31 \times 10^{7}\ \mathrm{m\ s^{-1}}$.

Determine the speed of the neutron immediately after the collision.

mass of a deuterium nucleus $= 3.34 \times 10^{-27}\ \mathrm{kg}$

[2 marks]

speed = ______________________ $\mathrm{m\ s^{-1}}$

0 5 . 5 Explain why there is a range of neutron speeds after neutrons have had one collision with a deuterium nucleus.

[2 marks]

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11

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 Which process will increase the kinetic energies of the particles involved?

[1 mark]

A boiling a liquid at its boiling point

B compressing a gas without heat transfer

C expanding a gas without heat transfer

D melting a solid at its melting point

0 7 Energy is transferred at the rate of $6.0\ \text{kW}$ to a water sample of mass $4.0\ \text{kg}$.
The water does not boil.
The specific heat capacity of water is $4.2\ \text{kJ kg}^{-1}\ \text{K}^{-1}$.

What is the initial rate of temperature rise of the water?

[1 mark]

A $3.6 \times 10^{-4}\ \text{K s}^{-1}$

B $1.3 \times 10^{3}\ \text{K h}^{-1}$

C $1.3\ \text{K h}^{-1}$

D $3.6 \times 10^{3}\ \text{K s}^{-1}$

Do not write outside the box

Questions **08** and **09** are about the equation $\Delta U = Q + W$

0 8 What are Q and W?

[1 mark]

	Q	W	
A	energy input **to** the system by heating	work done **by** the system	⬭
B	energy input **to** the system by heating	work done **on** the system	⬭
C	energy output **from** the system by heating	work done **by** the system	⬭
D	energy output **from** the system by heating	work done **on** the system	⬭

0 9 What is a unit for $\frac{\Delta Q}{t}$ where t is time?

[1 mark]

A K ⬭

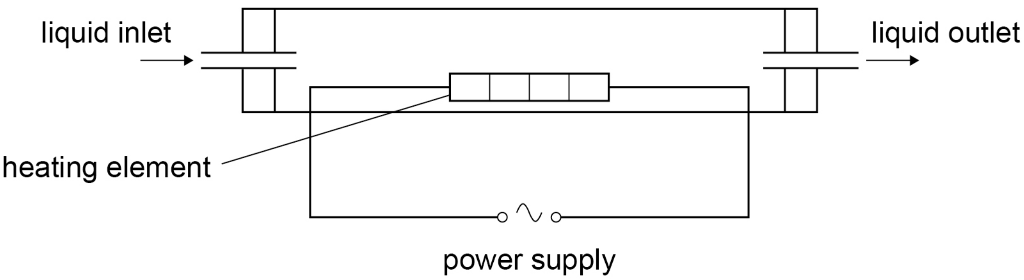
B $\mathrm{K\,s^{-1}}$ ⬭

C W ⬭

D $\mathrm{W\,s^{-1}}$ ⬭

Do not write outside the box

1 0 The diagram shows a liquid passing through a heater at a steady mass flow rate m. The rate of energy supply is P_1 and the rate of energy loss is P_2. The temperature rise of the liquid is ΔT.



Which set of conditions will result in a temperature rise of $2\Delta T$?

[1 mark]

	Rate of energy supply	Rate of energy loss	Mass flow rate	
A	$2P_1$	$2P_2$	m	⬭
B	$2P_1$	$0.5P_2$	m	⬭
C	P_1	$0.5P_2$	$0.5m$	⬭
D	P_1	$2P_2$	$0.5m$	⬭

Turn over for the next question

Do not write outside the box

1 1 An experiment to measure the specific heat capacity of a material is performed. Energy losses are negligible.

Which measurements for the material and for the heater are sufficient to calculate the specific heat capacity?

[1 mark]

	Measurements for the material	Measurements for the heater	
A	Initial and final temperature Mass	Power supplied	⬭
B	Initial and final temperature Volume	Energy supplied	⬭
C	Initial and final temperature Mass	Voltage Current	⬭
D	Initial and final temperature Volume Density	Energy supplied	⬭

1 2 Which is the fundamental (base) unit for specific heat capacity?

[1 mark]

A $\mathrm{m^2\ s^{-4}\ K^{-1}}$ ⬭

B $\mathrm{kg\ m^2\ s^{-2}\ K^{-1}}$ ⬭

C $\mathrm{kg^{-1}\ m^2\ s^{-2}\ K^{-1}}$ ⬭

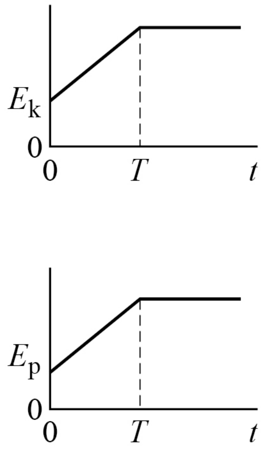
D $\mathrm{m^2\ s^{-2}\ K^{-1}}$ ⬭

1 3 A liquid is heated **at its boiling point** and at time T the liquid has completely boiled away. The gas continues to be heated.

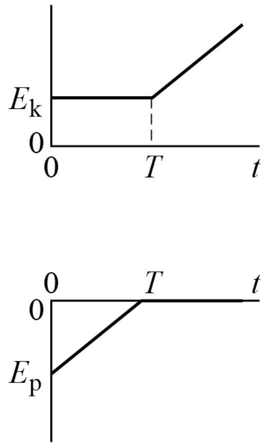
Which pair of graphs shows the variation with time t of the mean molecular kinetic energy E_k and the mean molecular potential energy E_p?

[1 mark]

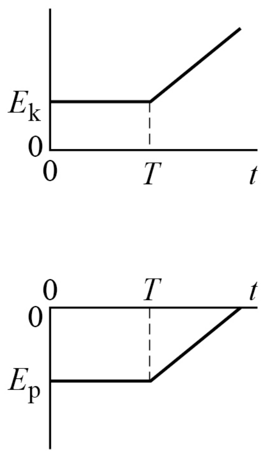
A



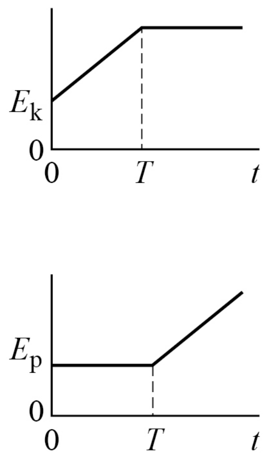
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

1 4 A wall **P** has thickness t and area A. The rate of heat transfer through **P** is W.

A second wall **Q** has thickness $2t$, area $\frac{A}{2}$ and twice the U-value of **P**.

The temperature difference across each wall is the same.

The rate of heat transfer through **Q** is

[1 mark]

A $\frac{W}{2}$ ⬭

B W ⬭

C $2W$ ⬭

D $4W$ ⬭

1 5 Which row gives the measured variables and the controlled variable for Boyle's law or Charles's law?

[1 mark]

	Law	Measured variables	Controlled variable	
A	Boyle's law	pressure and temperature	volume	⬭
B	Boyle's law	volume and temperature	pressure	⬭
C	Charles's law	pressure and temperature	volume	⬭
D	Charles's law	volume and temperature	pressure	⬭

1 6 A spherical flask is filled with an ideal gas and has a diameter of 1.66 m.
The gas has a pressure of 1.43×10^{5} Pa and a temperature of 15 °C.

What is the quantity of gas in the flask?

[1 mark]

A 1.43×10^{2} mol ⬭

B 1.15×10^{3} mol ⬭

C 2.75×10^{3} mol ⬭

D 2.20×10^{5} mol ⬭

1 7 What is the unit for $\dfrac{3R}{2N_A}$?

[1 mark]

A $\mathrm{J\ mol^{-1}\ K^{-1}}$ ⬭

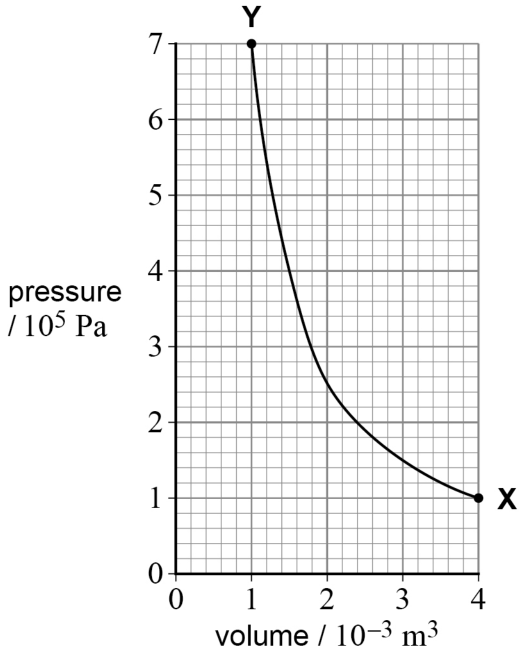
B $\mathrm{J\ K^{-1}}$ ⬭

C $\mathrm{J\ m^{-3}\ K^{-1}}$ ⬭

D $\mathrm{J\ kg^{-1}\ K^{-1}}$ ⬭

Turn over for the next question

1 8 The graph shows the variation of pressure with volume for a fixed mass of gas as it changes from condition **X** to condition **Y**.



Which row is correct for the change from **X** to **Y**?

[1 mark]

	Expansion or compression	Temperature of the system
A	expansion	constant
B	expansion	increase
C	compression	constant
D	compression	increase

1 9 Which set of processes could be carried out at constant temperature on an ideal gas?

[1 mark]

A compression and heat transfer to the gas

B compression and heat transfer from the gas

C expansion and no heat transfer

D expansion and heat transfer from the gas

Do not write outside the box

2 0 A sample of gas contains oxygen and helium. Oxygen has a molar mass of $32\ \mathrm{g}$ and helium has a molar mass of $4\ \mathrm{g}$.

What is $\dfrac{\text{rms speed of the oxygen molecules}}{\text{rms speed of the helium atoms}}$?

[1 mark]

A 0.12 ⬭

B 0.35 ⬭

C 2.8 ⬭

D 8.0 ⬭

2 1 An alpha particle is directed at a target nucleus.
The initial velocity of the alpha particle is v.

The distance of closest approach of the alpha particle to the nucleus is

[1 mark]

A directly proportional to $\sqrt{v}$. ⬭

B directly proportional to v^2. ⬭

C inversely proportional to $\sqrt{v}$. ⬭

D inversely proportional to v^2. ⬭

2 2 What is $\dfrac{\text{radius of } ^{56}_{26}\mathrm{Fe} \text{ nucleus}}{\text{radius of } ^{16}_{8}\mathrm{O} \text{ nucleus}}$?

[1 mark]

A 1.48 ⬭

B 1.52 ⬭

C 1.80 ⬭

D 1.87 ⬭

Do not write outside the box

2 3 The nuclear radius of ${}^{23}_{11}\mathrm{Na}$ is 3.6 fm.

What is the density of the nucleus of ${}^{14}_{7}\mathrm{N}$?

[1 mark]

A 9.4×10^{7} kg m^{-3} ⬭

B 2.0×10^{8} kg m^{-3} ⬭

C 9.4×10^{16} kg m^{-3} ⬭

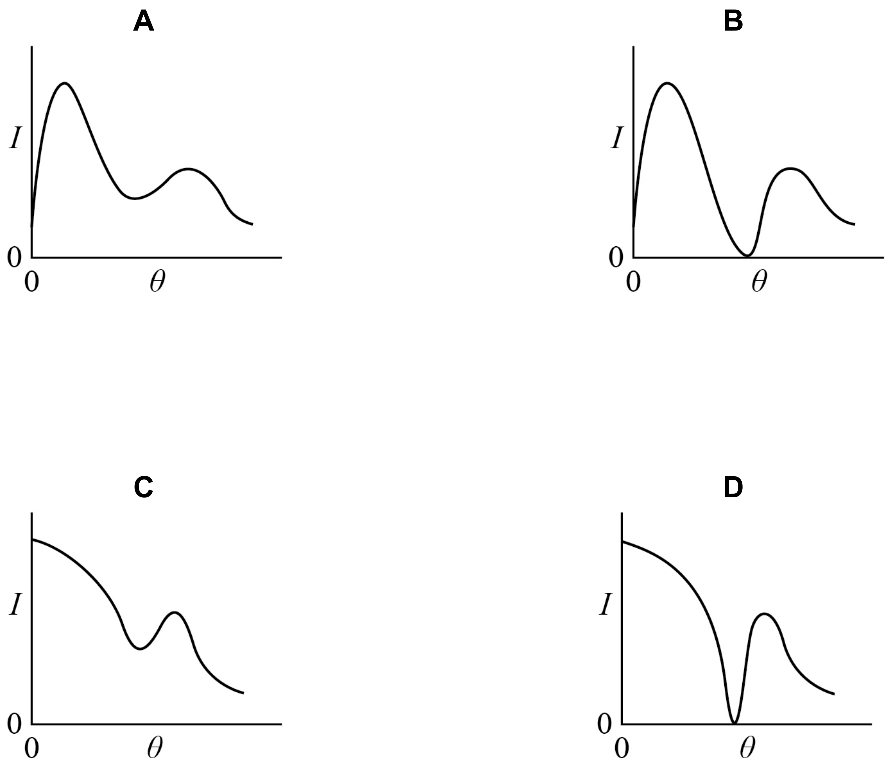
D 2.0×10^{17} kg m^{-3} ⬭

Do not write outside the box

2 4 Electrons are diffracted by the nuclei in a material.

Which graph shows the variation in intensity I of diffracted electrons with diffraction angle θ?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

Turn over for the next question

Do not write outside the box

2 5 What is the equivalent of 1 meV?

[1 mark]

A 1.1×10^{3} u

B 1.1×10^{-3} u

C 1.1×10^{-12} u

D 1.1×10^{-16} u

2 6 The equation shows a fission reaction for uranium−235.

$$\mathrm{U} + \mathrm{n} \rightarrow \mathrm{Ba} + \mathrm{Kr} + 3\mathrm{n}$$

Which shows the positive value for the change in mass for the reaction?

m_{U} = mass of U

m_{n} = mass of n

m_{B} = mass of Ba

m_{K} = mass of Kr

[1 mark]

A $m_{\mathrm{B}} + m_{\mathrm{K}} - m_{\mathrm{U}} - 3m_{\mathrm{n}}$

B $m_{\mathrm{B}} + m_{\mathrm{K}} - m_{\mathrm{U}} - 2m_{\mathrm{n}}$

C $m_{\mathrm{U}} - m_{\mathrm{B}} - m_{\mathrm{K}} - 2m_{\mathrm{n}}$

D $m_{\mathrm{U}} - m_{\mathrm{B}} - m_{\mathrm{K}} - 3m_{\mathrm{n}}$

Do not write outside the box

2 7 $^{239}_{94}\mathrm{Pu}$ undergoes fission to form $^{134}_{54}\mathrm{Xe}$ and $^{103}_{40}\mathrm{Zr}$.

What is the energy released in this fission reaction?

binding energy per nucleon of $^{239}_{94}\mathrm{Pu} = 7.56\ \mathrm{MeV}$

binding energy per nucleon of $^{134}_{54}\mathrm{Xe} = 8.41\ \mathrm{MeV}$

binding energy per nucleon of $^{103}_{40}\mathrm{Zr} = 8.43\ \mathrm{MeV}$

[1 mark]

A 86 MeV ☐

B 107 MeV ☐

C 188 MeV ☐

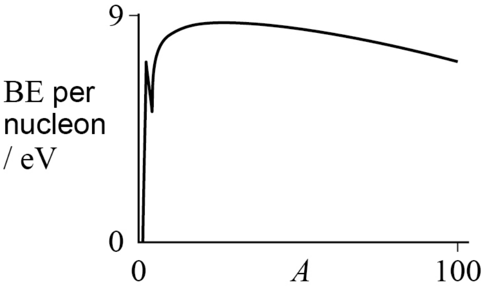
D 2200 MeV ☐

Turn over for the next question

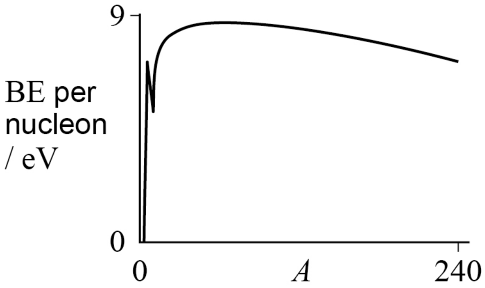
2 8 Which is the most accurate representation of a plot of binding energy (BE) per nucleon against nucleon number A?

[1 mark]

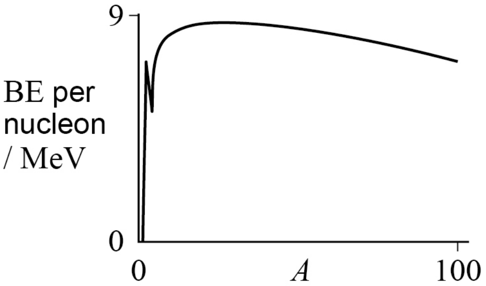
A



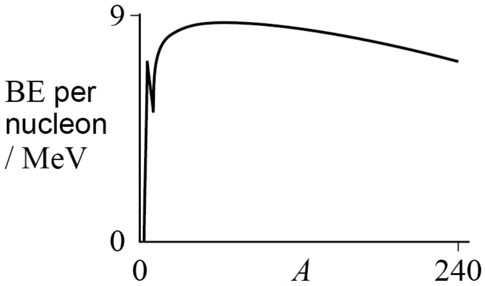
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

2 9 These statements are about mass changes in fusion and induced fission reactions in which there is a net release of energy.

Which statement is correct?

[1 mark]

A In induced fission, the total mass of the fission products is less than the mass of the fissile nucleus.

B In induced fission, the total mass of the fission products is greater than the total mass of the reactants.

C In fusion, the total mass of the products is less than the total mass of the reactants.

D In fusion, the total mass of the products is greater than the total mass of the reactants.

3 0 Which creates a significant risk from ionising radiation in the operation of a nuclear fusion reactor?

[1 mark]

A beta emitters produced by neutron absorption

B the nuclei produced in the fusion reaction

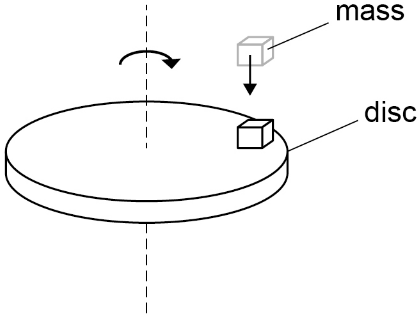
C alpha particles emitted in fusion

D beta particles emitted in fusion

Turn over for the next question

Do not write outside the box

3 1 A disc rotates at a constant speed with no external torque acting.
A mass falls onto the rotating disc and sticks to it.



What is conserved when the mass falls onto the disc?

[1 mark]

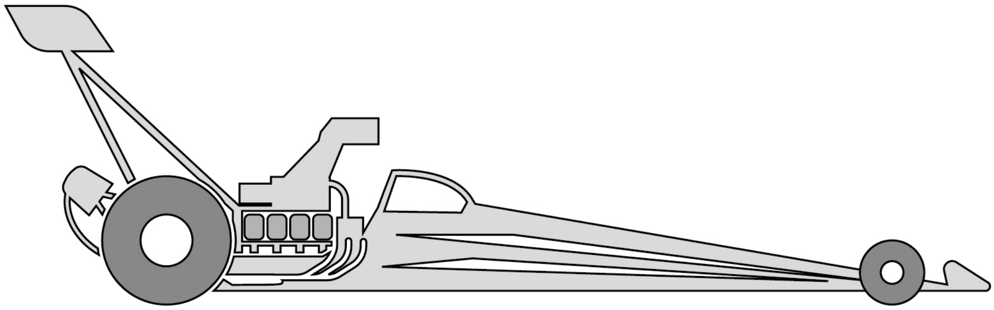
A rotational kinetic energy

B angular momentum

C both rotational kinetic energy and angular momentum

D neither rotational kinetic energy nor angular momentum

Questions **32** and **33** relate to the racing car shown in the diagram.
The front wheels each have a radius of r and a mass of m.
The rear wheels each have a radius of $2r$ and a mass of $8m$.
The wheels have similar mass distributions.



3 2 When the car is moving without the wheels slipping, the angular velocity of the front wheels is ω.

What is the angular velocity of the rear wheels?

[1 mark]

A $\frac{\omega}{4}$ ⬭

B $\frac{\omega}{2}$ ⬭

C 2ω ⬭

D 4ω ⬭

3 3 The moment of inertia of a front wheel is I.

What is the moment of inertia of a rear wheel?

[1 mark]

A $4I$ ⬭

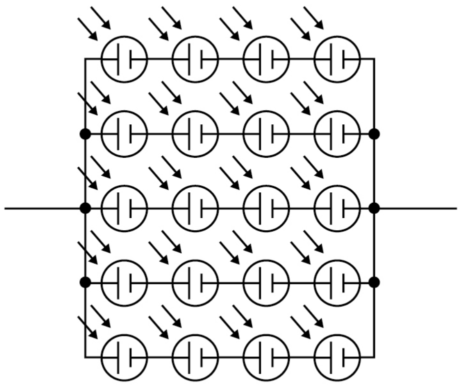
B $16I$ ⬭

C $32I$ ⬭

D $64I$ ⬭

Do not write outside the box

3 4 20 solar cells are connected together in the solar array shown.
Each cell has an output of 13 V and 3.0 A.



What is the potential difference and the current output of the array?

[1 mark]

	Potential difference / V	Current output / A	
A	52	12	⬭
B	52	15	⬭
C	65	12	⬭
D	65	15	⬭

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3 5 An ideal wind turbine has an output power P when the speed of the wind is v. The blade length is r.

A second ideal wind turbine operates when the wind speed is $\frac{v}{2}$ and has a blade length of $3r$.

What is the output power of the second wind turbine?

[1 mark]

A $\frac{4}{27}P$ ⬭

B $\frac{8}{9}P$ ⬭

C $\frac{9}{8}P$ ⬭

D $\frac{27}{4}P$ ⬭

30

END OF QUESTIONS

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