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

Tuesday 17 January 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.

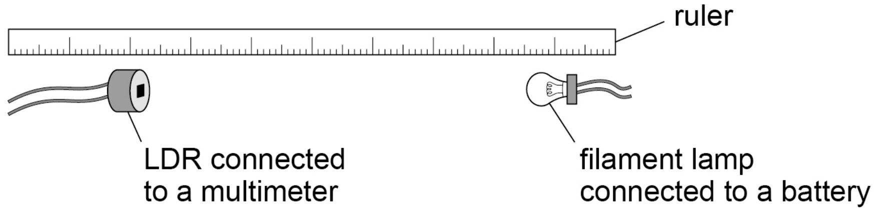
For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7–21	
TOTAL	

Section A

Answer **all** questions in this section.

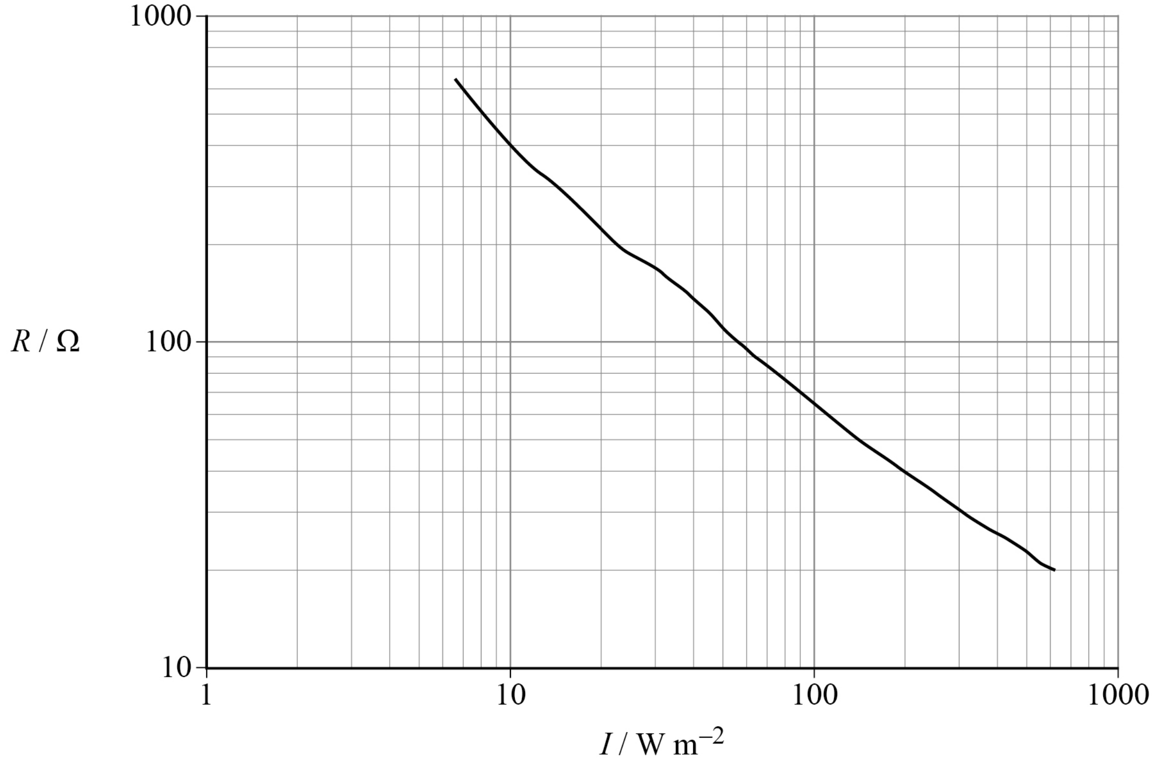
0 1 A student investigates the inverse-square law for light using a small filament lamp and an LDR as shown in **Figure 1**.

Figure 1



The student varies the distance d between the LDR and the lamp and records the resistance R of the LDR for each distance.
Figure 2 shows the variation of R with incident light intensity I for the LDR. The student uses **Figure 2** to determine I for each value of R.

Figure 2



Do not write outside the box

Table 1 shows the results for the investigation. One value for I is shown.

Table 1

d / cm	R / Ω	I / W m^{-2}
5.0	70	
10.0	200	23
15.0	400	

0 1 . 1 Complete **Table 1**.

[1 mark]

0 1 . 2 Discuss whether the results in **Table 1** support the inverse-square law for light.

[3 marks]

Question 1 continues on the next page

Do not write outside the box

0 1 . 3 The student performs the investigation in a darkened room to ensure that the results are valid.

State and explain **one** other practical procedure that the student must follow to ensure that the results are valid.

[2 marks]

____

____

____

____

____

____

6

Do not write outside the box

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

0 2 **Figure 3** shows a wheel **X** held at rest on a ramp. A white sticker **R** is placed on the side of the wheel where the rim of the wheel touches the ramp. The wheel is released at time $t = 0$ and accelerates uniformly down the ramp without slipping.

Figure 3

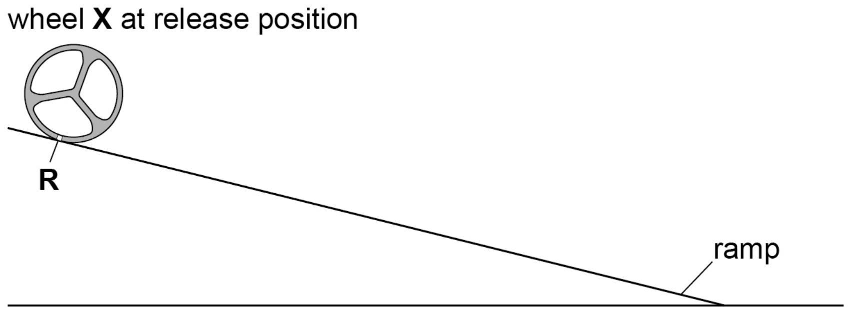
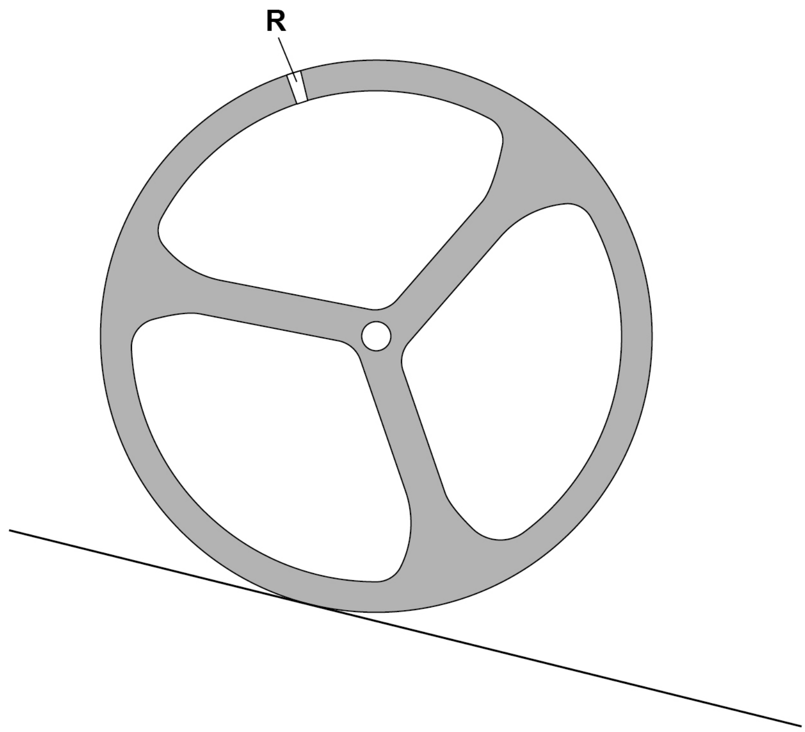


Figure 4 shows **X** at time t_1 when it has completed less than one rotation.

Figure 4



Do not write outside the box

The angular acceleration of **X** as it travels down the ramp is 3.6 rad s^{-2}.

0 2 . 1 Show, using **Figure 4**, that **X** has rotated by approximately 2.6 rad at t_1.

[2 marks]

0 2 . 2 Determine t_1.

[1 mark]

t_1 = ____________________ s

0 2 . 3 Calculate the angular speed of **X** as it completes its first rotation.

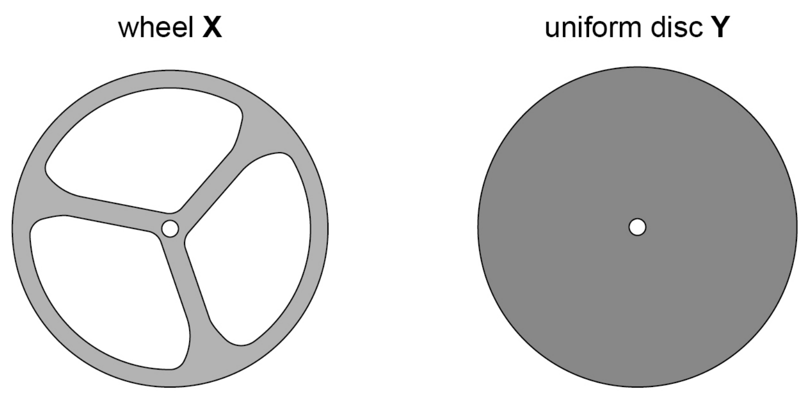
[2 marks]

angular speed = ____________________ rad s^{-1}

Question 2 continues on the next page

0 2 . 4 **Figure 5** shows wheel **X** and a uniform disc **Y**.
Y has the same mass and the same diameter as **X**.

Figure 5



X and **Y** are released from rest and allowed to accelerate down the same ramp.

Compare the angular acceleration of **X** with the angular acceleration of **Y**.

[3 marks]

____

____

____

____

____

____

____

____

0 3 . 1 State and explain **one** practical problem in achieving fusion in reactors.

[2 marks]

0 3 . 2 The equation below describes a fusion reaction that occurs in the Sun.

$$^{3}_{2}\mathrm{He} + ^{4}_{2}\mathrm{He} \rightarrow ^{7}_{4}\mathrm{Be} + \gamma$$

Table 2 shows the mass of each nuclide.

Table 2

Nuclide	**Mass / kg**
$^{3}_{2}\mathrm{He}$	5.00641×10^{-27}
$^{4}_{2}\mathrm{He}$	6.64466×10^{-27}
$^{7}_{4}\mathrm{Be}$	1.16482×10^{-26}

Calculate, in J, the energy released in this reaction.

[3 marks]

energy released = ____________________ J

Question 3 continues on the next page

Turn over ►

Do not write outside the box

0 3 . 3 The hydrogen cycle in the Sun involves three fusion reactions:

reaction **1** $\quad {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + e^{+} + \nu$

reaction **2** $\quad {}^{1}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He}$

reaction **3** $\quad {}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + 2{}^{1}_{1}\mathrm{H}$

The cycle produces one ${}^{4}_{2}\mathrm{He}$ nucleus from four ${}^{1}_{1}\mathrm{H}$ nuclei.

Deduce the number of times that reactions **1** and **2** occur in each cycle.

[2 marks]

Reaction **1** ____________________

____

____

Reaction **2** ____________________

____

____

7

Do not write outside the box

0 4 The energy sources on a small island consist of a combination of a wind farm and a pumped storage system (PSS).

0 4 . 1 Describe how this combination can provide a continuous supply of electrical energy.

[2 marks]

Question 4 continues on the next page

Do not write outside the box

0 4 . 2 The wind farm has several wind turbine generators (WTGs).
One WTG has a rotor diameter of $71\ \mathrm{m}$ and an efficiency of 28%.

Calculate the minimum wind speed that could produce a power output of $2.3\ \mathrm{MW}$ from the WTG.

density of air $= 1.3\ \mathrm{kg\ m^{-3}}$

[3 marks]

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

0 4 . 3 In the PSS, water flows from an upper reservoir through a pipe to a water turbine.
The water falls a vertical distance of $650\ \mathrm{m}$ before striking the turbine.

Calculate the maximum speed of the water striking the turbine.

Assume that there are negligible energy losses as the water flows through the pipe.

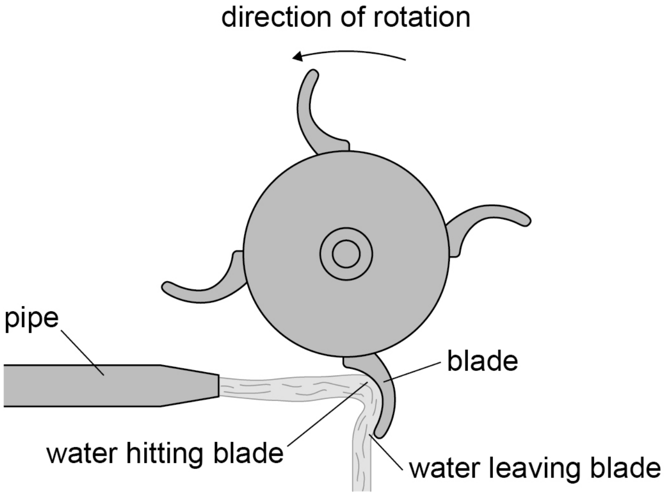
[2 marks]

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

Do not write outside the box

0 4 . 4 **Figure 6** shows water hitting a turbine blade. The water is travelling horizontally at a high speed when it hits the blade. The water leaves the blade in a different direction and with a much lower speed.

Figure 6



Explain how this process produces a torque on the turbine.

[4 marks]

____

____

____

____

____

____

____

____

____

11

0 5 Uranium fuel rods used in a thermal nuclear reactor contain uranium-238 and uranium-235.

0 5 . 1 **Table 3** gives the masses of a uranium-238 nuclide and a uranium-237 nuclide.

Table 3

Nuclide	Mass / u
$^{238}_{92}U$	238.00037
$^{237}_{92}U$	236.99831

Deduce whether a uranium-238 nucleus can decay into a uranium-237 nucleus and a neutron.

[2 marks]

0 5 . 2 Describe how a chain reaction occurs in the uranium-235 fuel.

[3 marks]

Do not write outside the box

0 5 . 3 State **one** substance that is used as a moderator in a thermal nuclear reactor.

[1 mark]

0 5 . 4 The neutrons required to produce fission in many reactors are thermal neutrons.

State why they are called thermal neutrons.

[1 mark]

0 5 . 5 Explain why the kinetic energy of the neutrons needs to be reduced for the chain reaction to occur.

[2 marks]

0 5 . 6 Neutrons lose kinetic energy by a series of collisions with nuclei of the moderator. Each neutron keeps an average of 84% of its incident kinetic energy in each collision.

One neutron has an initial kinetic energy of 2.0×10^{6} eV.

Deduce the average number of collisions the neutron makes to reduce its kinetic energy to 2.5×10^{-2} eV.

[2 marks]

average number of collisions = ________________

Question 5 continues on the next page

0 5 . 7 Liquid sodium is used as a coolant in some types of nuclear reactor.
Table 4 gives some properties of sodium.

Table 4

melting temperature / °C	98
latent heat of fusion / $\mathrm{kJ\ kg^{-1}}$	110
average specific heat capacity of solid / $\mathrm{kJ\ kg^{-1}\ K^{-1}}$	1.2
average specific heat capacity of liquid / $\mathrm{kJ\ kg^{-1}\ K^{-1}}$	1.3

Calculate the energy required to heat 3.3×10^{5} kg of sodium from an initial temperature of 20 °C to a final temperature of 560 °C.

[3 marks]

energy = ____________________ J

0 5 . 8 During the operation of the reactor, radioactive caesium-137 is produced. The caesium-137 is removed from the reactor as waste which needs to be stored.

Caesium-137 decays into stable barium-137 with the emission of beta particles and gamma radiation. The half-life of caesium-137 is 30 years.

Outline the problems associated with the storage of this waste.

[2 marks]

____

____

____

____

____

____

16

Turn over for the next question

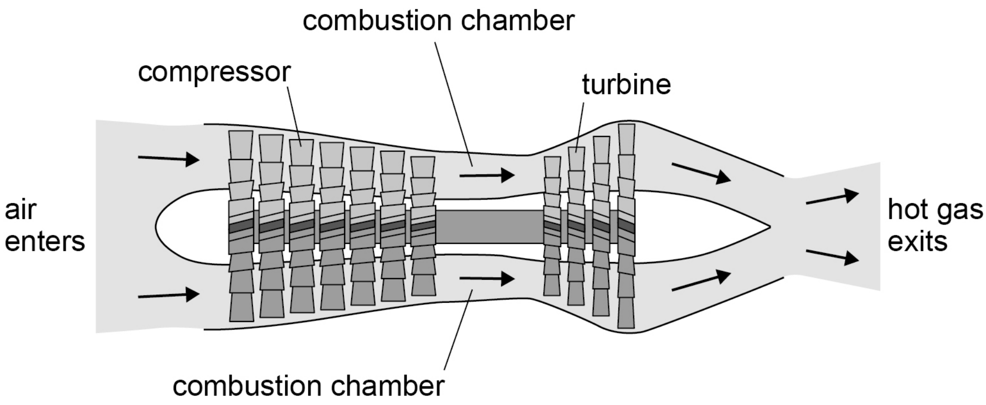
Do not write outside the box

0 6 **Figure 7** shows the flow of gases through a jet engine.

A jet engine has three sections:

- a compressor
- a combustion chamber
- a turbine.

Figure 7



Air enters the compressor at a pressure p_1 and an absolute temperature T_1.

The compressor rapidly compresses the air to a pressure p_2 and an absolute temperature T_2.

For this compression, $p_2 = 40p_1$.

Assume that the air behaves as an ideal gas.

0 6 . 1 The air enters the compressor with a density d_1 and exits the compressor with an increased density d_2.

Explain, with reference to the ideal gas equation, why $\frac{T_2}{T_1} < 40$ for this increase in density.

[2 marks]

Do not write outside the box

0 6 . 2 Explain, with reference to the first law of thermodynamics, why the temperature of the air increases as a result of this rapid compression.

[3 marks]

____

____

____

____

____

____

0 6 . 3 The pressures and temperatures of the air before and after this rapid compression are related by:

$$\frac{p_1}{p_2} = \left(\frac{T_1}{T_2}\right)^{3.5}$$

Calculate T_2 when $T_1 = 300$ K.

[3 marks]

T_2 = ______________________ K

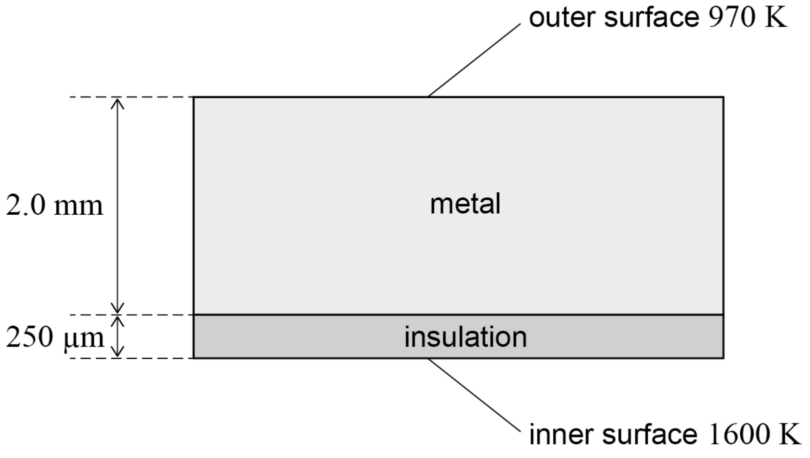
Question 6 continues on the next page

Do not write outside the box

In the combustion chamber, fuel is added to the compressed air. The air−fuel mixture burns to increase the gas temperature even more.

0 6 . 4 **Figure 8** shows a cross-sectional view of part of the wall of the combustion chamber. The wall of the combustion chamber is made of a metal and a layer of insulation. The inner surface of the wall is at a temperature of $1600\ \mathrm{K}$.
The outer surface is at a temperature of $970\ \mathrm{K}$.
The metal has a thickness of $2.0\ \mathrm{mm}$ and the insulation has a thickness of $250\ \mu\mathrm{m}$.

Figure 8



The rate of energy transfer through the metal is the same as the rate of energy transfer through the insulation.

Determine the temperature at the boundary between the metal and the insulation.

thermal conductivity of metal = $27\ \mathrm{W\ m^{-1}\ K^{-1}}$
thermal conductivity of insulation = $0.74\ \mathrm{W\ m^{-1}\ K^{-1}}$

[3 marks]

temperature = ______________________ K

0 6 . 5 The gas from the combustion chamber drives a gas turbine that is rotating at 1.0×10^4 revolutions per minute. The turbine extracts energy from the gas at a rate of 19 MW.

Calculate the torque exerted by the gas on the turbine.

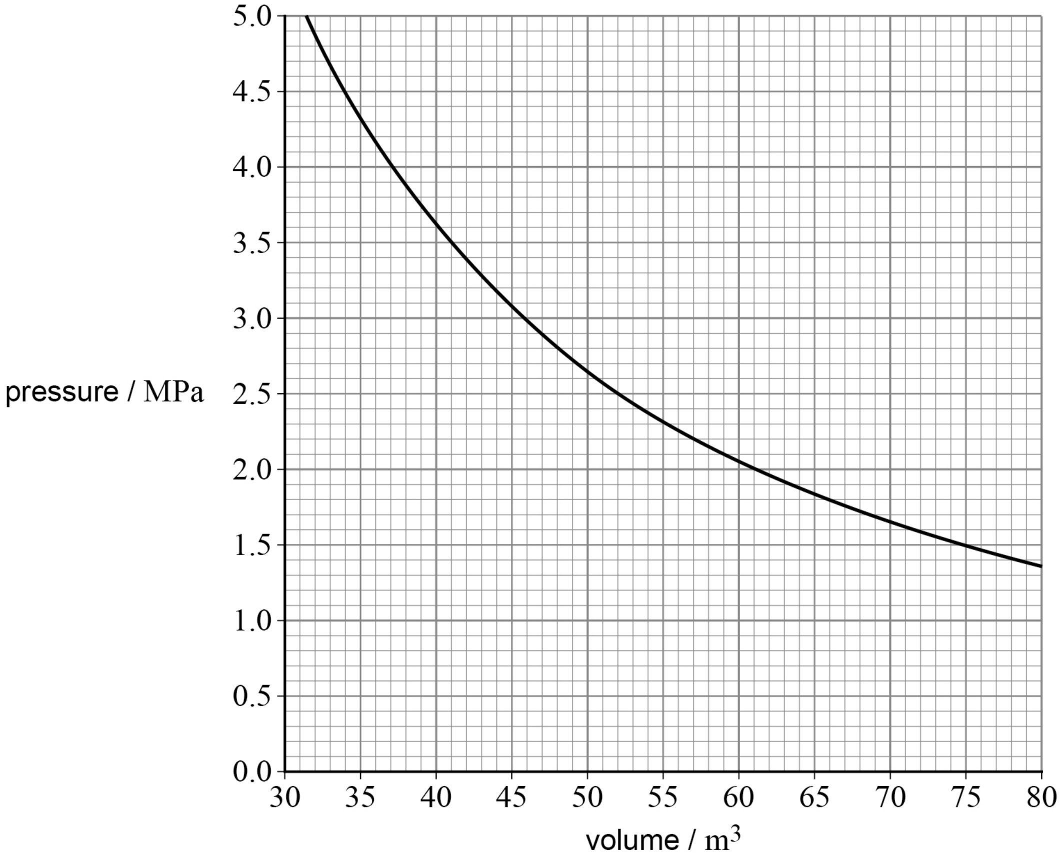
[3 marks]

torque = ______________________ N m

Question 6 continues on the next page

0 6 . 6 A fixed mass of gas moves through the turbine.
Figure 9 shows the variation of pressure with volume for this gas.

Figure 9



The gas enters the turbine at 4.3 MPa and leaves at 1.5 MPa.

Determine the work done by the fixed mass of gas on the turbine.

[3 marks]

work done by the gas = ______________________ J

17

END OF SECTION A

Do not write outside the box

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.

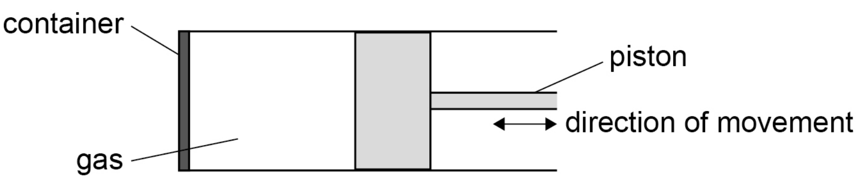
CORRECT METHOD WRONG METHODS

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 7 A container holds a fixed mass of an ideal gas at a constant pressure.
The container has a piston that is free to move horizontally.



Which values of ΔU and Q lead to the smallest change in the volume of the gas for this constant pressure?

[1 mark]

	ΔU / J	Q / J	
A	−45	−60	⬭
B	−15	+60	⬭
C	+30	−45	⬭
D	+60	+15	⬭

Do not write outside the box

0 8 The table shows information about four materials.

Material	Area / m^2	Thickness / mm	U-value / $W\ m^{-2}\ K^{-1}$
A	1.0	40	3.0
B	2.0	10	1.0
C	3.0	20	2.0
D	3.0	30	4.0

The rate of energy transfer through each material is the same.

Which material will have the greatest temperature difference across its surfaces?

[1 mark]

A ⬭

B ⬭

C ⬭

D ⬭

0 9 Which of these arises from a theoretical derivation rather than from an experimental observation?

[1 mark]

A Boyle's law ⬭

B Charles's law ⬭

C Brownian motion ⬭

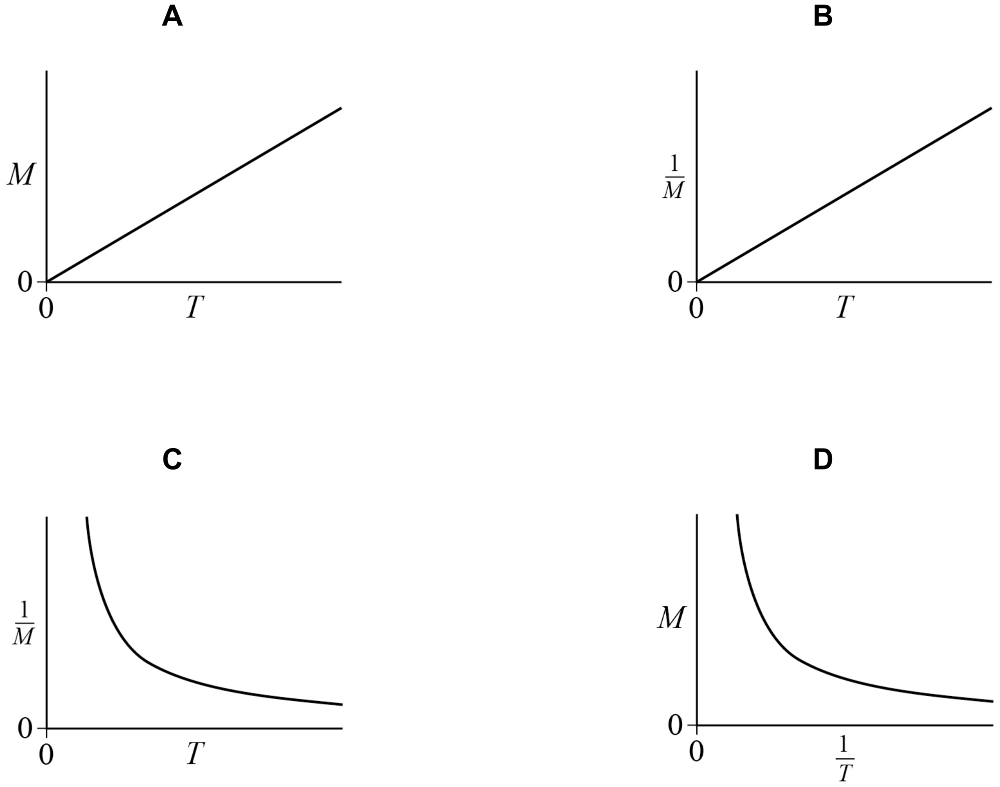
D the ideal gas equation ⬭

Do not write outside the box

1 0 The mass M of an ideal gas in a container is varied. The volume of the container is constant. For each mass M the temperature T of the gas is adjusted to keep the pressure constant.

What is the variation of M with T?

[1 mark]



A ○

B ○

C ○

D ○

Turn over for the next question

Do not write outside the box

1 1 The molar mass of methane is $16\ \mathrm{g\ mol^{-1}}$.

How many molecules are in $820\ \mathrm{kg}$ of methane?

[1 mark]

A 1.2×10^{25} ⬭

B 3.1×10^{25} ⬭

C 1.2×10^{28} ⬭

D 3.1×10^{28} ⬭

1 2 For one sample of an ideal gas, $c_{\mathrm{rms}} = v$.

The temperature of the gas is changed at constant volume so that the pressure is halved.

What is the new value of c_{rms}?

[1 mark]

A $\dfrac{v}{4}$ ⬭

B $\dfrac{v}{2}$ ⬭

C $\dfrac{v}{\sqrt{2}}$ ⬭

D $\sqrt{2}v$ ⬭

1 3 An insulated beaker of negligible heat capacity contains a liquid at a temperature of $10\ °\mathrm{C}$.
The mass of the liquid is $0.30\ \mathrm{kg}$.
A metal block of mass $0.10\ \mathrm{kg}$ is at a temperature of $90\ °\mathrm{C}$.
The metal is placed into the liquid.
The metal and liquid reach thermal equilibrium at a temperature of $28\ °\mathrm{C}$.
The specific heat capacity of the liquid is $1700\ \mathrm{J\ kg^{-1}\ K^{-1}}$.

What is the specific heat capacity of the metal?

[1 mark]

A $160\ \mathrm{J\ kg^{-1}\ K^{-1}}$ ⬭

B $1300\ \mathrm{J\ kg^{-1}\ K^{-1}}$ ⬭

C $1500\ \mathrm{J\ kg^{-1}\ K^{-1}}$ ⬭

D $1800\ \mathrm{J\ kg^{-1}\ K^{-1}}$ ⬭

1 4 Which pair of changes to the conditions of an ideal gas will always increase the internal energy of a fixed mass of the gas?

[1 mark]

	Gas pressure	**Gas volume**	
A	increase	increase	⬭
B	increase	decrease	⬭
C	decrease	increase	⬭
D	decrease	decrease	⬭

Turn over for the next question

1 5 An alpha particle with initial kinetic energy E approaches a stationary nucleus of proton number Z.

What is the distance of closest approach between the alpha particle and the nucleus?

[1 mark]

A $\dfrac{Ze}{\pi\varepsilon_0 E}$ ⬭

B $\dfrac{Ze}{2\pi\varepsilon_0 E}$ ⬭

C $\dfrac{Ze^2}{2\pi\varepsilon_0 E}$ ⬭

D $\dfrac{Ze^2}{4\pi\varepsilon_0 E}$ ⬭

1 6 Why is there a mass defect for a nucleus?

[1 mark]

A Smaller nuclei are always more stable than larger nuclei. ⬭

B Nucleons have less potential energy in the nucleus than as separate nucleons. ⬭

C A proton has a smaller mass than a neutron. ⬭

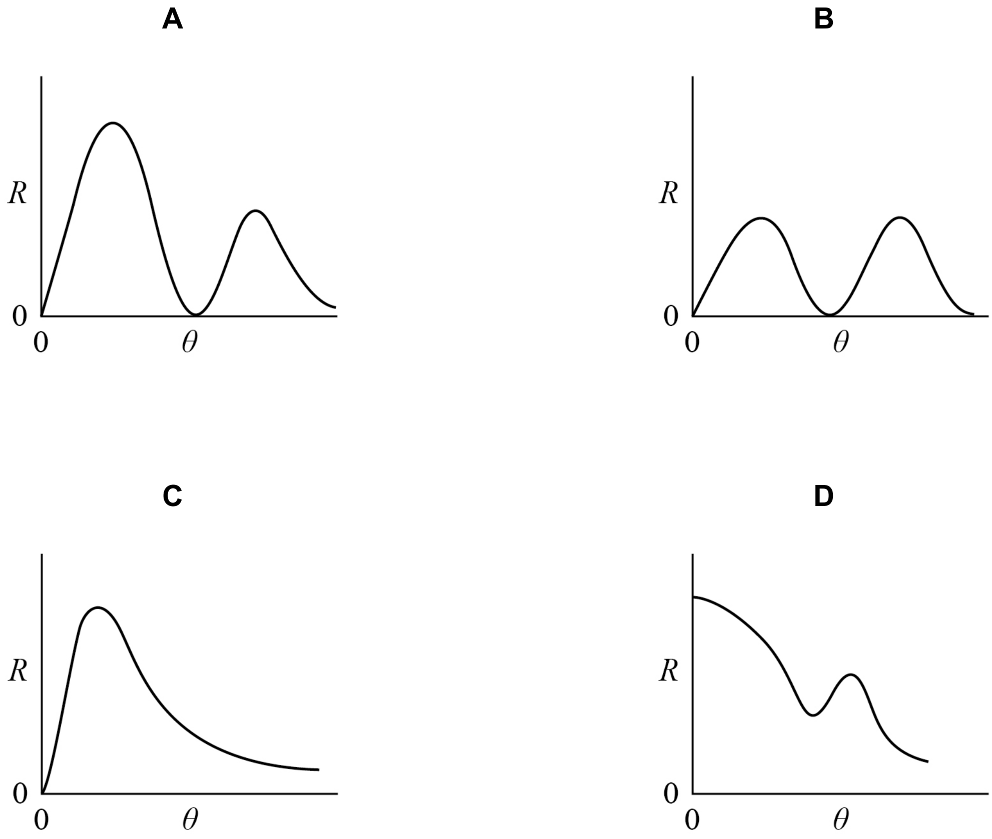
D There is electrostatic repulsion between protons. ⬭

Do not write outside the box

1 7 Electrons are diffracted by nuclei.
At a given diffraction angle θ the rate at which electrons are detected is R.

What is the variation of R with θ?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

Turn over for the next question

Do not write outside the box

1 8 The density of a $^{130}_{56}\mathrm{Ba}$ nucleus is $4.6 \times 10^{17}\ \mathrm{kg\ m^{-3}}$.

What is the radius of a $^{130}_{56}\mathrm{Ba}$ nucleus?

[1 mark]

A 2.5 fm ⬭

B 3.3 fm ⬭

C 3.7 fm ⬭

D 4.8 fm ⬭

1 9 The nuclide with the largest magnitude of binding energy per nucleon is

[1 mark]

A $^{2}_{1}\mathrm{H}$. ⬭

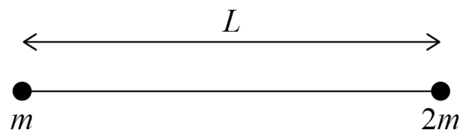
B $^{4}_{2}\mathrm{He}$. ⬭

C $^{62}_{28}\mathrm{Ni}$. ⬭

D $^{238}_{92}\mathrm{U}$. ⬭

Do not write outside the box

2 0 A system consists of two point masses m and $2m$ connected by a rigid rod of negligible mass.
The distance between the point masses is L.



What is the moment of inertia about the centre of mass of the system?

[1 mark]

A $\dfrac{2mL^2}{3}$ ⬭

B $\dfrac{3mL^2}{4}$ ⬭

C mL^2 ⬭

D $\dfrac{4mL^2}{3}$ ⬭

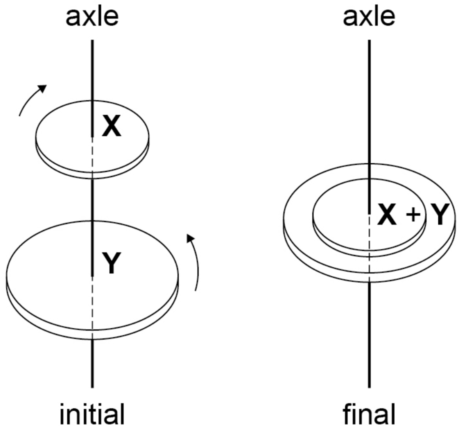
Turn over for the next question

Do not write outside the box

2 1 Two discs **X** and **Y** rotate freely on the same axle at different angular speeds. Initially, **X** rotates clockwise at $48\ \text{rad s}^{-1}$ and **Y** rotates anticlockwise at $22\ \text{rad s}^{-1}$.

X falls onto **Y** and the two discs rotate together with the same angular speed.

The moment of inertia of **X** is $1.2\ \text{kg m}^2$.
The moment of inertia of **Y** is $1.6\ \text{kg m}^2$.



What is the final angular speed and direction of rotation of the two discs?

[1 mark]

	Final angular speed / rad s^{-1}	Direction of rotation	
A	8	clockwise	⬭
B	22	clockwise	⬭
C	33	anticlockwise	⬭
D	93	anticlockwise	⬭

15

END OF QUESTIONS

Do not write outside the box

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Question number	**Additional page, if required. Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required. Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required. Write the question numbers in the left-hand margin.**