OXFORD AQA

INTERNATIONAL QUALIFICATIONS

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

Friday 17 January 2025 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	

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Section A

Answer **all** questions in this section.

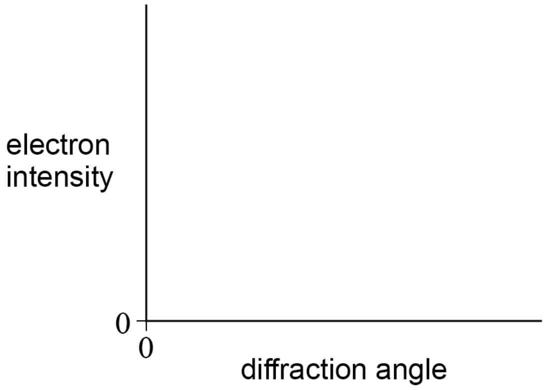
0 1 This question compares electron diffraction with alpha-particle scattering.

A narrow beam of electrons is passed through a thin foil of lead atoms.
The diffraction of the electrons is used to measure the diameter of lead nuclei.

0 1 . 1 Sketch, on **Figure 1**, the variation of electron intensity with diffraction angle of the electrons.

[1 mark]

Figure 1



The diameter of a lead-208 ($^{208}_{82}Pb$) nucleus is approximately equal to 11 fm.

0 1 . 2 Each electron in the beam has a momentum of 2.2×10^{-19} kg m s^{-1}.

Deduce whether the de Broglie wavelength of these electrons is suitable for the measurement of the diameter of lead-208 nuclei.

Support your answer with a calculation.

[3 marks]

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Lead-204 ($^{204}_{82}\text{Pb}$) is another isotope of lead.

0 1 . 3 Electron diffraction is now used to measure the diameter of a lead-204 nucleus.

Deduce whether using electron diffraction to measure nuclear diameter will produce different answers for $^{204}_{82}\text{Pb}$ and $^{208}_{82}\text{Pb}$ nuclei.

[1 mark]

____

____

____

0 1 . 4 An alpha particle with an initial kinetic energy of 8.4 MeV is aimed directly at a nucleus of $^{208}_{82}\text{Pb}$.

Assume that the $^{208}_{82}\text{Pb}$ nucleus remains stationary.

Calculate the distance of closest approach between the alpha particle and the nucleus.

[3 marks]

distance of closest approach = ____________________ m

0 1 . 5 The distance of closest approach is now determined with nuclei of $^{204}_{82}\text{Pb}$ using alpha particles with an initial kinetic energy of 8.4 MeV.

Deduce whether the distance of closest approach of the alpha particles will be different for $^{204}_{82}\text{Pb}$ and $^{208}_{82}\text{Pb}$ nuclei.

[1 mark]

____

____

____

9

Turn over ►

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0 2 . 1 A sample of gas is in a sealed container.

Explain how the molecules of the gas exert pressure on the walls of the container.

[4 marks]

Argon and xenon gases exist as single atoms that do not react.
One container contains an equal number of argon and xenon atoms at constant temperature.

mass of $1.00\ \text{mol}$ of argon = $0.040\ \text{kg}$
mass of $1.00\ \text{mol}$ of xenon = $0.132\ \text{kg}$

0 2 . 2 Determine $\frac{c_{\text{Ar}}}{c_{\text{Xe}}}$

where

c_{Ar} = root mean square speed (c_{rms}) of argon atoms
c_{Xe} = root mean square speed (c_{rms}) of xenon atoms

[3 marks]

$\frac{c_{\text{Ar}}}{c_{\text{Xe}}}$ = ____________________

Do not write outside the box

0 2 . 3 The argon atoms and the xenon atoms all contribute to the total pressure exerted by the gas in the container.

A student suggests that the xenon atoms make a greater contribution than the argon atoms to the total pressure.

Deduce whether the student is correct.

[2 marks]

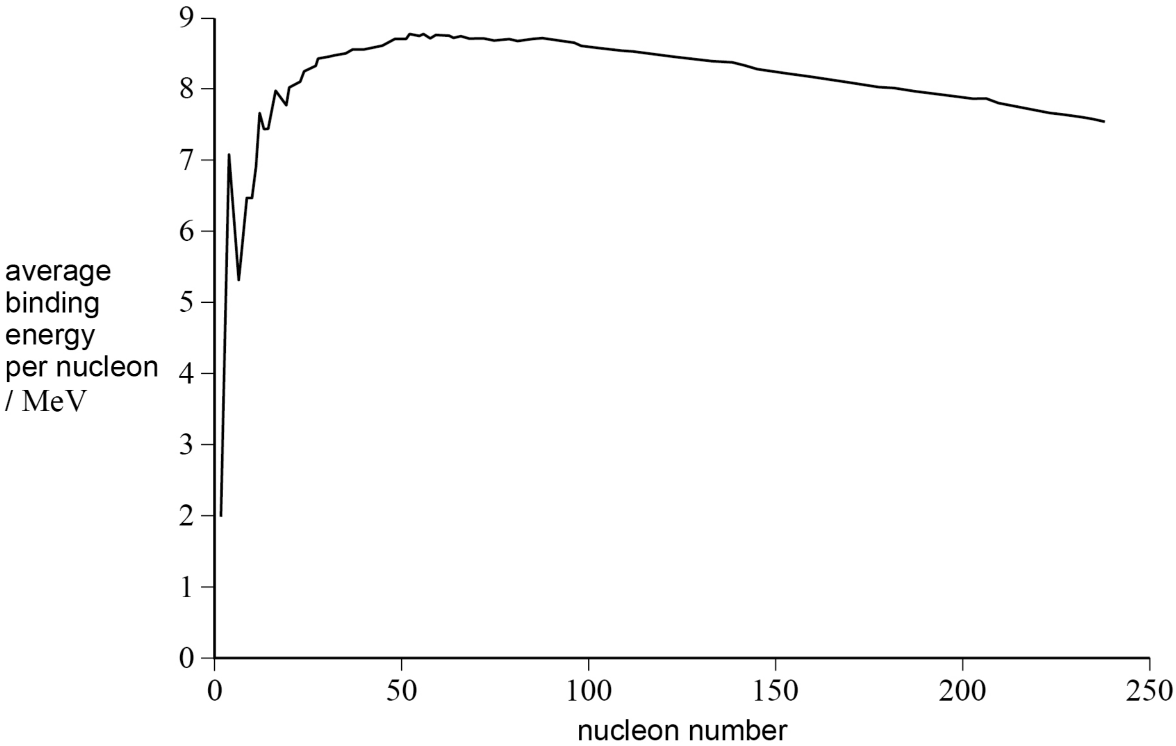
9

Turn over for the next question

0 3 Nuclear fission and nuclear fusion can each lead to a release of energy.

0 3 . 1 **Figure 2** is a plot of the variation of average binding energy per nucleon with nucleon number.

Figure 2



Compare the processes of nuclear fission and nuclear fusion in which energy is released.

In your answer:

- describe the nuclear changes involved in fission and fusion
- describe how each process can begin
- explain why fission reactions are confined to one part of **Figure 2** and fusion reactions are confined to a different part of **Figure 2**.

[6 marks]

0 3 . 2 Superconducting electromagnets are frequently used to contain the reactants in experimental fusion reactors.

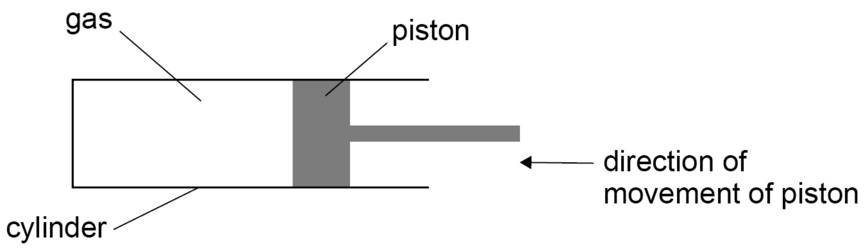
Explain why electromagnets are used in this application and why they need to be superconducting.

[3 marks]

9

0 4 A cylinder with a moveable piston contains a fixed mass of an ideal gas, as shown in **Figure 3**.

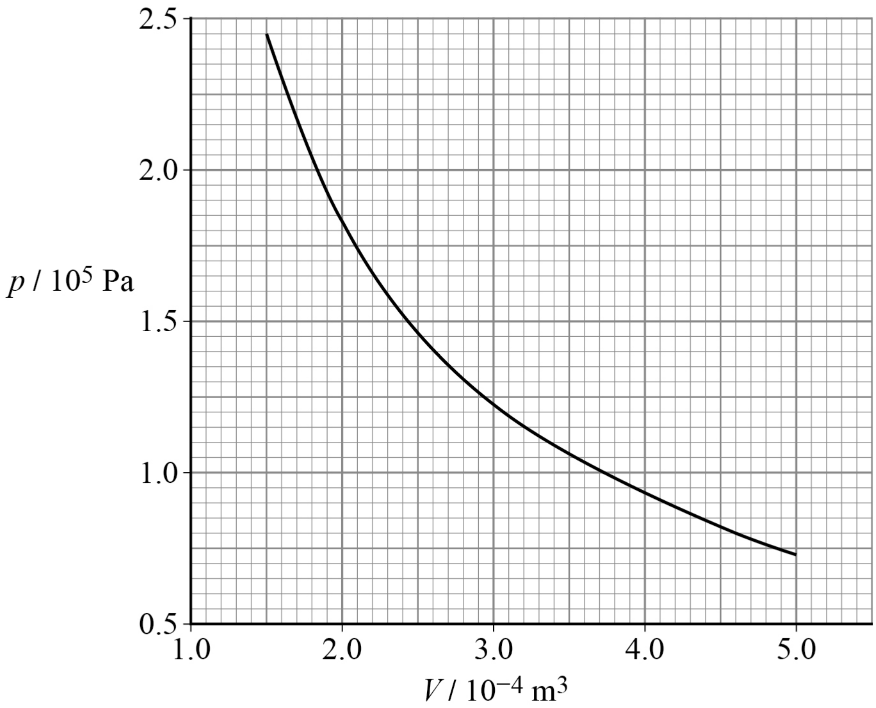
Figure 3



The gas is compressed by moving the piston to the left.

Figure 4 shows the variation of pressure p with volume V for the gas.

Figure 4



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0 4 . 1 Show that, for the compression in **Figure 4**, the temperature at the start of the compression is approximately the same as the temperature at the end of the compression.

[3 marks]

0 4 . 2 Determine the work done on the gas in the compression shown in **Figure 4**.

[3 marks]

work done = ____________ J

0 4 . 3 A gas is initially at the same temperature as its surroundings. The temperature of the surroundings remains constant.

Explain why it is **not** possible to compress the gas so that its temperature remains **exactly** constant, while doing work on it.
Refer to the first law of thermodynamics in your answer.

[2 marks]

Question 4 continues on the next page

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0 4 . 4 It is possible to compress the gas in the cylinder at a temperature that is **approximately** constant.

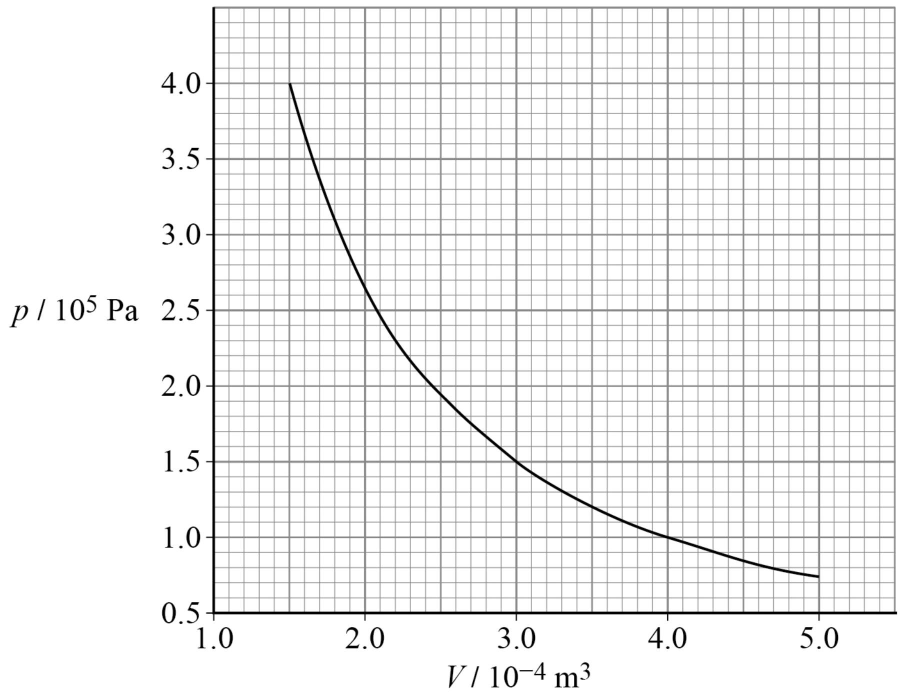
Describe how the compression must be done.

In your answer you should consider:
- the way in which the piston is moved
- a feature of the cylinder.

[2 marks]

The gas in **Figure 3** is now compressed in a different way so that its temperature changes significantly.
Figure 5 shows the variation of pressure p with volume V for the gas.

Figure 5



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The temperature of the gas immediately after the compression shown in **Figure 5** is 223 °C.

0 4 . 5 Calculate, in mol, the amount of gas in the cylinder.

[2 marks]

amount of gas = ____________________ mol

0 4 . 6 Calculate the temperature change of the gas during the compression shown in **Figure 5**.

[3 marks]

temperature change = ____________________ K

Question 4 continues on the next page

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0 4 . 7 The values of p and V used to plot **Figure 5** are connected by the relationship

$$pV^b = C$$

where b and C are constants.

The values of p and V can also be processed to produce a linear graph from which b can be determined.

Suggest axes for this linear graph.
Go on to explain how the value of b can be determined from this graph.

[2 marks]

17

Do not write outside the box

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

0 5 **Figure 6** shows an exercise bike and its drive system.

A rider turns the pedals to apply a torque to disc **A**. This torque is transmitted to hub **B** by a belt that does not slip. **B** is fixed to a larger disc **C** that rotates when the belt moves.

A spring pushes a friction pad against the edge of **C**, as shown in **Figure 7**. This causes a force F_s to act towards the centre of **C**.

Figure 6

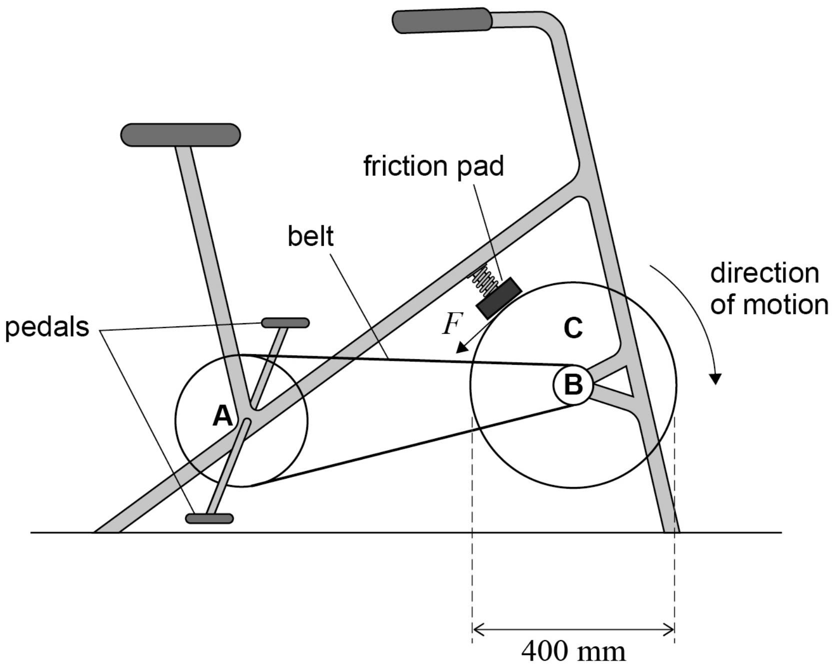
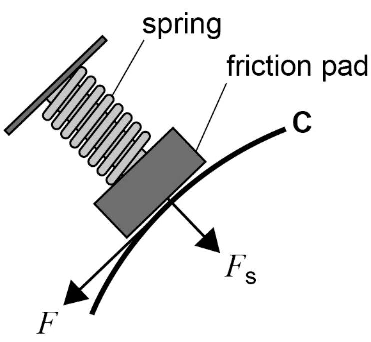


Figure 7



When **C** is turning, F_s leads to a frictional force F that acts on the surface of **C**. F produces a constant resistive torque of $4.5\ \mathrm{N\ m}$ about the centre of **C**. Assume that the drive system has an efficiency of 100%.

0 5 . 1 The magnitude of F is given by:

$$F = 0.62F_s$$

where F_s is the force in the compressed spring.

The spring constant of the spring is $2400\ \mathrm{N\ m^{-1}}$.
C has a diameter of $400\ \mathrm{mm}$.

Calculate, in m, the change in length of the spring.

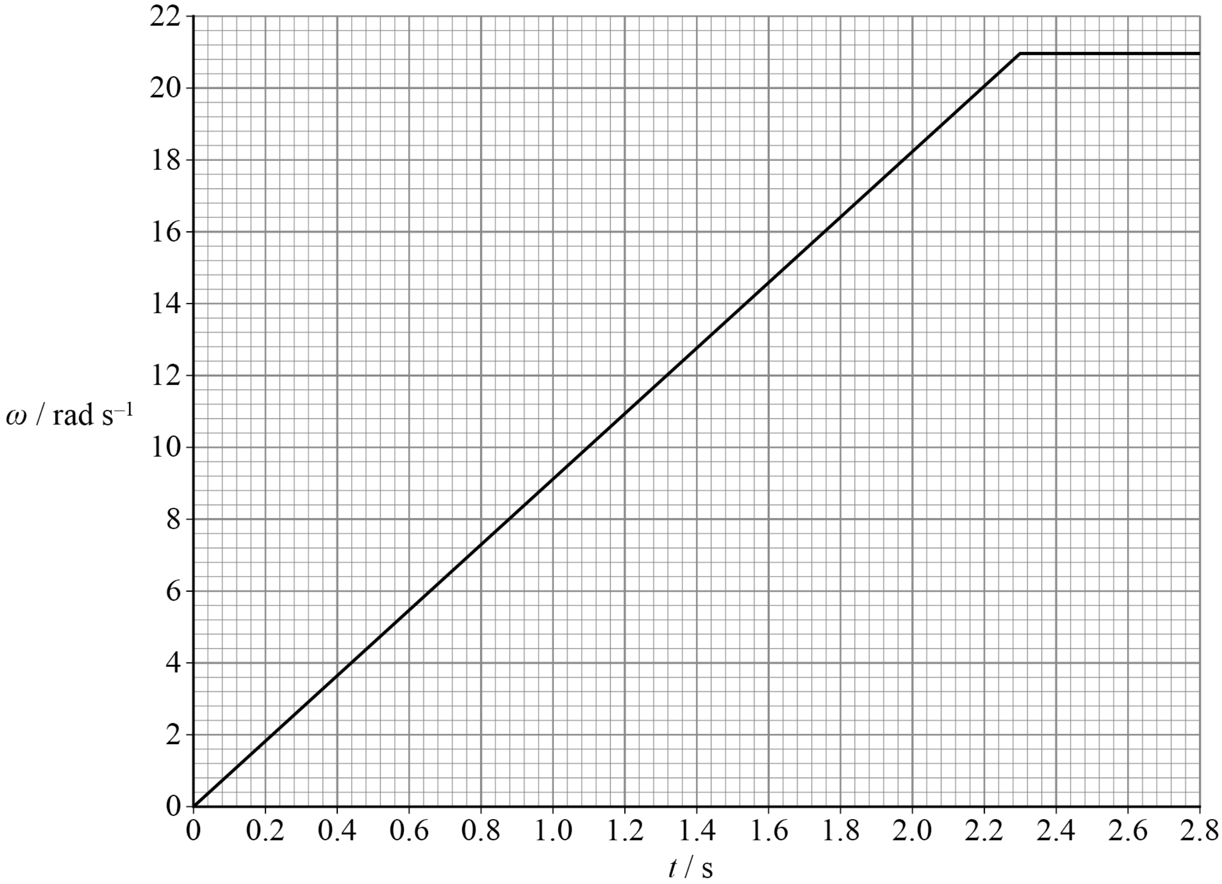
[3 marks]

change in length = ____________________ m

Question 5 continues on the next page

Figure 8 shows the variation of the angular speed ω of **C** with time t.

Figure 8



The resistive torque due to the friction pad remains constant at 4.5 N m.

0 5 . 2 Calculate the power delivered by the rider when $t = 2.4$ s.

[1 mark]

power = ____________________ W

Do not write outside the box

C has a moment of inertia of $0.21\ \mathrm{kg\ m^2}$.

0 5 . 3 Calculate the rotational kinetic energy of **C** when $t = 2.4\ \mathrm{s}$.

[1 mark]

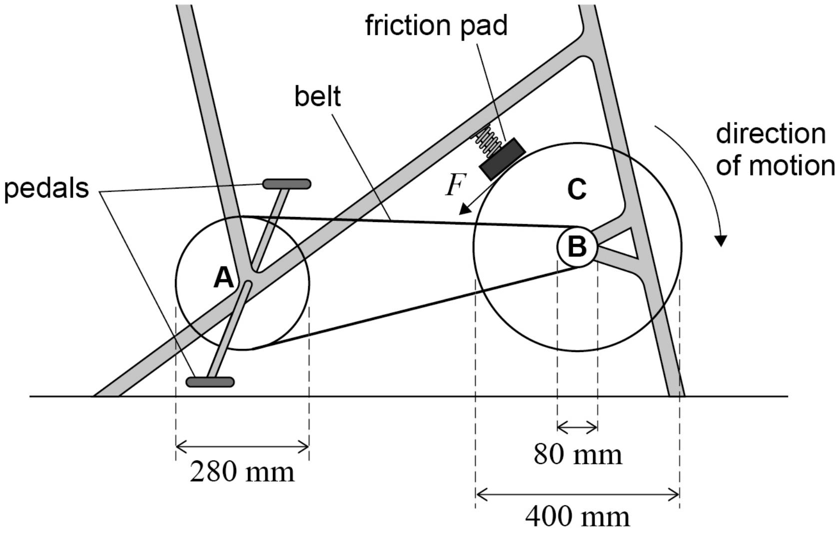
rotational kinetic energy = ____________________ J

Question 5 continues on the next page

Do not write outside the box

0 5 . 4 **Figure 9** shows the drive system of the exercise bike, with the values for the diameters of **A**, **B** and **C** marked.

Figure 9



Determine the torque exerted by the belt on **A** during the first 2.3 s of **Figure 8** on page 16.

[4 marks]

torque = ____________________ N m

Do not write outside the box

0 5 . 5 Describe the changes in the torque exerted by the rider during the time shown on the graph in **Figure 8** on page 16.

[2 marks]

11

Turn over for the next question

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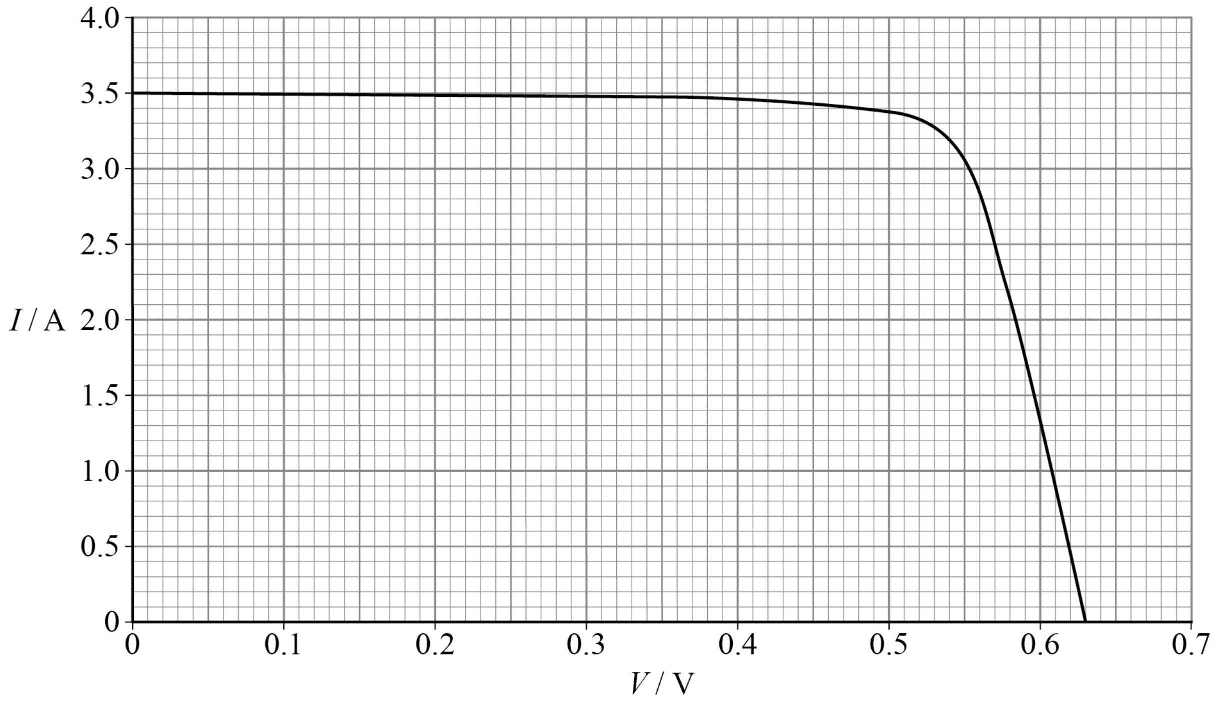
0 6 **Figure 10** shows the I–V characteristic for a solar cell.

Figure 10



The solar cell delivers its maximum power when the potential difference across its terminals is 0.54 V.

0 6 . 1 An engineer designs an arrangement of solar cells. Each solar cell has the I–V characteristic shown in **Figure 10**. The solar cells operate at their maximum power.

The arrangement must provide:

- a potential difference of at least 16 V
- a current of at least 10 A.

Determine how an arrangement of 120 solar cells can satisfy these conditions.

[2 marks]

space for calculation

Do not write outside the box

0 6 . 2 The internal resistance r of each solar cell is given by:

$$r = \frac{0.63\ \text{V}}{3.5\ \text{A}}$$

Explain why it is appropriate to use $0.63\ \text{V}$ and $3.5\ \text{A}$ to calculate r.

[2 marks]

$0.63\ \text{V}$ ____

____

____

$3.5\ \text{A}$ ____

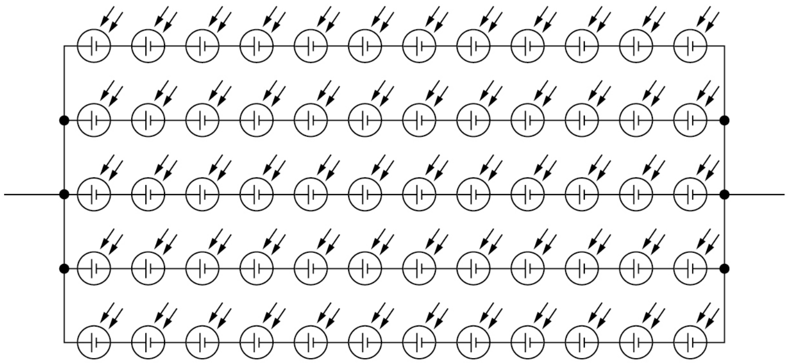
____

____

Question 6 continues on the next page

A different arrangement of solar cells has five parallel arms.
Each arm has 12 solar cells in series as shown in **Figure 11**.
Each cell has the I–V characteristic shown in **Figure 10** on page 20.

Figure 11



0 6 . 3 Determine the maximum power available from the arrangement in **Figure 11**.
[2 marks]

power = ____________________ W

0 6 . 4 Calculate the internal resistance of the arrangement in **Figure 11**.
[2 marks]

internal resistance = ____________________ Ω

Do not write outside the box

0 6 . 5 Solar radiation is incident normal to the top of the Earth's atmosphere with an intensity of $1350\ \mathrm{W\ m^{-2}}$.

The intensity of this solar radiation incident normal to the ground at the Earth's equator at midday is $1100\ \mathrm{W\ m^{-2}}$.

Show that this reduction in intensity is **not** consistent with an inverse-square law.

radius of the Earth's orbit = $1.50 \times 10^{11}\ \mathrm{m}$
thickness of the Earth's atmosphere = $100\ \mathrm{km}$

[2 marks]

10

END OF SECTION A

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 7 A solid material is melted at constant temperature to form a liquid.
The mean potential energy of the molecules in the material is E_p.
The mean kinetic energy of the molecules in the material is E_k.

What happens to E_p and E_k during the melting process?

[1 mark]

	E_p	E_k	
A	stays the same	increases	⬭
B	stays the same	stays the same	⬭
C	increases	increases	⬭
D	increases	stays the same	⬭

Do not write outside the box

0 8 The SI fundamental (base) unit of specific latent heat is:

[1 mark]

A $\mathrm{J\ kg^{-1}}$ ☐

B $\mathrm{kg\ m^{2}\ s^{-2}}$ ☐

C $\mathrm{m^{2}\ s^{-2}}$ ☐

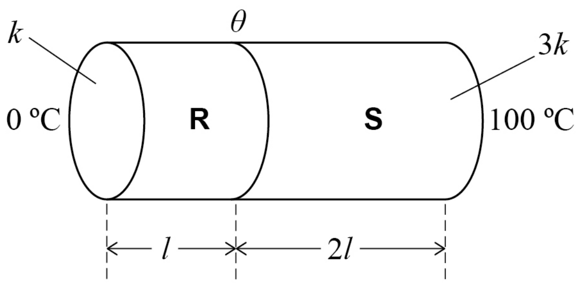
D $\mathrm{N\ m\ kg^{-1}}$ ☐

0 9 A bar is made from two metal cylinders **R** and **S**, each with the same cross-sectional area.

R has length l and thermal conductivity k.
S has length $2l$ and thermal conductivity $3k$.

The ends of the bar are maintained at temperatures of 0 °C and 100 °C.
The temperature at the junction between **R** and **S** is θ.

The rates of heat transfer through **R** and **S** are the same.



What is θ?

[1 mark]

A 40 °C ☐

B 50 °C ☐

C 60 °C ☐

D 67 °C ☐

Do not write outside the box

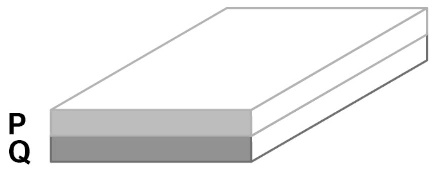
1 0 Two types of insulation block **P** and **Q** have the same dimensions.
The U-value of **P** is less than the U-value of **Q**.

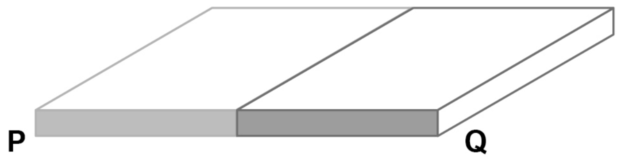
The diagrams show various combinations of these blocks.

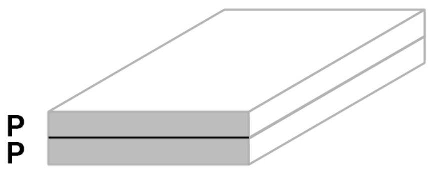
The temperature difference between the top and bottom of each combination is the same.

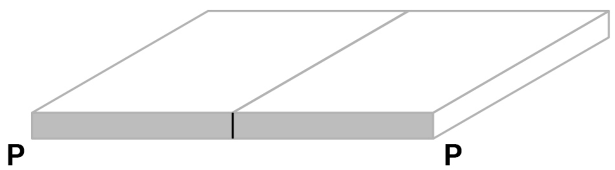
Which combination has the greatest rate of heat transfer?

[1 mark]

A 

B 

C 

D 

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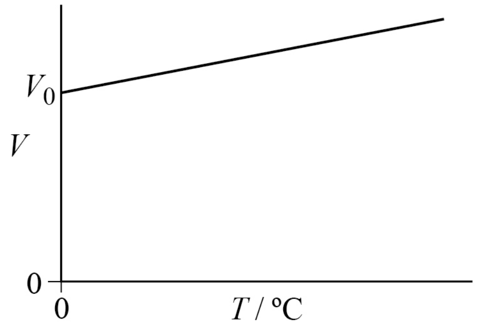
1 1 The graph shows the variation of volume V with temperature T for n mol of an ideal gas.
The pressure p of the gas remains constant.
The volume of the gas is V_0 at 0 °C.



The gradient of the graph is:

[1 mark]

A $\dfrac{p}{nR}$ ⬭

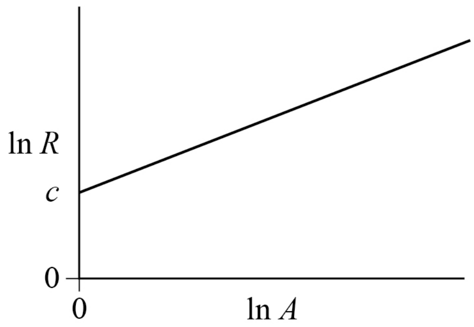
B $\dfrac{nRT}{V_0}$ ⬭

C $\dfrac{1}{273}$ ⬭

D $\dfrac{V_0}{273}$ ⬭

Turn over for the next question

1 2 A graph is drawn of $\ln R$ against $\ln A$, where R is nuclear radius and A is nucleon number.



The radius of a hydrogen (^1_1H) nucleus is R_0.

Which row shows R_0 and the gradient of the graph?

[1 mark]

	R_0	Gradient of graph	
A	c	$\frac{1}{3}$	⬭
B	e^c	3	⬭
C	c	3	⬭
D	e^c	$\frac{1}{3}$	⬭

Do not write outside the box

1 3 The table gives the nuclear masses of some nuclides.

Nuclide	**Nuclear mass / u**
$^{1}_{1}\text{H}$	1.00783
$^{2}_{1}\text{H}$	2.01410
$^{3}_{1}\text{H}$	3.01605
$^{3}_{2}\text{He}$	3.01603
$^{4}_{2}\text{He}$	4.00260
$^{7}_{3}\text{Li}$	7.01600
n	1.00866

Which reaction is possible without a net input of energy?

[1 mark]

A $^{2}_{1}\text{H} + ^{3}_{1}\text{H} \rightarrow ^{4}_{2}\text{He} + \text{n}$ ⬭

B $^{2}_{1}\text{H} + ^{7}_{3}\text{Li} \rightarrow 2\ ^{4}_{2}\text{He}$ ⬭

C $^{4}_{2}\text{He} + ^{2}_{1}\text{H} \rightarrow ^{3}_{2}\text{He} + ^{3}_{1}\text{H}$ ⬭

D $^{1}_{1}\text{H} + ^{1}_{1}\text{H} \rightarrow \text{p} + ^{2}_{1}\text{H}$ ⬭

Turn over for the next question

1 4 Which row gives desirable properties for the moderator, coolant and control rods in a thermal nuclear reactor?

[1 mark]

	Moderator	Coolant	Control rods	
A	poor neutron absorber	low specific heat capacity	good neutron absorber	⬭
B	low nucleon number	high specific heat capacity	good neutron absorber	⬭
C	good neutron absorber	high specific heat capacity	high nucleon number	⬭
D	low nucleon number	low specific heat capacity	high nucleon number	⬭

1 5 A solid sphere of uranium contains a mixture of uranium-235 and uranium-238 atoms. The uranium has a mass that is less than the critical mass.

Which change makes it possible for this mass of uranium to become critical?

[1 mark]

A increasing the ratio $\frac{\text{number of uranium-235 atoms}}{\text{number of uranium-238 atoms}}$ for the sphere ⬭

B surrounding the sphere with a material that absorbs neutrons ⬭

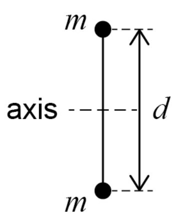
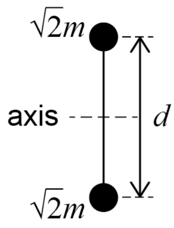
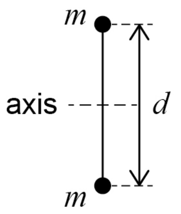
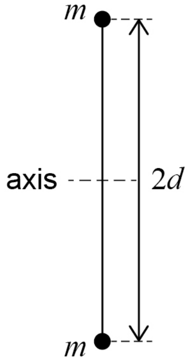
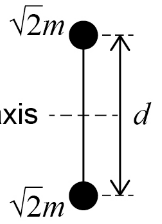
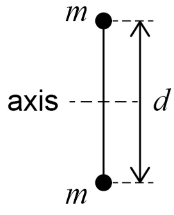
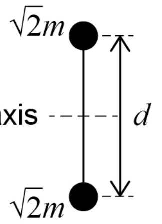
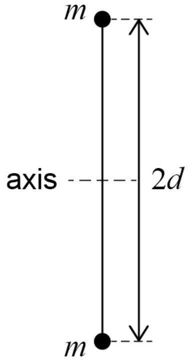
C changing the sphere into a cube of the same volume ⬭

D increasing the temperature of the sphere ⬭

1 6 In the diagrams below, each object is a pair of point masses connected by a light rod. The axis of rotation is shown in each case.

In which row is:
moment of inertia of **Object 2** $= 4 \times$ moment of inertia of **Object 1**?

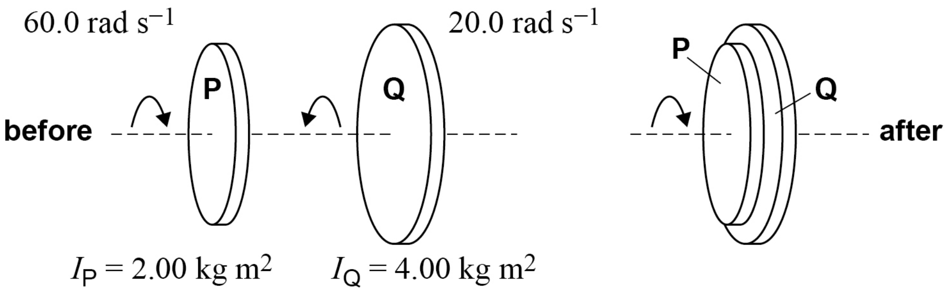
[1 mark]

	Object 1	Object 2
A		
B		
C		
D		

1 7 Disc **P** rotates freely with an angular speed of 60.0 rad s^{-1}.
P has a moment of inertia I_P of 2.00 kg m^2.

Disc **Q** rotates freely in the opposite direction to the rotation of **P**.
Q has an angular speed of 20.0 rad s^{-1}.
Q has a moment of inertia I_Q of 4.00 kg m^2.

P and **Q** have the same axis of rotation.



P and **Q** now combine and rotate together. No external torque is involved.

What is the total rotational kinetic energy of **P** and **Q** after they combine?

[1 mark]

A 130 J ⬭

B 270 J ⬭

C 3300 J ⬭

D 4400 J ⬭

1 8 A student designs an investigation to discover whether a sample of a gas obeys Boyle's law.

Which **two** properties of the gas should be kept constant?

[1 mark]

A pressure and volume of gas ⬭

B temperature and mass of gas ⬭

C pressure and mass of gas ⬭

D temperature and volume of gas ⬭

1 9 Which is **not** equivalent to $\frac{1}{2}\pi r^2 \rho v^3$ for a wind turbine?

[1 mark]

A the maximum power that the turbine can extract from the wind passing through the turbine

B the maximum power of the wind passing through the turbine

C $\frac{p^2}{2m}$ where m is the mass and p is the momentum of the air passing through the turbine in one second

D the kinetic energy of the air arriving at the area swept by the turbine's blades in one second

2 0 A student plans to determine the specific heat capacity c of a metal block by an electrical method.

She plans to heat the block and measure its temperature rise.
The initial temperature of the block is T_1.
The final temperature of the block is T_2.
The constant temperature of the surroundings is T_S.

She wishes to reduce the effect of heat transfer between the block and the surroundings on her value of c.

Which relationship between T_1, T_2 and T_S should she use?

[1 mark]

A $T_S < T_1 < T_2$

B $T_1 < T_2 < T_S$

C $T_1 < T_S < T_2$

D $T_S < T_2 < T_1$

Turn over for the next question

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2 1 Rain falling over an area of 280 km^2 is collected in a lake that is used by a hydroelectric power station.
The mean amount of rain falling in the area is 40 cm per year.
The turbine is 120 m below the water level in the dam. The water level of the lake stays constant.
The power station has an efficiency of 85%.

density of water $= 1.0 \times 10^3 \text{ kg m}^{-3}$

What is the mean output power available from the station?

[1 mark]

A 0.360 MW ⬭

B 3.6 MW ⬭

C 4.2 MW ⬭

D 420 MW ⬭

15

END OF QUESTIONS

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