

Please write clearly in block capitals.

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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	



J A N 2 3 P H 0 4 0 1

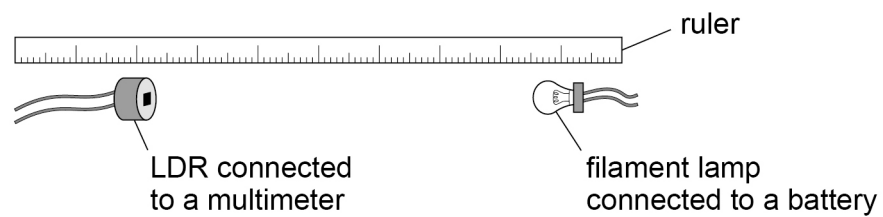
Section A

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

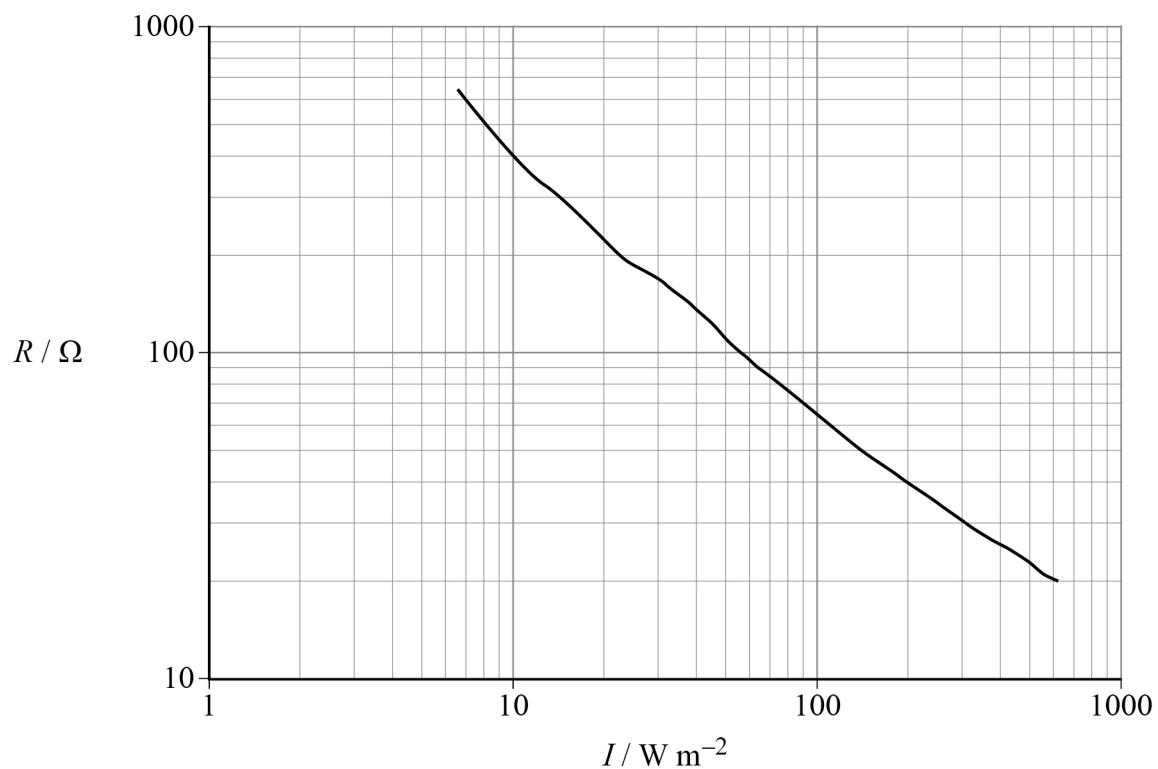


Table 1 shows the results for the investigation. One value for I is shown.

Table 1

d / cm	R / Ω	$I / \text{W m}^{-2}$
5.0	70	90
10.0	200	23
15.0	400	10

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]

inverse-square law: $I = k / d^2$, so $I \times d^2$ should be constant

$$d = 5.0 \text{ cm: } I d^2 = 90 \times 5.0^2 = 2250 \text{ W m}^{-2} \text{ cm}^2$$

$$d = 10.0 \text{ cm: } I d^2 = 23 \times 10.0^2 = 2300 \text{ W m}^{-2} \text{ cm}^2$$

$$d = 15.0 \text{ cm: } I d^2 = 10 \times 15.0^2 = 2250 \text{ W m}^{-2} \text{ cm}^2$$

$I d^2$ is constant to within about 2% for all three sets of data, so the results do support the inverse-square law (but only 3 results, so the support is limited).

Question 1 continues on the next page

Turn over ►



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]

Measure the distance d from the same position on the LDR (its face)

to the same position on the lamp (the filament) each time.

This is because the filament is not a point source, so measuring

consistently means any systematic offset in d can be corrected for.

6



Turn over for the next question

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ANSWER IN THE SPACES PROVIDED**

Turn over ►



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.

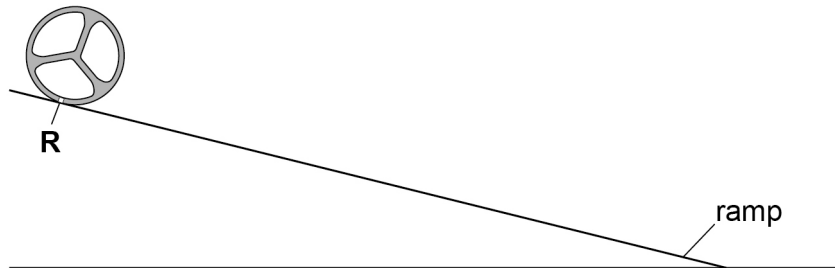
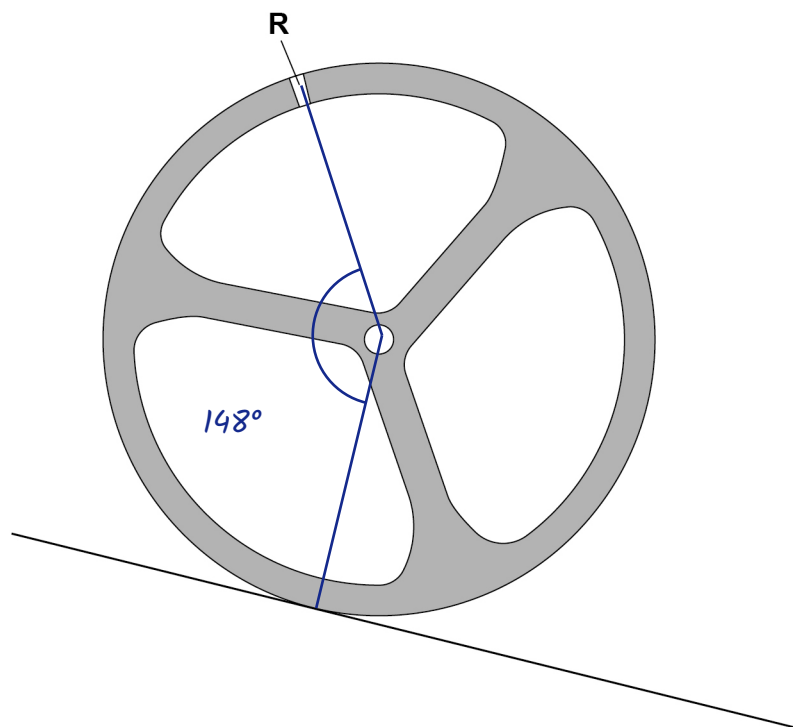
Figure 3wheel **X** at release position

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

Figure 4

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]

angle measured on Figure 4 between R and the contact point = 148°

$$\theta = 148 \times 2\pi / 360 = 148 \times \pi / 180$$

$$\theta = 2.58 \text{ rad} \approx 2.6 \text{ rad}$$

- 0 2 . 2** Determine t_1 .

[1 mark]

$$\theta = \frac{1}{2} \alpha t^2 \quad \text{so} \quad t_1 = \sqrt{2\theta / \alpha}$$

$$t_1 = \sqrt{2 \times 2.6 / 3.6} = 1.20 \text{ s}$$

$$t_1 = \underline{\quad 1.2 \quad} \text{ s}$$

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

[2 marks]

one rotation: $\theta = 2\pi \text{ rad}$

$$\omega^2 = \omega_0^2 + 2\alpha\theta = 0 + 2 \times 3.6 \times 2\pi = 45.2$$

$$\omega = \sqrt{45.2} = 6.72 \text{ rad s}^{-1}$$

$$\text{angular speed} = \underline{\quad 6.7 \quad} \text{ rad s}^{-1}$$

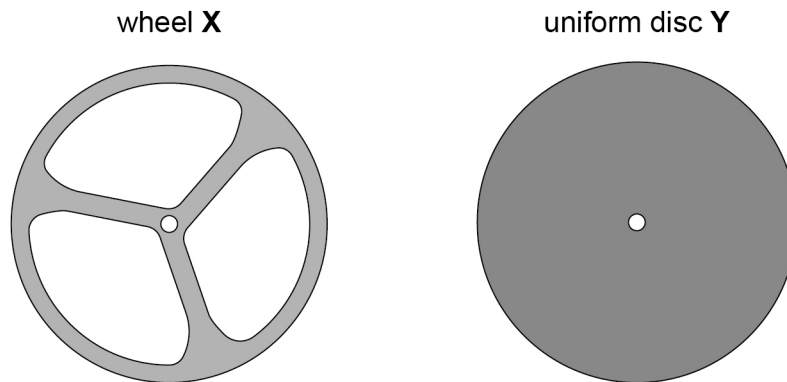
Question 2 continues on the next page

Turn over ►



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]

X and Y have the same mass and radius, but in X most of the mass is at the rim, far from the axis, whereas Y has its mass spread uniformly.

So the moment of inertia of X is greater than that of Y.

The torque (from the frictional force at the contact point, with the same weight and radius) is the same for X and Y.

Since $T = I\alpha$, $\alpha = T / I$, so the angular acceleration of X is smaller than the angular acceleration of Y.



0 3 . 1

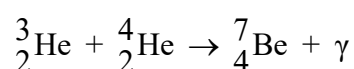
State and explain **one** practical problem in achieving fusion in reactors.**[2 marks]**

Fusion needs a plasma at a very high temperature (about 10^8 K) so nuclei can overcome the electrostatic repulsion.

Containing this plasma is difficult: it must not touch the walls, so strong magnetic fields are needed to confine it.

0 3 . 2

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

**Table 2** shows the mass of each nuclide.**Table 2**

Nuclide	Mass / kg
${}^3_2\text{He}$	5.00641×10^{-27}
${}^4_2\text{He}$	6.64466×10^{-27}
${}^7_4\text{Be}$	1.16482×10^{-26}

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

[3 marks]

$$\text{mass of reactants} = 5.00641 \times 10^{-27} + 6.64466 \times 10^{-27} = 1.165107 \times 10^{-26} \text{ kg}$$

$$\text{mass difference } \Delta m = 1.165107 \times 10^{-26} - 1.16482 \times 10^{-26} = 2.87 \times 10^{-30} \text{ kg}$$

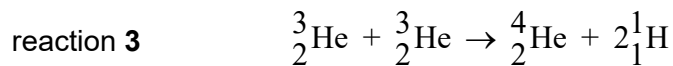
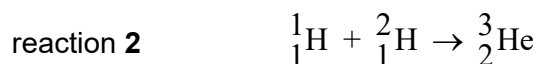
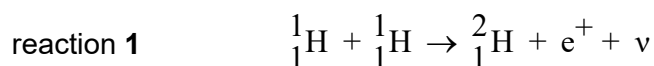
$$E = \Delta mc^2 = 2.87 \times 10^{-30} \times (3.00 \times 10^8)^2 = 2.58 \times 10^{-13} \text{ J}$$

$$\text{energy released} = \underline{2.6 \times 10^{-13}} \text{ J}$$

Question 3 continues on the next page**Turn over ►**

0 3 . 3

The hydrogen cycle in the Sun involves three fusion reactions:



The cycle produces one ${}_2^4\text{He}$ nucleus from four ${}_1^1\text{H}$ nuclei.

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

[2 marks]

Reaction 1 occurs 2 times (twice)

Reaction 2 must occur twice, so 2 ${}_1^2\text{H}$ are needed: reaction 1
must occur twice to make them.

Reaction 2 occurs 2 times (twice)

Reaction 3 needs 2 ${}_2^3\text{He}$ nuclei, and each ${}_2^3\text{He}$ is made in
one reaction 2, so reaction 2 must occur twice.

7



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

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

[2 marks]

When the wind farm produces more electrical energy than is demanded, the surplus is used to pump water up to the upper reservoir of the PSS, storing it as gravitational potential energy.

When the wind farm cannot meet the demand (e.g. wind speed is low or zero, or too high), water is released from the PSS to generate electricity.

Question 4 continues on the next page

Turn over ►



0 4 . 2

The wind farm has several wind turbine generators (WTGs).
One WTG has a rotor diameter of 71 m and an efficiency of 28%.

Calculate the minimum wind speed that could produce a power output of 2.3 MW from the WTG.

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

[3 marks]

$$\text{input power} = \text{output} / \text{efficiency} = 2.3 \times 10^6 / 0.28 = 8.21 \times 10^6 \text{ W}$$

$$P = \frac{1}{2} \rho A v^3 = \frac{1}{2} \pi r^2 \rho v^3, \quad r = 71 / 2 = 35.5 \text{ m}$$

$$v^3 = 2P / (\pi r^2 \rho) = 2 \times 8.21 \times 10^6 / (\pi \times 35.5^2 \times 1.3) = 3190$$

$$v = 14.7 \text{ m s}^{-1}$$

minimum wind speed = 15 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 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]

$$\text{loss of } E_p = \text{gain of } E_k: mgh = \frac{1}{2} mv^2$$

$$v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 650}$$

$$v = 113 \text{ m s}^{-1}$$

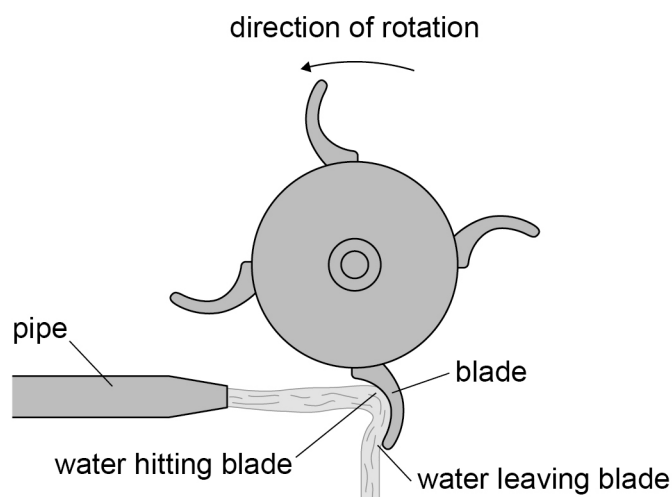
maximum speed of water = 110 m s^{-1}



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]

The water's velocity changes (direction and speed), so the momentum of the water decreases/changes as it hits the blade.

A rate of change of momentum requires a force ($F = \Delta p / \Delta t$), so the blade exerts a force on the water.

By Newton's third law, the water exerts an equal and opposite force on the blade.

This force acts on the blade at a perpendicular distance r from the axle, so it produces a torque $T = Fr$ that turns the turbine.

11

Turn over ►



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
${}_{92}^{238}\text{U}$	238.00037
${}_{92}^{237}\text{U}$	236.99831

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

[2 marks]

$$\text{mass of U-237} + \text{neutron} = 236.99831 + 1.00867 = 238.00698 \text{ u}$$

this is greater than the mass of U-238 (238.00037 u)

(total mass would increase by 0.00661 u)

So the decay cannot happen (it would need energy input).

0 5

. 2

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

[3 marks]

A (slow) neutron is absorbed by a uranium-235 nucleus, forming an unstable uranium-236 nucleus.

The U-236 nucleus splits (fission) into two smaller daughter nuclei, releasing energy and 2 or 3 fast neutrons.

These neutrons go on to be absorbed by other U-235 nuclei and induce further fissions, so the process is self-sustaining: a chain reaction.



0 5 . 3

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

[1 mark]

Graphite (carbon) or water.

0 5 . 4

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

State why they are called thermal neutrons.

[1 mark]

They are in thermal equilibrium with the moderator; they have the same average kinetic energy as the moderator atoms.

0 5 . 5

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

[2 marks]

For a chain reaction, at least one neutron from each fission must go on to cause another fission.

Fast neutrons are much less likely to be absorbed by U-235 nuclei (to induce fission) than slow ones, so they must be slowed down.

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]

$$E = E_0 \times 0.84^n: \quad 2.5 \times 10^{-2} = 2.0 \times 10^6 \times 0.84^n$$

$$0.84^n = 1.25 \times 10^{-8}$$

$$n = \ln(1.25 \times 10^{-8}) / \ln 0.84 = 104.4, \text{ so } 105 \text{ collisions}$$

average number of collisions = 105

Question 5 continues on the next page

Turn over ►



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 / kJ kg ⁻¹	110
average specific heat capacity of solid / kJ kg ⁻¹ K ⁻¹	1.2
average specific heat capacity of liquid / 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]

$$\text{heat solid } 20^\circ\text{C to } 98^\circ\text{C: } Q = mc\Delta\theta = 3.3 \times 10^5 \times 1200 \times 78 = 3.09 \times 10^{10} \text{ J}$$

$$\text{melt at } 98^\circ\text{C: } Q = mL = 3.3 \times 10^5 \times 1.10 \times 10^5 = 3.63 \times 10^{10} \text{ J}$$

$$\text{heat liquid } 98^\circ\text{C to } 560^\circ\text{C: } Q = 3.3 \times 10^5 \times 1300 \times 462 = 1.98 \times 10^{11} \text{ J}$$

$$\text{total} = 3.09 \times 10^{10} + 3.63 \times 10^{10} + 1.98 \times 10^{11}$$

$$\text{total} = 2.65 \times 10^{11} \text{ J}$$

energy = 2.65×10^{11} 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]

The gamma radiation is very penetrating, so the waste needs thick shielding (lead, steel or very thick concrete); it also releases thermal energy so it must be cooled (in water) at first.

The half-life is 30 years, so it stays dangerously radioactive for a long time and must be stored securely for at least 5 half-lives (about 150 years).

16

Turn over for the next question

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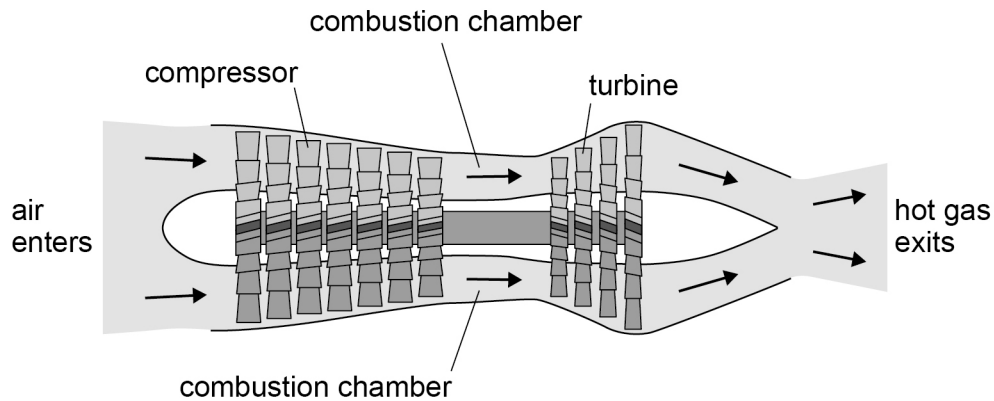
0 6

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]

For an ideal gas $pV = nRT$, and density $d = m / V$, so $V \propto 1/d$ for the fixed mass of air. This gives $(d_2T_2) / (d_1T_1) = p_2 / p_1 = 40$.

The density increases ($d_2 > d_1$, so $V_2 < V_1$), therefore $T_2 / T_1 = 40 \times d_1 / d_2 < 40$.



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]

First law: $\Delta U = Q + W$. Work is done on the air by the compressor (W positive).

The compression is rapid, so there is little time for heat transfer: $Q \approx 0$ (adiabatic).

So $\Delta U = W > 0$: the internal energy of the air increases, so its temperature increases.

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]

$$p_1 / p_2 = 1/40 = (300 / T_2)^{3.5}$$

$$300 / T_2 = (1/40)^{1/3.5} = 0.349$$

$$T_2 = 300 \times 40^{1/3.5} = 861 \text{ K}$$

$$T_2 = \underline{\quad 860 \quad} \text{ K}$$

Question 6 continues on the next page

Turn over ►

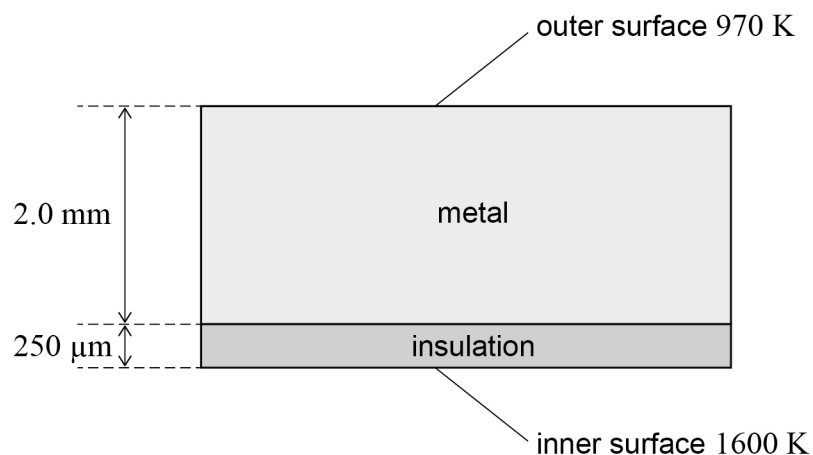


In the combustion chamber, fuel is added to the compressed air. The air–fuel mixture burns to increase the gas temperature even more.

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 K. The outer surface is at a temperature of 970 K. The metal has a thickness of 2.0 mm and the insulation has a thickness of 250 μm .

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 = $27 \text{ W m}^{-1} \text{ K}^{-1}$

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

[3 marks]

rate of energy transfer $Q/t = kA\Delta\theta / l$ is the same for both layers (same A)

$$0.74 \times (1600 - \theta) / 250 \times 10^{-6} = 27 \times (\theta - 970) / 2.0 \times 10^{-3}$$

$$2960 (1600 - \theta) = 13500 (\theta - 970)$$

$$16460 \theta = 1.783 \times 10^7 \quad \theta = 1083 \text{ K}$$

temperature = 1080 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]

$$\omega = 2\pi f = 2\pi \times 1.0 \times 10^4 / 60 = 1050 \text{ rad s}^{-1}$$

$$P = T\omega \quad \text{so} \quad T = P / \omega$$

$$T = 19 \times 10^6 / 1050 = 1.81 \times 10^4 \text{ N m}$$

torque = 1.8×10^4 N m

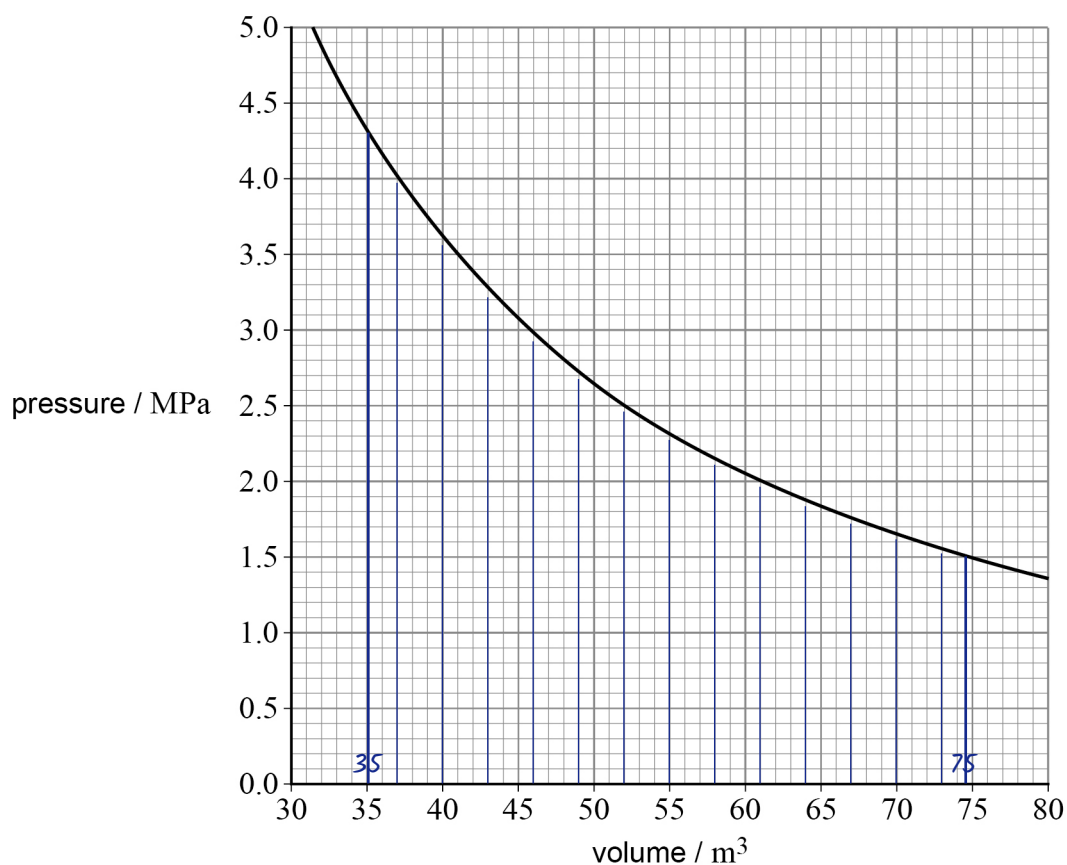
Question 6 continues on the next page

Turn over ►



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]

$$W = \text{area under curve from } 35 \text{ m}^3 (4.3 \text{ MPa}) \text{ to } 75 \text{ m}^3 (1.5 \text{ MPa})$$

$$\text{area} \approx 39 \text{ big squares; } 1 \text{ big square} = 5 \text{ m}^3 \times 0.5 \times 10^6 \text{ Pa} = 2.5 \times 10^6 \text{ J}$$

$$W = 39 \times 2.5 \times 10^6 = 9.8 \times 10^7 \text{ J}$$

work done by the gas = 9.8×10^7 J

17

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



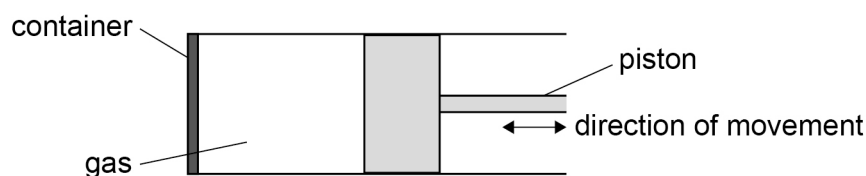
If you want to change your answer you must cross out your original answer as shown.

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 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]

	$\Delta U / \text{J}$	Q / J	
A	-45	-60	☒
B	-15	+60	☐
C	+30	-45	☐
D	+60	+15	☐

Turn over ►



0 8

The table shows information about four materials.

Material	Area / m ²	Thickness / mm	<i>U</i> -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**

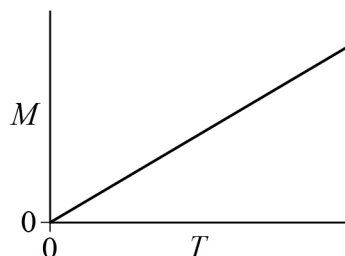
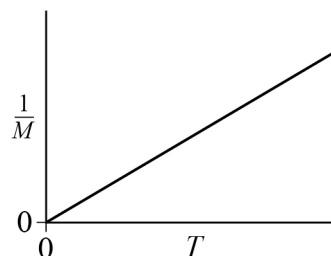
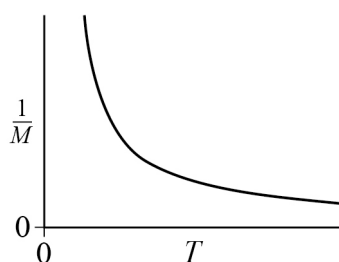
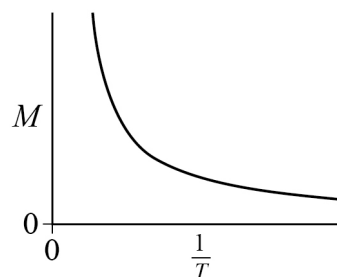
Which of these arises from a theoretical derivation rather than from an experimental observation?

[1 mark]**A** Boyle's law ☐**B** Charles's law ☐**C** Brownian motion ☐**D** the ideal gas equation ☒

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****A****B****C****D**

Turn over for the next question

Turn over ►



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

How many molecules are in 820 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, $c_{\text{rms}} = v$.

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 $\frac{v}{4}$ ☐

B $\frac{v}{2}$ ☐

C $\frac{v}{\sqrt{2}}$ ☒

D $\sqrt{2}v$ ☐



1 3

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

What is the specific heat capacity of the metal?

[1 mark]

A $160\text{ J kg}^{-1}\text{ K}^{-1}$ ☐

B $1300\text{ J kg}^{-1}\text{ K}^{-1}$ ☐

C $1500\text{ J kg}^{-1}\text{ K}^{-1}$ ☒

D $1800\text{ J kg}^{-1}\text{ K}^{-1}$ ☐

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

Turn over ►



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 $\frac{Ze}{\pi\epsilon_0 E}$ ☐

B $\frac{Ze}{2\pi\epsilon_0 E}$ ☐

C $\frac{Ze^2}{2\pi\epsilon_0 E}$ ☒

D $\frac{Ze^2}{4\pi\epsilon_0 E}$ ☐

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. ☒

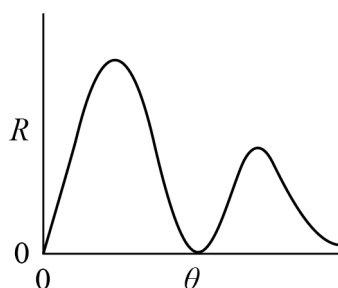
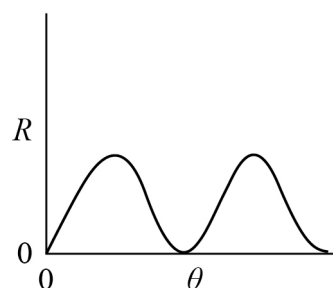
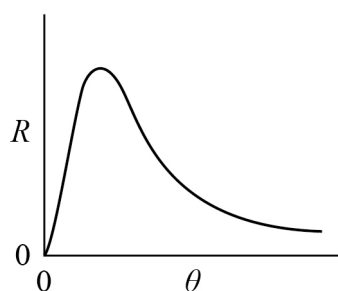
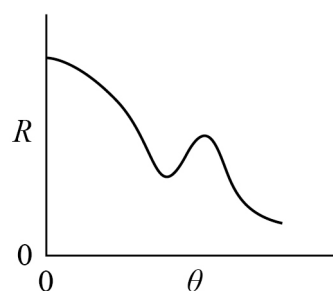
C A proton has a smaller mass than a neutron. ☐

D There is electrostatic repulsion between protons. ☐



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****A****B****C****D**

Turn over for the next question

Turn over ►



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

What is the radius of a $^{130}_{56}\text{Ba}$ 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_1H . ☐

B ^4_2He . ☐

C $^{62}_{28}\text{Ni}$. ☒

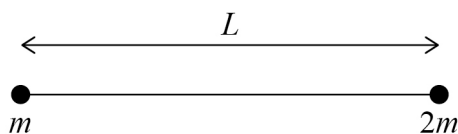
D $^{238}_{92}\text{U}$. ☐



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 $\frac{2mL^2}{3}$



B $\frac{3mL^2}{4}$



C mL^2



D $\frac{4mL^2}{3}$



Turn over for the next question

Turn over ►



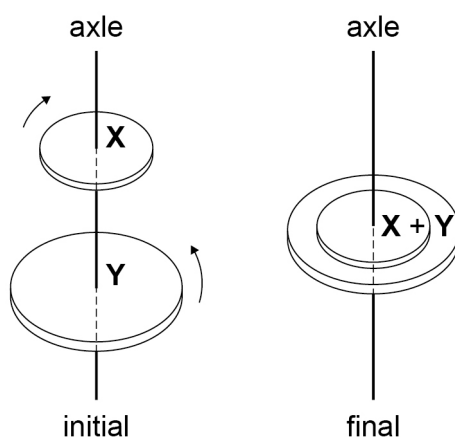
2 1

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

The moment of inertia of **Y** is 1.6 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



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