

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

Wednesday 20 January 2021

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	
8–22	
TOTAL	



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outside the
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ANSWER IN THE SPACES PROVIDED**



Section AAnswer **all** questions in this section.**0 1**The equation $pV = \frac{1}{3}Nm(c_{\text{rms}})^2$ applies to an ideal gas.**0 1 . 1**

The derivation of the equation depends on assumptions made about the gas.

State **two** of those assumptions.**[2 marks]**

1 _____

2 _____

0 1 . 2

A sample of an ideal gas has a temperature of 12.5 °C.

The mass of each particle of this gas is 6.6×10^{-26} kg.Calculate c_{rms} (root mean square speed) for the particles in the gas.
Give your answer to an appropriate number of significant figures.**[4 marks]** $c_{\text{rms}} =$ _____ m s^{-1} **6****Turn over ►**

0	2
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The mass of a nucleus of californium-252 (${}_{98}^{252}\text{Cf}$) is 252.03 u.

0	2	.	1
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Calculate, in kg, the mass defect of a nucleus of californium-252.

[3 marks]

mass defect = _____ kg



0 2 . 2 Spontaneous fission of a californium-252 nucleus produces a xenon-140 (${}_{54}^{140}\text{Xe}$) nucleus, a ruthenium-108 (${}_{44}^{108}\text{Ru}$) nucleus and four neutrons.

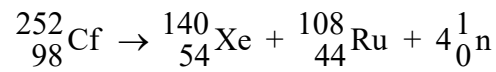


Table 1 gives the mass of each nuclide.

Table 1

Nuclide	Mass / u
${}_{98}^{252}\text{Cf}$	252.03
${}_{54}^{140}\text{Xe}$	139.89
${}_{44}^{108}\text{Ru}$	107.88

Calculate, in MeV, the amount of energy released in this fission.

[3 marks]

energy released = _____ MeV

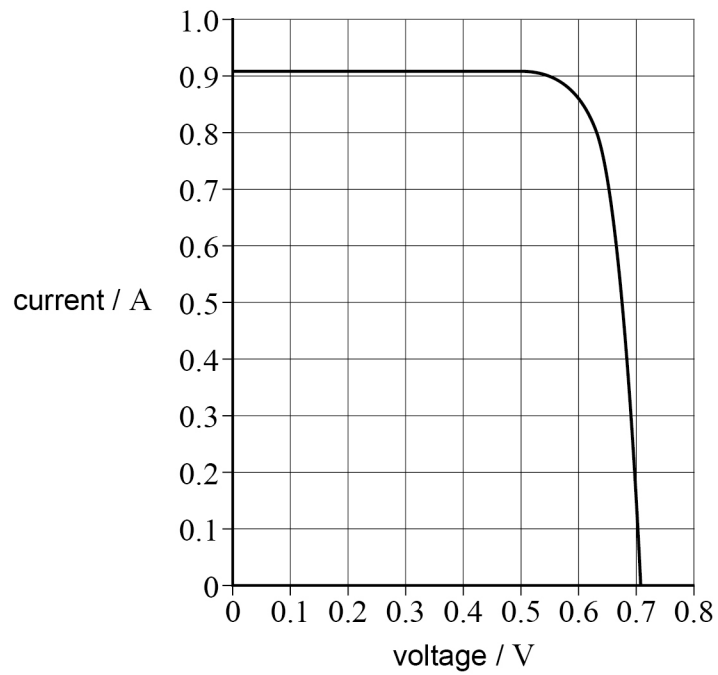
6

Turn over ►



0 3 . 1 Figure 1 shows the current–voltage characteristic for a solar cell.

Figure 1



Estimate the maximum power available from the solar cell.

[2 marks]

maximum power = _____ W



0	3	.	2
---	---	---	---

A different type of solar cell has an emf of 0.72 V and an internal resistance of $2.2\ \Omega$ when in use.

An array of solar cells of this type has an emf of 3.6 V and an internal resistance of $5.5\ \Omega$.

Deduce the number and arrangement of solar cells used to make this array.

[4 marks]

6

Turn over for the next question

Turn over ►



0 4

A gas has a density of 12 kg m^{-3} when its temperature is 860 K and its pressure is $2.1 \times 10^7 \text{ Pa}$.

0 4 . 1

Show that 60 kg of the gas contains approximately 9×10^{27} particles.

[3 marks]**0 4 . 2**

Calculate the molar mass of the gas.

State an appropriate unit for your answer.

[3 marks]

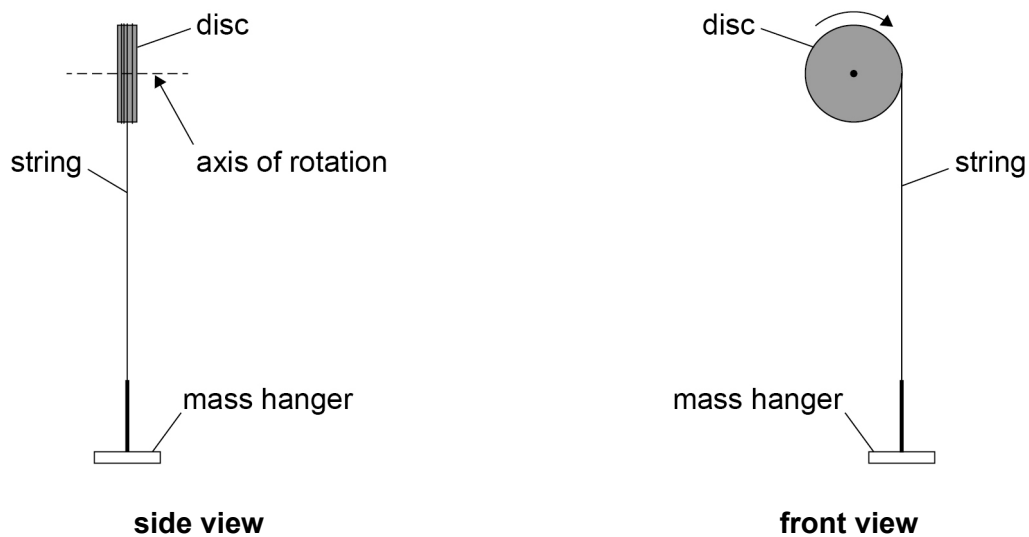
molar mass = _____

unit = _____



0 5

Figure 2 shows the equipment a student uses to find the moment of inertia of a disc. The student wraps a string of negligible mass several times around the disc. The student attaches a mass hanger to the free end of the string. The hanger is released from rest and falls. The disc rotates with a constant angular acceleration.

Figure 2

0 5 . 1

The disc makes exactly three rotations in a time of 2.2 s.

Show that the angular acceleration α of the disc is approximately 8 rad s^{-2} .

[3 marks]

The tension in the string exerts a torque on the disc.
The hanger has a mass m . It falls with a linear acceleration A .

0 5 . 2 Show that, in the absence of frictional forces,

$$\text{torque on the disc} = m(g - A)r$$

where r is the radius of the disc.

[2 marks]

0 5 . 3 The linear acceleration A is related to the angular acceleration α by

$$A = \alpha r$$

Determine, using the experimental data, the moment of inertia of the disc.

$$r = 2.0 \text{ cm}$$

$$m = 0.10 \text{ kg}$$

[3 marks]

moment of inertia = _____ kg m²

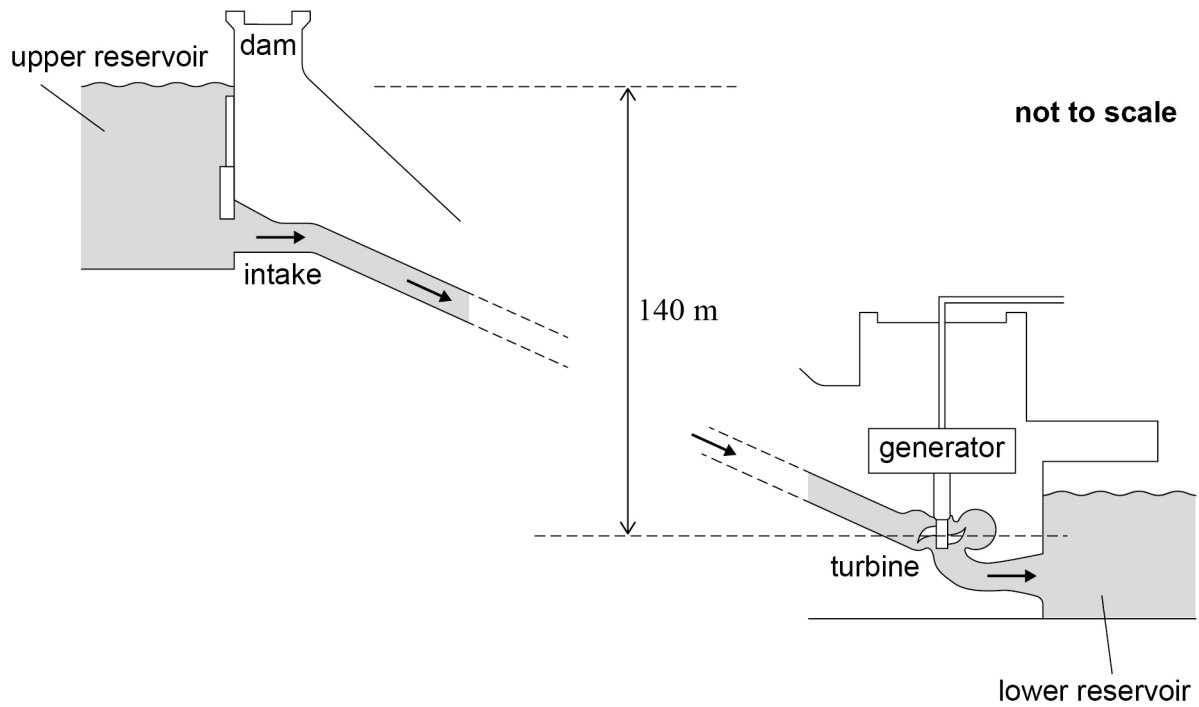
Question 5 continues on the next page

Turn over ►



0 6

Figure 3 shows a pumped storage system (PSS). Electricity is generated when water flows through a pipe from the upper reservoir to drive a turbine and a generator.

Figure 3

Question 6 continues on the next page

Turn over ►



The water level in the upper reservoir is initially 140 m above the turbine.
The PSS generates electrical energy for an operating time T .
During this operating time:

- the water level decreases by 20 m
- 30 TJ of gravitational potential energy is transferred
- there is a constant electrical power output of 1.8 GW.

0 6 . 1 Calculate the mass of water that leaves the upper reservoir when the water level decreases by 20 m.

[2 marks]

mass = _____ kg

0 6 . 2 The efficiency of the transfer from gravitational potential energy to electrical energy is 82%.

Calculate T in hours.

[3 marks]

$T =$ _____ hours



0 6 . 3

Outline why, during one complete cycle of operation, the efficiency of the PSS is less than 82%.

[2 marks]

0 6 . 4

Describe the benefits of using a PSS in an electrical power network.

[3 marks]

10

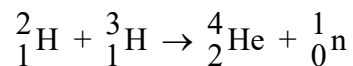
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07

Some proposed fusion reactors will use a fuel of deuterium (${}^2_1\text{H}$) and tritium (${}^3_1\text{H}$).

The fusion reaction produces helium-4 (${}^4_2\text{He}$) and a neutron.



07.1

Explain why this reaction will occur only when the fuel is at a very high temperature.

[2 marks]

07.2

The temperature of the fuel in one reactor is 1.2 GK.

Calculate the average kinetic energy of a deuterium nucleus in the fuel.
Assume that the fuel behaves as an ideal gas.

[1 mark]

average kinetic energy = _____ J

07.3

State how the average kinetic energy of a **tritium** nucleus in the fuel compares to your answer to Question 07.2.

[1 mark]



0 7 . 5 **Table 2** shows the binding energy per nucleon for two nuclides involved in the fusion reaction.

The energy released in this fusion reaction is 17.589 MeV.

Table 2

Nuclide	Binding energy per nucleon / MeV
${}^2_1\text{H}$	1.1123
${}^4_2\text{He}$	7.0739

Calculate, in J, the binding energy of the tritium (${}^3_1\text{H}$) nuclide.

[3 marks]

binding energy = _____ J



0 7 . 6

The fusion of a deuterium nucleus and a tritium nucleus initially produces a helium-5 nucleus. This nucleus quickly decays into an unexcited helium-4 nucleus and a neutron.

Show that the kinetic energy of the neutron is four times greater than the kinetic energy of the helium-4 nucleus.

Assume that the helium-5 nucleus is stationary before it decays.

[3 marks]

0 7 . 7

Designers of fusion reactors have to consider the risks associated with neutrons which have high kinetic energies.

Suggest **one** of these risks.

[1 mark]

14

END OF SECTION A**Turn over ►**

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 8 At absolute zero, an ideal gas will

[1 mark]

- A** condense to a liquid.
- B** exert zero pressure.
- C** have maximum potential energy.
- D** have zero electrical resistance.



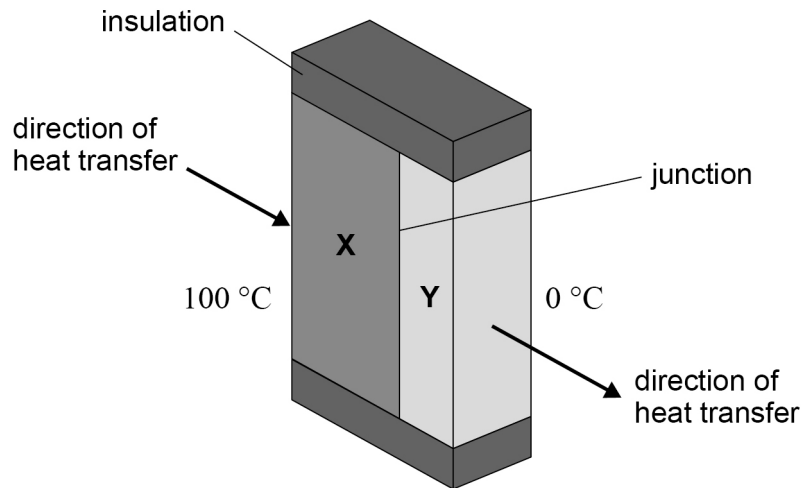
0 9

Two materials **X** and **Y** of equal cross-sectional area are joined together.

The left-hand surface of **X** is at a temperature of $100\text{ }^{\circ}\text{C}$. The right-hand surface of **Y** is at a temperature of $0\text{ }^{\circ}\text{C}$.

The rates of heat transfer through **X** and **Y** are the same.

Insulation prevents heat transfers from the top, bottom and sides of each material so that heat transfer occurs only in the direction shown.



The thermal conductivity of **X** is a quarter of the thermal conductivity of **Y**.

The thickness of **X** is twice the thickness of **Y**.

What is the temperature at the junction between **X** and **Y**?

[1 mark]

- A** $11\text{ }^{\circ}\text{C}$
- B** $25\text{ }^{\circ}\text{C}$
- C** $75\text{ }^{\circ}\text{C}$
- D** $89\text{ }^{\circ}\text{C}$

Turn over ►



1 0

A student plans an experiment to test Charles's law for a gas.

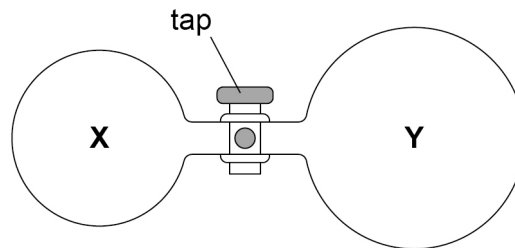
Which quantities of the gas must be measured and which must be kept constant?

[1 mark]

	Quantities to be measured	Quantities to be kept constant	
A	pressure and temperature	volume and mass	<input type="radio"/>
B	pressure and temperature	volume	<input type="radio"/>
C	volume and temperature	pressure and mass	<input type="radio"/>
D	volume and temperature	pressure	<input type="radio"/>

1 1

Bulb **X** and bulb **Y** are connected by a tube with a tap.



X has a volume of 2.0 m^3 and contains an ideal gas at an initial pressure of $4.0 \times 10^5 \text{ Pa}$ and an initial temperature of $30 \text{ }^\circ\text{C}$.

Y has a volume of 4.0 m^3 and initially contains no gas.

The tap is opened so that the gas in **X** and the gas in **Y** reach equilibrium.

How many gas particles are in **Y**?

[1 mark]

A 6.4×10^{25}

B 9.6×10^{25}

C 1.3×10^{26}

D 1.9×10^{26}

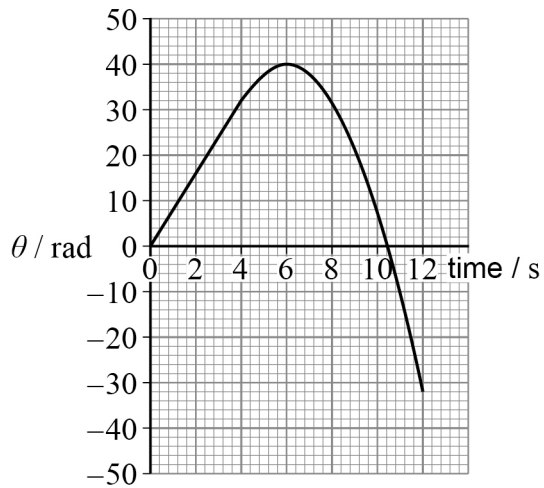
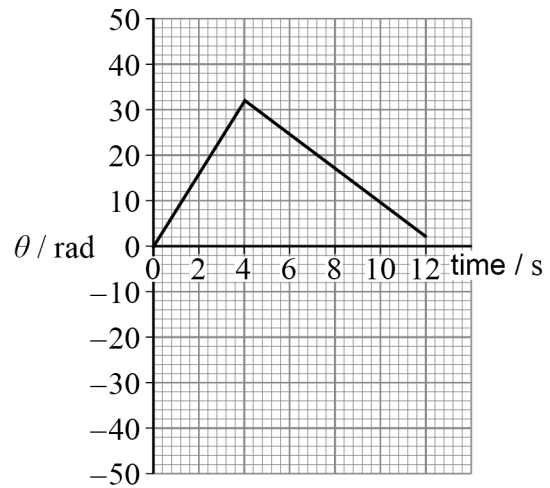
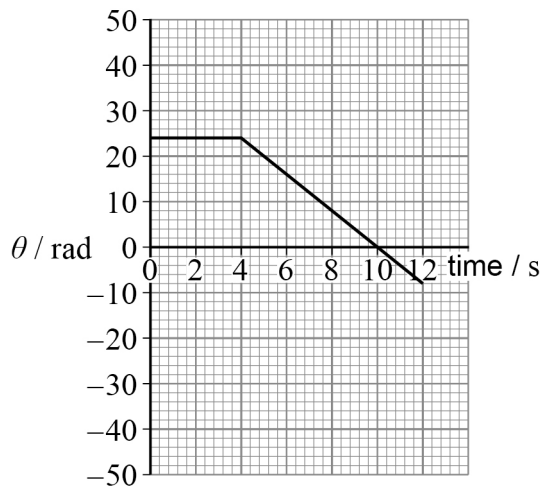
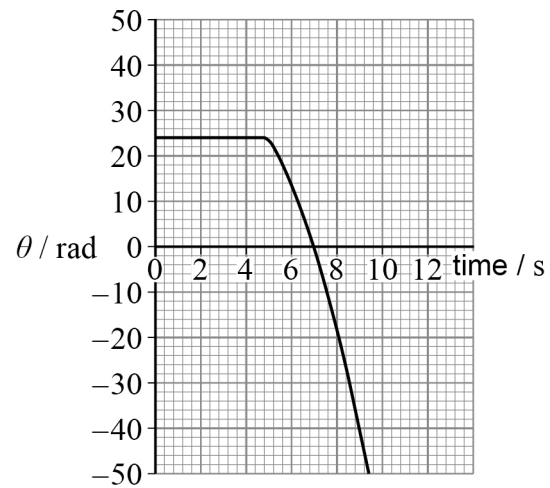


1 2

A disc rotates at a constant angular speed of 8.0 rad s^{-1} for a time of 4.0 s .

After the 4.0 s , a torque is applied to the disc. The disc has a constant angular acceleration of -4.0 rad s^{-2} .

Which graph shows the variation of angular displacement θ with time?

[1 mark]**A****B****C****D****A** **B** **C** **D** **Turn over ►**

1 3

A graph shows the relationship between nuclear radius R and atomic number A .

Which pair of axes will produce a graph with a straight line of gradient 3?

[1 mark]

	x-axis	y-axis	
A	$\ln A$	$\ln R$	<input type="radio"/>
B	$\ln R$	$\frac{\ln A}{3}$	<input type="radio"/>
C	$\ln\left(\frac{A}{3}\right)$	$\ln R$	<input type="radio"/>
D	$\ln R$	$\ln A$	<input type="radio"/>

1 4

The purpose of the moderator in a nuclear reactor is to

[1 mark]

- A** absorb all the heat produced.
- B** decrease the neutron speeds.
- C** absorb excess neutrons.
- D** prevent the reactor becoming critical.

1 5

Which reaction is part of the hydrogen cycle in the Sun?

[1 mark]

- A** ${}^1_1\text{H} + {}^1_1\text{H} \rightarrow {}^2_1\text{H} + \text{e}^- + \bar{\nu}$
- B** ${}^1_1\text{H} + {}^1_1\text{H} \rightarrow {}^2_1\text{H} + \text{e}^+ + \nu$
- C** ${}^2_1\text{H} + {}^3_2\text{He} \rightarrow {}^4_2\text{He} + {}^1_1\text{H}$
- D** ${}^2_1\text{H} + {}^2_1\text{H} \rightarrow {}^4_2\text{He} + \gamma$



1 6 What is angular impulse in fundamental (base) units?

[1 mark]

A kg m s^{-1}

B kg m s^{-2}

C $\text{kg m}^2 \text{s}^{-1}$

D $\text{kg m}^2 \text{s}^{-2}$

1 7 A wheel completes 4.5 revolutions as its angular speed changes from 3.6 rad s^{-1} to 8.2 rad s^{-1} . The angular acceleration is constant.

What is the angular acceleration of the wheel?

[1 mark]

A 0.081 rad s^{-2}

B 0.96 rad s^{-2}

C 1.9 rad s^{-2}

D 6.0 rad s^{-2}

1 8 A flywheel with moment of inertia I rotates at an initial angular speed ω .

A constant torque T on the flywheel increases the angular speed to 2ω in a time t . The angular displacement of the flywheel increases by θ .

What is the work done on the flywheel?

[1 mark]

A $\frac{3T\omega t}{2}$

B $\frac{5I\omega^2}{2}$


C $\omega T t$

D $\frac{2I\omega\theta}{t}$

Turn over ►



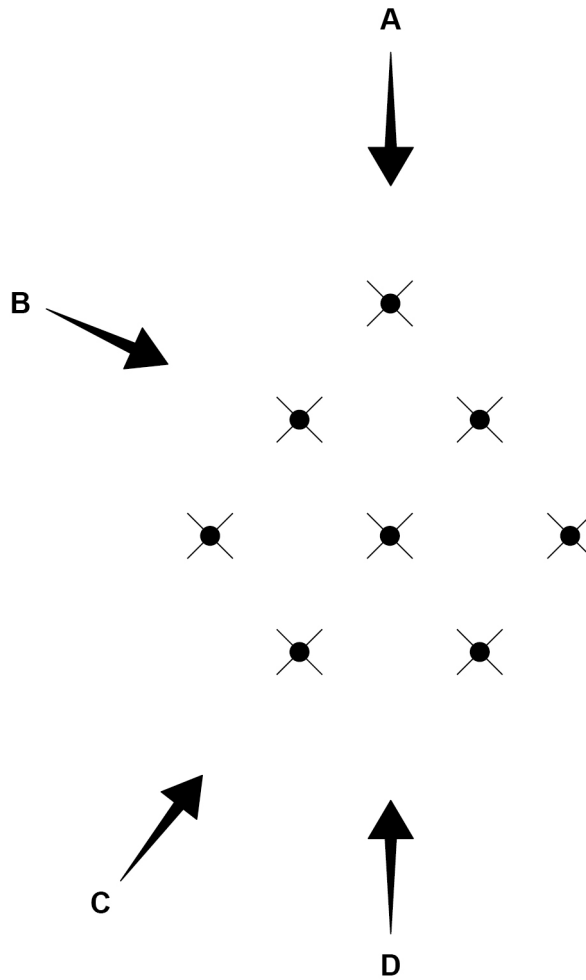
1 9

The diagram shows a plan view of an arrangement of wind turbines represented by .

The arrows represent four possible wind directions across the wind farm.

Which direction allows the maximum power to be transferred from the wind at any given wind speed?

[1 mark]



- A
- B
- C
- D



2 0

The speeds of five gas atoms are: 300 m s^{-1} , 200 m s^{-1} , 50 m s^{-1} , 150 m s^{-1} and 300 m s^{-1} .

What is c_{rms} for the atoms?

[1 mark]

A 99 m s^{-1}

B 185 m s^{-1}

C 200 m s^{-1}

D 221 m s^{-1}

2 1

The mean distance of Venus from the Sun is approximately twice the mean distance of Mercury from the Sun.

The radius of Venus is approximately 2.5 times the radius of Mercury.

What is the best estimate of $\frac{\text{total solar power incident on Venus}}{\text{total solar power incident on Mercury}}$?

[1 mark]

A $\frac{5}{8}$

B $\frac{5}{4}$

C $\frac{25}{16}$

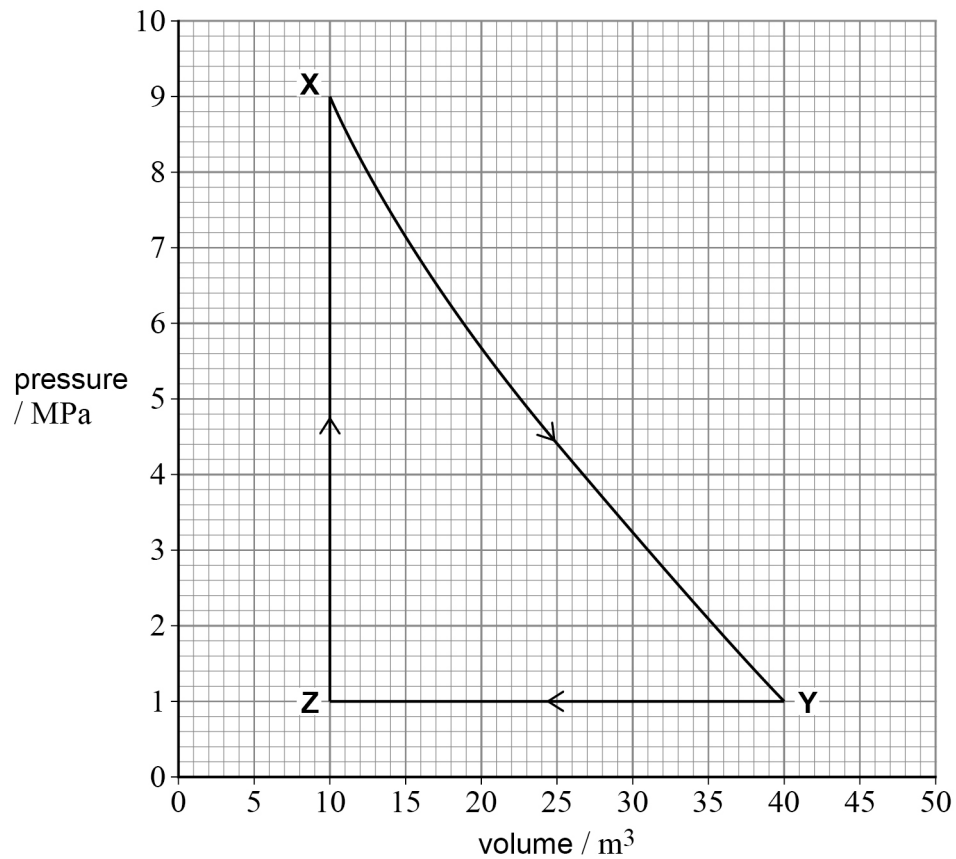
D $\frac{25}{8}$

Turn over for the next question

Turn over ►

2 2

An ideal gas goes through a cycle of changes **XYZX** as shown in the pressure–volume graph.



What is the net work done during the cycle **XYZX**?

[1 mark]

- A** $1.2 \times 10^8 \text{ J}$ on the gas
- B** $1.2 \times 10^8 \text{ J}$ by the gas
- C** $1.5 \times 10^8 \text{ J}$ on the gas
- D** $1.5 \times 10^8 \text{ J}$ by the gas

15

END OF QUESTIONS



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ANSWER IN THE SPACES PROVIDED**



