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

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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There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

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Section A

Answer **all** questions in this section.

0 1 The equation $pV = \frac{1}{3}Nm(c_{rms})^2$ 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 ____

____

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2 ____

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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_{rms} = ______________________ $m\ s^{-1}$

6

Turn over ►

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

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

[3 marks]

mass defect = ____________________ kg

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

$$ {}^{252}_{98}\mathrm{Cf} \rightarrow {}^{140}_{54}\mathrm{Xe} + {}^{108}_{44}\mathrm{Ru} + 4{}^{1}_{0}\mathrm{n} $$

Table 1 gives the mass of each nuclide.

Table 1

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

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

[3 marks]

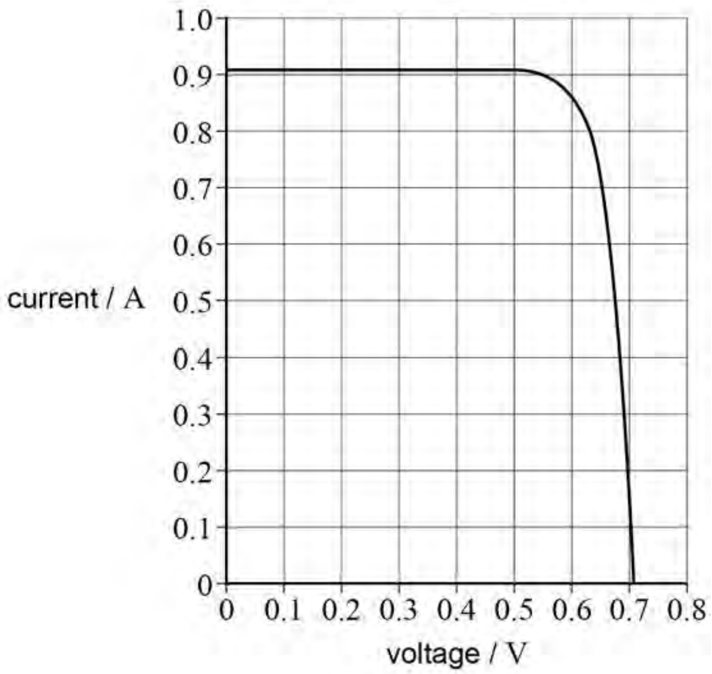
energy released = ____________________ MeV

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

Do not write outside the box

0 3 . 2 A different type of solar cell has an emf of $0.72\ \mathrm{V}$ and an internal resistance of $2.2\ \Omega$ when in use.

An array of solar cells of this type has an emf of $3.6\ \mathrm{V}$ 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

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0 4 A gas has a density of $12\ \text{kg m}^{-3}$ when its temperature is $860\ \text{K}$ and its pressure is $2.1 \times 10^{7}\ \text{Pa}$.

0 4 . 1 Show that $60\ \text{kg}$ 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 = ____________________

Do not write outside the box

0 4 . 3 The gas is heated at a rate of 75 MW as it flows through a pipe.
A mass of 60 kg of gas flows through the pipe each second.
The gas enters the pipe at a temperature of 860 K.

Calculate the temperature of the gas as it leaves the pipe.

specific heat capacity of the gas = 4.9×10^{3} J kg^{-1} K^{-1}

[3 marks]

temperature of the gas = ______________________ K

0 4 . 4 The hot gas now enters a cool turbine, forcing the turbine to rotate.

Discuss how the first law of thermodynamics applies to the gas as it forces the turbine to rotate.

[3 marks]

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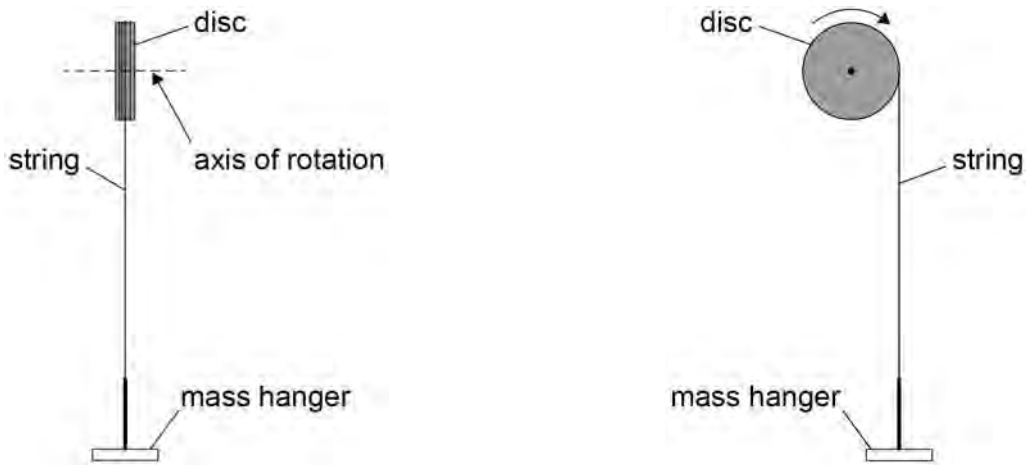
12

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



side view **front view**

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 $8\ \text{rad s}^{-2}$.

[3 marks]

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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,

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.

$r = 2.0$ cm
$m = 0.10$ kg

[3 marks]

moment of inertia = ____________________ kg m^2

Question 5 continues on the next page

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0 5 . 4 In practice, frictional forces act on the disc as it rotates.

These frictional forces affect the accuracy of the experimental value for the moment of inertia of the disc.

Discuss why.

[3 marks]

11

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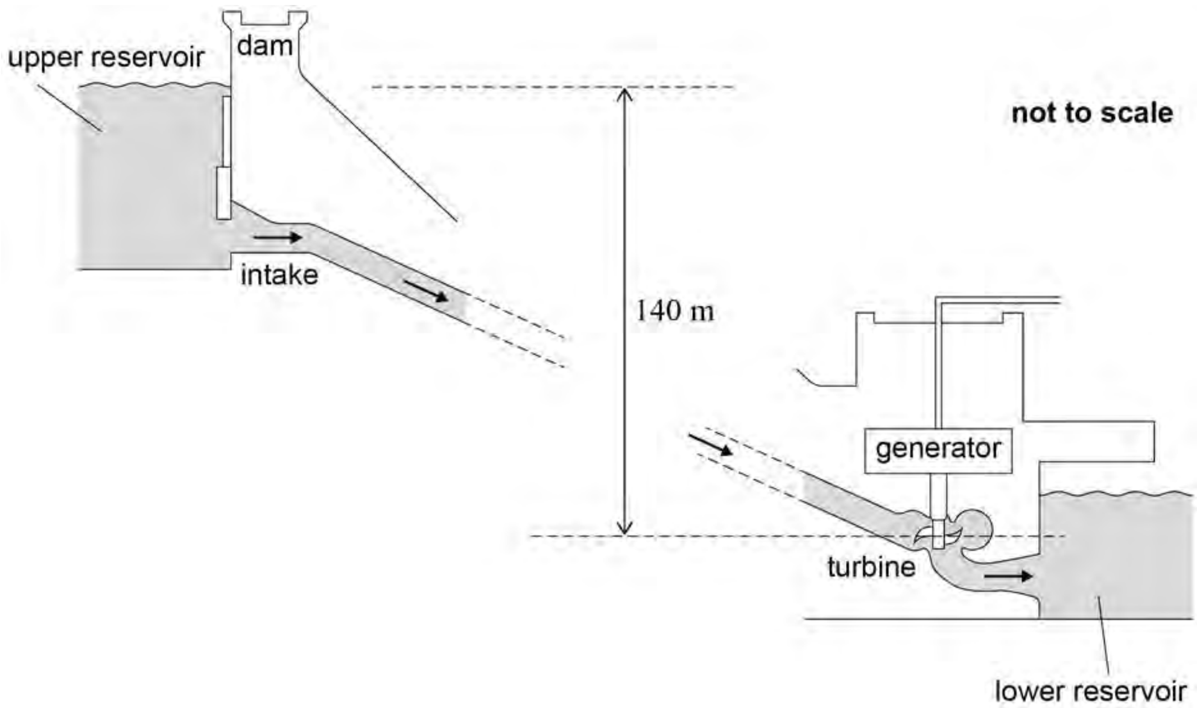
0 6 **Figure 3** shows a pumped storage system (PSS). Electricity is generated when water flows through a pipe from the upper reservoir to drive a turbine and a generator.

Figure 3



Question 6 continues on the next page

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

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

0 6 . 1 Calculate the mass of water that leaves the upper reservoir when the water level decreases by $20\ \mathrm{m}$.

[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

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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

Turn over ►

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0 7 Some proposed fusion reactors will use a fuel of deuterium $\left({}^{2}_{1}\mathrm{H}\right)$ and tritium $\left({}^{3}_{1}\mathrm{H}\right)$.

The fusion reaction produces helium-4 $\left({}^{4}_{2}\mathrm{He}\right)$ and a neutron.

$${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$

0 7 . 1 Explain why this reaction will occur only when the fuel is at a very high temperature.

[2 marks]

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0 7 . 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

0 7 . 3 State how the average kinetic energy of a **tritium** nucleus in the fuel compares to your answer to Question **07.2**.

[1 mark]

____

____

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0 7 . 4 An estimate of the closest approach between a deuterium nucleus and a tritium nucleus can be made using the answers to Question **07.2** and Question **07.3**.

Explain how this estimate can be made.

[3 marks]

Question 7 continues on the next page

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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**
${}^{2}_{1}\mathrm{H}$	1.1123
${}^{4}_{2}\mathrm{He}$	7.0739

Calculate, in J, the binding energy of the tritium $\left({}^{3}_{1}\mathrm{H}\right)$ nuclide.

[3 marks]

binding energy = ____________________ J

Do not write outside the box

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

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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 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.

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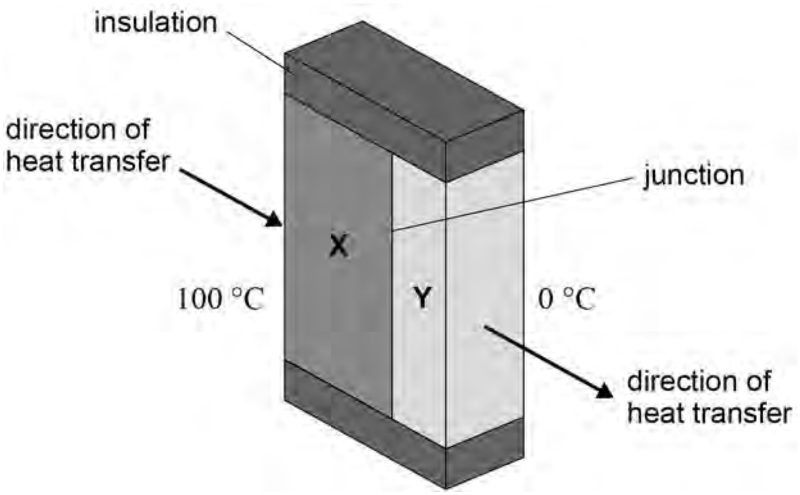
0 9 Two materials **X** and **Y** of equal cross-sectional area are joined together.

The left-hand surface of **X** is at a temperature of 100 °C. The right-hand surface of **Y** is at a temperature of 0 °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 °C ⬭

B 25 °C ⬭

C 75 °C ⬭

D 89 °C ⬭

Turn over ►

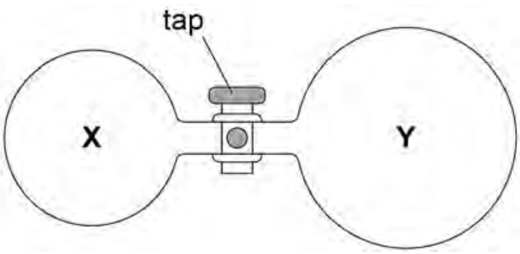
1 0 A student plans an experiment to test Charles's law for a gas.

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	⬭
B	pressure and temperature	volume	⬭
C	volume and temperature	pressure and mass	⬭
D	volume and temperature	pressure	⬭

1 1 Bulb **X** and bulb **Y** are connected by a tube with a tap.



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

Y has a volume of $4.0\ \mathrm{m}^3$ 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} ⬭

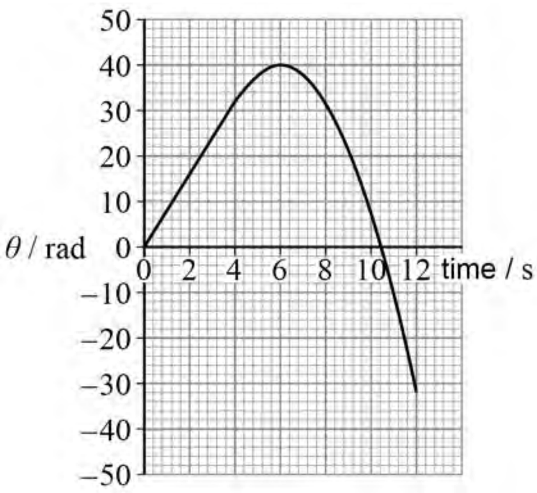
1 2 A disc rotates at a constant angular speed of $8.0\ \mathrm{rad\ s^{-1}}$ for a time of $4.0\ \mathrm{s}$.

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

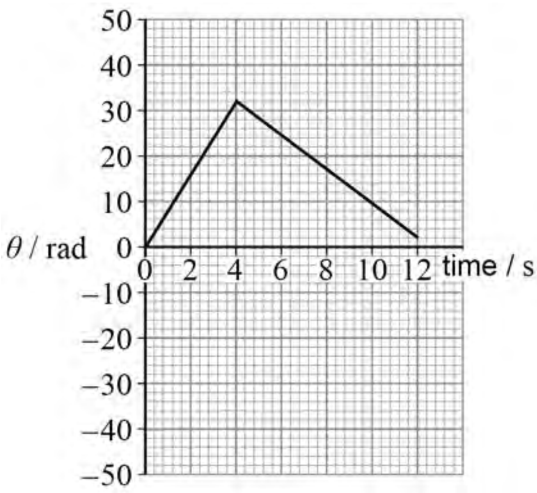
Which graph shows the variation of angular displacement θ with time?

[1 mark]

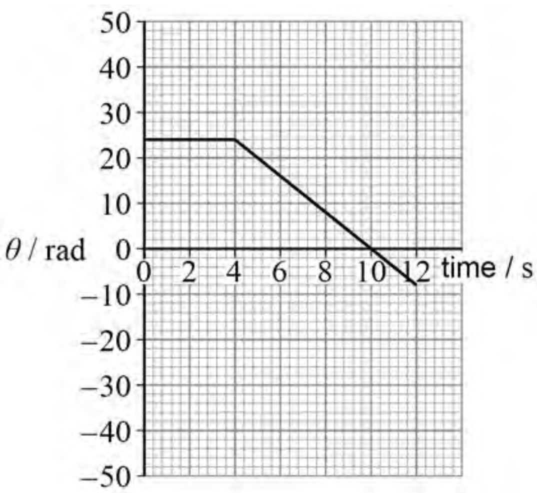
A



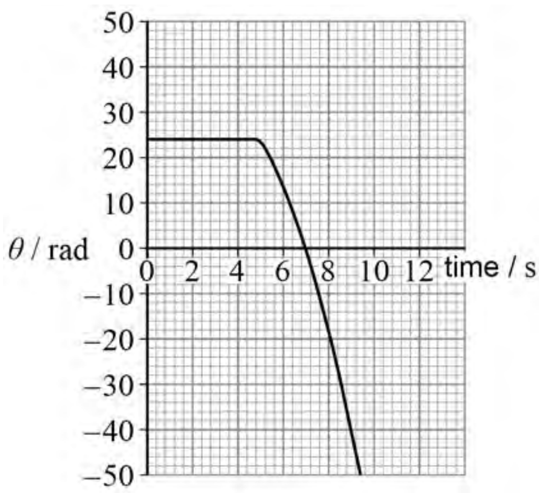
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

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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	$\ln A$	$\ln R$	⬭
B	$\ln R$	$\dfrac{\ln A}{3}$	⬭
C	$\ln\left(\dfrac{A}{3}\right)$	$\ln R$	⬭
D	$\ln R$	$\ln A$	⬭

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 ${}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + \mathrm{e}^{-} + \overline{\upsilon}$ ⬭

B ${}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + \mathrm{e}^{+} + \upsilon$ ⬭

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

D ${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + \gamma$ ⬭

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

[1 mark]

A kg m s^{-1} ☐

B kg m s^{-2} ☐

C kg m^2 s^{-1} ☐

D kg m^2 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 $\dfrac{3T\omega t}{2}$ ☐

B $\dfrac{5I\omega^2}{2}$ ☐

C $\omega T t$ ☐

D $\dfrac{2I\omega\theta}{t}$ ☐

Turn over ►

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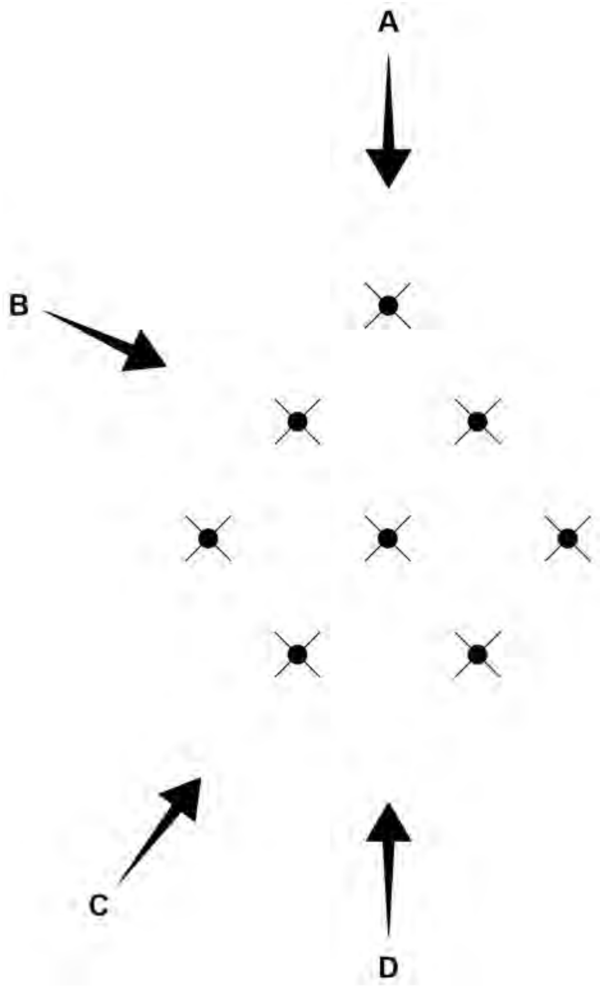
1 9 The diagram shows a plan view of an arrangement of wind turbines represented by .

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: $300\ \mathrm{m\ s^{-1}}$, $200\ \mathrm{m\ s^{-1}}$, $50\ \mathrm{m\ s^{-1}}$, $150\ \mathrm{m\ s^{-1}}$ and $300\ \mathrm{m\ s^{-1}}$.

What is c_{rms} for the atoms?

[1 mark]

A $99\ \mathrm{m\ s^{-1}}$

B $185\ \mathrm{m\ s^{-1}}$

C $200\ \mathrm{m\ s^{-1}}$

D $221\ \mathrm{m\ s^{-1}}$

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 $\dfrac{\text{total solar power incident on Venus}}{\text{total solar power incident on Mercury}}$?

[1 mark]

A $\dfrac{5}{8}$

B $\dfrac{5}{4}$

C $\dfrac{25}{16}$

D $\dfrac{25}{8}$

Turn over for the next question

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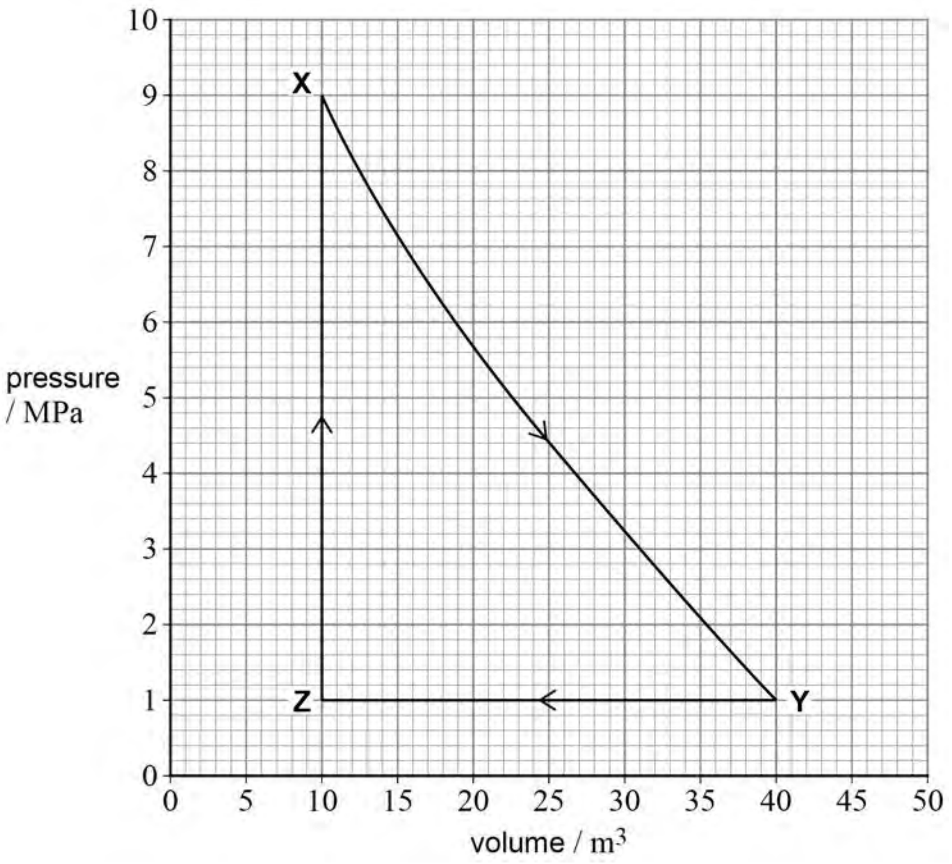
2 2 An ideal gas goes through a cycle of changes **XYZX** as shown in the pressure–volume graph.



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

[1 mark]

A 1.2×10^8 J **on** the gas

B 1.2×10^8 J **by** the gas

C 1.5×10^8 J **on** the gas

D 1.5×10^8 J **by** the gas

15

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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