Section A

Answer **all** questions in this section.

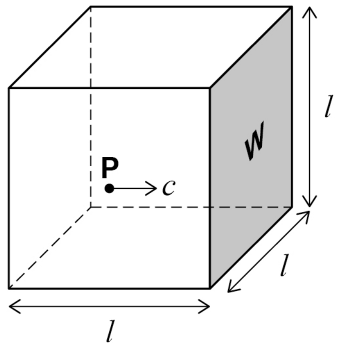
0 1 . 1 State what is meant by the internal energy of an ideal gas.

[1 mark]

combination of the particles kinetic energy and their potential energy

Figure 1 shows a single gas particle **P** of an ideal gas inside a hollow cube.

Figure 1



The cube has side length l and volume V.
P has mass m and is travelling at a velocity c perpendicular to side **W**.

0 1 . 2 Explain why **P** has a change in momentum of $-2mc$ during one collision with **W**.

[1 mark]

initial p = mc final = -mc
because it has changed direction
Therefore change = -mc - mc
= -2mc

0 1 . 3 **P** collides repeatedly with **W**.

Show that the frequency f of collisions is $\frac{c}{2l}$.

[1 mark]

time to travel from w to other wall & back : $s = \frac{d}{t} \Rightarrow t = \frac{d}{s} = \frac{2L}{c}$ seconds.

time between collisions is 2L/c and f=1/T so f=C/2L

0 1 . 4 Deduce an expression, in terms of m, c and V, for the contribution of **P** to the pressure exerted on **W**.
Refer to appropriate Newton's laws of motion.

[2 marks]

Δp for 1 collision is -2mc and there are c/2l collisions in a second
total Δp in 1 second is therfore

$$-2mc \times \frac{c}{2L} = -\frac{mc^2}{L}.$$

since Δp=fΔt and Δt = 1 we can say that -mc^2/l is also eqve use Newton's third law - so force on the wall is the same without the negative sign.

We therefore now need to divide by l^2 since that is the area of the wall w and Pressure = F/A

$$\Rightarrow P = \frac{\left(\frac{mc^2}{L}\right)}{L^2} = \frac{mc^2}{L^3} = \frac{mc^2}{V}$$

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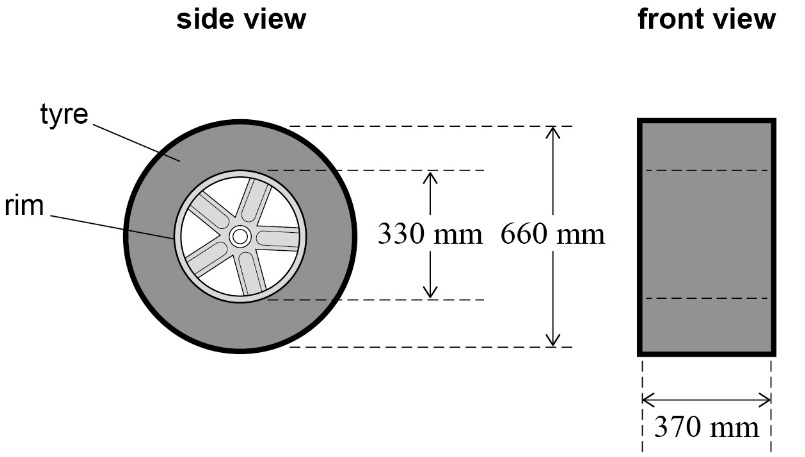
Turn over for the next question

0 2

Figure 2 shows a wheel used in motorsport. A rubber tyre is fitted around a cylindrical metal rim. The tyre is filled with a gas.
The dimensions shown in **Figure 2** are for the volume of the gas in the tyre.

Assume that this volume remains constant throughout this question.

Figure 2



0 2 . 1 The mass of the wheel is measured when the gas in the tyre is at a pressure of 1.01×10^5 Pa.
More of the same gas is added to the tyre and the mass of the wheel is measured again.

Table 1 shows the pressure in the tyre and the mass of the wheel before and after the addition of the extra gas.
The gas is kept at a constant temperature of 100 °C.

Table 1

	Pressure in tyre / Pa	**Mass of wheel / kg**
Before	1.01×10^5	14.897
After	2.11×10^5	14.991

$\pi r^2 h$

Vol of gas $\pi\left(\frac{0.66}{2}\right)^2 \times 0.37 - \pi\left(\frac{0.33}{2}\right)^2 \times 0.37 = 0.0944$ m³

$\Delta m = 14.991 - 14.897 = 0.094$ kg

Determine, in kg mol^{-1}, the molar mass of the gas.

[5 marks]

so we are after the number of moles n that are added.

n_1 = no of moles before $\quad \frac{p_1 V_1}{T_1 R} = n_1$

n_2 = after $\quad \frac{p_2 V_2}{T_2 R} = n_2$

V is const

T is 373 K

$$n_2 - n_1 = \frac{p_2 V_2}{T_2 R} - \frac{p_1 V_1}{T_1 R}$$

$$n = \frac{V}{TR}(P_2 - P_1) \Rightarrow n = \frac{0.0949}{373 \times 8.31}(2.11\times10^5 - 1.01\times10^5)$$

$n = 3.34$

$\Delta m = 0.094 \quad \therefore$ molar mass $= \frac{0.094}{3.34}$

molar mass = 0.028 kg mol^{-1}

0 2 . 2 Motorsport regulations specify a minimum amount of gas in the tyre.

The amount of gas in the tyre is checked by measuring the pressure before the wheel is put onto the car. The regulations also specify a maximum temperature for the tyre when making this measurement.

Explain why a maximum temperature is specified.

[2 marks]

you could heat up the tyre and this would mean you could get the required pressure but with less actual gas than is required in the tyre

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Section B

Each of Questions **08** to **32** 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 A 1000 W heater is 75% efficient. The heater is used to increase the temperature of some water from 10 °C to 85 °C in 7 hours.

What mass of water is heated?

this means that 1000X0.75 J are provided to heat the water every second

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

[1 mark]

energy supplied in 7 hours = 750*7*60*60= 1.89 x 10^7J

$\Delta E = mc\Delta\theta$

A 1.0 kg

B 13 kg

C 60 kg

D 110 kg

$\frac{\Delta E}{c\Delta\theta} = m$

$= \frac{1.89 \times 10^7}{4200 \times (85-10)} = 60\text{ kg}$

0 9 Which can lead to a value for the absolute zero of temperature?

[1 mark]

A Boyle's law – $p \propto 1/V$

B Brownian motion

C Charles's law $V \propto T$ ✓

D Rutherford scattering

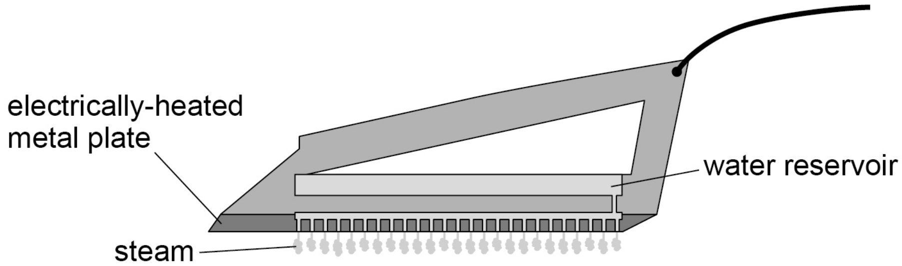
Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows an electric steam iron.

Figure 1



Water from a reservoir drips onto an electrically-heated metal plate. The water boils and steam escapes through holes in the metal plate.

The electrical power of the heater inside the iron is 2.1 kW.

Assume that all the energy from the heater is transferred to the metal plate.

0 1 . 1 The metal plate has a mass of 1.2 kg and is initially at a temperature of 20 °C. The heater is switched on. After a time t the metal plate reaches its working temperature of 125 °C.

Calculate t.

specific heat capacity of the metal = 450 J kg^{-1} K^{-1}

[2 marks]

$\Delta E = mc\Delta\theta \Rightarrow t = \frac{mc\Delta\theta}{P}$

Pt

$t = \frac{1.2 \times 450 \times 105}{2100}$

$t = 27$ s

$t =$ 27 s

0 1 . 2 The metal plate is maintained at its working temperature.
Water at 20 °C drips continuously onto the metal plate.
Steam at 100 °C emerges continuously from the iron.

$P = 2100\,W$

The maker claims that the iron can generate steam at a rate of $60\ g\ min^{-1}$.

Determine whether this claim is true.

specific latent heat of vaporisation of water $= 2.3 \times 10^6\ J\ kg^{-1}$
specific heat capacity of water $= 4200\ J\ kg^{-1}\ K^{-1}$

[3 marks]

find the mass that can be heated and then vapourised in 1 minute

$$2100 \times 60 = mc\Delta\theta + mL$$
$$= m(c\Delta\theta + L)$$

$$\frac{2100 \times 60}{(4200 \times 80) + 2.3 \times 10^6} = m$$

$$\Rightarrow m = 48\,g \quad (2sf)$$

this is less than the quoted 60g/min so the claim is false

5

0 2 . 1 In the kinetic theory model, it is assumed that there are many identical particles moving at random.

State **two** other assumptions made in deriving the equation $pV = \frac{1}{3}Nm\,(c_{\mathrm{rms}})^2$.

[2 marks]

1 all collosions are perfectly elastic

2 time between collisions is large compared to the time of the collision

point masses/volume of particles is small cf vol of gas
forces between partciles are 0 (negligible)

0 2 . 2 Explain why molecules of a gas exert a force on the walls of a container.
Refer to Newton's laws of motion in your answer.

[3 marks]

When a molecule collides with a wall its velocity changes direction which means its momentum has changed. From N2 we know that if there is a change in momentum of the molecule there must be a force acting on the molecule - which comes in this case from the wall.
N3 tells us that 'every force has an equal and opposite reaction acting on a different object' and so the particle also exerts a force on the wall.
Clearly the wall has an area so we know have a force acting over and area and hence a pressure

0 2 . 3 A sealed flask of volume $0.35\ \mathrm{m^3}$ contains an ideal gas at a pressure of $220\ \mathrm{kPa}$. The mean kinetic energy of the gas molecules is $6.7 \times 10^{-21}\ \mathrm{J}$.

Calculate the amount of gas in the container.

[3 marks]

$\frac{1}{2}m(c_{rms})^2 = \frac{3}{2}kT \Rightarrow \frac{6.7\times10^{-21} \times 2/3}{k} = T$

$T = 323.6\ldots\ \mathrm{K}$

$pV = nRT \Rightarrow n = \frac{pV}{RT} = \frac{220\times10^3 \times 0.35}{8.31 \times 323.6\ldots}$

amount of gas = 29 (2 sf) mol

0 2 . 4 **Figure 2** shows the variation of pressure with volume for a fixed mass of an ideal gas at constant absolute temperature T.

Draw, on **Figure 2**, the graph for the same gas at temperature $2T$.

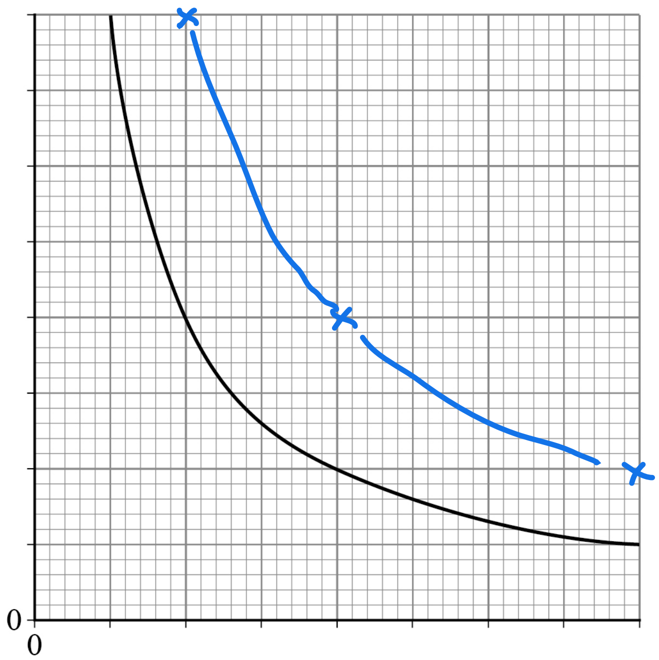
nice curve, obviously. At each volume the pressure will be twice as much

[2 marks]

Figure 2

$\frac{pV}{T} = \text{const}$

pressure



volume

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Section B

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CORRECT METHOD ⬬ WRONG METHODS ⊗ ⊙ ⊜ ✓

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0 7 An ideal gas, initially at $300\ \text{K}$, is compressed to half its original volume. It is then cooled at constant volume until the pressure is restored to its initial value.

What is the final temperature of the gas?

[1 mark]

A $150\ \text{K}$ ☒

B $200\ \text{K}$ ○

C $300\ \text{K}$ ○

D $600\ \text{K}$ ○

$P_1 = P_2$

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow \frac{T_1}{V_1} = \frac{T_2}{V_2}$

$\therefore T_2 = \frac{T_1 V_2}{V_1} = \frac{300 \times 1}{2}$

$= 150\text{K}$

0 8 A fixed volume of an ideal gas is heated.

Which row gives quantities that double when the kelvin temperature of the gas doubles?

[1 mark]

A	rms speed of the molecules	pressure of the gas	⬭
B	density of the gas	rms speed of the molecules	⬭
C	internal energy of the gas	density of the gas	⬭
D	pressure of the gas	internal energy of the gas	⬭

0 9 A planet of radius R and mass M has a gravitational field strength of g at its surface.

Which row describes a planet with a gravitational field strength of $4g$ at its surface?

[1 mark]

	Radius of planet	Mass of planet	
A	$2R$	$2M$	⬭
B	$R\sqrt{2}$	$\frac{M}{2}$	⬭
C	$\frac{R}{\sqrt{2}}$	$\frac{M}{2}$	⬭
D	$\frac{R}{\sqrt{2}}$	$2M$	⬭