OCR Physics Unit 4

Topic Questions from Papers

Thermal Physics

5 **(a)** The table shows the specific heat capacities *c* of alcohol and water.

	$c\,/\,\mathrm{J\,kg^{-1}\,K^{-1}}$
alcohol	2460
water	4180

(i) An alcohol thermometer is placed in 80 g of water at 20 °C. The mass of alcohol in the thermometer is 0.050 g. The water is then heated from 20 °C to 60 °C.

Calculate the ratio

$$\frac{\text{energy required to warm the water from 20 °C to 60 °C}}{\text{energy required to warm the alcohol from 20 °C to 60 °C}}.$$

ratio = ... **[2]**

(ii) State and explain a situation in which the very high value of specific heat capacity for water is useful.

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.... **[2]**

(b) Describe an electrical experiment to determine the specific heat capacity *c* of a liquid.

Include in your answer:

- a labelled diagram of the arrangement
- a list of the measurements to be taken
- an explanation of how the value of *c* would be determined from your results
- possible sources of uncertainty in your measurements and how these could be reduced.

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.... **[8]**

[Total: 12]

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6 **(a)** The ideal gas equation may be written as

$$pV = nRT.$$

State the meaning of the terms n and T.

n ....

T .... **[2]**

(b) Fig. 6.1 shows a cylinder that contains a fixed amount of an ideal gas. The cylinder is fitted with a piston that moves freely. The gas is at a temperature of 20 °C and the initial volume is $1.2 \times 10^{-4}\,\text{m}^3$. Fig. 6.2 shows the cylinder after the gas has been heated to a temperature of 90 °C under constant pressure.

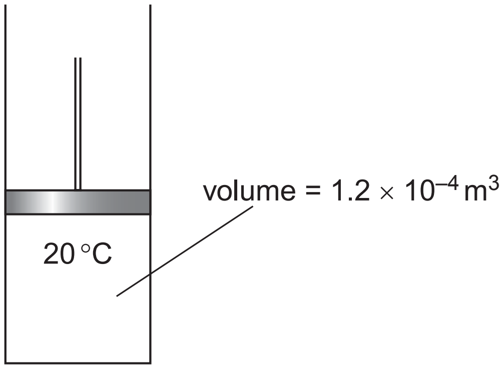

Fig. 6.1

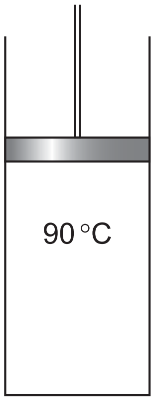

Fig. 6.2

(i) Explain in terms of the motion of the molecules of the gas why the volume of the gas must increase if the pressure is to remain constant as the gas is heated.

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.... **[4]**

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(ii) Calculate the volume of the gas at 90 °C.

volume = ... m^3 **[2]**

(c) The mass of each gas molecule is 4.7×10^{-26} kg. Estimate the average speed of the gas molecules at 90 °C.

speed = ... $m\,s^{-1}$ **[3]**

[Total: 11]

END OF QUESTION PAPER

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4 Fig. 4.1 shows smoke particles suspended in air. The arrows indicate the directions in which the smoke particles are moving at a particular instant. The lengths of the arrows indicate the different speeds of the particles.

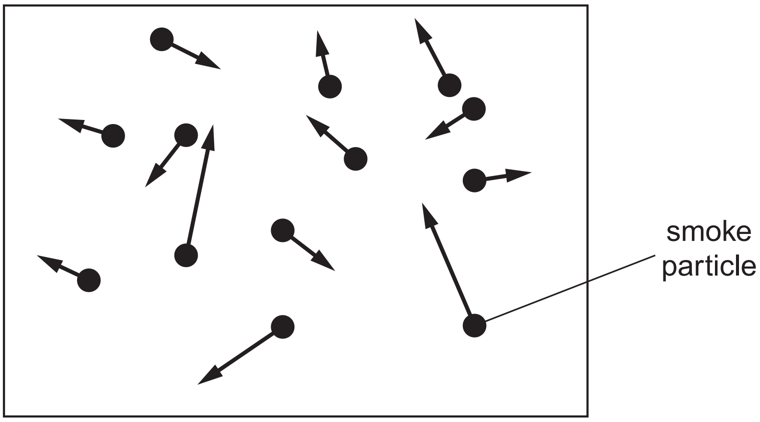

Fig. 4.1

(a) (i) State the name given to this type of random motion of smoke particles in air.

In your answer, you should use appropriate technical terms spelled correctly.

....

.... **[1]**

(ii) State **two** conclusions about the air molecules that may be deduced from the observed motion of the smoke particles.

....

....

....

.... **[2]**

(b) (i) The radius of an inflated football is 0.11 m. The temperature of the air inside the ball is 17 °C. Calculate the mass of air in the ball when the pressure inside it is 2.6×10^5 Pa.

The mass of one mole of air is 0.028 kg.

mass of air = ... kg **[4]**

(ii) The football is left in a room at a temperature of 0 °C until it reaches thermal equilibrium.

1 Explain the term *thermal equilibrium*.

....

....

.... **[1]**

2 Calculate the pressure exerted by the air inside the football when the temperature drops to 0 °C.

pressure = ... Pa **[2]**

[Total: 10]

5 A car of mass 970 kg is travelling at 27 m s^{-1} when the brakes are applied. The car is brought to rest in a distance of 40 m.

(a) (i) Calculate the kinetic energy of the car when it is travelling at 27 m s^{-1}.

kinetic energy = ... J **[1]**

(ii) Hence calculate the average braking force on the car stating any assumption that you make.

average braking force = ... N

assumption ....

.... **[3]**

(b) The car has four brake discs each of mass 1.2 kg. The material from which the discs are made has a specific heat capacity of 520 J kg^{-1} K^{-1}.

(i) Calculate the temperature rise of each disc after braking from a speed of 27 m s^{-1}. Assume all the kinetic energy of the car is converted into internal energy of the brake discs equally during braking.

temperature rise = ... °C **[2]**

(ii) State and explain **two** reasons why the actual temperature rise will be different.

....

....

....

....

....

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....

.... **[4]**

(iii) Suggest one modification to the design of the disc braking system that could reduce the temperature rise of the discs.

....

....

.... **[1]**

[Total: 11]

END OF QUESTION PAPER

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3 **(a)** **(i)** Define the *kilowatt-hour*.

....

.... **[1]**

(ii) A domestic refrigerator works at a mean power of 70 W. Calculate the cost of running this refrigerator for one week at a cost of 12 p per kW h.

cost = £ .... **[2]**

(b) A large jug containing 2.0 kg of milk is placed in a refrigerator. The milk cools from 18 °C to 3.0 °C over a time period of 100 minutes. The specific heat capacity of milk is 3800 J kg^{-1} K^{-1}.

Calculate

(i) the thermal energy removed from the milk as it cools from 18 °C to 3 °C

energy removed = ... J **[2]**

(ii) the rate at which thermal energy is removed from the milk.

rate = ... J s^{-1} **[1]**

(c) Another container full of milk is placed in a freezer and cooled from 18 °C to –18 °C.

Assume that thermal energy is removed at a constant rate and that the freezing-point of milk is 0 °C. The specific heat capacity of milk below 0 °C is significantly less than its value above 0 °C.

On Fig. 3.1 sketch a graph to show the variation with time of the temperature of the milk over the range 18 °C to –18 °C. Numbers are not required on the time axis.

Fig. 3.1 **[3]**

[Total: 9]

5 (a) A student investigates Brownian motion by observing through a microscope smoke particles suspended in air.

(i) Describe the behaviour of the smoke particles as observed by the student.

In your answer, you should use appropriate technical terms spelled correctly.

....

.... **[1]**

(ii) State how the observations lead to conclusions about the nature and properties of the molecules of a gas.

....

....

....

....

....

....

....

.... **[3]**

(b) The molar masses of hydrogen and oxygen are 0.0020 kg mol^{-1} and 0.032 kg mol^{-1} respectively. The mean speed of hydrogen molecules at room temperature is 1800 m s^{-1}.

Calculate the mean speed of oxygen molecules at the same temperature.

mean speed = ... m s^{-1} **[3]**

[Total: 7]

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6 **(a)** **(i)** State Boyle's law.

....

.... **[2]**

(ii) For a gas which obeys Boyle's law, sketch

1 on Fig. 6.1 a graph of pressure *p* against volume *V*

2 on Fig. 6.2 a graph of *p* against 1 / *V*. **[3]**

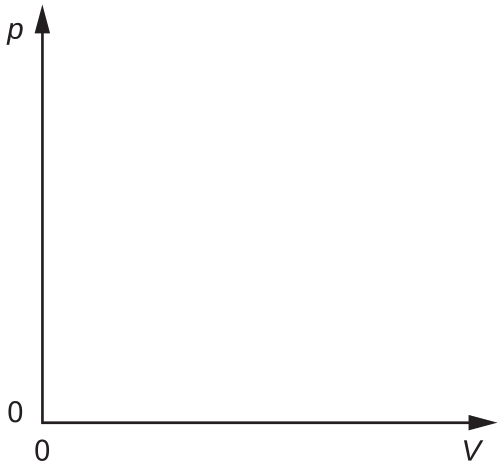

Fig. 6.1

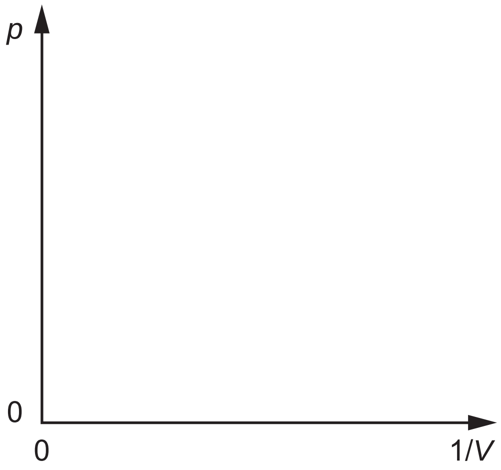

Fig. 6.2

Question 6 continues over the page.

(b) A cylinder of fixed volume 0.040 m^3 is filled with nitrogen gas at a pressure of 5.0 × 10^5 Pa and temperature 15 °C. The molar mass of nitrogen is 0.028 kg mol^{-1}.

(i) Calculate the number of moles of nitrogen in the cylinder.

number of moles = ... **[2]**

(ii) After a period of 100 days the pressure has fallen to 4.5 × 10^5 Pa, at the same temperature, because of leakage. Calculate the mass of nitrogen that has escaped.

mass = ... kg **[3]**

[Total: 10]

END OF QUESTION PAPER

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4 **(a)** *In your answer you should use appropriate technical terms spelled correctly.*

State the terms used to describe the thermal energy required to change

(i) a solid into a liquid at a constant temperature

.... **[1]**

(ii) a liquid into a gas at a constant temperature.

.... **[1]**

(b) Most households waste energy by overfilling electric kettles. Assume that, on average, 0.80 kg of water per household per day is unnecessarily boiled.

(i) Estimate the energy required when 0.80 kg of water, initially at 18 °C, is heated in an electric kettle. The kettle switches off automatically when the water is boiling steadily at 100 °C. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

heat energy = ... J **[2]**

(ii) State and explain **two** different reasons why the actual quantity of energy required to warm the water to 100 °C is greater than the estimate in **(i)**.

1. ....

....

2. ....

.... **[2]**

(iii) Calculate, in kW h, the average annual energy wasted per household by boiling too much water.

energy = ...kW h **[2]**

[Total: 8]

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5 **(a)** One assumption required for the development of the kinetic model of a gas is that molecules undergo perfectly elastic collisions with the walls of their containing vessel and with each other.

(i) Explain what is meant by a *perfectly elastic collision*.

....

.... **[1]**

(ii) State **three** other assumptions of the kinetic theory of gases.

1. ....

....

2. ....

....

3. ....

.... **[3]**

(b) Fig. 5.1 shows a cubical box of side length 0.20 m. The box contains one molecule of mass 4.8×10^{-26} kg moving with a constant speed of 500 m s^{-1}. The molecule collides elastically at right angles with the opposite faces **X** and **Y** of the box.

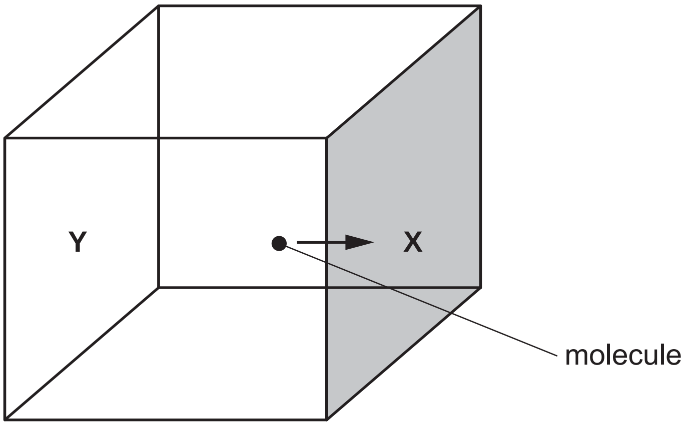

Fig. 5.1

(i) Calculate the change of momentum each time the molecule collides with face **X**.

change of momentum = ... kg m s^{-1} **[2]**

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(ii) Calculate the number of collisions made by the molecule with face **X** in 1.0 s.

number = ... **[1]**

(iii) Calculate the mean force exerted on the molecule by face **X**.

force = ...N **[2]**

(iv) Hence state the force exerted on face **X** by the molecule. Justify your answer.

....

.... **[1]**

(c) The single molecule in the box in **(b)** is replaced by 3 moles of air at atmospheric pressure.

(i) Calculate the number of air molecules in the box.

number = ... **[1]**

(ii) Suggest why the pressure exerted by the air on each of the six faces of the box is the same.

....

.... **[1]**

(iii) The temperature of the air inside the box is increased. Explain in terms of the **motion** of the air molecules how the pressure exerted by the air will change.

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.... **[2]**

[Total: 14]

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6 **(a)** **(i)** A container has **1 mole** of an ideal gas. The volume of the container is V cubic metres (m^3) and the gas exerts pressure p pascal (Pa). On Fig. 6.1, show the relationship between the product pV and the absolute temperature T of the gas. **[1]**

Fig. 6.1

(ii) State the value of the gradient of this graph.

.... **[1]**

(b) The volume of 1.5 moles of an ideal gas at –40 °C is 2.4×10^{-2} m^3. The gas is now heated at constant pressure p. Calculate

(i) the new volume of the gas at a temperature of 250 °C

volume = ... m^3 **[3]**

(ii) the value of the pressure p.

p = ... Pa **[2]**

[Total: 7]

END OF QUESTION PAPER

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4 **(a)** State the term used for the energy required to change a solid into a liquid.

You should use the appropriate technical term spelled correctly.

.... **[1]**

(b) **(i)** Define the *internal energy* of a system.

....

....

.... **[2]**

(ii) There is a change in internal energy when a mass of water at 100 °C becomes an equal mass of vapour at 100 °C. Explain why.

....

....

.... **[2]**

(c) **(i)** The air in a greenhouse has a volume of $15\,\text{m}^3$, a density of $1.2\,\text{kg}\,\text{m}^{-3}$ and a specific heat capacity of $990\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$. Immediately after sunset, the soil is transferring thermal energy to the air at an average rate of 12 W. Estimate the increase in temperature of the air in the greenhouse one hour after sunset as a result of this energy transfer from the soil.

increase in temperature = ... K **[3]**

(ii) Suggest two possible reasons why the actual increase in temperature of the air is likely to be much lower than this estimate.

....

....

.... **[2]**

[Total: 10]

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5 **(a)** **(i)** State what is meant by a *perfectly elastic collision*.

....

.... **[1]**

(ii) Explain, in terms of the behaviour of **molecules**, how a gas exerts a pressure on the walls of its container.

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.... **[4]**

(iii) Explain, in terms of the behaviour of **molecules**, why the pressure of a gas in a container of constant volume increases when the temperature of the gas is increased.

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.... **[2]**

(b) A weather balloon is filled with helium gas. Just before take-off the pressure inside the balloon is 105 kPa and its internal volume is $5.0 \times 10^3\,\text{m}^3$. The temperature inside the balloon is 20 °C. The pressure, volume and temperature of the helium gas change as the balloon rises into the upper atmosphere.

(i) The balloon expands to a volume of $1.2 \times 10^4\,\text{m}^3$ in the upper atmosphere where the temperature inside the balloon is –30° C. Calculate the pressure inside the balloon.

pressure = ... kPa **[3]**

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(ii) Suggest why it is necessary to release helium from the balloon as it continues to rise.

....

....

.... **[1]**

[Total: 11]

Question 6 is on page 10.

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6 **(a)** The molar mass of hydrogen gas is $2.02 \times 10^{-3}\,\mathrm{kg\,mol^{-1}}$. Calculate the mass of a hydrogen molecule.

mass = ... kg **[2]**

(b) The temperature of the Earth's upper atmosphere is about 1100 K. Show that at this temperature the mean kinetic energy of an air molecule is about 2×10^{-20} J.

[2]

(c) Show that the speed of a helium atom of mass 6.6×10^{-27} kg at a temperature of 1100 K is about $2.5\,\mathrm{km\,s^{-1}}$.

[2]

(d) The *escape velocity* from the Earth is $11\,\mathrm{km\,s^{-1}}$. The escape velocity is the minimum vertical velocity a particle must have in order to escape from the Earth's gravitational field. Explain why helium atoms still escape from the Earth's atmosphere.

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.... **[2]**

[Total: 8]

END OF QUESTION PAPER

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4 **(a)** **(i)** Define *specific heat capacity*.

....

....

.... **[1]**

(ii) Describe the difference between the *latent heat of fusion* and the *latent heat of vaporisation*.

....

....

.... **[1]**

(b) The graph in Fig. 4.1 shows the variation of temperature with time for a fixed mass of substance when heated by a constant power source. At **A** the substance is a solid; at **E** the substance is a vapour.

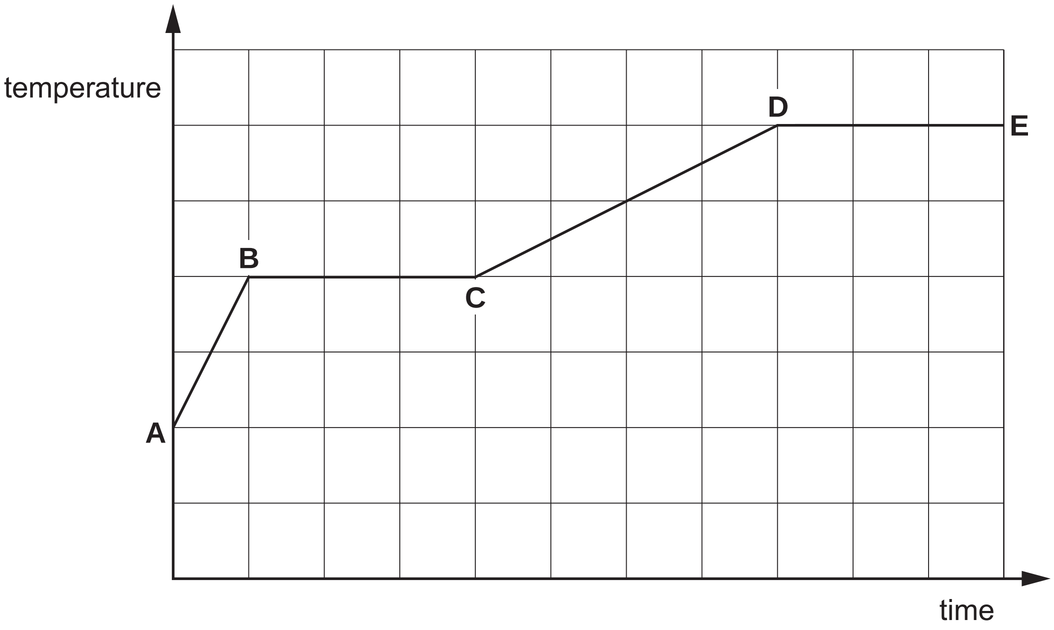

Fig. 4.1

(i) Describe the changes taking place in the kinetic energy and potential energy of the molecules for the following sections:

A to **B**

....

....

....

B to **C**

....

....

.... **[2]**

(ii) State and explain what you can conclude from Fig. 4.1 about the specific heat capacity of the substance in the solid state compared with the specific heat capacity of the substance in the liquid state.

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.... **[2]**

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(c) The electric heating element of a bathroom shower has a power rating of 5.0 kW. An attempt is made to test the accuracy of this value by measuring the rate of flow of the water and the temperature of the water before and after passing the element.

The results of the test and other required data are as follows:

temperature of water supply to the shower = 17.4 °C
temperature of water after being heated by the element = 36.7 °C
rate of flow of water = $3.60 \times 10^{-3}\ \text{m}^3\ \text{min}^{-1}$
density of water = $1000\ \text{kg}\,\text{m}^{-3}$
specific heat capacity of water = $4200\ \text{J}\,\text{kg}^{-1}\ \text{K}^{-1}$

(i) Show that the power of the heating element is approximately 5 kW.

[4]

(ii) State and explain a possible source of uncertainty that might affect the reliability of the test.

....

....

.... **[2]**

[Total: 12]

5 **(a)** State a conclusion about the movement of gas molecules provided by observations of Brownian motion.

In your answer, you should use appropriate technical terms, spelled correctly.

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.... **[1]**

(b) Fig. 5.1 shows a gas contained in a cylinder enclosed by a piston. The volume of the gas inside the cylinder is 120 cm^3. The pressure inside the cylinder is 350 kPa.

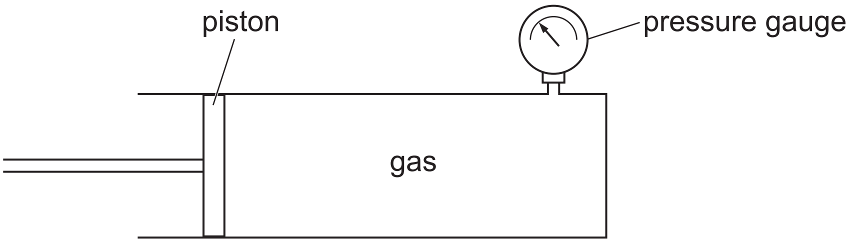

Fig. 5.1

(i) State a necessary condition for Boyle's law to apply to a fixed quantity of gas.

....

....

.... **[1]**

(ii) The piston in Fig. 5.1 is moved quickly so that the gas occupies a volume of 55 cm^3. Use Boyle's law to calculate the new pressure of the gas.

pressure = ...kPa **[2]**

(iii) In practice, the quick movement of the piston during compression of the gas causes an increase in the temperature of the gas. Explain this increase in temperature in terms of the **movement of the piston** and **the motion of the gas molecules**.

....

....

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.... **[2]**

[Total: 6]

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5 (a) (i) The pressure *p* and volume *V* of a quantity of an ideal gas at absolute temperature *T* are related by the equations $pV = nRT$ and $pV = NkT$. In these equations identify the symbols *n* and *N*.

n ....

N...
[1]

(ii) Choose one of the equations in **(i)** and show how Boyle's law follows from it.

....

....

.... **[2]**

(iii) Show that the product of *pV* has the same units as work done.

[1]

(b) The graph in Fig. 5.1 shows the variation of pressure, *p*, with the reciprocal of volume, 1/*V*, of 0.050 kg of oxygen behaving as an ideal gas.

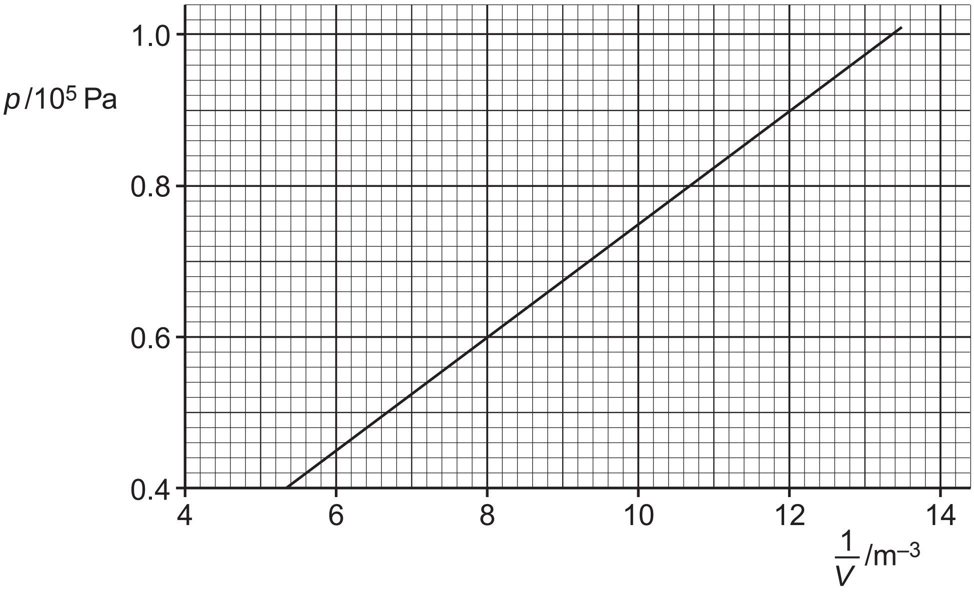

Fig. 5.1

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(i) Use the graph to show that the variation of p with $\frac{1}{V}$ is taking place at constant temperature.

[2]

(ii) The molar mass of oxygen is 0.016 kg mol^{-1}. Calculate the temperature, in °C, of the oxygen in **(i)**.

temperature = ... °C **[3]**

[Total: 9]

6 **(a)** Describe

(i) the motion of atoms in a solid at a temperature well below its melting point

....

.... **[1]**

(ii) the effect of a small increase in temperature on the motion of these atoms

....

.... **[1]**

(iii) the effect on the internal energy and temperature of the solid when it melts.

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.... **[2]**

(b) Fig. 6.1 shows the apparatus used to determine the specific heat capacity of a metal. A block made of the metal is heated by an electrical heater that produces a constant power of 48 W. In order to reduce heat loss from the sides, top and bottom of the block, it is covered by a layer of insulating material.

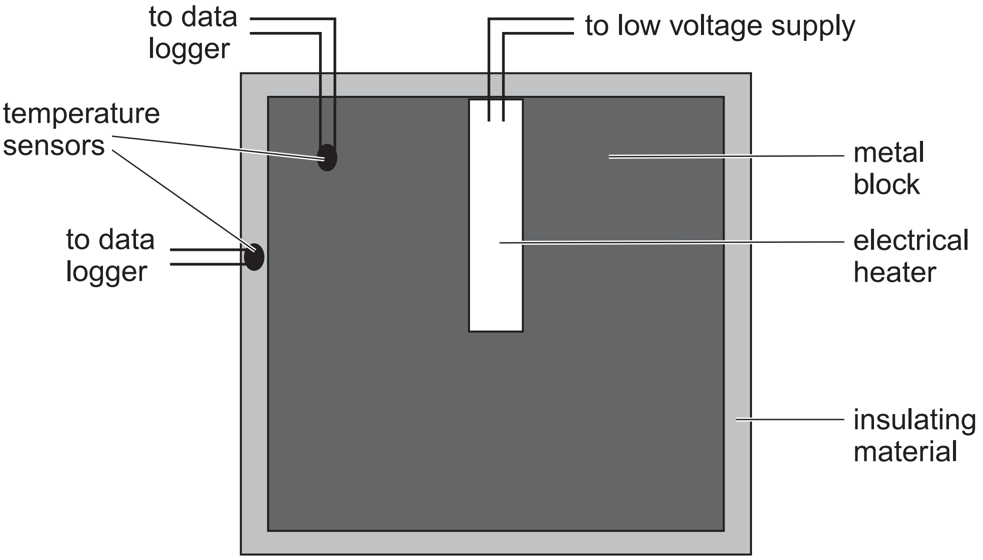

Fig. 6.1

Temperature sensors connected to a data logger show that the block and insulation are initially at the room temperature of 18 °C. The heater is switched on and after 720 seconds the sensors show that the temperature of the block is 54 °C and the average temperature of the insulating material is 38 °C.

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(i) Use the information given above and the data shown below to determine the specific heat capacity of the metal block.

mass of metal block = 0.98 kg
power of heater = 48 W
specific heat capacity of the insulating material = 850 J kg^{-1} K^{-1}
mass of the insulating material = 0.027 kg

specific heat capacity = ... J kg^{-1} K^{-1} **[4]**

(ii) A second experiment is done without the insulating material and with the block again starting at 18 °C. Discuss whether the value of the specific heat capacity calculated from the second experiment is likely to be lower, the same or higher than the value calculated in **(i)**.

....

....

....

.... **[2]**

[Total: 10]

END OF QUESTION PAPER

Data

Values are given to three significant figures, except where more are useful.

speed of light in a vacuum	c	3.00×10^{8} m s^{-1}
permittivity of free space	ε_0	8.85×10^{-12} C^2 N^{-1} m^{-2} (F m^{-1})
elementary charge	e	1.60×10^{-19} C
Planck constant	h	6.63×10^{-34} J s
gravitational constant	G	6.67×10^{-11} N m^2 kg^{-2}
Avogadro constant	N_A	6.02×10^{23} mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
Boltzmann constant	k	1.38×10^{-23} J K^{-1}
electron rest mass	m_e	9.11×10^{-31} kg
proton rest mass	m_p	1.673×10^{-27} kg
neutron rest mass	m_n	1.675×10^{-27} kg
alpha particle rest mass	m_α	6.646×10^{-27} kg
acceleration of free fall	g	9.81 m s^{-2}

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Conversion factors

unified atomic mass unit	$1\ \text{u} = 1.661 \times 10^{-27}\ \text{kg}$
electron-volt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$
	$1\ \text{day} = 8.64 \times 10^{4}\ \text{s}$
	$1\ \text{year} \approx 3.16 \times 10^{7}\ \text{s}$
	$1\ \text{light year} \approx 9.5 \times 10^{15}\ \text{m}$

Mathematical equations

arc length = $r\theta$

circumference of circle = $2\pi r$

area of circle = πr^2

curved surface area of cylinder = $2\pi rh$

volume of cylinder = $\pi r^2 h$

surface area of sphere = $4\pi r^2$

volume of sphere = $\frac{4}{3}\pi r^3$

Pythagoras' theorem: $a^2 = b^2 + c^2$

For small angle $\theta \Rightarrow \sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$

$\lg(AB) = \lg(A) + \lg(B)$

$\lg(\frac{A}{B}) = \lg(A) - \lg(B)$

$\ln(x^n) = n\ln(x)$

$\ln(e^{kx}) = kx$

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Formulae and relationships

Unit 1 – Mechanics

$F_x = F\cos\theta$
$F_y = F\sin\theta$

$a = \dfrac{\Delta v}{\Delta t}$

$v = u + at$

$s = \dfrac{1}{2}(u + v)t$

$s = ut + \dfrac{1}{2}at^2$

$v^2 = u^2 + 2as$

$F = ma$

$W = mg$

moment = Fx

torque = Fd

$\rho = \dfrac{m}{V}$

$p = \dfrac{F}{A}$

$W = Fx\cos\theta$

$E_\mathrm{k} = \dfrac{1}{2}mv^2$

$E_\mathrm{p} = mgh$

efficiency = $\dfrac{\text{useful energy output}}{\text{total energy input}} \times 100\%$

$F = kx$

$E = \dfrac{1}{2}Fx \qquad E = \dfrac{1}{2}kx^2$

stress = $\dfrac{F}{A}$

strain = $\dfrac{x}{L}$

Young modulus = $\dfrac{\text{stress}}{\text{strain}}$

Unit 2 – Electrons, Waves and Photons

$\Delta Q = I\Delta t$

$I = Anev$

$W = VQ$

$V = IR$

$R = \dfrac{\rho L}{A}$

$P = VI \qquad P = I^2R \qquad P = \dfrac{V^2}{R}$

$W = VIt$

e.m.f. = $V + Ir$

$V_\mathrm{out} = \dfrac{R_2}{R_1 + R_2} \times V_\mathrm{in}$

$v = f\lambda$

$\lambda = \dfrac{ax}{D}$

$d\sin\theta = n\lambda$

$E = hf \qquad E = \dfrac{hc}{\lambda}$

$hf = \phi + \mathrm{KE}_\mathrm{max}$

$\lambda = \dfrac{h}{mv}$

$R = R_1 + R_2 + \dots$

$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dots$

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Unit 4 – Newtonian World

$$F = \frac{\Delta p}{\Delta t}$$

$$v = \frac{2\pi r}{T}$$

$$a = \frac{v^2}{r}$$

$$F = \frac{mv^2}{r}$$

$$F = -\frac{GMm}{r^2}$$

$$g = \frac{F}{m}$$

$$g = -\frac{GM}{r^2}$$

$$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$$

$$f = \frac{1}{T}$$

$$\omega = \frac{2\pi}{T} = 2\pi f$$

$$a = -(2\pi f)^2\, x$$

$$x = A\cos(2\pi ft)$$

$$v_{\max} = (2\pi f)\, A$$

$$E = mc\Delta\theta$$

$$pV = NkT$$

$$pV = nRT$$

$$E = \frac{3}{2}\, kT$$

Unit 5 – Fields, Particles and Frontiers of Physics

$$E = \frac{F}{Q}$$

$$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{V}{d}$$

$$F = BIL\sin\theta$$

$$F = BQv$$

$$\phi = BA\cos\theta$$

induced e.m.f. = – rate of change of magnetic flux linkage

$$\frac{V_\mathrm{s}}{V_\mathrm{p}} = \frac{n_\mathrm{s}}{n_\mathrm{p}}$$

$$Q = VC$$

$$W = \frac{1}{2}\, QV \qquad W = \frac{1}{2}\, CV^2$$

time constant = CR

$$x = x_0 \mathrm{e}^{-\frac{t}{CR}}$$

$$C = C_1 + C_2 + \ldots$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$$

$$A = \lambda N$$

$$A = A_0\, \mathrm{e}^{-\lambda t}$$

$$N = N_0\, \mathrm{e}^{-\lambda t}$$

$$\lambda t_{½} = 0.693$$

$$\Delta E = \Delta mc^2$$

$$I = I_0\, \mathrm{e}^{-\mu x}$$

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