Thermal Properties of Materials

Question paper 5

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Thermal Properties of Materials
Sub Topic	
Paper Type	Theory
Booklet	Question paper 5

Time Allowed: **90 minutes**

Score: **/75**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 (a) Define *density*.

....[1]

(b) Liquid of density ρ fills a container to a depth h, as illustrated in Fig. 3.1.

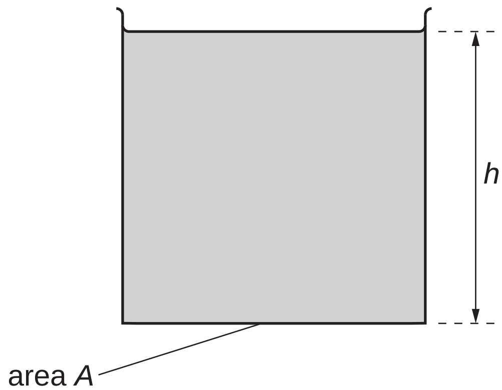

Fig. 3.1

The container has vertical sides and a base of area A.

(i) State, in terms of A, h and ρ, the mass of liquid in the container.

....[1]

(ii) Hence derive an expression for the pressure p exerted by the liquid on the base of the container. Explain your working.

[2]

(c) The density of liquid water is 1.0 g cm^{-3}. The density of water vapour at atmospheric pressure is approximately $\frac{1}{1600}$ g cm^{-3}.

Determine the ratio

(i) $\dfrac{\text{volume of water vapour}}{\text{volume of equal mass of liquid water}}$,

ratio = ...[1]

(ii) $\dfrac{\text{mean separation of molecules in water vapour}}{\text{mean separation of molecules in liquid water}}$.

ratio = ...[2]

(d) State the evidence for

(i) the molecules in solids and liquids having approximately the same separation,

....

....[1]

(ii) strong rigid forces between molecules in solids.

strong: ....

rigid: ....[2]

2 A light spring is suspended from a fixed point. A bar magnet is attached to the end of the spring,

as shown in Fig. 1.1.

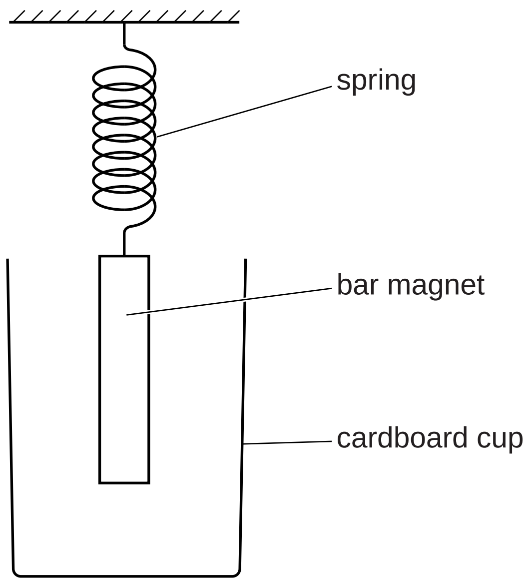

Fig. 1.1

In order to shield the magnet from draughts, a cardboard cup is placed around the magnet but does not touch it.
The magnet is displaced vertically and then released. The variation with time *t* of the vertical displacement *y* of the magnet is shown in Fig. 1.2.

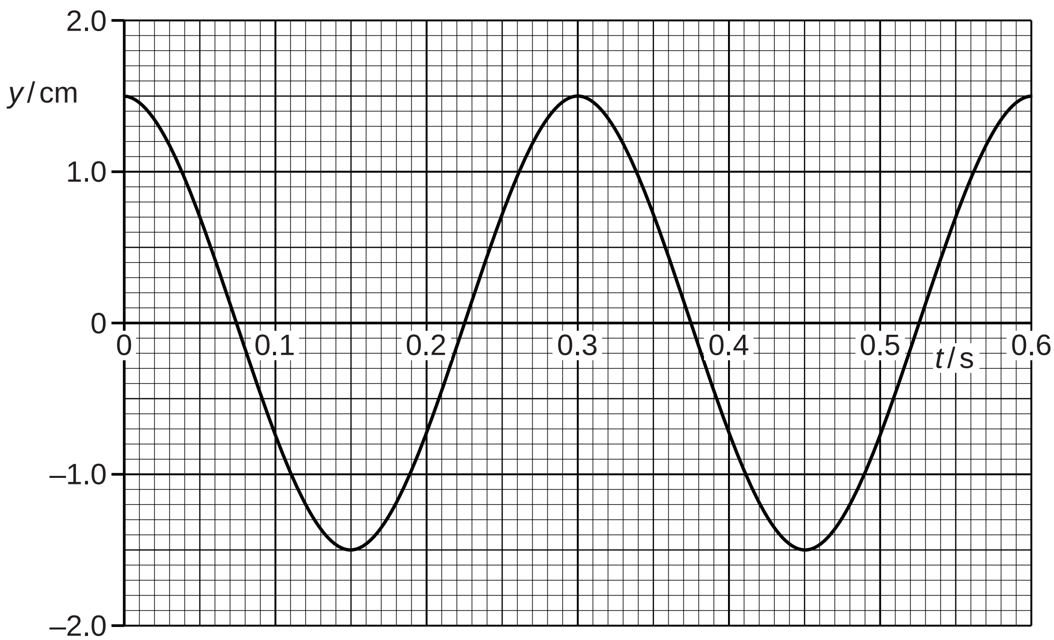

Fig. 1.2

The mass of the magnet is 130 g.

(a) For the oscillations of the magnet, use Fig. 1.2 to

(i) determine the angular frequency ω,

ω = ... rad s^{-1} [2]

(ii) show that the maximum kinetic energy of the oscillating magnet is 6.4 mJ.

[2]

(b) The cardboard cup is now replaced with a cup made of aluminium foil.
During 10 complete oscillations of the magnet, the amplitude of vibration is seen to decrease to 0.75 cm from that shown in Fig. 1.2. The change in angular frequency is negligible.

(i) Use Faraday's law of electromagnetic induction to explain why the amplitude of the oscillations decreases.

....

....

....

....

.... [3]

(ii) Show that the loss in energy of the oscillating magnet is 4.8 mJ.

[2]

(c) The mass of the aluminium cup in **(b)** is 6.2 g. The specific heat capacity of aluminium is 910 J kg^{-1} K^{-1}.
The energy in **(b)(ii)** is transferred to the cup as thermal energy.
Calculate the mean rise in temperature of the cup.

temperature rise = ... K [2]

3 A fixed mass of gas has an initial volume of $5.00 \times 10^{-4}\,m^3$ at a pressure of $2.40 \times 10^5\,Pa$ and a temperature of 288 K. It is heated at constant pressure so that, in its final state, the volume is $14.5 \times 10^{-4}\,m^3$ at a temperature of 835 K, as illustrated in Fig. 3.1.

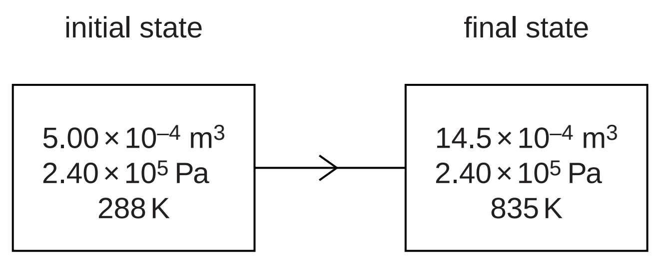

Fig. 3.1

(a) Show that these two states provide evidence that the gas behaves as an ideal gas.

[3]

(b) The total thermal energy supplied to the gas for this change is 569 J.

Determine

(i) the external work done,

work done = ... J [2]

(ii) the change in internal energy of the gas. State whether the change is an increase or a decrease in internal energy.

change in internal energy = ... J

.... [2]

4 The product of the pressure p and the volume V of an ideal gas is given by the expression

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

where m is the mass of one molecule of the gas.

(a) State the meaning of the symbol

(i) N,

....[1]

(ii) $\langle c^2\rangle$.

....[1]

(b) The product pV is also given by the expression

$$pV = NkT.$$

Deduce an expression, in terms of the Boltzmann constant k and the thermodynamic temperature T, for the mean kinetic energy of a molecule of the ideal gas.

[2]

(c) A cylinder contains 1.0 mol of an ideal gas.

(i) The volume of the cylinder is constant.
Calculate the energy required to raise the temperature of the gas by 1.0 kelvin.

energy = ... J [2]

(ii) The volume of the cylinder is now allowed to increase so that the gas remains at constant pressure when it is heated.
Explain whether the energy required to raise the temperature of the gas by 1.0 kelvin is now different from your answer in **(i)**.

....

....

....[2]

5 **(a)** One assumption of the kinetic theory of gases is that gas molecules behave as if they are hard, elastic identical spheres.

State two other assumptions of the kinetic theory of gases.

1. ....

....

2. ....

.... [2]

(b) Using the kinetic theory of gases, it can be shown that the product of the pressure p and the volume V of an ideal gas is given by the expression

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

where m is the mass of a gas molecule.

(i) State the meaning of the symbol

1. N,

....[1]

2. $\langle c^2\rangle$.

....[1]

(ii) Use the expression to deduce that the mean kinetic energy $\langle E_K\rangle$ of a gas molecule at temperature T is given by the equation

$$\langle E_K\rangle = \frac{3}{2}kT$$

where k is a constant.

[2]

(c) **(i)** State what is meant by the *internal energy* of a substance.

....

....

.... [2]

(ii) Use the equation in **(b)(ii)** to explain that, for an ideal gas, a change in internal energy ΔU is given by

$$\Delta U \propto \Delta T$$

where ΔT is the change in temperature of the gas.

....

....

.... [2]

6 **(a)** **(i)** State the basic assumption of the kinetic theory of gases that leads to the conclusion that the potential energy between the atoms of an ideal gas is zero.

....

.... [1]

(ii) State what is meant by the *internal energy* of a substance.

....

....

.... [2]

(iii) Explain why an increase in internal energy of an ideal gas is directly related to a rise in temperature of the gas.

....

....

.... [2]

(b) A fixed mass of an ideal gas undergoes a cycle PQRP of changes as shown in Fig. 2.1.

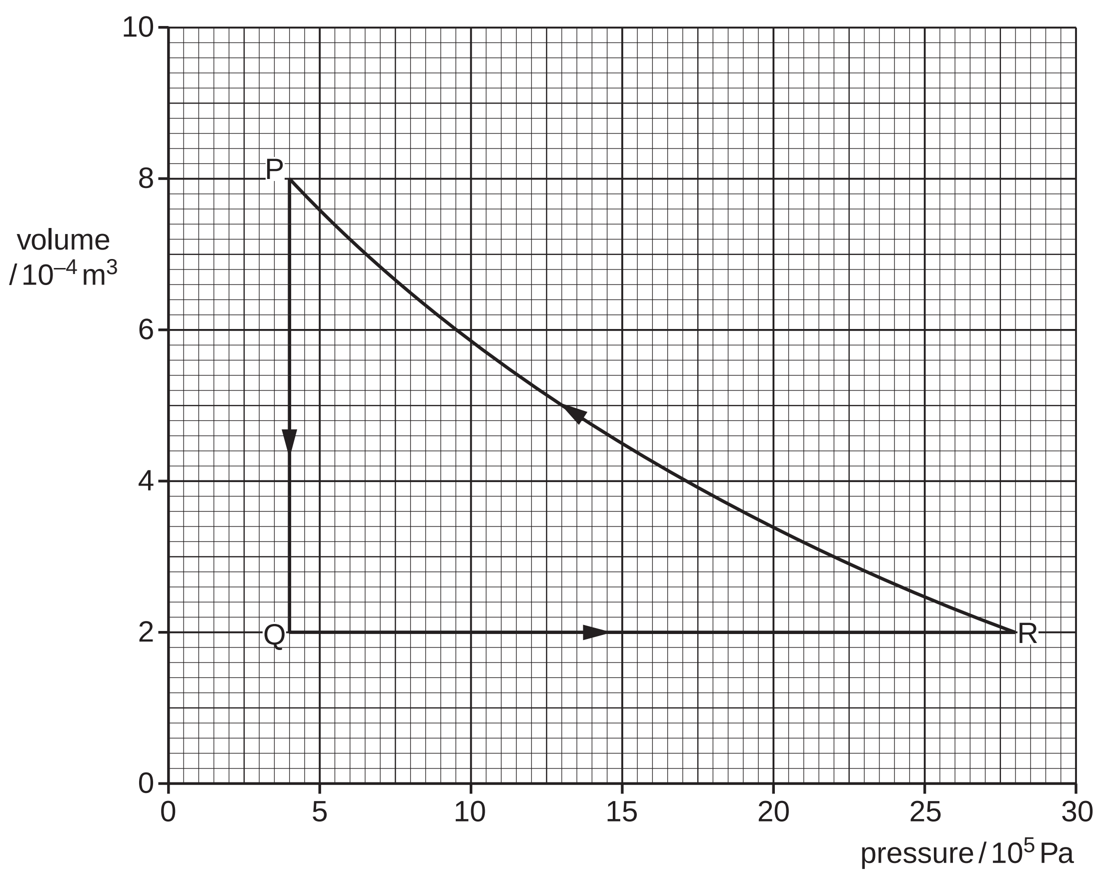

Fig. 2.1

(i) State the change in internal energy of the gas during one complete cycle PQRP.

change = ... J [1]

(ii) Calculate the work done on the gas during the change from P to Q.

work done = ... J [2]

(iii) Some energy changes during the cycle PQRP are shown in Fig. 2.2.

change	work done on gas / J	heating supplied to gas / J	increase in internal energy / J
P → Q	....	–600	....
Q → R	0	+720	....
R → P	....	+480	....

Fig. 2.2

Complete Fig. 2.2 to show all of the energy changes. [3]

7 **(a)** The resistance of a thermistor at 0 °C is 3840 Ω. At 100 °C the resistance is 190 Ω. When the thermistor is placed in water at a particular constant temperature, its resistance is 2300 Ω.

(i) Assuming that the resistance of the thermistor varies linearly with temperature, calculate the temperature of the water.

temperature = ... °C [2]

(ii) The temperature of the water, as measured on the thermodynamic scale of temperature, is 286 K.

By reference to what is meant by the thermodynamic scale of temperature, comment on your answer in **(i)**.

....

....

....

.... [3]

(b) A polystyrene cup contains a mass of 95 g of water at 28 °C.

A cube of ice of mass 12 g is put into the water. Initially, the ice is at 0 °C. The water, of specific heat capacity $4.2 \times 10^3\ \mathrm{J\,kg^{-1}\,K^{-1}}$, is stirred until all the ice melts.

Assuming that the cup has negligible mass and that there is no heat exchange with the atmosphere, calculate the final temperature of the water.

The specific latent heat of fusion of ice is $3.3 \times 10^5\ \mathrm{J\,kg^{-1}}$.

temperature = ... °C [4]

8 **(a)** A student states, quite wrongly, that temperature measures the amount of thermal energy (heat) in a body.

State and explain two observations that show why this statement is incorrect.

1. ....

....

....

2. ....

....

....

[4]

(b) A thermometer and an electrical heater are inserted into holes in an aluminium block of mass 960 g, as shown in Fig. 3.1.

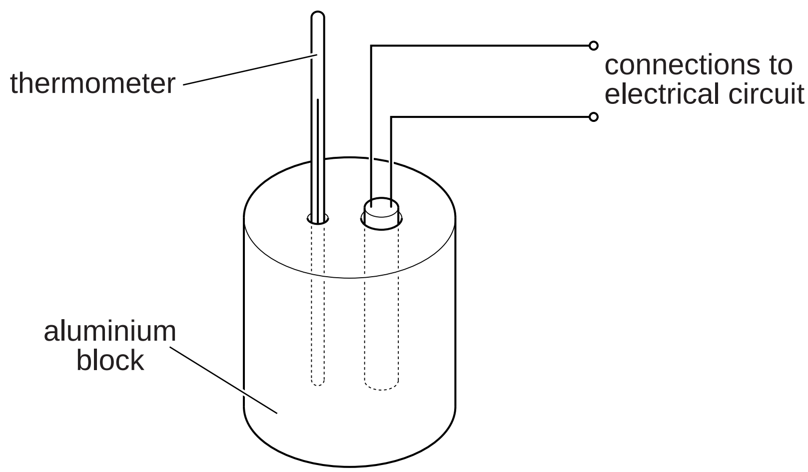

Fig. 3.1

The power rating of the heater is 54 W.

The heater is switched on and readings of the temperature of the block are taken at regular time intervals. When the block reaches a constant temperature, the heater is switched off and then further temperature readings are taken. The variation with time *t* of the temperature θ of the block is shown in Fig. 3.2.

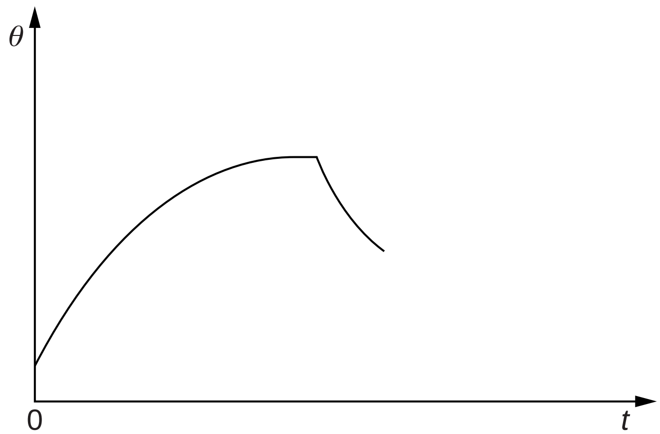

Fig. 3.2

(i) Suggest why the rate of rise of temperature of the block decreases to zero.

....

....

.... [2]

(ii) After the heater has been switched off, the maximum rate of fall of temperature is 3.7 K per minute.

Estimate the specific heat capacity of aluminium.

specific heat capacity = ... J kg^{-1} K^{-1} [3]