# 2. Thermal physics

## 2.2 Thermal properties and temperature

## Paper 3 and 4

Question Paper

# Paper 3

**Questions are applicable for both core and extended candidates**

1 Fig. 4.1 shows students walking to school. There are puddles of water on the ground.

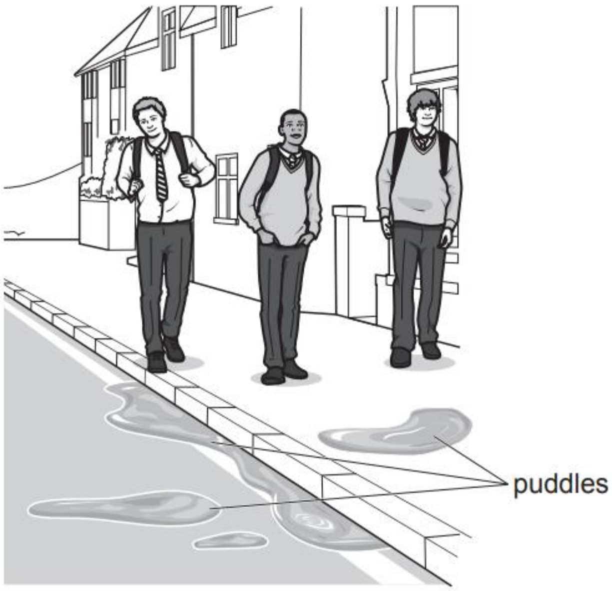


**Fig. 4.1**

After school, the puddles have disappeared and the ground is dry.

**(a) (i)** State the name of the process that causes the puddles to disappear.

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**(ii)** Describe the process that causes the puddles to disappear.
Use your ideas about molecules.

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2 A teacher fills a copper can with solid wax and heats the can. She measures the temperature of the wax every minute. She continues heating once the wax has melted and stops heating when the wax is boiling.

**(a) (i)** State the term used for the process that transfers thermal energy through the copper.

.................................................................................................................................... [1]

**(ii)** Fig. 6.1 shows how the temperature of the wax changes as it is heated.

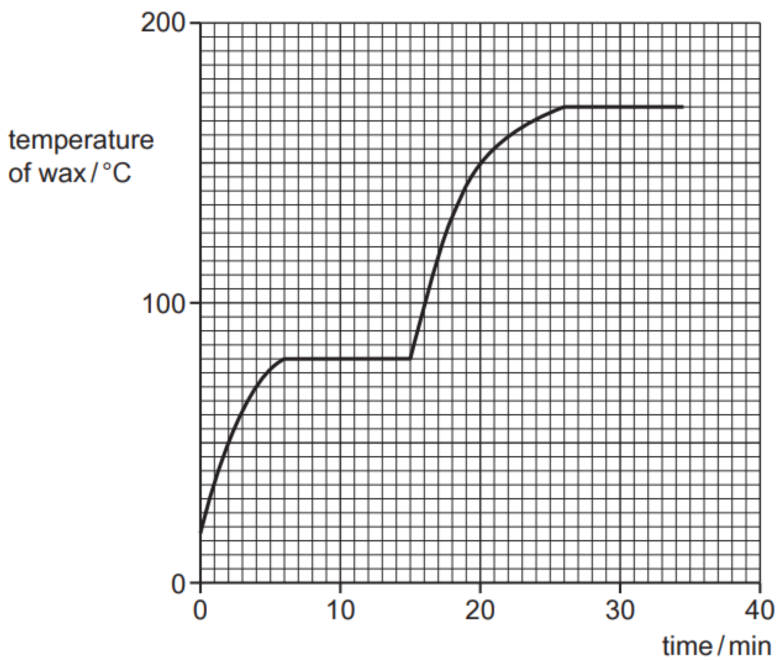


**Fig. 6.1**

Using the graph in Fig. 6.1, determine:

**1.** the melting point of the wax ...................................................... °C [1]

**2.** the boiling point of the wax ...................................................... °C [1]

**3.** the time at which the wax starts to boil. .................................................... min [1]

3 A beaker contains water. Some of the water evaporates.

**(a)** Describe and explain how the water evaporates. Use your ideas about molecules.

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**(b)** Evaporation changes the temperature of the water that remains in the beaker.

State and explain the change in temperature of the water due to evaporation.

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[Total: 5]

4 A liquid-in-glass thermometer is placed in some ice made from pure water. The ice is heated. It changes to water and then to steam.

The graph in Fig. 6.1 shows how the temperature varies with time. The values of temperature are missing from the y-axis.

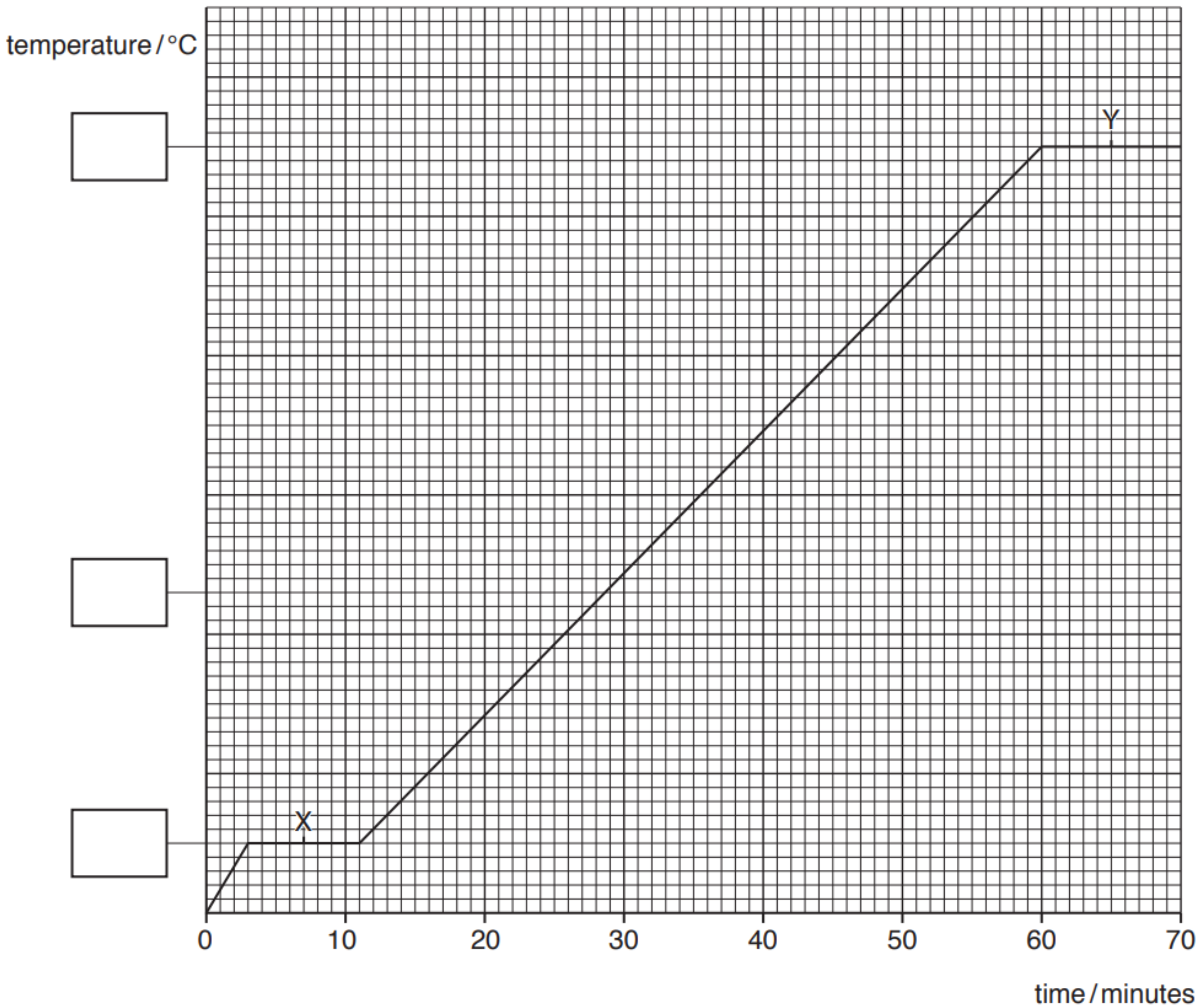


**Fig. 6.1**

**(a)** On Fig. 6.1, suggest a value for the temperature at each of the three points marked on the y-axis.

Write a value in each of the boxes. [2]

**(b)** In both section X and section Y the line on the graph is horizontal.

For each section, state the name for the process taking place and explain what is happening to the molecules.

**(i)** section X

name ..............................................................................................................

explanation ......................................................................................................

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[2]

**(ii)** section Y

name ..............................................................................................................

explanation ......................................................................................................

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[2]

[Total: 6]

5 A student places a balloon filled with air next to a window, as shown in Fig. 4.1. The Sun warms the air in the balloon.

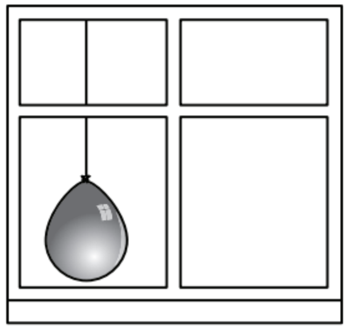

**Fig. 4.1**

**(a)** **(i)** Suggest what happens to the balloon as the air in it becomes hotter than the surroundings.

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**(ii)** Use ideas about molecules to explain your answer to **(a)(i)**.

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# Paper 4

**Questions are applicable for both core and extended candidates unless indicated in the question**

6 **(a)** Describe an experiment to determine the specific heat capacity of aluminium. You may draw a diagram.

Include in your answer: **(extended only)**

- the measurements made
- any equations needed.

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**(b)** An aluminium dish is initially at room temperature. Boiling water is poured into the aluminium dish as shown in Fig. 4.1.

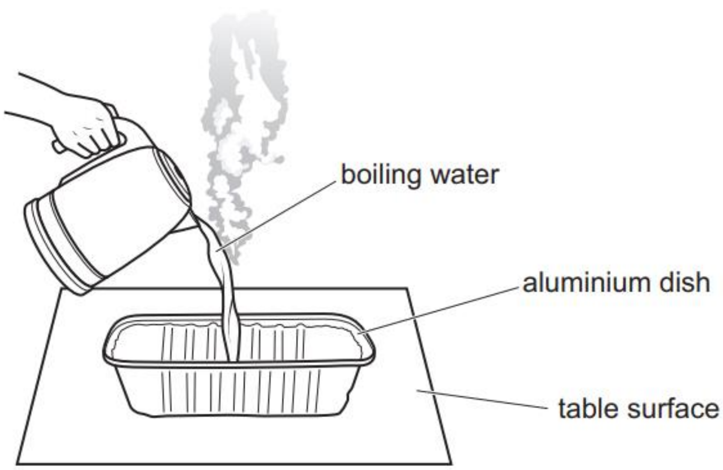


**Fig. 4.1**

**(i)** Explain why, after a short time, the dish and the water are the same temperature.

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**(ii)** Explain, in terms of its particles, why the aluminium expands as the boiling water is poured into the dish.

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**(iii)** The water in the dish evaporates.

Explain, in terms of the water molecules, what is meant by evaporation.

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[Total: 11]

7 Fig. 4.1 shows a pressure cooker on an electric heating element. The cooker has a tight-fitting lid.

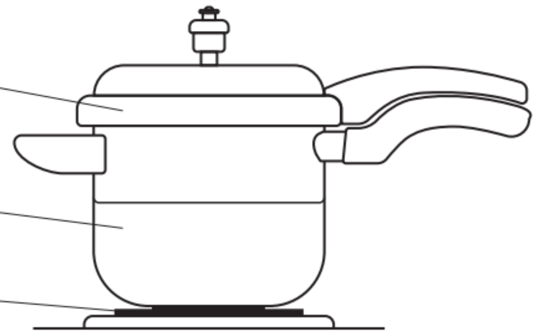


**Fig. 4.1**

**(a)** The pressure cooker is half-full of water. As the water is heated some water evaporates before the water boils. **(extended only)**
Describe **two** differences between evaporation and boiling of the water in the cooker.

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.................................................................................................................................... [2]

**(b)** As the water is heated, the pressure of the gas inside the cooker increases.
Explain this increase in pressure in terms of particles.

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.................................................................................................................................... [4]

[Total: 6]

8 **(a)** State **two** ways that evaporation differs from boiling. **(extended only)**

1 ..........................................................................................................................

2 ..........................................................................................................................
[2]

**(b)** Fig. 4.1 shows part of a container used to store a mixture of liquid and gaseous oxygen.

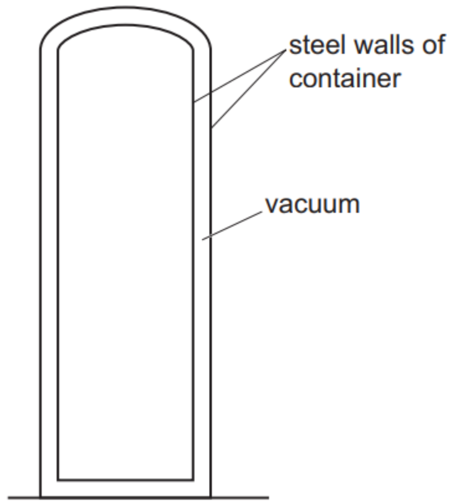


**Fig. 4.1**

The temperature of the liquid oxygen is –160 °C.

**(i)** Determine the temperature of the liquid oxygen in K.

temperature = ........................................................ K [1]

**(ii)** The container is made of steel and there is a vacuum between the inner and outer walls. The outer wall of the container is at room temperature.

State **two** methods of thermal energy transfer that a vacuum prevents.

1 ..........................................................................................................................

2 ..........................................................................................................................
[2]

**(c)** Describe, in terms of particles, how a gas exerts a pressure on the walls of its container.

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[Total: 8]

9 Fig. 2.1 shows an electric tumble dryer used to dry wet clothes.

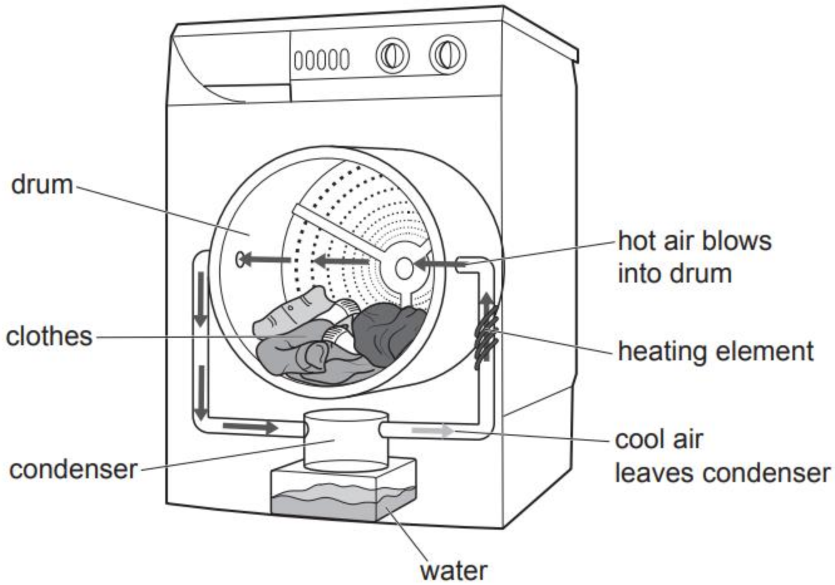


**Fig. 2.1**

**(a)** Hot air blows into the drum. The air gains water vapour from the clothes and then leaves the drum. The moist air enters the condenser. Cool air leaves the condenser, passes through the heating element and enters the drum again.

**(i)** State the process by which the hot air removes water from the wet clothes.

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**(ii)** The air is cooled as it passes through the condenser.

Describe and explain **one** other way in which the air leaving the condenser is different from the air entering the condenser.

description .............................................................................................................

explanation .............................................................................................................

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[2]

**(b)** The drum of the tumble dryer rotates, lifting up the wet clothes which then fall down through the hot air.

**(i)** Name the force that causes the clothes to fall down.

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**(ii)** When the drum rotates too fast the clothes remain in contact with the wall of the drum.
**(extended only)**

State the direction of the resultant force on the clothes during the circular motion.

............................................................................................................................. [1]

**(c)** Suggest why using a clothesline to dry clothes in the open air is better for the environment than using an electric tumble dryer.

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.................................................................................................................................... [1]

[Total: 6]

10 **(b)** The mass of water in the bottle is 0.18 kg. The specific heat capacity of water is 4200 J / (kg °C).

Calculate the thermal energy needed to increase the temperature of the water by 20 °C.
**(extended only)**

thermal energy = ......................................................... [2]

**(c)** Another plastic bottle is filled to the top with water. The height of the bottle is 40.0 cm. The density of water is $1.0 \times 10^3$ kg / $m^3$. **(extended only)**

Calculate the pressure difference between the top and bottom of the water.

pressure difference = ......................................................... [2]

11 A student investigates the efficiency of a filament lamp. Fig. 4.1 shows the filament lamp with its glass bulb immersed in water in a beaker.

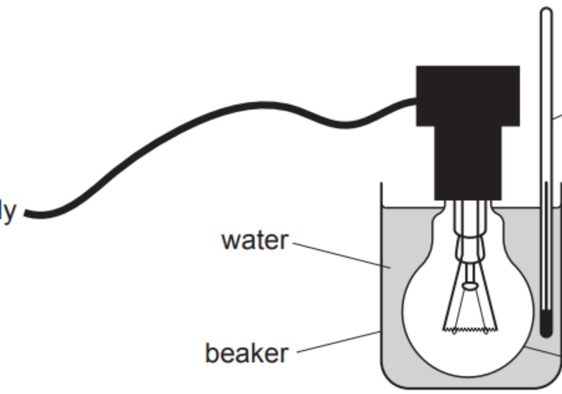


**Fig. 4.1**

The reading on the thermometer in the water is 19.0 °C.

Only the glass of the lamp is in contact with the water and the electrical connections are completely insulated.

The lamp is switched on.

At the end of the experiment, the temperature of the water is 21.5 °C.

**(a)** The mass of the water in the beaker is 600 g and the specific heat capacity of water is 4200 J / (kg °C).

**(i)** Show that the increase in the internal energy of the water is 6300 J.
**(extended only)**

[3]

**(ii)** In the experiment, the lamp is switched on for 500 s. The power supplied to the filament lamp is 13 W. The useful energy from the lamp is transferred as light. The energy that increases the temperature of the water is wasted energy. **(extended only)**

Determine the maximum possible efficiency of the filament lamp.

maximum possible efficiency = ........................................................ [4]

**(b)** The efficiency of the lamp is less than the value determined in **(a)(ii)**. **(extended only)**

Suggest **one** reason for this.

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.................................................................................................................................... [1]

[Total: 8]

12 **(a)** Fig. 5.1 shows an electric heater used to heat a room.

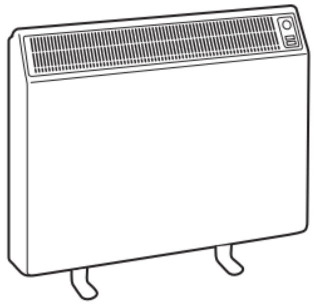

**Fig. 5.1**

The dimensions of the room are 4.5 m × 6.1 m × 2.4 m.
The density of air is 1.2 kg / m$^3$.

**(i)** Show that the mass of air in the room is 79 kg.

[2]

**(ii)** The power of the heater is 1100 W. The specific heat capacity of air is 1000 J / (kg °C).

Calculate the time taken to increase the temperature of the air in the room from 16.0 °C to 20.0 °C. **(extended only)**

time = ........................................................... [4]

**(iii)** Suggest **one** reason why the time calculated in **(a)(ii)** is the **minimum** time needed to increase the temperature of the air in the room from 16.0 °C to 20.0 °C. **(extended only)**

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**(b)** Fig. 5.2 shows a cross-section of a double-glazed window in the room.

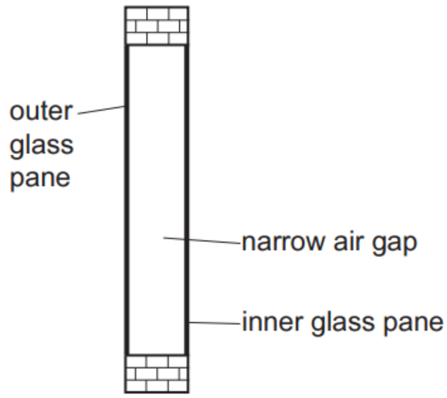


**Fig. 5.2**

State the main methods of thermal energy transfer from the room to outside which are reduced by this type of window.

............................................................................................................................ [1]

[Total: 8]

13 A quantity of gas is trapped by a piston in a cylinder with thin metal walls. The piston is free to move without friction within the cylinder.

Fig. 4.1 shows the cylinder and piston.

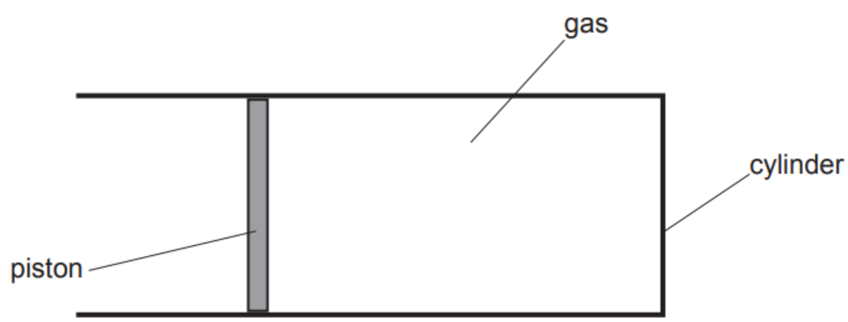


**Fig. 4.1**

The cylinder is placed inside a freezer.

**(b)** The initial temperature of the cylinder and the gas is 21 °C and, in the freezer, the temperature of the cylinder decreases to –18 °C. **(extended only)**

The thermal capacity of the cylinder is 89 J / °C.

Calculate the change in the internal energy of the cylinder.

change in internal energy = ......................................................... [2]

14 Fig. 5.1 shows an aluminium block after leaving a furnace in a factory.

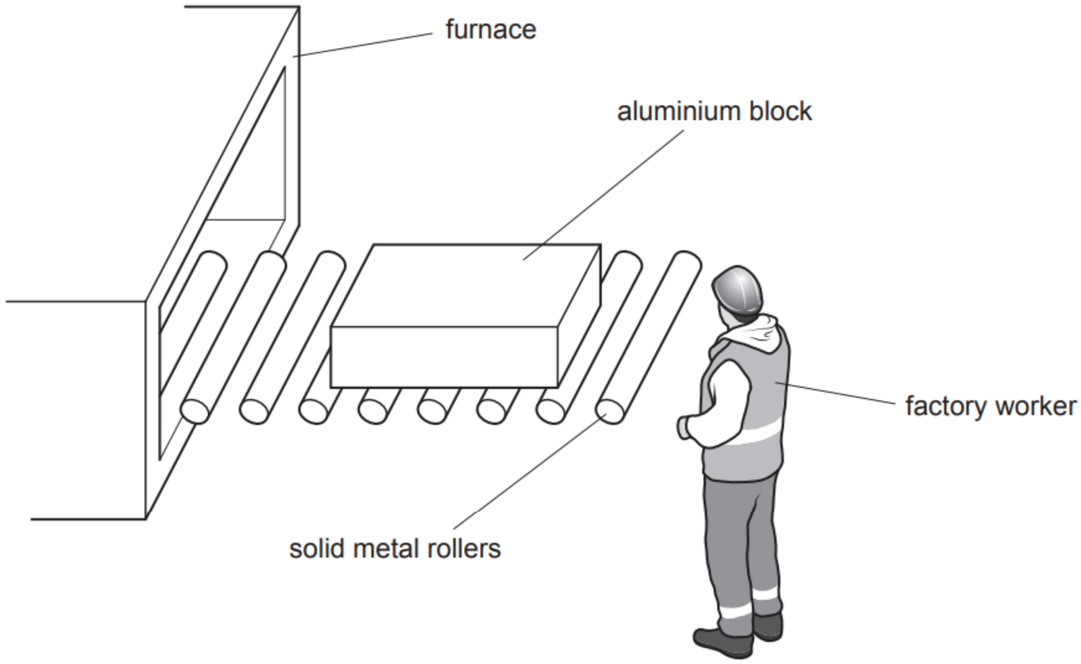


**Fig. 5.1**

**(a)** The mass of the block is 1200 kg and it is heated in the furnace from 20 °C to 380 °C. The aluminium block does not melt.
The specific heat capacity of aluminium is 960 J / (kg °C). **(extended only)**

Calculate the thermal energy gained by the block in the furnace.

thermal energy = ........................................................ [3]

15 During a picnic on a warm, dry day, a metal can of lemonade is wrapped in a damp cloth.

Evaporation cools the water in the cloth.

**(a)** Explain, in terms of molecules, how evaporation cools the water in the cloth.

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16 Fig. 5.1 shows a kitchen tap that supplies instant boiling water.

**Fig. 5.1**

Cold water passes over an electric immersion heater inside the tap.

The boiling point of water is 100 °C.

**(a)** State what is meant by boiling point.

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**(b)** The immersion heater is powered by the mains at a voltage of 230 V. When the tap is opened, the heater switches on and the current in the heater is 13 A.

**(i)** Calculate the thermal energy produced by the heater in 60 s.

thermal energy = ........................................................... [2]

**(ii)** The specific heat capacity of water is 4200 J / (kg °C). The cold water that enters the tap is at 22 °C. **(extended only)**

Calculate the rate at which water at its boiling point emerges from the tap.

rate = ........................................................... [4]

17 **(a)** State and explain the **two** features of a liquid-in-glass thermometer that are necessary for linearity.

statement 1 ..........................................................................................................

explanation ..........................................................................................................

statement 2 ..........................................................................................................

explanation ..........................................................................................................
[4]

**(b)** The value of the heat capacity of the hot junction of a thermocouple thermometer is important in ensuring that it can measure temperature changes very rapidly. **(extended only)**

Explain why.

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**(c)** The hot junction of a thermocouple thermometer has a heat capacity of 0.11 J / °C.

Calculate the thermal energy required to increase the temperature of the hot junction from 20 °C to 345 °C. **(extended only)**

energy = .......................................................... [3]

[Total: 9]

18 An aluminium saucepan with a plastic handle contains cold water.

Fig. 4.1 shows the saucepan on a hotplate.

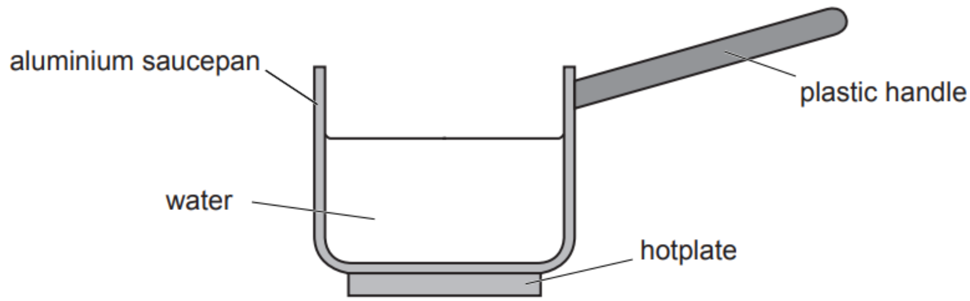


Fig. 4.1

**(a)** State why the pan is made from aluminium but the handle is made from plastic.

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............................................................................................................................... [1]

**(b)** The hotplate is switched on and, as the temperature of the water increases, the internal energy of the water increases.

**(i)** State, in terms of molecules, what is meant by *an increase in internal energy*. **(extended only)**

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............................................................................................................................... [1]

**(ii)** Explain, in terms of the atomic lattice and electrons, how thermal energy is transferred through the aluminium. **(extended only)**

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**(iii)** Eventually, the water reaches boiling point. Thermal energy from the hotplate is still being transferred to the water.

Explain, in terms of molecules, the effect of this thermal energy on the water.

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**(iv)** The mass of the water decreases by 0.11 kg in 300 s. The specific latent heat of vaporisation of water is $2.3 \times 10^6$ J/kg.

Calculate the rate at which the water gains thermal energy. **(extended only)**

rate of gain of energy = ........................................................ [3]

[Total: 11]

19 **(a)** Pollen particles are mixed into a liquid. They are seen to move when observed through a microscope.

**(i)** Describe this movement.

............................................................................................................................ [1]

**(ii)** Explain this movement in terms of the molecules of the liquid and the pollen particles.

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............................................................................................................................ [3]

**(b)** **(i)** Medical professionals sometimes rub ethanol over the skin of a patient. Ethanol evaporates readily at room temperature and has a high specific latent heat of vaporisation.

State whether the patient experiences heating, cooling or neither at the site where the ethanol is applied. Explain your answer. **(extended only)**

statement ............................................................................................................

explanation ..........................................................................................................

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............................................................................................................................ [3]

**(ii)** State any effect on the rate of evaporation of ethanol when a fan blows air over the patient's skin. **(extended only)**

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[Total: 8]

20 A large test-tube contains a liquid at room temperature. An electric heater is immersed in the liquid and is switched on. Thermal energy is supplied to the liquid by the heater. The temperature of the liquid increases until it reaches its boiling point. The liquid then starts to change into gas.

**(c)** **(i)** Explain, in terms of molecules, why a supply of thermal energy is needed to change the liquid into a gas.

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.................................................................................................................................. [1]

**(ii)** The density of the liquid in the test-tube is 0.86 g / $cm^3$. The volume of liquid in the test-tube is 50 $cm^3$.

The liquid reaches its boiling point. It now absorbs 18 000 J of thermal energy and all of the liquid changes into a gas.

Calculate the specific latent heat of vaporisation of this liquid. **(extended only)**

specific latent heat = ........................................................ [3]

21 **(a)** A solar panel receives energy from the Sun at a rate of 5.0 kW. **(extended only)**

Thermal energy is transferred from the solar panel to water with an efficiency of 20%.

Cold water of mass 15 kg enters the solar panel every hour.

The specific heat capacity of water is 4200 J / (kg °C).

Calculate the temperature increase of the water.

temperature increase = ...................................................... °C [4]