

## Thermal Energy

1. The relative masses of oxygen and hydrogen molecules are 32 and 2 respectively. For any given temperature, the ratio

$\frac{\text{root mean square speed of oxygen molecules}}{\text{root mean square speed of hydrogen molecules}}$  is given by

A  $\frac{1}{16}$

B  $\frac{1}{4}$

C 4

D 16

(Total 1 mark)

2. The average kinetic energy of the molecules in a gas is proportional to

A the number of molecules in the gas.

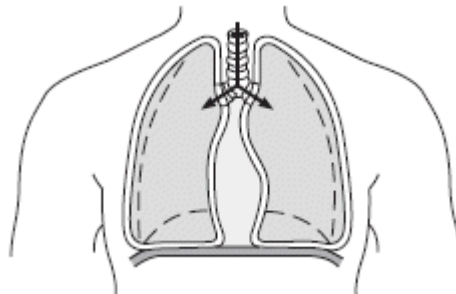
B the specific heat capacity of the gas.

C the temperature of the gas.

D the total mass of the gas.

(Total 1 mark)

3. When your diaphragm contracts, the pressure in the chest cavity is lowered below atmospheric pressure and air is forced into your lungs.



- (a) The diaphragm contracts and the lung capacity increases by 20%. State **two** assumptions you would need to make to calculate the new pressure in the lungs if the initial pressure is known.

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(2)

- (b) (i) The volume of air inhaled in a typical breath is  $2.5 \times 10^{-4} \text{ m}^3$  and an adult takes about 25 breaths per minute. Show that the mass of air taken into the lungs each second is about  $1 \times 10^{-4} \text{ kg}$ .

Density of air =  $1.2 \text{ kg m}^{-3}$

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(2)

- (ii) If body temperature is  $37.6 \text{ }^\circ\text{C}$  and the temperature outside the body is  $20.0 \text{ }^\circ\text{C}$ , calculate the rate at which energy is used to warm air up to body temperature.

Specific heat capacity of air =  $1000 \text{ J kg}^{-1} \text{ K}^{-1}$

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Rate = .....

(2)

(Total 6 marks)

4. A valid set of units for specific heat capacity is

A  $\text{kg J}^{-1} \text{K}^{-1}$

B  $\text{kg J K}^{-1}$

C  $\text{kg}^{-1} \text{J K}^{-1}$

D  $\text{kg J}^{-1} \text{K}$

(Total 1 mark)

5. An ideal gas is contained in a volume of  $2.0 \times 10^{-3} \text{ m}^3$ .

(a) Explain why the internal energy of an ideal gas is only kinetic.

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(2)

(b) The pressure of the gas is  $1.2 \times 10^5 \text{ Pa}$  and its temperature is  $27^\circ\text{C}$ . Calculate the number of molecules of gas within this container.

Number of molecules = .....

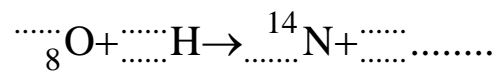
(2)

(Total 4 marks)

6. Read the following passage and answer the questions that follow.

A nova is a sudden brightening of a star. Novae are thought to occur on the surface of a white dwarf star which is paired with another star in a binary system. If these two stars are close enough to each other, hydrogen can be pulled from the surface of the star onto the white dwarf. Occasionally, the temperature of this new material on the surface of the white dwarf may become hot enough for the hydrogen to fuse to helium. This causes the white dwarf to suddenly become very bright. In a nova, this hydrogen fusion occurs by the “CNO” process, where helium-4 is produced by a series of steps in which protons react with various isotopes of Carbon, Nitrogen and Oxygen. Novae are used by astronomers as standard candles.

(a) Complete the equation which shows a typical part of the CNO process.



(3)

(b) What is a white dwarf ? Suggest why hydrogen fusion in the white dwarf is likely to be the CNO process.

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(3)

(c) The temperature required for these processes is  $10^7$  K.

(i) Calculate the mean kinetic energy, in keV, of the particles involved.

energy of particles = ..... keV (3)

(ii) Explain how this temperature arises.

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(2)

(d) Astronomers use novae as standard candles. Explain what a standard candle is, and suggest what this implies about the processes occurring in a nova.

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(3)

**(Total 14 marks)**

7. (a) What is meant by the absolute zero of temperature?

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(1)

(b) (i) The Football Association rules require a football to have a maximum volume of  $5.8 \times 10^{-3} \text{ m}^3$  and a maximum pressure of  $1.1 \times 10^5 \text{ Pa}$  above atmospheric pressure ( $1.0 \times 10^5 \text{ Pa}$ ). Assuming that the thickness of the material used for the ball is negligible and that the air inside the ball is at a temperature of  $10^\circ \text{C}$ , show that the maximum amount of air inside the football is about 0.5 mol.

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(4)

(ii) One mole of air has a mass of 0.029 kg. Calculate the maximum mass of air allowed in the football.

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Maximum mass = .....

(1)

- (iii) A football is also required to have a minimum pressure  $0.6 \times 10^5$  Pa above atmospheric pressure. Assuming the volume of the football remains constant, calculate the lowest temperature to which the air inside this ball could fall to while still meeting the pressure requirements.

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Lowest temperature = .....

(3)  
 (Total 9 marks)

8. A problem with warming milk in a saucepan is that it can suddenly boil over if it is not watched carefully. A student decides to take some measurements to find the time it takes for the milk to reach a temperature of  $96^\circ\text{C}$  so he can be ready for it without having to keep a constant watch.

- (a) The student first uses an electric hotplate to warm a saucepan of water from room temperature to  $96^\circ\text{C}$ . He measures the time taken to be 347 s.

He calculates the heat energy gained by the water to be  $1.63 \times 10^5$  J.

Show that the rate at which heat energy is supplied to the water by the electric hotplate is about 500W.

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(2)

- (b) The student then uses the following data to calculate the time taken for milk taken from a refrigerator to reach the temperature of  $96^\circ\text{C}$ .

mass of milk = 0.44 kg  
 initial temperature of milk =  $12^\circ\text{C}$   
 desired final temperature of milk =  $96^\circ\text{C}$   
 specific heat capacity of milk =  $3800 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}$

(i) Show that the heat energy the milk needs to gain is about  $1 \times 10^5$  J.

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(2)

(ii) Calculate the time it would take for the milk to reach the temperature of  $96^\circ\text{C}$ . Assume that the student uses the same hotplate as in (a).

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Time = .....

(2)

(c) The student warms up the milk and is surprised when the time taken is exactly the time calculated. He had expected it to take longer because of heat losses.

(i) Explain why he might expect it to take longer.

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(1)

(ii) Suggest why the calculated time was the same as the actual time.

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(1)

(Total 8 marks)



9. In a radio programme about space tourism, the presenter says that the Earth's atmosphere stops 100 km above the surface. A student decides to put this claim to the test, initially applying the following equation to gas molecules at this height:

$$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$$

where  $k$  is the Boltzmann constant.

- (a) (i) State the meanings of the other symbols used in the equation.

$m$  .....

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

$T$  .....

(3)

- (ii) What physical quantity does each side of the equation represent?

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.....

(1)

- (iii) Calculate a value for the velocity of an oxygen molecule at this height, where the temperature is  $-50^\circ\text{C}$ .

Mass of oxygen molecule =  $5.4 \times 10^{-26}$  kg

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Velocity = .....

(2)

(b) The student decides that if there really is no atmosphere above the height of 100 km this velocity must be equal to the escape velocity. The escape velocity is the minimum velocity needed for any particle to escape from the Earth's gravitational attraction. He obtains an expression for the escape velocity, starting with the total energy of a molecule at this height, i.e. its kinetic energy + its potential energy.

(i) He finds that the potential energy of a mass  $m$  at distance  $r$  from the centre of the Earth is given by  $-GMm/r$ , where  $M$  is the mass of the Earth. Hence show that the escape velocity is given by:

$$v_{\text{esc}} = \sqrt{\left(\frac{2GM}{r}\right)}$$

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(2)

(ii) Show that the escape velocity for an oxygen molecule from this height is more than  $10 \text{ km s}^{-1}$ .

Mass of Earth =  $5.98 \times 10^{24} \text{ kg}$

Radius of Earth =  $6.37 \times 10^6 \text{ m}$

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(2)

- (iii) The graph below shows the distribution of velocities for molecules in a sample of gas at  $-50\text{ }^{\circ}\text{C}$ .

Use the graph below to explain whether oxygen molecules are likely to escape.

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(2)  
(Total 12 marks)

10. (a) Describe how the concept of an absolute zero of temperature arises from

- (i) the ideal gas laws,

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(2)

- (ii) the kinetic model of an ideal gas.

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(2)

- (b) Name the temperature scale based on absolute zero.

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(1)

(c) The oven of a cooker has a volume of  $0.10 \text{ m}^3$ . The air in the oven is at normal atmospheric pressure,  $1.0 \times 10^5 \text{ Pa}$ .

(i) Calculate the mass of air in the oven at  $27^\circ\text{C}$ .

1 mole of air has a mass of  $0.029 \text{ kg}$ .

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Mass of air = .....

(4)

(ii) When the oven is heated the pressure of the air in the oven stays at atmospheric pressure but the density of the air changes. Calculate the ratio of the density of air at  $227^\circ\text{C}$  to its density at  $27^\circ\text{C}$ .

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(3)

(Total 12 marks)

11. (a) A student investigates how the pressure of a gas depends on its temperature.

(i) To carry out this experiment, two variables must be kept constant. What are they?

1 .....

2 .....

(2)

(ii) Draw a labelled diagram of the apparatus the student could use.

(4)

(iii) State **one** precaution the student should take to improve the quality of the results.

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(1)

(b) In the space below sketch a graph to show how the pressure of an ideal gas depends on its temperature. Add any key values to your temperature axis.

(3)

(Total 10 marks)

12. (a) (i) Define specific heat capacity.

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(2)

(ii) Explain the term internal energy.

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(2)

(b) A night storage heater contains a stack of bricks which is warmed in the night by electric power and then gives off its energy during the day to the room.

A heater of this type contains bricks of total mass 800 kg. Calculate the energy given out by this heater as it cools from 70 °C to 20 °C.

Specific heat capacity of brick =  $1.1 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$

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Energy = .....

(3)

(Total 7 marks)

13. In July 2003 there was an attempt to fly a manned, spherical balloon to a height of about forty kilometres. At this height the atmospheric pressure is only one thousandth of its value at sea level and the balloon would have expanded to a diameter of 210 m. The temperature at this height is  $-60\text{ }^\circ\text{C}$ . The attempt failed because the thin skin of the balloon split while it was being filled with helium at sea level.

(a) Make an estimate of the temperature at sea level, and hence obtain the volume of helium the balloon would have contained at sea level if it had been filled successfully.

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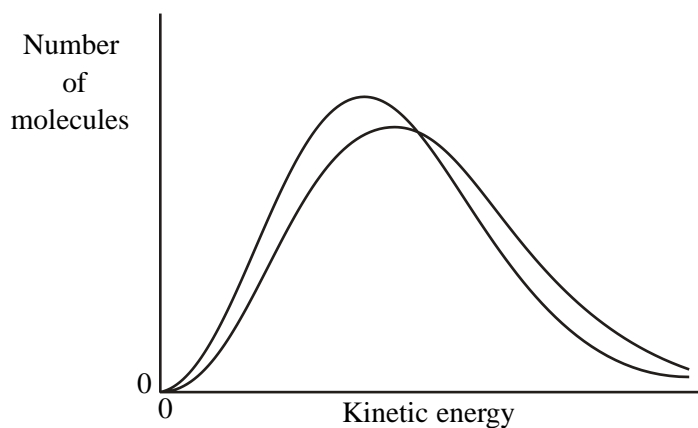
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(6)

- (b) The graphs below show the distributions of kinetic energy of the molecules in the atmosphere at sea level and at 40 km.



Label the sea level graph and give a reason for your answer.

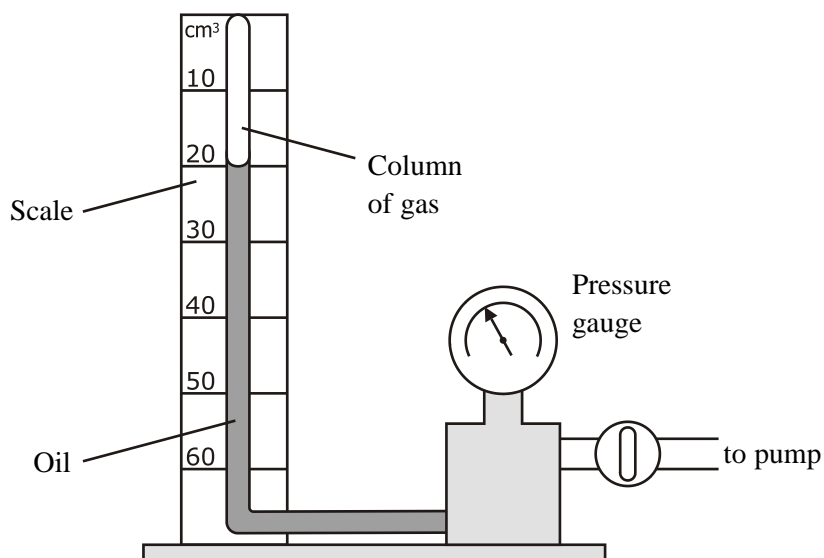
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(2)  
(Total 8 marks)

14. A student uses the following apparatus to measure the volume occupied by a fixed mass of gas at different pressures. The temperature of the gas remains at 22 °C throughout the experiment.





- (a) The volume of the gas is  $20 \text{ cm}^3$  when the gas pressure is  $200 \times 10^3 \text{ Pa}$ . Calculate the pressure exerted by the gas when its volume decreases by  $5.0 \text{ cm}^3$ .

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Pressure = .....

(3)

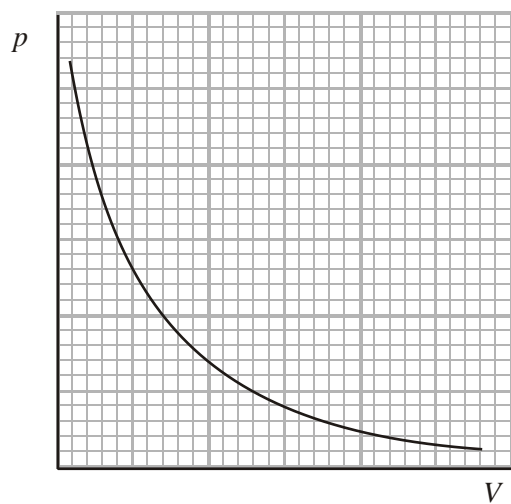
- (b) The column of oil in the tube has a cross-sectional area of  $7.9 \times 10^{-5} \text{ m}^2$ . Calculate the force exerted on the surface of the oil when the gas pressure is  $200 \times 10^3 \text{ Pa}$ .

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Force = .....

(2)

- (c) The student draws a sketch graph of her results and obtains the graph shown below.



- (i) She then correctly uses the pressure law to calculate the pressure exerted by  $20 \text{ cm}^3$  of the gas at  $35 \text{ }^\circ\text{C}$ . What value does she obtain?

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Pressure = .....

(3)

- (ii) Use the axes to sketch a graph the student would have obtained had the gas been at this higher temperature.

(2)

(Total 10 marks)

**15.** Water molecules oscillate when stimulated by high-frequency electromagnetic waves. A microwave oven heats food that contains water by forcing the water molecules to oscillate at their resonant frequency  $f_0$ .

- (a) Explain what is meant by resonance and suggest why the microwave frequency is chosen to be about  $f_0$ .

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(3)

- (b) A microwave oven is used to heat 1.2 kg of meat. The temperature of the meat increases by 75 K in the first 10 minutes.

The power of the microwave source is 800 W.

Calculate the efficiency of the heating process during this time. Take the specific heat capacity of the meat to be  $3200 \text{ J kg}^{-1} \text{ K}^{-1}$ .

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Efficiency = .....

Why does the temperature of the meat not continue to rise at this rate for the next 10 minutes?

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(4)

(Total 7 marks)

16. (a) Draw a labelled diagram of the apparatus you would use to verify that the pressure exerted by a fixed mass of gas at constant volume is directly proportional to its kelvin temperature.

(4)

- (b) State the readings you would take. Explain how you would use your measurements to verify this relationship between pressure and temperature. You may be awarded a mark for the clarity of your answer.

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(5)

- (c) State one precaution that you would take in order to ensure accurate results.

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(1)

(Total 10 marks)

17. The presence of people in a room warms the air in the room.

Use these figures to answer the questions below.

- Mass of air in room = 740 kg
- Number of people in room = 27
- Rate of thermal output from each person = 80 W
- Specific heat capacity of air =  $960 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}$

Calculate the amount of thermal energy the people in the room are providing each second.

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Amount of energy = .....

(1)

During the first 40 minutes that the people are in the room no window is open. Show that the temperature of the air might rise by about  $7\text{ }^{\circ}\text{C}$ .

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(3)

Explain whether the actual rise in temperature (with no window open) is likely to be more or less than your answer above.

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(2)

The room can be maintained at a steady temperature by having a window open, so that warm air from inside changes places with colder air from outside. The desired temperature difference between the air inside and outside the room is  $8\text{ }^{\circ}\text{C}$ .

Show that the air must be exchanged through the open window at a rate of about  $0.3\text{ kg s}^{-1}$  to maintain this steady temperature difference within the room.

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(2)

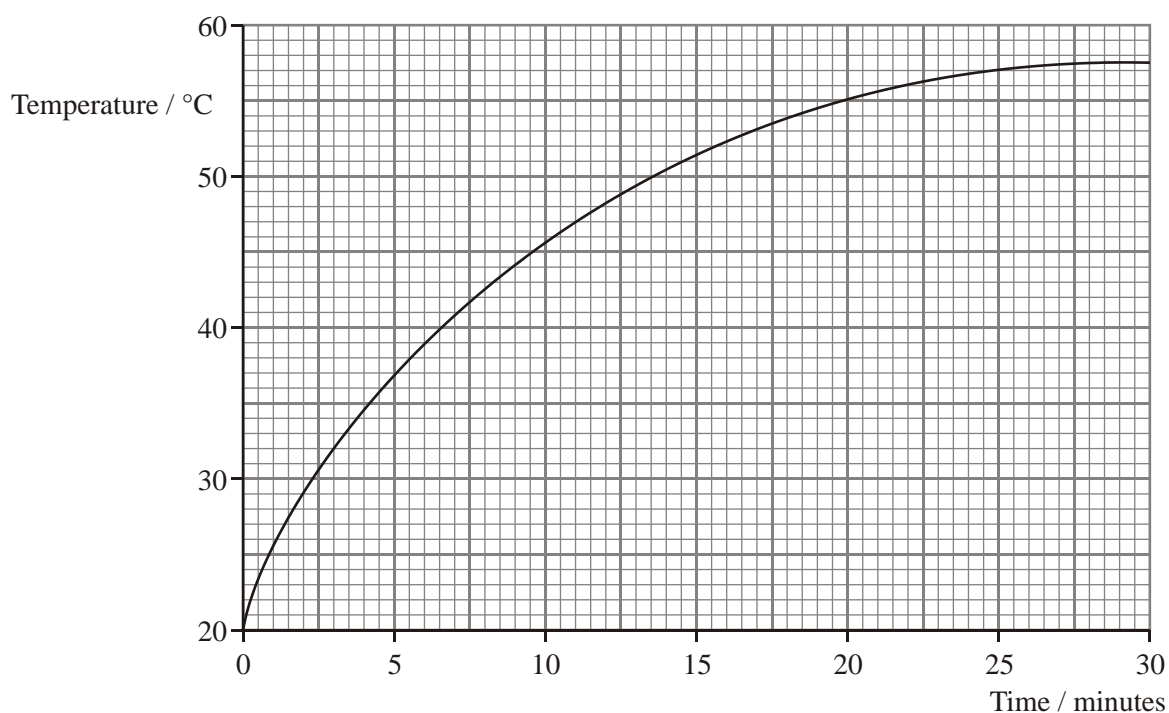
Calculate how long it will take at this rate to exchange all the air in the room.

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Time = .....

(1)  
(Total 9 marks)

18. A small electrical heater, operating at a constant power, was used to heat 64 g of water in a thin plastic cup. The mass of the cup was negligible. The temperature of the water was recorded at regular intervals for 30 minutes and a graph drawn of temperature against time.



- (a) (i) Use the graph to determine the initial rate of temperature rise of the water.

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Rate of temperature rise = .....

(2)

- (ii) The specific heat capacity of water is  $4200 \text{ J kg}^{-1} \text{ K}^{-1}$ . Determine the rate at which energy was supplied to the water by the heater.

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Rate of energy supply = .....

(3)

- (b) After 26 minutes the rate of temperature rise became very small. Explain why.

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(2)

- (c) The experiment was repeated using the same mass of water in a thick ceramic mug. The initial temperature of the water was the same and the water was heated for the same length of time.

- (i) Add to the axes opposite a possible graph of temperature against time for the water in the mug.

(2)

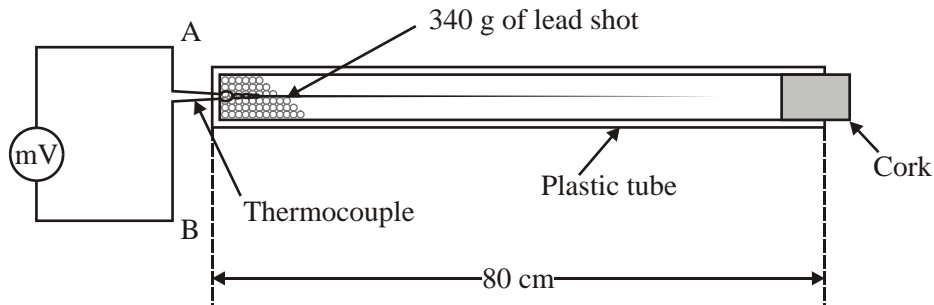
- (ii) Explain your reasoning for your graph.

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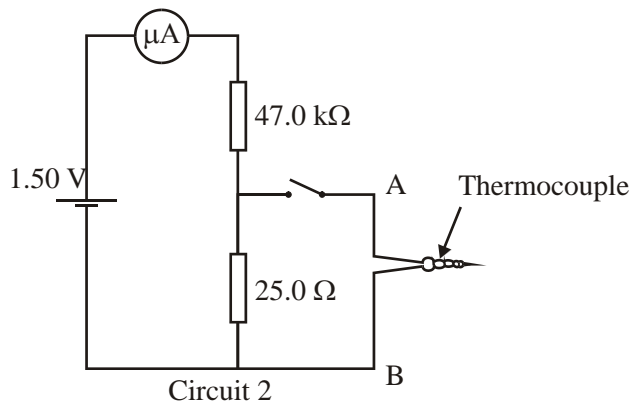
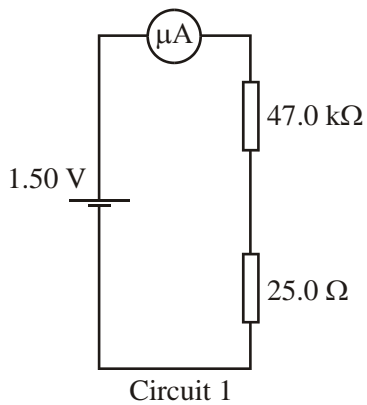
(2)

**(Total 11 marks)**

19. Some tiny spheres of lead (lead shot) of total mass 340 g are trapped in a long plastic tube. At one end there is an electrical thermometer called a thermocouple. This thermocouple registers changes in temperature as small voltages on a sensitive voltmeter.



The thermocouple generates only a fraction of a millivolt in experiments of this kind. In order to check this voltage a potential divider is used.



- (i) Calculate, to 3 significant figures, the potential difference across the  $25.0 \Omega$  resistor in circuit 1. State any assumption you make.

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(4)



(ii) At the end of the lead shot experiment, when the thermocouple is connected by closing the switch in circuit 2, there is no change in the reading of the microammeter. Suggest what voltage is being generated by the thermocouple.

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(iii) A thermocouple consists of two different metal wires twisted together to form a probe. What advantage does a thermocouple have over a mercury-in-glass thermometer in experiments of this kind, other than its mechanical robustness?

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(2)  
(Total 6 marks)

20. An office is cooled by water flowing through pipes. The complete system extracts heat from the building at a rate of 35 kW. The water flowing through the building is warmed through a temperature difference of 5 °C.

State how much heat energy is extracted from the building in one second.

Energy = .....

(1)

Calculate the mass of water flowing through the system in 1 s.

Specific heat capacity of water = 4200 J kg<sup>-1</sup> °C<sup>-1</sup>.

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Mass of water in 1 s = .....

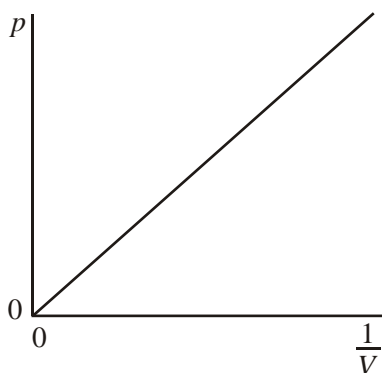
(3)

In an energy efficient office, the cooling water is pumped using energy from an array of solar cells. Explain one reason why solar cells are suitable for this purpose.

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(1)  
(Total 5 marks)

21. An experiment was carried out on the behaviour of a fixed mass of gas. Measurements were taken of the pressure  $p$  exerted by the gas and its volume  $V$ . The following graph was plotted.

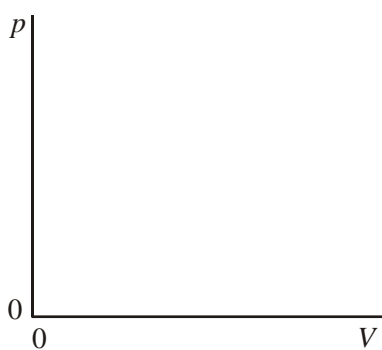


State, in words, the relationship represented by this graph.

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(2)

On the axes below sketch the graph that would be obtained if pressure were plotted against volume.



(2)

The ideal gas equation is

$$pV = nRT$$

Show that the product  $pV$  has the same units as energy.

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(2)

Explain, in terms of the kinetic model, how the molecules of a gas exert a pressure.  
You may be awarded a mark for the clarity of your answer.

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(5)

(Total 11 marks)

22. You are asked to measure the specific heat capacity of aluminium using a cylindrical block of aluminium that has been drilled out to hold an electrical heater and a thermometer. Draw a diagram of the apparatus, including the electrical circuit, which you would use.

(3)

List the measurements you would take.

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(4)

Explain how you would use these measurements to find the specific heat capacity of aluminium.  
State any assumptions you have made.

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(3)  
(Total 10 marks)

23. Define the term **specific heat capacity**.

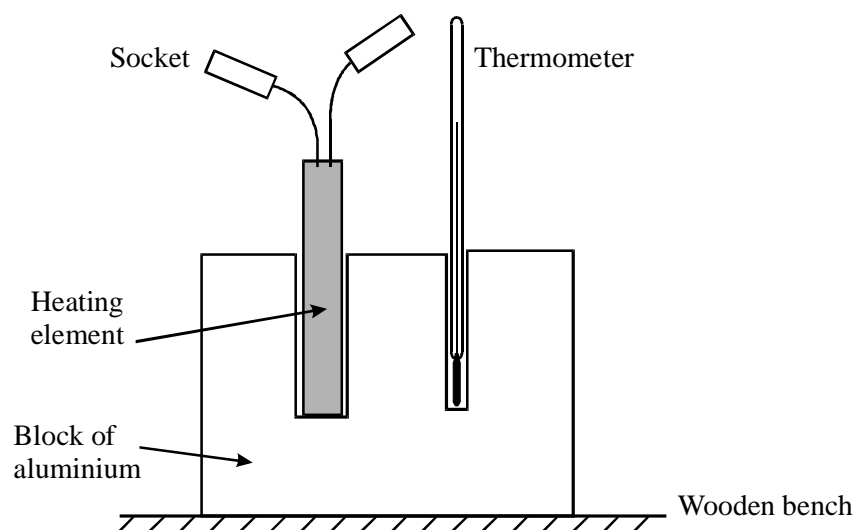
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(2)

A student decides to measure the specific heat capacity of aluminium by an electrical method. He selects his apparatus and then assembles the aluminium block, the thermometer and the heating element as shown.



The student intends to substitute his results into the relationship

$$mc\Delta T = VIt$$

Draw a diagram of the electrical circuit he would need to set up in order to be able to carry out the experiment.

(3)

What other pieces of apparatus would he need?

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(2)

He carries out the experiment and then calculates his value for the specific heat capacity of aluminium. He discovers that his value is higher than the accepted value of  $900 \text{ J kg}^{-1} \text{ K}^{-1}$ .

Suggest why his result is higher than  $900 \text{ J kg}^{-1} \text{ K}^{-1}$ .

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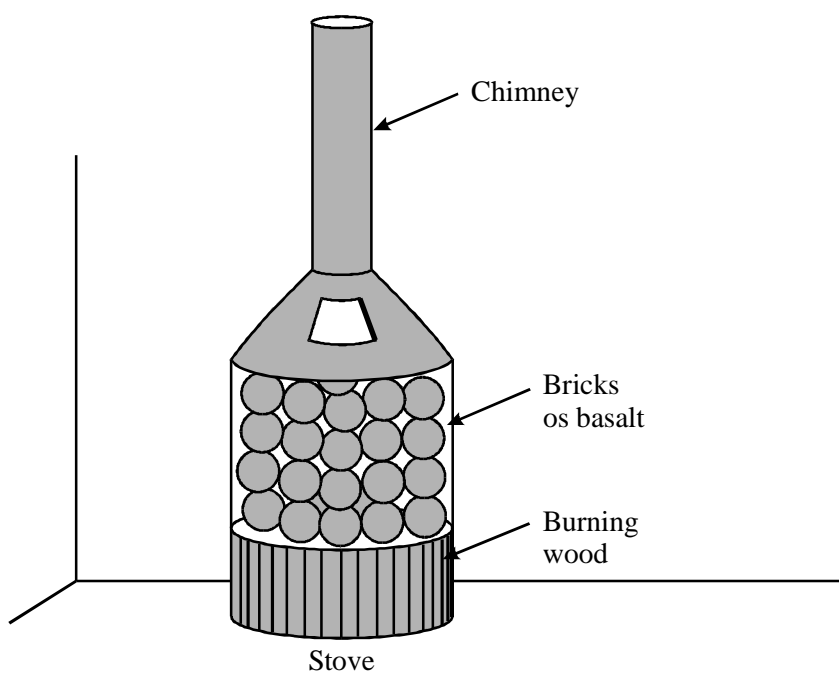
(1)

With reference to the apparatus shown in the diagram, state two modifications that he should make in order to minimise the discrepancy.

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2. ....  
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(2)  
(Total 10 marks)

24. A sauna is a room in which there is a stove containing very hot bricks of basalt over which water is poured.



Before use the basalt is tested for resistance to cracking by first heating the bricks to 750°C and then dropping them into cold water.

Each brick has a mass of 1.4 kg and an initial temperature of 22 °C. Each receives 860 kJ of energy from the burning wood. Show that the specific heat capacity of basalt is approximately 850 J kg<sup>-1</sup> K<sup>-1</sup>.

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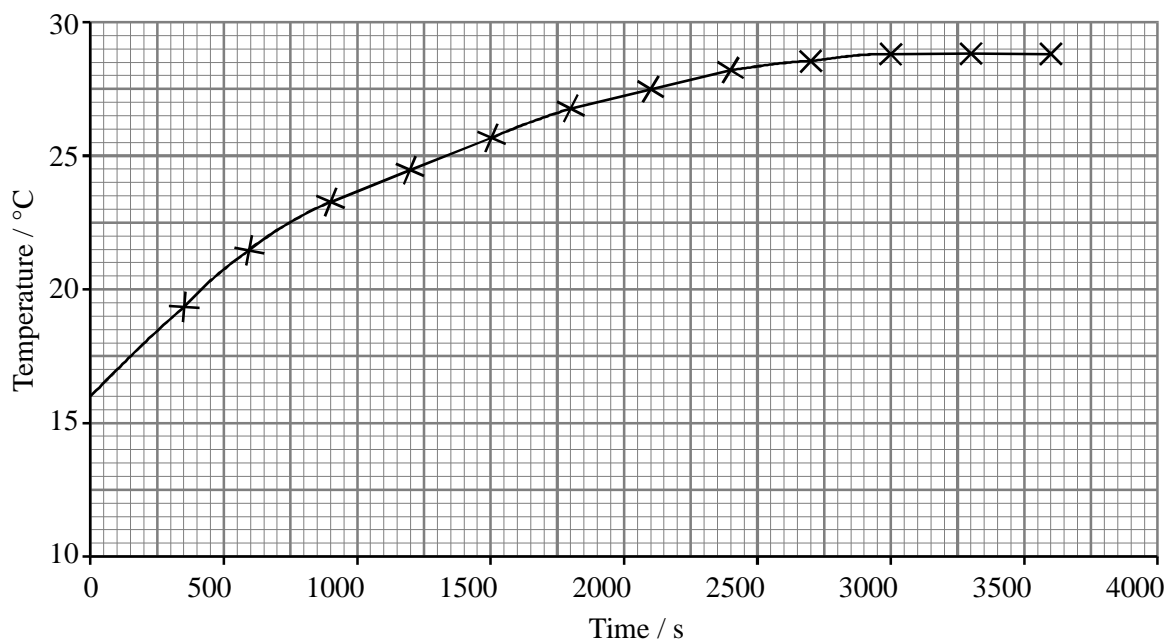
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(Total 3 marks)

25. A student about to fill a paddling pool for her younger brother noticed that the water left in the hose-pipe had already been warmed by the sun. She carried out an experiment to find the efficiency of this method of solar heating.

She cut a short length of hose-pipe and filled it with water from the cold tap. After taking the initial temperature she plugged both ends and placed the hose-pipe in the sunlight. She measured the temperature of the water at regular intervals for 1 hour during which time the amount of sunlight was constant. The graph shows her results.





Explain the shape of the graph.

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(2)

Use the graph to show that the initial rate of temperature increase was about  $0.01\text{ }^{\circ}\text{C s}^{-1}$ .

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(3)

Hence calculate the maximum amount of thermal energy gained by the water in one second.

Mass of water in hose-pipe =  $0.130\text{ kg}$   
Specific heat capacity of water =  $4200\text{ J kg}^{-1}\text{ }^{\circ}\text{C}^{-1}$

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Energy gained per second = .....

(2)

The area of hose-pipe exposed to the solar radiation was  $0.015 \text{ m}^2$ . At the time of the experiment the power delivered by the solar radiation to an area of  $1.0 \text{ m}^2$  was  $500 \text{ W}$ .

Calculate the initial efficiency of this process of heating water by solar energy.

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Efficiency = .....

(3)

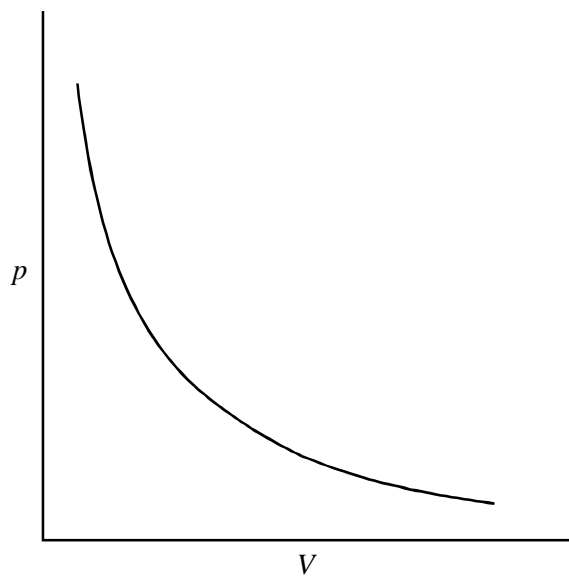
The student noticed that she spilled a small amount of water each time she removed the stopper to measure the temperature of the water. State and explain the effect this would have on the calculated value of efficiency.

.....  
.....  
.....

(2)

**(Total 12 marks)**

26. The graph shows the relationship between the pressure  $p$  and the volume  $V$  of a fixed mass of dry air.

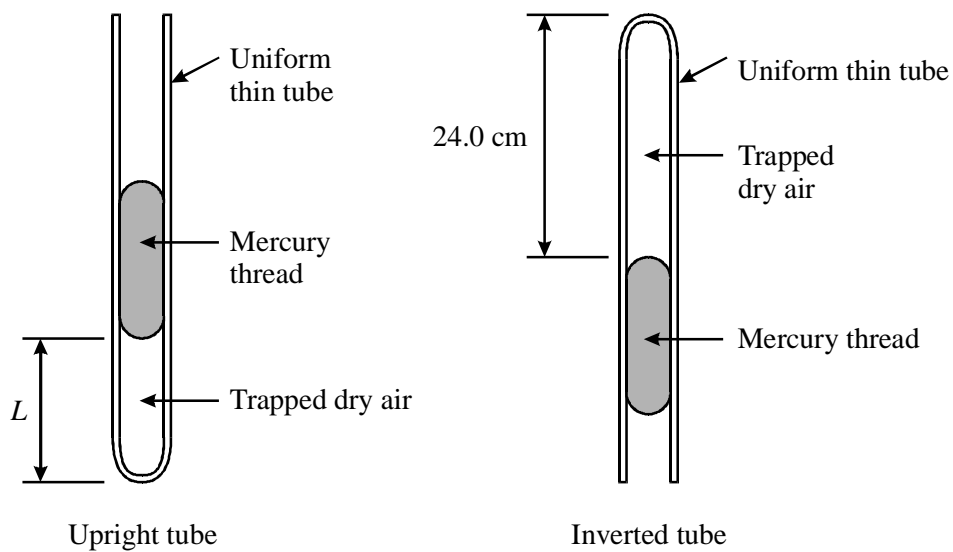


Write down the formula for this relationship.

.....

(1)

A uniform thin tube, sealed at one end, contains a thread of mercury which traps a column of dry air. The other end of the tube is open to the atmosphere.



The length of the column of air changes when the tube is inverted. In each case the thread of mercury exerts a pressure of  $0.20 \times 10^5$  Pa and atmospheric pressure is  $1.00 \times 10^5$  Pa.

What is the pressure of the trapped dry air

- (i) when the tube is upright?

.....

Dry air pressure = .....

- (ii) when the tube is inverted?

.....

Dry air pressure = .....

(2)

The final length of the column of air is 24.0 cm. Calculate the initial length  $L$  in centimetres, when the tube is upright.

.....  
.....  
.....

$L =$  .....

(3)

What assumption did you make about the dry air?

.....

(1)

(Total 7 marks)

27. Two physics teachers are getting hot drinks from a drinks machine. One teacher suggests that the machine must contain a reservoir of hot water. The other teacher says that there isn't room to store water inside the machine. He suggests that the water must come from the mains water supply and be heated by a heater in the machine, as it is needed.

The teachers take the following measurements to decide who is correct.

Mass of water in cup = 0.20 kg  
Room temperature = 22°C  
Temperature of water in cup = 75°C  
Time to fill cup = 6.0 s  
(Specific heat capacity of water = 4200 J kg<sup>-1</sup> °C<sup>-1</sup>)

Calculate the energy required to heat the water for one cup.

.....  
.....  
.....

Energy = .....

(3)

The drinks machine is marked "2500 W". Calculate the maximum thermal energy which the heater could supply in the time it takes to fill the cup.

.....  
.....  
.....

Energy = .....

(2)

Explain which suggestion is most likely to be correct.

.....  
.....  
.....

(1)

Heat losses were not considered. What would be the effect on the energy required to heat the water for one cup if heat losses were considered?

.....  
.....

(1)  
(Total 7 marks)

28. A scientist was investigating the effects of extreme pressure, as might be experienced deep in the ocean. He used a polystyrene cup in his investigation and a total pressure of  $3.5 \times 10^7$  Pa was applied to it, squashing the cup.

The volume of the air in the cup's polystyrene bubbles was originally  $7 \times 10^{-5}$  m<sup>3</sup>. Calculate the new volume in the bubbles in the squashed cup.

Assume that the temperature remains constant.  
Atmospheric pressure =  $1.0 \times 10^5$  Pa.

.....  
.....  
.....  
.....  
.....  
.....

Volume = .....

(3)

State one other assumption made in the calculation above.

.....  
.....  
.....  
.....  
.....

(1)

In reality, the temperature drops when going down into the ocean from 25°C at the surface to 10°C at the depth modelled in the experiment. Calculate the percentage change in the average kinetic energy of the air molecules as a result of this temperature change.

.....  
.....  
.....  
.....  
.....  
.....

(3)  
(Total 7 marks)

29. This question is about a bubble of air which is breathed out by a deep sea diver.

Write down the equation of state for an ideal gas.

.....

(1)

By making a suitable estimate, calculate the number of moles of air contained in the bubble which has a volume of 20 cm<sup>3</sup> at the surface of the sea. Assume the pressure inside the bubble is  $1 \times 10^5$  Pa.

.....  
.....  
.....  
.....  
.....  
.....

(3)

State what would happen to the volume of this bubble if the water were colder.

.....  
.....  
.....

(1)  
(Total 5 marks)

30. If you want to investigate how the pressure of the gas depends on the volume of the gas, two variables must be kept constant. What are they?

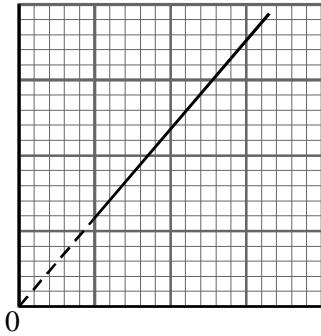
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(2)

Draw a labelled diagram of the apparatus you would use.

(3)





How would you process the readings you have taken in order to produce the graph shown above? Label both axes on the graph.

.....

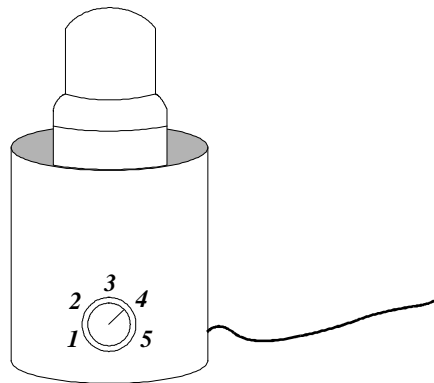
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.....

.....

(2)  
(Total 7 marks)

31. The diagram shows a warmer for a baby's bottle. The milk bottle is surrounded by water which is heated by an electrical heating element.



Katherine and John conducted an investigation into the heating of a baby's milk bottle. The mass of milk in the bottle was 0.20 kg.

They used temperature sensors and a datalogger to record the temperature of the milk in the bottle and the water surrounding it at intervals of 5 s until the desired temperature of 38.5 °C was reached.

The table below gives some of their results.

Time /s	Milk temperature /°C	Water in bottle warmer temperature /°C
0	13.0	13.5
30	13.0	16.0
60	13.0	26.5
90	15.0	33.0
120	16.5	39.0
150	18.5	44.0
180	20.0	49.0
210	23.0	54.0
240	24.0	58.5
270	28.5	61.5
300	31.5	64.5
330	34.5	68.0
360	35.5	71.0
390	37.5	72.0
420	38.5	72.0

The power of the electrical heating element is 140 W.

Show that the total electrical energy supplied in heating the milk to the required temperature is about 60 000 J.

.....  
.....

(2)

Calculate the total thermal energy transferred to the milk.  
(Specific heat capacity of milk is  $390 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}$ )

.....  
.....

Energy = ..... (2)

Calculate the efficiency of the bottle warmer when heating milk.

.....  
.....

Efficiency = ..... (2)

It would be more efficient to put the heating element in the milk. Explain why.

.....  
.....  
.....

(1)

With reference to the results for temperature, explain why using the bottle warmer is preferred, despite the reduction in efficiency.

.....  
.....  
.....

(1)

(Total 8 marks)

32. On the axes below, sketch a graph to show how the pressure of a fixed mass of air at room temperature depends on its volume.



(2)

In terms of the behaviour of molecules, explain qualitatively the shape of your graph.

.....

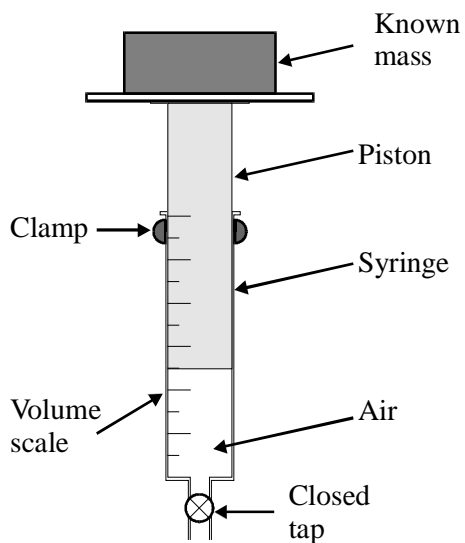
.....

.....

.....

(2)

The diagram shows apparatus which could be used to check the shape of your graph.



How would you calculate the pressure of the air in the syringe?

.....  
.....  
.....  
.....

(2)

Suggest one possible source of error in this experiment, other than errors in scale readings.

.....  
.....

(1)

(Total 7 marks)

33. According to kinetic theory, the pressure  $p$  of an ideal gas is given by the equation

$$p = \frac{1}{3} \rho \langle c^2 \rangle$$

where  $\rho$  is the gas density and  $\langle c^2 \rangle$  is the mean squared speed of the molecules.

Express  $\rho$  in terms of the number of molecules  $N$ , each of mass  $m$ , in a volume  $V$ .

.....  
.....

(1)

It is assumed in kinetic theory that the mean kinetic energy of a molecule is proportional to kelvin temperature  $T$ . Use this assumption, and the equation above, to show that under certain conditions  $p$  is proportional to  $T$ .

.....  
.....  
.....  
.....

(2)

State the conditions under which  $p$  is proportional to  $T$ .

.....  
.....  
.....

(2)

A bottle of gas has a pressure of 303 kPa above atmospheric pressure at a temperature of 0°C. The bottle is left outside on a very sunny day and the temperature rises to 35°C. Given that atmospheric pressure is 101 kPa, calculate the new pressure of the gas inside the bottle.

.....  
.....  
.....  
.....

Pressure = .....

(3)

(Total 8 marks)

34. A quantity of air is contained in a gas-tight syringe. The piston is clamped so that the volume of the air is fixed at 50 cm<sup>3</sup>. When the air is at 0 °C its pressure is  $1.00 \times 10^5$  Pa. The apparatus is now heated to 100 °C.

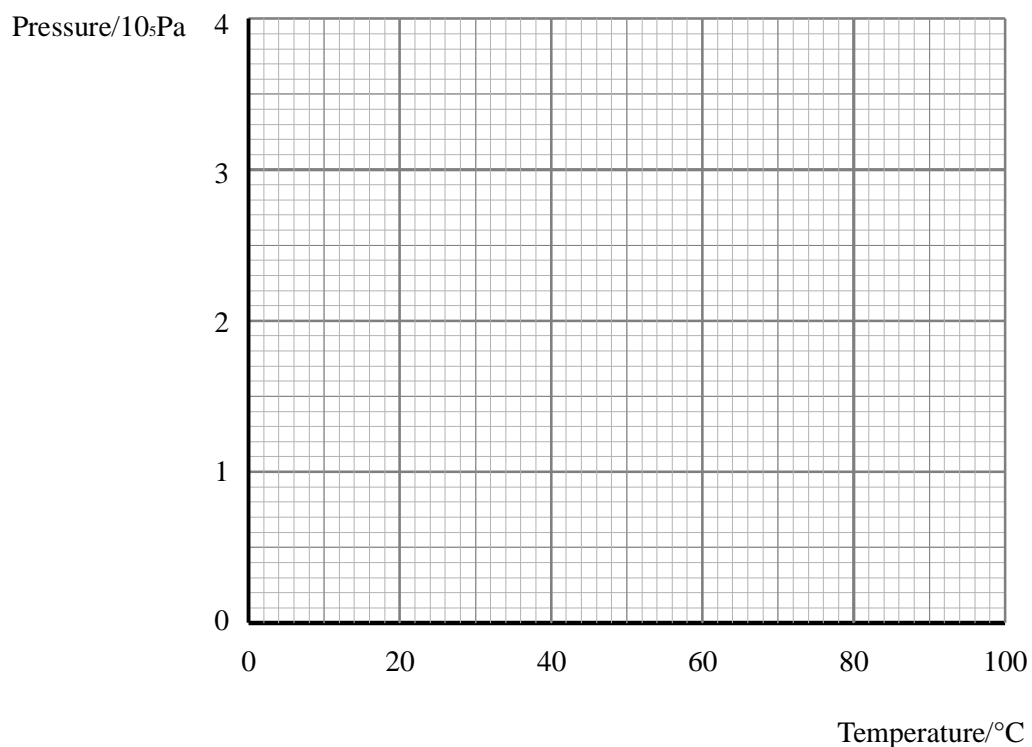
Calculate the pressure of the air at 100 °C.

.....  
.....

Pressure =.....

(2)

On the axes below draw a graph to show how the air pressure varies with temperature over the range 0 °C to 100 °C. Label your graph A.



(2)

The piston is pushed in until the air volume is 25 cm<sup>3</sup>. The piston is then clamped. On the same axes draw a second graph, labelled B, to show how the pressure would now vary over the same temperature range.

(2)

(Total 6 marks)