1 Lasers are often used to form precision-welded joints in titanium. To form one such joint it is first necessary to increase the temperature of the titanium to its melting point. Fig. 5.1 shows the joint and the volume of titanium to be heated.

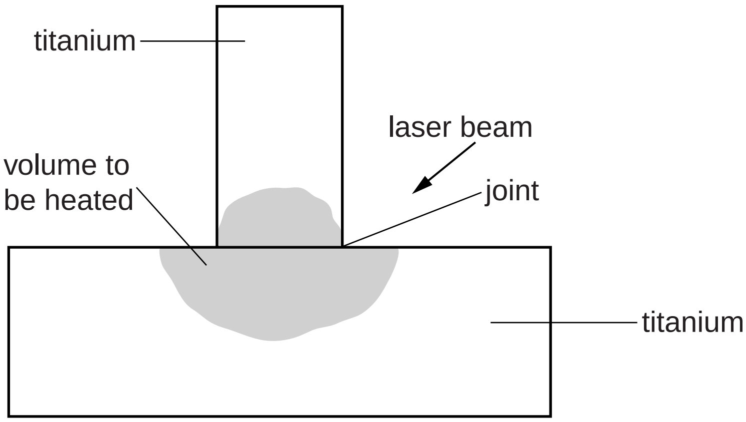

Fig. 5.1

The photon beam from the laser is focused onto the shaded volume of the joint and is converted into thermal energy in the titanium.

(a) The wavelength of the photons is 1.1×10^{-6} m.

Show that the energy of a photon in the beam is 1.8×10^{-19} J.

[1]

(b) Photons are emitted from the laser at a constant rate of $6.3 \times 10^{19}\,s^{-1}$.

Estimate the time taken to raise the temperature of the shaded volume of titanium shown in Fig. 5.1 to melting point. Use the data below for your calculations.

initial temperature = 20 °C
melting point of titanium = 1700 °C
density of titanium = $4.5 \times 10^3\,kg\,m^{-3}$
specific heat capacity of titanium = $520\,J\,kg^{-1}\,K^{-1}$
shaded volume of titanium being heated = $8.1 \times 10^{-12}\,m^3$.

time = ... s **[3]**

(c) In practice it takes a longer time to reach the melting point.
State and explain **two** factors that will increase the time taken.

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.... **[2]**

(d) To complete the weld more photons must be focused onto the joint. During this final stage the temperature remains constant. Explain why this is to be expected.

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.... **[1]**

2 **(a)** Fig. 6.1 shows how the volume V of a fixed mass of an ideal gas at constant pressure varies with temperature θ from 0 °C to 120 °C.

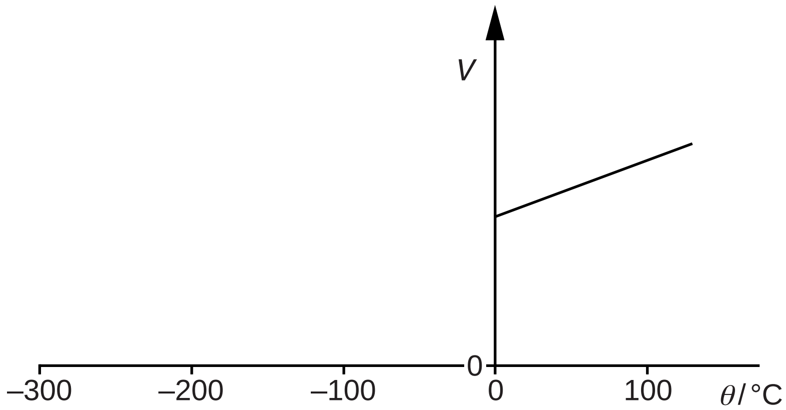

Fig. 6.1

Describe how this graph leads to the concept of an absolute zero of temperature.

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.... **[2]**

(b) A mass of gas is enclosed in a tank. The gas is cooled until it becomes a liquid. During this process its internal energy changes.

(i) State what is meant by the *internal energy* of the gas.

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.... **[1]**

(ii) Explain why the internal energy of the gas differs from that of its liquid phase.

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.... **[2]**

(c) A scuba diver uses air in which the percentage of nitrogen is reduced by adding helium to form a substance known as Trimix. A $1.2 \times 10^{-2}\,m^3$ rigid steel scuba diving tank contains 45 mol of air at a temperature of 20 °C.

(i) Calculate the pressure in the tank.

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

(ii) The tank is then connected to a cylinder of volume $2.0 \times 10^{-3}\,m^3$ containing helium at a pressure of 5.0×10^7 Pa and a temperature of 20 °C as shown in Fig. 6.2.

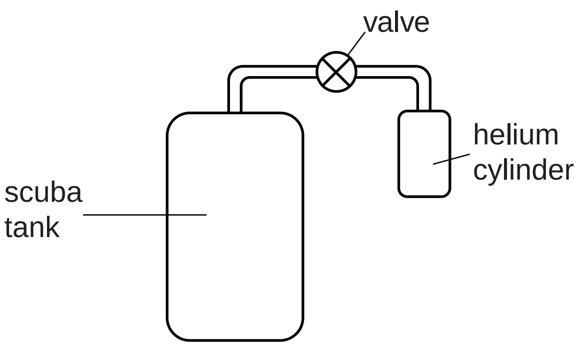

Fig. 6.2

The valve is opened allowing the gases to mix. When mixed the final temperature is 20 °C. Calculate the final pressure of the resulting Trimix in the scuba tank helium cylinder system.

pressure = ... Pa **[3]**

(iii) Explain why you would expect this pressure to decrease when the tank is used by a diver in water where the temperature is 4 °C.

....

....

.... **[1]**

3 You are provided with a small bottle of cooking oil and standard physics laboratory equipment.

With the help of a **labelled** diagram, describe an electrical experiment to determine the specific heat capacity *c* of the oil.
State **two** sources of uncertainty in your measurements and discuss how these could be reduced.

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

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.... **[6]**

[Total: 6]

4 Fig. 6.1 shows the apparatus used to observe Brownian motion using pollen grains suspended in a liquid.

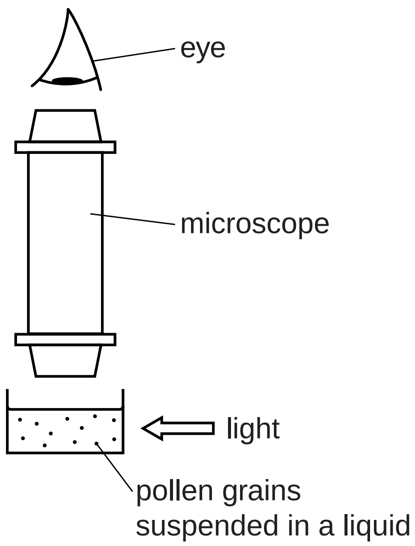

Fig. 6.1

(a) (i) State **two** conclusions that may be deduced about the molecules of the liquid from the motion of the pollen grains observed with the microscope.

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.... **[2]**

(ii) Suggest how the motion of these pollen grains could be increased.

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.... **[1]**

(b) **(i)** State **three** assumptions made in the development of the kinetic model of an ideal gas.

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

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.... **[3]**

(ii) Use the kinetic model of a gas and Newton's laws of motion to explain how a gas exerts a pressure on the walls of its container.

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.... **[4]**

(c) The ideal gas equation is $pV = nRT$.
Show that the pressure p exerted by a fixed mass of gas is given by the equation

$$p = \frac{\rho RT}{M}$$

where ρ is the density of the gas and M is the mass of one mole of gas.

[3]

(d) The Earth's atmosphere may be treated as an ideal gas whose density, pressure and temperature all decrease with height.
In 1924, Howard Somervell and Edward Norton set a new altitude record when attempting to climb Mount Everest. They managed to climb to a vertical height of 8570 m above sea level by breathing in natural air. At this height, the air pressure was 0.35 times the pressure at sea level and the temperature was −33 °C. At sea level, air has a temperature 20 °C and density 1.3 kg m^{-3}.

(i) Calculate the density of the air at a height of 8570 m at the time the record was set.

density = ... kg m^{-3} **[3]**

(ii) Determine the ratio

$$\frac{\text{number of air molecules present in Somervell's lungs at the top of his climb}}{\text{number of air molecules present in Somervell's lungs at sea level}}.$$

Assume that the volume of Somervell's lungs remained constant throughout the climb.

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

[Total: 18]

5 A room measures 4.5 m × 4.0 m × 2.4 m. The air in the room is heated by a gas-powered heater from 12 °C to 21 °C. The density of the air, assumed to remain constant, is 1.3 kg m^{-3}.

(a) Calculate the thermal energy required to raise the temperature of the air in the room. The specific heat capacity of air is 990 J kg^{-1} K^{-1}.

thermal energy = ... J **[3]**

(b) The heater has an output power of 2.3 kW. The heating gas has a density 0.72 kg m^{-3}. Each cubic metre of heating gas provides 39 MJ of thermal energy.

Use your answer to **(a)** to calculate

(i) the time required to raise the temperature of the air from 12 °C to 21 °C

time = ... s **[2]**

(ii) the mass of heating gas used in this time.

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

(c) Suggest **two** reasons why the time required and the mass of heating gas will in practice be greater than the values calculated in **(b)**.

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.... **[2]**

[Total: 9]