2.

The air in a kitchen has pressure 1.0×10^5 Pa and temperature 22°C. A refrigerator of internal volume $0.36\,m^3$ is installed in the kitchen.

(a) With the door open the air in the refrigerator is initially at the same temperature and pressure as the air in the kitchen. Calculate the number of molecules of air in the refrigerator.

(b) The refrigerator door is closed. The air in the refrigerator is cooled to 5.0°C and the number of air molecules in the refrigerator stays the same.

(i) Determine the pressure of the air inside the refrigerator. [2]

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(ii) The door of the refrigerator has an area of $0.72\,m^2$. Show that the minimum force needed to open the refrigerator door is about 4 kN. [2]

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(iii) Comment on the magnitude of the force in (b)(ii). [2]

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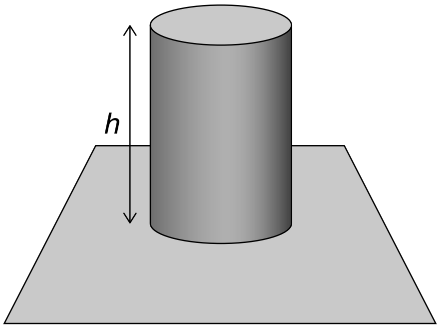
4. A solid cylinder of height *h* and density ρ rests on a flat surface.



(a) Show that the pressure p_C exerted by the cylinder on the surface is given by $p_C = \rho g h$. [2]

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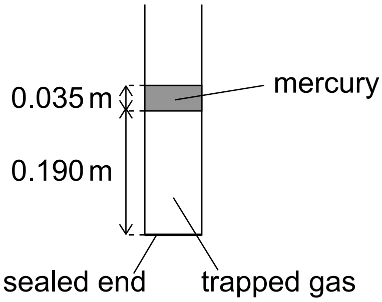
(b) A tube of constant circular cross-section, sealed at one end, contains an ideal gas trapped by a cylinder of mercury of length 0.035 m. The whole arrangement is in the Earth's atmosphere. The density of mercury is $1.36 \times 10^4\,\text{kg m}^{-3}$.



When the mercury is above the gas column the length of the gas column is 0.190 m.

(i) Show that $(p_o + p_m) \times 0.190 = \frac{nRT}{A}$ where

p_o = atmospheric pressure
p_m = pressure due to the mercury column
T = temperature of the trapped gas
n = number of moles of the trapped gas
A = cross-sectional area of the tube. [2]

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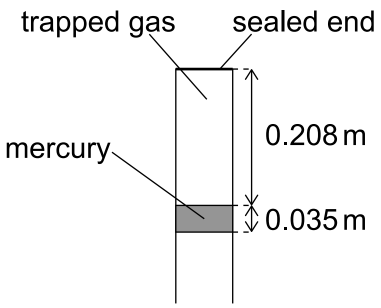
(This question continues on the following page)

(Question 4 continued)

(ii) The tube is slowly rotated until the gas column is above the mercury.

diagram not to scale



The length of the gas column is now 0.208 m. The temperature of the trapped gas does not change during the process.

Determine the atmospheric pressure. Give a suitable unit for your answer. [4]

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(iii) Outline why the gas particles in the tube hit the mercury surface less often after the tube has been rotated. [1]

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2. A container of volume $3.2 \times 10^{-6}\,\text{m}^3$ is filled with helium gas at a pressure of $5.1 \times 10^5\,\text{Pa}$ and temperature 320 K. Assume that this sample of helium gas behaves as an ideal gas.

(a) The molar mass of helium is $4.0\,\text{g mol}^{-1}$. Show that the mass of a helium atom is $6.6 \times 10^{-27}\,\text{kg}$. [1]

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(b) Estimate the average speed of the helium atoms in the container. [2]

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(c) Show that the number of helium atoms in the container is about 4×10^{20}. [2]

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(d) A helium atom has a volume of $4.9 \times 10^{-31}\,\text{m}^3$.

(i) Calculate the ratio $\dfrac{\text{total volume of helium atoms}}{\text{volume of helium gas}}$. [1]

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(ii) Explain, using your answer to (d)(i) and with reference to the kinetic model, why this sample of helium can be assumed to be an ideal gas. [2]

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Turn over

7. Liquid oxygen at its boiling point is stored in an insulated tank. Gaseous oxygen is produced from the tank when required using an electrical heater placed in the liquid.

The following data are available.

Mass of 1.0 mol of oxygen $= 32\,\text{g}$
Specific latent heat of vaporization of oxygen $= 2.1 \times 10^{5}\,\text{J kg}^{-1}$

(a) Distinguish between the internal energy of the oxygen at the boiling point when it is in its liquid phase and when it is in its gas phase. [2]

(b) An oxygen flow rate of $0.25\,\text{mol s}^{-1}$ is needed.

(i) Calculate, in kW, the heater power required. [2]

(ii) Calculate the volume of the oxygen produced in one second when it is allowed to expand to a pressure of 0.11 MPa and to reach a temperature of 260 K. [1]

(This question continues on the following page)

(Question 7 continued)

(c) State **one** assumption of the kinetic model of an ideal gas that does not apply to oxygen. [1]

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2. A closed box of fixed volume 0.15 m^3 contains 3.0 mol of an ideal monatomic gas. The temperature of the gas is 290 K

(a) Calculate the pressure of the gas. [1]

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(b) When the gas is supplied with 0.86 kJ of energy, its temperature increases by 23 K. The specific heat capacity of the gas is 3.1 $kJ\,kg^{-1}\,K^{-1}$

(i) Calculate, in kg, the mass of the gas. [1]

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(ii) Determine, in kJ, the total kinetic energy of the particles of the gas. [3]

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(c) Explain, with reference to the kinetic model of an ideal gas, how an increase in temperature of the gas leads to an increase in pressure. [3]

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2. (a) An ideal monatomic gas is kept in a container of volume $2.1 \times 10^{-4}\ \text{m}^3$, temperature 310 K and pressure 5.3×10^5 Pa.

(i) State what is meant by an ideal gas. [1]

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(ii) Calculate the number of atoms in the gas. [1]

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(iii) Calculate, in J, the internal energy of the gas. [2]

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(b) The volume of the gas in (a) is increased to $6.8 \times 10^{-4}\ \text{m}^3$ at constant temperature.

(i) Calculate, in Pa, the new pressure of the gas. [1]

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(ii) Explain, in terms of molecular motion, this change in pressure. [2]

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(Question 4 continued)

(b) Each side of the ice cube is 0.75 m in length. The initial temperature of the ice cube is –20 °C.

(i) Determine the energy required to melt all of the ice from –20 °C to water at a temperature of 0 °C. [4]

Specific latent heat of fusion of ice $= 330\ \text{kJ kg}^{-1}$
Specific heat capacity of ice $= 2.1\ \text{kJ kg}^{-1}\ \text{K}^{-1}$
Density of ice $= 920\ \text{kg m}^{-3}$

(ii) Outline the difference between the molecular structure of a solid and a liquid. [1]