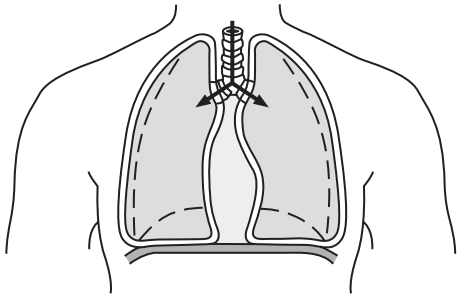
Thermodynamics QP1

1 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.

(2)

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(b) (i) The volume of air inhaled in a typical breath is 2.5×10^{-4} 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 1×10^{-4} kg.

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

(2)

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(ii) If body temperature is 37.6 °C and the temperature outside the body is 20.0 °C, calculate the rate at which energy is used to warm air up to body temperature.

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

(2)

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Rate = ...

(Total for Question = 6 marks)

2 (a) A typical aerosol can is able to withstand pressures up to 12 atmospheres before exploding. A 3.0×10^{-4} m^3 aerosol contains 3.0×10^{22} molecules of gas as a propellant. Show that the pressure would reach 12 atmospheres at a temperature of about 900 K.

1 atmosphere = 1.0×10^5 Pa

(2)

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*(b) Some such aerosol cans contain a liquid propellant. The propellant exists inside the can as a liquid and a vapour. Explain what happens when such an aerosol can is heated to about 900 K.

(3)

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(Total for Question 2 = 5 marks)

3 The heating element of a hair dryer supplies 2.1 kW to the air flowing past it.

(a) The hair dryer is connected to a 230 V supply.

Calculate the minimum current in the heating element.

(2)

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Current = ...

(b) (i) The fan in the hair dryer blows air at 20 °C across the heating element at a rate of 0.068 kg s^{-1}.

Calculate the temperature of the air emerging from the hair dryer.

specific heat capacity of air = 1.01×10^3 J kg^{-1} K^{-1}

(2)

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Exit temperature = ...

(ii) Describe the energy changes that occur as air is blown past the heating element.

(2)

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(Total for Question 3 = 6 marks)

4 A football has a diameter of 22.5 cm. It contains air at a temperature of 20°C and a pressure of $1.65 \times 10_5$ Pa. When the football is left in direct sunlight, the temperature of the air in the football increases to 40 °C.

In the following calculations, assume that the volume of the football remains constant.

(a) (i) Show that the new pressure exerted by the air in the football is about 2×10^5 Pa.

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(ii) State another assumption you made in your calculation.

(1)

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(b) Air is then released from the football until the pressure returns to its original value. Assuming that the temperature remains at 40 °C, calculate the number of molecules that escape.

(3)

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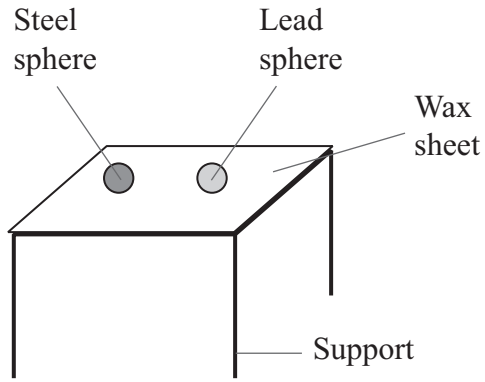
Number of molecules escaping = ...

(Total for Question 4 = 6 marks)

5 Two metal spheres of the same size are heated to a temperature of 100 °C in a water bath. One of the spheres is made of lead and the other of steel. The spheres are then placed onto a sheet of paraffin wax as shown. Paraffin wax melts at 55 °C.



	Mass / g	Specific heat capacity /J kg^{-1} K^{-1}
Lead sphere	50	130
Steel sphere	34	490

(a) The steel sphere melts through the wax sheet and drops to the floor. The temperature of the steel sphere when it reaches the floor is 53 °C.

Calculate the thermal energy lost by the steel sphere from the time when it was removed from the water bath.

(2)

Thermal energy lost = ...

(b) The lead sphere is only able to partially melt the wax, so does not drop to the floor.

Explain this observation.

(2)

(Total for Question 5 = 4 marks)

6 A magazine article states that an inflated balloon contains about two hundred billion trillion (2×10^{23}) air molecules.

(a) Taking the balloon to be a sphere of volume 8.2×10^{-3} m^3 in a room at a temperature of 22 °C, show that this figure for the number of molecules is correct.

pressure of air in balloon = 1.1×10^5 Pa

(2)

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*(b) The article also states that the internal energy of the air in the balloon could become zero if the temperature of the gas became low enough.

Explain what is meant by the internal energy of the air and discuss whether the statement is correct.

(4)

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(Total for Question 6 = 6 marks)