Access Tuition

A-Level Physics

Molecular Kinetic Theory

Question Paper

Time available: 64 minutes
Marks available: 60 marks

1. (a) State **two** assumptions made about the **motion** of the molecules in a gas in the derivation of the kinetic theory of gases equation.

(2)

(b) Use the kinetic theory of gases to explain why the pressure inside a football increases when the temperature of the air inside it rises. Assume that the volume of the ball remains constant.

(3)

(c) The 'laws of football' require the ball to have a circumference between 680 mm and 700 mm. The pressure of the air in the ball is required to be between 0.60×10^5 Pa and 1.10×10^5 Pa above atmospheric pressure.

A ball is inflated when the atmospheric pressure is 1.00×10^5 Pa and the temperature is 17 °C. When inflated the mass of air inside the ball is 11.4 g and the circumference of the ball is 690 mm.

Assume that air behaves as an ideal gas and that the thickness of the material used for the ball is negligible.

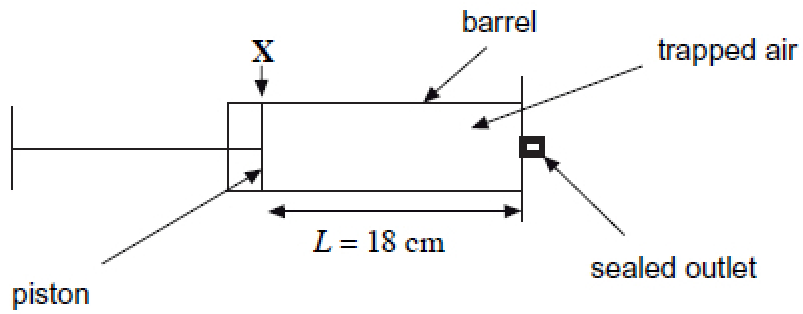
Deduce if the inflated ball satisfies the law of football about the pressure.

molar mass of air = 29 g mol^{-1}

(6)
(Total 11 marks)

2. **Figure 1** shows the cross-section of a bicycle pump with a cylindrical barrel. The piston has been pulled to the position marked **X** and the outlet of the pump sealed.

Figure 1



The length L of the column of trapped air is 18 cm and the volume of the gas is $1.7 \times 10^{-4} m^3$ when the piston is at position **X**. Under these conditions the trapped air is at a pressure p of 1.01×10^5 Pa and its temperature is 19°C.

Assume the trapped air consists of identical molecules and behaves like an ideal gas in this question.

(a) (i) Calculate the internal diameter of the barrel.

diameter ____________________ m

(2)

(ii) Show that the number of air molecules in the column of trapped air is approximately 4×10^{21}.

(3)

(iii) The ratio $\frac{\text{total volume of the air molecules}}{\text{volume occupied by the column of trapped air}}$ equals 7.0×10^{-4}.

Calculate the volume of one air molecule.

volume ____________________ m^3

(2)

(iv) The ratio in part **(a)(iii)** is important in supporting assumptions made in the kinetic theory of ideal gases.

Explain how the value of the ratio supports **two** of the assumptions made in the kinetic theory of ideal gases.

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(3)

(b) The mass of each air molecule is 4.7×10^{-26} kg.

Calculate the mean square speed of the molecules of trapped air when the length of the column of trapped air is 18.0 cm.
Give an appropriate unit for your answer.

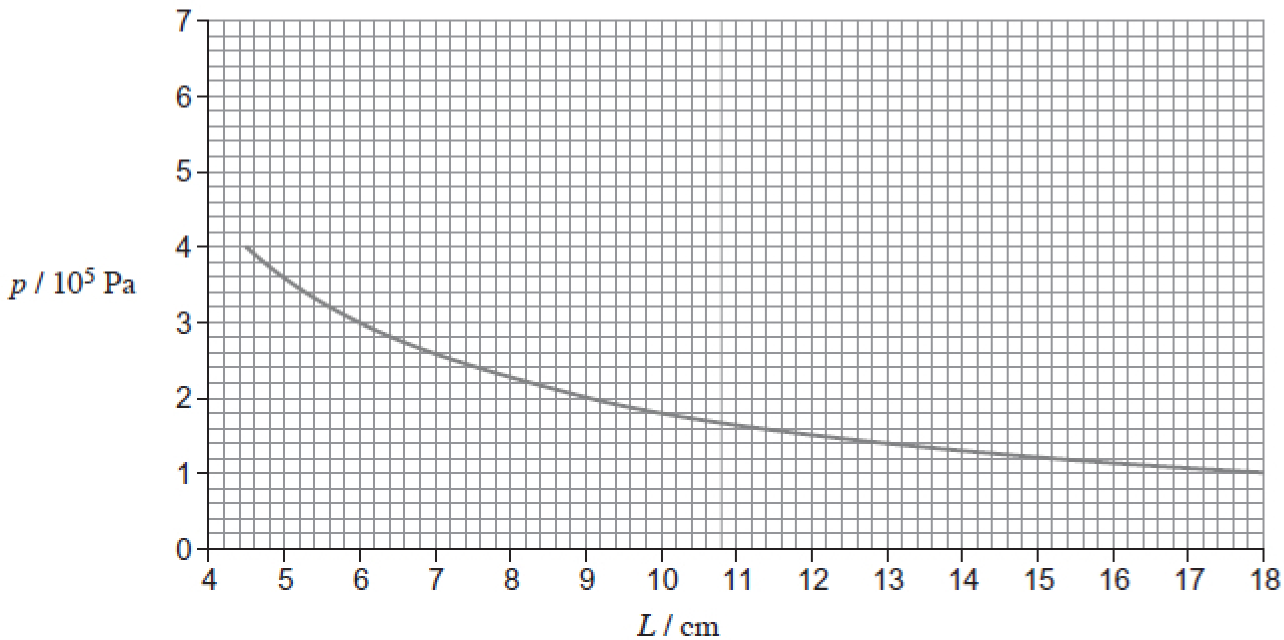
mean square speed ____________________ unit __________

(4)

(c) The piston is pushed slowly inwards until the length L of the column of trapped air is 4.5 cm.

Figure 2 shows how the pressure p of the trapped air varies as L is changed during this process.

Figure 2



(i) Use data from **Figure 2** to show that p is inversely proportional to L.

(3)

(ii) Name the physical property of the gas which must remain constant for p to be inversely proportional to L.

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(1)

(d) Explain how the relationship between p and L shown in **Figure 2** can be predicted using the kinetic theory for an ideal gas.

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(4)

(Total 22 marks)

3. (a) The concept of an absolute zero of temperature may be explained by reference to the behaviour of a gas.
Discuss **one** experiment that can be performed using a gas which would enable you to explain absolute zero and determine its value.
It is not necessary to give full details of the apparatus. Your answer should:

- include the quantities that are kept constant
- identify the measurements to be taken
- explain how the results may be used to find absolute zero
- justify why the value obtained is absolute zero.

The quality of your written communication will be assessed in your answer.

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(6)

(b) (i) State **two** assumptions about the **movement** of molecules that are used when deriving the equation of state, $pV = \frac{1}{3} N m (c_{rms})^2$ for an ideal gas.

1. ____

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2. ____

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(2)

(ii) Three molecules move at the speeds shown in the table below.

molecule	**speed / m s^{-1}**
1	2000
2	3000
3	7000

Calculate their mean square speed.

mean square speed ____________________ $m^2\ s^{-2}$

(1)

(c) The average molecular kinetic energy of an ideal gas is 6.6×10^{-21} J.
Calculate the temperature of the gas.

temperature ____________________ K

(2)

(Total 11 marks)

4. (a) The pressure inside a bicycle tyre of volume 1.90×10^{-3} m^3 is 3.20×10^5 Pa when the temperature is 285 K.

(i) Calculate the number of moles of air in the tyre.

answer = ____________________ mol

(1)

(ii) After the bicycle has been ridden the temperature of the air in the tyre is 295 K. Calculate the new pressure in the tyre assuming the volume is unchanged. Give your answer to an appropriate number of significant figures.

answer = ____________________ Pa

(3)

(b) Describe **one** way in which the motion of the molecules of air inside the bicycle tyre is similar and **one** way in which it is different at the two temperatures.

similar ____

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different ____

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(2)

(Total 6 marks)

5. (a) A cylinder of fixed volume contains 15 mol of an ideal gas at a pressure of 500 kPa and a temperature of 290 K.

(i) Show that the volume of the cylinder is 7.2×10^{-2} m^3.

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(ii) Calculate the average kinetic energy of a gas molecule in the cylinder.

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(4)

(b) A quantity of gas is removed from the cylinder and the pressure of the remaining gas falls to 420 kPa. If the temperature of the gas is unchanged, calculate the amount, in mol, of gas remaining in the cylinder.

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(2)

(c) Explain in terms of the kinetic theory why the pressure of the gas in the cylinder falls when gas is removed from the cylinder.

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(4)

(Total 10 marks)