General Physics II: Tutorial Material 8

1) In our outer space, the density of matter is 1 atom per cm^3. It is dominated by the hydrogen atom and at a temperature of 2.7 K. What is the rms-speed of those hydrogen atoms? What is the pressure there in the unit of atm? (*)

2) The lowest pressure attainable using the best available vacuum technique is about 10^{-12} Nm^{-2}. At such a pressure, how many molecules are there per cm^3 at 0° C?

3) Show that the rms-speed of gas molecules is given by $v_{rms} = \sqrt{3P/\rho}$, where P and ρ are the pressure and density of the gas respectively.

4) How many joules and kilocalories are generated when the breaks are used to stop the car running at 95 km/h and weight 1200 kg.

5) An ideal gas is kept in a container with rigid walls. How can we reduce the pressure of the gas? How much work the gas will do during that process?

6) There are N indistinguishable gas molecules uniformly distributed in a box with a volume V. Consider a small region in the box with a volume V_1.

   a) What is the probability to find any one but only one molecule in this region?

   b) What is the probability to find any n molecules in this region?

   c) What is the average number of molecules, $\langle n \rangle$, and its standard deviation $\Delta n \equiv \sqrt{\langle n^2 \rangle - \langle n \rangle^2}$, where $\langle n^2 \rangle$ is the average of n^2, in this region?

   d) If N is of the order of the Avogadro number, i.e. about 10^{24}, and the volume of the considered region is about 1% of the total volume, how large is $\Delta n / \langle n \rangle$? What does it mean?

NB: Following formula might be useful:

$$(p+q)^M = \sum_{m=0}^{M} \frac{M!}{m!\,(M-m)!} p^m q^{M-m}$$

$$\sum_{m=0}^{M} m \frac{M!}{m!\,(M-m)!} p^m q^{M-m} = Mp(p+q)^{M-1}$$

$$\sum_{m=0}^{M} m^2 \frac{M!}{m!\,(M-m)!} p^m q^{M-m} = Mp(p+q)^{M-1} + M(M-1)p^2(p+q)^{M-2}$$