Problem Set 4

Problems

1. Consider a "gas" consisting of a single He atom in a cubic one liter container. Assume the He atom moves one dimensionally as described in class with a speed of 600 m/sec.
   a) What is the force exerted on the container's wall when the atom collides with the wall?
   b) What is the pressure of the gas?
   c) Does it make sense to consider the gas's pressure? Explain.

2. One mole of gaseous He in a one liter container has a temperature of 300K. Assume the gas can be modeled as an Ideal Gas. Also assume the gas can be modeled as though all the atoms move one dimensionally as described in class. What is \(<u^2>\) for the gas particles?

3. In the van der Waals equation of state:
   \[
   \left( P + a \frac{n^2}{V^2} \right) (V - nb) = nRT
   \]
   the pressure is corrected from its Ideal value due to attractive forces between the gas molecules. The \(a\) term causes the pressure of the gas to be reduced. Thus, a molecule colliding with the wall does not carry as much momentum owing to the “pull” from the molecules of the gas. But one might expect the molecule leaving the wall to carry extra momentum, due to the attractive forces in the gas. Thus, there should be no van der Waals correction to the pressure. Criticize this argument.

4. Compute the Average Kinetic Energy of a mole of Oxygen gas at 300K.

5. We have shown:
   \[
   f(u^2) = A e^{-\beta u^2}
   \]
   Show explicitly that this result satisfies our requirement that:
   \[
   \frac{f'(x)}{f(x)} = \text{const}.
   \]
where \( x = u^2 \).

6. Calculate \(<c>, c_{mp} \text{ and } c_{rms} \) for Ar gas at 25\(^\circ\)C.

7. What fraction of molecules have speeds between \( c_{mp} \) and 2.5 \( c_{mp} \)?

Additional Problems for 527 Students

8. Derive an expression for the Points of Inflection in the three-dimensional speed distribution.

9. The median speed of a gas molecule is defined by:

\[
\int_0^{c_{med}} P(c) \, dc = \int_{c_{med}}^{\infty} P(c) \, dc = \frac{1}{2}
\]

where \( P(c) \) is the Maxwellian Distribution of Speeds. When solved, this gives:

\[
c_{med} = 1.538 \left( \frac{kT}{m} \right)^{1/2}
\]

However, this equation cannot be solved in a closed form. Write a program to numerically evaluate the integral and use the program to evaluate the constant 1.538 in the solution.

(You should pick one of the programming languages with which I am familiar: C, C++, FORTRAN, Ada, VB, Basic, Java, Perl, Squeak, Prolog, or Assembler (for the more hearty amongst us,)).