Assignment 9

1. The atomic mass number of a single nitrogen atom is 14 and the separation between the two atoms in N_2 is 1.5×10^{-10} m. Rotational kinetic energy is given by $L^2/2I$ where L is the angular momentum and I is the moment of inertia.
   a) What is the moment of Inertia I of a nitrogen molecule about an axis perpendicular to the line between the centers of the atoms at the center of mass?
   b) If the first excited rotational state has an angular momentum of $L = 2^{1/2} \hbar$, at what temperature would the ratio of N_2 molecules in the first excited state to those in the ground state be equal to e^{-1}?

2. Consider a N_2 molecule at room temperature. Find the following.
   a) Average velocity
   b) Average speed
   c) Root mean square speed
   d) Most probable speed

3. The density of air molecules at room temperature and atmospheric pressure is about 2.7×10^{25} molecules/m^3.
   a) Calculate the flux of particles moving in any one direction past any point in your room.
   b) If a micrometeorite punctured a hole 0.2 mm in diameter in the wall of a spaceship, at what rate would molecules leave if the air in the spaceship was held at atmospheric pressure and room temperature?

4. Consider a gas enclosed in a rigid volume. If the temperature of a gas is doubled, by what factor do the following things change:
   a) Mean free path
   b) Collision frequency

5. Consider a gas of atoms of mass M in an oven at a temperature T. A small hole of area A is punched into the oven wall allowing the atoms to escape to create a collimated atomic beam in the z direction.
   a) Write down an expression for the atom flux.
   b) Write down an expression giving the probability of velocities v_z in the atomic beam.