HW problem week 1

Your turned in assignment should be clearly written and easy to follow! Learning how to explain your work in a way that is as easy as possible to follow is an important part of your training as a physicist. An incoherent mess of equations with a correct final answer could receive less points than a solution which is clearly explained at every step but has an algebra mistake somewhere. Once you've solved the problem, you can rewrite it on a new piece of paper for clarity if you need to.

An experimentalist has a gas of N ionic molecules confined in a cubic box whose sides are length L. By applying an electric field in the z direction, they subject the molecules to a potential $V(z) = \alpha z$. The electric charge of the molecules is small and the gas is dilute enough so that you can neglect the coulomb force between different molecules and they are well described by statistical mechanics (i.e. they follow the Boltzmann distribution). If you need to plug in numbers in the following, let $L = 2$ mm, $\alpha = 10^{-19}$ J/m, and $N = 10^8$.

1. Derive the normalized distribution function for the height of molecules.
2. The experimentalist measures the number of particles in the lower half of the box and the upper half of the box separately, and finds that one number is 2 times as big as the other (which one is larger?). Use this information to determine the temperature.
3. Now, the experimentalist studies the speed distribution of the particles. After some careful measurements, they find that the number of particles with speeds between 4 and 4.0001 m/s is three times the number of particles with speeds between 4.2 and 4.2002 m/s. Use this information to calculate the mass of the molecules.
4. Bonus question (ungraded: for your enjoyment, or extra practice): What is the average energy of the molecules?