Physics 3180 (Thermal Physics)
spring 2020

Problem Set 8

(due Wednesday, April 1)

1. **For formal written solution:** Run the Interactive Molecular Dynamics simulation with 1000 or more atoms, adjusting the energy until the temperature is approximately 0.5. (The volume doesn't matter; the system may be in a solid, liquid, or gas state, or a combination.) After the system has equilibrated, use the data controls, with the data type set to "all atoms," to record an instantaneous snapshot of all of the atoms' positions and velocities. Copy this data into a spreadsheet for further analysis, and note the exact temperature as well. In the spreadsheet, compute the speed of each atom and then make a histogram of the speed values. I suggest using bins of width 0.2 velocity units; you should then need only about 15 bins. There are several ways to make a histogram in a spreadsheet, but all of them are a bit tricky so feel free to ask for help if you can't figure it out. (I like to use the COUNTIF function in Excel.) Then, on the same graph, plot the theoretical histogram according to the result of Problem 4, below (6.41 in the book). This too is a bit tricky because you need to take the number of atoms and the bin size into consideration. Your formal narrative should explain what you've done and include your computer-printed plot, a table of the numbers plotted, and a representative sample of your raw data (but not all 1000 rows!). There's no need to explain the simulation itself from scratch (you may assume that the reader is already familiar with it), but be sure to fully introduce this particular exericse. Also be sure to discuss the meaning of the results.

Additional problems:

2. Problem 6.36, page 246.

3. The atmosphere of Venus is mostly carbon dioxide, and the surface temperature is approximately 735 K (toasty!). At this temperature what fraction of the CO_2 molecules are moving faster than 500 m/s? What fraction are moving faster than 1000 m/s? (Hint: You'll have to evaluate the integrals numerically, as in the example on pages 245–246. I strongly suggest changing variables to x, as in that example. Please use a computer to evaluate the numerical integrals and turn in a printout showing what you typed along with the results. See http://physics.weber.edu/thermal/computer.html for examples of how to do numerical integrals in either Mathematica or Python.)

4. Problem 6.41, page 247.

5. Problem 6.44, page 251.

6. Problem 6.48, page 255.

7. Problem 6.52, page 256. (Clarification: "same logic as above" means the same as in the main text on pages 252–253.)

8. Problem 7.3, page 260. To check your answer you can look up the Saha equation (equation 5.130) in Section 5.6, which we didn't cover in the course. In that section

the equation is written in terms of partial pressures, but in an ideal gas the ratio of the partial pressures of two components is the same as the ratio of the numbers of the corresponding particles. As part of this problem, please also check the arithmetic in equation 5.131, which applies the Saha equation to hydrogen at the surface of the sun. This calculation will prepare you for the following problem.

9. Problem 6.8, page 227. Despite its location in the book, this question is a follow-up on the previous problem (that is, on Problem 7.3).