Recitation Problems for Week 15, Tuesday

9.C14. Viruses in the air have a mass of about $10^{-13}\,kg$. (a) At room temperature, $20^{\circ}\,C$, what do you expect the average height of these particels to be? (b) In the winter, the outside temperature is about $-10^{\circ}\,C$. What do you expect the average height of them to be?

9.C17. The star Rigel in the constellation Orion is a blue supergiant star with a mass about seventeen times that of our Sun. Its surface temperature is about $11000\,K$. What is the probability of finding an individual hydrogen atom in its first excited state?

9.S40. A composite system of total volume V is composed of two subsystems of volumes V_1 and V_2. We are told that $V_2 = 5V_1$, and a total of N particles are split between the them, with N_1 in subsystem one and N_2 in subsystem two. We are told that he entropy of the the two subsystems are given as

$$\begin{aligned} S_1(N_1, V_1) &= \alpha\, k_B\, N_1 \ln\left(\frac{V_1}{N_1}\right) \\ S_2(N_2, V_2) &= \beta\, k_B\, N_2 \ln\left(\frac{V_2}{N_2}\right). \end{aligned}$$

where α and β are positive constants. (a) If we start out with $N_2 = 5N_1$, under what conditions would particles move from subsystem one to subsystem two? (b) If $\alpha = 3\beta$, and partciles can move between the two subsystems, what fraction of all the partciles in the system would we expect to find in subsystem one?

9.S41. A composite system is composed of two subsystems. A total of N particles are split between the two subsystems, with N_1 in one and N_2 in two. In addition, the system has a total energy E with E_1 in subsystem one and E_2 in subsystem two. The entropy as a function of energy and number of partciles in the two subsystems are given as

$$\begin{aligned} S_1(N_1, E_1) &= \alpha\, k_B\, N_1 \ln\left(\frac{E_1}{N_1}\right) \\ S_2(N_2, E_2) &= \beta\, k_B\, N_2 \ln\left(\frac{E_2}{N_2}\right). \end{aligned}$$

Initially both systems have the same number of particles in them, but the energy is subsystem two three times that as in one, $E_2 = 3E_1$ with the systems thermally isolated from each other.. (a) In terms of N, E and k_B, what are the temperatures of the two systems? (b) The two subsystems are placed in thermal contact allowing energy to flow between them. After sufficicient time, what fraction of the energy is in subsystem one? (c) What is the temperture of subsystem two when the system is in thermal equilibrium?

9.S51. (a) Below temperatures of about $80\,K$, the specific heat per molecule of Hydrogen gas, H_2 is $c = \frac{3}{2}k_BT$. As the temperature is raised, the molcules start to rotate, and the specific heat rises to $c = \frac{5}{2}k_BT$. How far apart are the atoms in the molecule? (b) As we continue to rais the temperature of the gas, it becomes possible for it to start vibrating as well as rotating. At about $2000\,K$, the specific heat per molecule is $\frac{7}{2}k_BT$. Estimate the effective spring constant between the two atoms in the molecule.