Physics 576: Introduction to Solid State Physics
Spring 2016

Homework 1

(1) *Simon Book Problem 2.7: The Diatomic Einstein Solid*—Consider a solid made up of diatomic molecules, modeled as two particles in three dimensions. Each of the two particles is connected to each other via a spring, both at the bottom of a harmonic well with total energy E as

$$E = \frac{\mathbf{p}_1^2}{2m_1} + \frac{\mathbf{p}_2^2}{2m_2} + \frac{k}{2}\mathbf{x}_1^2 + \frac{k}{2}\mathbf{x}_2^2 + \frac{K}{2}(\mathbf{x}_1 - \mathbf{x}_2)^2, \tag{1}$$

where k is the spring constant holding both particles at the bottom of the well and K is the spring constant holding both particles together at the bottom of the well. Assume that both particles are distinguishable atoms.

(a) Calculate the classical partition function and show that the heat capacity is $3k_B$ per particle, so $6k_B$ in total.

(b) Calculate the quantum partition function and find an expression for the heat capacity. Sketch the heat capacity as a function of temperature if $K >> k$.

(c) How does the result change if the atoms are indistinguishable?

(2) *Simon Book Problem 2.8: Einstein versus Debye*—In both the Einstein model and the Debye model the high-temperature heat capacity is of the form

$$C = Nk_B(1 - \kappa/T^2 + ...). \tag{2}$$

For the Einstein model calculate κ in terms of the Einstein temperature, where $\hbar\omega = k_B T_{Einstein}$. Then for the Debye model calculate κ for the Debye temperature. From your results give an approximate ratio of $T_{Einstein}/T_{Debye}$.

Homework 1 is due at the beginning of class on Thursday, January 28.