Homework # 1; due Wednesday, Feb. 2

Reading: Chapter 9 of M. Fox's *Optical Properties of Solids*

1. Consider a defect in a crystalline lattice of an *alkali halide* (e.g., NaCl), where one of the halogen atoms is missing. Such a *vacancy* corresponds to a *color center* (a.k.a. *F-center*), and is responsible for optical absorption of the crystal. Assuming that F-center's electronic energy levels are those of an "electron in a box,"
    a. Verify that the order of magnitude of the excitation energy indeed corresponds to optical absorption;
    b. Find the dependence of the electron-excitation energy on the distance *a* between adjacent alkali and halogen atoms.

2. The energy splitting between the $M=0$ and $M=\pm1$ ground-state spin sublevels of the NV^- color center in diamond corresponds to a frequency of about 2.9 GHz. Assuming that the center is in thermal equilibrium with the environment, to what temperature should one cool the sample so that 90% of the population is in the lower ($M=0$) sublevel?

3. Estimate the root-mean-square (r.m.s.) value of $\delta r=r-r_e$, where r is the internuclear separation, and r_e is its equilibrium value, for a diatomic molecule in a low vibration state. Based on this, estimate the amplitude of atomic vibrations in a crystalline lattice for solids at low temperature ($k_B T << \hbar\omega$, where ω is the vibrational frequency).
    Hint: this problem is discussed in the recommended Atomic Physics book, but really, you should not even need to look there if you know about mass on a spring…