Your Name:_____

3.225 Quiz 2004: Electronic, Optical, Magnetic Properties

$e=1.602\times10^{-19}$ C $m_o=9.11\times10^{-31}$ kg $c=2.998\times10^{8}$ m/sec $\varepsilon_o=8.854\times10^{-12}$ F/m

$k_b=1.38\times10^{-23}$ J/K $h=6.626\times10^{-34}$ J-sec $\hbar=1.054\times10^{-34}$ J-sec $A=6.022\times10^{23}$ mole^{-1}

1. Imagine a 1-D Crystal with atom spacing **a**

(a) Sketch E vs. k for a 1cm long crystal in the reduced zone scheme, assuming the nearly free electron model (i.e. electron waves), but initially assuming that the potential on the ions is U=0. Sketch the first 3 bands only. Please make the y-axis have units of $\frac{\hbar^2\pi^2}{2ma^2}$.

(b) Determine E_F for the cases in which the atom in the crystal has a valence of 1, 2, or 3.

(c) Estimate the conductivity at room temperature for valence 1, 2, or 3.

(d) Now assume $U = \frac{1}{2}\frac{\hbar^2\pi^2}{2ma^2}$. Sketch E vs. k. Superimpose E_F for valence 1, 2, 3.

(e) For which valence, if any, do you expect the conductivity to change substantially? Explain.

(f) Re-sketch your answer in (d) for the case in which the 1-D crystal has length L=8a. How would the optical properties change?

2. GaAs has a band gap of 1.423eV, a dielectric constant of 12.9, an electron effective mass of $0.063m_o$, a hole effective mass of $0.5m_o$, and a lattice constant of 0.5653nm.

(a) GaAs is doped with Zn (column II) and R_H is observed to be positive, where as GaAs is doped with Si (column IV) and R_H is observed to be negative (i.e. like a good alkali metal). Describe what is happening.

(b) Compare the optoelectronic properties of a p-n junction and a p++-n++ junction in GaAs. Assume that the doping is 10^{16} cm^{-3} in the p-n diode and 10^{20} cm^{-3} in the p++-n++ diode. In your estimation, plot the absorption coefficient and photocurrent generated in the photodiode from the conversion of light into carriers vs. ω, for $0<\omega<10^{20}$ Hz. Indicate key frequencies, which should be quantitative, on the ω x-axis, but the y-axis "photocurrent" can be qualitative; although currents should be relative (i.e. y-axis is arbitrary units).

3. The relative dielectric constant of silica (SiO_2) is 3.9, the density is 2.3 g/cm^3, the index of refraction is 1.46, and the atomic weight of Si and O are 28 and 16, respectively.

(a) What is the electronic polarizability of silica? The ionic polarizability?

(b) Assuming classical models for electronic and ionic polarizability, sketch □ vs. □ from □=0 to □=10^{20} Hz.