ECE 340 # Homework Assignment #1 **Fall 2015**

DUE: FRIDAY, SEPTEMBER 4, 2015

Print your **name** and **NetID** legibly. Follow the guidelines and format given in the syllabus. Staple multiple pages. Show all units. Homework must be turned in at the **beginning** of class and any late homework assignments will not be accepted. Please contact the course director, Professor Dallesasse, should any issues with late homework arise.

1. COMMON UNITS OF MEASUREMENT IN SEMICONDUCTORS

A convenient unit of length for the description of solids is the nanometer (nm), which corresponds to the order of magnitude of typical distances between atoms in crystals (actual distances are between 0.1 nm and 1.0 nm). Many older texts use the angstrom ($\mathring{A}$), which equals 0.1 nm. A convenient unit of energy is the electron-volt (eV), defined as the energy gained by moving an electron through a potential difference of 1 V. Temperature is also almost always given in units of kelvin (K).

(A). Given a solid with an atomic density (atoms per unit volume) of $5\mathring{A}^{-3}$, what is the atomic density in cm^{-3} and nm^{-3}?

(B). Given the definition of an electron-volt, find out how many Joules are there per electron-volt ($1\,eV = \underline{?}\,J$).

(C). At room temperature (T = 300 K), find out the value of kT (where k is the Boltzmann constant) in units of electronvolts, i.e. $1\,kT = \underline{?}\,eV$.

2. LATTICE AND CRYSTAL STRUCTURES

Complete the following questions for the [1] simple cubic (sc) lattice, [2] body-centered cubic (bcc) lattice, [3] face-centered cubic (fcc) lattice, [4] diamond crystal structure, and [5] zinc blende crystal structure:

(A). Calculate the total number of atoms found inside the unit cell. Remember to pay special attention to atoms on the boundary of the unit cell itself.

(B). Calculate the nearest neighbor distance assuming a lattice constant of a.

(C). Calculate the packing fraction (atomic packing factor, the maximum fractional volume of the unit cell that can be occupied by hard spheres). **You can ignore zinc blende for this calculation.**

(D). Assuming a lattice constant of a for each lattice or crystal structure, which one has the largest atomic density? The smallest?

3. Ternary Alloys

In a III-V semiconductor, the compositions of each interpenetrating fcc lattice in the zinc blende crysal can be varied to form a ternary compound (such as AlGaAs or InGaAs). The fraction of each atom is typically represented by the subscript x, so a ternary compound with a fraction of x Al atoms would be represented as $Al_xGa_{1-x}As$. The value of x is typically called the mole fraction

(A). Assume the lattice constant of a ternary alloy varies linearly with the mole fraction (Vegard's law). What is the lattice constant of $Al_{0.15}In_{0.85}P$?

(B). Determine the density of aluminum atoms (in cm^{-3}) in $Al_{0.15}In_{0.85}P$.

4. Mass Density

Calculate the (mass) densities of Si and AlAs from their lattice constants (Appendix III), atomic weights, and Avogadro's number. Compare the results with the densities given in Appendix III.

5. Wavelength and Energy of Photons

If the wavelength of a photon is equal to the lattice constant of GaAs, what is its energy (in eV), and wave number (in cm^{-1})? If the energy of a photon is equal to the GaAs band gap, what is its wavelength (in nm) and how many lattice constants does it span?