# ECE 3040 Homework 2

1) Purpose: Understanding what the fermi-distribution function is telling us.
The fermi-distribution function depicted in Figure 2.15 describes the probability that a state is occupied at a given energy. Plot the probability that a state is empty.
2) Purpose: Understanding what the electron distribution is within each band - Problem Pierret 2.7
3) Purpose: Understanding special cases of doping - Problem Pierret 2.16
4) Purpose: Understanding the relationships between various energies - Problem Pierret 2.22
5) Purpose: Understanding of simple electron-hole concentration relationships.
Find the electron and hole concentrations as well as the fermi level and intrinsic energy positions for a silicon sample with the following conditions: (You may need data from tables 2.1 and 2.3 and assume ***Total ionization*** and a 27 C temperature)
   a) $10^{16}$ $cm^{-3}$ Al
   b) $9x10^{17}$ $cm^{-3}$ As and $8.95x10^{17}$ $cm^{-3}$ Al
   c) What is the majority carrier concentration for parts a, and b?
   d) What is the minority carrier concentration for parts a, and b?
   e) Is the material n-type or p-type in parts a, and b?

6) Purpose: Understanding of the partial ionization "real world" situation.
Find the electron and hole concentrations as well as the fermi level position for a silicon sample with the following conditions: (You may need data from tables 2.1 and 2.3, assume ***Partial ionization*** with the valence band edge, Ev, set equal to 0, and a 27 C temperature). For each case below, make a table including Ef guesses, each of the 4 terms in the partial ionization equation (free p, fixed ionized acceptors, free n and fixed ionized donors), and the left and right hand side values. Using a spreadsheet or math package would also be useful (and allowed) but be sure to show the work/codes.
   a) $9x10^{17}$ $cm^{-3}$ B and $8.95x10^{17}$ $cm^{-3}$ Sb
   b) $9x10^{17}$ $cm^{-3}$ In and $8.95x10^{17}$ $cm^{-3}$ Sb
   c) Speculate why is B more commonly used as an acceptor than In?

Notes on problem 6: Given the partial ionization equation from lecture 6:

$$p-\frac{N_A}{1+g_A\ e^{(E_A-E_f)/kT}}=n-\frac{N_D}{1+g_D\ e^{(E_f-E_D)/kT}}$$

$$N_v e^{(E_v-E_f)/kT}-\frac{N_A}{1+g_A\ e^{(E_A-E_f)/kT}}=N_c e^{(E_f-E_c)/kT}-\frac{N_D}{1+g_D\ e^{(E_f-E_D)/kT}}$$

You will almost never have the residuals (the individual 4 terms in the partial ionization equation) equate exactly. Instead, one needs to assume a fermi energy and find the value of the left and right hand sides. If they do not equal (which they will almost never exactly equal), assume a new fermi energy. If the second guess you made is closer than the first guess, the two sides will approach each other. This indicates your guess is headed in the correct direction. Make a 3rd guess. In each round, if the guess results in left/right side terms that diverge from one another your guess is headed in the wrong direction. If the sign of the left/right sides switches, you passed over the correct value. It helps greatly to include a table of values to see the trends in your guesses.