University of California, Berkeley
EE230 - Solid State Electronics *Prof. J. Bokor*

PROBLEM SET 5

(Due Thursday, May 1, 2008)

1. (Lundstrom 2.6) For alloys of compound semiconductors such as $Al_xGa_{1-x}As$, microscopic fluctuations in the alloy composition, x, produce perturbations in the conduction and valence band edges. The scattering rate for alloy scattering is:

$$S(p, p') = \frac{2\pi}{\hbar}\left(\frac{3\pi^2}{16}\right)\frac{|\Delta U|^2}{N\Omega}\delta(E' - E)$$

where N is the concentration of atoms, Ω is a normalization volume, and

$$\Delta U = x(1-x)(\chi_{GaAs} - \chi_{AlAs})$$

(χ is the electron affinity).

a) Explain why the alloy scattering rate vanishes at x=0 and x=1.

b) Derive an expression for $\tau_m(p)$ for alloy scattering.

2. (Lundstrom 2.9) Compute and compare the momentum relaxation times due to ionized impurity scattering under the following circumstances:

a) Find $1/\tau_m$ for electrons with the thermal average energy $E=3kT_L/2$ in GaAs doped at $N_D=10^{18}$ cm^{-3}. Assume T_L= 300K. Compare L_D with b_{max} and discuss whether the screened (Brooks-Herring) or unscreened (Conwell-Weisskopf) theory is most appropriate.

b) Repeat for electrons with E = 0.3 eV (injection across a heterojunction barrier).

3. The Γ- L intervalley scattering process (and it's reverse L- Γ process) play a crucial role in several GaAs based devices.

a) Calculate the Γ- L and L- Γ intervalley scattering rates for electrons in GaAs as a function of energy at 77K and 300K. [Hint: use 27.8 meV for the intervalley phonon energy. Other numerical values for material parameters that you need can be found somewhere in Lundstrom.]

b) Look in the literature for experiments on these scattering rates. Try to make a comparison between your calculation and experiment. [Hint: You might not find a simple experimental determination of these rates as a function of energy as you have calculated. If necessary, make additional calculations that will ultimately allow you to make a comparison to experimental results that you can find.]

4. In chapter 6 of Lundstrom, he shows how to use a uniformly distributed random number between 0 and 1 to generate collision times.

a) Write a computer program to select scattering times from eq. (6.17) in Lundstrom (same equation number in both 1st and 2nd editions). Choose $\Gamma_0 = 3.0E14$.

b) How many selections are required to make the average time between collisions come out correct within 10%, 5%, 1%?