Name ______________________________

Exam #1 — EE 482

Winter 2010

The test is open book/open notes. Show all work. Be sure to state all assumptions made and **check** them when possible. The number of points per problem are indicated in parentheses (50 total).

1. The electron concentration in a region of silicon depends linearly on depth with concentration of $5 \times 10^{15}\,\text{cm}^{-3}$ at surface ($x = 0$) and $10^{15}\,\text{cm}^{-3}$ at depth of $x = 500\,\text{nm}$. If the vertical electron current density in this region is constant at $J_n = 100\,\text{A/cm}^2$, calculate the electric field near $x = 500\,\text{nm}$. You may assume that the mobility is constant at $1250\,\text{cm}^2/\text{Vs}$. (12)

2. (a) Sketch the band diagram (E vs. k along main symmetry directions) for a semiconductor which has $\mu_p > \mu_n$ and $N_v < N_c$. The qualitative relations should be clear from your sketch. Assume scattering lifetimes are equal for holes and electrons. Briefly note reasoning. (10)

(b) Calculate the intrinsic carrier concentration at 300 K in a semiconductor which has a single valence band maxima given by $E = E_v - (\hbar^2 k^2 / 2m_0)$ and eight conduction band minima in the $\langle 111 \rangle$ directions with $E = E_c + 2\hbar^2 (k - k_0)^2 / m_0$ where $k_0 = (\pm a, \pm a, \pm a)$, $E_c - E_v = 1\,\text{eV}$ and m_0 is the free electron mass. (10)

3. A GaAs wafer is doped with $10^{16}\,\mathrm{cm}^{-3}$ donors and $2\times10^{15}\mathrm{cm}^{-3}$ acceptors. It is desired to make this material semi-insulating by doping with chromium, which has a deep acceptor level 0.7 eV above the valence band maximum.

   (a) What is the minimum required chromium concentrations to drop the majority carrier concentration to $10^{9}\,\mathrm{cm}^{-3}$ at 300 K? (10)

   (b) What would be the resulting resistivity of the material? What would be the sheet resistance of a $200\,\mu\mathrm{m}$ thick wafer of this material? (8)