Problems for chapter 8, due March 9, 2012

1. ***Impurity orbits.*** Indium antimonide has $E_g = 0.23$ eV; dielectric constant $\epsilon = 18$; electron effective mass $m_e = 0.015\ m$. Calculate (a) the donor ionization energy; (b) the radius of the ground state orbit. (c) At what minimum donor concentration will appreciable overlap effects between the orbits of adjacent impurity atoms occur? This overlap tends to produce an impurity band—a band of energy levels which permit conductivity presumably by a hopping mechanism in which electrons move from one impurity site to a neighboring ionized impurity site.

2

Cyclotron resonance for a spheroidal energy surface. Consider the energy surface

$$\epsilon(\mathbf{k}) = \hbar^2\left(\frac{k_x^2 + k_y^2}{2m_t} + \frac{k_z^2}{2m_l}\right) ,$$

where m_t is the transverse mass parameter and m_l is the longitudinal mass parameter. A surface on which $\epsilon(\mathbf{k})$ is constant will be a spheroid. Use the equation of motion (6), with $\mathbf{v} = \hbar^{-1}\nabla_{\mathbf{k}}\epsilon$, to show that $\omega_c = eB/(m_l m_t)^{1/2}c$ when the static magnetic field B lies in the xy plane. This result agrees with (34) when $\theta = \pi/2$. The result is in CGS; to obtain SI, omit the c.

3.

a) Compute the concentration of electrons and holes in an intrinsic sample of Si at room temperature. You may take $m_e = 0.7\ m_0$ and $m_h = m_0$.
b) Determine the position of the Fermi energy level under these conditions.

4.

Given these data for Si: $\mu_e = 1350\ \mathrm{cm^2/volt\text{-}s}$, $\mu_h = 475\ \mathrm{cm^2/volt\text{-}s}$, and $E_g = 1.1$ eV, calculate the following.
a) The lifetimes for the electron and for the hole.
b) The intrinsic conductivity σ at room temperature.
c) The temperature dependence of σ, assuming that electron collision is dominated by phonon scattering, and plot log σ versus $1/T$.