PHYS 225 – Spring 2011 **Marie Lopez del Puerto**

HW #25

1. **Derivation for Exam 4:** Derive the following expression for the intrinsic concentration of electrons in a pure semiconductor: $n_i = \sqrt{N_c N_v}\, e^{-E_{gap}/2kT}$.

   Useful integrals:
   $$\int_{E_c}^{\infty} (E - E_c)^{1/2} e^{-(E-E_F)/kT} dE = -\frac{\pi^{1/2}}{2}(kT)^{3/2} e^{-(E_c-E_F)/kT}$$
   $$\int_{0}^{E_v} E^{1/2}[1 - e^{-(E_F-E)/kT}]dE = \frac{\pi^{1/2}}{2}(kT)^{3/2} e^{-(E_F-E_V)/kT}$$

2. **(Kasap 5.1) Bandgap and photodetection**
   a) Determine the maximum value of the energy gap that a semiconductor, used as a photoconductor, can have if it is to be sensitive to yellow light (600 nm).
   b) A photodetector whose area is 5 x 10^{-2} cm^2 is irradiated with yellow light whose intensity is 2 mW/cm^2. Assuming that each photon generates one electron-hole pair, calculate the number of pairs generated per second.
   c) From the know energy gap of the semiconductor GaAs (1.42 eV), calculate the primary wavelength of photons emitted from this crystal as a result of electron-hole recombination.
   d) Is the above wavelength visible?
   e) Will a silicon photodetector be sensitive to the radiation from a GaAs laser? Why?

3. **(Kasap 5.5) Extrinsic Si** Find the concentration of acceptors required for a P-type Si crystal to have a resistivity of 1 Ω cm.

4. **(Kasap 5.6) Minimum conductivity**
   a) Consider the conductivity of a semiconductor, $\sigma = en\mu_e + ep\mu_h$. Will doping always increase the conductivity?
   b) Show that the minimum conductivity for Si is obtained when it is P-type doped such that the hole concentration is
   $$p_{\min} = n_i\sqrt{\frac{\mu_e}{\mu_h}}$$
   and the corresponding conductivity (maximum resistivity) is $\sigma_{\min} = 2en_i\sqrt{\mu_e \mu_h}$
   c) Calculate p_{min} and σ_{min} for silicon and compare with intrinsic values.

5. Which of the following pictures or descriptions represent n-type semiconductors and which represent p-type semiconductors?