ECE-606 Homework No. 6 Assigned: Sept. 25 Due: Oct. 2

1) The number of electrons and holes in Silicon undergoing radiative (light-emitting) recombination is small owing to silicon's indirect band structure. We will perform a short calculation below to convince ourselves that the indirect band gap is indeed the source of intrinsic Si not used as an opto-electronic material.

   a. A photon of wavelength of 10^4 A is incident on a piece of Silicon, assuming that the lattice constant of silicon is 5 A; prove that the momentum carried away by the photon is much less than the change in the electron momentum.

   b. What is the possible mechanism that would be able to carry off the large change in electron momentum? Explain briefly why this process has a very low probability of occurrence.

   c. Draw a detailed sketch showing the various ways radiative recombination can happen in Silicon. Sketch a comparable diagram for GaAs too.

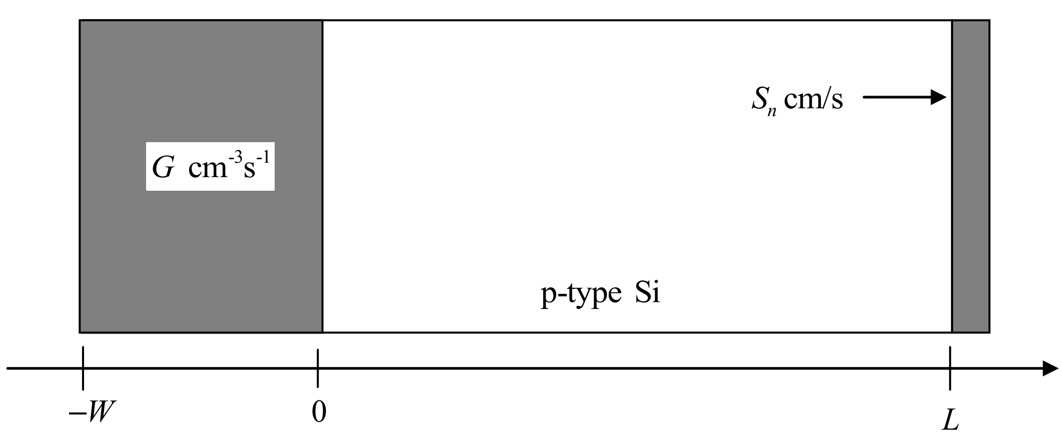
   d. The energy of the photon given off during a radiative electron-hole recombination event in Silicon is approximately equal to 1.2 eV. Will the light emitted by this process be visible to the human eye?

2) Solve ASF 5.6

3) Solve ASF 6.1

4) The purpose of this exercise is to familiarize you with minority carrier diffusion in semiconductors. Recall that for a uniformly doped, p-type semiconductor with a uniform electron-hold generation rate of G electron-hole pairs /cm^3.s, the excess minority carrier (electron) density is, $\Delta n = G\tau_n$, where τ_n is the minority carrier lifetime.

   Consider a semiconductor as shown below.



Assume that the electron-hole generation rate is G for $x \le 0$ and that the contact at $x = L$ is specified by a minority carrier surface recombination velocity S_n.

a. Assume that $\Delta n = G\tau_n$ for $x \le 0$ (this is an approximation that ignores edge effects near x = 0). Also assume that the diffusion length, $L_n = \sqrt{D_n \tau_n} << L$ and that $S_n \to \infty$. Derive an expression for $\Delta n(x)$ for $x > 0$.

b. Repeat part a) but this time assume that the diffusion length, $L_n = \sqrt{D_n \tau_n} >> L$ and that $S_n \to \infty$. Derive an expression for $\Delta n(x)$ for $x > 0$.

c. Repeat part b) but now assume that $S_n = 0$. Derive an expression for $\Delta n(x)$ for $x > 0$.

5) Inter-band impact generation of electron-hole pair in a high electric field is one of the many hot carrier effects. We will perform a simple calculation to estimate the equivalent electron temperature of a ***hot*** electron

Assume that the initial energy supplied by an energetic electron to form an electron-hole pair is $1.5E_g$, where E_g is the band gap of Silicon.

a. Compute the effective electron energy at room temperature

b. Calculate the equivalent electron temperature $\mathbf{T_{electron}}$ for the electron that initiated the electron-hole pair generation

6) A semiconductor with band gap E_g is irradiated with photon of energy $h\upsilon$. Assuming the energy of photon is greater than the band gap, electron-hole pairs are created through direct excitation of the electrons from the valence band. Determine the wave vector ***k*** and energy of the electrons and holes. The semiconductor is assumed to be direct band gap.

Your answer should be in terms of the Planck's constant, $\mathbf{E_c}$ (bottom of the conduction band), $\mathbf{E_v}$ (top of valence band), effective masses of electrons and holes at the bottom of conduction and top of valence bands respectively.