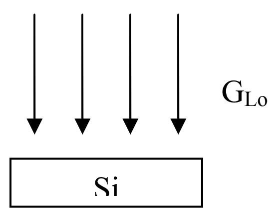
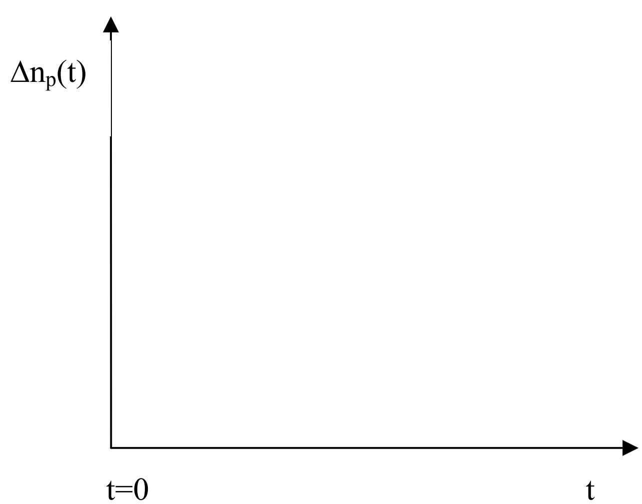
ECE 6453 Spring 2008
Homework 3 (Bonus)

Submission deadline for instructor's comments: <u>Noon, February 8, 2008 (Friday)</u>
Drop off your homework in my office's front-door pocket at
<u>Room 307, Bunger Henry Building</u>

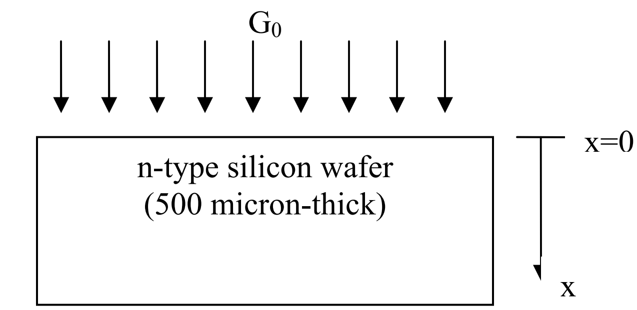
Note: The questions below are meant to give students an exercise for better understanding of topics on carrier transport. It will not be counted as the regular homework credits. *<u>No solutions will be provided on the class website before the first exam date</u> and you may opt not to turn in this homework.* However, if you do, the instructor will comment on your submitted solutions and *return to you on Monday February 11, 2008 (for your exam preparation, basically), if you may be able to drop by my office to pick it up.*

1. **Nonequilibrium carrier injection**
   a) An ultra thin silicon slice ($N_A=10^{14}cm^{-3}$, $\tau_n=10^{-6}s$, T=300K) is first illuminated for a long period of time t>> τ_n with light which uniformly generates $G_{Lo}=10^{13}$ EHP/cm^3 through out the volume of the silicon. At t=0 the light intensity is reduced to $G_{Lo}/2$. Determine and Plot $\Delta n_p(t)$ for t≥0.

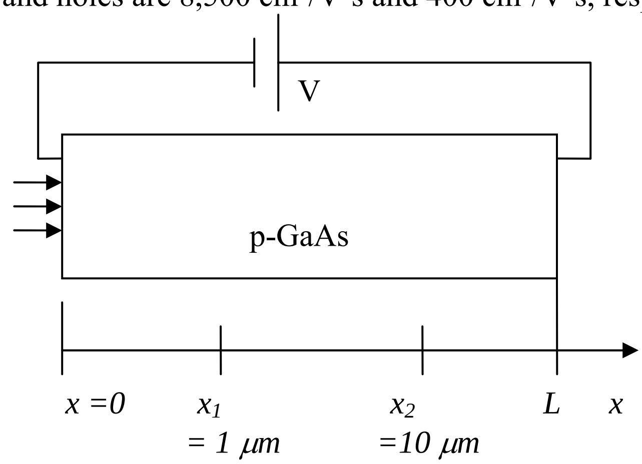




   b) In reality, a silicon wafer is 500-µm thick. The photon absorption in the bulk material is a function of position. Now, a high energy light is illuminated on the surface of a n-type silicon wafer and, at steady state, the photogeneration rate of G_o is established on the surface of the silicon at $t \le t_o$. At $t = t_o$, the light is turned off due to power failure. Assume low-level injection holds true in this case. Establish the time-dependent diffusion equations and the boundary conditions that are required to solve the excess carrier concentration $\Delta p_n(x,t)$



2. Consider a piece of p-type GaAs ($p = 1\times10^{15}$ cm^{-3}) with a length (L) of 2 mm. Through certain scheme, one is able to inject an amount of holes (like, the QNR in a PN junction) at $x = 0$. Assume that the minority carrier life time is 10^{-8} s and the mobility for electrons and holes are 8,500 cm^2/V-s and 400 cm^2/V-s, respectively.



   a) Assume that there is a constant supply of holes at $x = 0$. Draw the quasi-Fermi level for electrons and holes, repectively, at steady state, if the injected holes is $\Delta p(0) = 10^9$ cm^{-3} and the applied voltage $V = 0$.
   b) If the source of hole injection is removed at time $t = 0$. Find the excess carrier concentration as a function of time (t) and position (x). What are the responsible mechanisms for such carrier behavior?
   c) At $t \rightarrow \infty$, one may reset the timer to $t = 0$ and injects a pulse of excess electrons that is described by $\Delta n(x,t) = 10^7\ \delta(x)\ \delta(t)\ cm^{-3}$, where $\delta(i) = 1$ if $i = 0$, and $\delta(i) = 0$ otherwise. If $V = 20$ V, find the electron transport equation of this system.
   d) In c), if an oscilloscope is probed at positions x_1 and x_2, the peak amplitude of the induced current would be detected at t_1 and t_2, respectively. Determine the time difference $\Delta t(= t_2 - t_1)$ between the peak amplitude detection (Think Haynes-Shockley experiment)

e) In d), determine the time-domain pulse width (full-width at half maximum) detected at x_1 and x_2, respectively. If there is another probe attached to $x = 1\ mm$, what is the detected peak amplitude of the pulse when it arrives?

f) In the same setup, if the length of the bar is cut down to 1 μm and the applied voltage is reduced to V = 2 V. How would you modify your minority carrier transport equation and what approximation can you make to simplify your analysis?