ECE 340: Semiconductor Electronics

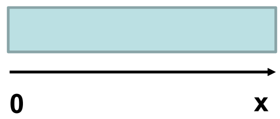
Practice problems for chapter 1 to 4

1. In an n-type silicon wafer ($N_d = 10^{17}$ cm^{-3}) illuminated uniformly with 10 mW/cm^2 of red light ($E_{ph} = 1.8$ eV). The absorption coefficient of red light in silicon is 10^{-3} cm^{-1}. The minority carrier lifetime is 10ms.

(a) Calculate the electron and hole densities
(b) Calculate the positions of the quasi-Fermi levels for the two carrier types and compare it to the Fermi energy in the absence of illumination.
(c) If the light was turned off at $t = 0$, find a formula for excess hole concentration $\delta p(t)$ for $t > 0$. Does low level injection condition satisfied in this case?

2. Image at one end of a n-type silicon, all minority carriers are constantly swept out (i.e. p=0 at x=0), while the majority carrier remains the same. The doping concentration is 10^{15} cm^{-3}. The hole mobility is 1000 cm^2/V-s, $\tau_p = 1\mu s$, T=300K. For simplicity, assume KT/q=25mV at 300K.

(a) What is the excess hole concentration δp at x=0?
(b) Find the minority carrier concentration distribution p(x) and sketch p(x) vs x.
(c) At $x = 50\mu m$, calculate the hole diffusion current.



3. A silicon crystal is know to contain 10^{-4} atomic percent of arsenic (As) as an impurity. It then receives a uniform doping of $2\text{x}10^{16}$ phosphorus (P) atoms and a subsequent uniform doping of $1\text{x}10^{16}$ Gallium (Ga) atoms. A thermal annealing treatment then completely activates all impurities. (silicon has $5\text{x}10^{22}$ atoms cm^{-3}, intrinsic carrier concentration for silicon is $1.5\text{x}10^{10}$ cm^{-3})

(a) What is the conductivity type of this silicon sample?
(b) What is the electron and hole concentration?
(c) Find the location of the Fermi-level.

4. A silicon bar with height of h=100um, width W=1cm and length of L=10 cm, was doped by diffusion. The doping profile is $N_d(x) = N_0(1 - x/h)$, where $N_0 = 10^{15}$ cm^{-3}. Calculate the resistance of this bar along the length direction. Assume mobility is uniform μ_n=1000 cm^2/V-s.