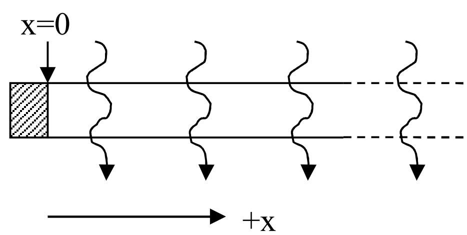
EE 207 [Spring 24-25] ***HW-4***

1. We have a semiconductor with bandgap 1.4eV, an intrinsic carrier concentration of $1.8\text{x}10^{6}$ cm^{-3} at room temperature, n-doping of $10^{14}cm^{-3}$, and electron (hole) mobility of 8000 (400) $cm^2V^{-1}s^{-1}$ Assume identical electron and hole effective mass. Suppose it is irradiated with light such that the steady-state electron-hole pair generation rate close to the top surface is $10^{20}s^{-1}cm^{-3}$.

(a) What is the steady-state concentration of electrons and holes close to the surface? Draw a quantitatively labeled band-diagram for that region in this scenario.

(b) Now, the excess minority carriers at the surface will diffuse into the bulk of the semiconductor, recombining as they go. The minority carrier lifetime is 100ns (1ns $=10^{-9}$s). What is their diffusion length λ? Derive an equation describing the state-state minority carrier concentration as a function of depth (you do not need to solve it).

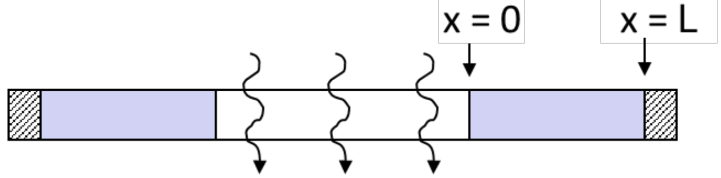
2. Consider the thin, semi-infinite, n-type semiconductor sample subjected to radiation shown below, resulting in a uniform steady-state generation rate of holes G_p deep in the bulk of the sample. Assume the recombination rate of excess holes is given by $R_p = \delta p/\tau_p$, where τ_p is the hole lifetime; the hole diffusivity is D_p and diffusion length is $\lambda_p = \sqrt{D_p\tau_p}$.



(a) The contact at $x=0$ acts as a sink to force the excess hole concentration to zero there. Derive an expression for the variation of the excess hole concentration with position x.

(b) In reality, the contact will not be the perfect sink that it is assumed to be in part (a). Suggest a way to quantify its effectiveness as a sink. (Please try to come up with your idea/s before looking up how this is conventionally done.)

3. Consider a semiconductor bar illuminated in the middle – illustrated below and discussed in class. The difference here is that the length of the unilluminated segment is not infinite, it is L.



Suppose the generation rate in the illuminated segment is G, and the minority carrier lifetime everywhere is τ. Assume that L is much less than the minority carrier recombination length λ, so that recombination of minority carriers can be neglected as they diffuse from x=0 to x=L. Derive an expression for the excess minority carrier concentration as a function of position in this region. Assume that the contact at x=L forces the excess carrier concentration to zero there.

4. We have discussed in class that majority carriers typically respond much faster than minority carriers. Therefore, we focused on the slower minority carrier response which dominates the dynamics, while just assuming charge neutrality due to the fast majority carriers. Here we examine the majority carrier response. Imagine a slab of metal (so we do not have to worry about minority carriers, or recombination) contacted at the bottom, whose top surface is subjected to a pulse-like disturbance that produces a non-equilibrium (excess) carrier concentration. This gives rise to a transient electric field and a transient current (pure drift, subject to Ohm's Law) flowing from the top surface towards the bottom contact.

(a) What are the relevant equations to analyze this scenario?

(b) Put them together to derive an expression for the time-dependence of the excess majority charge density at the top surface, and thereby, the majority carrier response time.