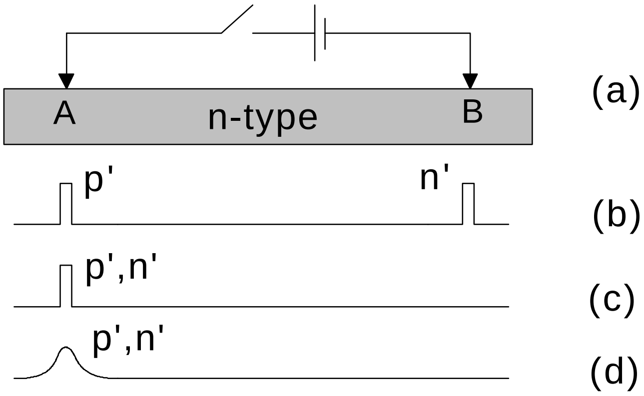
<u>Solid State III Problem Week 3 - supplement</u>

This question is intended to help you gain insight into the importance of minority carriers in determining the electronic response of semiconductor materials.

Consider the injection of a pulse of minority carriers, holes in this case, into an n-type semiconductor to create the following non-equilibrium distribution of carriers:



If the switch is closed in (a) for a short time a pulse of holes is injected at point A and a pulse of electrons is injected at point B as indicated by the excess carrier densities shown in (b) immediately after injection. However, after a very short time, of the order of a few dielectric relaxation times (~10^{12} secs), electrical neutrality will have been achieved at A by the redistribution of the <u>majority</u> carriers (electrons). The situation is as shown in (c), at this point in time there has been negligible recombination of the holes and electrons. Now over the period of several <u>minority</u> carrier lifetimes (~10^{-7}-10^{-3} secs) the pulse of holes and electrons will broaden due to diffusion and reduce in size (= area of pulse) due to recombination (d).

The continuity equation for hole minority carriers is:

$$\frac{\partial p'}{\partial t} = -\frac{p'}{\tau_p} + D_h \frac{\partial^2 p'}{\partial x^2} + \mu_h E \frac{\partial p'}{\partial x}$$

where τ_p is the minority carrier lifetime for the holes in n-type semiconductor and is a measure of the approximate net loss of carriers (difference between generation and recombination) at a given temperature. This has the solution for zero applied electric field:

$$p'(x,t) = \frac{P}{(4\pi D_h t)^{\frac{1}{2}}} \exp\left(-\frac{t}{\tau_p} - \frac{x^2}{4D_h t}\right)$$

where P is the initial number of holes (per unit cross section) injected into the semiconductor at x=0 and t=0.

(i) Show that this is indeed a solution of the above continuity equation.

(ii) Show that the total number of holes (area underneath the pulse) is decreasing as $\exp(\frac{-t}{\tau_p})$ due to recombination, and that the width of the pulse at time t is approximately $(D_h t)^{\frac{1}{2}}$.

(iii) Thus calculate the time it would take for the number of holes to decrease to one tenth of the initial number and what would the width of the pulse be at this time (for n-type silicon at 300K, τ_p= 2.5 ms; and m_h = 4.8 cm^{2}V^{-1}s^{-1})?