Example- Let's reverse this situation. Our thin sample of n-type ($N_d = 3 \times 10^{16}$ #/cm^3) GaAs (minority carrier lifetime of 40 ns) is at thermal equilibrium with no external electric field in the dark. At $t = 0$, a uniform beam of light is applied, causing excess charge carriers to be generated at a rate of 8×10^{21} #/cm^3·s. Determine what happens to the excess carriers.

For n-type GaAs, the minority carrier (i.e., holes/δp) transport equation is:

$$\frac{\partial(\delta p)}{\partial t} = D_p \frac{\partial^2(\delta p)}{\partial x^2} - \mu_p E \frac{\partial(\delta p)}{\partial x} + g' - \frac{\delta p}{\tau_{p0}}$$

- "thin sample" and "uniform beam of light" implies uniform distribution.

$$\Rightarrow \frac{\partial^2(\delta n)}{\partial x^2} = \frac{\partial^2(\delta p)}{\partial x^2} = 0.$$

- "no external electric field" and "uniform beam of light"

$$\Rightarrow E\frac{\partial(\delta n)}{\partial x} = E\frac{\partial(\delta p)}{\partial x} = 0.$$

Therefore, our n-type minority carrier transport equation reduces to

$$\frac{\partial(\delta p)}{\partial t} = g' - \frac{\delta p}{\tau_{p0}} \qquad \Rightarrow \qquad \frac{\partial(\delta p)}{\partial t} + \frac{1}{\tau_{p0}}\delta p = g'.$$

This first-order ODE has a natural solution $\delta p_n(t) = Ae^{-t/\tau_{p0}}$ and forced solution of $\delta p_f(t) = g'\tau_{p0}$. Adding these gives the general solution $\underline{\delta p(t) = Ae^{-t/\tau_{p0}} + g'\tau_{p0}}$.

Applying the initial condition that $\delta p(0) = 0 = A + g'\tau_{p0}$, leads to $A = -g'\tau_{p0}$ and $\delta p(t) = g'\tau_{p0}\left(1 - e^{-t/\tau_{p0}}\right)$ for $t \geq 0$.

Using the given minority carrier lifetime $\tau_{p0} = 40$ ns & $g' = 8 \times 10^{21}$ #/cm^3·s, we get

$$\boxed{\delta p(t) = \delta n(t) = 3.2 \times 10^{14}\left(1 - e^{-t/40\times10^{-9}}\right) \text{#/cm}^3 \text{ for } t \geq 0}.$$