Example- We have a sample of n-type ($N_d = 3 \times 10^{16}$ #/cm^3) GaAs where the minority carrier lifetime is 40 ns. A uniform beam of light has been shining on a thin sample of the GaAs for long enough to establish a uniform excess charge carrier concentration of 4×10^{14} #/cm^3. Assume there is no external electric field. At $t = 0$, the light shuts off. Determine what happens to the excess carriers.

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

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

- Low-level injection assumptions valid? Calculate ratio $\frac{N_d}{\delta n} = \frac{3\times 10^{16}}{4\times 10^{14}} = 75$.

  $\Rightarrow$ Yes, since $N_d >> \delta n$, the low-level injection assumption is valid.

- "uniform excess charge carrier concentration" 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" $\Rightarrow$ $\bar{E}\frac{\partial(\delta n)}{\partial x} = \bar{E}\frac{\partial(\delta p)}{\partial x} = 0$.

- "light shuts off" $\Rightarrow g' = 0$ for $t \geq 0$, i.e., stop generation of excess carriers.

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

$$\frac{\partial(\delta p)}{\partial t} = -\frac{\delta p}{\tau_{p0}} \qquad \Rightarrow \qquad \frac{\partial(\delta p)}{\partial t} + \frac{1}{\tau_{p0}}\delta p = 0.$$

This first-order ODE has a general solution $\delta p(t) = Ae^{-t/\tau_{p0}}$. Applying the initial condition that $\delta p(0) = 4 \times 10^{14}$ #/cm^3 and given minority carrier lifetime $\tau_{p0} = 40$ ns, we get

$$\boxed{\delta p(t) = \delta n(t) = 4\times 10^{14} e^{-t/40\times 10^{-9}} \text{ \#/cm}^3 \text{ for } t \geq 0}.$$