6.19 Consider a bar of p-type silicon that is uniformly doped to a value of $N_a = 2 \times 10^{16}\ \text{cm}^{-3}$ at $T = 300$ K. The applied electric field is zero. A light source is incident on the end of the semiconductor as shown in Figure P6.19. The steady-state concentration of excess carriers generated at $x = 0$ is $\delta p(0) = \delta n(0) = 2 \times 10^{14}\ \text{cm}^{-3}$. Assume the following parameters: $\mu_n = 1200\ \text{cm}^2/\text{V-s}$, $\mu_p = 400\ \text{cm}^2/\text{V-s}$, $\tau_{n0} = 10^{-6}$ s, and $\tau_{p0} = 5 \times 10^{-7}$ s. Neglecting surface effects, (*a*) determine the steady-state excess electron and hole concentrations as a function of distance into the semiconductor, and (*b*) calculate the steady-state electron and hole diffusion current densities as a function of distance into the semiconductor.

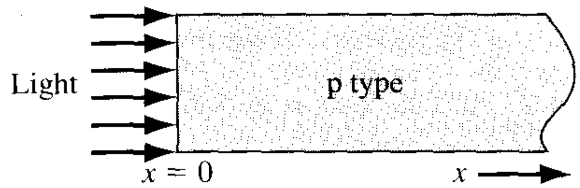

Figure P6.19 | Figure for Problems 6.19 and 6.21.

For a p-type semiconductor use (6.55)

$$\frac{\partial(\delta n)}{\partial t} = D_n \frac{\partial^2(\delta n)}{\partial x^2} + \mu_n E \frac{\partial(\delta n)}{\partial x} + g' - \frac{\delta n}{\tau_{n0}}$$

a) At steady-state, $\frac{\partial(\delta n)}{\partial t} = 0$

Given applied electric field is zero $\Rightarrow E = 0$

Only generating excess carriers @ $x=0 \Rightarrow g' = 0$

$$D_n \frac{\partial^2(\delta n)}{\partial x^2} - \frac{\delta n}{\tau_{n0}} = 0 \Leftarrow (6.62)$$

Define $L_n^2 = D_n \tau_{n0}$

$$(5.47)\quad \frac{D_n}{\mu_n} = \frac{k_B T}{e} \Rightarrow D_n = 1200\ \frac{8.617333 \times 10^{-5}\ eV/K\ (300K)}{e}$$

$$D_n = 31.0224\ \text{cm}^2/\text{s}$$

$$(6.45)\quad D' = D_n = 31.0224\ \text{cm}^2/\text{s}$$

a) cont. $L_n = \sqrt{31.0224(10^{-6})} = 5.569775 \times 10^{-3}\ \text{cm}$

$= 55.69775\ \mu m$

Per (6.65a) $\delta n(x) = \delta p(x) = \delta n(0)\, e^{-x/L_n} \quad x \geq 0$

$$\underline{\underline{\delta n(x) = \delta p(x) = 2 \times 10^{14}\, e^{-x/5.57 \times 10^{-5}}\ \frac{\#}{cm^3} \quad x \geq 0}}$$

b) (5.33) $J_{nx|dif} = e D_n \dfrac{dn}{dx} = e D' \dfrac{d\,\delta n(x)}{dx}$

$$J_{nx|diff} = \frac{1.6022 \times 10^{-19}(31.0224)\, 2 \times 10^{14}}{-5.57 \times 10^{-5}(100\,\frac{cm}{m})}\, e^{-\frac{x}{5.57 \times 10^{-5}}}$$

$$\underline{\underline{J_{nx|diff} = -0.17847\, e^{-x/5.57 \times 10^{-5}}\ A/cm^2 \quad x \geq 0}}$$

(5.34) $J_{px|dif} = -e D_p \dfrac{dp}{dx} = -e D' \dfrac{d\,\delta p(x)}{dx}$

$= -J_{nx|diff}$

$$\underline{\underline{J_{px|dif} = 0.17847\, e^{-x/5.57 \times 10^{-5}}\ A/cm^2 \quad x \geq 0}}$$