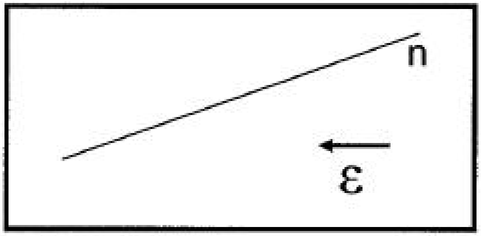
Prob. 4.13

Show current flow in the n-type bar and describe the effects of doubling the electron concentration or adding a constant concentration of electrons uniformally.



← electron diffusion (high to low concentration)
→ current density (J_n) for diffusion
→ electron drift
← current density (J_n) for drift

note: currents are opposite electron flow because of negative charge

initially:

J_n diffusion $= q \cdot D_n \cdot \frac{dn}{dx}$

J_n drift $= q \cdot n \cdot \mu_n \cdot \mathcal{E}$

double electron concentration :

J_n diffusion $= q \cdot D_n \cdot 2\frac{dn}{dx} \rightarrow$ doubles

J_n drift $= q \cdot 2n \cdot \mu_n \cdot \mathcal{E} \rightarrow$ doubles

add constant concentration (n_+) :

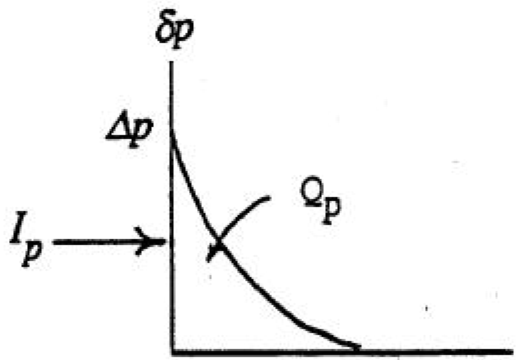
J_n diffusion $= q \cdot D_n \cdot \frac{dn}{dx} \rightarrow$ does not change

J_n drift $= q \cdot (n + n_+) \cdot \mu_n \cdot \mathcal{E} \rightarrow$ increases by $q \cdot n_+ \cdot \mu_n \cdot \mathcal{E}$

Prob. 4.14

Show the hole current feeding an exponential δp(x) may be found from Q_p/τ_p.

The charge distribution, Q_p, disappears by recombination and must be replaced by injection an average of τ_p seconds.
Thus, the current injected must be Q_p/τ_p.



$$Q_p = q \cdot A \cdot \int_0^\infty \delta p \cdot dx = q \cdot A \cdot \int_0^\infty \Delta p \cdot e^{-\frac{x}{L_p}} \cdot dx = q \cdot A \cdot L_p \cdot \Delta p$$

$$I_p = \frac{Q_p}{\tau_p} = \frac{q \cdot A \cdot L_p \cdot \Delta p}{\tau_p} = \frac{q \cdot A \cdot D_p \cdot \Delta p}{L_p}$$

Prob. 4.17

Include recombination in the Haynes-Shockley experiment and find τ_p.

To include recombination, let the peak value vary as $e^{-\frac{t}{\tau_p}}$.

$$\delta p = \frac{\Delta p \cdot e^{-\frac{t}{\tau_p}}}{\sqrt{4\pi \cdot D_p \cdot t}} \cdot e^{\frac{-x^2}{4 \cdot D_p \cdot t}}$$

peak V_p at x=0 = $B \cdot \frac{\Delta p \cdot e^{-\frac{t}{\tau_p}}}{\sqrt{4\pi \cdot D_p \cdot t}}$ where B is a proportionality constant

$$\frac{V_{p1}}{V_{p2}} = \frac{B \cdot \frac{\Delta p \cdot e^{-\frac{t}{\tau_p}}}{\sqrt{4\pi \cdot D_p \cdot t_1}}}{B \cdot \frac{\Delta p \cdot e^{-\frac{t}{\tau_p}}}{\sqrt{4\pi \cdot D_p \cdot t_2}}} = \sqrt{\frac{t_2}{t_1}} \cdot \frac{e^{-\frac{t_1}{\tau_p}}}{e^{-\frac{t_2}{\tau_p}}} = \sqrt{\frac{t_2}{t_1}} \cdot e^{\frac{t_2 - t_1}{\tau_p}}$$

$$\frac{80\text{mV}}{20\text{mV}} = \sqrt{\frac{200\mu\text{s}}{50\mu\text{s}}} \cdot e^{\frac{200\mu\text{s} - 50\mu\text{s}}{\tau_p}} \rightarrow \frac{150\mu\text{s}}{\tau_p} = \ln\frac{4}{\sqrt{4}} \rightarrow \tau_p = \frac{150\mu\text{s}}{\ln 2} = 216.4\mu\text{s}$$