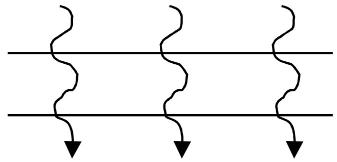
Case study: uniform steady-state illumination



$$G_n = G_p = G$$

What is the density of excess minority carriers (electrons)?

Continuity

$$\frac{\partial n}{\partial t} = \frac{1}{e}\frac{\partial J_n}{\partial x} + (G_n - R_n)$$

Steady-state

$$0 = \frac{1}{e}\frac{\partial J_n}{\partial x} + (G_n - R_n)$$

Uniform

$$J_n = 0 \Rightarrow G_n = R_n$$

Low-level injection

$$R_n = \frac{\delta n}{\tau_n}$$

$$\boxed{\delta n = G\tau_n}$$

Case study: uniform transient illumination

$$G_n(t) = G_p(t) = G \cdot \Theta(t) \qquad \delta n(t=0) = 0$$

How does the density of minority electrons vary with time?

Continuity

$$\frac{\partial n}{\partial t} = \frac{1}{e}\frac{\partial J_n}{\partial x} + (G_n - R_n) \qquad R_n = \delta n / \tau_n$$

$$\frac{\partial n}{\partial t} = \left(G - \frac{\delta n}{\tau_n}\right) \Rightarrow \frac{\partial(\delta n)}{\partial t} = \left(G - \frac{\delta n}{\tau_n}\right) \qquad J_n = 0$$

Uniform

$$\Rightarrow \frac{\partial(\delta n - G\tau_n)}{\partial t} = -\frac{\delta n - G\tau_n}{\tau_n}$$

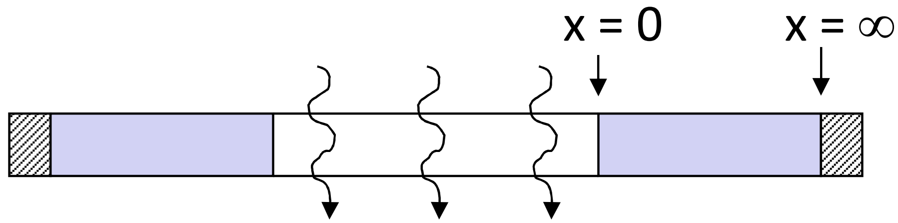
$$\Rightarrow (\delta n - G\tau_n) = (\delta n - G\tau_n)\Big|_{t=0} e^{-t/\tau_n} = -G\tau_n e^{-t/\tau_n} \qquad \delta n(0) = 0$$

$$\boxed{\delta n(t) = G\tau_n\left(1 - e^{-t/\tau_n}\right)}$$

Case study: diffusion with recombination

Steady-state

$$\delta n(x=0) = G\tau_n$$



$$\delta n(x=\infty) = 0$$

How does the density of minority electrons vary along x?

$$x \in [0,\infty) \qquad \frac{\partial n}{\partial t} = 0 = \frac{1}{e}\frac{\partial J_n}{\partial x} + (G_n - R_n) = \frac{1}{e}\frac{\partial J_n}{\partial x} - \frac{\delta n}{\tau_n}$$

Steady-state **No generation**

$$J_n = eD_n \frac{\partial n}{\partial x} \Rightarrow D_n \frac{\partial^2 n}{\partial x^2} = \frac{\delta n}{\tau_n} \Rightarrow \frac{\partial^2 (\delta n)}{\partial x^2} = \frac{\delta n}{\lambda_n^2}$$

$$\lambda_n^2 = D_n \tau_n$$

$$\delta n(x) = Ae^{+x/\lambda_n} + Be^{-x/\lambda_n} \qquad A = 0; B = \delta n(0)$$

Boundary conditions

$$\boxed{\delta n(x) = \delta n(0) e^{-x/\lambda_n} = G\tau_n e^{-x/\lambda_n}}$$

Without recombination?

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Artwork Sources:

1. Prof. Sanjay Banerjee
2. Prof. M.A. Alam
3. www.pveducation.org
4. britneyspears.ac