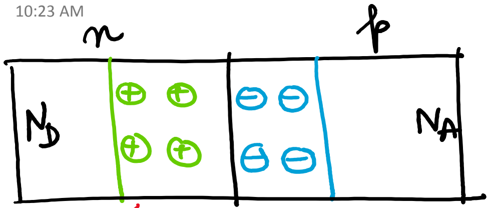
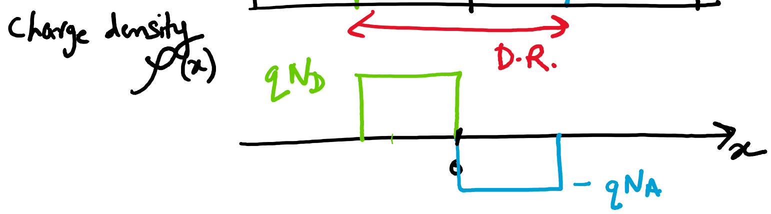
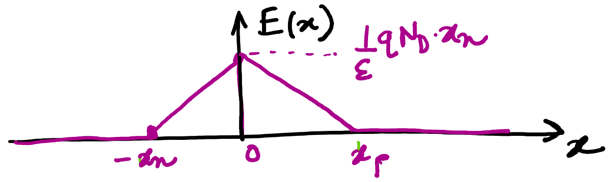
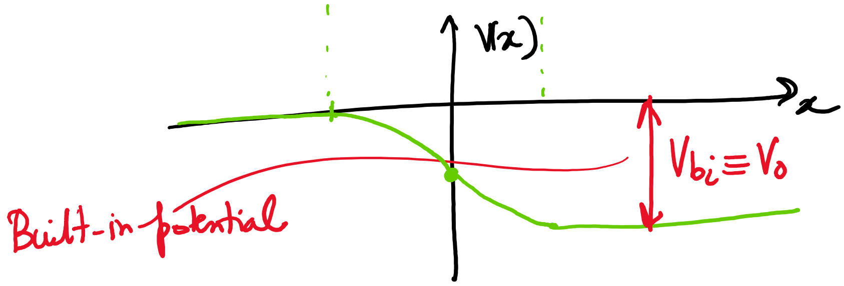
ECE 310 - Lecture 7

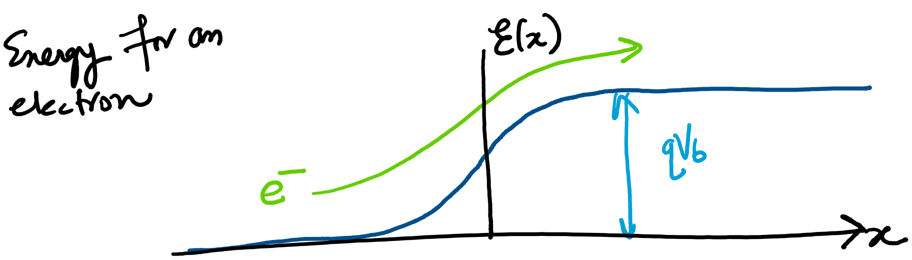
Friday, January 26, 2018 10:23 AM



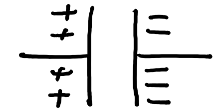








$\rho \rightarrow E \rightarrow V \rightarrow \mathcal{E}$



Poisson's Equation

$$\nabla \cdot E = \frac{\rho}{\varepsilon}$$

$$\frac{\partial E}{\partial x} = \frac{\rho}{\varepsilon}$$

$$\Rightarrow E = \frac{1}{\varepsilon} \int \rho(x)\, dx \longrightarrow (1)$$

$$\frac{1}{\varepsilon} qN_D x_n = \frac{1}{\varepsilon} qN_A x_p$$

$$\Rightarrow \boxed{N_D x_n = N_A x_p} \longrightarrow (2)$$

$$E = -\nabla V = -\frac{\partial V}{\partial x}$$

$$\Rightarrow V = -\int E(x) \cdot dx$$

Energy $\Rightarrow$ $\mathcal{E} = -qV(x)$

In Equilibrium

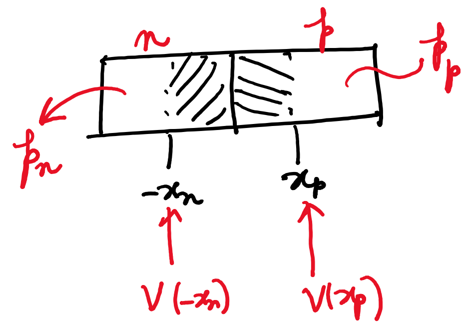
$|I_{drift}| = |I_{diffusion}|$ for both electrons & holes

$$\cancel{q}\mu_p p E = \cancel{q} D_p \frac{dp}{dx} \quad \text{for holes}$$

$$E = -\frac{dV}{dx}$$

$$\Rightarrow \quad -\mu_p \cdot p \frac{dV}{dx} = D_p \cdot \frac{dp}{dx}$$

$$\Rightarrow \quad -\mu_p \frac{dV}{dx} = D_p \cdot \frac{1}{p} \cdot \frac{dp}{dx}$$



$$\Rightarrow \quad -\mu_p \int_{V(-x_n)}^{V(x_p)} dV = D_p \int_{p_n}^{p_p} \frac{dp}{p}$$

$$\Rightarrow \quad \underbrace{V(x_p) - V(-x_n)}_{-V_{bi}} = -\frac{D_p}{\mu_p} \ln\left(\frac{p_p}{p_n}\right) \qquad p_p \to N_A, \quad p_n \to \frac{n_i^2}{N_D}$$

Einstein's relation

$$\frac{D_p}{\mu_p} = V_T = \frac{kT}{q}$$

$$= -\frac{kT}{q} \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$\boxed{V_{bi} = \frac{kT}{q} \ln\left(\frac{N_A N_D}{n_i^2}\right)}$$

depends upon the doping levels

Ex.

$N_A = 2 \times 10^{16}\ cm^{-3}$ $\quad T = 300K$

$N_D = 4 \times 10^{16}\ cm^{-3}$

$\Rightarrow \quad V_{bi} = 768\ mV$

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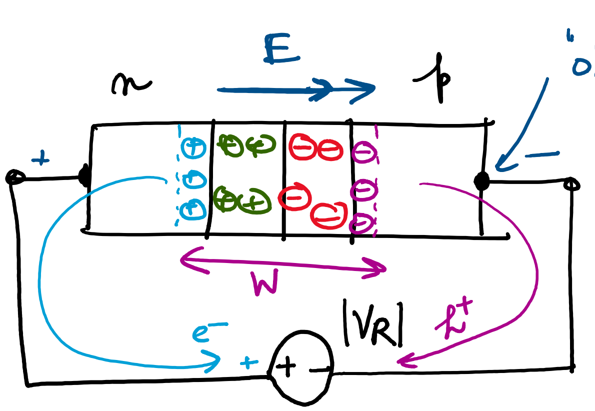
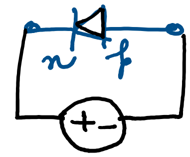
Reverse bias





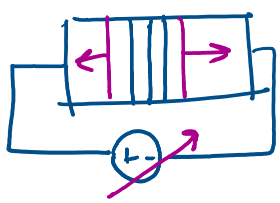
$V_R \rightarrow$ enhances the electric field

↳ sustained by a wider depletion region

↳ Still no current flow as the depletion region presents a barrier.

$$C = \frac{\varepsilon A}{d}$$

$$d \uparrow \Rightarrow C \downarrow$$

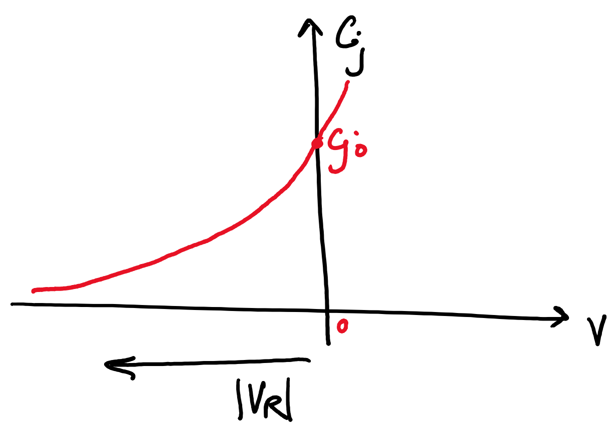


Junction Capacitance

Cap for no bias voltage

$$C_j = \frac{C_{j0}}{\sqrt{1 + \frac{|V_R|}{V_{bi}}}}$$

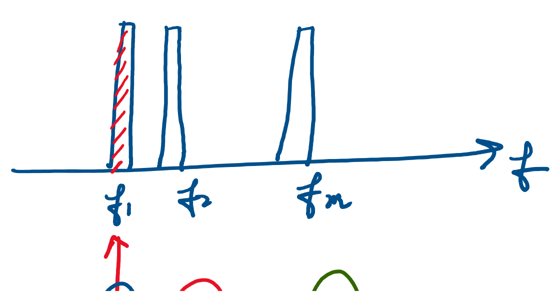
$$C_{j0} = \sqrt{\frac{q\,\varepsilon_{si}}{2}\left(\frac{N_A N_D}{N_A + N_D}\right)\cdot\frac{1}{V_{bi}}}$$

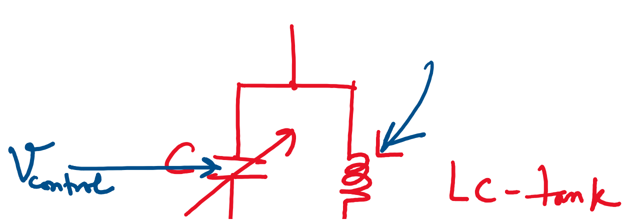


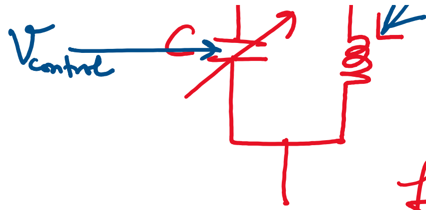
Voltage dependent Capacitor

"Varactor"

AM, FM, Cellphone, WiFi







LC-tank

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$