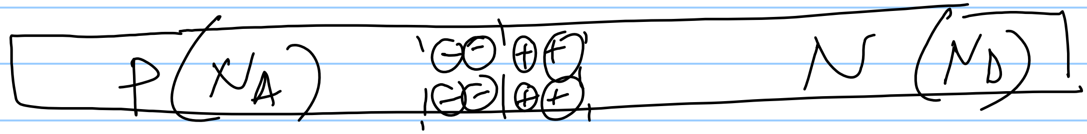
Application of Gauss Law in p-n junction

12/9/2014



$x=-x_{po}$ $x=0$ $x=x_{no}$

① $$\frac{d\mathcal{E}}{dx} = \frac{qN_D}{\epsilon} \qquad 0<x<x_{no}$$

② $$\frac{d\mathcal{E}}{dx} = -\frac{qN_A}{\epsilon}, \qquad -x_{po}<x<0$$

$$\int_{\mathcal{E}(x)}^{\mathcal{E}(x_{no})} d\mathcal{E}(x) = \frac{qN_D}{\epsilon}\int_{x}^{x_{no}} dx$$

$$-\mathcal{E}(x) = \frac{qN_D}{\epsilon}(x_{no}-x)$$

Depletion approx. within the transition region or space-charge region.

↓

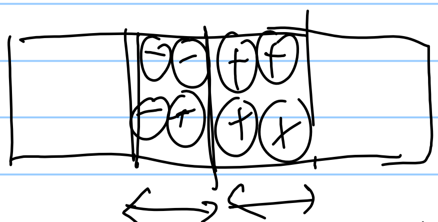
Depletion region

Abrupt junction

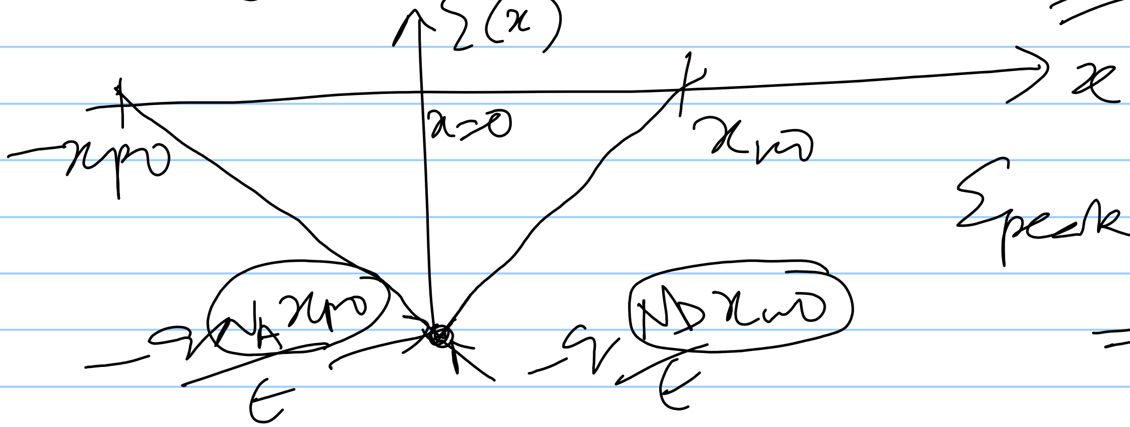
$$\mathcal{E}(x) = -\frac{qN_D}{\epsilon}(x_{no} - x) \quad --- \ (3) \qquad 0 < x < x_{no}$$

$$\int_{\mathcal{E}(-x_{po})}^{\mathcal{E}(x)} d\mathcal{E}(x) = -\frac{qN_A}{\epsilon}\int_{-x_{po}}^{x} dx \qquad -x_{po} < x < 0$$

$$\mathcal{E}(x) = -\frac{qN_A}{\epsilon}(x + x_{po}) \quad --- \ (4) \qquad -x_{po} < x < 0$$



$x_{po}N_A = x_{no}N_D$



$$\mathcal{E}_{peak} = \mathcal{E}_m = -\frac{qN_A x_{po}}{\epsilon} = -\frac{qN_D x_{no}}{\epsilon}$$

$$x_{p0} N_A = x_{n0} N_D$$

$x_{p0} + x_{n0} = \underline{\underline{W}}$ = width of the depletion region

$$x_{p0}\left(1 + \frac{N_A}{N_D}\right) = \underline{\underline{W}}$$

$$\underline{\underline{x_{p0}}} = \frac{W \cdot N_D}{N_A + N_D} \; ; \qquad \underline{\underline{x_{n0}}} = \frac{W \cdot N_A}{N_A + N_D}$$

If it is a p^+-n jn. $(N_A \gg N_D)$

$$x_{n0} \gg x_{p0}$$

$W \simeq x_{n0}$, $x_{p0} \simeq 0$

if p^{++}-n jn.

$$\mathcal{E}(x) = \ominus \frac{qN_D}{\epsilon}(x_{n0} - x) \qquad 0 < x < x_{n0}$$

$$\int_x^{x_{n0}} -\mathcal{E}(x)\,dy = \frac{qN_D}{\epsilon}\int_x^{x_{n0}} (x_{n0} - x)\,dx$$

$$\Rightarrow \quad V(x)\Big]_x^{x_{n0}} = \frac{qN_D}{\epsilon}\left[x_{n0}x - \frac{x^2}{2}\right]_x^{x_{n0}}$$

$$\Rightarrow \quad V(x_{n0}) - V(x) = \frac{qN_D}{\epsilon}\left[\frac{x_{n0}^2}{2} - x_{n0}x + \frac{x^2}{2}\right]$$

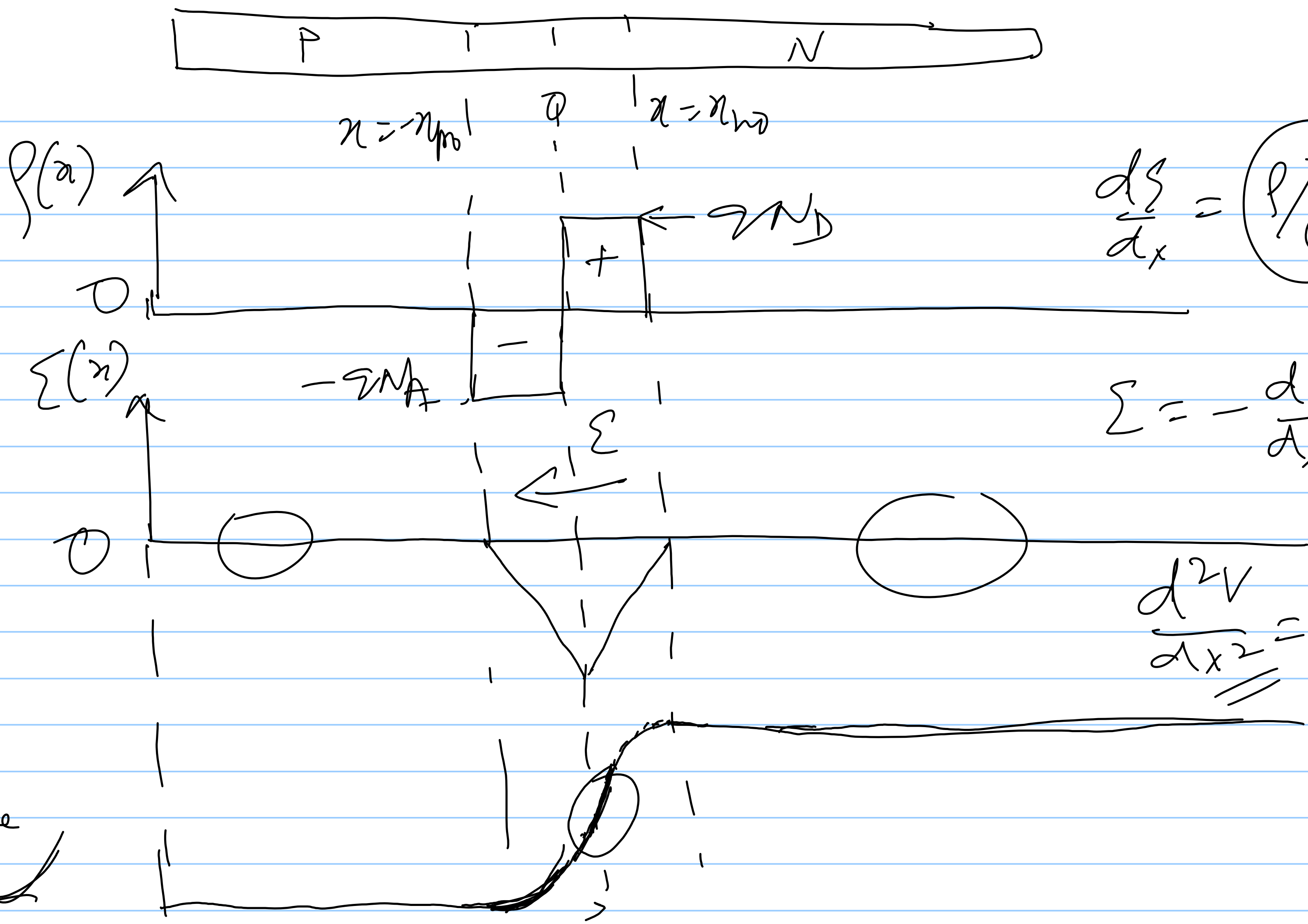
$$\ldots \quad 5$$

$$\mathcal{E}(x) = -\frac{qN_A}{\epsilon}(x + x_{po}) \qquad -x_{po} < x < 0$$

$$\int_{-x_{po}}^{x} -\mathcal{E}(x)\,dx = \frac{qN_A}{\epsilon}\int_{-x_{po}}^{x}(x + x_{po})\,dx \qquad \left[\frac{x^2}{2} + x_{po}x\right]_{-x_{po}}^{x}$$

$$V(x) - V(-x_{po}) = \frac{qN_A}{\epsilon}\left[\frac{x^2}{2} + x_{po}x + \frac{x_{po}^2}{2}\right]$$

$$\text{--- --- ---} \quad (6)$$

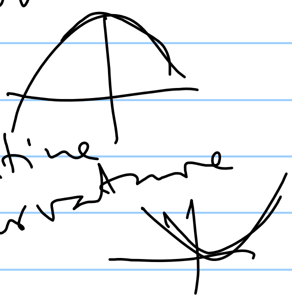


$$\frac{d\mathcal{E}}{dx} = \rho/\epsilon$$

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

$$\frac{d^2V}{dx^2} = -\rho/\epsilon$$

Negative curvature



positive curvature

$$V(x_{n0}) - V(0^+) = \frac{qN_D}{2\epsilon} x_{n0}^2$$

$$V(0^-) - V(-x_{p0}) = \frac{qN_A}{2\epsilon} x_{p0}^2$$

$x_{n0} \cdot N_D = x_{p0} N_A$

$$\underline{V(0^+) = V(0^-) = V(0)}$$

$$V_0 = V(x_{n0}) - V(-x_{p0}) = \frac{q}{2\epsilon}\left(N_D x_{n0}^2 + N_A x_{p0}^2\right)$$

Contact potential
Built-in pot.

$$J_{drift,p} + J_{diff,p} = 0$$

$$-\mathcal{E} = -V_T \frac{d}{dx} \ln(p(x))$$

$$V_0 = V(x_{n0}) - V(-x_{p0}) = -V_T \ln\left(\frac{p(x_{n0})}{p(-x_{p0})}\right)$$

$$V_D = V_T \ln\left(\frac{p(-x_{p0})}{p(x_{n0})}\right) \qquad p(-x_{p0}) = N_A$$

$$p(x_{n0}) = n_i^2/N_D$$

$$V_D = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$V_D = \frac{q N_D x_{n0}}{2\epsilon}(x_{n0} + x_{p0})$$

$$= \frac{q}{2\epsilon} N_D \frac{W^2 \cdot N_A}{N_A + N_D} \qquad V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$\Rightarrow \quad W = \sqrt{\frac{2\epsilon_{si} V_D}{q} \cdot \frac{N_A + N_D}{N_A N_D}}$$

$N_A = 10^{18}/cm^3$

$N_D = 10^{15}/cm^3$, $n_i = 1.5 \times 10^{10}/cm^3$

$T = 300K$

$V_0 = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right) = 0.754 V.$

$\epsilon_{si} = 11.8 \epsilon_0 = 11.8 \times 8.85 \times 10^{-14} F/cm$

$W_0 = 9.92 \times 10^{-5} cm$

$x_{no} = 9.92 \times 10^{-5} cm$

$x_{po} = 9.92 \times 10^{-8} cm$

$E_{peak} = -1.5 \times 10^{4} V/cm$