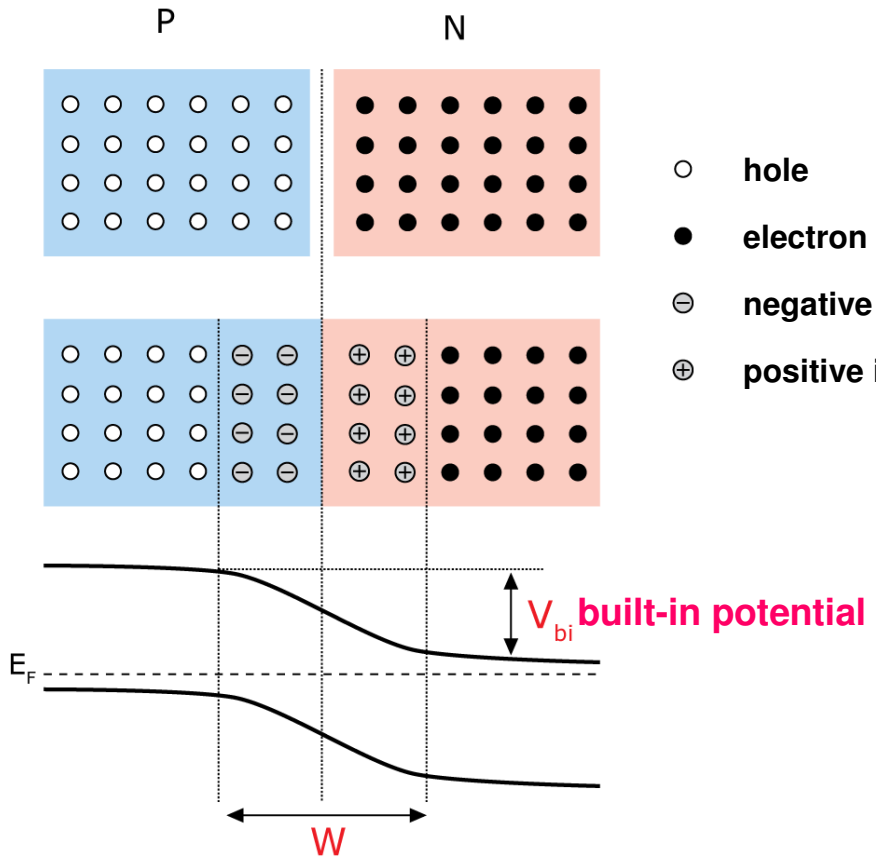
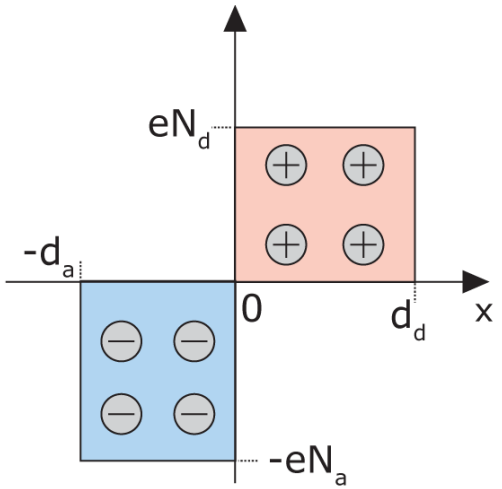
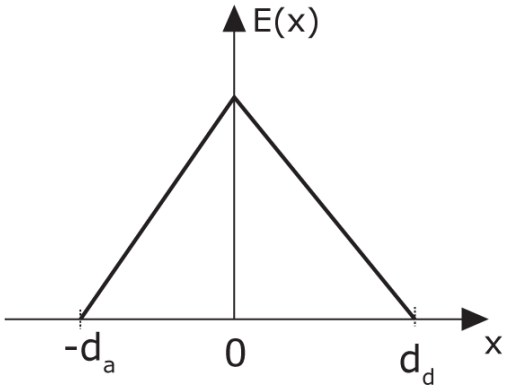
pn junction



W – depletion region
(region of space charge,
free holes and electrons remain outside)



charge distribution
in pn junction

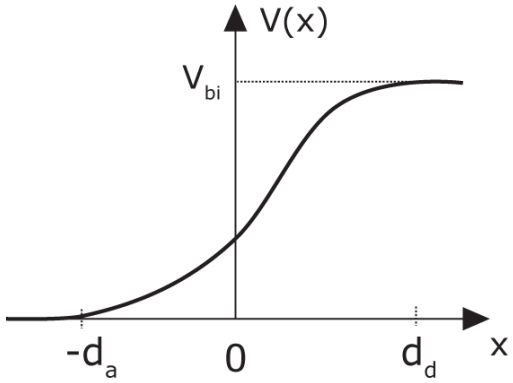


electric field distribution

$E(x) \sim eN_{a,d}\, x$

Height of the potential barrier V_{bi}

$$eV_{bi} = E_g - k_B T \ln\left[\frac{N_c N_V}{N_d N_a}\right] \leq E_g$$

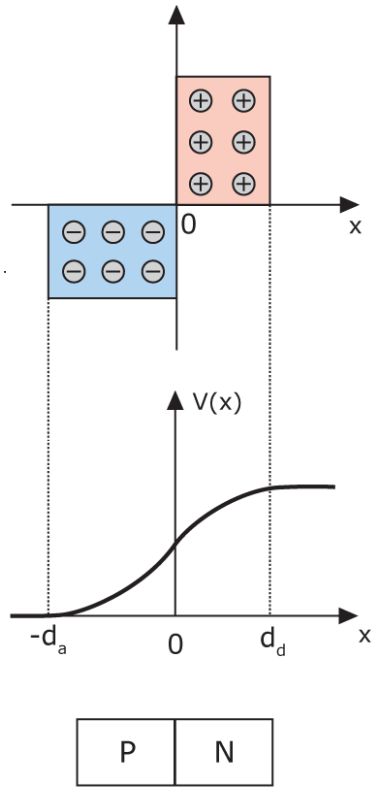


potential distribution

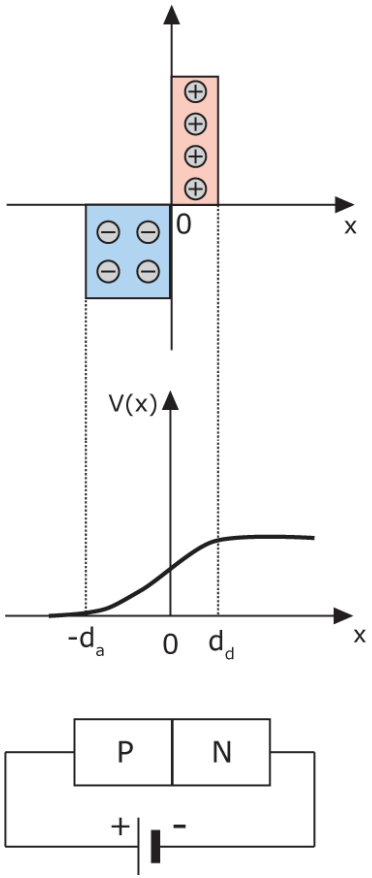
$V(x) \sim eN_{a,d}\, x^2$

junction under bias

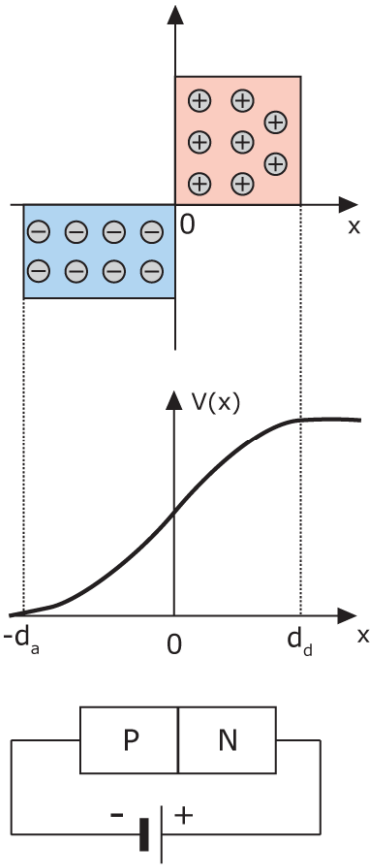
equilibrium, V=0



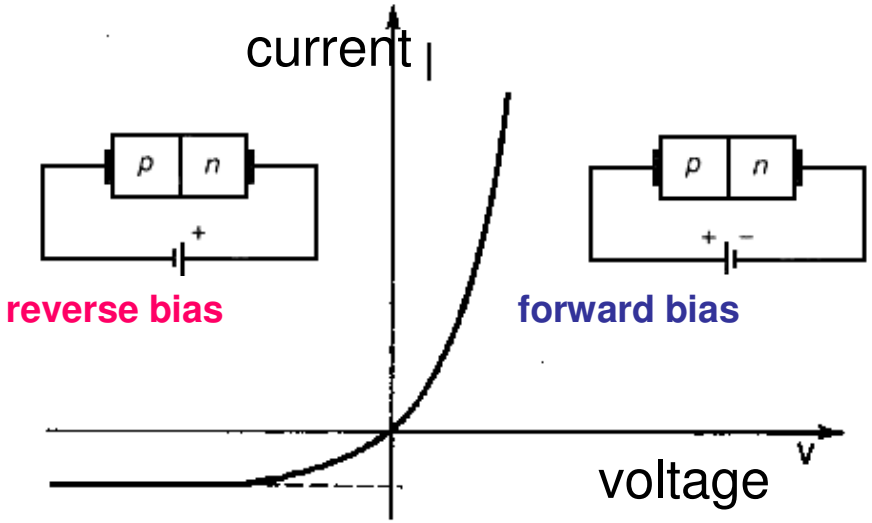
forward bias

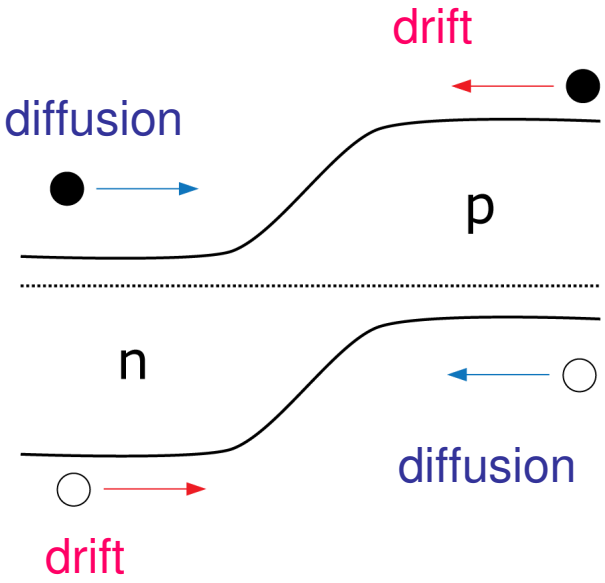


reverse bias

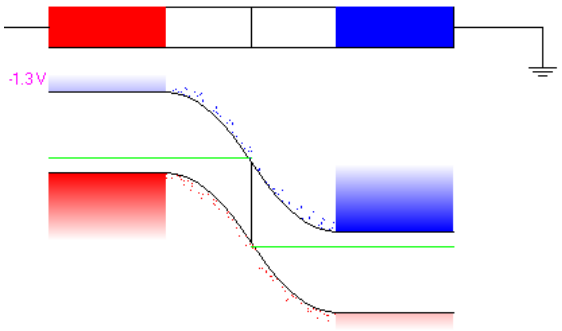


Current-voltage characteristics

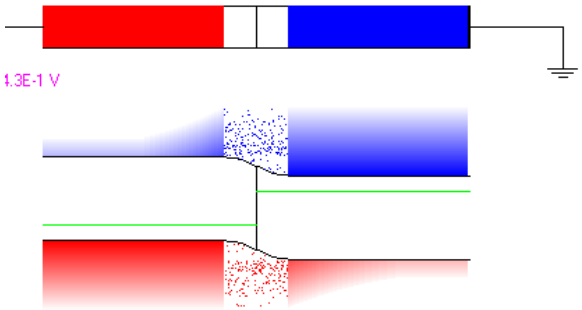




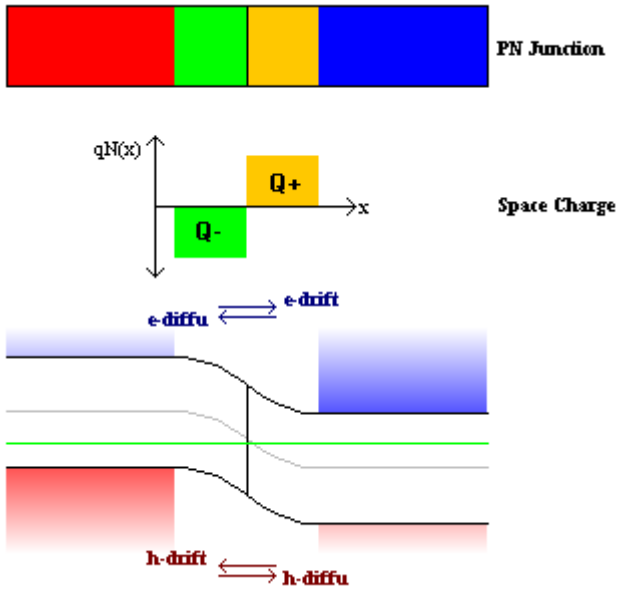
only drift current



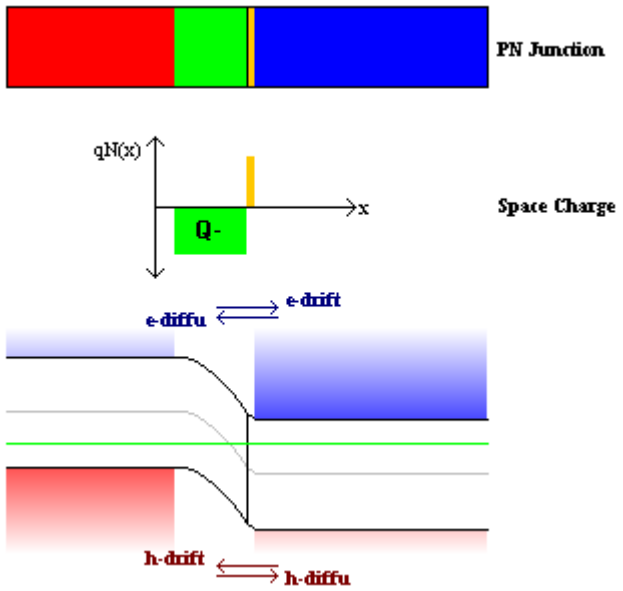
diffusion current



np and n+p junction



$N_a = N_d$
$W_n = W_p$



$N_a << N_d$
$W_p >> W_n$

$$W = W_n + W_p \text{ and } N_a W_p = N_d W_n$$

if $N_a << N_d$ then $W \cong W_p$

$$V_b = \frac{e}{2\varepsilon\varepsilon_o} N_a W^2$$

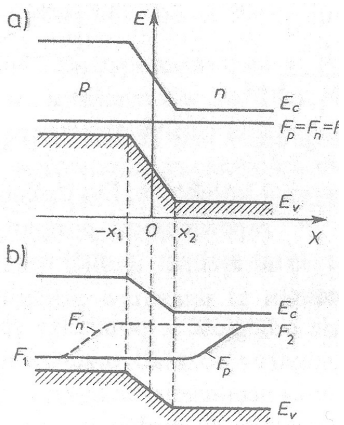
depletion layer width determined by low-doped part

Current voltage characteristics – ideal diode

$J_h = J_h^{diff} - J_h^{dr}$

$J_e = J_e^{diff} - J_e^{dr}$

$j = J_h + J_e$



$$j = (J_h^{dr} + J_e^{dr})\left(\exp\left\{\frac{eV}{k_B T}\right\} - 1\right)$$

$$J_h^{dr} = \frac{n_i^2}{N_d}\frac{L_p}{\tau_p}$$

$$J_e^{dr} = \frac{n_i^2}{N_a}\frac{L_n}{\tau_n}$$

$$j = J_o\left(\exp\left\{\frac{eV}{k_B T}\right\} - 1\right)$$

$$J_o = J_{oo}\exp\left\{\frac{-\Xi_g}{k_B T}\right\}$$

$$n_i^2 = \text{const} \bullet \exp\left\{-\frac{E_g}{k_B T}\right\}$$

non-ideal diode:

$$j = J_o\left(\exp\left\{\frac{eV}{Ak_B T}\right\} - 1\right)$$

$$J_o = J_{oo}\exp\left\{\frac{-E_a}{k_B T}\right\}$$

A – ideality factor,

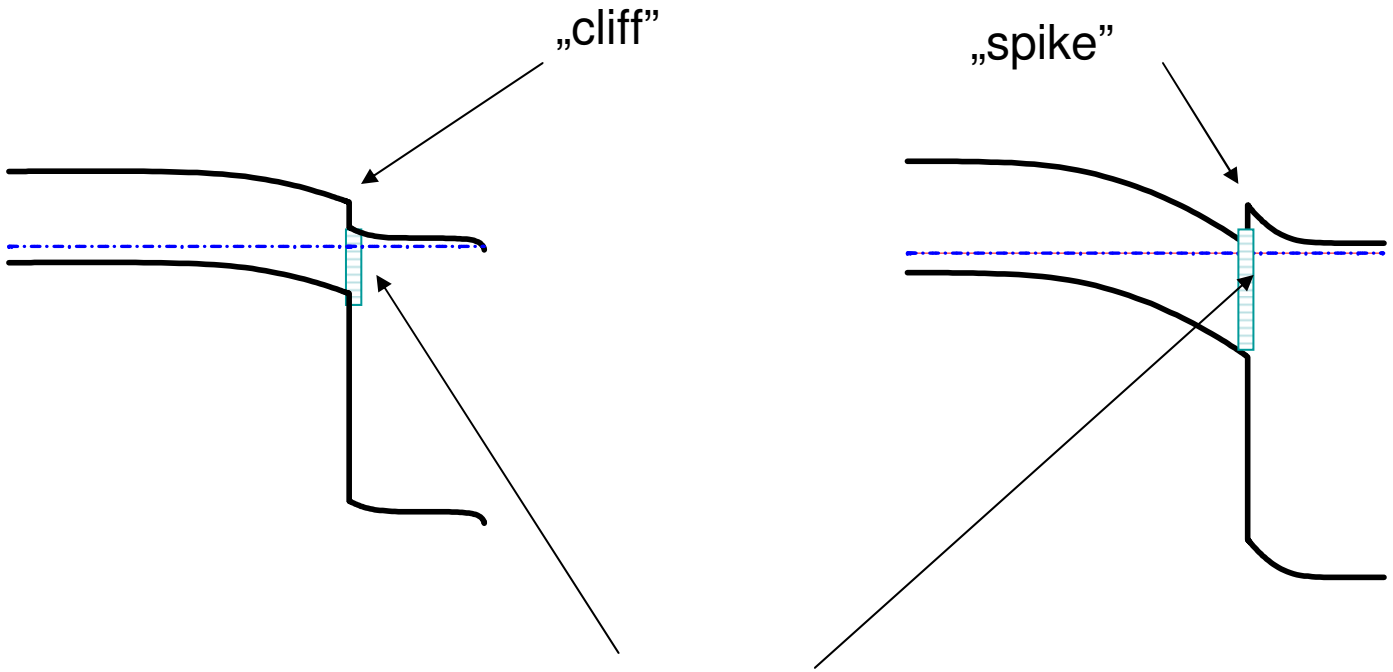
depends on dominating transport mechanism

$1 < A < 2$ $\quad E_a \leq E_g$

Heterojunction:
Two semiconductors with different bandgaps

Important factors not present in pn junctions:

- **conduction band discontinuities**
- **interface states**



pin junction