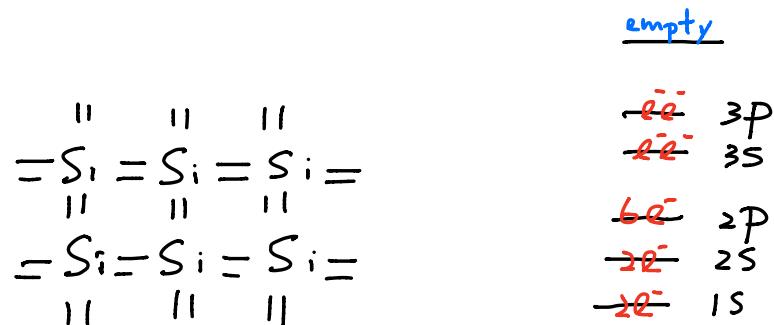
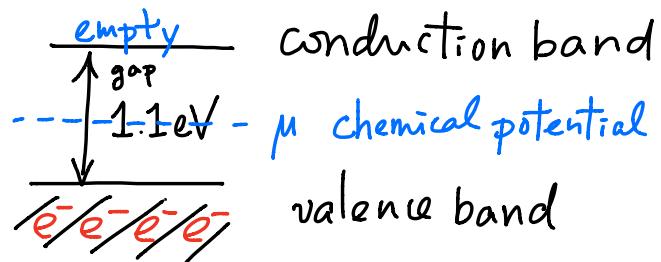


PN junction.... Foundation of semi-conductor components

Semi-conductor:



① $T=0$, all e^- are in the valence band



② $T \neq 0$, small

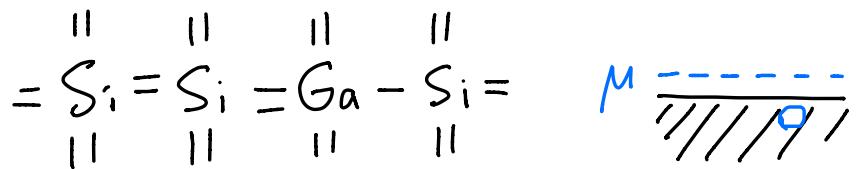
$$\text{fraction } e^{-\frac{\text{gap}}{2kT}}$$

of e^- are in the conduction band.

The same fraction of holes are in the valence band.

* kT is 25 meV at room temperature so this fraction is very small.

P type semi-conductor



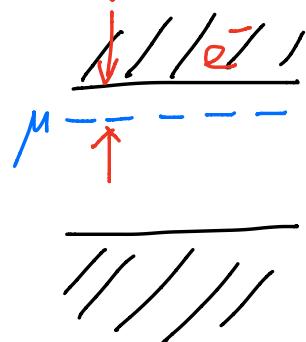
Gallium has only 3 valence electrons and is an electron acceptor.

When an electron hops, the vacancy (hole) moves in the opposite direction in the p-type semi-conductor.

N-type semiconductor



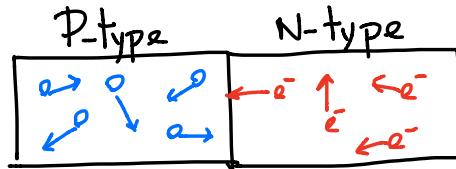
A phosphorous atom has 5 valence electrons. The extra one can easily break loose.



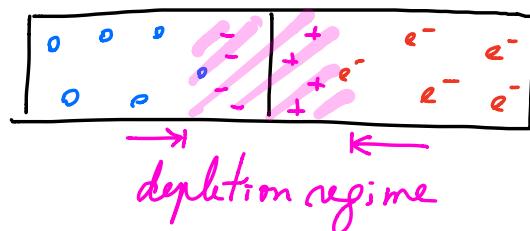
P is an electron donor

$\Rightarrow e^-$ can easily move in a n-type s.c.

PN junction: when electrons meets holes



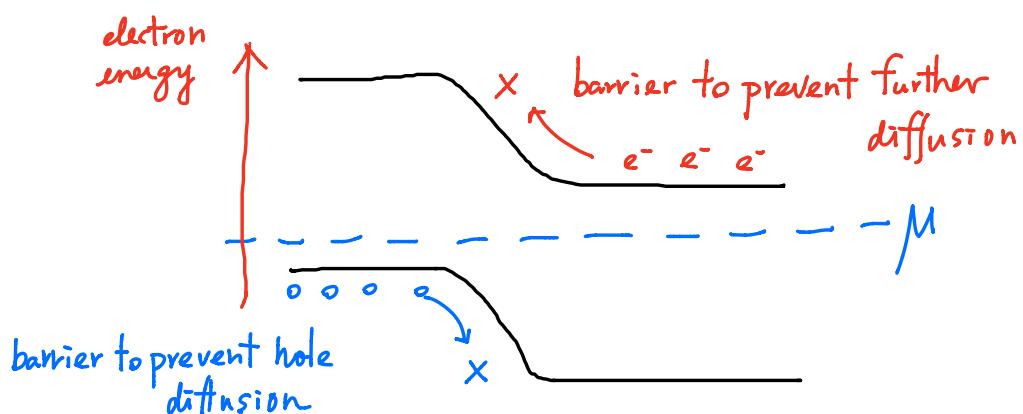
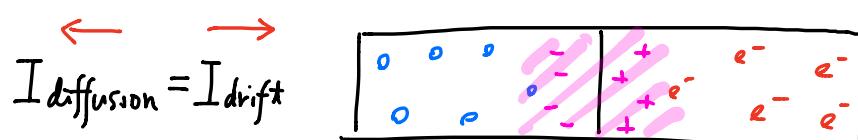
..... Random walk (diffusion) of e^- and holes



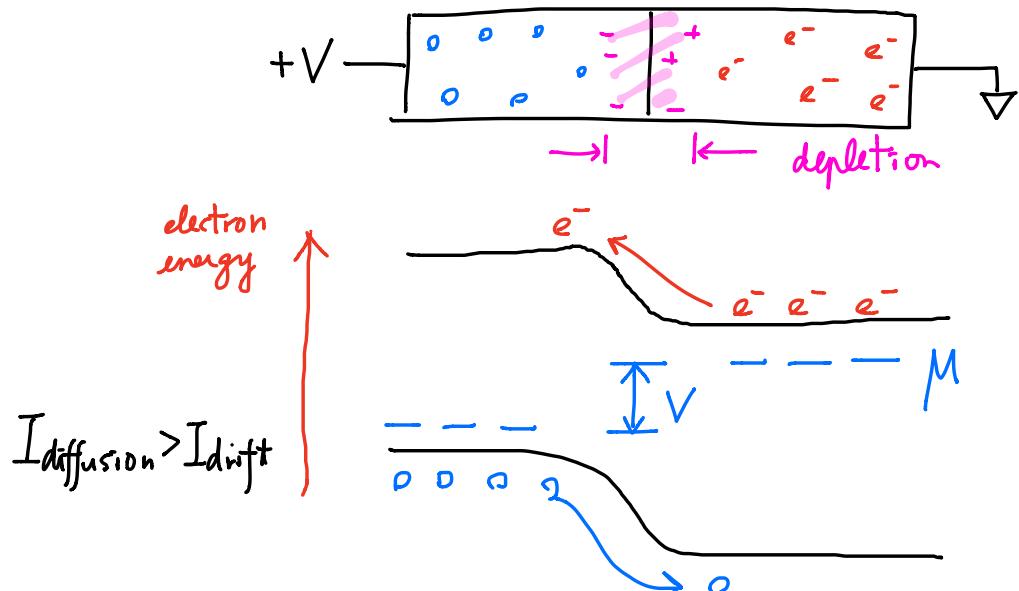
negatively charged on the left side
positively charged on the right side

Depletion regime has very few mobile charge carriers.

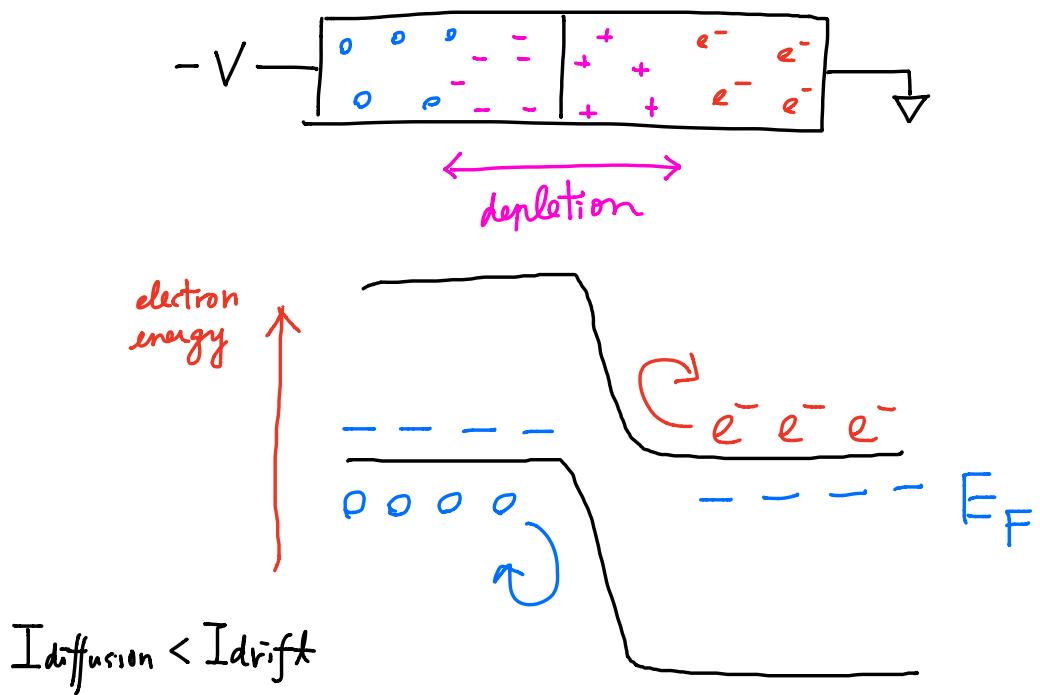
When equilibrium is established ... Diffusion balanced by electrical force.



Forward biased: depletion regime narrowed



Reverse bias: depletion regime widened

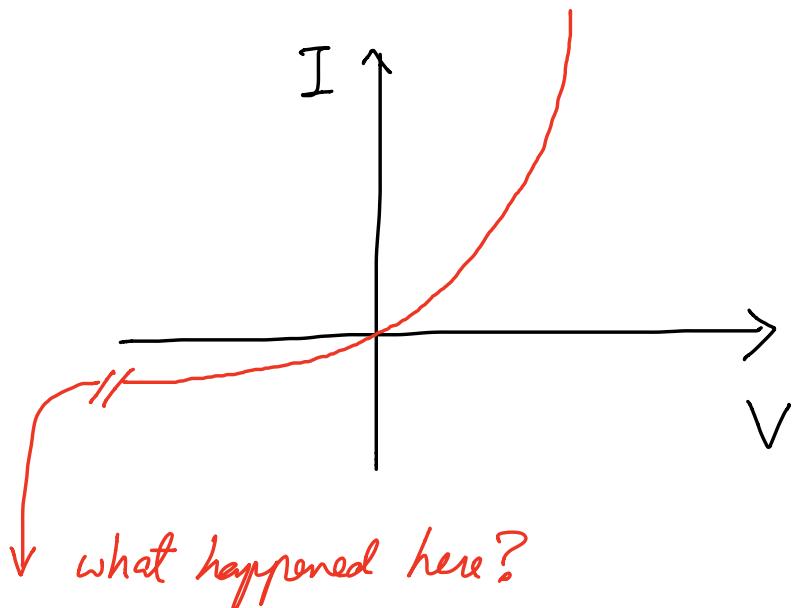


Current through a biased diode: A simplified derivation

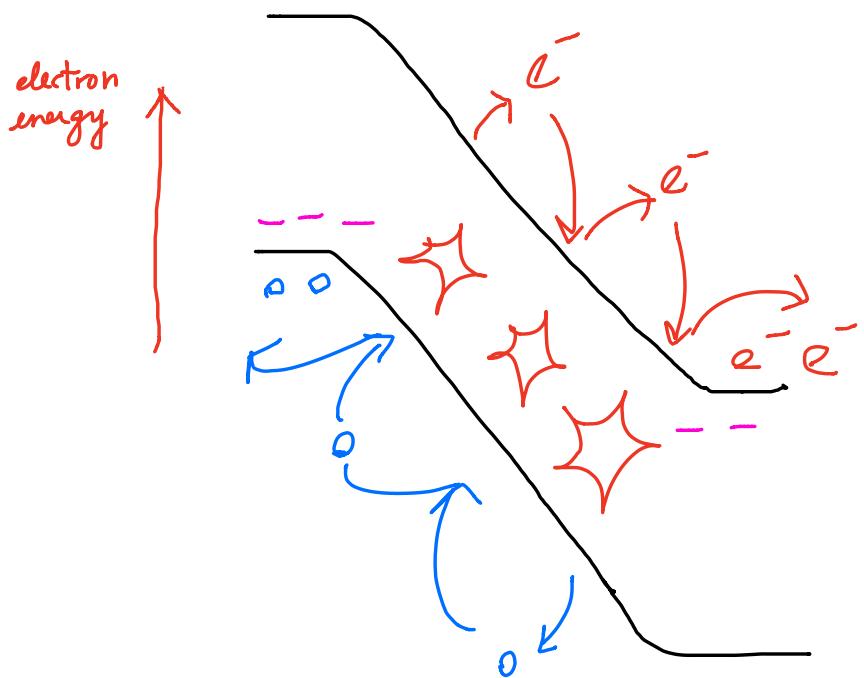
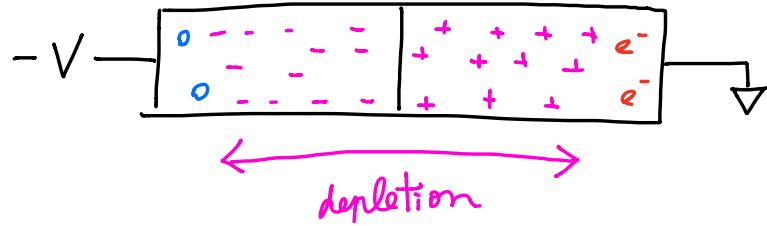
$$\begin{aligned} j_e &= j_{\text{diffusion}} - j_{\text{drift}} \approx j_{\text{hole}} \\ &= n_e e^{-(\mu - V)/kT} - j_{\text{drift}} \\ &= e^{V/kT} n_e e^{-M/kT} - j_{\text{drift}} \end{aligned}$$

Note that $j_e = 0$ when $V = 0 \Rightarrow n_e e^{-M/kT} = j_{\text{drift}}$

$$\begin{aligned} \Rightarrow j_e &= j_{\text{drift}} (e^{V/kT} - 1) \\ \Rightarrow I &= I_0 (e^{V/kT} - 1) \end{aligned}$$



Avalanche regime



★ : spontaneous e-hole pair generation or photon-induced e-hole pair.
(in photodiodes).