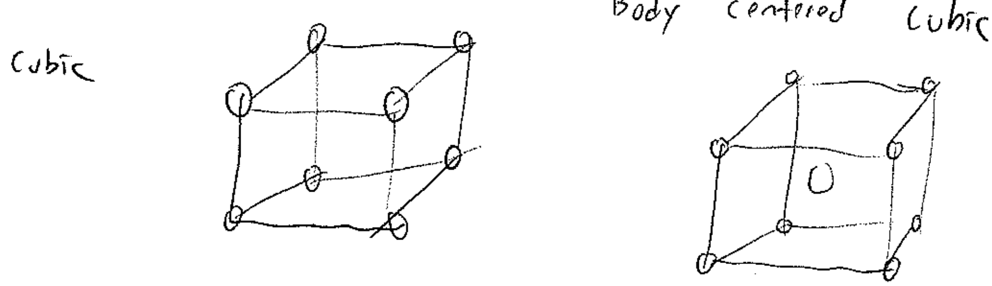
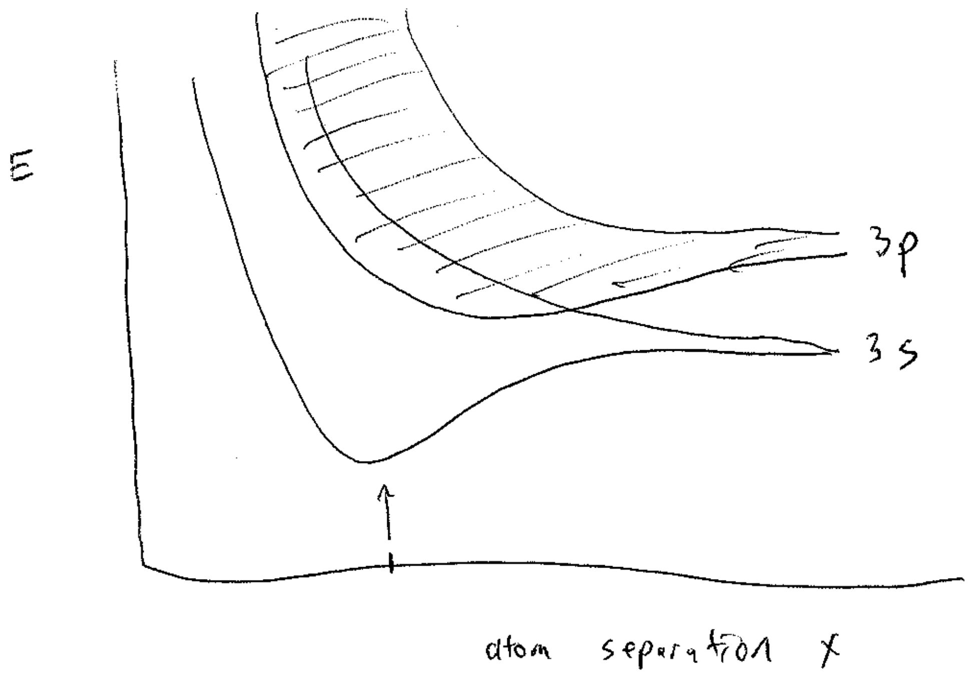
Conductors, Insulators and semiconductors

cyrstals, unit cells

Examples



electron probability densities can overlap and form electronic bonds

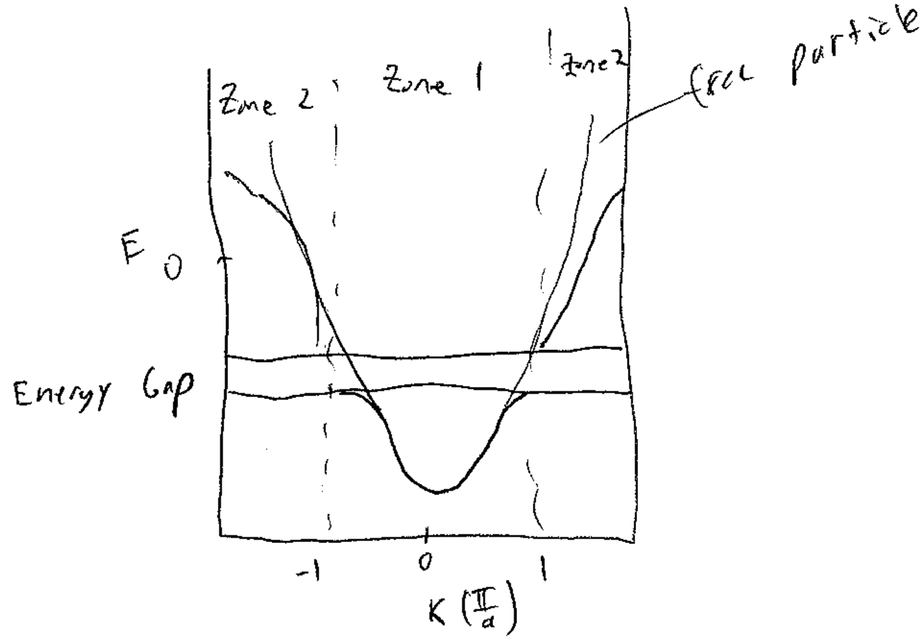


Overlapping bonds give rise to conductivity

Electrons behave like free electrons

$$E_K = \frac{p^2}{2m} = \frac{\hbar^2 k^2}{2m}$$

a is distance to closest atom



Bragg condition

prevents states

with $K = \pm \frac{n\pi}{a}$

Fermi Energy

$$\frac{dn}{dE} = p(E)\,\frac{1}{e^{(E-E_F)/kT}+1}$$

$$p(E) = \frac{8\sqrt{2}\,\pi\,m^{3/2}}{h^3}\sqrt{E}$$

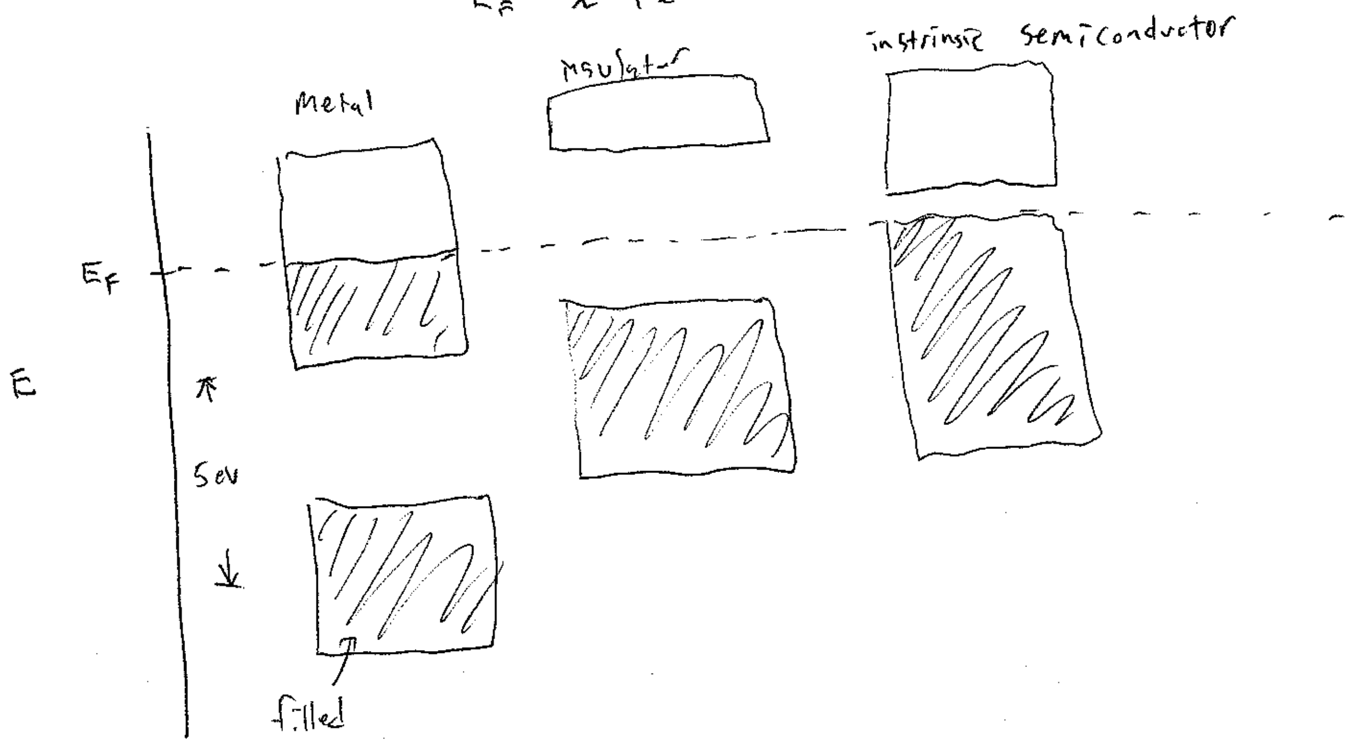
E_F is a constant so at $T=0$

$$n = \int_0^{\infty} \frac{8\sqrt{2}\,\pi\,m^{3/2}}{h^3}\,\frac{1}{e^{(E-E_F)/kT}+1} \rightarrow \frac{8\sqrt{2}\,\pi\,m^{3/2}}{h^3}\int_0^{E_F}\sqrt{E}\,dE$$

$$E_F = \left(\frac{h^2c^2}{8mc^2}\right)\left(\frac{3}{\pi}\right)^{2/3} n^{2/3}$$

for $n = \left(\frac{1}{0.3\,nm}\right)^3$

$$E_F \approx 4\,eV$$



Semi Conductors

Intrinsic Semi conductors

C	(diamond)	$E_g = 5.5\,eV$
Si		$E_g = 1.1\,eV$
Ge		$E_g = 0.7\,eV$
Sn		$E_g = 0.1\,eV$

density of conduction electrons

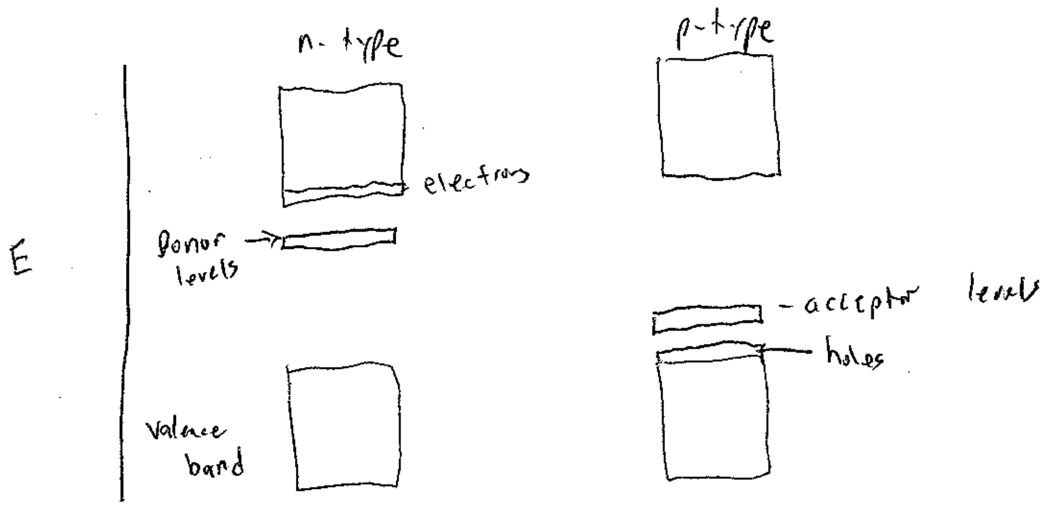
$$n_c \approx n\, e^{-E_g/KT}$$

Doped Semi conductors

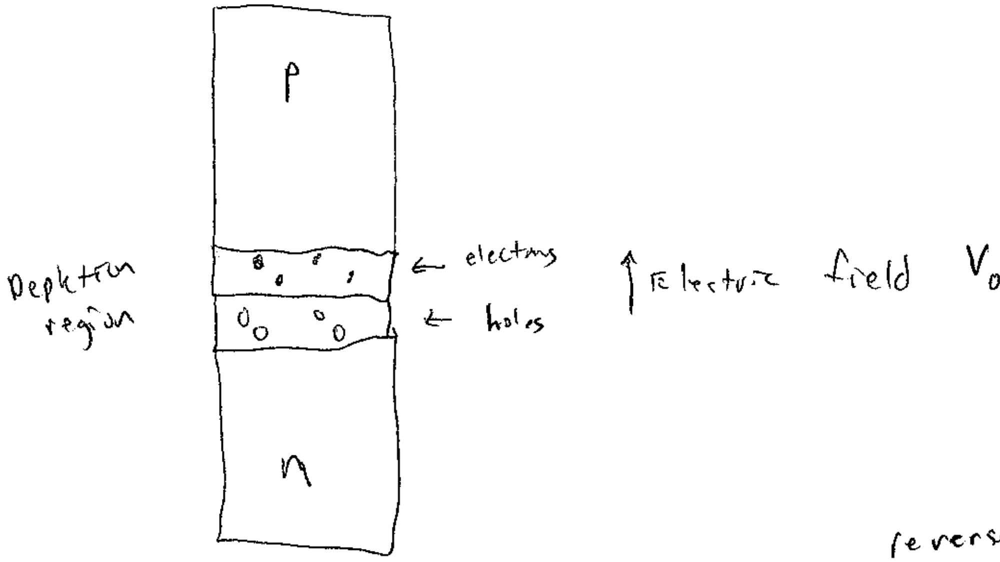
impurity atoms are added to an intrinsic semi conductor

n-type impurity has extra electron (n - negative)

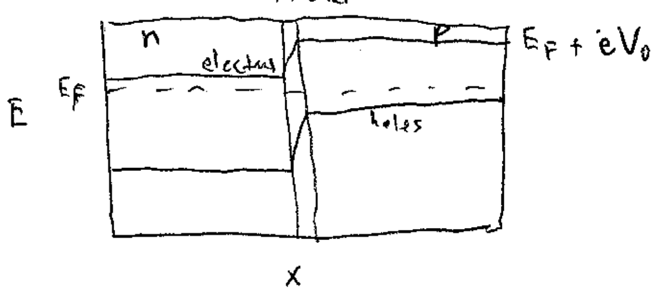
p-type impurity has one less electron (p - positive)



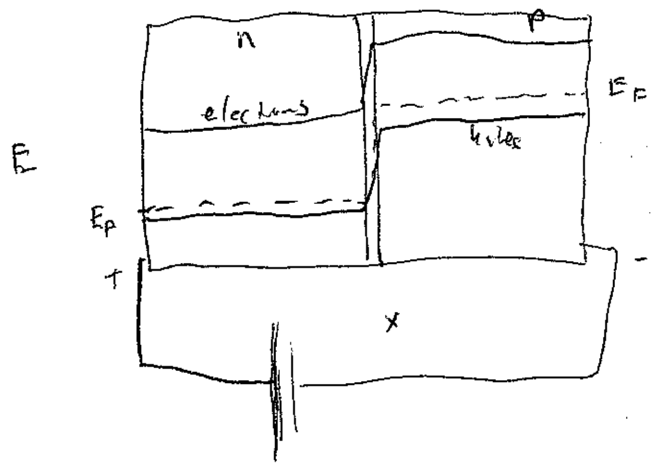
p-n junction



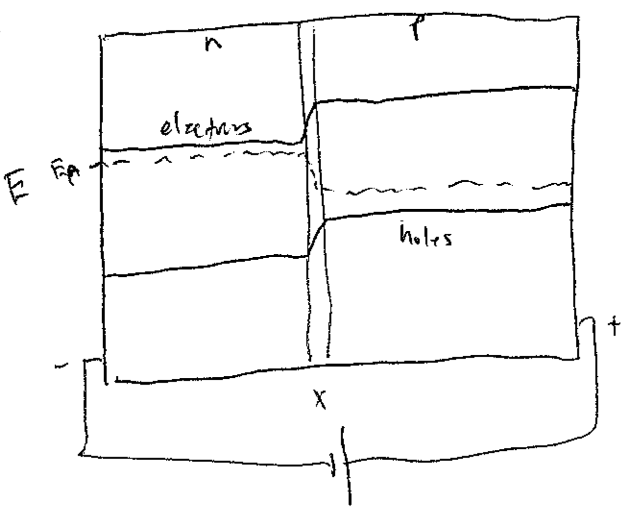
no field



reverse bias



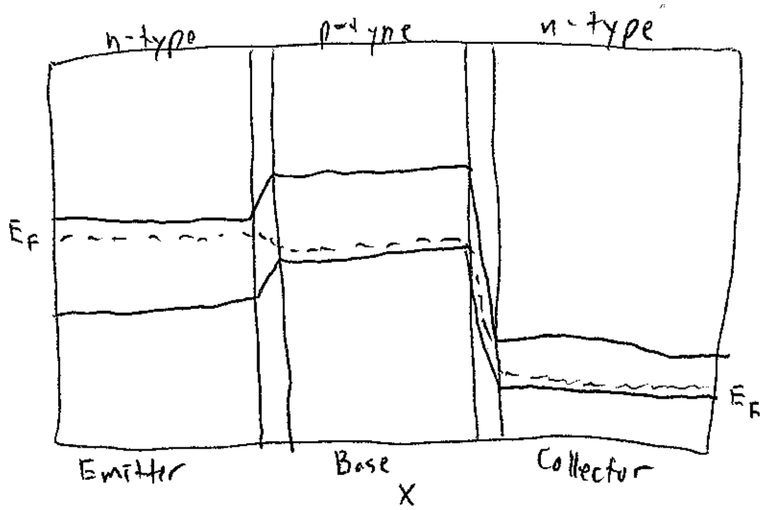
forward bias



Transistor

n-p-n or p-n-p junctions

for a n-p-n junction



emitter-base forward biased

base-collector reverse biased

Its energetically favorable for electrons to flow from Emitter to collector, but there is a barrier.

Removing electrons from the ~~[illegible]~~ base lowers the barrier.

$$I_c = \beta I_B \qquad \beta \sim 100$$

current is defined as flow of positive charges so