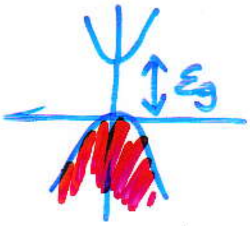
Lecture 8 Summary

Metal $g(\mathcal{E}_F) \neq 0$

Insulator, Semiconductor $g(\mathcal{E}_F) = 0$

SC are insulators at $T=0$, but at they are distinguished from one another by the relative probability of electron transitions from VB to CB ... i.e., the magnitude of $\mathcal{E}_g$.

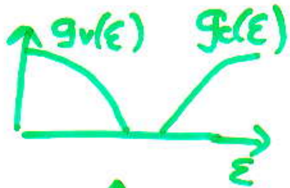


$n(\mathcal{E})$: distribution of electrons in the CB

$p(\mathcal{E})$: .... holes in the VB.

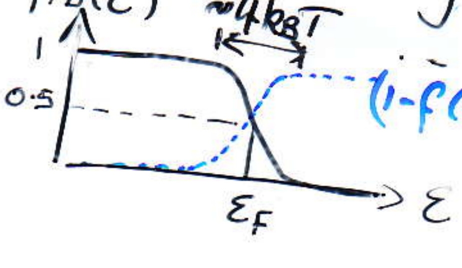
$$n(\mathcal{E}) = f_{FD}(\mathcal{E}) \times g_c(\mathcal{E})$$ → density of electron states in CB

$$p(\mathcal{E}) = [1 - f_{FD}(\mathcal{E})] \times g_v(\mathcal{E})$$ → VB.

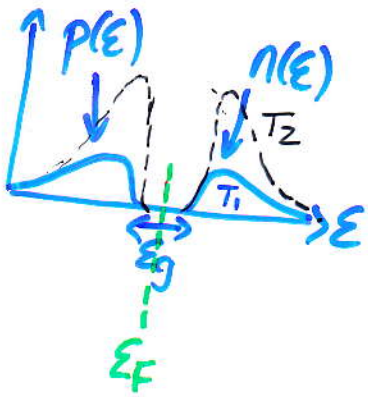


probability of a state being occupied by an electron

... state being empty.



NOTE: $g_v(\mathcal{E})$ and $g_c(\mathcal{E})$ are symmetrical if $m_e^* = m_h^*$



$T_2 > T_1 > 0K$

Fermi level must lie at centre of gap to maintain charge neutrality.

Thermal equilibrium concentration of electrons in CB

$$n_0 = \int_{\mathcal{E}_c}^{\infty} g_c(\mathcal{E}) f_{FD}(\mathcal{E}) d\mathcal{E}$$

Note: * upper limit is ∞ not top of CB.
* energies being considered are $\sim \mathcal{E}_c$ $\therefore$ since $\mathcal{E}_c - \mathcal{E}_F \gg k_B T$, we can use f_{MB}

$$\rightarrow \boxed{n_0 = N_c \exp\left[\frac{-(\mathcal{E}_c - \mathcal{E}_F)}{k_B T}\right]} \quad ①$$

* where N_c is the effective density of states function in the conduction band.

N_c is a material constant, for a given temperature.

It is $\propto (m_e^*)^{3/2}$ and $(T)^{3/2}$

Similarly $$\boxed{p_0 = N_v \exp\left[\frac{-(\mathcal{E}_F - \mathcal{E}_v)}{k_B T}\right]} \quad ②$$

In an INTRINSIC ($\rightarrow$ pure, no defects) SC, electrons in CB and holes in VB are created in pairs $\therefore$ $n_0 = p_0 = n_i$ and $\mathcal{E}_F = \mathcal{E}_{Fi}$ (intrinsic Fermi level)

intrinsic carrier concentration

$$① \times ② \Rightarrow \boxed{n_i^2 = N_c N_v \exp\left(\frac{-\mathcal{E}_g}{k_B T}\right)}$$