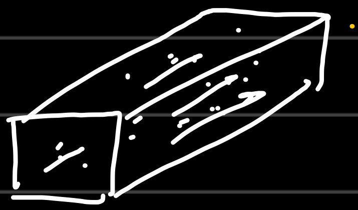
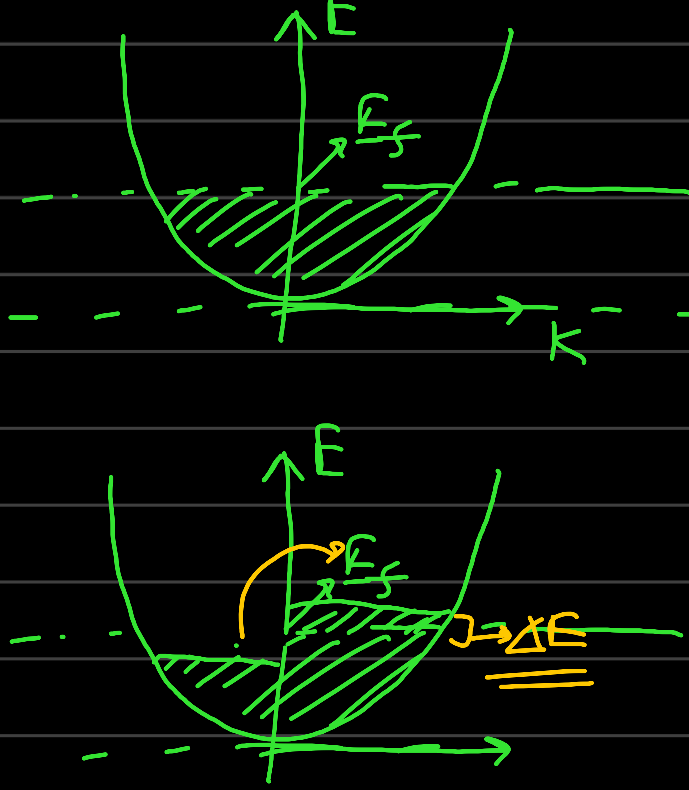
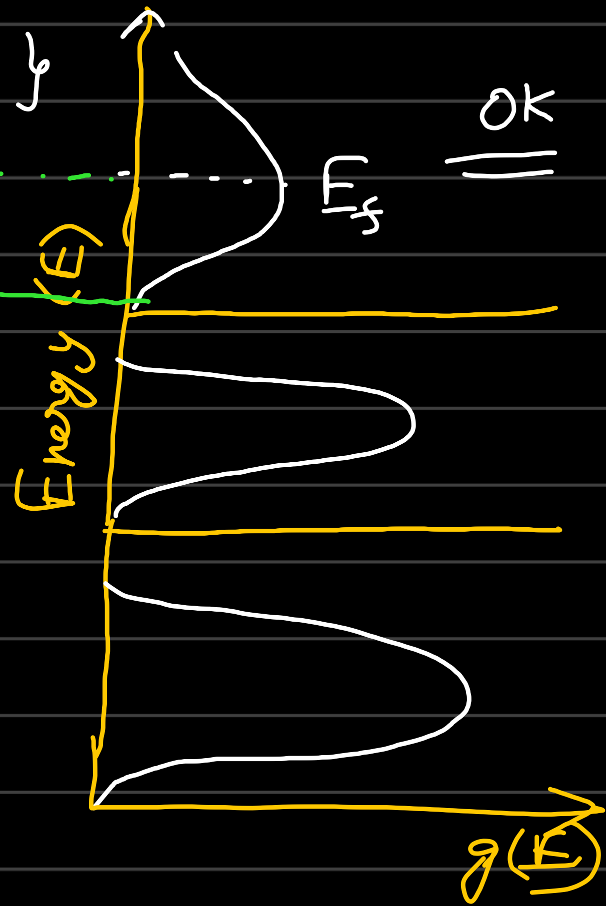
Quantum Conduction

→ Classical Conductivity: $\sigma = \frac{ne^2\tau}{m}$



Total no. of e^-
& valence





Modern theory for Solids:

Quantum Conductivity:

$$\boxed{\sigma = e^2\tau \cdot v_f^2\, g(E_f)}$$

↳ Classical theory cannot explain -ve Hall coefficients and linear resistivity vs temperature relation

$$v^2 g(E_f) \approx \frac{n}{m}$$

$v^2 \approx \frac{KE}{m} \rightarrow \boxed{\frac{KE}{m} g(E_f) = \frac{n}{m}}$

→ Not all electrons contribute to conductivity in solids.

→ density of states at fermi level dictates conductivity of solids.

Semiconductors:

↳ clear gap in Density of States.

↳ Clear gap b/w BO & ABO orbitals.

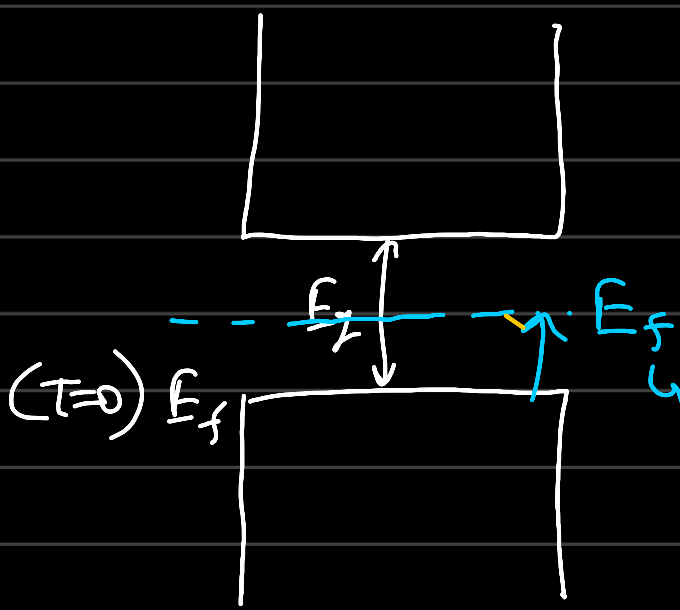
* A completely filled band will not conduct.
  ↳ no immediate energy level above fermi level.

→ $\sigma_{\text{semiconductor}} = 0$ at 0K

→ $\sigma_{\text{semi}} > 0$ at $T > 0K$ → excitation

→ Electron-hole pair creation:
  ↳ Thermal energy or EM photon incidence.

Carrier statistics in semiconductors:



$$P(E) = \frac{1}{1+e^{\beta(E-E_f)}}$$

Fermi-Dirac distribution.

↳ for symmetric distribution of electrons & holes

→ Fermion & Boson:

f —— 0, 1 {only two e^- per state}

b —— 0, 1, 2, 3, . . . 5 {all photons can fall down to the grnd state}

Intrinsic Semiconductor:

→ At any non-zero temp. The conduction band always has non-zero probability of occupation.

$$n_i = \int_{E_C}^{\infty} P(E) D(E)\, dE$$

→ Typical semiconductors have very small carrier density : $10^6 - 10^{15}/cm^3$

→ at any given time steady state density is $10^6 - 10^{13}/cm^3$ of electrons.

→ Conduction in semiconductors, is due to both electrons & holes.

$$\sigma_{semi} = \frac{ne^2\tau}{m} = ne\mu_n + pe\mu_p$$

$$\underbrace{\mu_n = \frac{e\tau_n}{m_e}}_{\text{mobility of electrons}} \qquad \underbrace{\mu_p = \frac{e\tau_p}{m_h}}_{\text{mobility of holes.}}$$

$$m = m_0 \, m_{eff}$$

m_0 ↓ rest mass $(9.1 \times 10^{-31} kg)$

m_{eff} → scaling factor.

→ electron does not move freely in a periodic potential.

$$E = \frac{\hbar^2 k^2}{2m} \rightarrow m = \frac{2E}{\hbar^2 k^2} \Rightarrow \frac{\partial^2 E}{\partial k^2} = \frac{\hbar^2}{m} \Rightarrow \boxed{m = \frac{\hbar^2}{\partial^2 E/\partial k^2}}$$