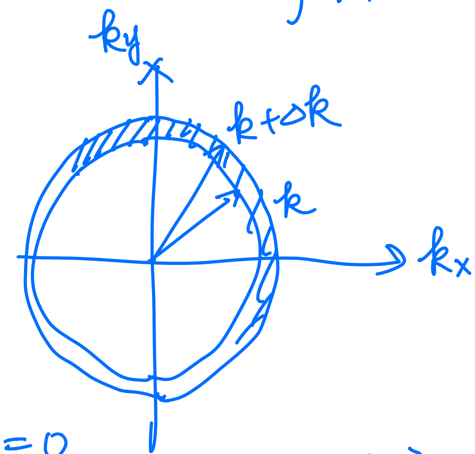
$$\alpha(\hbar\omega) = C_0 \underbrace{\frac{2}{V}\sum_{k} \delta(E_e - E_h - \hbar\omega)}\cdot |\hat{e}\cdot\vec{p}|^2 (f_v - f_c)$$

$$\int \rho_{r,2D}(\hbar\omega)\cdot\delta(\hbar\omega - (E_e - E_h))\, d\omega$$



$E_v = 0$

$$E_e = E_g + E_{e1} + \frac{\hbar^2 k^2}{2m_e^*}$$

$$-)\quad E_h = E_{h1} - \frac{\hbar^2 k^2}{2m_h^*}$$

$$E_e - E_h = \hbar\omega = \underbrace{E_g + E_{e1} - E_{h1}}_{E_{g,eff}} + \frac{\hbar^2 k^2}{2}\underbrace{\left(\frac{1}{m_e^*} + \frac{1}{m_h^*}\right)}_{\frac{1}{m_r^*}}$$

$$\hbar\omega = E_{g,eff} + \boxed{\frac{\hbar^2 k^2}{2m_r^*}}$$

kinetic energy of the electron-hole pair connected by the photon

Kinetic Energy $E_k = \frac{\hbar^2 k^2}{2m_r^*}$

$$dE_k = \frac{2\hbar^2 k}{2m_r^*}\Delta k$$

Total 2-D k-space area for states with electron-hole kinetic energy $= \frac{\hbar^2 k^2}{2m_r^*}$

$$\frac{2}{V}\sum_{k_t} = \frac{2}{L_x L_y L_z}\int \frac{2\pi k\, dk}{\left(\frac{2\pi}{L_x}\right)\left(\frac{2\pi}{L_y}\right)} = \frac{1}{L_z}\int \frac{4\pi k\, dk}{4\pi^2}$$

area per state

$$= \frac{1}{L_z\pi}\int k\, dk = \frac{1}{L_z\pi}\cdot\frac{m_r^*}{\hbar^2}\int dE = \underbrace{\frac{m_r^*}{\pi\hbar^2 L_z}}\int dE$$

In comparison, the electron 2D density of states is related only to electron kinenetic energy:

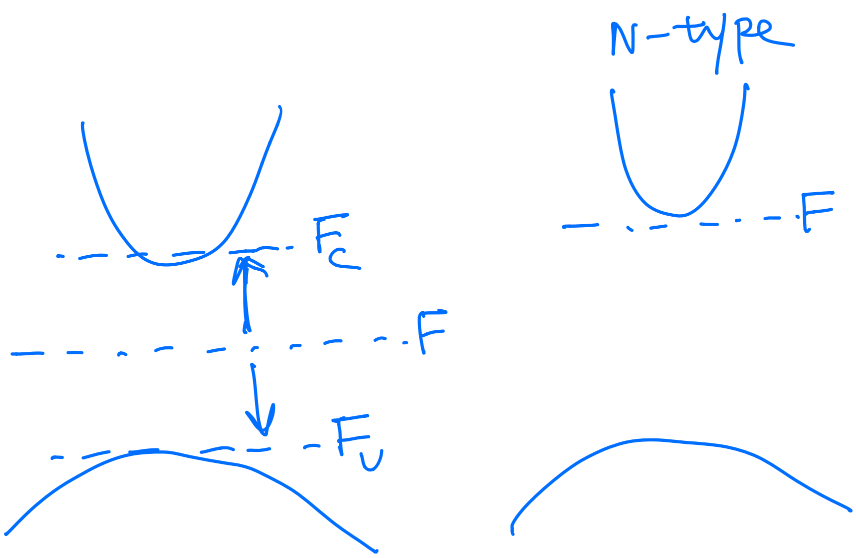
$$E_e = E_c + E_{n1} + \frac{\hbar^2 k^2}{2m_e^*}$$

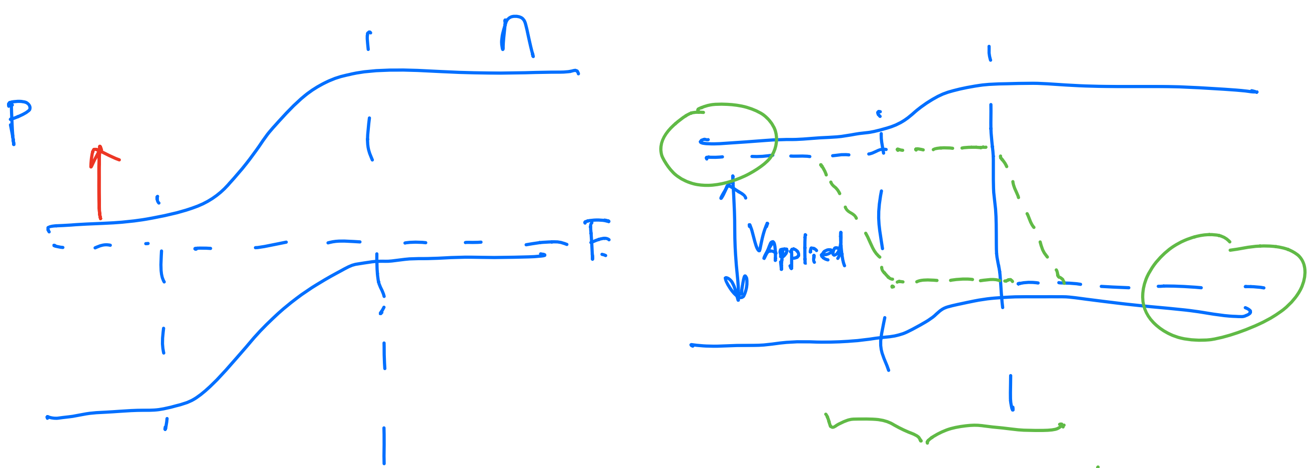
$$E_k = E_e - (E_c + E_{n1}) = \frac{\hbar^2 k^2}{2m_e^*} \Rightarrow dE_k = \frac{2\hbar^2}{2m_e^*} k\,dk$$

$$\frac{2}{C}\sum_k = \frac{2}{V}\int \frac{2\pi k\,dk}{\left(\frac{2\pi}{L_x}\right)\left(\frac{2\pi}{L_y}\right)} = \frac{1}{\pi L_z}\int k\,dk = \underbrace{\frac{1}{\pi L_z}\frac{m_e^*}{\hbar^2}}_{\rho_{e,2d}} \cdot \int dE$$

QW. $n_{2D} = \int \underline{\rho_{e,2d}(E)} \cdot f_c(E)\,dE$

Question about Quasi-Fermi levels





Question about $\langle u_c|\vec{P}|u_v\rangle$ in bulk semiconductor

$$|\langle u_s|P_x|u_x\rangle|^2 = 3M_b^2$$

Intuitively, you can think $u_v \sim \frac{1}{\sqrt{3}}u_x + \frac{1}{\sqrt{3}}u_y + \frac{1}{\sqrt{3}}u_z$

$$|\langle u_c|P_x|u_v\rangle|^2 = M_b^2$$

$\hookrightarrow \frac{1}{\sqrt{3}}u_x \Longleftarrow \frac{1}{\sqrt{3}}\langle u_c|P_x|u_x\rangle$

$\frac{1}{\sqrt{3}}u_y$

$\frac{1}{\sqrt{3}}u_z$