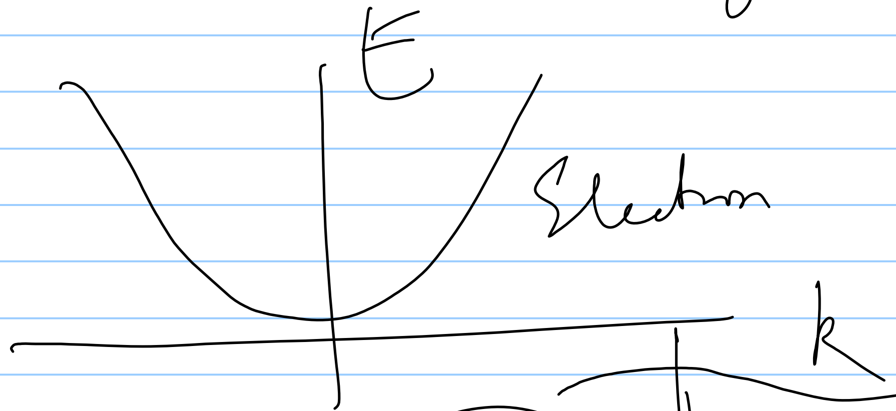
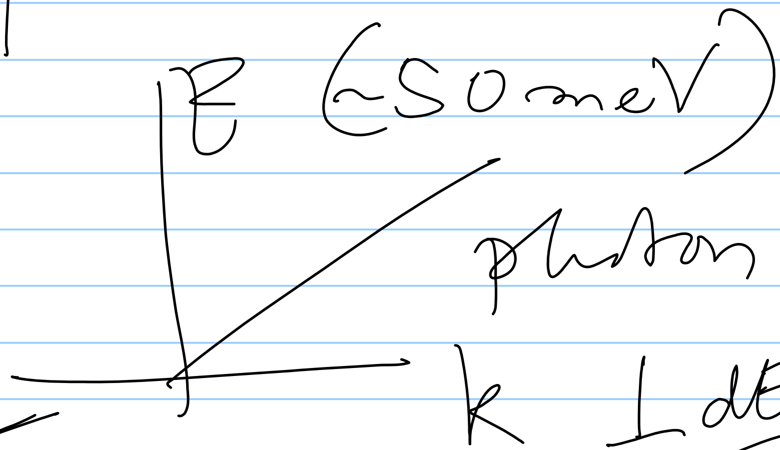
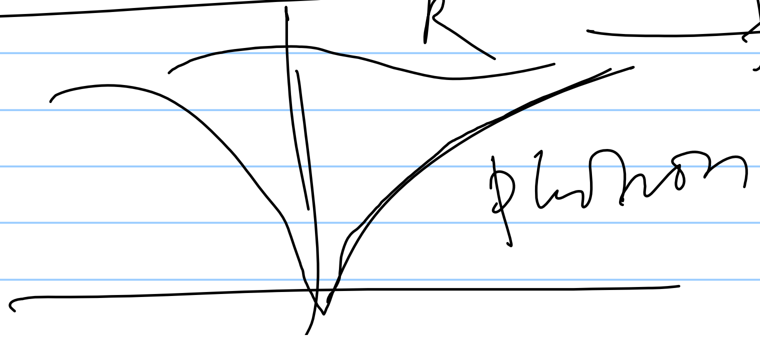
photon $\longrightarrow$ small p, high E

phonon $\longrightarrow$ high p, small E





$$\frac{1}{\hbar}\frac{dE}{dk} = v$$



photon $E = \hbar\omega$

$$\frac{1}{\hbar}\frac{dE}{dk} = \frac{d\omega}{dk} = c$$

$$\boxed{v = \frac{1}{\hbar}\frac{dE}{dk}} = \frac{1}{\hbar}\frac{\hbar^2 k}{m}$$

$$= \frac{\hbar k}{m} = v$$

$$E = E_0 + \frac{\hbar^2 k^2}{2m}$$

Donor level

$$E_H = -\frac{1}{2}\frac{m e^4}{(4\pi\epsilon_0)^2 n^2 \hbar^2} \simeq 13.6\,eV$$

$$\frac{E_{P-Si}}{E_H} = \frac{m_e^*}{m}\frac{1}{(\epsilon_{r.Si})^2}$$

$\epsilon_{r.Si} \to 11.8$

$\epsilon_0 \to \epsilon_0 . \epsilon_{r_{Si}}$

$m \to m_e^*$

$m_e^* = 0.5m$

$$E_{P-Si} = \frac{13.6}{(11.8)^2} \, 0.5 \approx 0.1 \, eV$$

B (acceptor) → 0.045 eV

Ga (acceptor) → 0.07 eV

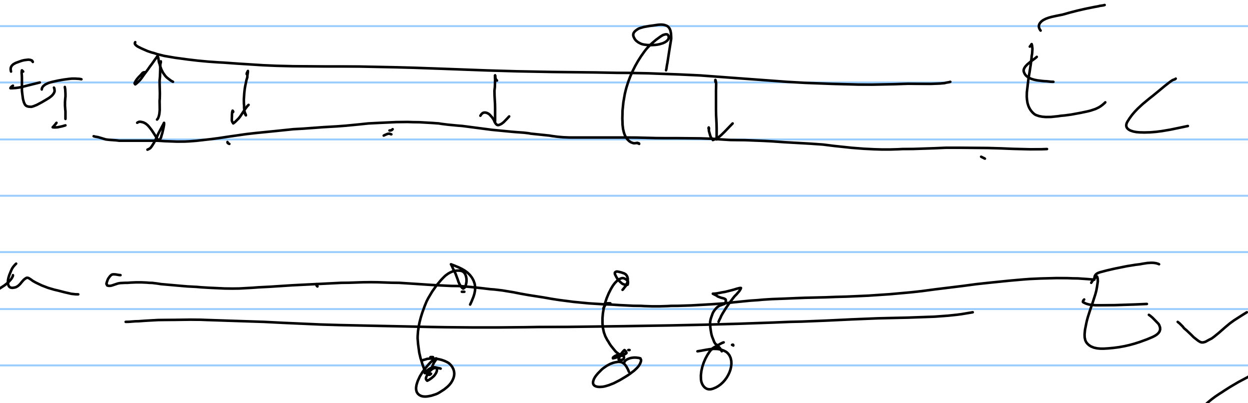
P (donor) → 0.045 eV

As (donor) → 0.055 eV

(E_I)

↳ ionization energy

$kT = 0.0259$ eV



E_d

Donor level (E_d)

Acceptor level (E_a)

$E_C - E_d = E_{Id}$

$E_a - E_V = E_{Ia}$

Ge $\qquad \epsilon_{Ge} \approx 16 \qquad E_I \sim 0'01 eV$

Calculation of n or p / cm^3

Density of Energy states / levels

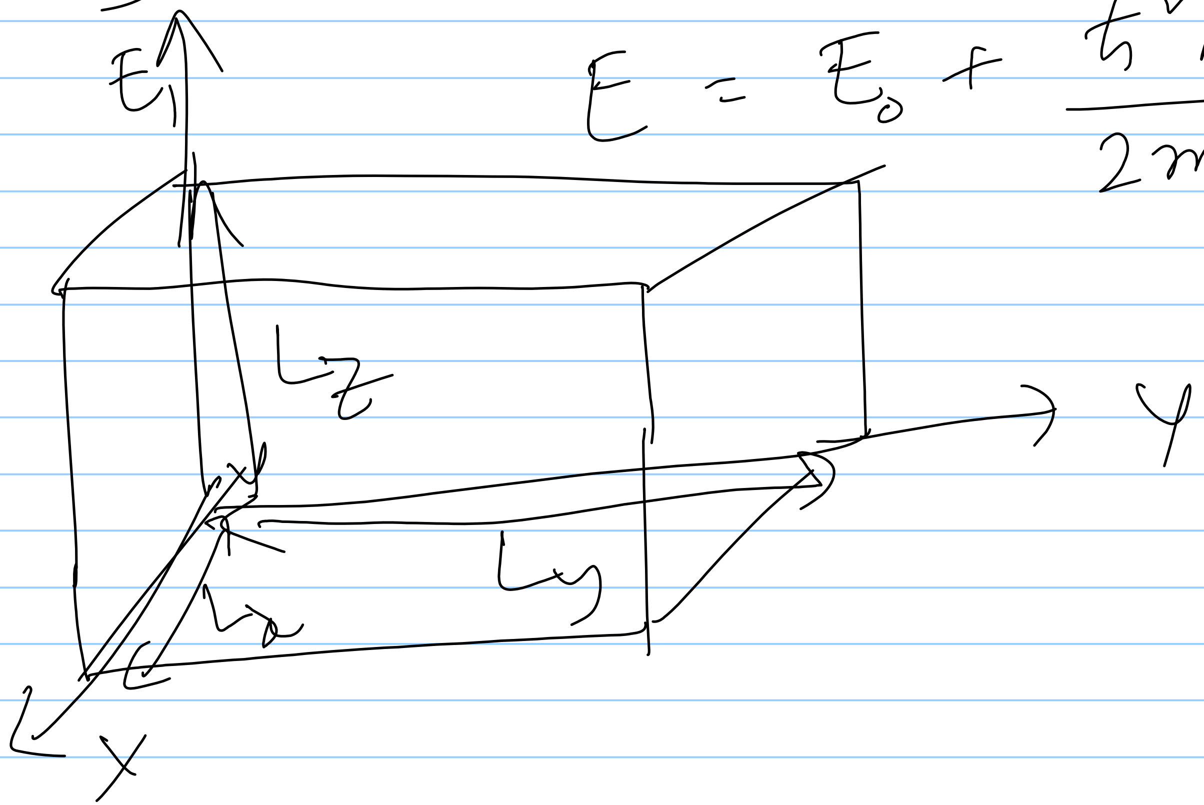
$E \to E+dE$

$D(E) \longrightarrow$ density of energy states per unit volume per unit Energy

$(/cm^3\text{-}eV)$

$B(E) \longrightarrow$ occupation factor

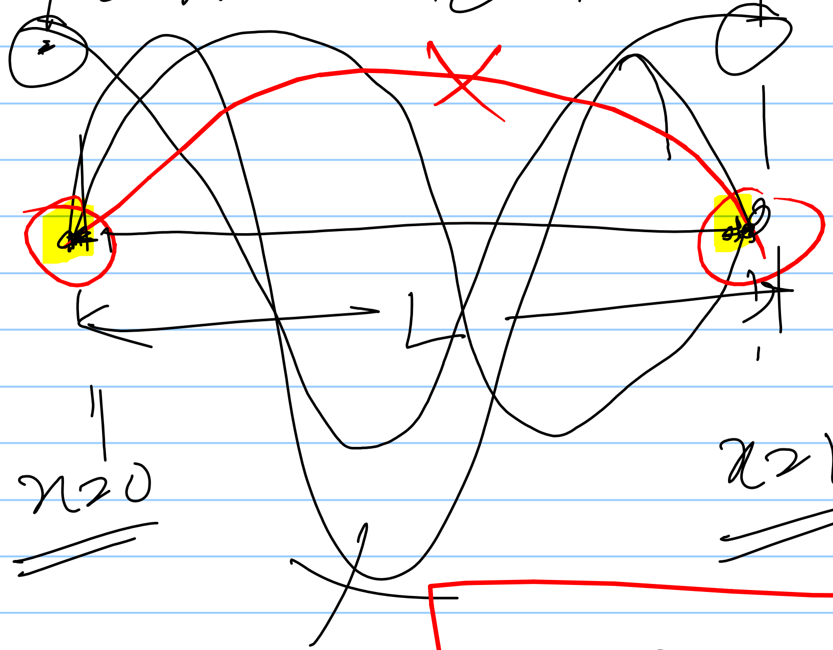
$$n = \int^{E_2} D(E)\, B(E)\, dE \quad / \mathrm{cm}^3$$



$$E = E_0 + \frac{\hbar^2 k^2}{2m^*}$$

$$V_\Omega = L_x L_y L_z$$

Periodic Boundary Condⁿ (PBC)



$$\psi = \psi_0 \sin(kx)$$

$$\psi = \psi_0 \cos(kx)$$

$$\boxed{\psi(x) = \psi(x+L)}$$

$$k_n L = 2 n \pi$$

$$k_1 = \frac{2\pi}{L} \qquad k_2 - k_1 = \frac{2\pi}{L}$$

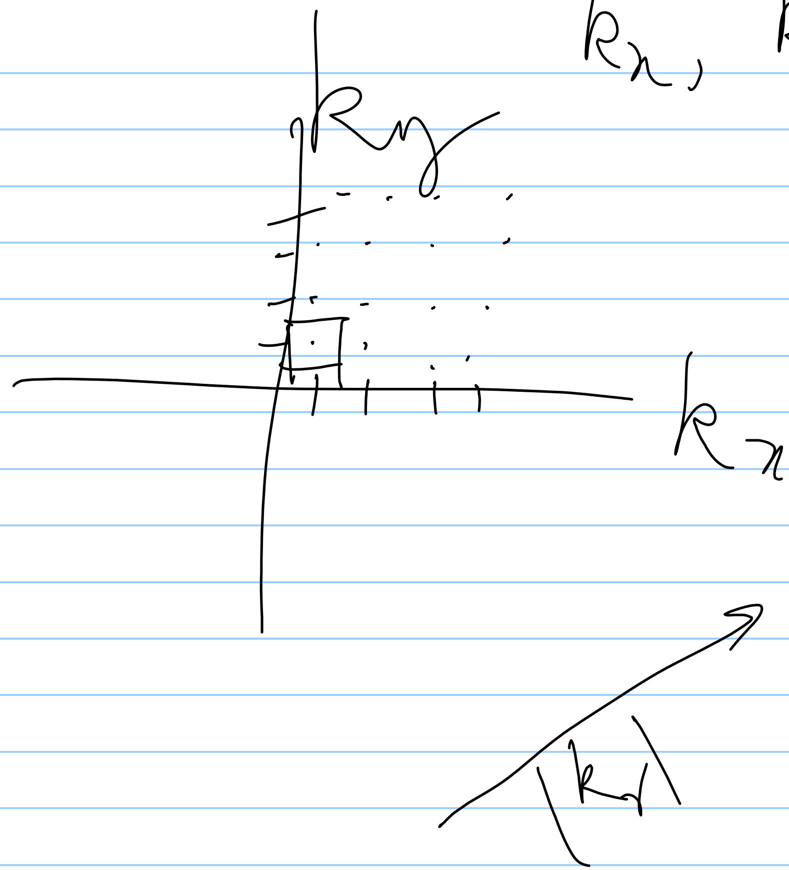
$$k_2 = \frac{4\pi}{L}$$

$$k_3 = \frac{6\pi}{L} \qquad k_3 - k_2 = \frac{2\pi}{L}$$

L

L

k_x, k_y, k_z



$$\frac{2\pi}{L_x} \times \frac{2\pi}{L_y} \times \frac{2\pi}{L_z} \to 1$$

$N(k_r) \to$ no. of k-states having $k \leq |k_r|$

$$\frac{4}{3}\pi k_r^3 \longrightarrow \frac{L_x L_y L_z}{\cancel{6}\,8\pi^3} \times \frac{\cancel{4}}{3}\pi k_r^3$$

$$\parallel$$

$$N(E) \longleftarrow N(k_r)$$

$$E = E_0 + \frac{\hbar^2 k_r^2}{2m} \Rightarrow k_r = \frac{1}{\hbar}\sqrt{2m^*(E-E_0)}$$

$$N(E_r) = ?$$

$$= \frac{V_n}{6\pi^2\hbar^3}\left\{2m^*(E-E_0)\right\}^{3/2}$$

$N(k_r) \longrightarrow N(E_r) \rightarrow$ no. of energy states having $E \leq E_r$

$\frac{1}{V_n} dN(E) \rightarrow$ no. of energy states within E and $E + dE$ per unit vol.

$D(E)\,dE \rightarrow$ no. of energy states per unit vol within E & $E + dE$

$$D(E)\,dE = \frac{1}{V_\Omega}\, dN(E)$$

$$D(E) = \frac{2 \times 1}{V_\Omega} \frac{dN(E)}{dE} = ?$$