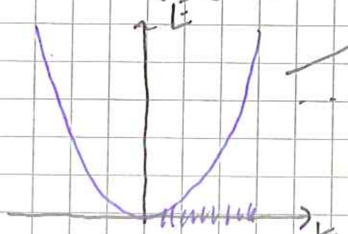
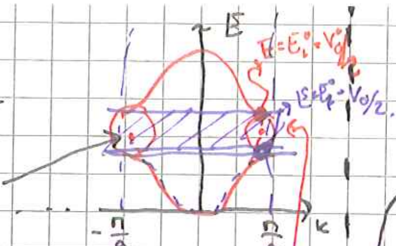
[redacted]

6/2-2013

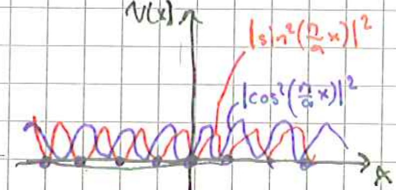
⑦ Förra gången:





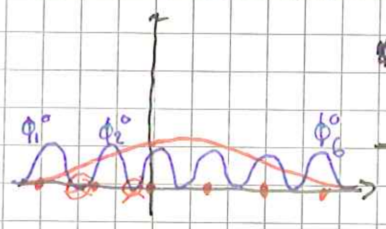
V(x) periodisk.
$H=H^0+V(x)$.
$\phi=c_1\phi_1^0+c_2\phi_2^0$.
approximativa egentillstånd.
$p\phi \neq \lambda\phi$

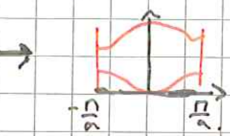
$\phi_n^0 \sim e^{ik_nx}$
$p\phi_n^0 = \hbar k_n \phi_n^0$
$|\phi_n^0| =$ konst.



NEFM: delokaliserade (utspridd över hela kristallen)
tillstånd + svagpotential → band.
Tight binding: lokaliserade tillstånd → mixar → → delokaliserade tillstånd, band.

$\psi=\sum_n c_n\phi_n^0$

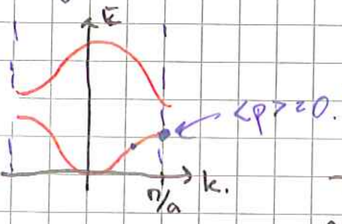


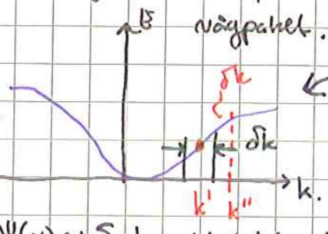


(se fig. 5.24, 5.25 s 133), 5.27.

FEM $\phi_n^0 \sim e^{ik_nx}$ egentillst. till $p=-i\hbar\frac{d}{dx}$

Våra nya tillstånd $H=H^0+V(x)$ generellt. p≠ħk.





$\Psi(x) \sim \sum c$ bandtillstånd

grupphastighet: $v_g=\frac{1}{\hbar}\frac{dE}{dk}$

$\psi_1+\psi_2$ | $\psi_1(x,t)=ce^{i(kx-\omega t)}$, $\omega=E/\hbar$
$\psi_2(x,t)=ce^{i([k+\delta k]x-[\omega+d\omega]t)}$

$\Rightarrow ce^{i(kx-\omega t)}\{1+e^{i(\delta kx-\delta\omega t)}\}$

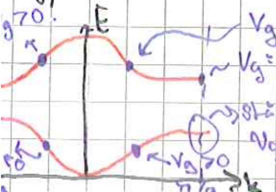
modulation: hur rör dem sig?

$\delta kx-\delta\omega t=$ konst

$\frac{d}{dt}: \delta k\cdot\frac{dx}{dt}-\delta\omega=0 \Rightarrow v_g=\frac{dx}{dt}=\frac{\delta\omega}{\delta k}=\frac{1}{\hbar}\frac{\delta E(k)}{\delta k}$, $\omega=E/\hbar$

fri e⁻ $E=\frac{\hbar^2k^2}{2m}$ $v_g=\frac{1}{\hbar}\frac{\partial E}{\partial k}=\frac{\hbar k}{m}=\frac{p}{m}$

Vågpaket vid k=k' $v_g=\frac{1}{\hbar}\frac{\partial E}{\partial k}\Big|_{k=k'}$ $v_g\neq\hbar k/m$.



Yttre kraft $F_{ext}=-e\mathcal{E}$

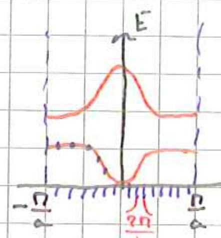
$\delta E=F_{ext}\cdot\delta_s=-e\mathcal{E}\cdot v_g\cdot\delta t$
$\delta E=\frac{dE}{dk}\cdot\delta k=\hbar v_g\delta k$ } $\hbar\delta k=-e\mathcal{E}\delta t$

$\hbar\frac{dk}{dt}=-e\mathcal{E}=F_{ext}$.

kap 2,4: Fria e⁻ F=0 "från början"

kap 5 i NFEM $F=-e\mathcal{E}$, $F=-\frac{dV}{dx}$, V(x) periodisk.

$-e\mathcal{E}$ $F_{tot}=-e\mathcal{E}-\frac{dV}{dx}$

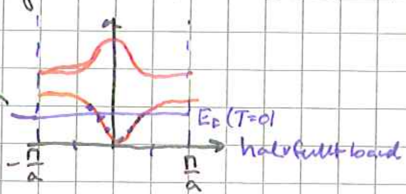


Hur många e⁻ får plats i ett band?

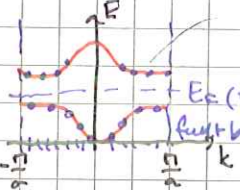
Antal k-punkter i BZ/band. $\frac{2\pi}{a}/\frac{2\pi}{L}=\frac{L}{a}=N_a$ st k-punkter, $L=N_a\cdot a$
⟺ N_a atomer i hela kristallen.

Spinn = 2e⁻/k-punkt → $2N_a$ tillstånd/band.

T=0. Antar atomslag med 1 valens e⁻/atom.
⟹ N_a st e⁻

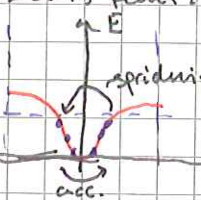


Antar 2 valens e⁻/atom
⟹ $2N_a$ st e⁻



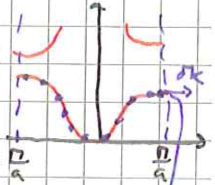
1 dim:
Udda antal valens e⁻ ⟹ halvfullt band
Jämnt antal -- ⟹ fullt band
3D: Udda ⟹ halvfullt.
jämnt ⇏ fullt band.
Ex) Mg ej fulla band
Si fulla band.

T=0, $\mathcal{E}\neq0$:
Delvis fullt:



$\hbar\frac{dk}{dt}=F_{ext}$.
kan leda ström.
⟹ metall

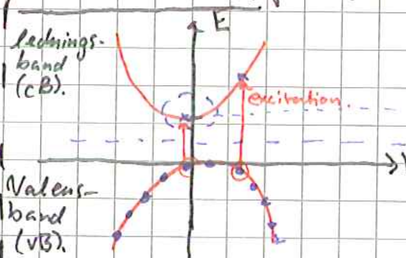
Fullt:



Ingen netto-omfördelning. $\phi\sim e^{i\pi/a\,x}$, $e^{-i\pi/a\,x}$
⟹ isolator / halvledare. kan inte leda ström

Kap 6. Halvledare

$2N_a$ tillst. / atom	
Si, Ge, diamant	2 atomer / prim cell
GaAs, InP, InAs	8 valens e⁻ / primcell.



(se fig 6.3 s 139) Nära extrempunkter: $E(k)=E(k_0)+(k-k_0)\frac{dE}{dk}\Big|_{k_0}+\frac{1}{2}(k-k_0)^2\frac{d^2E}{dk^2}\Big|_{k_0}+\ldots$, $\frac{dE}{dk}\Big|_{k_0}=0$

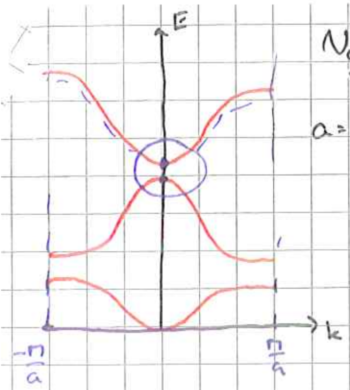
$=E_c+\frac{1}{2}(k-k_0)^2\frac{d^2E}{dk^2}\Big|_{k=k_0}$

Om vi definierar $\frac{1}{m_e^*}=\frac{1}{\hbar^2}\frac{d^2E}{dk^2}\Big|_{k=k_0}$ ⟹ $\frac{v_g}{m_e^*}$

$\Rightarrow E(k)=E_c+\frac{\hbar^2(k-k_0)^2}{2m_e^*}$ → effektiv massa.

$v_g=\frac{1}{\hbar}\frac{\partial E}{\partial k}=\frac{\hbar(k-k_0)}{m_e^*}$

$\Rightarrow E(k)=E_c+\frac{m_e^*v_g^2}{2}$
pot. energi, kin. energi



$v_g = \frac{1}{\hbar} \frac{dE}{dk} = \frac{\hbar(k-k_0)}{m_e^*}$

$a = \frac{dv_g}{dt} = \frac{1}{\hbar^2} \frac{\partial^2 E}{\partial k^2} \cdot \frac{\partial k}{\partial t}\hbar = \frac{F_{ext}}{m_e^*}$

$\frac{1}{\hbar^2} \frac{\partial^2 E}{\partial k^2} = \frac{1}{m_e^*}$, $\frac{\partial k}{\partial t}\hbar = F_{ext}$

Newton 2:a lag
$F = m \cdot a$.