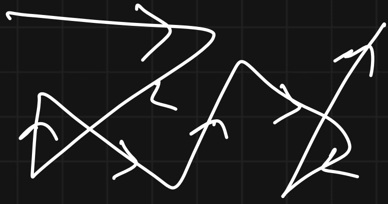
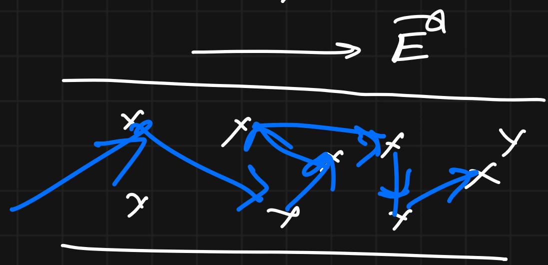
Careful of the terminology used in this field

Regimes of transport

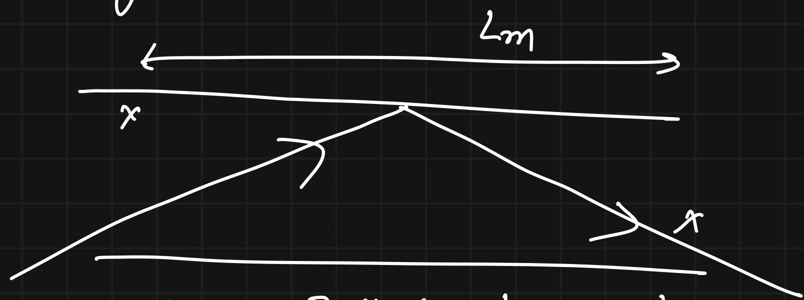


diffusive regime



Diffusive regime

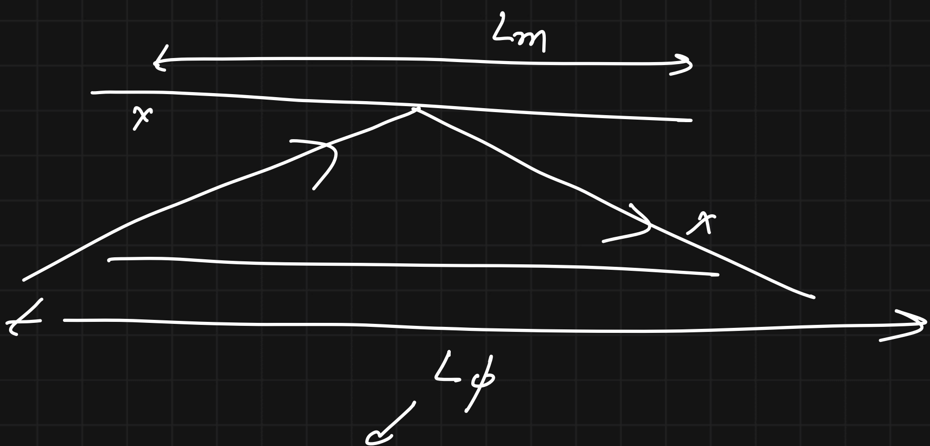
But very few scatters



✓ Ballistic transport

we want to have a ballistic (clean) systems

→ transport regime where



* L_ϕ is large → scattering is only at boundaries

∴ To study diff regimes of φ. transport, we need to keep in mind

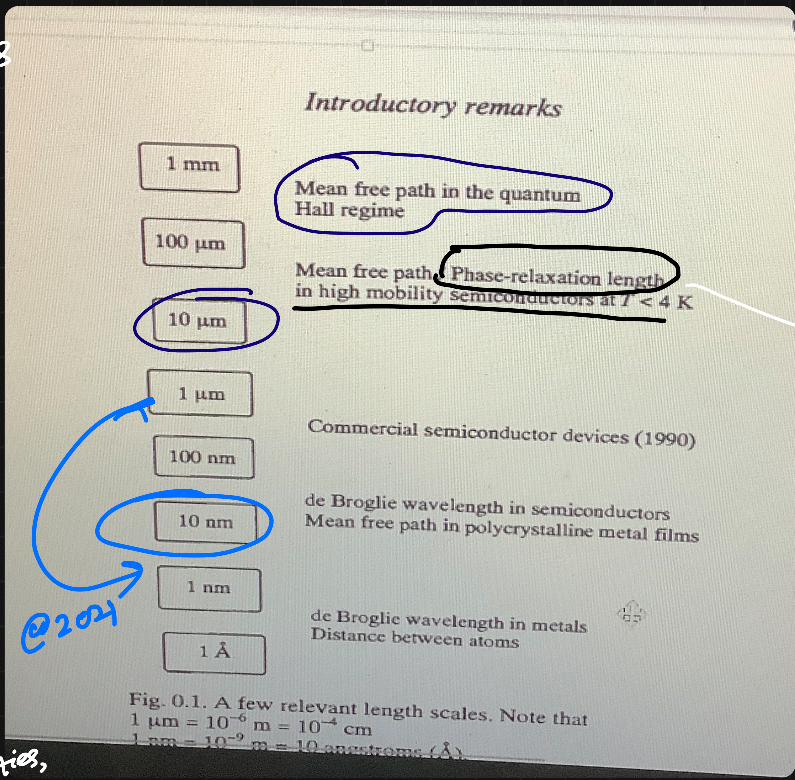
→ inelastic scattering lengthscale

L_m, L_ϕ, L_s, λ_{TF}

elastic scattering length → we'll assume a "phase coherent" & ballistic ("quasi-ballistic") transport.

↓

mean free path depends on sample's frozen impurities



→ L_ϕ

@2021

for metals, L_m & L_ϕ are rel. short.

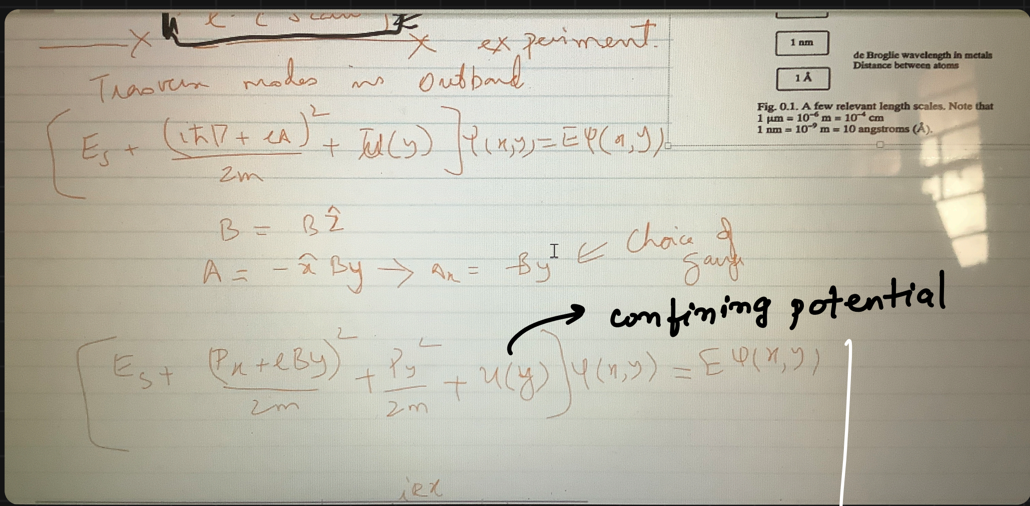
ring expt $L > L_\phi \sim$ few μm

coherence length
↳ magnetic impurities, magnons,

"why call it relaxatⁿ?"

explanation for the gate (1st lecture)

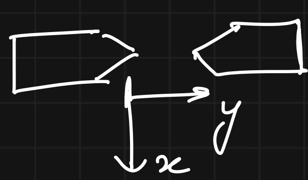
expt



we look at diff case of confining potential

Gate mediated potential
↓
basically gate effects this

Quadratic confinement



$$\psi(x,y) = \frac{1}{\sqrt{L}}\, e^{ikx}\, \chi(y)$$

$$\left[E_s + \frac{(\hbar k + eBy)^2}{2m} + \frac{p_y^2}{2m} + U(y)\right]\chi(y) = E\chi(y)$$

$$U(y) = \frac{1}{2} m\omega_0^2 y^2$$

now set $B=0$

$$\left[E_s + \frac{(\hbar k + eBy)^2}{2m} + \frac{p_y^2}{2m} + U(y)\right]\chi(y) = E\chi(y)$$

$$U(y) = \frac{1}{2} m\omega_0^2 y^2$$

$$\left[E_s + \frac{\hbar^2 k^2}{2m} + \frac{p_y^2}{2m} + \frac{1}{2} m\omega_0^2 y^2\right]\chi(y) = E\chi(y)$$

$$\chi_{n,k}(y) = u_n(q) \qquad q = \sqrt{m\omega_0/\hbar}\; y$$

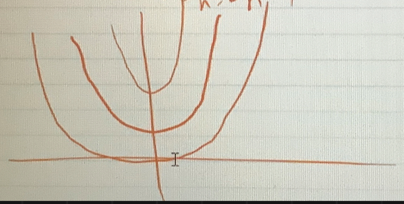
$$E(n,k) = \underbrace{E_s}_{\text{offset (rel. to band edge)}} + \underbrace{\frac{\hbar^2 k^2}{2m}}_{\text{parabolic disp}} + \underbrace{(n+1/2)}_{\text{band \#}}\hbar\omega_0$$

$$E(n,k) = E_s + \frac{\hbar^2 k^2}{2m} + (n+1/2)\hbar\omega_0$$

$$u_n(q) = e^{-q^2/2} H_n(q)$$

$$v(n,k) = \frac{1}{\hbar}\frac{\partial E}{\partial k} = \frac{\hbar k}{m}$$

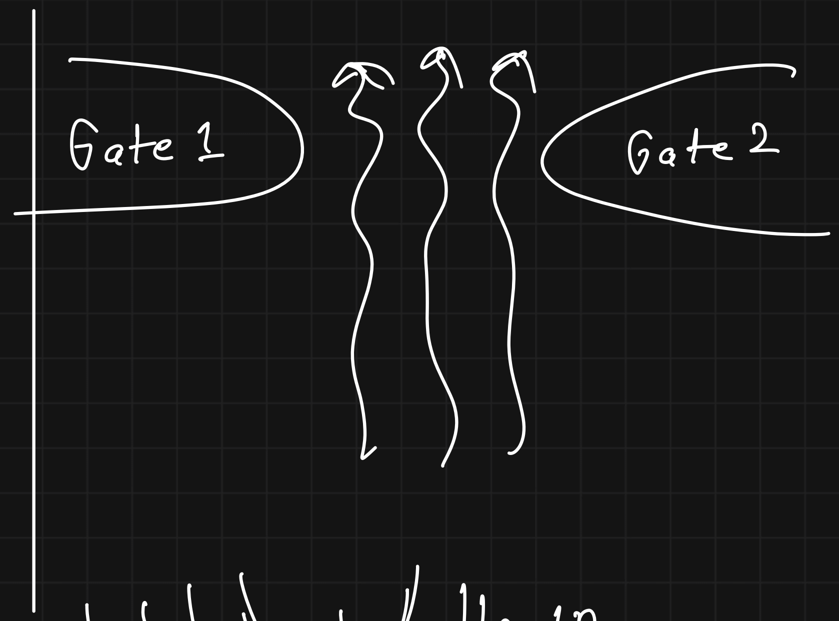
→ non-zero group velocity

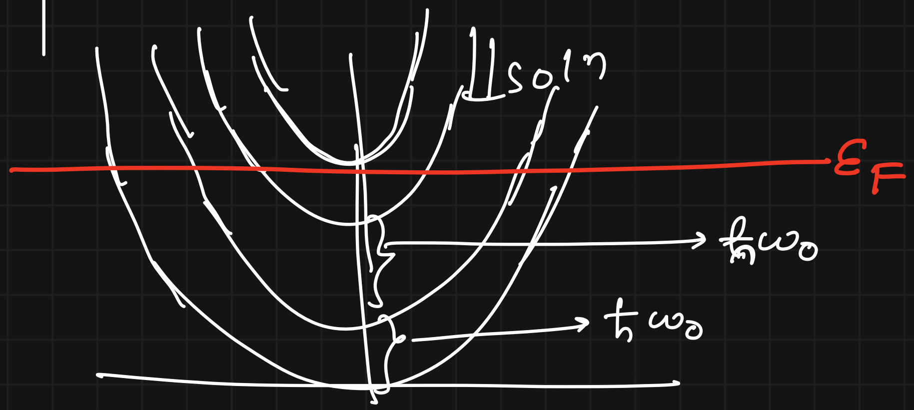


"Sub-bands"

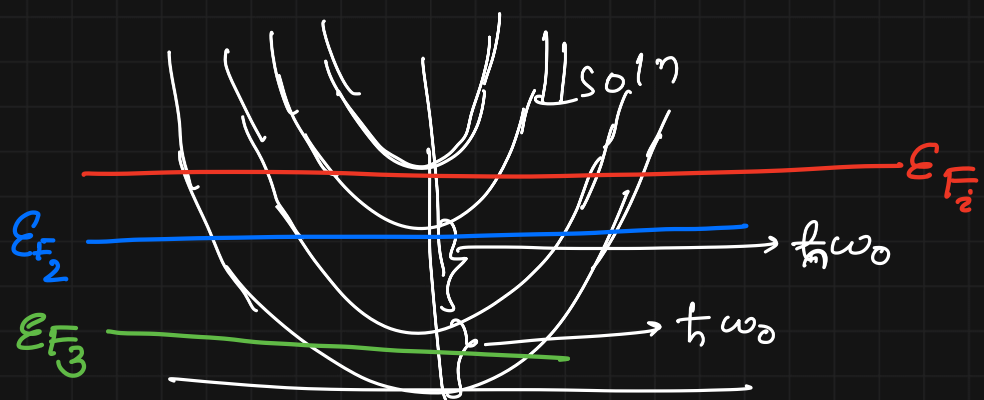
" paper by van Wees "

Back to Paper





as you change V_{gate}, the fermi energy gets tuned



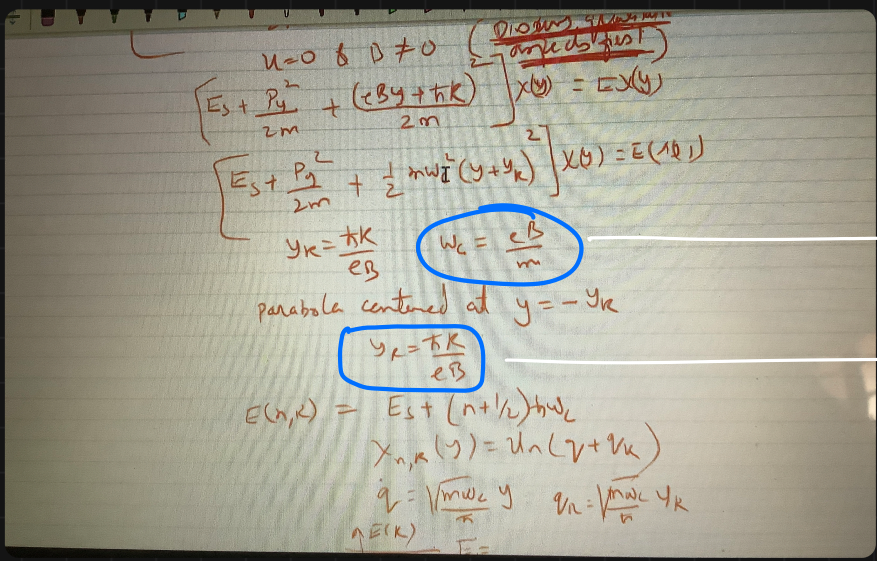
as $\varepsilon_F \downarrow$, # channels reduces $\longrightarrow$ # of modes reduces & each mode has a max^m. throughput voltage of $\frac{2e^2}{\hbar}$

$\longrightarrow$ no eff. on conductance & max^m. throughput of the channels

∴

Q. Hall

→ no confinement → $\vec{B} \neq 0$


$u = 0$ & $B \neq 0$

$$\left[E_s + \frac{P_y^2}{2m} + \frac{(eBy + \hbar k)^2}{2m}\right]\chi(y) = E\chi(y)$$

$$\left[E_s + \frac{P_y^2}{2m} + \frac{1}{2}m\omega_c^2 (y + y_k)^2\right]\chi(y) = E(\chi(y))$$

$y_k = \frac{\hbar k}{eB}$ $\quad \omega_c = \frac{eB}{m}$ → spring const. is tuned

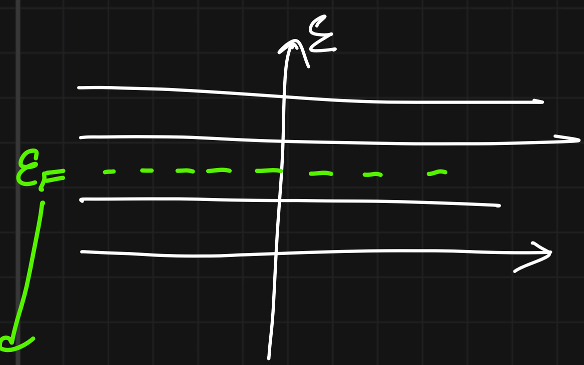
parabola centred at $y = -y_k$

$y_k = \frac{\hbar k}{eB}$ → shift

$$E(n,k) = E_s + (n + 1/2)\hbar\omega_c$$

$$\chi_{n,k}(y) = u_n(q + q_k)$$

$q = \sqrt{\frac{m\omega_c}{\hbar}}\, y$ $\quad q_k = \sqrt{\frac{m\omega_c}{\hbar}}\, y_k$



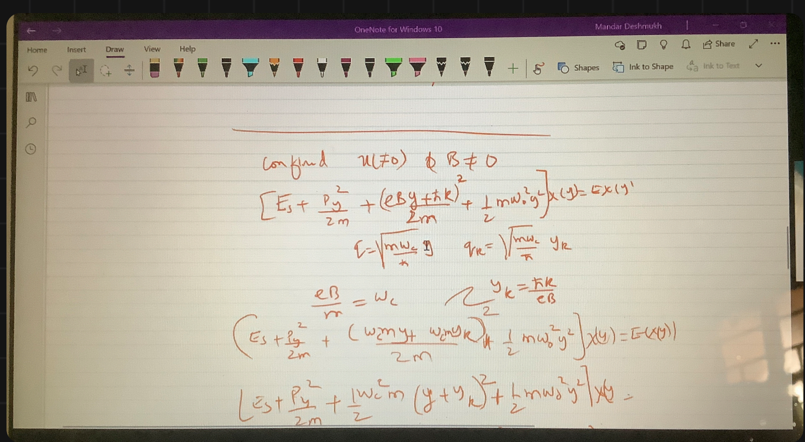
insulator

$$v_n = \frac{1}{\hbar}\frac{\partial E}{\partial k} = 0$$

"insulator"

So we started with a 2D "conductor", we end up with an insulator.

B + confining potential


Confined $u(\neq 0)$ & $B \neq 0$

$$\left[E_s + \frac{P_y^2}{2m} + \frac{(eBy + \hbar k)^2}{2m} + \frac{1}{2}m\omega_0^2 y^2\right]\chi(y) = E\chi(y)$$

$q = \sqrt{\frac{m\omega_c}{\hbar}}\, y$ $\quad q_k = \sqrt{\frac{m\omega_c}{\hbar}}\, y_k$

$\frac{eB}{m} = \omega_c$ $\quad y_k = \frac{\hbar k}{eB}$

$$\left(E_s + \frac{P_y^2}{2m} + \frac{(\omega_c m y + \omega_c m y_k)^2}{2m} + \frac{1}{2}m\omega_0^2 y^2\right]\chi(y) = E\chi(y)$$

$$\left[E_s + \frac{P_y^2}{2m} + \frac{1}{2}\omega_c^2 m (y + y_k)^2 + \frac{1}{2}m\omega_0^2 y^2\right]\chi(y) =$$

Parabola Parabola

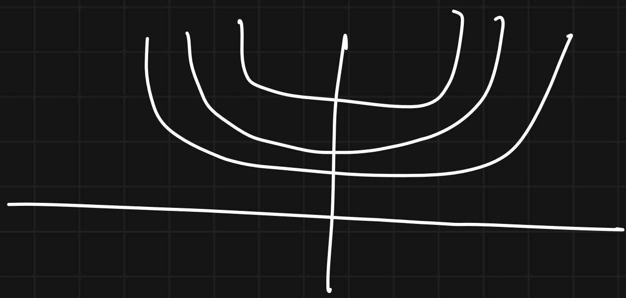
$$\left[E_s + \frac{p_y^2}{2m} + \frac{1}{2} m \frac{\omega_0^2 \omega_c^2}{\omega_{c0}^2} y_k^2 + \frac{1}{2} m \omega_{c0}^2 \left(y + \frac{\omega_c^2}{\omega_{c0}^2} y_k\right)^2\right] \chi(y) = E\chi(y)$$

$$\omega_{c0}^2 = \omega_c^2 + \omega_0^2$$

$$\chi_{n,k}(y) = u_n\left(q + \frac{\omega_c^2}{\omega_{c0}^2} q_k\right)$$

$$q = \sqrt{\frac{m\omega_{c0}}{\hbar}}\, y \quad ; \quad q_k = \sqrt{\frac{m\omega_{c0}}{\hbar}}\, y_k$$

$$E(n,k) = E_s + \left(n + \tfrac{1}{2}\right)\hbar\omega_{c0} + \frac{\hbar^2 k^2}{2m} \frac{\omega_0^2}{\omega_{c0}^2}$$



$$v(n,k) = \underbrace{\frac{\hbar k}{m} \times \frac{\omega_0^2}{\omega_c^2}}$$

non-zero

diff from Q. Hall system

1st hint that having a boundary changes the transport prop.

$$y_k = \frac{\hbar k}{eB}$$

$$\boxed{y_k = \frac{\hbar k}{eB}}$$

$\hookrightarrow$ offset for wavefⁿ in y-direction.

$k > 0 \longrightarrow$

$k < 0 \longrightarrow$

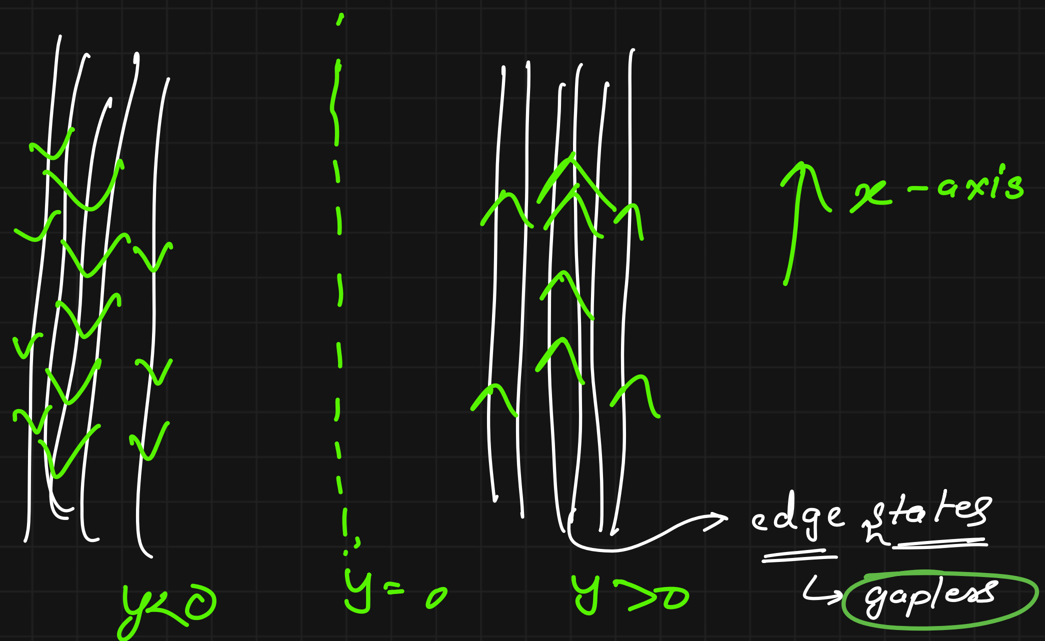
$v_k \propto y_k \rightarrow \therefore$ for $k > 0 \longrightarrow v_k > 0$

$y_k > 0 \rightarrow$ shifted to right

for $k < 0 \longrightarrow v_k < 0$

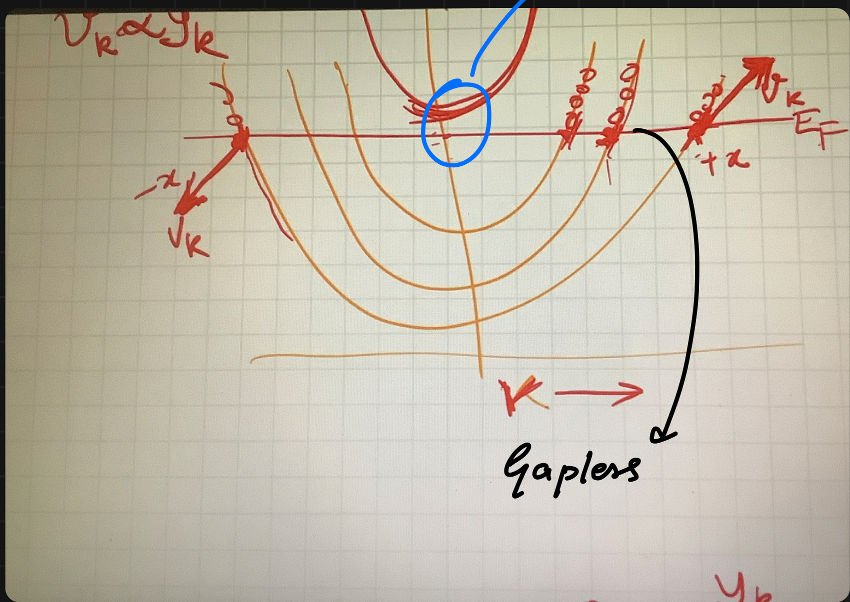
$y_k < 0 \rightarrow$ shifted to left

Top view of QHall



→ move in opposite direction.

what happens in bulk?



→ no state near fermi en.

↓

so no gapless excitation

↓

behaves like an insulator

→ at the level of BTE, $\delta f = \frac{-q\tau}{\hbar} E\, \partial_k f$

⇙

How do I explain the Bulk "insulator" ness within BTE?

↙ fermi energy

semi-classical ideas