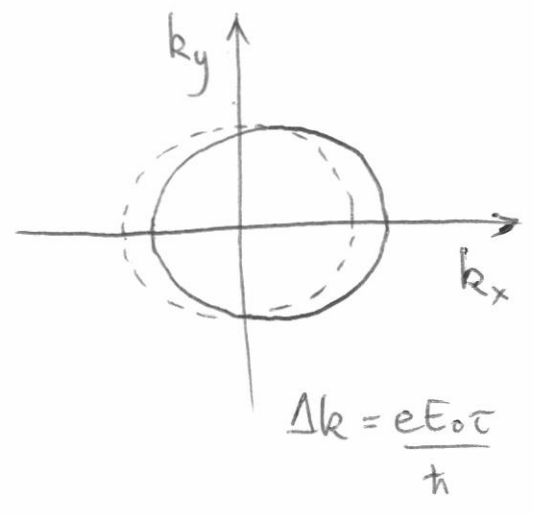


DAY 5

①

PH671

DIFFUSIVE TRANSPORT



Depends on strength of the \vec{E} -field.

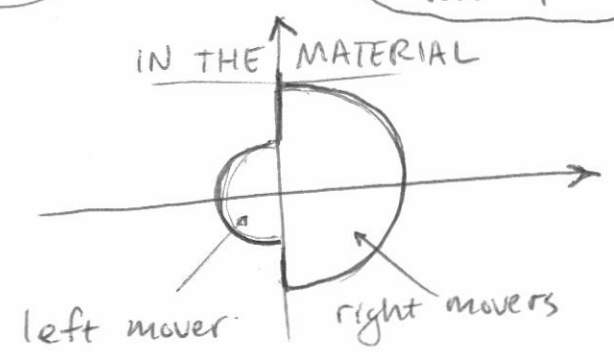
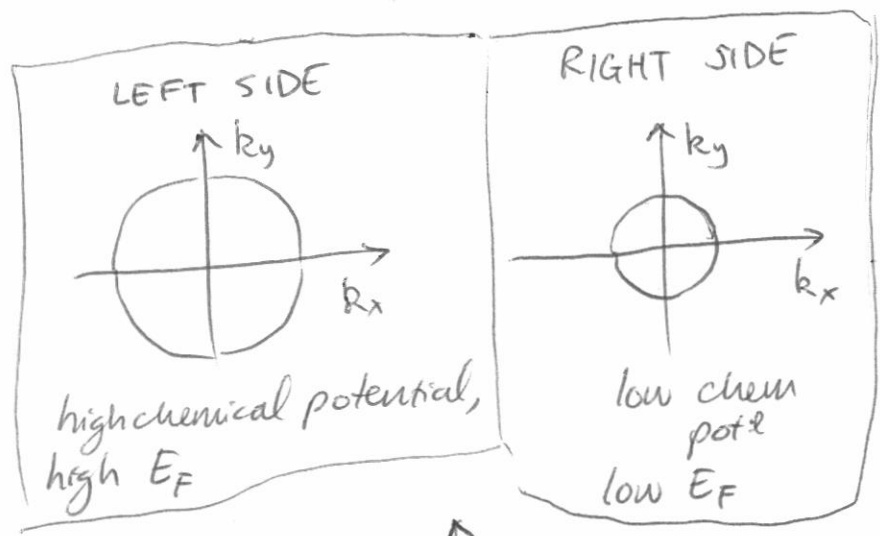
Electrons near the Fermi surface are constantly scattering ~~between~~ to different states.

BALLISTIC TRANSPORT

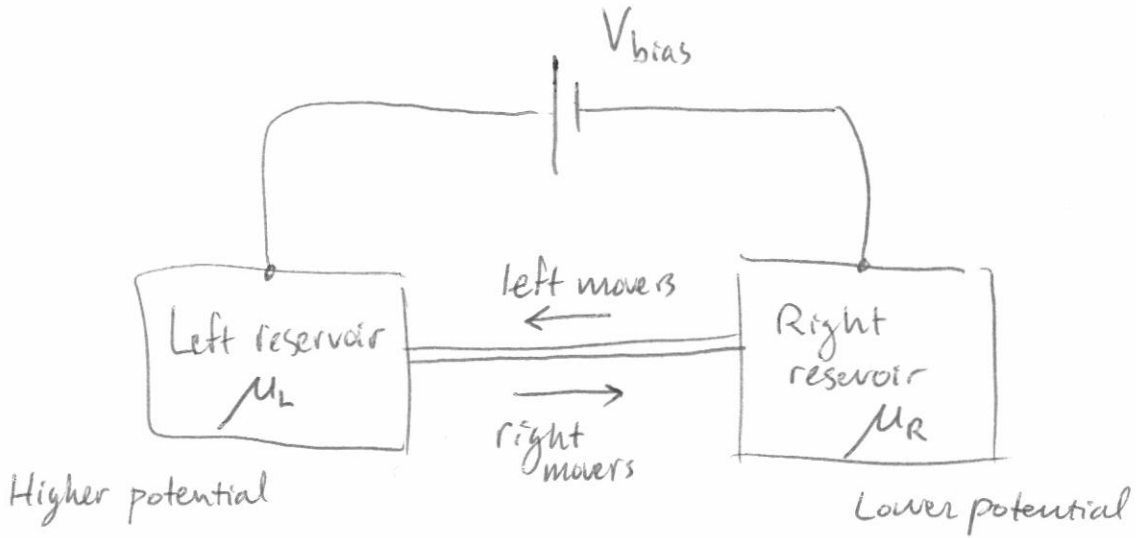
= No scattering
(no relaxation)

$\tau \rightarrow \infty$

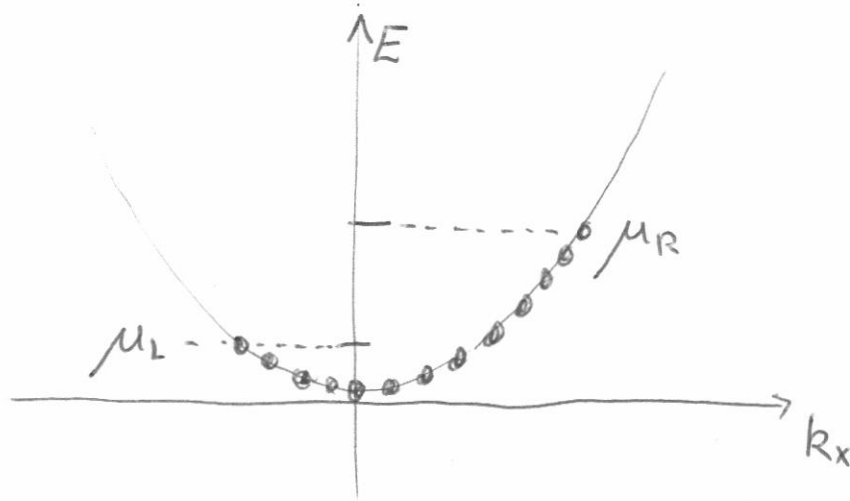
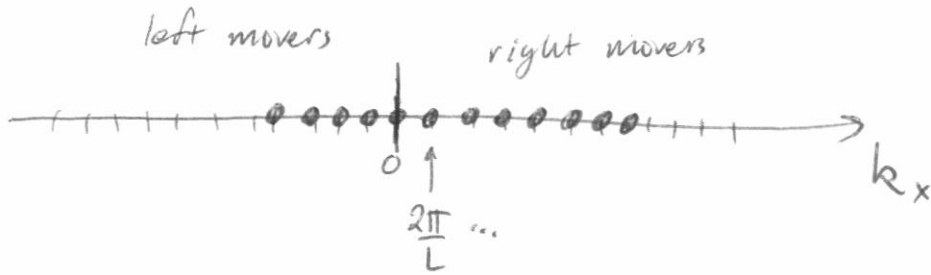
~~XXXXXXXX~~
If a bias is applied to the material, the occupation function is now governed by the chemical potential on the left & right sides



(2)

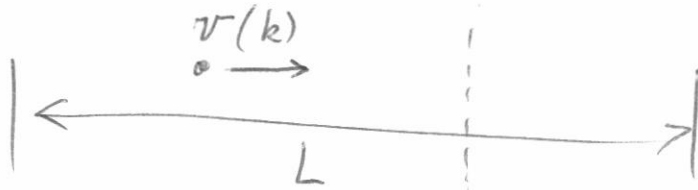


~~Exercise~~ Occupation of states in the CNT



(3)

Now calculate the current



will the electron cross the line?

Probability per unit time is $\frac{v}{L}$.

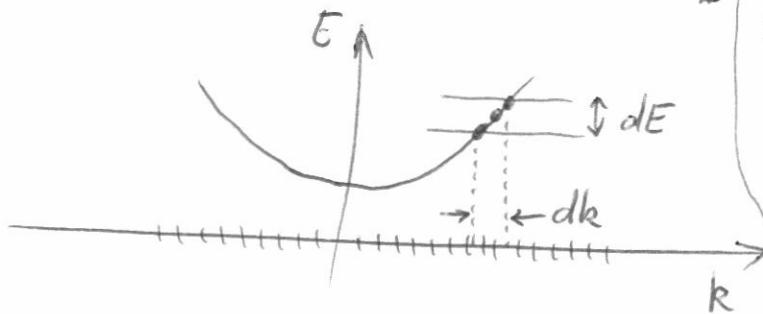
$$I = \sum_{\text{all states}} e \frac{v(k)}{L} \quad \text{[charge per unit time]}$$

Convert this into an energy integral (for ^{more} convenient calculation)

Only consider the imbalanced charge motion:

$$I = \int_{\mu_L}^{\mu_R} \frac{e v}{L} \text{DOS}(E) dE$$

$$= \int_{\mu_L}^{\mu_R + eV} \frac{e v}{L} 2 \frac{L}{2\pi} \left(\frac{dE}{dk} \right)^{-1} dE$$



of states

$$= 2 \cdot dk / \frac{2\pi}{L}$$

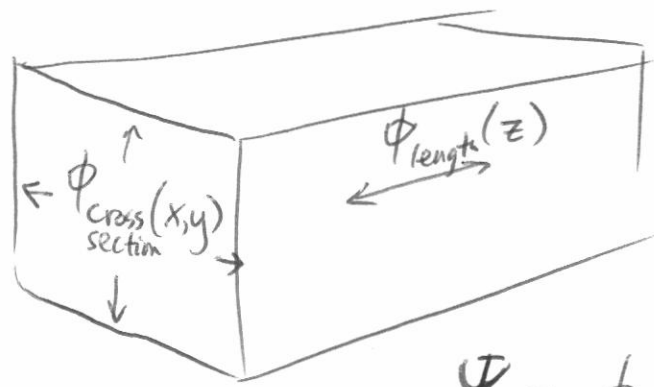
$$= 2 \cdot \frac{dE}{\text{slope}} / \frac{2\pi}{L}$$

$$= 2 \cdot \frac{L}{2\pi} \left(\frac{dE}{dk} \right)^{-1} dE$$

(5)

I chose the CNT example because CNTs are 1d...
Easy to analyze the # of states and their velocities.

To analyze a bigger material

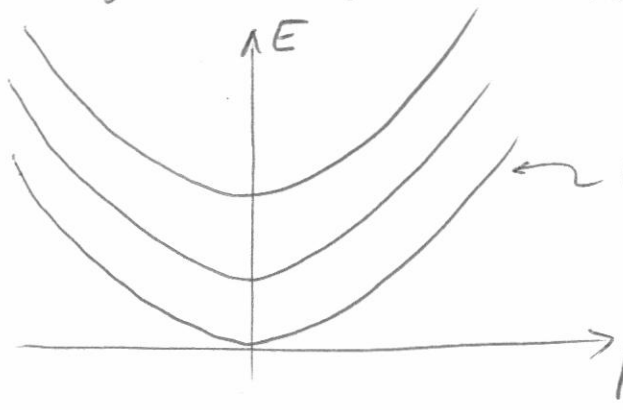


$$\Psi = \phi_{cross\ section} \cdot \phi_{length}$$

[wavefn is separable]

Each cross-sectional wavestate gives use a 1d channel along the length. For free e's in a rectangular wire

$$E = \frac{\hbar^2 k^2}{2m} = \frac{\hbar^2}{2m} \left(\frac{\pi^2 n_x^2}{L_x^2} + \frac{\pi^2 n_y^2}{L_y^2} + k_z^2 \right)$$



each curve corresponds to a different 1d channel, (or multiple channels if degeneracies exist).

If N channels are occupied, the ballistic conductance

$$is\ G = \frac{2e^2}{h} N$$

(6)

Example of an exam question:

Show that the # of occupied cross-sectional
wavestates in a metal is
 \approx # of atoms in the cross section.

CNTs have a pair of 1d channels, $N=2$

$$G = \frac{4e^2}{h} \quad (R = \frac{h}{4e^2} = 6.5 k\Omega)$$

A macroscopic wire (1mm x 1mm)

$$\text{has } N \sim \frac{(10^{-3})^2}{(3 \times 10^{-10})^2} = 10^{13}$$

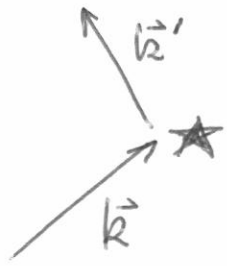
$$R_{\text{ballistic}} \approx \frac{10^4 \Omega}{10^{13}} = 10^{-9} \Omega$$

ADD SCATTERING TO THE BALLISTIC SYSTEM

(Interesting regime where only 1 or 2 scattering events).

Our approach will depend on the type of scattering

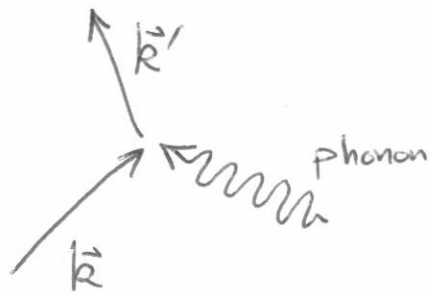
a) Elastic:



$$E(\vec{k}') = E(\vec{k})$$

Caused by a crystal defect like a missing atom or an impurity atom

b) Inelastic



$$E(\vec{k}') \neq E(\vec{k})$$

During elastic scattering, the phase of the wavefn is preserved.

During inelastic scattering, phase information is destroyed.