Normal metals & Landuer-Büttiker Formalism

Dr. Viktoriia Kornich[1] and Dr. Kristian Mæland[2]

[1]viktoriia.kornich@physik.uni-wuerzburg.de
[2] kristian.maeland@uni-wuerzburg.de

Problem 1

Consider two reservoirs for electrons at thermal equilibrium. Refer to them as left L and right R leads which extend in the x direction. Imagine we apply small voltages to the two leads which tunes their chemical potential by eV_L and eV_R.

- Starting from the scattering matrix approach, relate the states entering and leaving each lead at the interface.
- Within the second quantization formalism, write the formula for the electrical current. **Hint:** it will be useful later to write it as an energy integration.
- Taking advantage of the elements of the scattering matrix, identify in the previous formula the transmission function.
- Identify the equilibrium conductance

$$G = \frac{e^2}{h} \mathrm{Tr} \left[\mathbf{t}^\dagger(E_F) \mathbf{t}(E_F) \right] , \tag{1}$$

  where $\mathbf{t}(E_F)$ is the transmission matrix of our system evaluated at the Fermi energy E_F. What is the meaning of the eigenvalues of the hermitian matrix $\mathbf{t}^\dagger(E_F)\mathbf{t}(E_F)$?

Problem 2

Consider a wide conductor along x, e.g. width in y direction is large W while the height in z direction is small. The length in the x direction is large L.

Given information: The density of states of a 2D spin degenerate system is $\mathcal{D}_0 = m/\pi\hbar^2$. The transmission through a wire with length L is $T = L_0/(L + L_0)$, where L_0 is the mean free path. The conductivity is $\sigma = e^2\mathcal{D}_0 D$, where $D = v_F L_0/\pi$ is the diffusion coefficient and v_F is the Fermi velocity.

Using this information, relate the previous results for conductance G with the Ohm's law. I.e. does the relationship between G and conductivity σ correspond to Ohm's law.