Exercises for "Superconductivity, Josephson ..."   WS 2023/2024

Prof. Dr. A. Shnirman   **Exercise 5**

Dr. K. Piasotski   **Tutorial on 13.02.2024**

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1. Andreev bound states in an ideal long SNS contact.   **(40 Punkte)**

In the lecture we have considered a short SNS contact. The derivation for the long contact of length L is sketched in the script on page 93 (Equation 550). There the Andreev reflection amplitude is derived for the right NS interface. Provide an analogous derivation for the left interface. Obtain the quantisation condition and try to estimate the energies and the number of the Andreev bound states.

2. A non-ideal NS contact.   **(60 Punkte)**

In the lecture (see script) we have considered an ideal NS (normal metal - superconductor) contact and concentrated on one transverse channel (effectively one-dimensional wire). In this contact the superconducting order parameter vanishes for $x < 0$ and is equal to $|\Delta| e^{i\phi}$ for $x > 0$. Here we consider a non-ideal contact, which is modeled by adding a potential barrier at $x = 0$, namely $V(x) = H\delta(x)$. Write down the Bogoliubov-de Gennes equations for this case and find the scattering amplitudes in all possible scattering channels for an incoming (from the normal side) electron with energy E. Consider both cases $E < |\Delta|$ and $E > |\Delta|$. Consult if necessary the paper: G. E. Blonder, M. Tinkham, and T. M. Klapwijk, Phys. Rev. B 25, 4515 (1982).