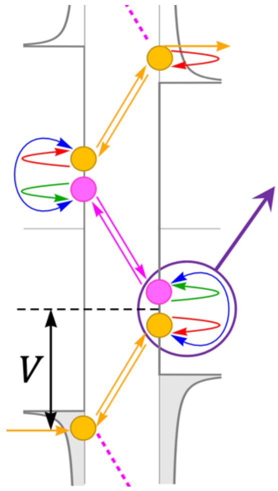
Master project: <u>Modelling electron transport across superconducting junctions</u>

Background: An often-used way to learn about quantum properties of matter are transport experiments, where two systems (such as, metals, magnets, or superconductors) are connected through a small mesoscopic constriction, such that a current begins to flow that equilibrates the two sides. Different from Ohm's law that we learn about in elementary courses — which states that the resulting current is proportional to the applied voltage bias with a constant of proportionality called the conductance — this current is often a highly nonlinear function of the voltage, and from the current-voltage characteristic, we can learn much about the quantum-mechanical properties of the system. For example, measurements of the current across a semiconductor-superconductor junction conducted by Ivar Giaever in the 60's were among the first to determine the superconducting gap and later to confirm phonons as responsible for the pairing mechanism in (BCS-type) superconductors.

Nowadays, much effort is devoted to detecting bound states that form in between exotic superconductors (such as the famous Majorana fermion states, which might be used in applications for quantum computing). Here, at specific voltages, electrons from one reservoir may hop onto the bound state level in the constriction and hop off into the other reservoir, giving rise to a characteristic tunnelling current. In junctions that are not well insulated from the reservoirs (called "transparent"), the current is mediated not just by a single tunnelling process, but more complicated processes may occur, for example, when a particle enters and crosses the junction, is reflected at the leads, crosses the junction again in the opposite direction, is reflected again, and so on.



Project proposal: The aim of the project is to model transport across a junction between two superconductors. Here, the reflection processes that occur are of a more exotic kind called Andreev reflections. A particular focus of the work will be the description of transport at finite temperature, and in order to do this, you will develop simple mean-field theories of superconductors at finite temperatures and provide parameters for transport calculations.

A basic knowledge of solid-state physics and superconductivity is essential for this project. There are existing numerical software packages to compute the current in superconducting junctions, so some programming experience would be useful. Office space in the physics department is available.

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