Problem set for Platforms for Quantum Technologies
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M3 Exercises, 24.03.2020, Session I - 14:15 - 16:00

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Problem 1: Fundamentals of superconductivity and Josephson junction

1. As a metal enters the superconducting state, its free energy decreases and it becomes more ordered. Explain the nature of this ordering. *Hint: pairing energy.*
2. What is a Cooper pair? How do they interact with lattice causing superconductivity?
3. Briefly describe a Josephson junction?
4. Derive the current density j crossing the junction and its relation in terms of the phases of the waves, φ_1 and φ_2, in the two superconductors.
5. What is dc Josephson effect and ac Josephson effect?

Problem 2: Superconducting flux qubit

Briefly explain the concept of a superconducting flux qubit as discussed in the lecture. Draw the circuit diagram and write the potential in terms of the phase difference across the junctions. Simplify the potential assuming one junction is weaker than the other two junctions, which operate identically, such that the energy of the weaker junction is a factor α times the energy of the other two junctions. The external flux is related to the phases of the Josephson junctions and is defined through a parameter $f = -\frac{\Phi_{\text{ext}}}{\Phi_o}$, which is the measure of fractions of external flux quanta. To understand the change in the potential, plot the potential for $f = -0.5$ and $\alpha = 1.0, 0.8, 0.6, 0.0$ and for $f = -0.5, -0.65$ with $\alpha = 1.0$.