LUND UNIVERSITY

Faculty of Science

FYST84, Physics: Superconductivity, 7.5 credits

Fysik: Supraledning, 7,5 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2023-12-06. The syllabus comes into effect 2023-12-06 and is valid from the autumn semester 2024.

General information

The course is an elective course for second-cycle studies for a Degree of Master of Science (120 credits) with a specialisation in physics.

Language of instruction: English

Main field of study	*Specialisation*
Physics	A1N, Second cycle, has only first-cycle course/s as entry requirements

Learning outcomes

The course aims to teach the fundamental theoretical concepts behind superconductivity. Students will also learn to apply analytical and numerical methods to investigate simple phenomena in superconductors based on the London equations, Ginzburg-Landau theory, and BCS theory. Additionally, they will gain basic knowledge of various methods for experimentally studying the properties of superconducting materials. The course will also provide insight into the use of superconductors in some technical applications, with a particular focus on quantum computers and other quantum technologies.

Knowledge and understanding

Upon completion of the course, the student shall be able to:

- Explain the fundamentals behind phenomenological theories of superconductivity (London and Ginzburg-Landau) and how to derive the central equations in these theories based on thermodynamic arguments.

- Describe the key steps in deriving the microscopic theory of superconductivity (BCS theory), how these equations give rise to a superconducting gap and the fundamental excitations in a superconductor, as well as simple theories for transport in systems with a superconductor coupled to a metal.
- Explain the relationship between current and phase difference in a Josephson junction.
- Describe how phase coherence in Josephson junctions can be utilized in various superconducting qubits, especially in so-called Cooper pair boxes and transmons.
- Provide an overview of how to experimentally investigate the properties of a superconducting material, such as the gap and coherence length.
- Discuss some more advanced concepts, which may vary depending on students' choice of projects. Examples include high-temperature superconductors, topological superconductors, superconducting logical circuits, and how to connect many superconducting qubits in a quantum computer.

Competence and skills

Upon completion of the course, the student shall be able to:

- Apply various (phenomenological and microscopic) theories of superconductivity to qualitatively, analytically, and numerically describe specific properties and phenomena within superconductivity.
- Apply their knowledge of basic theories of superconductivity to understand superconducting qubits.
- Demonstrate the ability to comprehend a more advanced topic within superconductivity and convey this knowledge in an educational manner to other students.

Judgement and approach

Upon completion of the course, the student shall be able to:

- Search for scientific literature and identify material relevant to the course projects.
- Convey advanced scientific material to other students in a lecture that maintains a high pedagogical standard.

Course content

The course covers:

- The fundamental theoretical descriptions of the superconducting phase and its properties.
- The London equations, type I and type II superconductors.
- Ginzburg-Landau theory as a more advanced version of the London equations.
- Microscopic theory of superconductors (BCS theory), superconducting gap, fundamental excitations, and transport in circuits with coupled superconductors (Josephson junctions) and with superconductors coupled to metallic contacts.

- Superconducting circuits, Coulomb blockade, and various types of superconducting qubits.
- A selection of in-depth topics in the form of student projects (varies based on students' interests).

Course design

The teaching consists of lectures and student-led lectures. Attendance at the student-led lectures is mandatory.

Assessment

The course is assessed through assignments, student-led lectures, and an oral examination. Attendance at student-led lectures is mandatory. Approved assignments are required to be eligible for the oral examination, which is based on the solutions to the assignments.

Students who do not pass the regular examination are offered an additional examination opportunity shortly thereafter.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Grades

Grading scale includes the grades: Fail, Pass, Pass with distinction
The grading scale includes the grades: Fail, Pass, Pass with Distinction. To pass the entire course, all examination components must be passed. Assignments are graded on a scale of Fail, Pass. Student-led lectures and the oral examination are graded on a scale of Fail, Pass, Pass with Distinction. For the final grade, these two components are weighted equally at 50%. If one component is graded Pass and the other Pass with Distinction, the final grade (Pass or Pass with Distinction) is determined through an overall assessment.

Entry requirements

To be admitted to the course, 75 credits in physics and 45 credits in mathematics are required, or a bachelor's degree in physics or equivalent – in both cases, including knowledge equivalent to FYSB22 Basic Quantum Mechanics, 7.5 credits, and FYSC23 Solid State Physics, 7.5 credits. Additionally, English 6/B and basic eligibility are required.

Further information

The course is fully co-taught with [FFFN40, Superconductivity, 7.5 credits], which is a course at Lund University's Faculty of Engineering, LTH.

The course's examination schedule follows LTH's examination schedule.

The course is offered by the Department of Physics, Lund University.