SK2759 Superconductivity and applications (6 hp) – Autumn 2018

Introduction

The unique properties of superconducting materials are already commercially used in a large number of applications, including magnetic resonance imaging, magnets for accelerators and laboratories, NMR magnets, superconducting interference devices, microwave filters etc and other applications are emerging like levitating trains, superconducting power lines, motors, generators and transformers, Josephson junctions are used as voltage standards and sensitive sensors of magnetic fields etc. This course will cover the fundamental theoretical models of superconductivity together with a description of various applications of superconductivity.

Aim

The course aims at giving the students in depth knowledge and know-how within the theory of superconductivity in order to understand and describe the principles behind various superconducting applications. After the course, the students should be able to:

- describe different theories of superconductivity and their ranges of validity
- in detail describe the difference between good conductors, perfect conductors and superconductors
- apply London theory, modified London theory and Ginzburg-Landau theory for superconductivity for both derivations and numerical calculations
- explain type-I and type-II superconductivity based on thermodynamic calculations of the Gibbs free energy for a superconductor
- discuss vortices and their properties in a superconductor both quantitatively and qualitatively, especially concerning energy losses in superconducting wires
- apply Bean critical state model
- derive equations for Josephson junctions and relate this to different applications within superconducting electronics
- describe various applications of superconductivity (superconducting wires, magnets, Maglev trains, SQUID:s, tomographs, measurement normals, superconducting electronics etc)

Textbook

M. Andersson, “Introduction to applied superconductivity”, compendia, KTH (sold at the Physics course expedition at Albanova). Price: 100 kr.

Other course books can be used, but do not contain all the material in the course.

Topics covered in the course

Properties of superconductors, Meissner effect, London theory for superconductors
Thermodynamics for superconductors, type-I and type-II superconductivity
Vortices in type-II superconductors, energy losses, Bean critical state model
Josephson junctions, quantum interferometers (SQUID:s), short and long Josephson junctions
Ginzburg-Landau theory for superconductors, BCS theory
Large scale applications (e.g. magnets, energy storage, advanced transportation) and applications in electronics (e.g. SQUID instruments, computers, measurement normals).

Course home page

All information about the course can be found at the KTH Learning Management System (Canvas). You reach this system through the link https://kth.instructure.com by logging in using the KTH login service.

Examination

The formal examination in the course contains two different parts, which both have to be passed. Each part gives points that are added to a final grade in the course.

Short written exams, 3 credits (KON1)

After each of the three main course modules, there is a short one hour written exam. These exams tests two skills in the course - understanding of the main theoretical proofs in the course and the conceptual understanding of the subject. In total, this part can give 3x8 point.

Group hand-in problems and assignments, 3 credits (INL1)

In this part of the course, you will work together within a study group of 3-4 students with joint tasks - solve problems and write essays evaluating superconducting applications.

Part A - problem solving (3x4 points)
For each of the 3 modules, 4 problems will be given and they should first be attempted individually as a home assignment and then assessed in your study group before handing in. The structure follows what can be called concurrent problem solving, i.e. each of the participants should first do their best to individually solve each one of the problems and then they should meet and discuss their solutions before handing in their common final solutions. It is the result of the group hand-in that is graded for the examination. The solution that is handed in should be correct without any mistakes and nicely presented. In addition, the group home assignment evaluation sheet should be handed in to make it possible for me to see how much each of you has contributed. Nobody will be punished for low contributions as long as it involves a sufficient effort, but if some student(s) is contributing considerably more on the hand-in problems than the other students in the group, maximum 3 bonus points could be given to them for their pedagogic work in the group.

Part B - evaluation of superconducting application (2x6 points)
In this part, you make a group evaluation of two suggested superconducting applications (one power application and one electronic application). Each evaluation should result in a written report (2-3 pages) where the group should argue whether or not it is reasonable for a company to engage in developing or using the suggested application. The evaluation should include two parts:

- A correct technical evaluation about how superconductors can be used for the suggested application including both advantages and disadvantages.
- A correct societal analysis of the use of the suggested application, considering the following factors: competing technologies, environmental, health, safety and economical aspects. Detailed considerations are not requested, but all of the important factors should have been found and the overall argumentation must be correct.

Grading

Each of the two parts (KON1 and INL1) are graded using the following scale (max 24 points):
Grade A: ≥ 22 points
Grade B: 20-21.5 points
Grade C: 18-19.5 points
Grade D: 16-17.5 points
Grade E: 15-15.5 points
Grade FX: 14-14.5 points
Grade F: < 14 points

Final grading

The final grade is given by the sum of all received points on the two parts mentioned above (KON1 and INL1). To obtain a final grade, the student must have minimum grade E on each of the parts (KON1 and INL1). The grading is as follows (maximum is 48 points):
Grade A: ≥ 44 points
Grade B: 40-43.5 points
Grade C: 36-39.5 points
Grade D: 32-35.5 points
Grade E: 30-31.5 points
Grade FX: 28-29.5 points
Grade F: < 28 points