SK2759 Superconductivity and applications (6 hp) – Autumn 2019

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).

Contacts
Examiner and course responsible teacher: Magnus Andersson, magnusan@kth.se
Administrative issues: kursexp@physics.kth.se

Course management
All relevant information about this year's course can be found in the KTH Learning Management System (Canvas).

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 - understanding of the main theoretical proofs in the course and the conceptual understanding of the subject. This part can give a maximum of 3x8=24 points.

Grading
Grade A: ≥ 22 points
Grade B: 20-21.5 points
Grade C: 17-19.5 points
Grade D: 15-16.5 points
Grade E: 14-14.5 points
Grade FX: 13-13.5 points
Grade F: < 13 points

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 =12 points)
In each module, each study group will get 4 problems to solve. These problems should first be attempted individually and then assessed at a meeting in the study group before handing them in. The group hand-in is graded and the solution that is handed in should be correct without any mistakes and nicely presented. In addition, the group home assignment evaluation sheet must be handed in to make it possible for me to assess each ones contribution to the group work. Based on this, I may redistribute maximum ±1 point among the participants.

Part B - evaluation of superconducting application (2x6 = 12 points)
You will make a group evaluation of two suggestions for superconducting applications (one power application and one electronic application). Each evaluation should result in a written report (2-3 pages) where the group argue whether or not it is reasonable for a company to engage in developing or using the application. The evaluation must 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 parts: competing technologies, environmental, health, safety and economical aspects. Details are not required, but important factors should be found and the argumentation must be correct.

Grading
Grade A: ≥ 23 points
Grade B: 22-22.5 points
Grade C: 19-21.5 points
Grade D: 18-18.5 points
Grade E: 17-17.5 points
Grade FX: 16-16.5 points
Grade F: < 16 points

Final grade
The final grade requires a minimum grade of E on both KON1 and INL1 and is based on the sum of all received points on KON1 and INL1. Grading is as follows (maximum is 48 points):
Grade A: ≥ 44 points
Grade B: 41-43.5 points
Grade C: 36-40.5 points
Grade D: 33-35.5 points
Grade E: 31-32.5 points