

## **IM2661 Superconductivity and applications (6 hp)**

### **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 logical circuits 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 during the lectures). Price: 100 kr.

Other textbooks that contain large parts of the course material are:

T. P. Orlando and K. A. Delin, "Foundations of Applied Superconductivity", Addison-Wesley, Reading, Mass. 1991. This book is no longer available for purchase. However, it may be possible to borrow from a library.

M. Tinkham, "Introduction to superconductivity", second edition, McGraw-Hill International Editions, ISBN 0-07-114782-9. This is the standard textbook on superconductivity that uses CGS units and is rather weak on applications.

K. Fossheim and A. Sudbø, "Superconductivity - physics and applications", John Wiley & Sons Ltd, ISBN 0-470-84452-3. Reasonable content, but highly shifting depth on the subjects.

### **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

Large scale applications (e.g. magnets, energy storage, advanced transportation) and applications in electronics (e.g. SQUID instruments, computers, measurement normals).

## Course home page

More detailed information about the course can be found at the official course home pages:  
<https://www.kth.se/social/course/IM2661/>

## Examination

The written examination in the course consists of four different parts:

- Part A – problem solving, home assignment (3x4 points)
- Part B – theory, written exam during lecture time (3x4 points)
- Part C – conceptual understanding, written exam during lecture time (3x4 points)
- Part D – evaluation of superconducting application, home exam (2x6 points)

Part A is a combined individual and group examination, parts B and C are individual examinations and part D is a group examination. The final grade in the course is determined from the total number of points on the four different parts (maximum 48 points):

A	≥ 44 points
B	40-43.5 points
C	36-39.5 points
D	32-35.5 points
E	30-31.5 points
Fx	28-29.5 points
F	< 28 points

## Details about the different parts in the examination

Parts A-C are examined continuously during the course (in three modules) and part D is examined at the end of the course. Each part has equal weight for the total grade in the course (25% per part or equivalently 12 points per part).

- Part A – In each module, 4 different problems are distributed to first be solved individually and then assessed in a student group before handing in. It is the result of the group hand-in that is graded for the examination.
- Part B – An individual theory exam on the most important theoretical proofs in the course.
- Part C – An individual exam that tests the conceptual understanding of the course content.
- Part D – A group evaluation of two suggested 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 for a specific purpose. The evaluation should include two parts:
  - i) A correct technical evaluation about how superconductors can be used for the suggested application, including both advantages and disadvantages.
  - ii) 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 required, but all important factors should have been found and the overall argumentation must be correct.