IM2661 Superconductivity and applications (6 hp)

General
The course is a joint master and PhD course having the same course content. PhD students should, however, register on the PhD course number 2B5236 Superconductivity and applications. The only difference between the courses is in the requirements on the exam.

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). The compendia is sold at the lectures and costs 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.

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/

Topics covered in the course
Properties of superconductors, Meissner effect, good conductors and perfect conductors
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).

Examination
The written examination in the course consists of four different parts:
• Part A – problem solving, home exam (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)
Parts A and D are group examinations while parts B and C are individual examinations. 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

For PhD students registered on the course number 2B5236 with a Pass/Fail grading system, they must achieve at least grade C in the ordinary course to pass the examination, i.e:

Pass	≥ 36 points
Fail	< 36 points

Details about the different parts in the examination
The course material is divided into three modules and each module is examined separately in part A-C in the examination. Part D is an overall examination of the whole course.
• 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 examination 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 the suggested application. The evaluation should include two parts:
i) A correct technical description 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, security and economical aspects. Detailed considerations are not required, but all important factors should have been found.