University of Maryland
Department of Physics

Spring 2022 Prof. Steven Anlage

Physics 798C

Title:
Physics 798C: Superconductivity: An introduction to the phenomenology and theory of superconductivity. The emphasis will be on physical concepts rather than theoretical rigor and sophisticated treatments. The student should gain a working quantitative understanding of the BCS and Ginzburg-Landau theories of superconductivity. Principles that underlie applications of superconductivity will also be emphasized. This is a 3 credit course. There are three hours of lecture per week.

Prerequisite:
Phys 623 or 613: Graduate quantum mechanics. An undergraduate or (preferably) graduate course in solid-state or condensed matter physics will also be helpful.

Instructor:
Prof. Steven Anlage, Room 1363 (Physics/QMC). You can find QMC either by 1) going through the blue door labeled "Quantum Materials Center" in the basement of the Toll physics building, or
2) entering from the plaza between the Math and Physics buildings.
Phone: 5-7321, e-mail: anlage@umd.edu.

Schedule:
Two lectures weekly,
Tuesday and Thursday 9:30 to 10:45 AM in Room Z-1204 (Toll Physics building).
We may re-arrange some classes around the week of the APS March Meeting.

Required Text:
M. Tinkham, *Introduction to Superconductivity*, Second Edition, McGraw-Hill. This book has been republished by Dover ($21.99 at Amazon). ISBN: 978-0486435039.
Other useful books are:
1) James Annett, *Superconductivity, Superfluids and Condensates*, Oxford University Press, 2004 ($41.26 at Amazon). ISBN: 978-0198507567.
2) J. B. Ketterson, S. N Song, *Superconductivity*, Cambridge University Press, New York, 1999 (~$135.00 new on Amazon, cheaper used). ISBN: 978-0521565622.
3) J. R. Waldram, *Superconductivity of Metals and Cuprates*, Institute of Physics Publishing, Bristol and Philadelphia, 1996 ($140.00 on Amazon, cheaper used). ISBN: 978-0852743379.
4) Terry P. Orlando and Kevin A. Delin, *Foundations of Applied Superconductivity*, Addison-Wesley, Reading MA, 1991. ISBN: 978-0201183238.

See the class web site for a bibliography of books on superconductivity.

Homework: Homework will be assigned every week. It is imperative that you do the homework and keep up with the material being covered in lecture. I may assign two students to write up solutions to each of the homework assignments. You may work together on the homework assignments, but what you submit for grading should be in your own hand

Class Web Sites:
Both class web sites will announce all homework assignments, and have general class information available. The "open" web site can be found at
https://www.physics.umd.edu/courses/Phys798C/AnlageSpring22/index.html.
You can also get to the class web site from my research web site:
http://anlage.umd.edu/AnlageNewTeaching.htm.
Please check the web site periodically.

Office Hours:
Prof. Anlage's office hours are W 4 – 5 PM. The office hours will be in hybrid format (both in-person and online). We will meet in room 0360 in the QMC of Toll/Physics. You are encouraged to attend office hours and discuss the course material, homework, etc.

Final Grade:
Based approximately on homework (~50%), and semester paper on a topic in superconductivity (~50%). Active class and office hour participation (i.e. asking questions!) will improve your chances of obtaining a high letter grade.

Tentative Course Outline:
1) Brief review of key topics in solid state physics
2) Introduction – Basic superconducting phenomena, perfect conductivity, perfect diamagnetism, critical temperature, fields, and currents, type-I and type-II, high-temperature superconductors, kinetic inductance, applications.
3) Simplest theory: perfect conductivity, the London equations, and the macroscopic quantum model.
4) Microscopic theory: Second quantization and BCS theory. Cooper pairing instability, ground state wavefunction, quasiparticles, the energy gap.
5) BCS electrodynamics and generalizations to inhomogeneous materials.

6) Ginzburg-Landau (GL) theory: general Landau and GL theories, application to superconductors. Time-dependent Ginzburg-Landau theory. Numerical solutions to the TDGL equations.
7) GL theory and type-II superconductors (conventional and high-temperature.) Critical currents and fields, vortices, vortex interactions, the structure of an isolated vortex.
8) Fluctuation effects in low and high-T_c superconductors: GL theory, Kosterlitz-Thouless transition, scaling, vortex phase transitions.
9) Proximity effect, Andreev scattering.
10) Josephson effect: Basic equations, shunted junction models, SQUIDs, qubits.

Course Objective:
To introduce you to the language and gestalt of superconductivity. The goal is to provide the student with all of the tools required to be a creative and productive researcher in fundamental, as well as applied, superconductivity.