Term Paper Guidelines
PHYS 798C
Fall 2025
Prof. Steven Anlage

The goal is to write 2 papers on technical topics in superconductivity. The first (due Oct. 30) is about a fundamental topic in superconductivity. The second (due at the end of the semester) will be about an applied topic. The objective is to drill down (a little bit) on a fundamental topic of interest to you, and to summarize what you learn in a clear and compelling document. The paper does not have to be long, 4 or 5 pages of text are fine.

Format: Follow the format of Physical Review A/B/E articles for references, sections, figures, etc. Include an abstract, introductory section (including a brief outline of the paper), and conclusions. This paper *may* pass as your "scholarly paper" requirement for the Physics Ph.D. program. The paper should be typed in LaTex (or REVTex) and double spaced, 12 pt type or larger. Style and clarity are important in all writing; have a friend proof-read your paper. Please have a native English speaker read and correct the paper, or use a large language model to clean it up. Figures must be used, but figures taken from other sources should be referenced. Please include a descriptive figure caption *in your own words* for all figures. Please have the figures integrated into the text, rather than collected together in a Figure section at the end of the paper.

Plagiarism: Please do not copy from any other sources. Also, when submitting the paper, explain the extent to which you employed large language models (e.g. ChatGPT) to "improve" your manuscript. Verbatim copying of passages from other papers, published or unpublished or transparent paraphrasing of other work, is forbidden. You may use the results of other papers, of course, but they must be referenced.

Content: Write an overview of your topic that can be read and understood by the other students in the class. Define terms and acronyms (i.e. SQUID), avoid the use of jargon, and put things in a logical order. Clearly define all quantities that appear in equations! This paper should introduce an intelligent newcomer to the topic. An exhaustive listing of all references in the field, or a repetitive unenlightening summary (in 2014, Smith made wiffnium, with a T_c of 102 K. In 2015, Jones made woofnium, with a T_c of 103 K, etc.) is not desirable. Also please do not choose a topic that is already well documented with wiki pages and review articles, if possible. An understandable discussion of key ideas, simple calculations and quantitative estimates, and anything else which indicates that you understand something about superconductivity and can explain it to beginning researchers in the field is desirable.

It is also important to focus the paper and go into quantitative detail on at least one or two aspects of the subject. For example, one should not simply mention a stream of results without any further discussion. **Something should be discussed in depth, with quantitative and detailed analysis presented**. Also avoid the use of qualitative statements such as "superconducting XYZ devices are clearly superior to normal metal XYZ devices." Give numbers and quantitative justification for all claims. Don't hesitate to introduce equations which illustrate the physics behind your arguments. If you write a paper on an experimental topic, be sure to include a discussion of theory relevant to the experiment. If you write on a theoretical topic, be sure to discuss experimental consequences of the theory.

To broaden your horizons a bit, choose a paper topic that is not directly related to your research. If you want to write about a topic not on the list, please discuss it with me.

Bonus points will be awarded for anyone who develops a stand-alone "legacy product" that benefits future students and researchers. This could include, for example, code to calculate surface impedance, tunneling conductance, and other quantities in BCS theory or its generalizations, or numerical solutions to common problems in Eliashberg theory or the Bogoliubov equations, the BTK model, time-dependent Ginzburg-Landau theory, etc. Another possibility is to create a thoughtful PhET-like interactive computer simulation/demonstration related to superconductivity. Consult with me.

Please upload your pdf paper by 23 October, 2025. A copy will be returned to you with comments, and these comments should be helpful for composing your second paper.

Possible Fundamental Superconductivity Topics

Andreev reflection, bound states at surfaces of unconventional superconductors
Angle-Resolved Photoemission spectroscopy (ARPES) of the Fermi surface and energy gap in HTS
What lies beyond BCS theory?
The Bernoulli Effect in superconductors
C_{60} superconductors, field-effect in C_{60} films
Coexistence of antiferromagnetism and superconductivity in HTS and other superconductors
Coexistence of ferromagnetic and superconducting order
Critical behavior of superconductors (heat capacity, thermal expansion, penetration depth, etc.)
Dynamic Casimir Effect measured with SQUID mirror
Electric Field Effect (electronic doping) in superconductors
The Electron-Phonon mechanism in superconductors (including the isotope effect)
Enhancement of superconductivity by engineering the dielectric environment
Fluctuation diamagnetism above T_c in the pseudogap region
Hall Effect below T_c in LTS and HTS
Higgs mode in superconductors
High Field (>30 T) properties of superconductors. Fulde-Ferrell-Larkin-Ovchinikov State
Hubbard model and HTS pairing mechanism
Hydride superconductivity
Infrared and Optical properties of superconductors - The sum rule in HTS
Kosterlitz-Thouless transition in superconducting thin films
Leggett mode in multi-band superconductors
Light-induced (mostly THz) transient superconductivity
Magnetic and non-Magnetic impurities in HTS
Marginal Fermi Liquid theory of HTS
Mesoscopic superconductors - Andreev scattering, Andreev billiards
Using metamaterial structures to modify the superconducting pairing interaction
MgB_2 superconducting properties and/or applications
Multi-terminal Josephson junctions
Nano-scale superconductivity, proximity effect
Nernst Effect above T_c in the pseudogap region
Neutron spectroscopy of collective modes in HTS and other superconductors
NMR measurements in superconductors
Nonlinear Meissner effect
Non-equilibrium superconductivity (quasiparticle and phonon dis-equilibrium induced by microwaves)
Organic superconductors
p-wave pairing in superconductors and superfluids
The Proximity Effect, superconductor/ferromagnet proximity coupling
Pseudogap phenomenon in HTS - stripe phase
Theory of and Evidence for a Quantum Critical Point in the HTS phase diagram
High-field quantum oscillation measurements in cuprates and other superconductors
Quasi-1D superconducting films grown on carbon nanotubes
Room temperature superconductivity – where is it? What would it look like? Do we already have it?
Practical utility, or lack thereof, of room temperature superconductors
Rotating superconductors and the London moment
S/F/S Josephson junctions, spin-triplet proximity effect
SO(5) theory of antiferromagnetism and HTS
Spin-charge separation, Charge fractionalization, Visons
Spin fluctuation pairing mechanism in HTS and pnictide superconductors
SQUID ground state wavefunction pairing symmetry experiments
STM and tunneling spectroscopy of superconductors
Superconducting experiments and detectors operating in earth orbit and beyond.
Superconductivity in carbon nanotubes, twisted-bilayer graphene and doped diamond
Superconductivity in the presence of spin imbalance
Superconductivity in the Gravity-Probe B experiment

Time-reversal symmetry breaking states in superconductors and their measurement
Topological superconductivity and Majorana Fermions
Ultrasonic attenuation in unconventional superconductors
Vortex imaging techniques (neutrons, magnetic force microscopes, SQUID microscopes, etc.)
Vortex Glass - Vortex Liquid - Vortex solid phase transitions
Exotic vortex phases - Bose glass, hexatic phase, etc.

Possible Applied Superconductivity Topics (2nd paper)

Classical superconducting digital computers (choose a focused topic)
HTS and MgB_2 wire production
HTS Tape coating methods (Rabits, IBAD, etc.)
Quantum superconducting computers (choose a focused topic)
ReBCO HTS tapes for use in high-field magnets – impact on nuclear fusion
Extremely low-level measurements using SQUIDs
Superconducting X-ray detectors
Superconducting single photon detectors
Superconducting microwave kinetic inductance detectors
Superconducting detectors used in astronomical observations
Transition edge sensors

Some Previous Term Paper Titles:
Transport Properties of the Electron-doped Superconducting Cuprates
Superconductors for Wireless Applications
Imaging Techniques for Vortices in Superconductors
Scanning Tunneling Microscopy and Scanning Tunneling Spectroscopy on Superconductors
Extremely Low-Level Measurements Using DC SQUID
Report on Rapid Single Flux Quantum (RSFQ) Logic
Proximity Effects of Superconductors
Infrared and Optical Properties of Superconductors
Extremely Low Level Measurements Using SQUIDs
Kosterlitz-Thouless Transition in Two-Dimensional Superconductors
Manifestations of the Casimir effect in superconductors

Superconductors in Rotation
Superconductors in the presence of weak inertial and gravitational fields
The pseudogap of the angle resolved photoemission spectroscopy and the resonating valence bond model in high temperature superconductors
Thermally-Driven Melting of the Vortex Lattice
Quantum phase transition: in cuprate superconductors
High-T_c Superconductors and the Hubbard Model
Models for the proximity effect
Chaos and Nonlinear Dynamics in Josephson Junctions
Vortex Imaging Techniques
Magnetic Levitation with Superconductors
Andreev Reflection