

Physics 239 : Superconductivity

- I. Introduction
 - A. Basic phenomenology: zero resistance, Meissner effect, persistent currents and flux quantization, thermodynamic signatures, tunneling
 - B. Thermodynamics of superconductors
 - C. London theory
- II. Ginzburg-Landau theory
 - A. Landau free energy and Ginzburg-Landau free energy functional
 - B. Fundamental length scales: penetration depth and coherence length
 - C. Domain walls and vortices; type I *vs.* type II superconductivity
- III. BCS theory
 - A. Binding and dimensionality; Cooper's problem
 - B. Many body theory of the electron gas
 - i. Screening and $\epsilon(\mathbf{q}, \omega)$
 - ii. Thomas-Fermi screening and random phase approximation (RPA)
 - iii. Plasmons
 - iv. Electron-phonon interaction
 - C. Reduced BCS Hamiltonian
 - i. Solution by Bogoliubov transformation
 - ii. BCS gap, condensation energy, upper critical field
 - iii. Excited states: quasiparticles
 - iv. Finite temperature
 - v. Effect of repulsive interactions: λ and μ^*
 - D. BCS and Bose condensation
 - i. BCS wavefunction in real space
 - ii. Quantum XY model and granular superconductors
 - iii. Bose Hubbard model and superconductor-insulator transition
- IV. Consequences of the BCS theory
 - A. Tunneling
 - i. Tunneling Hamiltonian
 - ii. Tunneling between normal metals
 - iii. Spectral functions
 - iv. N-S tunneling
 - v. Tunneling between superconductors
 - vi. Josephson tunneling
 - B. Josephson effect
 - i. Quantum XY model
 - ii. Effect of in-plane magnetic fields
 - iii. Josephson interferometry

- iv. Critical current
- v. RCSJ model
 - a. Josephson plasma oscillations
 - b. retrapping current in underdamped junctions
- vi. AC and DC SQUIDS
- vii. Josephson junction arrays
- C. Linear response of superconductors
 - i. Case I and Case II probes
 - ii. Acoustic attenuation
 - iii. Nuclear magnetic relaxation
 - iv. Electromagnetic properties
 - a. gauge invariance and charge conservation
 - b. nonlocal electrodynamics
- D. Effects of impurities
- V. Vortices
 - A. Single vortex states
 - B. Vortex-vortex interactions
 - C. Abrikosov vortex lattice
 - D. Vortex pinning
 - E. Dynamical phases of vortex matter
- VI. Inhomogeneous superconductivity
 - A. Bogoliubov-de Gennes equations
 - B. Semiclassical approximation
 - C. Caroli-de Gennes-Matricon theory of vortex cores
 - D. Andreev reflection
- VII. Unconventional superconductivity
 - A. Symmetry of the Cooper pair
 - B. Point group symmetries: p and d wave superconductors
 - C. Phenomenology of unconventional superconductors
 - D. Multicomponent order parameters