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 $\epsilon(\boldsymbol{q}, \omega)$

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