

QUANTUM STATISTICAL MECHANICS AND CONDENSED MATTER

[Asier Eiguren and Jens Siewert]

Introduction

Second quantization: Second quantization. Harmonic oscillator. Displaced harmonic oscillator. Coherent states. Non interacting Fermion and Boson fields. Application in some simple examples with exact solution. Numerical solution of simple Hamiltonians.

Greens function approach: Interaction representation and perturbative expansion. Wicks theorem. Feynman diagrams. Self-energy operator and Dyson equation.

Greens function at finite temperature: Retarded and advanced Greens functions. Matsubara frequencies and Matsubara summations. Response function in terms of Matsubara frequencies. Analytic continuation by means of Padé approximation.

Some exactly solvable problems: Potential scattering problem. Independent particle model and Einstein model.

Electron-phonon coupling: Fröhlich Hamiltonian. Perturbation theory in term of Greens function. Brillouin-Wigner and Rayleigh Schrodinger perturbative approaches and connection with Greens function approach. Metals.

Literature:

Gerald D. Mahan, Many-particle physics (3th Edition). Springer Science 2000.

Bruus, Henrik, Many-body quantum theory in condensed matter physics: an introduction. Oxford University Press, 2004

Phenomenology of superconductivity: Superconducting materials - absence of low-energy excitations; isotope effect; the Meissner-Ochsenfeld effect; perfect diamagnetism; type I and type II superconductivity. London theory, flux quantization and Ginzburg-Landau equations.

Electrons in metals: Non-interacting Fermi gas; second quantization for fermions; distribution function for non-interacting Fermi gas; electron-phonon interaction; repulsive and attractive electron-electron interaction.

The BCS theory of superconductivity: Mean-field Hamiltonian; Cooper pairs; the BCS wave function; energy gap and quasiparticle states; the critical temperature; electron tunneling between normal and superconducting metals.

The Josephson effect: Cooper-pair tunneling between superconductors

Inhomogeneous superconductors: Bogolubov-deGennes equations; Andreev reflection; Andreev bound states.

Literature:

P.G. de Gennes, Superconductivity of Metals and Alloys, Benjamin 1966.

M. Tinkham, Introduction to Superconductivity, 2nd Edition, McGraw-Hill 1996.

Assessment of the course will be done with a combination of homework and a final written exam.