QUANTUM STATISTICAL MECHANICS AND CONDENSED MATTER

[María Blanco and Jens Siewert]

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

Green's function approach: Interaction representation and perturbative expansion. Wick's theorem. Feynman diagrams. Self-energy operator. Dyson equation.

Green's function at finite temperature: Retarded and advanced Green's functions. Matsubara frequencies and Matsubara summations. Response function. Analytic continuation methods.

Application to an exactly solvable problem: Potential scattering.

Strongly correlated systems: Hubbard's Hamiltonian and Green's-function based approximations (equation of motion, Hubbard-I, DMFT). Effective low-energy models (Löwdin's downfolding). t-J model.

Magnetic excitations: Heisenberg Hamiltonian. Magnons.

Literature:

Gerald D. Mahan, Many-Particle Physics (3rd Edition). Springer Science 2000.

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

Ottfried Madelung, Introduction to Solid-State Theory, Springer, 2012 Ed.

Patrick Fazekas, Lecture Notes on Electron Correlation and Magnetism, World Scientific, 1999.

Robert M. White, Quantum Theory of Magnetism, Springer, 2007 Ed.

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.

* 33 % solving practical cases
* 67 % written exam