Many body theory
MSc in Physics, 6 ECTS

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The course aims at providing basic concepts and techniques in the theory of many particle physics, at low energies, *i.e.* in the non-relativistic regime. Selected examples from condensed matter theory will be treated in some detail.

The course requires basic knowledge of standard Quantum mechanics, Complex calculus, as well as Thermodynamics, Statistical mechanics, and Structure of matter.

Second quantization. Identical particles. Bosons and fermions. Fock space. Creation and annihilation operators. Field operators. Examples: kinetic energy, spin, density, current, Coulomb interaction. Harmonic oscillator and electromagnetic field in second quantization: photons. Degenerate electron gas. Phonons. Electron-phonon interaction.

Zero-temperature Green's functions. Time dependence: Schrödinger, Heisenberg, and interaction pictures. Time ordering. Gell-Mann–Low's theorem. Green's functions and their physical meaning. Green's functions for fermions at $T = 0$. Particles and holes. Lehmann representation. Advanced and retarded Green's functions. Causality and dispersion relations. Wick's theorem.

Perturbation theory. Two-body interaction. Feynman diagrams. Goldstone's theorem. Self-energy. Dyson equation. Hartree-Fock approximation. Renormalization: quasiparticles. Microscopic foundations of Landau theory of Fermi liquids. Polarizability and density-density correlation function. Random Phase Approximation.

Linear response theory. Kubo formulas and correlations. Single impurity in a degenerate electron gas: screening. Dielectric function and Lindhard function. Friedel oscillations. Plasmons.

Suggested reading

1. A. L. Fetter, J. D. Walecka, *Quantum Theory of Many-Particle Systems,* Dover (2003).
2. A. A. Abrikosov, L. P. Gorkov, I. E. Dzyaloshinski, *Methods of Quantum Field Theory in Statistical Physics,* Dover (1975).
3. Ch. P. Enz, *Many-Body Theory Applied to Solid-State Theory,* World Scientific (1998).
4. G. D. Mahan, *Many-Particle Physics,* Plenum Press (1990).
5. J. W. Negele, H. Orland, *Quantum Many-Particle Systems,* Addison-Wesley (1988).
6. N. H. March, W. H. Young, S. Sampanthar, *The Many-Body Problem in Quantum Mechanics,* Dover (1995).