Condensed Matter Theory (Benoît Douçot, Laura Messio, Benoît Estienne)

To understand the metallic state has been one of the first successful applications of quantum mechanics to condensed matter physics. Although a simple classical model (Drude) gives a simple and convenient picture for the residual resistivity of metals, it turns out that the Pauli principle plays a crucial role in shaping the low temperature thermodynamic properties of the metallic state. One of our first goals will be to explain why a nearly free electron picture works so well in the metallic state. This is by no means obvious, because the Coulomb interaction is very strong in conventional metals. The key point here is that this interaction is efficiently screened by collective excitations of the electronic fluid. At low energies, there remain some additional excitations, named *quasi-particles*, which have the same quantum numbers as free fermions, and from which the main thermodynamic properties of the metallic state can be inferred. This important piece of many body physics, widely known as *Fermi liquid theory*, has been built to a large extent by Landau and his pupils in the middle of the previous century, and still remains an essential concept in contemporary condensed matter physics. The course and classroom exercises will provide an introduction to this cornerstone of condensed matter physics.

Topics

Introduction to the method of second quantization for fermion systems.

Analysis of particle-hole susceptibility: Friedel oscillations around impurities, RKKY interaction. Screening of Coulomb interaction, plasma modes and Landau damping. Magnetic moment formation in solids as an example of the mean-field method.

Single particle properties: calculation of the electronic lifetime for various types of interactions: electron-phonon coupling and electronic interactions. Quasi-particle concept. Connection between electronic spectral function and photoemission spectra.

Quantum kinetic equations and applications to transport properties of Fermi liquids.

Suggested texts

1) *Concepts in solids*, P.W. Anderson (Addison Wesley).
2) *Methods of quantum field theory in statistical physics*, A. Abrikosov, L. Gorkov, I. Dzyaloshinskii (Dover).
3) *The theory of quantum liquids*, D. Pines, and P. Nozières (Addison Wesley).