Many-Body Theory

1. Second quantisation
   - Identical particles, many particle wavefunction, symmetrisation, Slater determinant, particle number representation.
   - Second quantisation: second quantised form of one and two particle operators, creation and annihilation operators, commutation/anticommutation relations, field operators.
   - Second quantised form of the Hamiltonian of free and Bloch electrons, and the interacting electron gas.
2. Screening and Hartree-Fock approximation
   - Screening of a point charge, induced charge, Friedel oscillations.
   - Kohn anomaly, dynamic screening. Plasmon oscillations, reflectivity of metals.
   - Interacting free electron spectrum, metallic bonding, Wigner crystal.
3. Spin density waves
   - Static susceptibility, quasi-one dimensional system, nesting.
   - SDW instability, diagonalization of the mean field Hamiltonian below the critical temperature, quasiparticles.
   - Gap equation, specific heat jump.
4. Linear response and Green's functions
   - Linear response, causality, Kubo formula. Dissipative and elastic response, spectral resolution. Kramers-Kronig relation.
   - Transport processes and coefficients, Onsager relations. Fluctuation-dissipation theorem.
   - Lehmann spectral representation, analytic properties of Green's functions.
5. Perturbation theory and diagrammatic techniques
   - Heisenberg, Schrödinger and interaction pictures. Time evolution, Gell-Mann-Low theorem.
   - Diagram techniques. Wick's theorem, Feynman diagrams.
   - Resummations. Self-energy, Dyson equation, vertex function, skeleton diagrams.
6. Fermi liquid theory and beyond
   - Fundamentals of Fermi liquid theory.
   - Self-energy, Dyson equation, Hartree-Fock approximation.
   - Random phase approximation, correlation energy of a three dimensional electron gas.
   - Vertex function, screening, Friedel oscillations.
   - One-dimensional Fermi systems and renormalisation group techniques.
7. Interacting bosons
   - Bose–Einstein condensation.
   - Ground state of weakly interacting bosons, determination of the spectrum of excitations by Bogoliubov transformation, superfluidity.
   - Interacting phonon systems. Polarons, Peierls instability.
8. Superconductivity
   - Electron-phonon interaction, Cooper instability.
   - Mean field theory of superconductivity.
9. Interacting electrons
   - Wannier basis, one band Hubbard model and its properties.
   - Perturbation theory of 1D interacting Fermi systems.
   - Perturbation theory for dense electron gas in 3D, Wigner crystal.

Recommended courses

BMETE11MF41 Modern Solid State Physics
BMETE15MF50 Many-Body Physics 1
BMETE15MF44 Statistical Physics 2

Recommended literature

- R. P Feynman: Statistical Mechanics: A Set Of Lectures (Advanced Book Classics, Perseus Books) [second quantized formalism]
- A. Abrikosov, L. P. Gorkov, and I. E. Dzyaloshinski: Methods of Quantum Field Theory in Statistical Physics (Dover Editions) [For T=0 temperature diagrammatics, see Chapter 2. Concise but elegant]
- G. D. Mahan: Many-Particle Physics (Plenum Press) [very detailed, thorough, sometimes old-fashioned]
- A. L. Fetter, J. D. Walecka: Quantum Theory of Many-Particle Systems (Dover Books in Physics) [old school but very detailed]
- H. Bruus, K. Flensberg: Many-Body Quantum Theory in Condensed Matter Physics: An Introduction (Oxford Graduate Texts) [a modern account on many-body theory with fresh applications]