

QM III: Quantum Many-Body Physics

Prerequisites:

- Quantum Mechanics: QM I
- Experimental Condensed-Matter Physics, Statistical Physics: Basic Knowledge

Content:

Part A: Foundations

- Second Quantization
- Fermi Gas and Fermi Liquid: Phenomenological Landau Theory
- Interacting Many-Body Systems: Quasi-particle Concept
- Connection with Experiment: Photoemission
- Green's Functions and the Concept of Elementary Excitations: Photoemission, Optical and Magnetic Excitations

Part B: Theoretical Tools and Key Applications

- Green's Functions: Diagrammatic (Feynman Diagrams) Perturbation Theory
- Applications: Life time of a Quasi-particle, Fingerprints of Luttinger- (one-dimensional) versus Fermi- (two- and three-dimensional) liquids
- Connection with Experiment: Bandstructure of Metals, Semiconductors and Insulators
- Magnetic Order (Ferro-, Antiferro-Magnetism): Concept of Spontaneous Symmetry Breaking
- Superconductivity: BCS Theory (weak electronic correlations)
- Superconductivity: Theory for high-Temperature Superconductivity (strong correlations)
- Correlation-induced (Mott-Hubbard) Insulator and Superconductor

Part C: Numerical Techniques:

- Mean-Field Theory (Dynamical Mean-Field Theory)
- Density-Functional Theory
- Exact-Diagonalization and Quantum-Cluster Theories
- Renormalization-Group Theory: Idea of the "Poor-Man Scaling" to an effective low-Energy Theory

→ Some of these themes can be expanded in "Mini-Forschung" Seminars

Literature:

Introduction:

- D. Pines: *Elementary excitations in solids* (Benjamin)
- W. Nolting: *Grundkurs Theoretische Physik*, Band 7 (Springer)
- E.K.U. Gross and E. Runge: *Vielteilchentheorie* (Teubner)
- A. Fetter and D. Walecka: *Quantum theory of many particle systems* (McGraw-Hill)
- G. Mahan: *Many particle physics* (Plenum)

Special Topics:

- P. Nozieres and D. Pines: *Theory of quantum liquid I & II* (Addison-Wesley)
- N. Nagosa: *Quantum field theory in condensed matter physics* (Springer)
- S. Doniach and E. Sondheimer: *Green's function for solid state physicists* (Addison-Wesley)
- F. Gebhard: *The Mott Metal-Insulator Transition* (Springer)
- H.E. Stanley: *Phase Transitions and Critical Phenomena* (Academic)
- A. Altland B.D. Simons: *Condensed Matter Field Theory* (Cambridge)
- J.R. Schrieffer: *Theory of superconductivity* (Addison-Wesley)
- W. Nolting: *Quantentheorie des Magnetismus I & II* (Teubner)

Special Methods:

- A. Abrikosov, L. Gorkov and I. Dzyaloshinski: *Methods of quantum field theory in statistical physics* (Dover)
- J. Negele and H. Orland: *Quantum many particle systems* (Addison-Wesley)
- R.M. Dreizler and E.K.U. Gross: *Density Functional Theory* (Springer)