Condensed Matter Theory B – Many-body Physics

Spring 2024

INSTRUCTOR: Congjun Wu (Office: E4-235)

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Time/Place: Tuesday and Thursday (8:50–10:35am), E10-312

(office: E4-235)TBA

Course webpage: TBA

TA: TBA

Text Books and reference books:

1. Alexander Altland, Ben D. Simons, Condensed Matter Theory, Cambridge University Press; 2nd edition (April 30, 2010)
2. P. Coleman, Introduction to Many-Body Physics, 1st Edition Cambridge University Press; 1 edition (February 1, 2016)
3. P. W. Anderson, Basic Notions of Condensed Matter Physics, The Benjamin /cummings Publishing Company, Inc.
4. J. M. Ziman, Principles of the Theory of Solids, Cambridge University Press; 2 edition (November 30, 1979)

Grade Policy:

40% Problem sets; 30% Midterm; 30% Final exam;

Homework Assignments:

Homework will be assigned every two weeks. Points will be deducted if assignments are submitted late depending on how late they are.

Class Schedule

Part I: Preparation

1. **Reviews**

   Lecture -1: Single-particle physics

   Lecture 0: The 2nd quantization method

Part II: Many-body physics without field theory

1. **Elementary topics**

   Lecture 1 : Hartree-Fock theory

   Lecture 2 : Density-functional theory

   Lecture 3 : Hubbard model, Heisenberg model, spin wave

2. **Interacting fermions**

   Lecture 4 : Interacting Electron Gas – Lindhard response, Plasmon, Screening

   Lecture 5 : Fermi liquid theory (I) – quasi-particles and Landau interaction parameters

   Lecture 6 : Fermi liquid theory (II) – renormalization to physical properties

   Lecture 7: Fermi liquid theory (III) – The Boltzmann equation and zero sound

   Lecture 8: Electron phonon interaction in metals

3. **Superconductivity**

   Lecture 9: Phenomenology of superconductivity

   Lecture 10: Bardeen-Cooper-Schrieffer theory to superconductivity

   Lecture 11: Thermodynamic properties, McMillan formula, linear response and Coherence factor

   Lecture 12: Ginzburg-Landau formalism, dirty superconductor

   Lecture 13: Josephson effect

   Lecture 14: Unconventional superconductivity

Part III: Field theory description of many-body physics

1. **Formalism development**

   Lecture 15: Path integral for quantumr mechanics

   Lecture 16: Operator formalism, response functions

   Lecture 17: Path integral for functional fields and fermions

   Lecture 18: Perturbation theory for fermions

2. **Fermi liquid and superconductivity**

   Lecture 19: RPA, correlation energy

   Lecture 20: Quasiparticle life time, Fermi surface

   Lecture 21: Spin waves in itinerant ferromagnets

   Lecture 22: Vertex functions, Ward identities

   Lecture 23: Luttinger theorem

   Lecture 24: Anderson-Higgs mechanism

   Lecture 25: Eliashberg theory for superconductivity

   Lecture 26: Low dimensional superfluidity

   Lecture 27: Renormalization group theory for the K-T transition

3. **Impurity problem**

   Lecture 28: The T-matrix method

   Lecture 29: Kondo problem, the poor-man scaling, spin-boson model

   Lecture 30: Disordered electrons, scaling, non-linear sigma model