Condensed Matter Many-Body-Physics & Field Theory II

TMP-TA4

LMU WiSe 2023/24
Prof. F. Grusdt

ORGANIZATION:

This is the third & final course taught in the series

- THP-TA1: Theor. Cond. Mat. Phys.
- THP-TA3: Cond. Mat. Many-Body-Phys. & Field Thy. I
- THP-TA4: Cond. Mat. Many-Body-Phys. & Field Thy. II

I will assume the following topics are known from previous theoretical physics courses:

* basics of classical mechanics & quantum mechanics
* basics of electromagnetism & statistical physics
* basic (quantum) theory of solids (band-theory, point-group symmetries, phonons, basic transport theory, ...)
* Feynman's diagrammatic perturbation theory
* Many-body path-integral formalism & methods

Basic organization:

- We will have 2 lectures / week:

  MO $14^{\underline{15}} - 15^{\underline{45}}$, A449 starting Oct. 16

  FR $12^{\underline{15}} - 13^{\underline{45}}$, A450

- We will have problem sets: 1 sheet / week

  ⇒ no grading, but solutions; first set on FR, Oct. 20

- We will have tutorials held by Lukas Hauzier / Nader Mostaan TUE 16–18

  ⇒ First tutorial on: TUE Oct. 24 (1st solutions on Oct 31)

- We will have a final exam on: TBA

- The lecture is worth 9 ECTS

Webpage:

https://www2.physik.uni-muenchen.de/lehre/vorlesungen/wise_23_24/TMP-TA4/index.html

0) CONTENTS:

Goal: The goal of this lecture is to apply the tools developed in the first part of the lecture to describe quantum many-body systems, and deepen your knowledge about new quantum many-effects. Doing so, we'll get to know some of the most fascinating phenomena – including (charge) fractionalization, anyonic braiding statistics, quantum spin-liquids, etc – which remain topics of active ongoing research.

Highlights include:

- The Anderson-Higgs mechanism describing charged superconductors coupled to a dynamical gauge-field
- Quantum gauge theories, their relation to topological order and strongly correlated electron systems
- The basics of quantum spin-liquids and Anderson's resonating-valence-bond (RVB) paradigm; and the non-linear σ-model: the field theory of a quantum magnet with $SU(2)$ symmetry

- The integer and fractional <u>quantum Hall effects</u> of interacting electrons in a strong magnetic field
- The basics of the <u>Kondo effect</u> and its relation to heavy-fermion physics and non-Fermi liquids; In this context, we'll apply flow-equation methods, as an example of a (numerical) renormalization group (RG) approach
- Some basic phenomenology of the doped Fermi-Hubbard model and its application to <u>high-temperature superconductivity</u>;

Other topics that could be/are sometimes taught in this course at LMU but that will <u>not</u> be covered include:

- Phase transitions and renormalization group (RG)
  ⇒ see also advanced statistical physics
- Functional renormalization group (FRG)
  ⇒ ask the chair of Prof. J. von Delft
- Luttinger liquids and 1D chains
  ⇒ see classic textbook by Giamarchi

- Keldysh formalism: non-equilibrium path-integral
  - ⇒ see e.g. lecture notes by J. Berges: arXiv:1503.02907

- Two-dimensional quantum materials: graphene, bilayer graphene, twisted bilayer graphene (twistronics), transition-metal dichalcogenides (TMDs)

  etc.

Literature:

- P. Coleman: "Introduction to Many-Body Physics"
- E. Fradkin: "Field Theories of Condensed Matter Physics"
- A. Auerbach: "Interacting Electrons & Quantum Magnetism"
- S. Sachdev: "Quantum Phase Transitions"
- X.-G. Wen: "Quantum Field Theory of Many-Body Systems"
- A. Altland, B. Simons: "Condensed Matter Field Theory"
- E. Fradkin: "Quantum Field Theory"
- S. Kehrein: "The flow-equation approach to Many-Body Problems"