Announcement

Condensed Matter Theory: Phase Transitions in Condensed Matter Systems

Description

The transition between different phases of matter (e.g., from ice, to (liquid) water, to vapor) is probably one of the most fascinating concepts in physics; and it is also one of the most complex ones.

Why does one actually observe a succession of phases in many systems as for example temperature rises? The basic reason is the competition between lowering energy and increasing disorder (and whereby entropy) in the free energy, which has to be minimized by a thermal equilibrium state.

Phase transitions are thus intimately related to a change in the order of the system (leading to the concept of an order parameter) and oftentimes also connected with a "breaking" of a symmetry, which is another very fundamental concept in physics.

In the first part of this lecture, we will focus on generic aspects of phase transitions. We will learn, how to identify universal aspects, for instance, in critical exponents of power laws for various experimental observables close to a phase transition. Methods and models to describe critical phenomena at phase transitions, like Ginzburg-Landau theory, the concept of scaling, and renormalization group ideas will be introduced. In the second part of the lecture, we will look in more detail at some of the phase transitions being of particular relevance in modern condensed matter theory, like superconductivity and superfluidity.

Grading will be based on weekly assignments and a project presentation/seminar talk at the end of the semester.

Content

- A short introduction to phase transitions and critical phenomena
- The Ising model
- Mean-field theory
- Anomalous dimensions and scaling
- Renormalization group
- Examples of phase transitions in condensed matter systems:
  superfluidity and superconductivity

Prerequisites: Bachelor courses: Quantum mechanics & Thermodynamics/statistics

Literature

This course is not based on any particular book. Below an (incomplete) list of books on phase transitions and critical phenomena helpful for certain parts of the lecture.

- E. Stanley: Phase transitions and critical phenomena
- Pfeuty and Toulouse: Introduction to the Renormalization Group and to Critical Phenomena
- N. Goldenfeld: Lectures on Phase Transitions and the RG
- L. Kadanoff: Statistical Physics: Statics, Dynamics, and Renormalization
- J. Sethna: Statistical Mechanics: Entropy, Order Parameters, and Complexity

Additional Information

3h lectures and 2h seminars
6 ECTS credits

Lecturer: Dr. Björn Kubala