Advanced Condensed Matter Theory

Content

In this course, we will cover selected topics in condensed matter theory and quantum many-body physics at an advanced and in-depth level.

Specific topics will vary from year to year. Typical selections will include:

- Renormalization group for condensed matter systems
- 1D interacting models, Luttinger liquids and bosonization
- Overview of the Sine-Gordon model and the BKT phase transition
- Quantum phase transitions and the Ising model
- Majorana modes and topological superconductors
- Berry's phase
- Topological insulators
- Topological order and the toric code
- Anyons and topological quantum computation
- Quantum Hall physics

There are two **main objectives** for this course:

1. To complete the preparation of the students interested in pursuing research in the theory of condensed matter, quantum many-body and statistical physics.
2. To bring students closer to the research activities in this area, by working on selected topics of their choice in the recent literature.

The course will adopt the operator description of many-body physics taught in Advanced Quantum Mechanics and Condensed Matter Theory 1.

The language of field theory will be used as well for some of the topics of this course. The necessary tools from field theory will be discussed during the course, based on either the functional path integral taught in Condensed Matter Theory 2 or the quantum field formulation taught in Quantum Field Theory 1.

Learning outcome

Skills

The students will acquire a set of strategies to investigate the physics of complex quantum many-body systems. The course will indeed present several theoretical techniques to describe the main features of a selection of quantum many-body systems of current interest in the scientific community.

In this respect, the students will be invited to think like researchers and describe complex systems by trying different approaches in their analysis.

The training of the students to this kind of research activity will include getting into a new topic by reading original research papers, learning to identify new questions, and distilling key physical principles at play in complex phenomena. In particular, each student will investigate a specific topic, carrying out detailed calculations and writing a final report on his/her understanding and findings.

Knowledge

At the end of the course, the student will know the fundamentals of the year's selected topics and their connections to other areas of modern physics. The knowledge will be at a level such that the participants will be prepared to follow and conduct research in the given area.

Competences

After this course the students will be experienced in a method for starting research in a new area. They will be able to extract the needed information from existing literature and to think about new directions for the research area in question.

Literature

To be announced on Absalon.

Recommended Academic Qualifications

The student is expected to have passed courses on mathematics, quantum mechanics and statistical physics on the level covered in the corresponding Bachelors courses in Physics at UCPH.

Knowledge of quantum mechanics on the level taught in ”Advanced Quantum Mechanics” at UCPH is required.

Basic knowledge on the main condensed matter physics systems is expected.

Knowledge of quantum field theory or functional path integral is an advantage.

Teaching and learning methods

The course will present a mixture of lectures, problem sessions and group activities.

Several mandatory assignments are foreseen, including exercise sets and a final report on a topic related to the contents of the course chosen by the student.

Workload

CATEGORY	HOURS
Lectures	40
Preparation	122
Theory exercises	10
Project work	24
Guidance	10
TOTAL	**206**

Feedback form

Written
Oral
Individual
Continuous feedback during the course of the semester.
Written feedback will be given about the final report.

Exam

Credit
    7,5 ECTS

Type of assessment
    Continuous assessment
    Written assignments
    The evaluation is based on the following homework assignments:
    • Problems sets (counting for 50% of the final grade)
    • Final report (counting for 50% of the final grade)

Exam registration requirements
    80% attendance

Marking scale
    7-point grading scale

Censorship form

No external censorship

One internal examiner plus one internal censor.

Re-exam

To qualify for a re-exam, a student must resubmit either the solution of a new problem set or a new final report, as indicated by the course coordinator.

The format of the re-exam is an oral examination (30 minutes with no preparation time).

Criteria for exam assessment

See **learning outcome**.