GHENT UNIVERSITY

Course Specifications

Valid in the academic year 2022-2023

Strongly Correlated Quantum Systems (C004071)

Course size *(nominal values; actual values may depend on programme)*

Credits 6.0		**Study time 180 h**		**Contact hrs**	52.5h

Course offerings and teaching methods in academic year 2022-2023

A (semester 2)	English	Gent	lecture	42.5h
			seminar: coached exercises	7.5h
			project	2.5h

Lecturers in academic year 2022-2023

Haegeman, Jutho	WE05	lecturer-in-charge
Vanderstraeten, Laurens	WE05	co-lecturer

Offered in the following programmes in 2022-2023	**crdts**	**offering**
Master of Science in Teaching in Science and Technology(main subject Mathematics)	6	A
Master of Science in Teaching in Science and Technology(main subject Physics and Astronomy)	6	A
Master of Science in Mathematics	6	A
Master of Science in Physics and Astronomy	6	A
Exchange Programme in Mathematics (master's level)	6	A
Exchange Programme in Physics and Astronomy (Master's Level)	6	A

Teaching languages

English

Keywords

Spin systems, quantum phase transistions, topological order, entanglement.

Position of the course

The goal of this course is to teach a number of general concepts and recent developments from the field of quantum many body physics, complemented by a modern point of view using the theory of entanglement.

Contents

1 Introduction: second quantisation, interacting electrons, the Hubbard model and its descendants
2 Quantum Ising model in transverse magnetic field: exact solution via Jordan Wigner, Fourier and Bogoliubov transform. Quantum phase transitions and criticality. Order an disorder. Duality. Excitations and domain walls. Entanglement entropy: area laws and logarithmic divergence.
3 Half-integer spin chains: Heisenberg antiferromagnets, Lieb-Schultz-Mattis theorem, order and disorder, Goldstone-bosons, Mermin-Wagner theorem, exact solution via coordinate Bethe ansatz.
4 Integer spin chains: Haldane's conjecture, Affleck-Kennedy-Tasaki-Lieb model, introduction to MPS (Matrix Product States) and tensor networks. Gapless edge modes and symmetry protected topological order.
5 Topological classification of free fermion systems: periodic table of topological insulators and superconductors, Su-Schriefer-Heeger model and Kitaev's quantum wire: topological degeneracy and majorana edge modes.
6 Spin models in higher dimensions, spin liquids, gauge theories and Kitaev's toric code model, topological order and anyons

There will also be a group project, which can be chosen as either a literature review (e.g. quantum hall effect, Levin-Wen string net models, topological insulators, entanglement renormalization for critical systems, entanglement entropy in conformal field theory, ...) or (density matrix renormalization group algorithm, tensor renormalization group, ...).

Initial competences

Proper knowledge of quantum mechanics, basic knowledge of quantum field theory.

Final competences

1 Familiarity with a number of basic concepts in quantum many body systems and condensed matter physics.
2 Having an overview about different phases of quantum matter, and the associated phenomenology (gapless edge modes, topological entanglement entropy,...)
3 Ability to read scientific papers about recent developments and to start research in this field.

Conditions for credit contract

Access to this course unit via a credit contract is determined after successful competences assessment

Conditions for exam contract

This course unit cannot be taken via an exam contract

Teaching methods

Lecture, Project, Seminar: coached exercises

Extra information on the teaching methods

Project: students make a literature review or a computational assignment in small teams. They make a report and a presentation about this work.

Learning materials and price

Lecture notes and research papers
Available via Ufora

References

- Assa Auerbach, "Interacting electrons and quantum magnetism"(Springer, 1998)
- Eduardo Fradkin, "Field theories of Condensed Matter Physics"(2nd edition, Cambridge University Press, 2013)

Course content-related study coaching

Outside lecture hours, the teachers are available for further explanation.

Assessment moments

end-of-term assessment

Examination methods in case of periodic assessment during the first examination period

Oral examination, Open book examination

Examination methods in case of periodic assessment during the second examination period

Oral examination, Open book examination

Examination methods in case of permanent assessment

Report

Possibilities of retake in case of permanent assessment

examination during the second examination period is possible

Extra information on the examination methods

- Periodic evaluation: Oral exam (with written preparation)
- Project: report and presentation

Calculation of the examination mark

- 35% continuous assessment (project assignment)
- 65% end-of-term evaluation (oral examination)