GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2024-2025

Strongly Correlated Quantum Systems (C004071)

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

Credits 6.0 **Study time 180 h**

Course offerings and teaching methods in academic year 2024-2025

A (semester 2)	English	Gent	lecture
			seminar

Lecturers in academic year 2024-2025

Haegeman, Jutho	WE05	lecturer-in-charge
Bultinck, Nick	WE05	co-lecturer

Offered in the following programmes in 2024-2025	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
Master of Science in Physics and Astronomy	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. Quantum to classical mapping. Correlation functions and their relation to neutron scattering and other experimental techniques.
3 Half-integer spin chains: Heisenberg antiferromagnets, Holstein-Primakoff representation, Lieb-Schultz-Mattis theorem, order and disorder, Goldstone-bosons and the single-mode approximation, Mermin-Wagner theorem, exact solution via coordinate Bethe ansatz, Majumdar-Gosh model.
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, ground state degeneracy, 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

Seminar, Lecture

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.

Study material

Type: Syllabus

Name: Strongly Correlated Quantum Systems
Indicative price: Free or paid by faculty
Optional: no
Language : English
Number of Pages : 172
Available on Ufora : Yes
Online Available : Yes
Available in the Library : No
Available through Student Association : No

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 and continuous assessment

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

Oral assessment

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

Oral assessment

Examination methods in case of permanent assessment

Assignment

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

- 30% continuous assessment (project assignment)

- 70% end-of-term evaluation (oral examination)