GHENT UNIVERSITY

Course Specifications

Valid in the academic year 2018-2019

Strongly Correlated Quantum Systems (C004071)

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

Credits 6.0	Study time 180 h	Contact hrs	52.5 h

Course offerings and teaching methods in academic year 2018-2019

A (semester 2)	English	lecture	30.0 h
		seminar: coached exercises	7.5 h
		project	15.0 h

Lecturers in academic year 2018-2019

Haegeman, Jutho	WE05	lecturer-in-charge

Offered in the following programmes in 2018-2019	crdts	offering
Master of Science in Physics and Astronomy	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, exact solution via coordinate Bethe ansatz.
4. Integer spin chains: Haldane' conjecture, Affleck-Kennedy-Tasaki-Lieb model, introduction to MPS (Matrix Product States) and tensor networks. Gapless edge modes and symmetry protected topological order.
5. Kitaev' fermion chain: topological degeneracy and majorana edge modes.
6. Spin models in higher dimensions, AKLT and PEPS (Projected Entangled Pair States), Mermin-Wagner theorem, spin wave theory.
7. Toric code, quantum dimers, anyons and topological order, topological entanglement entropy.

and possibly

1. Fermi liquid theory from an RG perspective
2. Bosonization and luttinger liquids

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

Learning materials and price

Lecture notes and research papers
Available via Minerva.

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.

Evaluation methods

end-of-term evaluation

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

Open book examination, oral examination

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

Open book examination, oral examination

Examination methods in case of permanent evaluation

Report

Possibilities of retake in case of permanent evaluation

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

40% continuous assessment (project assignment)
60% end-of-term evaluation (oral examination)