GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2025-2026

Many-body Physics (C004515)

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

Credits 6.0 **Study time 180 h**

Course offerings in academic year 2025-2026

A (semester 2) English Gent

Lecturers in academic year 2025-2026

Van Neck, Dimitri WE05 lecturer-in-charge

Offered in the following programmes in 2025-2026	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

Many-body physics, second quantization, mean field, propagator, collective states, superfluidity, superconductivity

Position of the course

In this course the theoretical description of quantum mechanical many-particle systems is the object of study. Based on examples from molecular, atomic, condensed matter, and nuclear physics, a unified treatment is provided through the concept of the Green's function or propagator in a many-body system.

Contents

Second quantization for fermions and bosons. Two-paricle states and interactions. Mean-field techniques. Perturbation series for the single-particle propagator. Feynman diagrams. Dyson equation, two-particle propagator and vertex function. Nonperturbative aspects. Hartree-Fock in atoms and molecules. Study of second-order selfenergy: static and dynamic contributions. Quasiparticles in Landau-Migdal framework. Excited states. Collective motion. Random phase approximation. Plasmon excitations in the electron gas. Repulsive short-range interactions. Ladder diagrams. Saturation in nuclear matter. Boson systems. Bose-Einstein condensation. Gross-Pitaevskii equation for ultracold atomic gases. Bogoliubov perturbation theory. Hugenholtz-Pines theorem. first-order results for dilute Bose gas. Superfluidity in Helium-4. Pairing in fermion systems. BCS theory and metallic superconductivity. Non-Fermi liquids.

Initial competences

Good knowledge of quantum mechanics

Final competences

1 Acknowledge the coherence of typical many-body aspects and mechanisms in a wide range of physical systems.
2 Be able to discuss the applicability and limitations of mean-field techniques in electronic and nuclear systems.
3 Understand the structure of normal fermion systems and the concept of quasiparticles.
4 Calculate and manipulate Feynman diagrams in a many-body context.
5 Practical use of propagators as an alternative to wave functions, and their link with experimental quantities, in various problems.
6 Understand the BCS theory for metallic superconductors.

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: the students have to choose a numerical exercise from a list. They have to solve it using their software of choice, and to hand in a written report.

Study material

Type: Handbook

Name: Many-Body Theory Exposed: propagator description of quantum mechanics in many-body systems
Indicative price: Free or paid by faculty
Optional: yes
Author : W.H. Dickhoff and D. Van Neck

Additional information: World Scientific 2005, ISBN 981-256-294-X

References

"A guide to Feynman diagrams in the many-body problem", R.D. Mattuck, Dover Publications; 2nd edition (June 1, 1992)

Course content-related study coaching

The lecturer is available for explanation during and after the lectures. There is assistance during the tutorial classes and for the projects. Interactive support through Ufora (e-mail).

Assessment moments

end-of-term and continuous assessment

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

Oral assessment, Written assessment with open-ended questions

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

Oral assessment, Written assessment with open-ended questions

Examination methods in case of permanent assessment

Assignment

Possibilities of retake in case of permanent assessment

examination during the second examination period is possible

Calculation of the examination mark

Permanent evaluation (25%) + Periodical evaluation (75%)