

## 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 2024-2025**

A (semester 2)

English

Gent

**Lecturers in academic year 2024-2025**

Van Neck, Dimitri

WE05

lecturer-in-charge

**Offered in the following programmes in 2024-2025**

[Master of Science in Physics and Astronomy](#)

[Exchange Programme in Physics and Astronomy \(Master's Level\)](#)

**crdts**

**offering**

6

A

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-particle 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

Type: Handouts

Name: Lecture material

Indicative price: € 10

Optional: no

**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%)