

The Theory of Metals: from Path Integrals to Experiment (C004513)

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

Credits 6.0

Study time 180 h

Course offerings in academic year 2026-2027

A (semester 1)

English

Gent

Lecturers in academic year 2026-2027

Bultinck, Nick

WE05

lecturer-in-charge

Offered in the following programmes in 2026-2027

[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

Quantum mechanics, many-body systems, interacting electrons and bosons

Position of the course

Contents

- 1 **Basic concepts:** Second quantization. The free Fermi gas and the Fermi surface. The quantum mechanical description of phonons. Semiclassical equations of motion for electrons. Fermi liquid theory and quasi-particles.
- 2 **Green's functions and path Integrals:** Definition of Green's functions, and a discussion of the physical information they contain about quasi-particles. Derivation of the path integral representation of the partition function for interacting electrons and bosons. Derivation of the Feynman rules for perturbative/diagrammatic studies of interacting electron and boson systems (both in imaginary and real time). Applications: An electron in a random potential, and the screening of the Coulomb interaction in a metal.
- 3 **Interacting electron-phonon systems:** Derivation of the Frohlich Hamiltonian. Mass renormalization of electrons by the interaction with phonons. The instability of a metal towards the formation of a superconductor.
- 4 **Linear response theory:** The interaction picture and the definition of linear response coefficients. Connection between linear response theory and different experimental probes of quantum many-body systems. Applications: calculation of the tunneling current in a scanning tunneling microscope experiment, and the cross section in a angle-resolved photo-emission experiment. The Kubo formula for the electric conductivity of a quantum many-body system. Diagrammatic derivation of the Drude conductivity.

Initial competences

Quantum mechanics, solid state physics

Final competences

The student can make a connection between the theoretical and quantum mechanical description of interacting electrons and bosons, and experimentally measurable quantities.

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**Study material**

Type: Syllabus

Name: The theory of metals: from path integrals to experiment

Indicative price: Free or paid by faculty

Optional: no

Available on Ufora : Yes

Online Available : Yes

Available in the Library : No

Available through Student Association : No

References**Course content-related study coaching****Assessment moments**

end-of-term assessment

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

Oral assessment, Written assessment open-book

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

Oral assessment, Written assessment open-book

Examination methods in case of permanent assessment**Possibilities of retake in case of permanent assessment**

not applicable

Calculation of the examination mark

Oral assessment of the theory (60%), and written open-book assessment of the exercises (40%).