GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2025-2026

Quantum Field Theory (C004506)

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 1)	English	Gent

Lecturers in academic year 2025-2026

Mertens, Thomas	WE05	lecturer-in-charge

Offered in the following programmes in 2025-2026	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
Exchange Programme in Mathematics (master's level)	6	A
Exchange Programme in Physics and Astronomy (Master's Level)	6	A

Teaching languages

English

Keywords

Quantum field theory

Position of the course

This course builds further towards the quantum mechanical description of nature, as was studied earlier in Quantum Mechanics 1 and 2. The focus is on quantizing systems with many degrees of freedom, or field theories in the continuum limit.
The resulting quantum field theory describes a universal structure that emerges in many situations where a continuum description is appropriate. Next to its main use as the language of elementary particle physics, and as building block of models of quantum gravity (e.g. string theory), quantum field theory is also relevant to describe critical phenomena in solid state physics.
The concepts are illustrated with quantum electrodynamics (QED) as the main example. The emphasis is on understanding the physical concepts and their relation to the mathematical model.

Contents

The course contains 7 chapters:
1. Free quantum fields
We start by studying free field theories (Klein-Gordon, Maxwell, Dirac) and their treatment as quantum mechanical systems. The most important concepts are Noether's theorem and its applications, and the many-particle interpretation of the Hilbert space of quantum field theory.
2. Interacting quantum fields
We introduce non-linearities in the field equations, and study the quantization of these models in perturbation theory. The resulting perturbation series can be diagrammatically represented in terms of Feynman diagrams. This leads to the concrete evaluation of particle scattering processes.
3. Path integrals
We study an alternative treatment of quantization through a continuous infinite generalization of integrals: Feynman's path integral formalism. Next to the deep

physical insights into the nature of quantum mechanics, this leads to an equivalent elegant derivation of the results of chapter 2.

4. Introduction to renormalization

The calculation of loop diagrams in quantum field theory leads to divergences. We give an introduction to the physical interpretation of these infinities, and learn how to deal with them in concrete computations.

5. Yang-Mills gauge theories

We expand our arsenal of models, and generalize Maxwell theory, based on the abelian U(1) group, to general non-abelian (compact) Lie groups. This mathematical generalization is of direct physical relevance in elementary particle physics for the description of the strong and weak force.

6. Spontaneous symmetry breaking

We study spontaneous symmetry breaking in a number of physical systems, emphasizing the physical implications in terms of Goldstone bosons and the Higgs mechanism.

7. Electroweak interactions

We end the course with a physical application of quantum field theory: electroweak unification and the Glashow-Weinberg-Salam model. All of the techniques and insights from previous chapters are combined and applied in this culmination of the course.

Initial competences

"Relativity and electromagnetism" and "Quantum Mechanics 2".

Final competences

The student has a thorough understanding of the fundamentals of field theory and is prepared for research in quantum field theory, elementary particle physics and theoretical physics in general (e.g. theoretical solid state physics).

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

Guided exercise classes.
Learning material: Entire course (pdf) available on Ufora.

Study material

Type: Syllabus

Name: Quantum Field Theory
Indicative price: Free or paid by faculty
Optional: no
Language : English
Number of Pages : 200
Available on Ufora : Yes
Online Available : Yes
Available in the Library : No
Available through Student Association : No

References

An introduction to quantum field theory. M. Peskin and D. Schroeder, Addison Wesley (1995)

Course content-related study coaching

Support orally or via email by teacher and collaborators.

Assessment moments

end-of-term 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

Possibilities of retake in case of permanent assessment

not applicable

Extra information on the examination methods

Theory: oral and written.
Exercises: written.

Calculation of the examination mark

1/2 (written theory)+1/4 (oral)+1/4 (exercises)