Faculty of Science

FYTN19, Theoretical Physics: Introduction to Quantum Field Theory, 7.5 credits

Teoretisk fysik: Introduktion till kvantfältteori, 7,5 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2022-06-08 to be valid from 2022-06-08, spring semester 2023.

General Information

The course is an elective course for second-cycle studies for a Degree of Master of Science (120 credits) with a specialisation in physics.

Language of instruction: English

Main field of studies	*Depth of study relative to the degree requirements*
Physics	A1F, Second cycle, has second-cycle course/s as entry requirements

Learning outcomes

The overall goal of the course is to give a basic knowledge of fundamental concepts of quantum field theory in the canonical formulation, based on quantum mechanics and the theory of special relativity, that is needed to describe relativistic particles and their interactions.

Knowledge and understanding

Upon completion of the course, the student shall be able to:

- explain the basics of Hamilton and Lagrange formulations of classical field theory and the relation between symmetries of the Lagrange function and conservation laws,
- describe the Klein-Gordon, Dirac and Maxwell equations with their different symmetry properties, as well as the properties of the solutions to these,
- explain the quantization of scalar, fermion and vector fields including their propagators, physical states and properties under charge conjugation, parity and

time-reversal,
- describe the perturbative expansion of correlation functions as well as scattering and decay processes and how these calculations can be simplified using Feynman diagrams,
- explain the philosophy of perturbation theory including asymptotic states, cross sections and decay widths,
- explain at a basic level how the theory can be reformulated in a consistent way in order to include processes with higher order radiative corrections.

Competence and skills

Upon completion of the course, the student shall be able to:

- calculate conserved quantities such as energy and momentum from the Lagrange density,
- perform transitions between the Heisenberg, Schrödinger and interaction pictures and use them appropriately,
- derive the Feynman rules for simple theories such as the Yukawa theory and quantum electrodynamics from the Lagrange density,
- make simple calculations of processes at tree level in quantum electrodynamics such as electron-positron scattering and Compton scattering as well as to relate different processes using crossing relations.

Judgement and approach

Upon completion of the course, the student shall be able to:

- argue the importance of formulating theories in a Lorentz invariant way and how this manifests itself for different kinds of fields and other representations of the Lorentz group.

Course content

The course deals with:

- Elements of classical field theory in Hamilton and Lagrange formulations,
- The Klein-Gordon, Dirac and Maxwell equations and their solutions with quantization, Lorentz transformation properties and discrete symmetries,
- Principles of perturbation theory and the calculation of cross sections and decay widths using Feynman diagrams,
- Feynman rules for simple theories such as the Yukawa theory and quantum electrodynamics,
- Calculation of tree level processes in quantum electrodynamics,
- Radiative corrections with infrared and ultraviolet divergencies and the notion of renormalisation.

Course design

The teaching consists of lectures and problem solving sessions.

Assessment

The examination consists of written hand-in assignments during the course and an oral theory exam at the end of the course. It is required to pass the hand-in assignments to take part in the oral theory exam.

Students who do not pass the regular exam are offered a re-examination shortly after the regular exam.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Subcourses that are part of this course can be found in an appendix at the end of this document.

Grades

Marking scale: Fail, Pass, Pass with distinction.
To pass the entire course, it is required to pass both the oral theory exam as well as the written hand-in assignments.

The grading scale for the written hand-in assignments are Fail, Pass, whereas the oral theory exam is graded according to the scale Fail, Pass, Pass with distinction.

The final grade is determined by the result on the oral theory exam.

Entry requirements

The prerequisites required for admission to the course are 135 credits of science studies out of which 90 credits in Physics and 45 credits in Mathematics or a Bachelor of Science in Physics, in both cases including quantum mechanics (particularly time-dependent perturbation theory) corresponding to FYSN17, Quantum Mechanics, 7.5 credits and advanced knowledge corresponding to at least one of the courses FYTN18, Theoretical Particle Physics, 7.5 credits or FYST37, Advanced Quantum Mechanics, 7.5 credits as well as English 6/B or the equivalent.

Further information

The course replaces FYTN10 Introduction to Quantum Field Theory, 7.5 credits, and it may not be credited towards a degree together with this course.

Knowledge in mathematics corresponding to FYTN01, Mathematical Methods of Physics, 7.5 credits, is also recommended but is not required.

The course is offered at the Department of Astronomy and Theoretical Physics, Lund University.

Subcourses in FYTN19, Theoretical Physics: Introduction to Quantum Field Theory

Applies from V23

2301 Written hand-in assignments, 2,5 hp
Grading scale: Fail, Pass

2302 Oral theory exam, 5,0 hp
Grading scale: Fail, Pass, Pass with distinction