



# SI2390 Relativistic Quantum Physics

## 7.5 credits

### Spring 2026, Period 3

## General Information

### Intended Learning Outcomes

After completion of the course you should be able to:

- apply the Poincaré group as well as classify particle representations.
- analyze the Klein–Gordon and the Dirac equations.
- solve the Weyl equation.
- know Maxwell’s equations and classical Yang–Mills theory.
- quantize Klein–Gordon, Dirac, and Majorana fields as well as formulate the Lagrangian for these fields.
- use perturbation theory in simple quantum field theories.
- formulate the Lagrangian for quantum electrodynamics as well as analyze this.
- derive Feynman rules from simple quantum field theories as well as interpret Feynman diagrams.
- analyze elementary processes in quantum electrodynamics.
- compute radiative corrections to elementary processes in quantum electrodynamics.

## Syllabus

The course consists of two parts:

Part I. Relativistic quantum mechanics: Tensor notation. The Lorentz and Poincaré groups. Casimir operators. Irreducible representations of particles. The Klein–Gordon equation. The Dirac equation. The structure of Dirac particles. The Dirac equation: central potentials. The Weyl equation.

Part II. Introduction to relativistic quantum field theory: Neutral and charged Klein–Gordon fields. The Dirac field. The Majorana field. Maxwell’s equations and quantization of the electromagnetic field. Introduction to Yang–Mills theory. Asymptotic fields: LSZ formulation. Perturbation theory. Introduction to quantum electrodynamics. Interacting fields and Feynman diagrams. Elementary processes of quantum electrodynamics. Introduction to regularization, renormalization, and radiative corrections.

## Prerequisites

The following courses are mandatory:

- Advanced Quantum Mechanics
- Special Relativity

The following course is recommended:

- Symmetries in Physics

## Lectures and Lecturers

The course contains 36 h lectures ( $18 \times 2$  h), which will be given in English. The lecturers and course responsables of the course are:

**Dr. Sampsa Vihonen** (lectures 1–12)

Department of Physics, KTH Royal Institute of Technology

Visiting address: Roslagstullsbacken 21, floor 5, room A5:3011

E-mail: [vihonen@kth.se](mailto:vihonen@kth.se)

**Professor Tommy Ohlsson** (lectures 13–18)

Department of Physics, KTH Royal Institute of Technology

Visiting address: Roslagstullsbacken 21, floor 5, room A5:1029

Telephone: 08-7908261

E-mail: [tohlsson@kth.se](mailto:tohlsson@kth.se)

The examiner of the course is: **Professor Tommy Ohlsson**

# Course Literature

The course literature consists of one book (mainly):

- T. Ohlsson, *Relativistic Quantum Physics — From Advanced Quantum Mechanics to Introductory Quantum Field Theory*, Cambridge (2011)

Further recommended reading:

- A.Z. Capri, *Relativistic Quantum Mechanics and Introduction to Quantum Field Theory*, World Scientific (2002)
- W. Greiner, *Relativistic Quantum Mechanics — Wave Equations*, Springer (2000)
- F. Gross, *Relativistic Quantum Mechanics and Field Theory*, Wiley (1993)
- F. Mandl and G. Shaw, *Quantum Field Theory*, rev. ed., Wiley (1994)
- J. Mickelsson, T. Ohlsson, and H. Snellman, *Relativity Theory*, KTH (2005)
- M.E. Peskin and D.V. Schroeder, *Introduction to Quantum Field Theory*, Harper-Collins (1995)
- F. Schwabl, *Advanced Quantum Mechanics*, Springer (1999)
- S.S. Schweber, *An Introduction to Relativistic Quantum Field Theory*, Dover (2005)
- F.J. Ynduráin, *Relativistic Quantum Mechanics and Introduction to Field Theory*, Springer (1996)

# Requirements

Hand in assignments (INL1; 4.5 ECTS credits) and an oral exam (TEN1; 3 ECTS credits).

## Examination

*INL1*. There will be three sets of homework problems, which each consists of two parts, during the course. The first parts (Part I) will be examined through Canvas using *Safe Exam Browser* in scheduled times in particular rooms and the second parts (Part II) need to be presented (mandatory) after they have been handed in. The three sets of homework problems will be distributed and should be handed in according to the following scheme:

Homework Problems	Out	In
Set # 1 – Part I	Lecture 5 (Jan. 20, 2026)	Jan. 29, 2026 @ 15:00–16:00 in FB55
Set # 1 – Part II	Lecture 5 (Jan. 20, 2026)	Feb. 3, 2026 @ 23:59
Presentation of Part II	–	Feb. 4, 2026 @ 15:15–18:00 in FB52
Set # 2 – Part I	Lecture 11 (Feb. 3, 2026)	Feb. 12, 2026 @ 13:00–14:00 in FB52
Set # 2 – Part II	Lecture 11 (Feb. 3, 2026)	Feb. 17, 2026 @ 23:59
Presentation of Part II	–	Feb. 18, 2026 @ 09:15–12:00 in FB52
Set # 3 – Part I	Lecture 17 (Feb. 23, 2026)	Mar. 2, 2026 @ 11:00–12:00 in FB55
Set # 3 – Part II	Lecture 17 (Feb. 23, 2026)	Mar. 9, 2026 @ 23:59
Presentation of Part II	–	Mar. 10, 2026 @ 14:15–17:00 in FB52

*TEN1*. The oral examinations will take place on March 11 and 12, 2026 between 10:00 and 17:00 in A5:1003. Each oral examination will take approximately 15 minutes. The time for the oral examination will be agreed upon between the student and the examiner.

## Grading

The different grades are: A, B, C, D, E, Fx, and F. The grades will be awarded according to the following scheme:

Grade	Homework Problems (INL1)	Oral Examination (TEN1)
F	< 50 % of all problems correct	Failed
Fx	< 50 % of all problems correct	Passed
Fx	≥ 50 % of all problems correct	Failed
E	≥ 50 % of all problems correct	Passed
D	≥ 60 % of all problems correct	Passed
C	≥ 70 % of all problems correct	Passed
B	≥ 80 % of all problems correct	Passed
A	≥ 90 % of all problems correct	Passed

In addition, you need to obtain at least 50 % on each homework problem set in order to obtain a passing grade (E or higher). If you obtain a total result of more than 50 %, but do not fulfill this criterion on each individual homework problem set, you will be given the grade Fx and a chance to make a completing task for the grade E.

Good luck with the course!

# Schedule and Program

## Schedule of Lectures, Quizzes, Presentations, and Oral Examinations

#	Week	Day	Date	Time	Room	Contents
1	3	Tuesday	January 13, 2026	10-12	FB55	Introduction
2		Wednesday	January 14, 2026	15-17	FB55	General description of relativistic states
3		Friday	January 16, 2026	10-12	FB55	The Klein–Gordon equation
4	4	Monday	January 19, 2026	10-12	FB55	The Dirac equation
5		Tuesday	January 20, 2026	10-12	FB54	—”—
6		Friday	January 23, 2026	10-12	FB55	The Dirac equation
7	5	Monday	January 26, 2026	08-10	FA31	Quantization of the non-relativistic string
8		Tuesday	January 27, 2026	08-10	FB55	Introduction to relativistic quantum field theory
9		Friday	January 30, 2026	10-12	FB55	Quantization of the Klein–Gordon field
10	6	Monday	February 2, 2026	10-12	FA31	Quantization of the Dirac field
11		Tuesday	February 3, 2026	10-12	FB55	Maxwell’s equations and quantization of the electromagnetic field
12		Friday	February 6, 2026	10-12	FB55	Introduction to Yang–Mills theory
13	7	Monday	February 9, 2026	10-12	FB55	Asymptotic field and the LSZ formalism
14		Tuesday	February 10, 2026	10-12	FB55	Perturbation theory
15	8	Monday	February 16, 2026	10-12	FB55	—”—
16		Wednesday	February 18, 2026	15-17	FB55	—”—
17	9	Monday	February 23, 2026	10-12	FB55	Elementary processes of quantum electrodynamics
18		Friday	February 27, 2026	10-12	FA31	Introduction to regularization, renormalization, and radiative corrections
Q1	5	Thursday	January 29, 2026	15-16	FB55	Quiz 1
P1	6	Wednesday	February 4, 2026	15-18	FB52	Student presentation 1
Q2	7	Thursday	February 12, 2026	13-14	FB52	Quiz 2
P2	8	Wednesday	February 18, 2026	9-12	FB52	Student presentation 2
Q3	10	Monday	March 2, 2026	11-12	FB55	Quiz 3
P3	11	Tuesday	March 10, 2026	14-17	FB52	Student presentation 3
		Wednesday	March 11, 2026	10-17	A5:1003	Oral examinations
		Thursday	March 12, 2026	10-17	A5:1003	—”—

## Program of Lectures

Below, RQP refers to the textbook T. Ohlsson, *Relativistic Quantum Physics – From Advanced Quantum Mechanics to Introductory Quantum Field Theory*, Cambridge (2011).

**Lecture 0:** Refresh chapter 1 in Mickelsson, Ohlsson & Snellman or some similar material on special relativity theory!

**Lecture 1:** Tensor notation. The Lorentz and Poincaré groups. Casimir operators. Irreducible representations of particles.

*Literature:* Chapter 1 in RQP.

**Lecture 2:** General description of relativistic one-particle states.

*Literature:* Chapter 1 in RQP.

For the interested student: E. Wigner, *On Unitary Representations of the Inhomogeneous Lorentz Group*, Ann. Math. **40**, 149 (1939).

**Lecture 3:** The Klein–Gordon equation. The Klein paradox.

*Literature:* Chapter 2 in RQP.

**Lecture 4:** The Dirac equation. Gamma “gymnastics”.

*Literature:* Chapter 3 in RQP.

**Lecture 5:** The structure of Dirac particles. The Dirac equation: central potentials.

*Literature:* Chapter 3 in RQP.

**Lecture 6:** The hydrogenic atom. The Weyl equation.

*Literature:* Chapter 3 in RQP.

**Lecture 7:** Quantization of the non-relativistic string.

*Literature:* Chapter 4 in RQP.

**Lecture 8:** Introduction to relativistic quantum field theory.

*Literature:* Chapter 5 in RQP.

**Lecture 9:** Neutral and charged Klein–Gordon fields.

*Literature:* Chapter 6 in RQP.

**Lecture 10:** The Dirac field. The Majorana field.

*Literature:* Chapter 7 in RQP.

**Lecture 11:** Maxwell’s equations and quantization of the electromagnetic field.

*Literature:* Chapter 8 in RQP.

**Lecture 12:** Introduction to Yang–Mills theory.

*Literature:* Chapter 9 in RQP.

**Lecture 13:** Asymptotic fields: LSZ (Lehmann–Symanzik–Zimmermann) formulation.  
*Literature:* Chapter 10 in RQP.

**Lecture 14:** Perturbation theory.  
*Literature:* Chapter 11 in RQP.

**Lecture 15:** see lecture 14.  
*Literature:* Chapter 11 in RQP.

**Lecture 16:** Introduction to quantum electrodynamics. Interacting fields and Feynman diagrams.  
*Literature:* Chapter 11 in RQP.

**Lecture 17:** Elementary processes of quantum electrodynamics.  
*Literature:* Chapter 12 in RQP.

**Lecture 18:** Introduction to regularization, renormalization, and radiative corrections.  
*Literature:* Chapter 13 in RQP.