UAB Universitat Autònoma de Barcelona	Advanced quantum mechanics Code: 100178 Credits: 6	2026/2027

Degree programme	Type	Course
Physics	OP	4

Contact lecturer

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Group languages

You can consult this information at the end of the document.

Prerequisites

Recommendation: Quantum physics. Quantum mechanics and theoretical mechanics.

Objectives

Introduce the most basic concepts (conceptual and mathematical) of quantum field theory. Special emphasis is placed on the connection with non-relativistic quantum mechanics, as well as with classical field theory. In addition, the student must acquire the ability to apply calculation tools with agility to different types of problems.

Learning outcomes

1. Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals
2. Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, in front of both specialist and general publics.
3. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
4. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
5. Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.
6. Establish the phenomenological consequences of relativistic wave equations.
7. Apply gauge invariance for the Lagrangian determination of quantum electrodynamics.
8. Obtain transitional amplitudes for electromagnetic processes using Feynman's rules.
9. Calculate cross sections for simple electromagnetic processes.
10. Study collisions with identical particles.
11. Establish the bases for the comprehensive formulation of quantum field theory and its applications.
12. Analyse the consequences of Dirac's equation on the nonrelativistic limit.
13. Analyse the limits of simple high and low energy electromagnetic processes.
14. Use phase-space integration correctly.
15. From a specific initial and final state, structure and develop the strategy and calculation for the cross section of an electromagnetic process.
16. Identify situations in which a change or improvement is needed.
17. Identify the social, economic and environmental implications of academic and professional activities within one's own area of knowledge.
18. Use Noether's theorem in quantum field theories.

19. Obtain irreducible representations of the Poincaré group and apply them to particle states.

Contents

4.

(b) Associated Lie algebra.

6.

(c) One particle irreducible representation. Wigner method. Little group. Spin, helicity. Massive and massless case

8.

(d) Discrete symmetries: C, P, T (*)

5. Free scalar field

2.

(a) Klein-Gordon real field. Propagator and causality

4.

(b) Continuous symmetries Noether theorem: associated charges and currents. Energy-momentum tensor

(c) Klein-Gordon complex field. Charge symmetry. Antiparticle.

(d) Wick theorem

6. Interaction

(a) Interaction picture, time ordering and S matrix

(b) Cross Section and S matrix

(c) Motivation for causal (free) fields

7. Interaction (scalar case). Tree level scattering for $\lambda\varphi^4$ and $\lambda\varphi^3$ theory

6.

8. Field for a massless spin-one particle: Electromagnetic field

9. Generalized Feynman rules

10. Scalar/Non-relativistic Quantum Electrodynamics (QED)

2.

(a) Quantization of scalar QED

4. (b) Elementary processes of scalar QED to $O(e^2)$ (tree level Feynman diagrams).

For example: $\pi^+K^- \to \pi^+K^-$, $\pi^+\pi^+ \to \pi^+\pi^+$, $\pi^+\pi^- \to \pi^+\pi^-$,
$K^+K^- \to \pi^+\pi^-$, and the scalar Compton scattering $\pi^-\gamma \to \pi^-\gamma$.

6.

(c) About gauge invariance. Ward identities

11. Non-relativistic Quantum Electrodynamics (QED)

(a) Quantization of Non-relativistic QED

8.

(b) Non-relativistic Quantum mechanics from Quantum Field Theory

(c) Decays. Radiative transitions of hydrogen

(d) Interaction with a classical field

12. Elements of Quantum Gravity (*)

(*) These items will be given depending on the evolution of the course

Learning activities and methodology

Title	Hours	ECTS	Learning outcomes
Problems class	16	0.64	3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Theoretical classes	33	1.32	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Problems solved in group or autonomously	30	1.2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Study of theoretical foundations	42	1.68	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Discussion, work in groups	22	0.88	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

There will be teaching lectures where the theory will be explained in detail.

There will be teaching lectures where a selection of the list of exercises will be discussed.

The student should digest at home the theory explained in class, and perform the list of exercises suggested during the lectures.

Annotation: within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continuous assessment activities

Title	Weight	Hours	ECTS	Learning outcomes
Homework	5%	1	0.04	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
Exam 1	45%	2	0.08	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19
resit exam	95%	2	0.08	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Exam 2	50%	2	0.08	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 19

1st partial exam: 45% of the grade.
2nd Partial exam: 50% of the grade.
Selective delivery of problems: 5% of the grade.

In order to be able to take part in the recovery exam, one should have been previously presented to both exams.
Examination of recovery of the two partials: 95% of the note. There is no minimum mark to be able to opt for the
recovery.

Unique assessment

Students who have accepted the single assessment modality will have to take a final test which will consist of a theory exam. You will then have to do a problem test. When it is finished, you will deliver the requested deliveries.The student's grade will be the weighted average of the three previous activities, where the theory exam will account for 45% of the grade, the problem exam 50% and the assignments 5%. If the final grade does not reach 5, the student has another opportunity to pass the subject through the remedial exam that will be held on the date set by the degree coordinator. In this test you will be able to recover 95% of the grade corresponding to theory and problems. The delivery part is not recoverable.

Bibliography

• A. Pineda, Introduction to Quantum Field Theory

• A. Cornellà and J.I. Latorre, Teoria clàssica de camps

• D. Lurie, Particles and Fields

• S. Weinberg, The Quantum Theory of Fields

• L.H. Ryder, Quantum Field Theory

• F.J. Yndurain, Elements of grup theory. https://arxiv.org/pdf/0710.0468

• C. Itzykson and J. Zuber, Quantum Field Theory

• S. Pokorsky, Gauge Field Theories

• B. Hatfield, Quantum Field Theory of Point Particles and Strings

• M. Peskin and D. Schroeder, An introduction to Quantum Field Theory

• J.F. Donoghue, E. Golowich, B.R. Holstein, Dynamics of the Standard Model

Software

General calculus programs like Mathematica

Course groups and languages

The information provided is provisional until November 30. After this date, you will be able to consult the language of each group through this link. To access the information, you will need to enter the course CODE

Type of teaching	Group	Language	Semester	Shift
(TE) Theory	1	English	second semester	morning-mixed
(PAUL) Classroom practices	1	English	second semester	afternoon