Introduction to Quantum Field Theory	2016/2017
Code: 42863 ECTS Credits: 6	

Degree	Type	Year	Semester
4313861 High Energy Physics, Astrophysics and Cosmology	OT	0	1

Contact

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Use of languages

Principal working language: english (eng)

Prerequisites

It is recommended to have followed the course Introduction to the Physics of the Cosmos.

Objectives and Contextualisation

The main purpose of this course is to learn the basic concepts and techniques behind the theory of quantum fields, with aplications to elementary particle physics, in particular Quantum Electrodynamics.

Skills

- Apply the main principles to specific areas such as particle physics, astrophysics of stars, planets and galaxies, cosmology and physics beyond the Standard Model.
- Formulate and tackle problems, both open and more defined, identifying the most relevant principles and using approaches where necessary to reach a solution, which should be presented with an explanation of the suppositions and approaches.
- Use acquired knowledge as a basis for originality in the application of ideas, often in a research context.
- Use critical reasoning, analytical capacity and the correct technical language and formulate logical arguments.
- Use mathematics to describe the physical world, select the appropriate equations, construct adequate models, interpret mathematical results and make critical comparisons with experimentation and observation.

Learning outcomes

1. Analyze the concept of renormalization and apply it in to electromagnetic processes.
2. Apply the language of Feynman diagrams in quantum field theory .
3. Apply quantum field theory electromagnetic processes.
4. Calculate cross sections of electromagnetic processes .
5. Understand the basics of quantum field theory.

Content

1. **Introduction**

1.1 Motivation

1.2 Elements of classical field theory.

1.2.1 Functional calculus.

1.2.2 Lagrangian and Hamiltonian. Euler-Lagrange equations.

1.3 Natural units

2. **Quantization of free fields**

2.1 Non-relativistic fields. Bosons and Fermions. Number operator and statistics.

2.2 Field of Klein-Gordon real. Propagators and causality.

2.3 Continuous symmetries. Noether theorem: currents and energy-momentum tensor.

2.4. Discrete symmetries: C,P,T.

2.5 Field of Klein-Gordon complex. Charge symmetry.

2.6 Dirac field. Propagators, symmetries, spin: helicity and quirality.

2.7 Electromagnetic field.

3. **Interaction**

3.1 Cross section and S matrix.

3.2 Interaction picture and S matrix.

3.3 Wick theorem.

3.4 First computation at tree level: $\lambda \phi^4$.

3.5 Feynman diagrams.

3.6 Decays.

4. **QED**

4.1 Quantization of QED.

4.2 S-matrix to $O(e^2)$.

4.3 Compton scattering at tree level. Feynman diagrams and computational techniques: traces, spin, ...

4.4 About gauge invariance. Example of Ward identity.

4.5 Generalized Feynman rules and for QED.

4.6 Other elementary QED processes at tree level: $e^+e^- \to \mu^+\mu^-$, ...

4.7 Radiative transitions of Hydrogen.

5. **Beyond tree level. Introduction**.

5.1 Infinities and dimensional regularization.

5.2 Vacuum polarization.

5.3 Renormalization of the electric charge.

5.4 Optical theorem.

6. **Beyond perturbation theory.**

6.1 LSZ formalism and crossing symmetry (examples).

Methodology

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.

Activities

Title	Hours	ECTS	Learning outcomes
Type: Directed			
Theory and problems	44	1.76	1, 2, 3, 4, 5
Type: Autonomous			
Study, exercises	85	3.4	1, 2, 3, 4, 5

Evaluation

Exam: 50%

Exercises delivery: 50%

Evaluation activities

Title	Weighting	Hours	ECTS	Learning outcomes
Exam	50%	3	0.12	1, 2, 3, 4, 5
Exercises delivery	50%	18	0.72	1, 2, 3, 4, 5

Bibliography

D. Lurie. Particles and Fields

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

L.H. Ryder. Quantum Field Theory

S. Weinberg. The Quantum Theory of Fields

C. Itzykson and J. Zuber. Quantum Field Theory