# Syllabus

## Subject

| | |
|---|---|
| **Subject / Group** | 11286 - Quantum Field Theory / 1 |
| **Degree** | Master's in Advanced Physics and Applied Mathematics |
| **Credits** | 3 |
| **Period** | 1st semester |
| **Language of instruction** | English |

### Professors

| Lecturers | Office hours for students | | | | | |
|---|---|---|---|---|---|---|
| | Starting time | Finishing time | Day | Start date | End date | Office / Building |
| Oreste Piro Perusin<br>oreste.piro@uib.es | You need to book a date with the professor in order to attend a tutoring session. | | | | | |

## Context

Quantum Field Theory (QFT) is the most successful physical framework to understand the world of sub-atomic particles and their interactions. The ultimate embodiment of this theory is the so called "Standard Model" widely accepted as the most accurate unified description at the quantum level of three of the four fundamental interactions in Nature (namely, the electromagnetic, weak and strong forces) with remarkable predictions whose experimental confirmation is now at the forefront of the fundamental physics. The QFT framework, however, applies to many other branches of physics -outside of high energy physics- wherever systems that involve a large (in fact infinite) number of coupled degrees of freedom arises such as in many instances of Condensed Matter and Statistical Mechanics. This course is an introduction to the collection of techniques developed for QFT as well as to the most striking applications mentioned above. Quantum Field Theory ispart of the Quantum Systems module of the Master inPhysics (FAMA) at the UIB.The course will be given either in Spanish or English upon students request.

Dr. Oreste Piro earned his PhD in Theoretical Physics at the National University of La Plata, Argentina, in 1984 where he also became professor in 1986. He has a wide and mutidiscilplinary reserach experience and his contributions expands overseveral branches of physics including Particle Physics and Field Theory, Plasma Physics,Dynamical Systems,Fluid Dynamics,Nolinear Physics, Biophysics, and others. He has worked in several top institutions such as The James Frank Institute(The University of Chicago), Los Alamos National Laboratory, Brookhaven National Laboratory,Queen Mary College at University of Londonand CNRS-University of Nice,France. Starting in 1980he has been in charge of many undergraduate and graduate courses spanning almost all areas of theoretical physics. He has more than 100 articles published in high impact journals, with over 1800 citations and a Hirsh number of 24.

## Requirements



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### Recommended

Its reccomended that the students have a solid knowledge of quantum mechanics and methods of mathematical physics at a graduate level.

## Skills

### Specific

* ESQ1: Understanding of the basic concepts involved in the quantification of systems with an infinite number of degrees of freedom.
* ESQ2: Knowledge of the most common analytical tools for quantum fields such as perturbation theory, Feynmann diagrams, renormalization group, etc. as well as their application to the fundamental interactions between elementary particles.
* CE1: Students must possess the learning skills that enable them to combine specialized knowledge in Astrophysics and Relativity, Geophysical Fluids, Materials Physics, Quantum Systems or Applied Mathematics, with the versatility that provides an open training curriculum.

### Generic

* CG1: Systematic understanding of a field of study and mastery of skills and methods of research associated with that field.
* CB7: Students can apply the broader (or multidisciplinary) acquired knowledge and ability to solve problems in new or unfamiliar environments within contexts related to their field of study.
* CB10: Students gain the learning skills that enable them to continue studying in a way that will be largely self-directed or autonomous.

### Basic

* You may consult the basic competencies students will have to achieve by the end of the Master's degree at the following address: http://estudis.uib.cat/master/comp_basiques/

## Content

### Range of topics

1. Introduction
   Classical fields and the need for their quantization. Second quantization. Canonical vs. Path integral quantization.

2. Quantum theory of scalar fields
   Cuantization of the Klein-Gordon field. Green functions and propagators. Scattering amplitudes, causalityand particle creation.

3. Interacting fields and perturbation theory
   A simple example of interacting fields: the phy-fourth model. Perturbation theory. Perturbation expansions of correlation functions. The Wick's theorem and Feynmann diagrams. Divergences and their regularization. Renormalization group.


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4. Quantization of spinor fields
   The Dirac equation. Quantization of the Dirac field. Spin and Statistics. The Dirac propagator. Symmetries. Grassman variables in the path-integral method.
5. Gauge Theories and their quantization.
   Global and local phase invariance. The necesity of gauge fields and the minimal substitution. Abelian and non-abelian gauge theories.Quantization of gauge theories. Quantum Electrodynamics. Electro-weak unification and an introduction to the Standard Model.

## Teaching methodology

### In-class work activities (1 credits, 25 hours)

| Modality | Name | Typ. Grp. | Description | Hours |
|---|---|---|---|---|
| Theory classes | Lectures | Large group (G) | The lecturer will give a basic introducion of the concepts related to each of the course contents and provide with examples and extensions to be elaborated autonomously by the student. | 18 |
| Practical classes | Exercises and Seminars | Large group (G) | To guide the student through the solution of problems and excercises related to the course program, and eventually present special topics and monitor the evolution and results of the autonomous self-study. | 5 |
| Assessment | Oral Presentation | Large group (G) | The student will orally present the results of his assigned project. | 2 |

At the beginning of the semester a schedule of the subject will be made available to students through the UIBdigital platform. The schedule shall at least include the dates when the continuing assessment tests will be conducted and the hand-in dates for the assignments. In addition, the lecturer shall inform students as to whether the subject work plan will be carried out through the schedule or through another way included in the Aula Digital platform.

### Distance education tasks (2 credits, 50 hours)

| Modality | Name | Description | Hours |
|---|---|---|---|
| Individual self-study | Individual project | The student will elaborate a subject proposed by the professor and write a detailed report to be submitted for asessment and orally defended. | 25 |
| Group or individual self-study | Theoretical complements and exercises | The student will resource to the sugested bibliography to complement the notions presented in the lectures and solve proposed problems and excersices. Both tasks will be logged on a notebook to be submitted for asessment. | 25 |


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### Specific risks and protective measures

The learning activities of this course do not entail specific health or safety risks for the students and therefore no special protective measures are needed.

## Student learning assessment

### Frau en elements d'avaluació

In accordance with article 33 of Regulation of academic studies, "regardless of the disciplinary procedure that may be followed against the offending student, the demonstrably fraudulent performance of any of the evaluation elements included in the teaching guides of the subjects will lead, at the discretion of the teacher, a undervaluation in the qualification that may involve the qualification of "suspense 0" in the annual evaluation of the subject".

#### Oral Presentation

| | |
|---|---|
| Modality | Assessment |
| Technique | Oral tests **(non-retrievable)** |
| Description | The student will orally present the results of his assigned project. |
| Assessment criteria | |

Final grade percentage: 20%

#### Individual project

| | |
|---|---|
| Modality | Individual self-study |
| Technique | Papers and projects **(retrievable)** |
| Description | The student will elaborate a subject proposed by the professor and write a detailed report to be submitted for asessment and orally defended. |
| Assessment criteria | |

Final grade percentage: 50%



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### Theoretical complements and exercises

| | |
|---|---|
| Modality | Group or individual self-study |
| Technique | Learning file **(retrievable)** |
| Description | The student will resource to the sugested bibliography to complement the notions presented in the lectures and solve proposed problems and excersices. Both tasks will be logged on a notebook to be submitted for asessment. |

Assessment criteria

Final grade percentage: 30%

## Resources, bibliography and additional documentation

### Basic bibliography

*An Introduction to Quantum Field Theory*, Michael E. Peskin & Daniel V. Schroeder, Perseus 1995
*Quantum Field Theory, a Modern Introduction*, Michio Kaku, Oxford Univ. Press 1993.

### Complementary bibliography

*The Quantum Theofy of Fields Vols I, II and III*, Steven Weinberg, Cambridge Univ. Press 2002

### Other resources

Otros recursosDiversos apuntes disponibles en internet.



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