

|               |                              |
|---------------|------------------------------|
| Academic year | 2017-18                      |
| Subject       | 11286 - Quantum Field Theory |
| Group         | Group 1, 1S                  |
| Syllabus      | A                            |
| Language      | English                      |

## Subject

|                 |                                                                 |
|-----------------|-----------------------------------------------------------------|
| <b>Name</b>     | 11286 - Quantum Field Theory                                    |
| <b>Credits</b>  | 1 in-class (25 hours) 2 distance (50 hours) 3 total (75 hours). |
| <b>Group</b>    | Group 1, 1S (Campus Extens)                                     |
| <b>Period</b>   | First semester                                                  |
| <b>Language</b> | English                                                         |

## Lecturers

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

## Context

Quantum Field Theory (QFT) is the most successful physical framework to understand the world of subatomic 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 is part of the Quantum Systems module of the Master in Physics (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 multidisciplinary research experience and his contributions expand over several branches of physics including Particle Physics and Field Theory, Plasma Physics, Dynamical Systems, Fluid Dynamics, Nonlinear 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 London and CNRS-University of Nice, France. Starting in 1980 he 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 Hirsch number of 24.

## Requirements

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### Recommended

It is recommended 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..
- \* ESQ3: Understanding of the basic concepts and techniques inherent in the characterization of interacting quantum systems..
- \* 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..
- \* CE2: Students must possess the ability to use and adapt mathematical models to describe physical phenomena of different nature..
- \* CE3: To acquire edge-line knowledge in the international scientific research context and demonstrate a full comprehension of theoretical and practical aspects, together with the scientific methodology..

#### 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/](http://estudis.uib.cat/master/comp_basiques/)

### Content

#### Theme content

##### 1. Introduction

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

##### 2. Quantum theory of scalar fields

Quantization of the Klein-Gordon field. Green functions and propagators. Scattering amplitudes, causality and particle creation.

3. Interacting fields and perturbation theory

A simple example of interacting fields: the  $\phi^4$  model. Perturbation theory. Perturbation expansions of correlation functions. The Wick's theorem and Feynmann diagrams. Divergences and their regularization. Renormalization group.

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 necessity 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

| Modality          | Name                   | Typ. Grp.       | Description                                                                                                                                                                                                  | Hours |
|-------------------|------------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| Theory classes    | Lectures               | Large group (G) | The lecturer will give a basic introduction 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 exercises 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 Campus Extens platform.

### Distance education work activities

| 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 assessment and orally defended. | 25    |



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| Modality                       | Name                                  | Description                                                                                                                                                                                                                    | Hours |
|--------------------------------|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| Group or individual self-study | Theoretical complements and exercises | The student will resource to the suggested 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    |

### 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

#### Oral Presentation

|                         |                                                                      |
|-------------------------|----------------------------------------------------------------------|
| Modality                | Assessment                                                           |
| Technique               | Oral tests ( <b>non-retrievable</b> )                                |
| 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 ( <b>retrievable</b> )                                                                                                    |
| 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%                                                                                                                                           |

#### Theoretical complements and exercises

|                         |                                                                                                                                                                                                                                |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Modality                | Group or individual self-study                                                                                                                                                                                                 |
| Technique               | Learning file ( <b>retrievable</b> )                                                                                                                                                                                           |
| Description             | The student will resource to the suggested 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





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*Quantum Field Theory, a Modern Introduction*, Michio Kaku, Oxford Univ. Press 1993.

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### Complementary bibliography

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

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### Other resources

Otros recursosDiversos apuntes disponibles en internet.

