COURSE DATA

DATA SUBJECT

Code: 43293
Name: Quantum field theory 2
Cycle: Master's Degree
ECTS Credits: 6
Academic year: 2025-26

STUDY (S)

Degree	Center	Acad. year	Period
2150 - Master's degree in Advanced Physics	Facultat de Física	1	First quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
2150 - Master's degree in Advanced Physics	Fundamental interactions	ELECTIVES

COORDINATION

NAVARRO SALAS JOSE

SUMMARY

In the Quantum Field Theory II course the student will learn the elements of quantum field theory at an advanced level. The course covers the following topics: i) QFT and particle creation by external sources. ii) Operator approach to QFT. Regularization and renormalization. Renormalization group. iii) Functional integral approach to QFT. Symmetries, Ward identities and anomalies. iv) One-loop divergences and renormalization of QED. v) Non-abelian gauge theories. Perturbative quantization.

Some other advanced aspects QFT may be covered as well.

PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

There are no specified enrollment restrictions with other subjects of the curriculum.

OTHER REQUIREMENTS

COMPETENCES / LEARNING OUTCOMES

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Analizar una situación compleja extrayendo cuales son las cantidades físicas relevantes y ser capaz de reducirla a un modelo parametrizado.

Comprender de una forma sistemática el campo de estudio de la Física y el dominio de las habilidades y métodos de investigación relacionados con dicho campo.

Concebir, diseñar, poner en práctica y adoptar un proceso sustancial de investigación con seriedad académica.

Conocer y saber utilizar la invariancia de gauge local como punto de partida en la formulación de las interacciones fundamentales.

Elaborar una memoria clara y concisa de los resultados de su trabajo y de las conclusiones obtenidas en el área de la Física.

Estar en disposición para seguir los estudios de doctorado y la realización de un proyecto de tesis doctoral.

Evaluar la validez de un modelo o teoría propuesto por otros miembros de la comunidad científica.

Exponer y defender públicamente el desarrollo, resultados y conclusiones de su trabajo en el área de la Física.

Ostentar la preparación para tomar decisiones correctas en la elección de tareas y en su ordenación temporal en su labor investigadora y/o profesional.

Poseer la capacidad para el desarrollo de una aptitud crítica ante el aprendizaje que le lleve a plantearse nuevos problemas desde perspectivas no convencionales.

Realizar un análisis crítico, evaluación y síntesis de ideas nuevas y complejas en el área de la Física.

Saber construir modelos de acuerdo con el contenido en partículas y en simetrías de la teoría. Analizar y comprender los límites de validez de las teorías físicas.

Saber modelizar matemáticamente los problemas físicos sencillos nuevos, conectados con problemas conocidos. Ser capaz de expresar en términos matemáticos nuevas ideas.

Saber organizarse para planificar y desarrollar el trabajo dentro de un equipo con eficacia y eficiencia.

Ser capaz de gestionar información de distintas fuentes bibliográficas especializadas utilizando principalmente bases de datos y publicaciones internacionales en lengua inglesa.

Students should apply acquired knowledge to solve problems in unfamiliar contexts within their field of study, including multidisciplinary scenarios.

Students should be able to integrate knowledge and address the complexity of making informed judgments based on incomplete or limited information, including reflections on the social and ethical responsibilities associated with the application of their knowledge and judgments.

Students should communicate conclusions and underlying knowledge clearly and unambiguously to both specialized and non-specialized audiences.

Students should demonstrate self-directed learning skills for continued academic growth.

Students should possess and understand foundational knowledge that enables original thinking and research in the field.

DESCRIPTION OF CONTENTS

1. QFT and particle creation by external sources

Canonical quantization. Vacuum energy. Quantum fields under external conditions. Scalar and electromagnetic sources. Particle creation and the Schwinger effect. QFT in an expanding universe. Particle creation and the frequency-mixing mechanism. Black holes and the Hawking effect.

2. Operator approach to QFT. Regularization and renormalization. Renormalization group

S matrix and time-ordered products. LSZ reduction formula. Perturbative expansion. Feynman rules. The Kallen-Lehmann spectral representation.One-loop divergences in scalar field theories. Dimensional regularization. Schwinger-Feynman parametrization. UV divergences and power counting.
Renormalized perturbation theory. Counterterms and renormalization schemes. On-shell and Minimal subtraction schemes. Coupling constant, mass, and wave-function renormalization. Renormalization group.

Beta functions, anomalous dimensions. Running coupling constants.

3. Functional integral approach to QFT. Symmetries, Ward identities and anomalies

Generating functional. Functional integral. Interactions and Feynman rules. Complements. path integrals in quantum mechanics. Gaussian integrals. Gauge invariance. Path integrals for fermions. Path integrals for spin 1 fields. Faddeed-Popov method. Ghost fields. Schwinger-Dyson equations. Symmetries in QFT. Ward identities. Anomalies

4. One-loop divergences and renormalization of QED

Detailed one-loop calculations in QED: vacuum polarization, electron-self-energy, electron-photon vertex. Ward identity.

5. Non-abelian gauge theories. Perturbative quantization

Basic facts about Lie algebras and representations. Non-Abelian gauge theories. Yang-Mills Lagrangian and theta angle. Gauge redundancies and gauge fixing. Quantization of gauge fields by the Faddeed-Popov method. Ghost fields. Feynman rules for gauge theories. BRS symmetry. Renormalization of gauge theories. Beta function of SU(N) Yang-Mills theory.

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Theory	40,00
Seminar	3,00
Other activities	3,00
Total hours	**46,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	21,00
Independent study and work	0,00
Preparation of lessons	43,00
Preparation for assessment activities	0,00
Resolution of case studies	40,00
Total hours	**104,00**

TEACHING METHODOLOGY

1) Lectures, covering the topics of the curs.

2) Resolution of a series of proposed sets of guided exercices.

EVALUATION

The evaluation of the subject will be based on:

- Written examination on the lectures and practices: based on learning outcomes and specific objectives of the course (50%). Usually, due to the extension of the exercicies and questions, the final examination will be in the form of a take-home-exam.

- Continuous evaluation of the student in the lectures and practices: resolution of proposed problems

(50%).

This evaluation system will be used for both the first and second call.

REFERENCES

- T.P Cheng and L.-F.Li, Gauge theory of elementary particle Physics, 1984, Oxford University Press.
- C. Itzykson and J.B. Zuber, "Quantum Field Theory", McGraw-Hill, 1980
- M. E. Peskin and D. V. Schroeder, An Introduction to Quantum Field Theory, Reading, MA: Addison-Wesley (1995).
- M. D. Schwartz, Quantum Field Theory and the Standard Model, Cambridge University Press, 2014
- M. Srednicki, Quantum Field Theory, Cambrdige University Press (2007)
- A. Zee, Quantum Field Theory in a nutshell, Princenton University Press, 2010