



COURSE DATA

Data Subject

Code	43295
Name	Strong interactions
Cycle	Master's degree
ECTS Credits	6.0
Academic year	2023 - 2024

Study (s)

Degree	Center	Acad. year	Period
2150 - M.D. in Advanced Physics	Faculty of Physics	1	First term

Subject-matter

Degree	Subject-matter	Character
2150 - M.D. in Advanced Physics	2 - Fundamental interactions	Optional

Coordination

Name	Department
PAPAVASSILIOU, JOANNIS	185 - Theoretical Physics

SUMMARY

In the course “**Strong interactions**” the student will learn a plethora of basic concepts and techniques about Quantum Chromodynamics (QCD). We will study the symmetries of the QCD Lagrangian, its covariant path integral quantization, and will derive the Feynman rules describing the interaction between gluons, quarks, and ghosts. One-loop results will be computed in detail, and the concepts associated with renormalization and the asymptotic freedom will be introduced. A brief introduction to non-perturbative techniques will be presented.

PREVIOUS KNOWLEDGE



Relationship to other subjects of the same degree

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

Other requirements

Quantum Field Theory

OUTCOMES

2150 - M.D. in Advanced Physics

- 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.
- Ser capaz de gestionar información de distintas fuentes bibliográficas especializadas utilizando principalmente bases de datos y publicaciones internacionales en lengua inglesa.
- Saber organizarse para planificar y desarrollar el trabajo dentro de un equipo con eficacia y eficiencia.
- 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.
- Estar en disposición para seguir los estudios de doctorado y la realización de un proyecto de tesis doctoral.
- 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.
- Realizar un análisis crítico, evaluación y síntesis de ideas nuevas y complejas en el área de la Física.
- Analizar una situación compleja extrayendo cuales son las cantidades físicas relevantes y ser capaz de reducirla a un modelo parametrizado.
- Evaluar la validez de un modelo o teoría propuesto por otros miembros de la comunidad científica.
- Saber modelizar matemáticamente los problemas físicos sencillos nuevos, conectados con problemas conocidos. Ser capaz de expresar en términos matemáticos nuevas ideas.
- Elaborar una memoria clara y concisa de los resultados de su trabajo y de las conclusiones obtenidas en el área de la Física.
- Exponer y defender públicamente el desarrollo, resultados y conclusiones de su trabajo 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.
- Conocer y saber utilizar la invariancia de gauge local como punto de partida en la formulación de las interacciones fundamentales.
- Comprensión de las propiedades fundamentales de la interacción fuerte (confinamiento, libertad asintótica y simetría quiral) y su relación con la distancia.

LEARNING OUTCOMES

At the end of the teaching-learning process the student will have learned to:

1. Select and correctly use various sources of information in both traditional and electronic format. Know the basics of file own field: inspire, spiers, arXiv.
2. Properly handle and interpret qualitative and quantitative physical data which validate the known theories in the field.
3. Analyze information from physical systems.
4. Prepare documents and reports in a text written in an understandable way organized, documented and illustrated.
5. Articulate oral discourse, structured, consistent, with good diction and use of technical vocabulary.
6. Understand the arguments used in the field of theoretical physics.
7. Understanding the mathematical description of physical processes of particle creation and destruction. Understanding the formalism of quantum field theory in the mathematical description of physical models.
8. Use the basic concept of a constituent of matter. Knowing the phenomenology of elementary particles. Know how to classify the elementary particles and fundamental interactions.
9. Describe the processes of collision and disintegration of particles at the tree. Being able to develop and use the techniques of approximation in the calculation of particle interactions. Being able to predict physical quantities (cross sections, lifetimes, ...) of particles from a given theory.



10. Understand the concept of particle-mediated interaction and the methodology of quantum field theory.

DESCRIPTION OF CONTENTS

1. Quarks and colour

The quark model. Colour. Jets. Confinement.
Asymptotic freedom.

2. The QCD Lagrangian

Gauge symmetry. QED. $SU(N)$ gauge theory.
Gluons. Global symmetries

3. Covariant quantization-Faddeev-Popov construction

Introduction to path integral quantization. Gauge fixing and ghosts.
Feynman rules of QCD.

4. One-loop calculations

Dimensional regularization and Feynman parametrization.
Self-energies of gluon, ghost, quark.

5. Renormalization of QCD

Classification of divergences. Superficially
divergent diagrams. Renormalization

6. Renormalization group

Effective running coupling. Asymptotic
freedom. Anomalous dimensions. Quark masses.

7. BRST symmetry

BRST symmetry. Derivation of Slavnov-Taylor identities.
Comparison with Ward-Takahashi identities.

**8. Optical theorem and ghosts**

The optical theorem in general.

The case of gluons as external states and the role of the ghosts

9. Nonperturbative aspects

Lattice formulation of gauge theories.

Introduction to Schwinger-Dyson equations.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	40,00	100
Seminars	3,00	100
Other activities	3,00	100
Development of group work	10,00	0
Development of individual work	11,00	0
Preparing lectures	43,00	0
Preparation of practical classes and problem	40,00	0
TOTAL	150,00	

TEACHING METHODOLOGY

MD1 - Standar theory lecture

MD2 - Discussion of articles (readings).

MD3 - Problem solving

MD4 - Problems

MD8 - Conference of experts

EVALUATION

SE1 - Written exam on the theory and practical lectures: based on the results of learning and the specific objectives of each subject (50%).



SE5 - Evaluation of non-presential activities related to theory and practical lectures: Problem sets submitted (50%).

REFERENCES

Basic

- P. Pascual y R. Tarrach, QCD: Renormalization for the Practitioner, Springer-Verlag, 1984.
- F. J. Yndurain, The theory of Quark and Gluon Interactions, 4Ed, Springer-Verlag, 2006, ISBN 354033209X.
- T. Muta, Foundations of Quantum Chromodynamics, World Scientific, 1987