COURSE DATA

DATA SUBJECT

Code: 43291
Name: Elementary particles
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	Introduction to theoretical physics	ELECTIVES

COORDINATION

SANZ GONZALEZ VERONICA

SUMMARY

In the Elementary Particles course, students will learn the phenomenology of elementary particles, their classification, and the fundamental interactions. The course includes an introduction to quantum field theory, symmetries and conservation laws, and the basics of the Standard Model and its possible extensions. Experimental aspects and connections with cosmology will also be addressed.

PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

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

OTHER REQUIREMENTS

A prior background in quantum mechanics, special relativity, and modern physics at undergraduate level is recommended.

COMPETENCES / LEARNING OUTCOMES

2150 - Master's degree in Advanced Physics

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

Conocer la fenomenología de las partículas elementales. Conocer cómo se clasifican las partículas elementales y las interacciones fundamentales. Comprender la relación entre el microcosmos y la formación del macrocosmos.

Conocer los dispositivos experimentales. Conocer la experimentación con la materia elemental y manejar los resultados.

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.

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.

DESCRIPTION OF CONTENTS

1. Introduction to Elementary Particle Physics

From Democritus to the LHC. Basic concepts of particle physics. Types of particles: fermions and bosons. Classification according to interactions. Energy scales in the universe. Motivation for studying elementary particles.

2. Scalar fields

Classical fields and Lagrangian formulation. Klein-Gordon field. Symmetries and conservation laws. Noether¿s theorem. Relativistic kinematics and Mandelstam variables.

3. Fermionic fields

The Dirac equation and spinors. Antiparticles and the Dirac sea. Electron spin. Helicity and the case of the neutrino. Chirality and parity. Fermi¿s Lagrangian.

4. Quantization of free fields

Canonical quantization of the Klein-Gordon field. The vacuum and particles. The Feynman propagator.

5. Interacting fields

Teoria primitiva de Yukawa. Teoria φ^4. Camps de gauge. El mecanisme de Higgs.

6. The strong interaction and quarks

Isospin. Strangeness. Quark model of hadrons. Parity and charge conjugation. Classification of hadrons: multiplets. Additional flavours.

7. The Glashow-Weinberg-Salam model of the electroweak interaction

Fermi¿s contact interaction, V-A interaction and massive vector bosons. The GWS model, the Higgs boson and the origin of mass. Flavour phenomenology.

8. Quantum Chromodynamics and Strong Interaction Phenomena

Introduction to QCD as a non-Abelian gauge theory. Experimental evidence for quarks and color. Energy scales and behaviour of the strong coupling. Confinement and asymptotic freedom. Jet production and QCD signatures in colliders. Effective models for hadrons.

9. Physics beyond the Standard Model

Limitations of the Standard Model and motivations for new physics: mass hierarchy, dark matter, massive neutrinos, symmetry assumptions. Theoretical extensions: supersymmetry, extra dimensions, extended gauge models. Experimental techniques for the search of new physics in colliders and precision measurements. Connections to astrophysics and cosmology.

10. Cosmology and Particle Physics

Introduction to the early universe and its evolution. Cosmic inflation and observational consequences. Matter formation and its relation to fundamental interactions. Cosmic neutrinos and thermal decoupling. Dark matter and dark energy. Cosmological bounds on new physics. Primordial gravitational waves as a probe of high-energy phenomena.

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	10,00
Independent study and work	0,00
Preparation of lessons	43,00
Preparation for assessment activities	11,00
Resolution of case studies	40,00
Total hours	**104,00**

TEACHING METHODOLOGY

MD1 - Theoretical classes with participative lectures.
MD2 - Discussion of selected articles (readings).
MD3 - Problem-solving sessions.
MD4 - Assigned problems.
MD8 - Guest lectures by experts.

EVALUATION

The evaluation will consist of a written exam (70% of the final grade) and a collaborative project with an oral presentation (30%). To pass the course, students must achieve at least 4 out of 10 in the written exam.

This evaluation system will apply to both the first and second examination periods.

Students are expected to use artificial intelligence tools responsibly. Any AI-assisted work must be explicitly acknowledged and must not replace genuine learning or compromise academic integrity.

REFERENCES

Basic References:

David Griffiths, Introduction to Elementary Particles, Wiley-VCH, 2008.

Edward W. Kolb and Michael S. Turner, The Early Universe, Addison-Wesley Publishing Company, 1990.

Michael E. Peskin and Daniel V. Schroeder, An Introduction to Quantum Field Theory, CRC Press Press, 1995.