COURSE DATA

Data Subject	
Code	34264
Name	Nuclear and particle physics
Cycle	Grade
ECTS Credits	7.5
Academic year	2021 - 2022

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	4	First term

Subject-matter

Degree	Subject-matter	Character
1105 - Degree in Physics	15 - Expansion of Physics	Obligatory

Coordination

Name	Department
DIAZ MEDINA, JOSE	180 - Atomic, Molecular and Nuclear Physics
MARTINEZ VIDAL, FERNANDO	180 - Atomic, Molecular and Nuclear Physics

SUMMARY

Nuclear and Particle Physics is a compulsory subject that is taught in the first quarter of the fourth year of undergraduate studies in Physics. It comprises a total of 7.5 credits, of which 4.5 are theoretical, 1.5 are theoretical-practical (problem solving), and 1.5 laboratory work. This course is part of the Expansion of Physics, and allows the graduate acquire basic knowledge about the structure of matter and its properties.

Nuclear Physics is the scientific discipline that studies the atomic nuclei, their properties and the forces acting between its constituents (protons and neutrons, generically called nucleons). Today we know that nucleons are in turn composed of even more fundamental physical systems called quarks, which do not have structure and are also constituents of what we call elementary particles. Particle Physics studies the constituents of matter at its most fundamental level, understanding the patterns of elementary particles and the properties and laws governing their interactions. Both Nuclear and Particle Physics have a character of fundamental science, but today there are countless applications in several areas: scientific, industrial, medical, etc. Therefore, a modern approach to the subject requires the presentation of both basic and applied science contents.

The general aspects in which lies the importance of this discipline and that have been considered to define the content and approach of the subject are the following:

- Understanding the fundamental structure of matter and their interactions has been and remains today one of the greatest intellectual and technological challenges of mankind since the late nineteenth century. In addition, the study of nuclear and subnuclear matter has been instrumental in the evolution of Physics.
- Nuclear and Particle Physics is related to a variety of research areas of great relevance today, such as Nuclear Astrophysics, Astroparticles, Solid State Physics, Nanoscience and Nanotechnology, Quantum Computation, etc.
- The technical requirements associated with the development of this discipline have led to a large number of technological applications that have direct impact on improving our life quality. These include accelerators, nuclear medicine (for both diagnosis and therapy), energy sources, industrial applications of all kinds, telecommunications, environmental protection, etc.

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 good knowledge of basic subjects studied in previous courses, especially Quantum Physics and Electromagnetism, is required. It is recommended to pursue this matter together with Quantum Mechanics, Classical Electrodynamics and Solid State Physics. Additional subjects are Atomic Physics and Radiation, Nuclear Instrumentation, Advanced Quantum Mechanics and Quantum Field Theory. Semiconductor Physics and Electronics are also a good complement to the instrumental aspects of the subject.

OUTCOMES

1105 - Degree in Physics

- Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.
- To know how to apply the knowledge acquired to professional activity, to know how to solve problems and develop and defend arguments, relying on this knowledge.
- Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .
- Theoretical understanding of physical phenomena: have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena).

- Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.
- Physics general culture: Be familiar with the most important areas of physics and with those approaches which span many areas in physics, or connections of physics with other sciences.
- Basic & applied Research: acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.
- Foreign Language skills: Have improved command of English (or other foreign languages of interest) through: use of the basic literature, written and oral communication (scientific and technical English), participation in courses, study abroad via exchange programmes, and recognition of credits at foreign universities or research centres.
- Literature Search: be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development.
- Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.
- Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.
- Students must have acquired knowledge and understanding in a specific field of study, on the basis of general secondary education and at a level that includes mainly knowledge drawn from advanced textbooks, but also some cutting-edge knowledge in their field of study.
- Students must be able to apply their knowledge to their work or vocation in a professional manner and have acquired the competences required for the preparation and defence of arguments and for problem solving in their field of study.
- Students must have the ability to gather and interpret relevant data (usually in their field of study) to make judgements that take relevant social, scientific or ethical issues into consideration.
- Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.
- Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

LEARNING OUTCOMES

- To know which are the ultimate constituents of matter as well as the characteristics of their interactions and the associated conservation laws.
- To understand the building blocks of the atomic nuclei and its basic properties: binding energies, sizes and forms, decay modes, electromagnetic properties, etc.
- Learn some of the main scientific, medical, energetic, industrial, environment, etc. applications of the field.

- To acquire an historical perspective of the development of the discipline since the end of the 19th century, as a tool to show the students how the scientific method works and gives raise to new knowledge from the complex relation between theory, experiment and technology.
- To know some of the devices and experimental techniques in Nuclear and Particle Physics, which have allowed (and allow) to accumulate all the necessary information to identify, characterize, model, etc.
- To start the student in the usage of basic ionizing radiation detectors, encapsulated radioactive sources and the application of basic radiological protection procedures.
- To develop abilities for systematic and well organized laboratory work, produce scientific reports, and make oral scientific presentations.

DESCRIPTION OF CONTENTS

1. Theory

1. Objectives, limitations and methods of Nuclear and Particle Physics.
2. Radiation sources: particle accelerators, cosmic rays and radioactive sources.
3. Interaction of radiation with matter.
4. Overview of particle detectors.
5. Interactions, kinematics, phase space. Decay processes. Alpha, beta and gamma decays. Observables.
6. The nucleon-nucleon interaction. Spin, isospin and parity. Hadrons: baryons, mesons and resonances.
7. Nuclear sizes, shapes and moments.
8. Nuclear binding energies. Semi-empirical mass formula. Nuclear stability.
9. Nuclear models: shell and collective. Alpha decay. Fission.
10. Particle phenomenology: interactions, classification, conservation laws and structure. Strangeness. Quark model of hadrons.
11. Symmetries: P, C, CP, T, CPT. Flavour oscillations. Isospin.
12. Quantum electrodynamics. Feynman diagrams.
13. Weak interactions. Fermi model. P violation and V-A interaction. Cabibbo mixing.
14. Standard electroweak model. GIM and KM mechanisms. CP violation. Higgs mechanism.
15. Strong interactions. Quantum chromodynamics.
16. Neutrinos.
17. Nuclear and Particle Astrophysics. The primitive universe.
18. Applications of Nuclear and Particle Physics to medicine, energy and other fields.

2. Laboratory

1. Introduction to the laboratory particle detectors and data processing.
2. Experiment 1: plateau curve and counting statistics with a Geiger-Müller detector, beta spectrum and Kurie plot using a magnetic spectrometer, time resolution.
3. Experiment 2: gamma spectroscopy with a NaI (Tl) detector, study of photon scattering, photon attenuation in lead, half-life of a nuclear state.
4. Experiment 3: direct observation of particles with a diffusion cloud chamber, atmospheric radon

concentration, decay in flight of cosmic muons.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	60,00	100
Laboratory practices	15,00	100
Development of individual work	47,50	0
Preparation of evaluation activities	20,00	0
Preparing lectures	30,00	0
Preparation of practical classes and problem	15,00	0
TOTAL	**187,50**	

TEACHING METHODOLOGY

The subject has three parts each with a different methodology:

Theory lectures. There will be three lectures (sessions) per week during the quarter, of masterful character, where the contents of the subject will be showcased. There will be special emphasis on the understanding of the physics behind the concepts (rather than in its formalism), the relationship with other concepts previously introduced (in the same or other courses), and the implications on experiments or theoretical models and its practical applications. The teacher will promote the participation of students through direct questions, both conceptual and practical, that students should evaluate by themselves and answer openly and with 'no fear' in the classroom. Whenever possible, long formal proofs will be avoided; in those cases where these are necessary only the main steps shall be indicated so that the student should be able to reproduce them completely as part of its individual work. The use of electronic presentations looks especially appropriated for the lectures due to its high content of graphics showing experimental results, comparisons with theory, diagrams, schemes, tables, experimental devices and practical applications, and all kinds of visual material that allows the student to relate the contents with their applications. These presentations can be used as teacher's notes. However, by no means the student's individual work should be restricted to them. The use of the bibliography is essential to understand the contents and achieve the course objectives. The teacher will provide this material to students through the Aula Virtual platform prior to the start of each unit.

Practical sessions. The weekly practical class will focus on problem solving. The teacher will deliver previously the collection of exercises, either directly or through the virtual classroom platform. The exercises in the collection will be of two types. First, problems to be solved in the classroom, in general reference exercises, that will be worked by the teacher mainly on the blackboard with the participation of the students. Second, proposed problems, addressed to the students as part of their individual work and evaluation. With this arrangement it is intended that the practical classes serve as an illustration of techniques and procedures discussed in the theory lectures, thus contributing to learning by carrying out standard exercises and problems that, as far as possible, refer to real practical situations. The development of the practical sessions will closely follow that of the theory lectures, avoiding time lags and ensuring that the minimum necessary theoretical background is available.

Laboratory sessions. Laboratory activities are the best teaching tool to complement the contents of the subject discussed in the classroom. Laboratory classes aim to illustrate the content of the classroom; train the students in the usage of experimental devices and measurement techniques; and empower the training in the scientific method and skills to analyze experimental data and the abilities to interpret and evaluate the experimental results on the light of the physics behind. These classes consist of 5 sessions of 3 hours each one. Attendance at these sessions is mandatory and a necessary condition to pass the course. Scripts containing the description of the different experiments will be provided to the students before the start of each session through the virtual platform, thus the students have to come to the laboratory having read carefully the script. The experiments are carried out by groups of two students. At the beginning of the session, the teacher will oversee the understanding of the script and will help the students to understand the conceptual and technical aspects necessary to properly perform the assembly of the experimental setup and the data acquisition. Each student must have a laboratory logbook (either electronic or handwritten) where he/she has to register the most relevant aspects (data, calculations, observations, etc.) of the experimental development.

EVALUATION

The evaluation system is as follows:

1) Written exam: a first part will assess the understanding of the theoretical and conceptual aspects of the subject, both through conceptual/numerical questions and simple case examples. A second part will assess the ability for problem solving. Correct argumentation and adequate justification are essential.

2) Continuous evaluation: assessment of the activities, questions and problems closely related to aspects discussed in the classroom proposed to the students, oral presentations of solved exercises, or any other method involving close student-teacher interaction. Likewise, attendance to and active participation in the classroom will be highly valued as a fundamental element of such interaction.

3) Laboratory evaluation: continuous evaluation based on the in-situ student’s tracking and the experiments’ reports, in which the fundamental aspects of the experimental work, data analysis and critical discussion of the results should be summarized.

The weight for each of the previous sections will be 50, 20 and 30 out of 100, respectively. To compensate between the different sections and pass the course, students will need to obtain a minimum score of 4 out of 10 in sections 1) and 3).

REFERENCES

Basic

- A. Ferrer, Física Nuclear y de Partículas, PUV, 2015 (3a ed).
- E. M. Henley, A. García, Subatomic Physics, World Scientific, 2007 (3rd ed). Solutions manual, 2008 (3rd ed).

- K. S. Krane, Introductory Nuclear Physics, Wiley, 1987.
- A. Bettini, Introduction to Elementary Particle Physics, Cambridge University Press, 2014 (2nd ed) & 2008 (1st ed).

Additional

- W.S.C. Williams, Nuclear and Particle Physics, Oxford University Press, 1991. Solutions Manual for Nuclear and Particle Physics, 1994.
- D. Griffiths, Introduction to Elementary Particles, Wiley, 2008 (2nd ed), 1987 (1st ed).
- J. Lilley, Nuclear Physics. Principles and Applications, John Wiley & Sons, 2001.
- B. R. Martin, G. Shaw, Particle Physics, Wiley, 2017 (4th ed).
- W.M. Gibson, B.R. Pollard, Symmetry principles in elementary particle physics, Cambridge University Press, 1976.
- Y. Lim, Problems and solutions on Atomic, Nuclear and Particle Physics, World Scientific, 2007.
- G.F. Knoll, Radiation detection and measurements, Wiley, 2010 (4th ed).

ADDENDUM COVID-19

This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council

TEACHING METHODOLOGY:

In case that health situation requires blended teaching, the teaching model approved by the Academic Degree Committee on July 23, 2020 will be adopted.

— Compulsory subjects: 50% student attendance in the classroom, while the rest of students attend the class in streaming broadcast. Two groups will be set with alternate days attendance to the classroom in order to guarantee 50% of teaching hours attendance for all students. Laboratory sessions will have a 100% attendance.

— Optional subjects: 100% attendance in all activities.

If a total reduction in attendance is necessary, classes will be broadcast by synchronous videoconference at their regular schedule, along the period determined by the Health Authority.