

**COURSE DATA****Data Subject**

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|----------------------|------------------------------|
| Code | 34273 |
| Name | Atomic and radiation physics |
| Cycle | Grade |
| ECTS Credits | 4.5 |
| Academic year | 2022 - 2023 |

Study (s)

| Degree | Center | Acad. Period |
|--------------------------|--------------------|---------------------|
| 1105 - Degree in Physics | Faculty of Physics | 4 Second term |

Subject-matter

| Degree | Subject-matter | Character |
|--------------------------|-----------------------------|------------------|
| 1105 - Degree in Physics | 16 - Complements of Physics | Optional |

Coordination

| Name | Department |
|------------------------|---|
| VIJANDE ASENJO, JAVIER | 180 - Atomic, Molecular and Nuclear Physics |

SUMMARY

Atomic and Radiation Physics is a subject that is taught on an optional basis in the 2nd quarter of the 4th year of undergraduate studies in Physics. It comprises a total of 4.5 ECTS 3 ECTS of which are theoretical and theoretical-practical 1.5 ECTS (problem solving). This subject matter is part of Complements of Physics and enable students to supplement their knowledge of Atomic and Nuclear Physics.

It is intended that the student after the course to obtain a thorough knowledge of atomic and ionizing radiation. This is studied first, atomic structure and behavior of atoms in magnetic fields, then we study the modes of interaction of radiation with matter. Finally, we present the most important technological applications of radiation physics.

Different disciplines such as medical physics, nuclear physics or particle physics, require knowledge of Atomic Physics and Radiation, so this course is particularly recommended for students wishing to specialize in one of these branches Physics.

**PREVIOUS KNOWLEDGE****Relationship to other subjects of the same degree**

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

Other requirements

To take this subject, knowledge of Quantum Physics I, Mathematical Analysis, Mechanics and Electromagnetism is required. Other subjects as Quantum Physics II and Nuclear and Particle Physics are convenient to deepen into certain aspects of this subject, although not indispensable. The Nuclear Instrumentation subject can be studied simultaneously.

COMPETENCES (RD 1393/2007) // LEARNING OUTCOMES (RD 822/2021)**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.
- Ability to collect and interpret relevant data in order to make judgements.
- 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 .
- 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 (RD 1393/2007) // NO CONTENT (RD 822/2021)**SKILLS TO ACQUIRE**

- Knowledge of the evolution of concepts in Atomic Physics and their historical evolution.
- Knowledge of the structure and spectroscopy of monoatomic atoms and its application to Astrophysics and other non-atomic systems.
- Knowledge of the structure and spectroscopy of complex atoms.
- Interpretation of the chemical properties of the elements and the structure of the periodic table in terms of atomic structure.
- Knowledge of the behavior of atoms in electric and magnetic fields and their spectroscopy, with applications to Astrophysics.
- Knowledge of the spectroscopic characteristics of X-rays, their production and their application to elemental analysis methods such as X-ray fluorescence
- Knowledge of atomic structure.
- Knowledge of different types of radiation and its mechanisms of production.
- Compression of the different processes of interaction of photons with matter
- Understanding the mechanisms of interaction of charged particles with matter
- Compression of the mechanisms of interaction of neutrons with matter
- Knowledge of the key measures of protection against radiation
- Knowledge of some important applications of radiation physics.

SOCIAL SKILLS

- Develop critical thinking skills and application of scientific method.
- Be able to identify problems, including the similarities with others whose solution is known, and devise strategies for their solution.
- Develop the ability to plan and organize own learning, based on individual work, from the literature and other sources.
- Evaluate the different causes of a phenomenon and its relative importance.



- Identify the essential elements of a complex situation, make the approximations needed to construct simplified models that describe and to understand their behavior and in other situations.
- Be able to perform an update of existing information on a specific problem, sort and analyze it critically.
- Building capacity to work together in addressing the complex problems that require collaboration with others.
- To promote the acquisition of resources for speaking and writing to carry out a clear and coherent scientific argument.
- Encourage communication skills of the physical concepts involved in a problem by speaking and writing.
- Promote understanding and use of new information technologies.
- Rigor when assessing the work yourself. Encourage critical thinking and encourage the spirit of excellence to unexpected or erroneous results.
- Ability to argue from rational and scientific criteria, both academic and informative, avoiding those social prejudices.
- Ability to identify and assess the importance of concepts and scientific resources studied their applications to other fields of science and improved social welfare.
- Attitudes and values that create conditions for developing ethical behavior in the development of professional activity.

DESCRIPTION OF CONTENTS

1. The atom an its components

Atoms and molecules.
Atomic weights.
Avogadro's number.
The components of the atom. The electron.
The components of the atom. The nucleus.
The photon.
Atomic spectra.
Bohr's model
X-Ray Spectrum. Moseley's Law.
Atomic magnetism

2. Single electron atoms

General.
Coulombian potential
The free Dirac equation.
Dirac's equation in an em field.
Dirac's equation at a central potential.
Selection rules.
The Lamb effect.
Exotic atoms



3. Multielectronic atoms

Hamiltonian of complex atoms.
Shielding. Effective charge penetration.
Noble gases.
Alkaline atoms.
Two-electron atoms (He).
Alkaline-earth atoms.
Trivalent atoms.
Transition metals.
Rare earths. Lanthanides and actinides.
Hartree and Hartree-Fock method.
Solve the complete Hamiltonian. LS and jj couplings.

4. Atoms in electric and magnetic fields

Stark effect.
Normal Zeeman effect.
Paschen-Back effect.
Anomalous Zeeman effect.
General Zeeman effect.

5. Hyperfine structure

Hyperfine structure.
Magnetic dipole hyperfine structure.
Applications of the hyperfine structure.

6. Charged particle interaction with matter

Radiation-matter interaction
Energy loss mechanisms
Maximum energy transfer in a collision
Stopping power

7. Neutron interaction with matter

Neutron sources
Neutron classification
Interactions with matter
Elastic dispersion
Inelastic dispersion.

**8. Photon interaction with matter**

Processes of interaction of photons with matter

Fluence

Photon cross section

Coherent scatter

Compton effect.

Photoelectric effect

Pair production

Attenuation coefficients

Energy absorption

9. Radiation dosimetry

Magnitudes and units for ionizing radiation

Time frame of radiation effects

Physical and chemical effects in irradiated wáter

Examples of traces of charged particles in wáter

Biological effects and cellular damage

Tracks and DNA

Effects of radiation on humans

Radiotherapy

Dosimetric quantities: equivalent and effective dose

Operational magnitudes

Dose limits

WORKLOAD

| ACTIVITY | Hours | % To be attended |
|--|---------------|------------------|
| Theory classes | 45,00 | 100 |
| | 0,00 | 100 |
| Attendance at events and external activities | 2,00 | 0 |
| Study and independent work | 10,00 | 0 |
| Preparation of evaluation activities | 10,00 | 0 |
| Preparing lectures | 30,00 | 0 |
| Preparation of practical classes and problem | 15,50 | 0 |
| TOTAL | 112,50 | |



TEACHING METHODOLOGY

The course has two parts with a distinct methodology:

- Theory classes. There will be classes, usually seminars, where the professor will present the contents of the subject listed above. The use of new technologies (electronic filing) is especially appropriate for much of the presentations, given its high content of presenting graphical diagrams, charts, tables, Photographs of experimental devices and practical applications, and all kinds of visual material that allows the student to relate the content with their applications. The use of literature is essential to understand the contents and the objectives of the course. The teacher will offer this material to students (directly or through the Virtual Classroom platform) prior to the beginning of each topic.
- Practical classes. In the lab weekly solve problems for each topic of the course. Professor previously delivered a collection of problems in each chapter, either directly or through the Virtual Classroom. Not all exercises will be solved, some of them will be left for the students to do as part of their personal preparation of the subject.

This structure is intended to serve as practical classes practical illustration of techniques and procedures presented in the lectures, and provide a professional training, raising issues and problems such that, as far as possible, make reference to real life situations as possible.

EVALUATION

The assesment system is as follows:

1. Written examinations: One part will assess the understanding of the theoretical-conceptual and formal nature of the subject, both through theoretical questions, conceptual questions and numerical or simpleparticular cases. Another part will assess the applicability of the formalism, by solving problems and critical capacity regarding the results. Proper argumentations and adequate justifications will beimportant in both cases (70%). A minimum grade of 3.5 out of 10 is expected.
2. Continuous assessment: assessment of exercices and problems presented by students, questions proposed and discussed in class, oral presentation of problems solved or any other method that involves an interaction with students (30%).

REFERENCES

Basic

- James E. Turner, Atoms, radiation and radiation protection , Wiley-VDH, 3rd. ed.
- B. H. Bransden, C.J. Joachain, Physics of atoms and molecules, Prentice-Hall, 2nd ed.



Additional

- E. B. Podgorsak, Radiation Physics for Medical Physicists, Springer, 2nd ed.
- H. Haken, H.C. Wolf, The Physics of Atoms and Quanta, Springer, 6th ed.

