SUBJECT TEACHING GUIDE

G58 - Quantum Physics and the Structure of Matter IV: Nuclei and Particles

Double Degree in Physics and Mathematics
Degree in Physics

Academic year 2020-2021

1. IDENTIFYING DATA					
Degree	Double Degree in Physics and Mathematics Degree in Physics			Type and Year	Compulsory. Year 3 Compulsory. Year 3
Faculty	Faculty of Sciences				
Discipline	Subject Area: Quantum Physics and the Structure of Matter Central Module				
Course unit title and code	G58 - Quantum Physics and the Structure of Matter IV: Nuclei and Particles				
Number of ECTS credits allocated	6	Term		Semester based (2)	
Web					
Language of instruction	Spanish	English Friendly	Yes	Mode of delivery	Face-to-face

Department	DPTO. FISICA MODERNA
Name of lecturer	SATURNINO MARCOS MARCOS
E-mail	saturnino.marcos@unican.es
Office	Facultad de Ciencias. Planta: + 1. DESPACHO PROFESORES (1066)
Other lecturers	ALICIA CALDERON TAZON

3.1 LEARNING OUTCOMES

- Students must:
  - Acquire basic knowledge of the atomic nuclei structure, nuclear processes, elementary particles.
  - Acquire knowledge of the interaction of alpha, beta, high-energy electromagnetic radiation and hadrons, leptons and gauge bosons with the matter, and also about the corresponding detection methods and some important applications in the industry and medicine.
  - Acquire a basic understanding of the characteristics of weak and strong interactions (within the Standard Model), for example in what concerns the nucleon-nucleon potential.
  - Be able to calculate one-nucleon states with simple central potentials and approximate macroscopic nuclear properties.
  - Acquire a basic understanding of the characteristics of the ground and excited nuclear states, as well as of the nuclear decay mechanisms.
  - Understand the concept of cross section and the parameters that control a typical nuclear reaction or, more generally, between particles, paying attention to the conservation laws.
  - Acquire a basic understanding of the fission and fusion nuclear processes, as well as their most important applications.
  - Be able to interpret Feynman diagrams.

4. OBJECTIVES

To acquire basic knowledge of atomic nuclei, nuclear processes, elementary particles and their interactions (in the scheme of the Standard Model), as well as the effects of the passage of ionizing radiation (due to alphas, betas, gammas or hadrons) through the matter and the methods for detecting these radiations. It is also intended to give a basic idea of possible applications of the Nuclear Physics and ionizing radiation in the industry and medicine fields.

6. COURSE ORGANIZATION

	CONTENTS
1	Chapter 1. Basic Concepts 1.1 Introduction 1.2 Classification of subatomic particles 1.3 Strength and range of interactions 1.4 Symmetries and conservation laws. Parity operator 1.5 Composition of the nucleus: The nucleon 1.6 Exchange of virtual particles on the interaction and the force range. Coulomb and Yukawa potentials 1.7 The nucleon-nucleon interaction. The deuteron. Charge independence and charge symmetry of the nuclear interaction. The Isospin concept 1.8 Units: Length, mass and energy
2	Part I: Nuclear Structure Chapter 2. Nuclear Properties 2.1 Terminology. Stable and unstable nuclei 2.2 Effective cross section. Rutherford scattering 2.3 Nucleus size. Mass and charge distribution 2.4 Binding energy. Semi-empirical Mass Formula. Beta stability. Nucleon separation energy Chapter 3. The Shell Model 3.1 Evidence for nuclear shell structure 3.2 One-nucleon states 3.3 Spin-orbit interaction 3.4 Energy levels 3.5 Ground state: Spin and Parity 3.6 Excited states 3.7 Mirror nuclei 3.8 Electromagnetic moments: Electrical and magnetic multipoles Chapter 4. The Collective Model 4.1 Vibrational states 4.2 Rotational states
3	Part II: Nuclear Decay and Nuclear Reactions Chapter 5. Nuclear Decay 5.1 General properties: Decay constant and lifetime. Quantum considerations. Dating 5.2 Alpha decay 5.3 Beta decay. Allowed and forbidden transitions. Parity violation. Electron capture 5.4 Gamma decay: Classical theory. Quantum description. Selection rules. 5.5 Internal conversion Chapter 6. Nuclear Reactions 6.1 Classification and conservation laws. 6.1 Inelastic scattering 6.2 Nuclear reactions with change of identity. Reaction heat 6.3 Reactions with neutrons 6.4 Nuclear Fission 6.5 Nuclear Fusion

4	Part III: Particle interactions with matter. Nuclear Instrumentation Chapter 7. Interaction of ionizing radiation with matter 7.1 Basic concepts: Range, Interaction length and Attenuation 7.2 Charged particles interactions: Coulomb scattering. Dispersion and Ionization. 7.3 Bethe-Block formula. Dependence with the particle type and medium. 7.4 Brehmsstralumg. Radiation length and Critical Energy. 7.5 Cherenkov effect 7.6 Gamma rays: Photoelectric effect, Compton scattering, and Pair production. Attenuation. 7.7 Hadrons interaction. 7.8 Shower phenomena. Chapter 8. Detectors and instrumentation 8.1 Gas detectors: Ionization chambers, Proportional and Geiger-Mueller counters. 8.2 Scintillation counters and Photomultipliers 8.3 Solid state detectors 8.4 Accelerators. Particle detectors in colliders.
5	Part IV: Particle Physics Chapter 9. Leptons, Quarks, and Hadrons 9.1 Leptons 9.2 Lepton multiples and Lepton numbers 9.3 Neutrinos. Neutrino mixing and Oscillations. 9.4 Quarks 9.5 Evidence for quarks. Quark generations and quark numbers 9.6 Hadrons 9.7 Flavor independence and charge multiples 9.8 Quark model spectroscopy Chapter 10. Strong Interaction 10.1 Colour and Quantum Chromodynamics (QCD) 10.2 Heavy quarks bound states 10.3 The strong coupling constant and asymptotic freedom 10.4 Jets and Gluons 10.5 Deep inelastic scattering experiments Chapter 11. Electroweak interaction 11.1 Charged and Neutral currents: W and Z 11.2 Symmetries of the weak interactions 11.3 Spin structure of the weak interaction 11.4 Weak interactions of hadrons

7. ASSESSMENT METHODS AND CRITERIA

Description	Type	Final Eval.	Reassessn	%
At the end of each chapter of these blocks, a question will be proposed to students for them to anser it in class. The assessment of this activity may represent up to 40% of the total mark for blocks 1-3 (that is, approximately 20% of the total mark for t	Written exam	No	Yes	50,00
During the development of these blocks, three checks will be made proposing some questions to the students to carry out in class. The valuation of this activity may represent up to 40% of the total grade for the blocks (that is, approximately 20% of the t	Written exam	No	Yes	50,00
Passing the final exam requires the same conditions as those mentioned for the partial exams. The final exam grade may be 100%.	Written exam	Yes	Yes	0,00
These works will be voluntary and can be used to raise grades, up to a maximum of 1 point out of 10, for those students whose final grade is less than 10 points.	Work	No	No	0,00
TOTAL				100,00

Observations

To pass the course, students must meet the requirements specified for blocks 1-3 and 4-5, independently, and obtain an overall average mark of at least 5 points out of 10. The precise contribution of blocks 1-3 and 4 -5 to the total grade will correspond to the number of actual teaching hours dedicated to each of them. Students will have the possibility of passing the course taking into account the marks corresponding to the continuous assessment plus the partial assessment or through the final exam.

Were it not possible to teach in the classroom, videoconferences would be used to carry out this activity. Were it not possible to realize the exams in the classroom, the Moodle application would be used for it.

Observations for part-time students

Part-time students will receive facilities so that they can follow the course

8. BIBLIOGRAPHY AND TEACHING MATERIALS

BASIC

1. Richard A. Dunlap: An Introduction to the Physics of Nuclei and Particles, Ed. Thompson Broocks/Cole, Canada 2004 (Partes I y II))
2. B. R. Martin: Nuclear and Particle Physics, segunda edición, Ed. John Wiley, NY 2009 (Parte IV)