Bachelor in Physics
(Academic Year 2022-23)

Atomic and Molecular Physics	Code	800524	Year	4th	Sem.	1st
Module	Fundamental Physics	**Topic**	Obligatory of Fundamental Physics	**Character**	Optional	

	Total	Theory	Exer. / Sem.	Lab.
ECTS Credits	6	4	2	
Semester hours	45	30	9	6

Learning Objectives (according to the Degree's Verification Document)

By the end of the course students will be able:

- To evaluate the main interactions within a many-electron atom, comprehending how they determine its description, properties, and energy levels.
- To identify the effects of external factors (electric and magnetic fields, and collisions) on atoms.
- To recognize the structure of diatomic and polyatomic molecules.
- To understand the properties of radiation emission and absorption by atoms and molecules.
- To comprehend the fluorescence and phosphorescence processes, and the basis of the main spectroscopic techniques.

Brief description of contents

Many-electron atoms; electrostatic and spin-orbit interactions; angular momentum coupling; interaction with static external fields; molecular structure; diatomic and polyatomic molecules.

Prerequisites

Quantum Physics I and II (basis of quantum mechanics, stationary perturbation theory, angular momentum coupling).

Structure of Matter (Hydrogen atom, many-electron systems, central-field approximation, spin-orbit coupling, notions of molecular structure).

Coordinator	Jaime Rosado Vélez		Dept.	EMFTEL
	Office	241 3rd floor	**e-mail**	jaime_ros@fis.ucm.es

Theory/Exercises – Schedule and Teaching Staff

Group	Lecture Room	Day	Time	Professor	Period/ Dates	Hours	T/E	Dept.
B	1	M-W	14:00-15:30	Nieto Castaño, Daniel	Whole semester	39	T/E	EMFTEL

T: Theory, E: Exercises

Office hours

Group	Professor	Schedule	E-mail	Location
B	Nieto Castaño, Daniel	M y J: 11:30-13:00 (resto online)	d.nieto@ucm.es	17, 3rd floor

COMPUTER LABORATORIES				
Group	**Lecture Room**	**Sessions**	**Professor**	**Hours**
L6	15	L 05/10 12:00-13:30 L 19/10 12:00-13:30	Nieto Castaño, Daniel	3.0

LABORATORY				
Group	**Laboratory**	**Sessions**	**Professor**	**Hours**
L12	Atomic Nuclear and Particle Physics Lab.	X 26/10 12:00-13:30 X 14/12 12:00-13:30	Nieto Castaño, Daniel	3.0
L13		V 13/10 12:00-13:30 V 09/12 12:00-13:30		3.0

Syllabus

Atomic Physics (60% approx.)

1. **Introduction to many-electron atoms**
   - Handling of antisymmetric wavefunctions
     - Configurations, degeneracy, periodic system
   - Approximation methods
     - Statistical and Hartree methods. Variational methods (Hartree-Fock)
2. **Corrections to the central field approximation**
   - Electrostatic interaction. Electrostatic terms and their determination
     - Calculation of corrections due to electrostatic interaction
   - Spin-orbit interactions
     - Total angular momentum *J* and eigenstates. Calculation of spin-orbit constants
   - Russel-Saunders approximation
     - Limits to *LS* coupling
     - Other coupling models, *JJ* coupling, intermediate coupling, and their effects
3. **Atoms in external constant fields**
   - Magnetic fields. Zeeman and Paschen-Bach effects
4. **Emission and absorption of radiation by atoms**
   - Interaction with the electromagnetic field. Einstein coefficients and their calculation
   - Selection rules. Spectral lines.

Molecular Physics (40% approx.)

5. **Introduction to molecular structure**
   - Born-Oppenheimer approximation
   - Structure of diatomic molecules
   - Nuclear wave function. Vibrational and rotational states
   - Electronic wave function. Potential curves
6. **Emission and absorption of radiation by diatomic molecules**
   - Coupling of angular momenta
   - Pure-rotational spectra
   - Vibrational-rotational spectra
   - Electronic transitions. Franck-Condon principle
7. **Polyatomic molecules**
   - Molecular orbitals. Delocalization
   - Rotational and vibrational states
   - Spectroscopy

Bibliography

Basic:

- B.H.Bransden, C.J.Joachain, *Physics of atoms and molecules* (Pearson)
- I.I.Sobelman, *Atomic Spectra and Radiative Transitions* (Springer Verlag)
- G.K.Woodgate, *Elementary atomic structure* (McGraw Hill)
- P.W. Atkins, *Molecular Quantum Mechanics* (Oxford Univ. Press)
- F. Blanco Ramos, *Introducción a la Física de Átomos y Moléculas* (Amazon)

Complementary:

- H.G.Kuhn, *Atomic Spectroscopy* (Academic Press)
- A.P. Thorne, *Spectrophysics* (Chapman and Hall)
- B.W. Shore and D.H. Menzel, *Principles of Atomic Spectra* (John Wiley)
- R.D.Cowan, *The theory of atomic structure and spectra* (Univ. California Press)
- I.N. Levine, *Espectroscopía molecular* (Ed. AC, D.L.)
- C. Sánchez del Río, *Introducción a la teoría del átomo* (Ed. Alhambra)

Online Resources

Online learning resources and materials will be provided via the virtual campus.

Methodology

Theory lectures will be carried out using blackboard and computer presentations. The theoretical concepts explained will be reinforced with the solution to problems and exercises interspersed during the classes. The participation of the students in these exercises will be encouraged, and they may be requested to hand them in after the lecture.

After each subject-matter is covered, a problem set will be delivered that will be solved completely or will come with partial indications so that the students can carry them out by themselves.

There will be two numerical calculation practices in the computer room and two experimental laboratory practices. All the four practices are mandatory.

Depending on the number of students enrolled, they may present to the class on topics relevant to the course contents. This activity may be carried out in groups or individually.

Evaluation Criteria

Exams	Weight:	70%

A final exam that consists of solving exercises of similar difficulty to those worked out during the course. The students will be allowed to consult their own notes, books, solved problems, etc/.

Other Activities	Weight:	30%

Four practices, whose completion is mandatory to pass the course. In addition, optional assignements may be proposed to increase marks.

Final Mark

The final exam will include two parts, one corresponding to atomic physics, another one to molecular physics, that will be assessed separately. A mark lower than 3.5 over 10 in any of the two parts will be assigned as the final mark for the course, regardless of the rest of the marks. The marks of each part of the exam in the ordinary call may be kept for the extraordinary call.

The four compulsory practices will contribute to the final mark with a weight of 30% of the total. If any of them are not done, the final mark for the course will be 0.

Optional assignments may be proposed to increase marks.