Bachelor in Physics
(Academic Year 2021-22)

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	43	28.5	8.5	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).

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Theory/Exercises – Schedule and Teaching Staff

Group	Lecture Room	Day	Time	Professor	Period/ Dates	Hours	T/E	Dept.
B	3	M-W	14:00-15:30	Nieto Castaño, Daniel	Whole semester	37	T/E	EMFTEL

T: Theory, E: Exercises

Office hours

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

Numerical calculus exercises				
Group	**Lecture Room**	**Sessions**	**Professor**	**Hours**
B I1.4	M2	Wed. 06/10/2021 14:00-15:30	Nieto Castaño, Daniel	1.5
B I2.4	M2	Wed. 20/10/2021 14:00-15:30		1.5

Attendance for these sessions is not mandatory but encouraged.
Remote participation will be enabled for all sessions.

Laboratory				
Group	**Laboratory**	**Sessions**	**Professor**	**Hours**
L.B1	Laboratorio de Física Atómica y Molecular	Wed. 27/10/2021 14:00-15:30	Nieto Castaño, Daniel	1.5
L.B2	Laboratorio de Física Atómica y Molecular	Wed. 03/11/2021 14:00-15:30		1.5
L.Y1	Laboratorio de Física Atómica y Molecular	Wed. 27/10/2021 17:00-18:30		1.5
L.Y2	Laboratorio de Física Atómica y Molecular	Fri. 29/10/2021 12:00-13:30		1.5
L.Y3	Laboratorio de Física Atómica y Molecular	Fri. 29/10/2021 14:00-15:30		1.5

There will be no theory lectures during any of the laboratory sessions above.
Make-up laboratory sessions may be arranged upon duly justified case.

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

On-campus teaching 100% (Scenario 0)

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.

Semi-online teaching (Scenario 1)

Modality A. Theory and problem-solving lectures, as well as the numerical calculation sessions, will be broadcast live so that students who cannot go to the classroom or computer room can follow them remotely. Recordings of all lectures and sessions will be made available on the Virtual Campus.

Explanatory videos of the laboratory practices will be made available on the Virtual Campus along with other supporting materials. Students must view the video of each practice before doing it individually in the laboratory. In addition, sets of measurements will be provided for those laboratory practices that cannot be carried out totally in person.

Online teaching (Scenario 2)
The theory lectures and exercise sessions will be broadcasted, recorded and will be available on the Virtual Campus. Student participation through the discussion of problems and clarification of doubts will be encouraged during class hours. The laboratory and practical sessions will be carried out virtually. To this purpose, explanatory videos of the experiences will be made available on the Virtual Campus along with other supporting materials and sets of measurements.

Evaluation Criteria		
Exams	**Weight:**	60%
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 during the exam.		
Other Activities	**Weight:**	40%
Four practices, whose completion is mandatory to pass the course, and two assignments, one for each part of the course.		
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. The two assignments will contribute to the final mark with a weight of 10%. They will not be compulsory to pass the course but, if not delivered, they will be scored as 0, maintaining the indicated weight of 10%.		