COURSE OUTLINE

(1) GENERAL

SCHOOL	NATURAL SCIENCES		
ACADEMIC UNIT	DEPT. OF PHYSICS		
LEVEL OF STUDIES			
COURSE CODE	**M129**	**SEMESTER**	**2**
COURSE TITLE	Atomic and Molecular Physics		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*	**WEEKLY TEACHING HOURS**	**CREDITS**
	4	7
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (d).		

COURSE TYPE *general background, special background, specialised general knowledge, skills development*	Specialised general knowledge
PREREQUISITE COURSES:	
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	
IS THE COURSE OFFERED TO ERASMUS STUDENTS	Specialised general knowledge
COURSE WEBSITE (URL)	http://www1.physics.uoi.gr/atomol/index_files/Page 3239.htm

(2) LEARNING OUTCOMES

Learning outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.

Consult Appendix A

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B*
- *Guidelines for writing Learning Outcomes*

The aims of this course are to develop an understanding of the atomic and molecular structure. Other aims include the understanding of the interaction of atomic and molecular systems with external homogeneous static electric, magnetic fields as well as with electromagnetic radiation. On successful completion of this course, the student will be able to:

- Understand the nature of approximations made on the quantum description of atomic and molecular systems.
- Apply approximation techniques involved in the calculations concerning energy level corrections, transition matrix elements, etc.
- Understand similarities and differences between hydrogen atom and single valence electron atoms, as well as helium atom and two-valence electron atoms.
- Understand the autoionization process.
- Draw conclusions on the atomic and molecular structure on the basis of experimental data.
- Understand the nature of the various internal molecular degrees of freedom.
- Be able to apply Group Theory to determine the symmetry of electronic/vibronic states

and the transitions selection rules.

- Understand the interaction of atoms with static and homogeneous electric and magnetic fields.
- Understand the interaction of atoms and molecules with electromagnetic fields and the expected evolution.
- Understand the dynamics of excited molecular states.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

Search for, analysis and synthesis of data and information, with the use of the necessary technology	*Project planning and management*
Adapting to new situations	*Respect for difference and multiculturalism*
Decision-making	*Respect for the natural environment*
Working independently	*Showing social, professional and ethical responsibility and sensitivity to gender issues*
Team work	*Criticism and self-criticism*
Working in an international environment	*Production of free, creative and inductive thinking*
Working in an interdisciplinary environment	*……*
Production of new research ideas	*Others…*
	…….

Search for, analysis and synthesis of data and information, with the use of the necessary technology.
Working independently.
Team work.
Working in an interdisciplinary environment.
Production of free, creative and inductive thinking.

(3) SYLLABUS

Hydrogenic atoms: Bound and continuum wave-functions. Perturbation theory for degenerate states. Relativistic energy corrections.
Multi-electron atoms: Pauli's principle, Shells, subshells, configurations. Average configuration energies, Hartree theory. Slater determinants. Periodic Table. Residual Coulomb potential, spin-orbit coupling. Coupling schemes (LS, jj and intermediate).
Alkali atoms: Valence electron under the action of a parametric potential. Spin-orbit coupling. Rydberg states, quantum (penetration and polarization) defects.
Helium-like atoms (or ions): Two valence electron (1/r12) interaction term and uncoupled valence electron approximation. Energy level corrections (first order perturbation theory, J and K integrals/variational method). Multi-pole expansion of 1/r12. Configuration interaction. Autoionization. Doubly excited states of He, ground state of H^-.
Interaction between atoms and electromagnetic fields: Dipole approximation. Time dependent perturbation theory. Single-photon atomic transitions. Wigner-Eckart theorem. Multi-photon transitions (Dalgarno-Lewis method). Ionization. Selection rules. AC Stark shift.
Interaction between atoms and static electric fields: Hydrogen atom, first order perturbation theory (excited states), second order perturbation theory (ground state). Multi-electron atoms, second order perturbation theory.
Interaction between atoms and static magnetic fields: Zeeman και Paschen-Back effects.

Quantum mechanical description of a molecular system. Born-Oppenheimer approximation. Approximation methods for the calculation of molecular wave-functions. The variational method. Molecular Orbital (MO) approximation. Molecular states and molecular energy. Molecular symmetry and Group theory. Molecular rotation. The rotational selection rules and rotational spectra. The vibration of molecules. Ro-vibronic spectra. Electronic transitions, Franck-Condon factor, selection rules. Absorption and emission (fluorescence, phosphorescence) spectra. Molecular dissociation. Molecular ionization. Multiphoton excitation. Radiationless processes. Beyond adiabatic approximation (conical intersections). Spectroscopic techniques (Raman, MPI, Mass spectrometry, photoelectron, pump/probe, etc).

(4) TEACHING and LEARNING METHODS - EVALUATION

<table>
<tr><td>DELIVERY
Face-to-face, Distance learning, etc.</td><td>Face-to- face</td></tr>
<tr><td>USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY
Use of ICT in teaching, laboratory education, communication with students</td><td>Use of ICT in teaching and communication with students
(http://www1.physics.uoi.gr/atomol/index_files/Page3239.htm)</td></tr>
<tr><td>TEACHING METHODS
The manner and methods of teaching are described in detail.
Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.

The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS</td><td>
<table>
<tr><th>Activity</th><th>Semester workload</th></tr>
<tr><td>Lectures</td><td>52</td></tr>
<tr><td>Tutorials</td><td>26</td></tr>
<tr><td>Study of bibliography</td><td>47</td></tr>
<tr><td>Non-directed study</td><td>47</td></tr>
<tr><td>Exams</td><td>3</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Course total</td><td>175</td></tr>
</table>
</td></tr>
<tr><td>STUDENT PERFORMANCE EVALUATION
Description of the evaluation procedure

Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other

Specifically-defined evaluation criteria are given, and if and where they are accessible to students.</td><td>- solving selective problems
- essay on an topic
-written exams for the evaluation of conclusive understanding and problem solving capabilities</td></tr>
</table>

(5) ATTACHED BIBLIOGRAPHY

- Suggested bibliography:
- Related academic journals:

-Introduction to Molecular Spectroscopy, G. M. Barrow, McGraw Hill (1962)
-Molecular Physics: theoretical principles and experimental methods, Demtröder W., Wiley VCH (2005)
-Light-Matter Interaction, Wendell T. Hill, Chi H. lee, Willey VCH(2007)
-Φυσικοχημεία, Peter Atkins, J. De Paula, Πανεπιστημιακές Εκδόσεις Κρήτης (2014).
-Molecular quantum mechanics, Peter Atkins, Rionald Friedman (Oxford University Press)
-Review papers
-"Κβαντομηχανική ΙΙ", Σ. Τραχανάς, Παν/κές Εκδόσεις Κρήτης (2008)
-"Quantum Mechanics of one- and two electron atoms" Bethe H.A. Dover (2008)
-"Light, Vol2, Laser Light Dynamics" H. Haken , North Holland (1986)
-"The theory of atomic structure and Spectra" Univ. of California Press (1981)