COURSE OUTLINE

(1) GENERAL

SCHOOL	SCHOOL OF SCIENCES		
ACADEMIC UNIT	PHYSICS DEPARTMENT		
LEVEL OF STUDIES	GRADUATE		
COURSE CODE	**M112**	**SEMESTER**	**1**
COURSE TITLE	**EXPERIMENTAL 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**
	5	10
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*	general background, skills development
PREREQUISITE COURSES:	Solid state physics, Statistical Physics, Introduction to Astrophysics (undergraduate level)
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	Greek or English
IS THE COURSE OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	

(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*

With the successful completion of the course that includes extensive experimental work the students will acquire specific knowledge, skills and competences. Specifically:

- The four (4) experiments on the phase transitions of soft materials (**A**) aim in the in-depth understanding of the physics of phase transitions (according to Landau). This advanced experimental physics project includes the following experimental techniques: differential scanning calorimetry, polarizing optical microscopy, dielectric spectroscopy and rheology. In particular, the student should be able to differentiate between first order and weakly ordered phase transitions, to extract the change in enthalpy and entropy at the transition, to obtain the critical temperature (Curie) and the critical exponent(s).
- The scope of conducting experiments (**B-F**) is to bring the postgraduate students in position to: deepen their knowledge, concepts and experimental methods regarding the characterization, investigation, interpretation and comprehension of the

structure of solid state materials in bulk and nanoscale forms, as well as the relation among the structure and morphology of materials with their physical properties (electronic, magnetic, optical, electric, thermal), combine and express accordingly in the form of scientific reports the results originating from the relative studies using particular experimental methods in real materials, aiming to deliver the necessary conclusions referred to the structure and properties of these materials.

- The detection of the cosmic muons (**G**) is a classical experiment which allows a student to develop his knowledge in modern detection technics used widely in the experiment particle physics. The student using scintillator detectors will measure the rate, the directivity and the lifetime of the cosmic muons. After the successful completion of the experiment the student is in position: To possess advanced knowledge in the detection of the cosmic muons, to possess advanced knowledge in experimental setups and techniques on the elementary particle detection, to develop experimental setups for the signal processing from scintillator detectors.
- The practical work within the Astronomy lab (**H**) aims to familiarize and train students with the search, reduction and deduction of basic physical properties from astronomical data. Upon successful completion of the lab the students will be able: to locate and retrieve astronomical data from various sources and databases, to become acquainted with astronomical data formats, to become acquainted with the pipeline of reduction of raw data to data suitable for scientific analysis, to apply basic analysis methods of astronomical data to observations and to be able to retrieve basic physical parameters and draw conclusions from their analysis.
- The aim of this two weeks workshop on Nuclear Physics (**I**) is to provide students the basic methods and techniques used in the nuclear physics research.
- The laboratory exercises dealing with the emission/scattering of light from molecular systems and the generation of high order harmonics from noble gases (**J**) aim at the understanding of the interaction of an electromagnetic field with atoms and molecules. At the same time, it is possible to engage in modern non-linear optics. Upon completion of the exercises, the student will be able to combine experimental data with the structure of matter. He/she will also have experience in laser systems and laser beam propagation, detection and spectral characterization of light beam as well as signal processing.

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…*
	…….

(3) SYLLABUS

(A) Physics of phase transitions in soft matter

This advanced experimental physics project includes the following experiments: differential scanning calorimetry, polarizing optical microscopy, dielectric spectroscopy and rheology. The aim of the project is the understanding of the physics of phase transitions (1st order, 2nd order, weak transitions) in soft materials (e.g. liquid crystals). Specifically, with differential scanning calorimetry the transition temperature and the change of enthalpy, entropy at the transition are discussed. With polarizing optical microscopy the succession of phases (crystalline-smectic-nematic-isotropic) is obtained. With dielectric spectroscopy (dielectric permittivity and dielectric loss) the physics of the transition from the nematic to the isotropic phase is discussed with emphasis on the critical exponent(s). Lastly, with mechanical spectroscopy (rheology) the mechanical fingerprint of each phase is identified and the elastic modulus and shear viscosity is obtained within each phase.

(B) Structural characterization of 2D and 3D materials: X-ray diffraction from polycrystalline materials, qualitative and quantitative determination of crystal structures using X-ray diffraction diagrams (Rietveld method), crystal structure studies of different types of graphenes, layered materials and nanocrystals.

(C) Electron Paramagnetic Resonance Spectrosocpy: Buliding of Spin Hamiltonians using Heisenberg formalism. Lattice dynamics. Photon-Electron coupling. Unpaired electrons in 2D lattices (graphene), 3D semiconductors. Valence band electrons, conduction band electros. Electrons in quantum confined structures. Electrons in magnetic phases.

(D) Mössbauer spectroscopy: Detailed quantum-mechanical description of the recoilless (zero-phonon process) resonant emission and absorption of γ rays by atomic nuclei in solids. Hyperfine interactions. Study of the structural-lattice, electronic and magnetic properties of crystalline and amorphous solids with Fe and Sn. Special phenomena: electron delocalization, charge ordering, magnetic frustration, superparamagnetism.

(E) Laser-Raman & Diffuse-Reflectance spectrosocopy in solids: Optoelectronic properties of solids and nanostructures. Band gap in semiconductors. Kubelka-Munk theory. Raman scattering. Near field theory. Plasmon resonance. Surface Enhanced Raman by metallic nanoparticles. Structural characterization of nanostructures by Laser-Raman. Detection of hot-spots.

(F) Magnetic measurements: Magnetic structure and magnetic properties of diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic, ferromagnetic and superparamagnetic materials. Magnetic properties of materials at the nanoscale. Magnetic measurements of materials using Vibrating Sample Magnetometer (VSM) and determination of the magnetic properties of bulk and nanostructured materials.

(G) Experiment for the detection of cosmic muons

The sources of the cosmic rays. Detection methods for muons and scintillator detectors. NIM type signal process electronics and time coincidence units. Measurements of the rate, the directivity and the lifetime of the cosmic muons.

(H) Astronomical data analysis

The two-week practical work will consist of both theoretical and practical segments, amounting to 30% and 70% of the allocated time, respectively, and will contain the following: familiarize with the equipment of the Astronomy Lab (telescope, CCD camera), familiarize with astronomical databases (CDS, VSO), reduction of CCD data (removal of bias, removal of dark current, flat-fielding, removal of cosmic rays, treatment of saturation, background subtraction, de-noising), processing of interferometric data (calibration, dirty image, self-calibration, deconvolution), basics of astronomical data analysis I (co-alignment, image enhancement, deduction of basic temporal and spatial scales), basics of astronomical data analysis II (deduction of basic physical parameters from astronomical observations).

(I) Nuclear Physics

The available laboratory equipment will facilitate the familiarization of the student with the techniques of radiation detection and measurement. Additionally, the students will be introduced to nuclear data analysis techniques and to the physical interpretation of the experimental results, according to quantum-mechanics and the available theoretical models.

(J) Interaction of electromagnetic radiation with matter

1. The objective of the first series of experiments is twofold: a) record laser induced emission spectra (fluorescence / phosphorescence) from liquid solutions (LiF) and b) record pulsed laser induced Raman spectra. Using an optical multichannel analyzer, the emission spectrum of a liquid solution will be recorded, thus probing the dynamics of an electronic excited state by utilizing time-gated detectors. In the Raman experiments, pulsed laser induced spectra from substances illuminated with photons at 532nm and 355nm will be recorded. We will study the spectrum dependence on the polarization of the incoming beam and characterize the observed vibrational modes.

2. The generation of odd-order harmonics using a fs laser on a noble gas is a modern experimental tool for producing “light” in the range from ~ 200 nm to ~ 1 nm. In this exercise we will study the production of the 3rd, 5th and 7th order harmonics (266-115 nm) from Ar noble gas, the dependence of the efficiency on the gas pressure, the focusing conditions, the intensity of the laser beam, etc. In addition, the spectral characterization of the harmonics will be recorded as a function of the experimental parameters

(4) TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Face-to-face; experimental physics
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	Laboratory education, communication with students and practical examples, notes distributed via *ecourse*
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,*	see table below

Activity	***Semester workload***
Seminars	50
Laboratory practice	150
project	25
essay writing	25

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*	<table><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td>**250**</td></tr></table>
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.*	laboratory work, essay/report based on experimental measurements, laboratory work, oral examination, public presentation.

(5) ATTACHED BIBLIOGRAPHY

- Suggested bibliography:

- Solid State Physics, Ashcroft and Mermin, ISBN 0-03-049346-3.
- Atomic and Electronic Structure of Solids, E. Kaxiras, Cambridge University Press, 2003, ISBN 0521523397
- "Techniques for Nuclear and Particle Physics Experiment", W.R.Leo, ISBN:0-387-57280-5, Springer-Verlang.
- "The Review of Particle Physics", Particle Data Group, Chin. Phys. C, 40, 100001 (2017) Reviews for Cosmic Rays and Passage of particles through matter.
- Léna, P., Rouan, D., Lebrun, F., Mignard, F. & Pelat, D.: 2012, Observational Astrophysics, (3rd edition), Springer, ISBN: 978-3-642-21814-9

- Related academic journals:

- Nature Materials
- Nature Photonics
- Physical Review Letters
- Physical Review B
- Physical Review A