Course Outline Structure for the Interdepartmental Postgraduate Programme (MSc Program) Microsystems and Nanodevices

COURSE OUTLINE

(1) GENERAL INFORMATION

SCHOOL	OF APPLIED MATHEMATICAL AND PHYSICAL SCIENCES		
DEPARTMENT	OF APPLIED MATHEMATICAL AND PHYSICAL SCIENCES		
LEVEL OF STUDIES	POSTGRADUATE		
MSc PROGRAM	MICROSYSTEMS AND NANODEVICES		
COURSE CODE	**9950**	**SEMESTER**	**1**
COURSE TITLE	STATISTICAL PHYSICS		

INDEPENDENT TEACHING ACTIVITIES *In cases where credits are awarded to discrete parts of the course (e.g., Lectures, Laboratory Exercises, etc.), specify them. If credits are awarded as a whole, specify weekly teaching hours and total credits.*	**WEEKLY TEACHING HOURS**	**ECTS**
Lectures – Exercises	4	7.5
Laboratory		
Assignments		
(Additional rows may be added if necessary. Detailed descriptions of teaching organization and methods are provided in section (d).)		

COURSE TYPE *general background, specialized background, specialization, skill development*	GENERAL BACKGROUND (for Core Courses)]
PREREQUISITES:	[REQUIRED BACKGROUND KNOWLEDGE]: KNOWLEDGE EQUIVALENT TO A GRADUATE IN PHYSICS
LANGUAGE OF INSTRUCTION and EXAMINATION:	GREEK OR ENGLISH
COURSE AVAILABLE TO ERASMUS STUDENTS	NO
COURSE WEBSITE (URL)	https://helios.ntua.gr/course/index.php?categoryid=197 https://helios.ntua.gr/course/view.php?id=4102

(2) LEARNING OUTCOMES

Learning Outcomes

This section describes the learning outcomes of the course, specifying the knowledge, skills, and competencies at the appropriate level that students will acquire upon successful completion of the course.

Refer to Appendix A:

- *Description of the Level of Learning Outcomes for each cycle of studies according to the European Higher Education Area Qualifications Framework*
- *Descriptive Indicators for Levels 6, 7, & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B.*
- *Concise Guide to Writing Learning Outcomes*

Knowledge:

The course focuses on the microscopic study of macroscopic systems. For a system in equilibrium, we derive general conclusions from microscopic properties, laying the foundations of the field of Statistical Physics. This microscopic approach provides all the results of Thermodynamics and allows us to calculate macroscopic parameters based on the microscopic properties of the system.

Essential components for such an analysis include defining the system's state, the concept of the statistical ensemble, the assumption of equal a priori probabilities, and probability calculations.

Key concepts include:

- Statistical weight $\Omega(E)$: Number of accessible states of the system within a specific energy range (between E and $E+\delta E$).
- Interactions between macroscopic systems (thermal, mechanical, general).
- Statistical thermodynamics and equilibrium conditions between interacting macroscopic systems.
- Microcanonical, canonical, and grand canonical distributions.
- Paramagnetism, Gibbs paradox.
- Quantum theory of the statistical ensemble: The density matrix.
- Quantum statistics of ideal gases (Bose-Einstein statistics, photon statistics, Fermi-Dirac statistics) and the classical limit.
- Conductivity electrons in metals, Pauli paramagnetism.
- Bose-Einstein condensation, black body radiation.
- Ferromagnetism, mean field theory. The Ising model

Skills:

Upon successful completion of the course, the student will be able to:

- Understand that Classical Statistical Physics can be derived Quantum Statistical Mechanics as a mathematical approximation (integrals instead of sums over microstates).
- Explain that knowledge of the quantum structure of a system, as represented by the Hamiltonian *H*, is essential for the study of any macroscopic system.
- Describe the "specifications" needed for the construction of a macroscopic system, the concept of the statistical ensemble, and accessible states.
- Understand the differences between Fermi-Dirac and Bose-Einstein statistics and solve related problems.

General Competencies *Considering the general competencies that graduates are expected to acquire (as stated in the Diploma Supplement), which competencies does this course aim to develop?*	
Data search, analysis, and synthesis, utilizing necessary technologies *Adaptability to new situations* *Decision-making* *Independent work (primarily through assignments completed at home)* *Teamwork* *Working in an international environment* *Working in an interdisciplinary environment*	*Generation of new research ideas* *Project design and management* *Respect for diversity and multiculturalism* *Respect for the natural environment* *Exhibiting social, professional, and ethical responsibility and sensitivity to gender issues* *Critical and self-critical thinking* *Promotion of free, creative, and inductive thinking* *More…*

Competencies:

Upon successful completion of the course, students will develop the ability to:

- Work independently, especially through home assignments which can help them clarify key topics.
- Understand concepts related to macroscopic systems.
- Formulate questions necessary to investigate the behavior of macroscopic systems.
- Realize that problem-solving in Physics (and beyond) requires reaching concrete results and verifying their consistency.

(3) COURSE CONTENT

Classical Statistical Mechanics. Fundamental principles, micro-canonical ensemble, phase space, ergodic hypothesis, equilibrium, entropy, classical ideal gas, mixture entropy and Gibbs paradox. Canonical and grand canonical ensemble. Canonical ensemble, partition function, energy fluctuations in the canonical ensemble, equipartition theorem, ideal gas. Grand canonical ensemble, Gibbs entropy, ideal gas, chemical reactions. Quantum Statistical Mechanics. Fundamental principles, density matrix, ensembles in quantum statistical mechanics, ideal Fermi gas, Landau diamagnetism, Pauli paramagnetism, ideal Bose gas, photons, phonons, Bose-Einstein condensation, Bose- Fermi-Boltzmann gas comparisons. Interacting systems and phase transformation. Examples of interacting systems, van der Waals liquids, gas-liquid transitions, vdW state equations, critical points, failure of vdW equation, mean field theory for phase transitions, Landau approximation and order parameter, Polymers, Ising model, mean field approximation and ferromagnetism. Field theory techniques. Landau theory for phase transitions, failure of mean field theory. Systems under external excitations. Linear response theory, generalized susceptibilities, non-equilibrium statistical physics, Boltzmann equation and transport properties. Special subjects on statistical physics

(4) TEACHING AND LEARNING METHODS - ASSESSMENT

TEACHING METHOD *In person, Distance Learning etc.*	In-person. In cases of extraordinary circumstances, the course is offered via distance learning.
USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) *Use of Information and Communication Technologies (ICT) in Lecturing, Laboratory Training, Communication with Students*	ICT is used for communication with students. Lecture notes and assignments are sent to students (via the online platform Helios or email). Students may submit solutions of problems in person during class or via email.

<table>
<tr><td>ORGANIZATION OF TEACHING
A detailed description of the teaching methods and approaches used in the course, which may include:

Lectures, Seminars, Laboratory Exercises, Fieldwork, Study and Analysis of Bibliography, Tutorials, Internships, Clinical Exercises, Art Workshops, Interactive Teaching, Educational Visits, Project Development, Report Writing/Assignments, Artistic Creation.

The student’s study hours for each learning activity, as well as hours of independent study, are outlined in accordance with ECTS principles.</td>
<td><table>
<tr><th>Activity</th><th>Semester Workload</th></tr>
<tr><td>Lectures</td><td>13*4=52 hours</td></tr>
<tr><td>Study</td><td>13*4=52 hours</td></tr>
<tr><td>Home assignments</td><td>10*3=30 hours</td></tr>
<tr><td>Laboratory</td><td></td></tr>
<tr><td>Completion/Presentation of Project</td><td></td></tr>
<tr><td>Educational visits</td><td></td></tr>
<tr><td>Examinations</td><td>4 hours</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Total Course Load</td><td>138 hours</td></tr>
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<tr><td>STUDENT ASSESSMENT
Description of the Assessment Process

Language of Assessment, Assessment Methods, Formative / Summative Assessment Methods, Multiple-choice tests, Short-answer questions, Essay-style questions, Problem-solving exercises, Written assignments, Reports, Oral examinations, Public presentations, Laboratory work, Clinical patient examinations, Artistic interpretations, Other methods, as appropriate

The assessment criteria are clearly defined and provided to students, ensuring transparency in the evaluation process. These criteria are accessible through the course’s online platform where students can review them at any time.</td>
<td>Language of Assessment: Greek or English
(for Erasmus students: English)

Midterm exams: 60% of the final grade

Final Examination (problem-solving): 40% of the final grade

These criteria are explicitly referenced on the Helios electronic platform.</td></tr>
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(5) RECOMMENDED BIBLIOGRAPHY

Statistical Physics, F. Mandl	Wiley
Statistical Physics, L. D. Landau, E, M. Lifshitz	Pergamon Press
Statistical Mechanics, P. K. Pathria	Elsevier
Statistical Mechanics, K. Huang	John Wiley

Lecture material (approximately 250 slides) is available through the Helios electronic platform of NTUA.