Statistical Physics

Academic Year: (2023 / 2024) **Review date: 12-02-2024**

Department assigned to the subject: Physics Department

Coordinating teacher: TRIBALDOS MACIA, VICTOR

Type: Compulsory ECTS Credits : 3.0

Year : 3 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Probability and Statistics,
Mechanics and Relativity,
Quantum Physics.

SKILLS AND LEARNING OUTCOMES

CB1. Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2. Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CB3. Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4. Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CB5. Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.
CG2. Learn new methods and technologies from basic scientific and technical knowledge, and being able to adapt to new situations.
CG3. Solve problems with initiative, decision making, creativity, and communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the engineering activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG4. Solve mathematical, physical, chemical, biological and technological problems that may arise within the framework of the applications of quantum technologies, nanotechnology, biology, micro- and nano-electronics and photonics in various fields of engineering.
CG5. Use the theoretical and practical knowledge acquired in the definition, approach and resolution of problems in the framework of the exercise of their profession.
CE13. Understand and handle solid state physical principles relevant to engineering and, in particular, semiconductors for application in electronic and photonic components, as well as the fundamentals and applications of analog and digital electronics and microprocessors.
CE15. Understand and handle the physical principles associated with light-matter interaction and to apply them to the use and design of various photonic devices and complete photonic systems, as well as to apply photonic devices and systems in different branches of physics, engineering and biology.
CE17. Understand and handle the fundamental concepts of Quantum Physics, its relationship with Classical Physics, and its application to the understanding of the physics of atoms and molecules, as well as solving simple one- and three-dimensional quantum problems and applying approximate resolution methods.
CE18. Understand and handle the fundamental concepts of Statistical Physics and their relationship with macroscopic reality, the statistics of classical and quantum systems, and the application of these statistics to relevant situations in Physics and Engineering.
CT1. Work in multidisciplinary and international teams as well as organize and plan work making the right decisions based on available information, gathering and interpreting relevant data to make judgments and critical thinking within the area of study.

RA1. To have acquired sufficient knowledge and proved a sufficiently deep comprehension of the basic principles, both theoretical and practical, and methodology of the more important fields in science and technology as to be able to work successfully in them.
RA2. To be able, using arguments, strategies and procedures developed by themselves, to apply their

knowledge and abilities to the successful solution of complex technological problems that require creating and innovative thinking.
RA3. To be able to search for, collect and interpret relevant information and data to back up their conclusions including, whenever needed, the consideration of any social, scientific and ethical aspects relevant in their field of study.
RA6. To be aware of their own shortcomings and formative needs in their field of specialty, and to be able to plan and organize their own training with a high degree of independence.

OBJECTIVES

CB1. Students have demonstrated knowledge and understanding in a field of study that builds upon their general secondary education, and is typically at a level that, whilst supported by advanced textbooks, includes some aspects that will be informed by knowledge of the forefront of their field of study
CB2. Students can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of study
CB3. Students have the ability to gather and interpret relevant data (usually within their field of study) to inform judgments that include reflection on relevant social, scientific or ethical issues
CB4. Students can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences
CB5. Students have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy
CG2. Learn new methods and technologies from basic scientific and technical knowledge, and being able to adapt to new situations.
CG3. Solve problems with initiative, decision making, creativity, and communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the engineering activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG4. Solve mathematical, physical, chemical, biological and technological problems that may arise within the framework of the applications of quantum technologies, nanotechnology, biology, micro- and nano-electronics and photonics in various fields of engineering.
CG5. Use the theoretical and practical knowledge acquired in the definition, approach and resolution of problems in the framework of the exercise of their profession.
CE13. Understand and handle solid state physical principles relevant to engineering and, in particular, semiconductors for application in electronic and photonic components, as well as the fundamentals and applications of analog and digital electronics and microprocessors.
CE15. Understand and handle the physical principles associated with light-matter interaction and to apply them to the use and design of various photonic devices and complete photonic systems, as well as to apply photonic devices and systems in different branches of physics, engineering and biology.
CE17. Understand and handle the fundamental concepts of Quantum Physics, its relationship with Classical Physics, and its application to the understanding of the physics of atoms and molecules, as well as solving simple one- and three-dimensional quantum problems and applying approximate resolution methods.
CE18. Understand and handle the fundamental concepts of Statistical Physics and their relationship with macroscopic reality, the statistics of classical and quantum systems, and the application of these statistics to relevant situations in Physics and Engineering.
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RA2. To be able, using arguments, strategies and procedures developed by themselves, to apply their knowledge and abilities to the successful solution of complex technological problems that require creating and innovative thinking;
RA3. To be able to search for, collect and interpret relevant information and data to back up their conclusions including, whenever needed, the consideration of any social, scientific and ethical aspects relevant in their field of study;
RA6. To be aware of their own shortcomings and formative needs in their field of specialty, and to be able to plan and organize their own training with a high degree of independence.

DESCRIPTION OF CONTENTS: PROGRAMME

1. Foundations of Statistical Physics.
   - Microscopic and macroscopic states.
   - Thermodynamic limit.
   - Phase space.
   - Liouville's theorem.

2. Microcanonical ensemble - Equilibrium of an isolated system.
   - Entropy and the second Principle of Thermodynamics.
   - Application to the ideal gas and the two state system.
   - First Principle of Thermodynamics.
3. Canonical and Grand canonical ensembles - Equilibrium of a system with an energy reservoir and an energy and particle reservoir.
   - Partition Function.
   - Density Matrix.
   - Fluctuations.
   - Maximizing Entropy.
   - Free Energy.
   - System of Harmonic Oscillators.
   - Application to Paramagnetism.
4. Classical Gases.
   - Ideal Gas.
   - Equipartition Theorem.
   - Virial Theorem.
   - Gibbs Paradox.
   - Maxwell Distribution. Maxwell-Boltzmann Statistics.
   - Diatomic Gas.
5. Quantum Gases I.
   - Density of States.
   - Relativistic Systems.
   - Photon Gas.
   - Phonon Gas.
6. Quantum Gases II.
   - Bosons and Fermions.
   - Bose-Einstein statistics.
   - Ideal Bose Gas.
   - Bose-Einstein condensates.
   - Fermi-Dirac statistics.
   - Ideal Fermi Gas.
   - Electron Gas.

LEARNING ACTIVITIES AND METHODOLOGY

AF1. THEORETICAL-PRACTICAL CLASSES. Weekly sessions of 100 minutes, divided in two 50 minutes parts with a break, where the theoretical concepts are explained. Students will have basic reference texts to facilitate the understanding of the classes. In the recitations the problems and activities proposed after the theoretical sessions are solved and discussed. There will be mid term tests for evaluating the competences and skills acquired by the students and for helping them improving their learning strategies. This entails 22 hours in face-to-face sessions for 3 ECTS courses.
AF2. TUTORING SESSIONS. Every week there will be a one hour face-to-face tutoring session available for students in the subject webpage.
AF3. STUDENT INDIVIDUAL WORK OR GROUP WORK. Student's individualized work is fundamental for understanding results, proofs and exercises and develop problem solving skills. Discussing concepts and solving problems in small groups of students is an excellent complementary activity for improving teamwork competences and for self-assessment.
AF9. FINAL EXAM. Global assessment of knowledge, skills and capacities acquired throughout the course. It entails 4 hours 100% on-site.

MD1. THEORY CLASS. Classroom presentations by the teacher on the blackboard or with IT and audiovisual support in which the subject's main concepts are developed and where material and bibliography to complement student learning is provided.
MD2. PRACTICAL CLASS. Resolution of practical cases and problem, posed by the teacher, and carried out individually or in a group.
MD3. TUTORING SESSIONS. Individual or in-group tutorial sessions for the resolution of doubts by the teacher.
MD6. LABORATORY PRACTICAL SESSIONS. Applied/experimental learning in workshops and laboratories under the tutor's supervision.

ASSESSMENT SYSTEM

SE1. END-OF-TERM EXAM. Global assessment of the knowledge, skills and abilities acquired throughout the course. The percentage of the evaluation for this subject will be 60% of the final grade.
SE2. CONTINUOUS EVALUATION. Assesses papers, projects, class presentations, debates, exercises and laboratory reports throughout the course. The percentage of the evaluation for this subject will be 40% of the final grade.

Despite the final mark is obtained with the indicated percentages, to pass the course it is COMPULSORY to:

- Attend all laboratory sessions and deliver all laboratory reports.
- Obtain a grade equal or greater than 3 points out of 10 in the end-of-term exam.

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

BASIC BIBLIOGRAPHY

- F. Mandl Statistical Physics, Wiley, 1988
- L.D. Landau and E.M. Lifshitz Statistical Physics Volume 5, Butterworth-Heinemann, 1980
- R.K. Pathria and P.D. Beale Statistical Mechanics, ELSEVIER, 2011

BASIC ELECTRONIC RESOURCES

- David Tong . Lectures on Statistical Physics: http://www.damtp.cam.ac.uk/user/tong/statphys.html