

**COURSE DATA****DATA SUBJECT****Code:** 34246**Name:** Statistical physics**Cycle:** Undergraduate Studies**ECTS Credits:** 4.5**Academic year:** 2025-26**STUDY (S)**

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Facultat de Física	3	First quarter, Second quarter
1928 - Double Degree Program Physics-Mathematics	Facultat de Ciències Matemàtiques	5	First quarter
1929 - Double Degree Program in Physics and Chemistry	Facultat de Física	4	First quarter, Second quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
1105 - Degree in Physics	Thermodynamics and statistical physics	COMPULSORY
1928 - Double Degree Program Physics-Mathematics	Quinto Curso (Obligatorio)	COMPULSORY
1929 - Double Degree Program in Physics and Chemistry	Cuarto Curso (Obligatorio)	COMPULSORY

COORDINATION

CERVERA MONTESINOS JAVIER

MANZANARES ANDREU JOSE ANTONIO

GARCIA MORALES VLADIMIR

SUMMARY

This document is a guide to the Statistical Physics course, a third-year, 4.5-credits core course of the Physics degree and the Double Degrees in Physics-Chemistry and Physics-Mathematics. The subject has strong links with other courses of the degrees, especially with Thermodynamics (Statistical Physics and Thermodynamics constitute the Thermal Physics core of the Physics degree), but also with Mechanics, Waves, Atmospheric Physics, Quantum Physics and Solid State Physics.

Statistical Physics has one primary objective: to show how the macroscopic properties of systems with



many particles can be related to the microscopic states of the system making use of statistical methods. A strong emphasis will be placed on understanding the relationship between macroscopic behavior and microscopic characteristics. The course is based on the Gibbs ensemble theory and the Boltzmann entropy. The applications covered include classical (Maxwell-Boltzmann) and quantum (Fermi-Dirac and Bose-Einstein) ideal gases as well as an introduction to systems of interacting particles and phase transitions based on the mean field approach.

No matter what area of physics you pursue in your career, the concepts (entropy, temperature, chemical potential, etc.) and tools (the partition function formalism, computer simulations, etc.) in this course are core knowledge for any physicist. Indeed, Statistical physics finds application in Nuclear Physics, Nanotechnology, Molecular Biophysics, Condensed Matter Physics, Quantum Optics, Earth Physics and Astrophysics. The fundamental nature and applicability of statistical physics have been emphasized throughout the course. The concepts and tools developed are immediately applied to a broad range of multidisciplinary problems. This applied focus is expected to encourage the study of the subject and facilitate further application of the concepts to other fields of physics.

PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

There are no specified enrollment restrictions with other subjects of the curriculum.

OTHER REQUIREMENTS

Because this subject is taught in the third, fourth or fifth year, the student is expected to be familiar with: fundamental concepts of mechanics (phase space, equipartition theorem, etc.), thermodynamics (internal energy, entropy, temperature, and chemical potential, thermodynamic equilibrium, phase transitions, etc.) and quantum physics (quantum states and energy levels of simple systems, identical particles: fermions and bosons, etc.); basic concepts of electromagnetism.

COMPETENCES / LEARNING OUTCOMES

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Basic & applied Research: acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.

Be able to understand and master the use of the most commonly used mathematical and numerical methods.

Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.

Foreign Language skills: Have improved command of English (or other foreign languages of interest)



through: use of the basic literature, written and oral communication (scientific and technical English), participation in courses, study abroad via exchange programmes, and recognition of credits at foreign universities or research centres.

Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.

Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.

Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.

Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .

Students must be able to apply their knowledge to their work or vocation in a professional manner and have acquired the competences required for the preparation and defence of arguments and for problem solving in their field of study.

Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.

Students must have acquired knowledge and understanding in a specific field of study, on the basis of general secondary education and at a level that includes mainly knowledge drawn from advanced textbooks, but also some cutting-edge knowledge in their field of study.

Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

Students must have the ability to gather and interpret relevant data (usually in their field of study) to make judgements that take relevant social, scientific or ethical issues into consideration.

Theoretical understanding of physical phenomena: have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena).

To know how to apply the knowledge acquired to professional activity, to know how to solve problems and develop and defend arguments, relying on this knowledge.

DESCRIPTION OF CONTENTS

1. Statistical description of macroscopic systems.

Combinatorial mathematics. Probability and distributions. Spin Systems. Phase space. Ensembles and basic postulates of Statistical Physics. Microcanonical ensemble: entropy and temperature. Boltzmann



entropy. Entropy and irreversibility.

2. Partition function.

Boltzmann factor and partition function. Canonical ensemble, average values and fluctuations. Application to the ideal gas. The equipartition theorem. Classical limit. Gibbs factor and grand partition function. Grand canonical ensemble, average values and fluctuations. Statistical ensemble equivalence.

3. Ideal gases. Classical and quantum study.

Fermi-Dirac and Bose-Einstein distributions. Bose-Einstein Condensation. Classical limit: Maxwell-Boltzmann distribution. Electron gas. Photon gas.

4. Particle interactive systems.

The configurational partition function. Real gases and interaction potentials. The mean field approach: van der Waals fluid. The Ising Model. Monte Carlo simulations.

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Tutorials	7,00
Theory	38,00
Total hours	45,00

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	0,00
Independent study and work	37,50
Preparation of lessons	30,00
Preparation for assessment activities	0,00
Resolution of case studies	0,00
Total hours	67,50

TEACHING METHODOLOGY

Classroom activities: 40%



Theoretical and practical lectures address the conceptual and formal aspects of the subject and present a set of problems as applications of the theoretical concepts. They are based mainly on classroom lectures allowing continuous dialogue with students and make use of teaching tools as experimental demonstrations, animations or videos, graphical representation of the solutions to problems, projections and other presentations.

Tutorial sessions in small working groups are focused on student individual work and require his/her active participation. These sessions are intended to clarify doubts concerning the theoretical concepts, problem solving, reinforcement in areas of great difficulty, and other questionnaires. All activities are focused on the continuous evaluation and verification of student progress in the field.

Student's personal work: 60%

- Study of the theoretical lectures.
- Problem-solving, questions and, eventually, assignments (individual or in small groups)
- Individual tutorials are devoted to specific queries on student's doubts. Students are expected to ask for help concerning any difficulty found in the study of theory and solutions to the problems. Discussion of other topics of interest and queries on relevant bibliography are also possible.

You will find more specific information on the teaching methodology in Aula Virtual.

EVALUATION

Course evaluation and student's marking is divided in two blocks:

- **Written examination (EE, marks between 0 and 10)**: one part will assess the understanding of the conceptual and theoretical formalism of the subject through conceptual and numerical exercises. Another part of the examination will verify the student's capacity to apply the formalism to problem solving as well as assess his/her critical reasoning. In both parts, the correct argumentation of the solution and the appropriate justification of the approximations made will be considered.

- **Continuous monitoring and evaluation of student's work (EC, marks between 0 and 10)**: short written questions solved in the classroom, or problems issued by students, or oral presentation of problems or any other method to assess the students progress will be considered.

The final mark (F, between 0 and 10) is calculated as:

- If $EE \geq 4.0$ and $EC \geq 4.0$, then $F = \max(0.7EE + 0.3EC, EE)$ or $F = EE + 0.2 EC [1 - (EE/10)^3]$.
- If $EE < 4.0$ or $EC < 4.0$, then $F = EE$.

The same criteria apply to the second call as to the first.

COMMENTS: Lecturers will provide a more specific information of the evaluation through Aula Virtual.

REFERENCES

Basic



- R. Baierlein, *Thermal physics*, Cambridge U. P., 1999.
- D. V. Schroeder, *An introduction to thermal physics*, Oxford U. P., 2021

Additional

- J. L. Castillo y P. L. García, *Introducción a la termodinámica estadística mediante problemas*, Sanz y Torres, 1994.
- C. Fernández Tejero y J. M. Rodríguez Parrondo, *100 problemas de física estadística*, Alianza Ed., 1996.
- H. Gould y J. Tobochnik, *Statistical and thermal physics: with computer applications*, Princeton U. P., 2010.
- R. K. Pathria y P.D. Beale, *Statistical Mechanics*, Academic Press, 2022.
- G. Skacej y P. Zihelr, *Solved problems in thermodynamics and statistical physics*, Springer, 2019.
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- K. K. Likharev, *Statistical mechanics: problems with solutions*, IOP Publishing, 2019.
- T. Engel, *Physical chemistry: Thermodynamics, statistical thermodynamics, and kinetics*, Pearson, 2021.