

**COURSE DATA****Data Subject**

<b>Code</b>	34245
<b>Name</b>	Thermodynamics
<b>Cycle</b>	Grade
<b>ECTS Credits</b>	7.5
<b>Academic year</b>	2023 - 2024

**Study (s)**

<b>Degree</b>	<b>Center</b>	<b>Acad. year</b>	<b>Period</b>
1105 - Degree in Physics	Faculty of Physics	2	First term
1928 - D.D. in Physics-Mathematics	Double Degree Program Physics and Mathematics	2	First term
1929 - D.D. in Physics-Chemistry	Double Degree Program Physics and Chemistry	2	First term

**Subject-matter**

<b>Degree</b>	<b>Subject-matter</b>	<b>Character</b>
1105 - Degree in Physics	7 - Thermodynamics and statistical physics	Obligatory
1928 - D.D. in Physics-Mathematics	2 - Segundo Curso (Obligatorio)	Obligatory
1929 - D.D. in Physics-Chemistry	2 - Segundo Curso (Obligatorio)	Obligatory

**Coordination**

<b>Name</b>	<b>Department</b>
GARCIA MORALES, VLADIMIR	345 - Earth Physics and Thermodynamics
MANZANARES ANDREU, JOSE ANTONIO	345 - Earth Physics and Thermodynamics

**SUMMARY**

Thermodynamics is a compulsory subject of 7.5 ECTS. Given that the concepts and methods of thermodynamics are applicable to macroscopic systems of any nature, the subject is closely related to many other subjects of the degree, although its complementarity with the Laboratory of Thermodynamics and Statistical Physics stands out. It is also basic for the development of the subject Physics of the Atmosphere.



## PREVIOUS KNOWLEDGE

### Relationship to other subjects of the same degree

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

### Other requirements

Differential calculus of several variables. Integral calculus of one variable. Units and orders magnitude of quantity of matter, density, energy, temperature, ... Energy concept. Basic concepts of elasticity of one-dimensional systems. Basic concepts of electrical and magnetic polarization of materials.

## OUTCOMES

### 1105 - Degree in Physics

- Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.
- 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.
- 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 .
- Theoretical understanding of physical phenomena: have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena).
- Be able to understand and master the use of the most commonly used mathematical and numerical methods.
- 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.
- 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.
- 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.
- Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.



- 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.
- 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 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 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.
- Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.
- Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

## LEARNING OUTCOMES

Understanding of the influence of thermal motion on the dynamics of macroscopic systems. Comprehension of concepts such as internal energy, entropy, temperature, thermodynamic potentials, fundamental thermodynamic relation, reversibility, etc. Methods of Thermodynamics: derivation of thermodynamic relations, use of different representations (entropic, Gibbs, Helmholtz, ...), thermodynamic diagrams, etc.. Application to diverse physical systems. Experimental measurement techniques for thermodynamic quantities.

## DESCRIPTION OF CONTENTS

### 1. Introduction to thermodynamics

Thermodynamic systems and their interactions. General principle. State quantities. Zeroth law. Internal energy. Independent variables and state functions. Thermodynamic phenomena.

### 2. The principles of thermodynamics

Thermodynamic processes. Work. First law. Heat. Heat capacity. Entropy of a perfect gas. Second law. Entropy production in some irreversible processes. Third law.

**3. Gibbs, Euler and Gibbs-Duhem equations**

Gibbs equations. Equilibrium conditions. Euler and Gibbs-Duhem equations. Differential calculus in thermodynamics. Thermal and energetic coefficients. Maxwell relations. Thermodynamic stability conditions.

**4. Thermodynamic potentials**

Statements of the second law for different constraints. Thermodynamic representations. Gibbs-Helmholtz equations. Maximum work theorem. Exergy

**5. Statistical thermodynamics applied to some systems**

Boltzmann entropy equation. Lattice gas. Thermal radiation. Crystalline solid. Heat capacity of diatomic and polyatomic gases. Ideal quantum gases.

**6. Gases and gas mixtures**

Real gas equations of state. Fugacity. Joule-Thomson throttling. Gas mixtures.

**7. Phase transitions**

Phase diagrams  $p$ - $v$ - $T$ . Discontinuous phase transition. Biphasic systems. Clausius-Clapeyron equation. Continuous phase transitions. Magnetic phase transitions.

**8. Thermodynamics of elastic filaments**

Thermodynamic description of elastic filaments. Ideal elastic systems. Rubber elasticity. Shape memory alloys

**9. Mixtures and solutions**

Binary mixtures. Activity. Mixing and excess quantities. Colligative properties of solutions. Isothermal liquid-vapour equilibria. Isobaric phase equilibria. Gibbs phase rule. Partial molar quantities.

**10. Interfacial thermodynamics**

Interfacial excess quantities. Young-Laplace equation. Monocomponent interfacial systems. Kelvin equation. Gibbs-Thomson-Freundlich equation. Homogenous nucleation. Binary interfacial systems. Gibbs adsorption equation. Nanothermodynamics.

**11. Chemical equilibria**

Chemical equilibria in gas phase. Chemical equilibria in solution. Electrochemical processes.

**12. Thermodynamics of irreversible processes**

Thermodynamics of continuous media. State quantities for non-equilibrium systems. Phenomenological equations. Heat conduction. Thermoelectric phenomena. Balance equations and conservation equations.

**WORKLOAD**

ACTIVITY	Hours	% To be attended
Theory classes	60,00	100
Tutorials	15,00	100
Development of individual work	3,00	0
Preparation of evaluation activities	45,00	0
Preparing lectures	28,50	0
Preparation of practical classes and problem	36,00	0
<b>TOTAL</b>	<b>187,50</b>	

**TEACHING METHODOLOGY**

In the lectures the syllabus is developed using both the blackboard and the video projector. The material is presented following a logical, rigorous and well-structured approach that the students should master to describe accurately the behaviour of macroscopic systems.

Questions designed to promote teacher-student interaction will be addressed when convenient. They serve to identify and clarify the more difficult concepts. Students should prepare the lectures to optimize learning. Further reading is strongly recommended.

Practical sessions are intended primarily to get the students actively involved in problem solving. They must solve, individually or in groups, the problems with the help of the lecturer. In addition to the problems worked out in class, books containing solved exercises are also recommended.

In the tutorial sessions, the students may get answers for question on theoretical concepts as well as on the resolution of exercises.



## EVALUATION

Learning is assessed through a written exam (mark EE, between 0 and 10) and continuous assessment (mark EC, between 0 and 10) through exercises proposed in the lectures.

If  $EE \geq 3.5$  and  $EC \geq 3.5$ , the final grade (between 0 and 10) is  $F = EE + 0.2EC [1 - (EE/10)^3]$ .

If  $3.5 > EE$  or  $3.5 > EC$ , then  $F = EE$ . The requirement to pass the course is  $F \geq 5$ .

The written exam consists of a theoretical module (60 % weight) and a problem-solving module (40 %). The first one consists of four questions that can be practical (resolution of a short exercise), conceptual or numerical (requiring knowledge of conversions of units and typical orders of magnitude) that must be resolved without notes or books, only calculator. The problem-solving module contains two problems, and use of a personal collection of formulas (stapled, maximum of 5 double-sided pages or 10 pages on one side) is allowed.

## REFERENCES

### Basic

- Carrington, G. Basic Thermodynamics, Oxford U. P., Oxford, 1996.
- Fernández Pineda, C.; Velasco, S. Termodinámica, Ed. Univ. Ramón Areces, Madrid, 2009.

### Additional

- Velasco, S.; Fernández Pineda, C. Problemas de Termodinámica, Ed. Univ. Ramón Areces, Madrid, 2010.
- Pellicer, J.; Manzanares, J. A. 100 Problemas de Termodinámica, Alianza Editorial, Madrid, 1996.
- Pellicer, J.; Mafé, S. Cuestiones de Termodinámica, Alhambra Universidad, Madrid, 1989.
- Pellicer, J.; Tejerina, F. Problemas de Termodinámica con soluciones programadas, Universidad de Valladolid, Valladolid, 1997.
- Zamora, M.; Termo, Vols. 1 y 2 (problemas), Secr. Publ. Univ. Sevilla, Sevilla, 1998.
- Skacej, G.; Zihelr, P.; Solved Problems in Thermodynamics and Statistical Physics, Springer, Cham, 2019.
- Pitzer, K. S.; Thermodynamics, McGraw-Hill, New York, 1995.
- Callen, H.B.; Thermodynamics and an Introduction to Thermostatistics, Wiley, New York, 1985.