Bachelor in Physics
(Academic Year 2021-22)

Thermodynamics		Code	800499	Year	2nd	Sem.	1st
Module	General Core	Topic	Classical Physics			Character	Obligatory

	Total	Theory	Exercises
ECTS Credits	7.5	4.5	3
Semester hours	67.5	37	30.5

Learning Objectives (according to the Degree's Verification Document)

To get knowledge of:

- Thermodynamic Laws and their consequences.
- First Law as the general principle of energy conservation with an equation of state, the internal energy
- Entropy and how its properties affect the thermodynamic behavior of systems.
- Thermodynamic potentials as a complete information of a thermodynamic system.
- Relationship between thermodynamic formalism and experiments.

Brief description of contents

Zeroth Law. Concept of temperature. First Law: internal energy and heat. Second Law: entropy. Thermodynamic potentials, stability and equilibrium. Open systems, phase changes, critical points. Third Law.

Prerequisites

Calculus. Fundamental Physics.

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Theory/Exercises – Schedule and Teaching Staff

Group	Lecture Room	Day	Time	Professor	Period/ Dates	Hours	T/E	Dept.
B	10	Mo,Tu, Fr	9:00-10:30 9:00-11:00	Juan Pedro García Villaluenga	First semester	67.5	T/E	EMFTEL

T: Theory, E: Exercises

Office hours

Group	Professor	Schedule	E-mail	Location
B	Juan Pedro García Villaluenga	Th: 9:00-12:00 Campus virtual or email (3 h Mo-Fr)	jpgarcia@ucm.es	East wing, 1st floor, room 117

Syllabus

1.- Introduction and fundamental concepts.

Microscopic and macroscopic descriptions. Thermodynamic systems. Thermodynamic variables. Equilibrium. Changes in equilibrium states and processes.

2.- Temperature and the Zeroth Law of Thermodynamics.

Thermal equilibrium. Zeroth Law of Thermodynamics. Empirical temperature. Temperature scales.

3.- Phenomenological description of most common thermodynamics systems.

Thermodynamic equilibrium. Hydrostatic systems. Description of other simple systems.

4.- The concept of work in Thermodynamics.

Work in a hydrostatic system and in other simple systems. General equation of work.

5.- The First Law of Thermodynamics.

Adiabatic work. Internal energy function. Heat flow. First Law of Thermodynamics. Heat concept. Heat capacity. Illustrative applications of the first Law of Thermodynamics.

6.- The Second Law of thermodynamics.

Classical statements of the second Law of Thermodynamics. Entropy. Entropy and irreversibility. Principle of increase of entropy.

7.- Thermodynamic formalism of closed systems.

Fundamental equation of Thermodynamics. Entropy and internal energy representations. Equilibrium and stability in a homogeneous closed system.

8.- Alternative representations.

Thermodynamic potentials. Helmohltz and Gibbs functions. Maxwell' s relations. Equilibrium and stability in the alternative representations.

9.- Practical equations in Thermodynamics

Practical equations for the entropy, the internal energy and the thermodynamic potentials.

10.- Open systems

Second Law of Thermodynamics for open systems. Chemical potential. Fundamental equation and chemical potentials. Equilibrium conditions. Gibbs phase rule.

11.- Phase transitions

Classification of phase transitions. First-order phase transitions. Clausium-Clapyeron equation. Other phase transitions. Critical points.

12.- Third Law of Thermodynamics

Statements and consequences of the Third Law of Thermodynamics.

Bibliography

Basic:

- D. Kondepudi, I. Prigogine, *Modern Thermodynamics* (Wiley)
- M. W. Zemansky, R. H. Dittman, Heat and Thermodynamics (McGraw-Hill)
- C.J. Adkins, *Equilibrium thermodynamics* (McGraw-Hill)

Complementary:

- W. Greiner, L. Neise y H. Stöcker. *Thermodynamics and Statistical Physics* (Springer Verlag)
- M. Kardar. *Statistical Physics of Particles* (Cambridge University Press)
- Münster, *Classical Thermodynamics* (Wiley-Interscience)

Online Resources

Virtual campus

http://phet.colorado.edu/es/simulations/category/physics/heat-and-thermodynamics

http://www.sc.ehu.es/sbweb/fisica/estadistica/estadistica.htm

http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

http://entropysite.oxy.edu/

Methodology

On-campus teaching 100% (Scenario 0)

The following formative activities will be developed:

* Theory lessons where the main concepts of the subject will be explained (approximately 3 hours per week)

* Practical lessons involving resolution of exercises and supervised activities (approximately 2 hours per week)

Students will be provided with a collection of exercises prior to their resolution in class.

Professor will receive students in the specified schedule of tutorials in order to solve doubts and expand concepts.

Semi-online teaching (Scenario 1)

The same activities proposed in the teaching classroom will be developed, but in this case both theory lessons and practical classes of problems and directed activities will be taught following modality A: Teacher will deliver lessons in the classroom to one of the student subgroups while the rest of students attend online. The subgroups will rotate weekly to attend the teaching classroom. To follow online classes, the tools Microsoft Teams of Moodle, Google Meet or similar will be used. These will allow online participation of students along with at least one of the following methods: slides presentation, electronic whiteboard or similar, or traditional class using whiteboard transferred with a camera. Classes will not be recorded. This methodology is subjected to the provision of the necessary equipment by the center.

Problem statements will be delivered in advance through the Virtual Campus, as well as the necessary material for teaching the classes.

Teacher will organize with the students the face-to-face or online tutoring, at their specified time, in order to answer questions or expand concepts.

Online teaching (Scenario 2)

The same activities proposed in the teaching classroom will be developed, but in this case both theory lessons and practical classes of problems and directed activities will be taught online through the tool Microsoft Teams of Moodle, Google Meet or similar, or through material recorded in advance and made available to the student in the Virtual Campus of the subject.

Problem statements will be delivered in advance through the Virtual Campus, as well as the necessary material for teaching the classes.

Teacher will organize with the students online tutoring, at their specified time, in order to answer questions or expand concepts.

Evaluation Criteria		
Exams	**Weight:**	70 %
There will be a practical final exam, consisting of solving problems and exercises, in which class notes and freely chosen books of theory can be used. If due to force majeure the face-to-face exam cannot be performed, the online exam will be carried out and it will have the same format as the face-to-face exam.		
Other Activities	**Weight:**	30 %
The continuous evaluation activities will consist of problems and/or exercises delivered throughout the course individually and/or in group, and/or small individual tests carried out during the course.		
Final Mark		
The final grade (F) will be the best of the following two: $F = 0.3\ A + 0.7\ E$ $F = E$ where A is the final grade for “Other Activities” and E is the final exam grade (both over 10). To pass the course by applying the first equation, a minimum of 4 out of 10 will be required in the grade corresponding to the final exam. The final grading criteria will be also maintained for the extraordinary session, as well as the corresponding grade for other activities.		