Proyecto/Guía docente de la asignatura

Si la docencia fuese en parte online, deben respetarse los horarios tanto de clase como de tutorías.
La planificación académica podrá sufrir modificaciones de acuerdo con la actualización de las condiciones sanitarias.

TEACHING GUIDE/Course Information

If the teaching is partly online, the class and tutoring schedules must be respected.
Academic planning may undergo modifications in accordance with the update of sanitary conditions.

Subject	Thermodynamics of materials (Termodinámica de materiales)		
Matter			
Module (of specialization)	Physics of materials (Física de materiales)		
Title	*Master in Physics* (Master en Física)		
Plan	617	Code	54403
Teaching Period	First half/First semester	Type/Character	Optional
Degree	Master	Level/Course	1º
ECTS Credits	3		
Language	Castellano (English. French)		
Teachers	Prof. Dr. D. José Carlos Cobos Hernández Prof. Dr. D. Isaías García de la Fuente Prof. Dr. D. Juan Antonio González López Prof. Ayudante Dr. D. Luis Fernando Hevia de los Mozos		
Department	Applied Physics (Física Aplicada)		
Contact information (E-mail, Phone,)	josecarlos.cobos@uva.es +(34) 983.42.31.37 isaias.garcia@uva.es +(34) 983.42.37.40 jagl@termo.uva.es +(34) 983.42.37.57 luisfernando.hevia@uva.es +(34) 983.42.31.36 Offices B326, B325, B324 and B310 (Despachos) 3rd floor. Central block (B). Science Faculty		
Laboratory	Master's Laboratory (B002) *"G.E.T.E.F."* Research Laboratory (B007) Main floor. Central block (B). Science Faculty.		

Meeting rooms (Cisco Webex) for *Remote classroom activity*:

Click: https://universidaddevalladolid.webex.com/meet/josecarlos.cobos
https://universidaddevalladolid.webex.com/meet/isaias.garcia
https://meetingsemea38.webex.com/meet/pr1755926842
https://universidaddevalladolid.webex.com/meet/luisfernando.hevia

1. Situation / Meaning of the Subject

1.1 Contextualization

"Thermodynamics of materials" is an **optional subject** carried out along the **first half of the first semester**. The whole Master's degree last for two semesters.

"Thermodynamics of materials" is divided into **two parts**:
The **first one** (14 hours) is concerned with the presentation of key concepts in the field (lectures) and resolution of some related problems. This part is developed in the classroom with all the students present.
The **second part** (12 hours) is experimental and takes place at the **Master's Laboratory** (**B002**) and *"G.E.T.E.F."* **Research Laboratory** (**B007**), where subgroups of 1 or 2 students perform a number of experiments. Specifically, the laboratories are located on the main floor of the Science Faculty. It belongs to the research laboratories of the Applied Physic Department.

As Master's Report indicates, the *"G.E.T.E.F."* (**Grupo Especializado en la Termodinámica de los Equilibrios entre Fases**/Group Specialised in Thermodynamics of Phase Equilibria) [*A Recognized Research Group of the University of Valladolid*], is dedicated to the study of: **"Thermodynamic behaviour of the equilibria between fluid and condensed phases that appear in gas, liquid and solid mixtures"**.

Let us now examine the organization of the Course.

STRUCTURE AND CONTENTS

Spanish Royal Decree 861/2010, of July 2, which modifies Spanish Royal Decree 1393/2007, of October 29, concerned with the order of official university education, establishes, in its introduction, that Universities can consider specialties in the design of their Master's degrees, alluding to a specific curricular intensification.

The ***Master in Physics*** includes **3 specialties**, made up of optional subjects, but it is clearly stated that the student will never be forced to choose a specialty, since students can design the choice of electives to their liking.

The Master structure is outlined on two levels: *Modules* and *Subjects*

It does not seem appropriate to consider the level of the subjects due to the *transversal nature of the Master's contents*. It is more convenient to present the *Module level* to guide the possible specialization itineraries which are accessible to students.

The Master in Physics contains 5 *Modules*, two required and three optional. They are the following:

- ✓ ***Common Module***: all the students must follow this *Module*. It is formed by three **required *subjects*** that establish the minimum necessary bases for the three specialization modules.
- ✓ **Specialization in *Materials Physics***: *Module* based on the development of ***subjects*** whose content is related to the study and characterization of materials.

- ✓ **Specialization in *Atmospheric Physics and Climate***: *Module* based on the development of the atmospheric physics and the techniques of measurement of its components, both from the ground and from satellite, with the general aim of presenting the latest research in the study of climate change.
- ✓ **Specialization in *Mathematical Physics***: *Module* based on deepening in specific mathematical techniques applied to problems of theoretical physics.
- ✓ ***Master's Thesis***: **required** for all students.

The skills acquired by the students throughout the Master are supported by the **basic skills of the degree**. Students must:

- Possess and understand the knowledge that provides a basis or opportunity to be original in the development and / or application of ideas, often in a research context.
- Know how to apply the acquired knowledge and their problem-solving capacity in new or little-known environments within broader (or multidisciplinary) contexts related to their area of study.
- Be able to integrate knowledge and face the complexity of formulating judgments from information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
- Know how to communicate their conclusions –and the ultimate knowledge and reasons that support them–to specialized and non-specialized persons in a clear and unambiguous manner.
- Possess the learning skills that allow them to continue studying in a way that will have to be largely self-directed or autonomous.

1.2 Relationship with other subjects

Below, we break down the ***subjects*** of the ***Modules*** that are here of our interest. The corresponding ECTS credits are also given. **1 ECTS is equivalent to 25 hours** of dedication by the student.

"Common *Module*" Subjects — **9 ECTS**

Computing in Physics	**3 ECTS**
Scientific methodology and knowledge transfer	**3 ECTS**
Data analysis and Big Data techniques in Physics	**3 ECTS**

This *Module* aims to establish the basic transversal concepts required to follow the subjects included within the three specialization blocks that follow.
The subject "Scientific methodology and knowledge transfer" is purely theoretical, while the other two matters have a practical part performed in a computer lab.

Subjects of the Specialization *Module* in "Materials Physics" — **33 ECTS**

Thermodynamics of Materials	**3 ECTS**
Static and dynamic structural characterization of materials: Diffractometry and Vibrational Spectroscopy	**3 ECTS**
Semiconductor materials for optoelectronics and integrated circuits	**3 ECTS**
Polymers	**3 ECTS**

Nanoscience and quantum confinement in nanomaterials	**3 ECTS**
Magnetic materials	**3 ECTS**
Selective porous materials	**3 ECTS**
Biomaterials	**3 ECTS**
Multiphase materials and cellular materials	**3 ECTS**
Experimental techniques of characterization of semiconductors and insulators	**3 ECTS**
Biomaterial experimentation	**3 ECTS**
Computational modeling of semiconductors and technological processes	**3 ECTS**
Quantum simulations of nanomaterials	**3 ECTS**
Properties and computational modeling of metamaterials	**3 ECTS**

This *Module* consists of a specialization in **"Physics of Materials"**, a matter highly demanded at present in the labour market, accessed by graduates in Physics, Engineering, Biotechnology and Chemistry.

It deepens in the characterization at electrical, optical and mechanical levels of materials, and also in various electronic devices, nanomaterials, biomaterials and selective cellular and porous materials. Therefore, this is a module highly weighted by Electronics, Electromagnetism, Quantum Physics, Chemistry and Solid State Physics, which present their techniques for the characterization of materials. The module also includes specific computational simulation courses to model this part of Physics.

Most of such subjects are experimental and include laboratory practices, so part of the credits will contain 15 contact hours per credit, due to the requirement of the teacher's supervision.

TFM *Module*: Master's Thesis (Required) 18 ECTS

The student will carry out an initiation work in the field of research, with regards to some of the topics considered in the subjects included in the Master, or linked to investigation lines developed by the participating research groups.

The whole Master is built by a total offer of **9 obligatory ECTS**, from the required *Module*, plus 123 optional ECTS (distributed as 33, 42 and 48 ECTS of the three specialties, respectively), from which **the student must select 33 ECTS**, plus **18 ECTS corresponding to the TFM,** whose character is mandatory.

***MODULES* IN PHYSICS MASTER'S DEGREE**	
COMMON	9 ECTS
ATMOSPHERIC PHYSICS AND CLIMATE	33 ECTS
MATERIALS PHYSICS	42 ECTS
MATHEMATICAL PHYSICS	48 ECTS
Master's Thesis (Trabajo Fin de Master)	18 ECTS

To conclude, let us emphasize, in particular, that the "**Thermodynamics of Materials**" is present in all the postgraduate degrees offered by the Universities and Research Institutes that have programs related to materials.

The thermodynamic study of a material is essential for any graduate in Physics, Chemistry, Biotechnology and Engineering who wants to expand his knowledge in the field of materials.

This course will allow the student to understand the new concepts that will appear in the remaining subjects that make up the materials module of the Master.

1.3 Prerequisites

Although, according to the memory that regulates the Master, access does not require specific training supplements, students coming from different degrees (Degree in Physics or the double Degree in Physics and Mathematics, Mathematics, Engineering, Chemistry and Biotechnology), will receive indications regarding the appropriate itinerary to follow, according to their profile, as it is summarized below:

- Graduate profile in Physics or Physics and Mathematics: all itineraries are recommended.
- Graduate profile in Mathematics: the module "Mathematical Physics" is recommended.
- Profile of graduate in Chemistry and Biotechnology, graduate in Industrial, Computer or Telecommunications Engineering: "Atmospheric Physics and Climate" or "Physics of Materials" are recommended.

Similarly, the same report indicates that: «the evaluation scales considered in the admission of students will be, in the following order of priority:

Origin Degree: **priority to** Physics, Physics + Mathematics, Mathematics, Engineering, Chemistry and Biotechnology. **Low priority** to other degrees.
Assessment of the academic record.
Assessment of the Academic Committee of the Title, after personal interview. »

Therefore, as it is obviously inferred from indications provided in sections 1.1 and 1.2, it is highly desirable that students have completed their undergraduate studies in Science (Physics, Chemistry, Biology, Biotechnology, etc.) or in any Engineering, having successfully completed some subject related to ***"Thermodynamics"***.
In addition, students must be skilled in the use of the necessary ***"Mathematical" tools***. In any case, this prior requirement should be considered by the student in order to successfully pass the subject.

2. Competences

The competences described in the *Verification Report of the Master in Physics* indicated below

2.1 General (transversal)

G1. Ability to apply acquired knowledge.
G2. Critical analysis and synthesis capacity.
G3. Communication skills.
G4. Autonomous learning ability.
G5. Capacity for teamwork.

2.2 Specific and of the "Materials Physics" Module

C1. Understanding the scientific bases of computing.
C3. Ability to establish orders of magnitude and to choose the most appropriate measurement system in each case.
C4. Ability to extract relevant information from large sets of experimental data using appropriate statistical treatments.
C5. Ability to establish algorithms to address problems with multiple solutions.
C6. Ability to optimize resources.
C8. Knowledge of advanced physical foundations in the different matter states.
C10. Knowledge of the theoretical bases of study in Physics
C11. Knowledge of physical systems at the cutting-edge of knowledge.

Other specific skills acquired by students who follow this specialization:

- Knowledge of new technology-based materials.
- Understanding of the physical properties leading to the characterization of materials.
- Interpretation of specific computing techniques in the modeling of material structures.
- Ability to participate in international scientific activities and in scientific decision-making at the international level.

3. Objectives (learning outcomes)

According to the ***Verification Report of the Master in Physics***, when studying the *Module **"Physics of Materials"***:

> «The student will acquire a specialized training in the characterization of materials from the mechanical, electrical and optical points of view. Some specialized knowledge of characterization of different types of materials (semiconductors, biomaterials, nanomaterials) is also included. The student will learn and develop specific computational simulation techniques for the materials study. The student will receive additional learning in laboratory techniques related, which will be developed in the research laboratories of the Departments…»

In particular, after completing the ***subject "Thermodynamics of Materials"***, the student must be able to:

- Present a broad and unitary vision of the thermodynamics of materials in different fields (Physics, Chemistry, Engineering, etc. ...), homogenizing the different levels of training with which students arrive from the respective Bachelor's degrees.
- Use a basic terminology in Thermodynamics, and communicate with the precision required in Science, formulating ideas, concepts and relationships between them, and being able to reason in scientific terms.
- Provide the operational capacity to apply and relate laws and concepts, as well as mastering the different procedures for solving thermodynamic problems of materials, including the necessary mathematical skills. It is intended that the student knows how to interpret the results and discuss them.
- Show the interrelation of the subject with other sciences, especially Physics, Chemistry and Biotechnology.
- Offer the necessary knowledge to face any challenge that may arise in the student's professional career.
- Design and assemble experimental setups in the field of Thermodynamics of Materials, take measurements, perform their mathematical treatment, their interpretation in terms of physical laws and their presentation in the form of a scientific article.
- Study and plan their learning activities, either individually or in groups, by searching, selecting, or summarizing information from the different bibliographic sources.

And, still more particularly (see the next section, "4.c Contents"), after completing the subject ***"Thermodynamics of Materials"***, the student must:

- Have acquired the necessary knowledge to approach the study and thermodynamic characterization of any material.
- Know the information that the techniques of Differential Thermal Analysis (DTA) and Differential Scanning Calorimetry (DSC) can provide in the thermal characterization of materials.
- Know the information that the technique of Dielectric Spectroscopy can provide in the characterization of materials.

4. Contents and / or thematic blocks

ECTS credits workload: 3

4.c. Contents

The contents included in the Master's Report are the following:

Subject: *"Thermodynamics of Materials"*

- Balances between phases: fugacity.
- Condensed phases: excess functions and models.
- Polymeric systems.
- Thermal spectroscopy using DSC and determination of the Solid–Liquid Equilibrium.
- Dielectric characterization of materials in liquid phase.

These contents are now given in detail so that the fields of study that are intended to be covered can be better appreciated:

- Closed and open homogeneous systems. Gibbs–Duhem equation. Phase rule. Chemical potential. Fugacity and activity. Raoult's Law. Thermodynamic properties from volumetric data.
- Intermolecular forces, corresponding states, and osmotic systems.
- Fugacities in gas mixtures. Lewis rule of fugacity. Fugacity at high densities. Solubilities of solids in liquids.
- Fugacities in liquid mixtures. Excess functions. Fundamental relationships of excess functions. Activity and activity coefficients. Models for the Gibbs excess function. Solid-liquid equilibrium and diagrams.
- Brief characterization of polymeric species.
- Characterization of materials using thermal analysis techniques (DSC and MDSC)
- Electrical characterization of materials in condensed phase.

All this results in the following program and time planning

4.e. Workplaning

Total temporal duration: 7 weeks, 26 hours, divided into two parts:

The **first one** (14 hours) is concerned with the presentation of key concepts in the field (lectures) and resolution of some related problem sets. This part is developed in the **classroom** with all the students present. The **second part** is experimental (12 hours) and takes place at the **Master's Laboratory (B002)** and ***"G.E.T.E.F."*** **Research Laboratory (B007),** with subgroups of 1 or 2 students.

P R O G R A M

Topic 1 (3 hours)

PVT behaviour of pure substances. Virial and cubic state thermal equations. Generalized correlations for gases and liquids.- Thermodynamic potentials for the evaluation of the properties of homogeneous phases. Residual properties.- Two-phase systems. Thermodynamic diagrams.- Phase rule. Duhem's theorem. Vapour–Liquid Equilibrium (VLE): qualitative behaviour. Simple models for calculating VLE.

Topic 2 (5 hours)

Chemical potential and phase equilibrium. Partial molar properties. Ideal gas mixtures. Fugacity and fugacity coefficient in pure substances and mixtures.- The ideal solution. Activity and activity coefficient. Excess properties.- Properties of the liquid phase from the VLE data. Excess Gibbs function models. Thermal and energetic properties in mixtures and solutions.

Topic 3 (4 hours)

Gamma / phi formulation of the VLE.- VLE from the state thermal equations.- Equilibrium and stability. –Liquid–Liquid Equilibrium (LLE). –Solid–Liquid Equilibrium (ESL).- Solid-Vapour Equilibrium (SVE).- Adsorption.

Topic 4 (2 hours)

Polymer properties. Brief characterization of polymeric species.

Topic 5 (6 hours)

Differential Thermal Analysis (DTA) and Differential Scanning Calorimetry (DSC).- Study of endothermic and exothermic transitions as a function of temperature. Glass transition, melting, crystallization, curing, curing kinetics, oxidation processes and heat capacities. Application to different materials.

Topic 6 (6 hours)

Dielectric characterization of materials in condensed phase.

4.g Teaching material

Esta sección será utilizada por la Biblioteca para etiquetar la bibliografía recomendada de la asignatura (curso) en la plataforma Leganto, integrada en el catálogo Almena y a la que tendrán acceso todos los profesores y estudiantes.

UVa – Ex Libris Leganto
https://buc-uva.alma.exlibrisgroup.com/leganto/readinglist/searchlists

4.g.1 Recommended texts

* W.D. Callister y D.G. Rethwisch. "*Ciencia e Ingeniería de los materiales*". 2ª Edición [en español, 9ª en inglés]. Editorial Reverté (2015).

* W.D. Callister and D.G. Rethwisch. "*Materials Science and Engineering. An Introduction*". 10th Edition. Wiley (2018).

* F.C. Campbell. "*Phase Diagrams. Understanding the basics*". A.S.M International (2012).

* Y.A. Cengel and A.J. Ghajar. "*Heat and Mass Transfer: Fundamentals and Applications*". 5th Ed. McGraw–Hill (2015).

* Y.A. Chang and W.A. Oates. "*Materials Thermodynamics*". John Wiley & Sons (2010).

* A. Chelkowshi. [Studies in physical and theoretical chemistry 9] "*Dielectric Physics*". Elsevier (1980).

* D.R. Gaskell and D.E. Laughlin. "*Introduction to the Thermodynamics of Materials*". 6th. Ed. CRC Press (2018).

* J.P. O'Connell and J.M. Haile. "*Thermodynamics: Fundamentals for Applications*". Cambridge University Press (2005).

* B.E. Poling, J.M. Prausnitz and J.P. O'Connell. "*The Properties of Gases and Liquids*". 5th. Ed. McGraw–Hill (2000).

* J.M. Prausnitz, R.N. Lichtenthaler y E. Gomes de Azevedo. "*Termodinámica molecular de los equilibrios entre fases*". 3ª Edición. Editorial Prentice–Hall. Madrid (2000).

* J.M. Prausnitz, R.N. Lichtenthaler and E. Gomes de Azevedo. "*Molecular Thermodynamics of Fluid-Phase Equilibria*". 3rd Edition. Pearson (1998).

* D.V. Ragone. [MIT series in materials science and engineering] "*Thermodynamics of Materials*". Volume 1 and 2. John Wiley & Sons (1995).

* J.S. Rowlinson and F.L. Swinton. "*Liquids and Liquid Mixtures*". 3rd Edition. Butterworths Sci. Pub. London (1982).

* J.M. Smith, H.C. Van Ness y M. M. Abbott. "*Introducción a la Termodinámica en Ingeniería Química*". 6ª Edición. McGraw–Hill. México (2003).

* J.M. Smith, H.C. Van Ness and M. M. Abbott. "*Introduction to Chemical Engineering Thermodynamics*". 7th Edition. McGraw–Hill Higher Education (2005).

* T.M. Tritt. "*Thermal Conductivity. Theory, Properties and Applications*". Kluwer Academic (2004).

* H.C. Van Ness and M.M. Abbott. "*Classical Thermodynamics of Nonelectrolyte Solutions - with Applications to Phase Equilibria*". McGraw–Hill (1982).

* E. Wilhelm and T.M. Letcher "*Heat Capacities: Liquids, Solutions and Vapours*". Royal Society of Chemistry (2010).

* E. Wilhelm and T.M. Letcher "*Volume Properties: Liquids, Solutions and Vapours*". Royal Society of Chemistry (2014).

* E. Wilhelm and T.M. Letcher "*Enthalpy and Internal Energy: Liquids, Solutions and Vapours*". Royal Society of Chemistry (2017).

4.g.2 Further readings (Complementary bibliography)

Experimental Data and Tables

* **Rumble, J.R. (Editor)**. *Handbook of Chemistry and Physics*. CRC Press (101st Edition) (2020).

Quantities, Units and Symbols

* **B.I.P.M.** "*The International System of Units (SI) – 9th edition – Complete brochure*". B.I.P.M. (2019).
https://www.bipm.org/documents/20126/41483022/SI-Brochure-9.pdf/

* **I.U.P.A.C.** (G. J. Leigh, H. A. Favre, W. V. Metanomski) "*Principles of Chemical Nomenclature. A Guide to IUPAC Recommendations*". IUPAC (1998).
http://publications.iupac.org/books/principles/principles_of_nomenclature.pdf

* **I.U.P.A.C.** (Prepared for publication by I. Mills, T. Cvitas, K. Homann, N. Kallay and K. Kuchitsu) "*Quantities, Units and Symbols in Physical Chemistry*". IUPAC *Green Book*, 2 Ed, IUPAC & RSC Publishing (1998).
http://old.iupac.org/publications/books/gbook/green_book_2ed.pdf

* **Real Decreto 493/2020, de 28 de abril,** por el que se modifica el **Real Decreto 2032/2009, de 30 de diciembre, por el que se establecen las unidades legales de medida**.
https://www.boe.es/boe/dias/2020/04/29/pdfs/BOE-A-2020-4707.pdf

* **Real Decreto 2032/2009, de 30 de diciembre,** por el que se establecen las unidades legales de medida. Ministerio de Industria, Turismo y Comercio. Boletín Oficial del Estado (21/01/2010), Nº 28, 5607–5619. Versión consolidada, disponible en el enlace:
https://www.boe.es/buscar/pdf/2010/BOE-A-2010-927-consolidado.pdf

Este **Real Decreto 2032/2009,** traspone la **directiva 80/181/CEE**, por la que **el Consejo de las Comunidades Europeas estableció el uso del sistema internacional de unidades como sistema legal de unidades**, y sus modificaciones posteriores, además de hacer suyos los acuerdos de la Conferencia General de Pesas y Medidas.

* **Ley 32/2014, de 22 de diciembre, de Metrología**. Boletín Oficial del Estado (23/12/2014), Nº 309, 104386–104408. Disponible en: https://www.boe.es/boe/dias/2014/12/23/pdfs/BOE-A-2014-13359.pdf

* **Real Decreto 244/2016, de 3 de junio, por el que se desarrolla la Ley 32/2014, de 22 de diciembre, de Metrología**. Boletín Oficial del Estado (07/06/2016), Nº 137, 37689–37858. Versión consolidada, disponible en el enlace: https://www.boe.es/buscar/pdf/2016/BOE-A-2016-5530-consolidado.pdf

4.g.3 Other resources (knowledge pills, blogs, videos, digital magazines, Massive Online Open Courses (MOOC), ...)

https://www.aenor.com/
http://www.aemet.es/es/portada
https://www.bipm.org/en/about-us/
https://www.bipm.org/en/publications/si-brochure/
https://www.cem.es/
http://www.ciemat.es/
https://www.csic.es/
https://www.iso.org/home.html
https://iupac.org/
https://iupac.org/what-we-do/periodic-table-of-elements/
https://www.nist.gov/topics/metrology
https://www.nist.gov/pml/periodic-table-elements
https://webbook.nist.gov/chemistry/
https://www.npl.co.uk/
https://www.oiml.org/en/publications/other-language-translations/other-language-translations
https://www.ptb.de/cms/en.html
https://www.une.org/

4.h. Necessary resources

5. Teaching methods and methodological principles

As explained previously, the subject has **two complementary parts**: a **first part** devoted to Theory and Problem sets, which takes place in the classroom with the entire group of students, and a **second experimental part** carried out place at the **Master's Laboratory** (**B002)** and ***"G.E.T.E.F."*** **Research Laboratory** (**B007**), with subgroups of 1 to 2 students.

Therefore, the teaching methods and methodological principles applied in each part are clearly different: Teaching Theory and Problems (in the classroom), is NOT the same as teaching how to work in a Research Laboratory, where safety precautions must first be exposed, rigorously followed, etc.

To achieve the desired objectives, the procedure will be as follows:

(1) Theory and Problem sets.- 7 blackboard classes (2 hours): 8 hours of theory (lectures) and 6 hours of problems spread over six weeks.

In theoretical classes, the teacher exposes the *theoretical contents* by means of materials that will be provided to students (slides, notes, figures and diagrams), as well as bibliographic references.
For each theoretical topic, a *collection of problems* will be given. Some typical problems will be solved by the teacher. The remaining of them will be solved by the students, who will submit them for correction and evaluation.
In addition, the teacher will propose some applied work to be delivered and evaluated.
Directly related to these face–to–face classes are the **mandatory tutorials** (2 hours), where the teacher must actively monitor the work and progress of the students, in addition to solving the questions raised.

(2) Laboratory sessions.- 3 sessions of approximately 4 hours of duration. If it is possible, there will be 2 or 3 sessions per week. These sessions are aimed to small groups, with a teacher assigned to each subgroup

Lab work:

- **Heat insulation/Heat conduction** (PHYWE -- Laboratory Experiments).
- **Measurement of Thermal Conductivity by Lees' method.**
- **A Study of the Thermal Properties of a Binary/Eutectic Alloy of Tin(Sn)/Lead(Pb).**
- **Differential Thermal Analysis (DTA) of substances as a method of materials research.**

The **laboratory reports** written by the students will be based on these experiments.

6. Table of student dedication to the subject

Total temporal duration: 7 weeks. 26 hours divided into two parts:

The **first one** (14 hours) is concerned with the presentation of key concepts in the field (lectures) and resolution of some related problems. This part is developed in the classroom with all the students present.
The **second part** (12 hours) is experimental and takes place at the **Master's Laboratory** (**B002**) and ***"G.E.T.E.F."*** **Research Laboratory** (**B007**), with subgroups of 1 or 2 students.

CLASSROOM ACTIVITY	Hours	NON PRESENTIAL ACTIVITIES	Hours
Theoretical/Practical lessons (T) 4 blackboard classes x 2 hours	8	**Autonomous study and problems solving**	25
Problem lessons (A) 3 blackboard classes x 2 hours	6	**Bibliographic searches**	2
Laboratory work (L) 4 hours/session x 3 sessions	12	**Writing laboratory reports**	8
External, clinical or field practices			
Seminars (S)			
Tutoring (T) 1 hour/tutorials x 2 tutorials	2		
Evaluation Sessions 2 hours x 1 exam	2	**Exam preparation**	10
Total classroom or laboratory activities	30	**Total non presential activities**	45
Total			75

7. Assessment details

Criteria for evaluation:

The evaluation of the subject will be done considering the two different parts indicated: **(1)** Theory and problems, and **(2)** Laboratory work, with a weighted combination of continuous assessment and final exam.

The evaluation of both parts is done separately, with the following criteria:

(1) Assessment of theory and problems

The evaluation of this part will be done through a **written exam** **(40%)**. The mark obtained will be added to the corresponding one obtained from the **proposed problem sets** (continuous evaluation phase) along the course **(20%)**.
The problem sets solved by the students during the course will be evaluated and scored from **0** to **10** by the teacher. The total mark is determined from the sum of the individual scores obtained in each problem, divided by the total number of problems proposed.

(2) Laboratory work evaluation

The laboratory work is evaluated on the basis of the **reports written by the students**, for each work carried out at the laboratory. The evaluation will be **40% of the total score**.

Grading.- The total grade for the whole course will be computed via: 40% (theory and problems assessment) + **20%** (evaluation of proposed problems) + **40%** (laboratory work evaluation).

PROCEDURE	WEIGHT on FINAL NOTE	OBSERVATIONS
Final exam (written)	**40%**	A written exam of questions and problems
Exercises/Problem sets	**20%**	Total mark sum of the individual scores, divided by the total number of problems
Laboratory work	**40%**	Laboratory work is evaluated on the basis on the reports written by the students for each of the works carried out

QUALIFICATION CRITERIA
Ordinary examination call:
○ The student must demonstrate their **knowledge of the subject** when solving problems and questions and their work in the laboratory..
Extraordinary examination call:
○ The student must demonstrate their **knowledge of the subject** when solving problems and questions and their work in the laboratory..

8. Final thoughts