Bachelor in Physics
(Academic Year 2022-23)

Physics Laboratory II		**Code**	800506	**Year**	2nd	**Sem.**	Annual
Module	General Core	**Topic**	Physics Laboratory			**Character**	Obligatory

	Total	**Theory**	**Exercises**
ECTS Credits	7.5	1.4	6.1
Hours	89,5	13,5	76

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

- To acquire knowledge of principles, analysis techniques, measurement instruments and experimental phenomena of interest in Thermodynamics, Mechanics and Waves, Electricity and Magnetism, and Quantum Physics.
- To acquire the skill in handling measuring devices and instrumentation.
- To evaluate the limits of measurement methods due to interference, to the simplicity of the models and from effects that are neglected in the method of measurement.
- To be capable to prepare a report and to document a measurement process in respect to the fundamental principles, the required instrumentation and the results presentation.
- To analyze the obtained experimental results and to draw conclusions using statistical techniques.

Brief description of contents

Laboratories of Thermodynamics, Mechanics and Waves, Electricity and Magnetism, Quantum Physics. Data treatment techniques. Basic statistics.

Prerequisites

Energy conservation, rigid body rotation, waves on strings, interference of waves, diffraction of waves, stationary waves, oscillatory movement, and dispersive media.

Heat and temperature: Temperature and thermal equilibrium. Ideal gas law. Specific heat. First law of Thermodynamics. Adiabatic processes in an ideal gas. Second law of Thermodynamics.

Direct and alternating current. Resistors and capacitors. Biot-Savart and Faraday laws.

Planck hypothesis about light emission and absorption. Photoelectric effect. Photons. Discrete energy levels spectrum. Bohr atomic model.

It is recommended to be studying Thermodynamics, Classical Mechanics and Quantum Physics I.

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Theory – Schedule and Teaching Staff						
Group	**Lecture Room**	**Day**	**Time**	**Professor**	**Hours**	**Dept.**
B	10	(sem.1) Mo Th	12:00-13:30 12:00-13:30	Mohamed Khayet Souhaimi	7.5	EMFTEL
				Andrey Malyshev	3.0	FM
	4A	(sem.2) Th Fr	9:00-10:00 12:00-13:30	Ruth Martínez Casado	1.5	FM
				Álvaro Muñoz Noval	1.5	FM

Office hours				
Group	**Professor**	**Schedule**	**E-mail**	**Location**
B	Mohamed Khayet Souhaimi	1st semester, We: 12:00-15:00 2nd semester, We: 11:00-14:00 (+ 3h online, campus virtual or email)	khayetm@fis.ucm.es	Room 01.106.0, 1st Floor, East
	Andrey Malyshev	Th: 10.00-13.00 (+3h online)	a.malyshev@ucm.es	Room 126,0 2nd Floor, East
	Ruth Martínez Casado	Th: 10.00-13.00 (+3h online)	mariarum@ucm.es	Room 107.0 2nd Floor, East
	Álvaro Muñoz Noval	Mo, We, Fr: 13h-15h	almuno06@ucm.es	Room 107.0 2nd Floor, East

Laboratories – Groups in English and Teaching staff			
Group	**Professor**	**Dpto**	**e-mail**
L13	José Miguel Miranda Pantoja (Thermo.)	EMFTEL	miranda@ucm.es
	Ándrey Malyshev (1st semester. M&W)	FM	a.malyshev@ucm.es
	Henrik Lyder Andersen (2nd semester. M&W)	FM	henrikla@ucm.es
	Rainer Schmidt (E&M)	FM	rschmidt@ucm.es
	Nicolas Fabre	OP	nfabre@ucm.es
L14	Loreto García Fernández (1st semester. Thermo.)	EMFTEL	loreto.garcia@ucm.es
	Atreyee Sinha (2nd semester. Thermo.)		asinha@ucm.es
	Ándrey Malyshev (1st semester. M&W)	FM	a.malyshev@ucm.es
	Henrik Lyder Andersen (2nd semester. M&W)	FM	henrikla@ucm.es
	Rainer Schmidt (EyM)	FM	rainer.schmidt@fis.ucm.es
	Nicolas Fabre	OP	nfabre@ucm.es

Laboratories in English- Schedule: Dates and Hours		sessions	21
Group	**Dates**	**Hours**	**Lab**
L13	Sep. 20th/22, Sep. 27th/22, Oct. 04th/22, Oct. 19th/22	15:00-18:00	Thermo
	Oct.18th/22, Oct.25th/22, Nov.8th/22, Nov.15th/22	15:00-19:00	M&W
	Feb.7th/23, Feb.14th/23, Feb.21st/23	15:00-19:00	E&M
	Feb.28th/23, Mar.7th/23, Mar.14th/23	15:00-19:00	M&W
	Mar21st/23, Mar28th/23, Apr11th/23, Apr18th/23, Apr25th /23	15:00-19:00	Thermo
	Mar20th/23 and Mar27th/3	17:00-19:00	QP

L14	Oct26th/22, Nov02nd/22, Nov16th/22, Nov23rd/22	15:00-18:00	Thermo
	Sep.21st/22, Sep.28th/22, Oct.05th/21, Oct.19th/22	15:00-19:00	M&W
	Feb.8th/23, Feb.15th/23, Feb.22nd/23	15:00-19:00	E&M
	Mar.1st/23, Mar.8th/23, Mar.15th/23	15:00-19:00	M&W
	Mar22nd/23, Mar29th/23, Apr12th/23, Apr19th/23, Apr26th/23	15:00-19:00	Thermo
	Mar23rd/23 and Mar30th/23	17:00-19:00	QP

IMPORTANT NOTICE: Inscription of students in the various laboratory groups (including L13 and L14) is only possible through the UCM online registration system. Two laboratory groups in English are currently scheduled, with a limited number of places. In case these groups are filled up, students should register in one of the Spanish groups (L01-L12, see '*Laboratorio de Física II*'). Their laboratories will be evaluated in Spanish, even if they belong to Group B.

Students not belonging to Group B are kindly requested not to register into the laboratory English groups (L13 and L14), giving Group B students priority

Notice for students of the double degree

In the first semester, the double degree students of the group A will attend the theory classes of groups C or E.

In the second semester, ALL students of the double degree will attend the theory classes of the group where they are registered, except for the E&M class that will be done separately.

IMPORTANT NOTICE FOR STUDENTS REPEATING THE YEAR

Repeating students who have passed ALL the laboratory courses MUST register in LABORATORY GROUP L17.

Marks obtained in laboratory courses in the academic year 2021-2022 will be retained for 2022-2023 (just for a single academic year).

General Observations on the laboratory sessions:

- *In some cases, the laboratory report on the practical will be handed in at the end of the same session.*
- *Part of the laboratory session will be devoted to the discussion of the results obtained in the session, as well reports handed in previously.*
- *In Quantum Physics the laboratory work will be monitored in each session.*
- ***BECAUSE OF THE NEEDS OF THE CALENDAR, THE QUANTUM PHYSICS PRACTICALS WILL BE ON A DIFFERENT DAY OF THE WEEK FROM THE USUAL ONE.***

Notation used in the tables for the laboratories:

Thermo: Laboratory of Thermodynamics. Basement.
M&W: Laboratory of Mechanics and Waves. Basement, east wing (105).
E&M: Laboratory of Electricity and Magnetism. Basement, central block (204).
QP: Laboratory of Quantum Physics.

Syllabus. Theoretical classes. Fall Semester
1. Temperature and thermal equilibrium. Thermometric scales. 2. Calorimetry. Specific heat of gases, liquids and solids. 3. Enthalpy of vaporization. 4. Law of the conservation of energy. Total mechanical energy, kinetic energy and potential energy. 5. Rotational movement of a rigid body. Precession and nutation of a gyroscope. 6. Coupled oscillators. Normal modes of oscillation. 7. Stokes viscometer. Terminal velocity.
Syllabus. Theoretical classes. Spring Semester
1. Data analysis. Non-linear curve fitting. The *solver* algorithm of MS-Excel. 2. First order phase transitions. The Clausius-Clapeyron equation. 3. Real gases. Critical points. 4. Thermal expansion. 5. Thermal conductivity. 6. Propagation of surface waves in water. 7. Acoustic waves. Interference. 8. Stationary waves on a string. Harmonics. 9. Revision of alternating current. 10. Discrete and continuous probablilities. Probability distributions.

Syllabus. Laboratory Sessions (Thermodynamics)	Sessions
1. Calibration of a thermometer	1
2. Adiabatic index of gases	1
3. Specific heat of liquids	1
4. Enthalpy of vaporization of liquid nitrogen	1
5. Specific heat of solids	1
6. Isotherms of a real gas	1
7. Water vaporization curve and its enthalpy of vaporization	1
8. Thermal expansion coefficient of solids and liquids	1
9. Thermal conductivity of solids	1
Syllabus. Laboratory Sessions (Mechanics & Waves)	**Sessions**
1. Maxwell's disc	1
2. Stokes viscometer	1
3. Moments of inertia and angular momentum. Three-axis gyroscope	1
4. Coupled pendulums	1
5. Ripple tank	1
6. Quincke's tube": interferometry of acoustic waves	1
7. Vibrations on a string: stationary waves	1

Syllabus. Laboratory Sessions (Electricity & Magnetism)	Sessions
1. Electrical measurements	1
2. Use of the oscilloscope: RC circuits	1
3. Biot-Savart's laws and electromagnetic induction	1
Syllabus. Laboratory Sessions (Quantum Physics) **(only 2 experiences among the following list will be done. 2 per session)**	**Sessions**
1. Blackbody radiation: Stefan-Boltzman law	1
2. Franck-Hertz experiment	1
3. Balmer's spectral lines	1
4. Sodium visible spectrum	1
5. Brownian motion	1
6. Paramagnetic spin resonance	1
7. Photoelectric effect	1

Bibliography

Basic

- *Introducción a la Termodinámica,* C. Fernández-Pineda y S. Velasco. Ed. Síntesis (2009).
- *Termodinámica*, J. Aguilar. Ed. Pearson Educación (2006).
- *Física. Vol. 1. Mecánica.* M. Alonso, E. J. Finn. Ed. Addison Wesley Logman (1999).
- *Física. Vol. 2. Campos y Ondas.* M. Alonso, E. J. Finn. Ed. Addison Wesley Logman (1998).
- *Física. Vol. 3. Fundamentos Cuánticos y Estadísticos.* M. Alonso, E. J. Finn. Ed. Addison Wesley Logman (1986).
- *Estadística Básica para Estudiantes de Ciencias*, J. Gorgas, N. Cardiel y J. Zamorano (available at: http://www.ucm.es/info/Astrof/user/jaz/ESTADISTICA/libro_GCZ2009.pdf)

Complementary

- *Termodinámica*, H.B. Callen. Ed. AC (1985).
- *Termodinámica*, C. Fernández-Pineda y S. Velasco. Ed. Ramón Areces (2009).
- *Berkeley Physics Course. Volumen 1. Mecánica.* Kittel. Ed. Reverté (2005).
- *Berkeley Physics Course. Volumen 3. Ondas.* Crawford. Ed. Reverté (2003).

Online Resources

This course has a dedicated site at the UCM intranet (Campus Virtual)
Links to additional online resources can be found on the Campus Virtual site

Methodology
The course has classroom lectures during the first weeks of each semester, and 21 laboratory sessions. The lectures will deal with Experimental Thermodynamics, Mechanics and Waves, Electricity and Magnetism, as well as basic statistics and data analysis. Laboratory work and safety will also be reviewed. Students in pairs will perform practicals in the various laboratories. These pairs will be the same for all the laboratory courses throughout the academic year. The guides to the different laboratory practicals are available to students in advance at the UCM Campus Virtual. Students are expected to read and carefully study these guides before attempting the laboratory work. At all laboratory sessions a designated instructor will be present to assist the students (with further explanations, answering questions, results, and so on).

Grading: THERMODYNAMICS		
Exams	**weight:**	30%
There is a written thermodynamics final exam at the end of each semester		
Other activities	**weight:**	70%
Laboratory experiences. Attendance at theoretical sessions will be taken into account. Students are expected to deliver a written report on each one of the thermodynamics experiences. Reports should include, at least, a description of the experimental results, together with an estimation of their accuracy, as well as a short discussion. The Professor assigned to the laboratory group will grade the reports. Additionally, during lab sessions, the professor may ask questions (either orally or in writing) about the experience, and grade the student answers. Final thermodynamics grade is a weighted combination of these four numbers (fall and spring exams and laboratories), provided that all exam grades ≥ 4 (out of 10) and all laboratory grades ≥5 (out of 10).		

Grading: MECHANICS & WAVES		
Exams	**Weight:**	30%
There will be a written exam at the end of each semester.		
Other activities	**Weight:**	70%
The laboratory work will be evaluated from reports prepared by the students. Each report must include the measurements made and an error analysis of them, together with a discussion of the results. In the laboratory sessions the professor may ask questions (orally or in writing) about the practical, which may also be included in the evaluation. Attendance at theoretical sessions will be taken into account. The final grade will consist of a weighted combination of these components, provided that all exam grades ≥ 4 (out of 10) and all laboratory grades ≥ 5 (out of 10).		

Grading: ELECTRICITY & MAGNETISM		
Other activities	**Weight:**	100%
The subject of Electricity and Magnetism will be evaluated from the laboratory work. The experimental work performed during the laboratory sessions will be taken into account, together with the marks obtained in the written reports that will be prepared preferably during the laboratory sessions. Additionally, during lab sessions, the professor may ask questions (either orally or in writing) about the practical, and grade the student answers.		

Grading: QUANTUM PHYSICS		
Other activities	**Weight:**	100%

The evaluation of the Quantum Physics Laboratory will be carried out by completing and answering the questions raised at the end of the script of every assigned practical. The questionnaire will be completed one week after the end of the corresponding session and will be evaluated over 10 points. In addition, at the end of each session, the instructor can make a brief written control, which may account up to 20% of the mark of the respective practice.

The final mark will be the average of the grades obtained in each practice.

Final Grade

In order to pass the subject, it is necessary to perform all the laboratory experiences and to deliver all the results. If all the four disciplines are passed, a Final Grade will be assigned to each student as an average according to the following formula:

Thermodynamics: 0.42; Mechanics & Waves: 0.37; Electricity & Magnetism: 0.14; Quantum Physics: 0.07

The formula above applies to both the first and second chance exams. For the second chance exam only the discipline (either thermo or M&W) failed in the first chance need to be retaken.

Both in Thermodynamics and in Mechanics & Waves, the second chance exam will be on all the material seen throughout the academic year (first and second semesters).