Universidad Europea

1. OVERVIEW

Subject area	Mechanics and Waves II
Degree	Bachelor's Degree in Physics
School/Faculty	Architecture, Engineering and Design
Year	2º
ECTS	6
Type	Compulsory
Language(s)	Spanish
Delivery mode	On campus
Semester	2º

2. INTRODUCTION

Mechanics and Waves II deepens and broadens the knowledge acquired in the subject area Fundamentals of Physics I and in the term-one subject area Mechanics and Waves I.

The subject Mechanics and its formalism, aims to establish the principles upon which the subject areas in later years of the degree are based. It provides a useful foundation for a better and more in-depth understanding of the subjects studied later in the programme, such as: Experimental Project II, Statistical Physics, Quantum Mechanics I and II, Nuclear and Particle Physics and Relativistic Mechanics.

The main aim of this subject area is for students to build a solid understanding of the core aspects of classical mechanics in its more theoretical formalism. Students will study and analyse classical dynamics problems, finding a system's dynamic equations and solving them. The subject area is designed to familiarise students with scientific methodology and for them to incorporate this methodology in their work. Students will understand and learn how to apply key concepts and theories, establishing the approximations needed to create a simplified model of a physical system. They will also explore the subsequent mathematical formalisation of the model, resolve the resulting equations and critically discuss the obtained results.

The subject area expands on Newtonian mechanics in the following areas: Non-inertial systems, systems of particles, kinematics and rigid-body dynamics. Newtonian mechanics is linked to the new formalism and procedures of Lagrangian and Hamiltonian mechanics. Classical relativistic mechanics is introduced, and wave motion is studied.

The aim is for students to be able to identify, model, propose and resolve situations that involve these aspects of mechanics and their application in solving problems inherent to the subject. Students will also have the opportunity to update their knowledge, information management practices and independent learning skills. Students will become familiar with the scientific method by completing research-based practical activities and exercises. Students will also learn to interpret mechanical systems and their theoretical modelling, learning to apply different problem-solving strategies using the formalisms of different theoretical structures and forming relevant conclusions. They will be able to identify similarities in the mathematical formulation of different problems, applying known procedures or solutions to new problems.

3. SKILLS AND LEARNING OUTCOMES

Basic skills and general skills (CB and CG, respectively, by their acronym in Spanish):

- **CB1**. Students have shown their knowledge and understanding of a study area originating from general secondary school education, and are usually at the level where, with the support of more advanced textbooks, they may also demonstrate awareness of the latest developments in their field of study.
- **CB4**. Students can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
- **CG1**. To understand key concepts, methods and findings in the different branches of physics while gaining a historical perspective of their development.

Transversal skills (CT, by the acronym in Spanish):

- **CT4**. Written communication/Oral communication: Ability to communicate and gather information, ideas, opinions and viewpoints in order to understand and be able to act upon them, whether they are through spoken word and gestures, or through written word and/or visual aids.
- **CT5**. Problem solving: Be able to critically evaluate information, separate complex situations into their constituent parts, recognise patterns, and consider alternatives, different approaches and perspectives in order to find optimal solutions and negotiate efficiently.

Specific skills (CE, by the acronym in Spanish):

- **CE2**. To describe and analyse physical systems, identifying fundamental concepts and principles to make the approximations needed to build a simplified model.
- **CE3**. To understand the inherent limitations of classical physics that led to the emergence of the general and special theories of relativity and quantum mechanics, resulting in solutions to new physics problems.
- **CE4**. To understand the laws and principles of physics, to identify their logical and mathematical structure, their experimental basis and the phenomena described through them.
- **CE5**. To understand and know how to use the mathematical and numerical methods used in physics and in handling experimental data.

Learning outcomes (RA, by the acronym in Spanish):

- **RA1**. To correctly apply Newtonian, Lagrangian and Hamiltonian formulations to solve mechanical problems, including, in particular, the study of small oscillations around equilibrium points.

- **RA2.** To correctly use the mathematical formulation of classical mechanics in the practical study of mechanical systems in motion.

- **RA3.** To connect the symmetries and conservation laws in physics, using them to complete practical exercises.

The following table shows how the skills developed in the subject area match up with the intended learning outcomes:

Skills	Learning outcomes
CB1, CB4, CG1, CT4, CT5, CE2, CE3, CE4, CE5	RA1. To correctly apply Newtonian, Lagrangian and Hamiltonian formulations to solve mechanical problems, including, in particular, the study of small oscillations around equilibrium points.
CB1, CB4, CG1, CE2, CE4, CE5	RA2. To correctly use the mathematical formulation of Classical Mechanics in the practical study of mechanical systems in motion.
CT5, CE2, CE3, CE4	RA3. To connect the symmetries and conservation laws in physics, using them to complete practical exercises.

4. CONTENTS

This subject is organised into six learning units or topics.

1. **Small oscillations.**

   Simple harmonic oscillator. Damped oscillator. Forced oscillator and resonance. Introduction and definitions. Normal modes of oscillation. Normal frequencies. Amplitudes of the modes. Normal coordinates. Generalisation of a linear system. Small oscillations in non-linear systems.

2. **Non-inertial frames of reference.**

   Non-inertial frame of reference. Orbital frame of reference. Rotating frame of reference. Coriolis acceleration and centrifugal acceleration. Time derivatives in each frame of reference. Acceleration and velocity transformations. Fictitious forces: Coriolis and centrifugal. Frame of reference on Earth. Rotating and orbital frame of reference. General case.

3. **Systems of particles.**

   Magnitudes in systems of particles. Centre of mass of systems of particles. Dynamics for systems of particles. Movement of the centre of mass. Linear momentum for systems of particles. Conservation of the total momentum. Impulse of forces. Total energy in systems of particles. Frame of reference.
   Centre of mass. Collisions. Variable-mass systems. Reduced mass: the two-body problem. Angular momentum of a system of particles (internal and orbital). Conservation of angular momentum. Torque. Cross section. Rutherford scattering.

4. **Rigid bodies.**

   Kinematics of rigid bodies. Instantaneous centre of rotation. Linear momentum. Angular momentum. Kinetic energy. Rigid-body dynamics. Inertia tensor. Equations of motion. Euler angles. Euler equations. Rigid body with a fixed point. Movement around a fixed point. Gyroscope.

5. **Wave motion.**

Concept of waves. Harmonic waves. Wave equation. Fourier analysis. Standing waves. Energy. Plane and spherical waves.

6. **Special relativity**

Postulates and principles of special relativity. Lorentz transformations. Minkowski space. Four-vectors. Composition of velocities. Relativistic four-momentum. Relativistic energy. Mass–energy equivalence. Relativistic dynamics.

(The course content will not necessarily be taught in this order)

5. TEACHING/LEARNING METHODS

The types of teaching/learning methods are as follows:

- **Lectures**: Presentations by the professor with the necessary technological tools to maximise comprehension of the learning content.
- **Collaborative learning:** Students complete collaborative activities to find creative, comprehensive and constructive solutions to questions and problems that arise from the given case studies, using all relevant knowledge and material resources available.
- **Problem-based learning**: Students are given problems and asked to solve them, working individually or in groups.
- **Guided academic activities:** Individual and group work that is more independent, including information searches, written summaries and public defence of projects.

6. LEARNING ACTIVITIES

The types of learning activities, plus the amount of time spent on each activity, are as follows:

On campus:

Learning activity	Number of hours
Lectures	37
Oral presentations of projects	7.5
Report writing	7.5
Assessment	6
Practical activities (problems, projects, lab work)	21.5
Tutorials	16
Independent working	54.5

TOTAL	**150**

7. ASSESSMENT

The assessment systems, plus their weighting in the final grade for the subject area, are as follows:

On campus:

Assessment system	Weighting
Knowledge tests (assessment system 1 or SE1) Individual on-campus knowledge tests (theory and/or practice). Students will take a compulsory midterm exam, which accounts for 10% of the final grade. The final exam on the full content of the subject area has a weighting of 40% (**minimum grade 4**). The final exam can compensate for and improve the grade for the midterm exam.	50%
Submission of group and/or individual exercises (SE2) Submission of group and/or individual reports, written work, projects or exercises. Exercises will be planned for individual or group submission that complement or reinforce the subject area content.	35%
Oral defence (SE3) Students will give group or individual presentations on a subject topic or research problem. The aim is to expand on or clarify a specific concept or procedure from the syllabus.	5%
Performance observation (SE4) This is a subjective grade that is based on attendance, participation in class, collaboration with classmates and respect for others in the classroom. *This grade will only be awarded if the student has attended over 50% of the classes, whether on campus or online during class hours.*	10%

On the Virtual Campus, when you open the subject area, you'll find details of your assessable tasks, including the submission dates and assessment procedures for each task.

8. BIBLIOGRAPHY

The reference material for the subject area is as follows:

- D. Morin, "*Introduction to Classical Mechanics: With Problems and Solutions*", (Cambridge University Press, 1ª Ed, 2008).
- H. Goldstein, C.P. Poole, J.L. Safko, "*Classical Mechanics*", (Addison Wesley, 3rd edition, 2001).J.R. Taylor, "Classical Mechanics", (University Science Books, 2005).
- S.T. Thornton, J.B. Marion, "*Classical Dynamics of Particles and Systems*", (Brooks Cole, 5th edition, 2003).
- A. Fernández Rañada, "*Dinámica Clásica*", (FCE, 2ª edición, 2005).
- T.W.B. Kibble, F.H. Berkshire, "*Classical Mechanics*", (World Scientific Publishing Company, 5th edition, 2004).
- A. A. Kamal, "1000 Solved Problems in Classical Physics", (Springer, 2001).
- V. M. Pérez, L. Vázquez, A. Fernández-Rañada, "100 Problemas de Mecánica", (Alianza Ed., 1997)
- B.Schutz, "A First Course in General Relativity". 2ª ed. Cambridge University Press (2009) • E.F.Taylor & J.A. Wheeler, "Spacetime Physics: Introduction to Special Relativity", Ed. WH Freeman (1992).
- W.Rindler, "Introduction to Special Relativity". Oxford (1991).

The recommended bibliography is indicated below:

- L.D. Landau, E.M. Lifshitz, "*Mecánica (Curso de Física Teórica Vol. 1)*", (Editorial Reverté, 2ª edición, 1994).
- M. Alonso y E.J. Finn, *"Física*". Addison-Wesley Iberoamericana (1995). o P.A. Tipler y G. Mosca, "*Física para la Ciencia y la Tecnología*", Vol. 1 y 2. 6ª ed. Ed. Reverté (2010).
- H.D. Young, R.A. Freedman, F.W. Sears y M.W. Zemansky, "*Física universitaria, Vol. 1 y 2*". 12ª ed. Pearson Education (2013)