Mechanics and relativity

Academic Year: (2023 / 2024)　　　　　　　　　　　　　　　　**Review date: 12/02/2024 12:59:19**

Department assigned to the subject: Physics Department

Coordinating teacher: MARTIN SOLIS, JOSE RAMON

Type: Compulsory　ECTS Credits : 6.0

Year : 2 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Physics I, Linear Algebra, Calculus I and II of the first year

LEARNING OUTCOMES

CB1. Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2. Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CB3. Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4. Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CB5. Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.
CG1. Analyze and synthesize basic problems related to physics and engineering, solve them and communicate them efficiently.
CG2. Learn new methods and technologies from basic scientific and technical knowledge, and being able to adapt to new situations.
CG3. Solve problems with initiative, decision making, creativity, and communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the engineering activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG5. Use the theoretical and practical knowledge acquired in the definition, approach and resolution of problems in the framework of the exercise of their profession.
CE5. Understand and handle the basic concepts of the general laws of mechanics, thermodynamics, fields and waves and electromagnetism and apply them to the resolution of engineering problems.
CE16. Understand and handle the physical principles of Newtonian, Lagrangian and Hamiltonian mechanics and their applications in the different branches of physics and engineering, as well as the basic principles of the special theory of relativity.
CT1. Work in multidisciplinary and international teams as well as organize and plan work making the right decisions based on available information, gathering and interpreting relevant data to make judgments and critical thinking within the area of study.

RA1. To have acquired sufficient knowledge and proved a sufficiently deep comprehension of the basic principles, both theoretical and practical, and methodology of the more important fields in science and technology as to be able to work successfully in them.
RA2. To be able, using arguments, strategies and procedures developed by themselves, to apply their knowledge and abilities to the successful solution of complex technological problems that require creating and innovative thinking.
RA3. To be able to search for, collect and interpret relevant information and data to back up their conclusions including, whenever needed, the consideration of any social, scientific and ethical aspects relevant in their field of study.
RA6. To be aware of their own shortcomings and formative needs in their field of specialty, and to be able to plan and organize their own training with a high degree of independence.

OBJECTIVES

The course on Mechanics and Relativity constitutes an extension of the Mechanics learned during the first year in the Physics I course. In the first place, new ways of formulating and solving problems in Classical Mechanics, alternative to the Newton¿s laws studied during the first year, will be presented: the Analytical Mechanics. Its fundamentals, advantages and disadvantages will be presented. Particular attention will be paid to the method based on the Lagrange¿s equations. Applications will be also presented to the study of the motion of the rigid body in space for which an essential tool, the Inertia Tensor, will be introduced. A generalized analysis of the small oscillations about the equilibrium position of systems with several degrees of freedom will be also addressed. The last part of the course will be devoted to one of the main areas of Modern Physics, developed during the first half of the twentieth century: the Relativistic Mechanics. The two postulates on which it is based will be presented, together with some of their main consequences such as a new approach to the concepts of space and time, or the well-known mass-energy equivalence.

The following competences and skills should be acquired:

- Ability to know and understand what does it mean the Analytical Mechanics and some of the main tools developed within it to solve mechanical problems, particularly, among them, the Lagrange¿s equations.
- Ability to understand the general motion of a rigid body in space, based on the tool of the inertia tensor
- Ability to understand the application of the Lagrange¿s method to the generalized analysis of small oscillations in systems with several degrees of freedom, as well as the meaning of the normal modes and frequencies
- Ability to understand the meaning of the postulates of the special theory of relativity, and some of their main consequences: revision of the concepts of space and time, the mass-energy equivalence, etc
- Ability to understand and use the mathematics involved in the physical models
- Ability to develop skills to solve problems
- Ability to use scientific instruments and analyze experimental data
- Ability to verify in the laboratory some of the results obtained in the theoretical classes
- Ability to retrieve and analyse information from different sources
- Ability to work in a team.

DESCRIPTION OF CONTENTS: PROGRAMME

PART I ANALYTICAL MECHANICS
1. Introduction to Analytical Mechanics
    1.1 Introduction
    1.2 Generalizad Coordinates
    1.3 Systems with Constraints
    1.4 Kinetic Energy and Generalized Momenta
        1.4.1 Generalized Velocity
        1.4.2 Kinetic Energy
        1.4.3 Generalized Momenta
    1.5 Virtual and Real Displacements
    1.6 Virtual Work. Generalized Forces
        1.6.1 Virtual Work
        1.6.2 Generalized Forces
        1.6.3 Virtual Work and Forces of Constraint
2. The Lagrange¿s Equations
    2.1 Introduction
    2.2 Derivation of the Lagrange¿s Equations
    2.3 Lagrange¿s Equations for Conservative Forces. The Lagrangian of a Mechanical
        System
    2.4 Lagrange¿s Equations for Conservative and Non-Conservative Forces
    2.6 Lagrangian Mechanics and Newtonian Mechanics
    2.7 Cyclic Coordinates and Conservation Theorems
        2.7.1 Constants of Motion
        2.7.2 Definition of Cyclic (or Ignorable) Coordinates. Conservation Theorem for
            Cyclic Coordinates
3. The Hamilton¿s Equations. The Hamilton¿s Principle
    3.1 Introduction
    3.2 Derivation of the Hamilton¿s Equations. The Hamiltonian of a Mechanical System

11.4.1 Kinetic Energy
11.4.2 Definition of the Total Energy
11.4.3 Mass-Energy Equivalence
11.4.4 Energy-Momentum Relation

LEARNING ACTIVITIES AND METHODOLOGY

* Lectures where the theoretical concepts are explained

The lecturer will provide the following information (1 week in advance)
-       Main topics to be discussed during the session
-       Chapters/sections in each of the text books provided in the bibliography where the student can read about these topics

* Activities for the solution of problems

The main skills to be acquired in these activities are:
-       To understand the statement of a problem (for instance drawing an scheme that summarizes the statement)
-       To identify the physical phenomenon and the physical laws involved in the problem
-       To develop an strategy to reach the objective (for instance breaking the problem in small subproblems)
-       To be careful in the use of mathematics
-       To be able to make a critical analysis of the results (is the final number sensible?, are the dimensions consistent?)

* Small tasks focused to search for scientific information from different sources (mainly internet)

* Laboratoy sessions (20 - 30 students divided in 2 people groups)

The main skills to be developed in this activity are:
-       To understand that physics is an experimental science and that they can verify the laws that have been theoretically explained in the lectures
- To use scientific instruments and to be careful in its operation
-       To be careful in the acquisiton of experimental data.
-       To learn the basis for the management of a scientific data set
-       To be able to write a report with the main results of the experiment
-       To be able to discuss in a critical way the experimental results: have we achieved the goals of the experiment?

*   Times for individualized tutorial sessions will be fixed via Aula Global. It will be possible to fix other sessions by appointment with the lecturer

ASSESSMENT SYSTEM

% end-of-term-examination/test:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

* Laboratory sessions (15% of final mark)

Attendance to the laboratory sessions is compulsory. The students must also write a report on each of the experiments carried
out in every session. The mark will be common for all the members of each group.

* Activities in groups (25% of final mark)

The evaluation will take into account attendance and student attitude, short exams periodically proposed, as well as the
student performance in the proposed activities.

* Written exam (60% of final mark)

The exam will take place at the end of the semester and it will be common for all the students. Contents:

% end-of-term-examination/test: 60

% of continuous assessment (assigments, laboratory, practicals…):   40

- Problems to be solved covering the main topics of the program.
- Short theoretical questions.

A minimum mark of 3 out of 10 will be required in the written exam in order to pass the course.

BASIC BIBLIOGRAPHY

- GOLDSTEIN, H., POOLE, C., SAFKO, J. CLASSICAL MECHANICS, Pearson, 2013

- THORNTON, S.T., MARION, J.B. CLASSICAL DYNAMICS OF PARTICLES AND SYSTEMS, Brooks/Cole, 2003

- TIPLER, P.A., MOSCA, G PHYSICS for Scientists and Engineers, W.H. Freeman, 2007

ADDITIONAL BIBLIOGRAPHY

- FRENCH, P.A. SPECIAL RELATIVITY, The M.I.T. Introductory Physics Series, CRC Press, 2017

- SERWAY, R.A., JEWETT, J.W PHYSICS for Scientists and Engineers, Brooks/Cole, 2012

- SYMON, K.R. MECHANICS, Addison Wesley, 1971