Universitat Autònoma de Barcelona

2020/2021

Mechanics Theory and Non-linear Systems

Code: 100172
ECTS Credits: 6

Degree	Type	Year	Semester
2500097 Physics	OT	4	1

The proposed teaching and assessment methodology that appear in the guide may be subject to changes as a result of the restrictions to face-to-face class attendance imposed by the health authorities.

Contact

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Use of Languages

Principal working language: english (eng)

Some groups entirely in English: Yes

Some groups entirely in Catalan: No

Some groups entirely in Spanish: No

Prerequisites

It is advisable that the student has completed successfully a course on Classical Mechanics.

Re mathematical prerequisites, it is advisable that the student has previous knowledge of Calculus with a Complex Variable and Group Theory.

Objectives and Contextualisation

The main goal in this course is to introduce the student to Theoretical Mechanics.

This introduction is supposed to give the student all the necessary knowledge which should be the basis for studying modern physics.

In more concrete terms, these are the three main objectives:

1. To introduce the student to the different formalisms of Classical Mechanics: D'Alembert's formalism, Lagrange's, Hamilton's, canonical and Hamilton-Jacobi's;
2. To complete an adequate education of the student in the field of Classical Mechanics;
3. To introduce the student to Classical Field Theory.

Apart from the aforementioned goals, it will also be very important to estimulate a critical view in the student and to encourage a research-oriented attitude.

Competences

- Apply fundamental principles to the qualitative and quantitative study of various specific areas in physics
- Be familiar with the bases of certain advanced topics, including current developments on the parameters of physics that one could subsequently develop more fully
- Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, and before both specialist and general publics

- Develop the capacity for analysis and synthesis that allows the acquisition of knowledge and skills in different fields of physics, and apply to these fields the skills inherent within the degree of physics, contributing innovative and competitive proposals.
- Formulate and address physical problems identifying the most relevant principles and using approximations, if necessary, to reach a solution that must be presented, specifying assumptions and approximations
- Know the fundamentals of the main areas of physics and understand them
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation
- Work independently, have personal initiative and self-organisational skills in achieving results, in planning and in executing a project
- Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Learning Outcomes

1. Apply Lagrangian and Hamiltonian formalism to different physical systems to obtain equations of motion.
2. Apply canonical transformations to obtain equations of motion.
3. Apply ligation conditions within a system to find the relevant degrees of freedom and dynamic variables.
4. Apply the method of canonical perturbation theory.
5. Applying Lagrange and Hamilton formalism to discrete relativistic systems and to field theories describing the fundamental interactions of nature.
6. Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, in front of both specialist and general publics.
7. Compare the applicability of the equations of motion and laws of conservation in different fields of science.
8. Construct a Lagrangian based on the symmetries of the physical system.
9. Construct magnitudes conserved from Noether's theorem.
10. Describe properties of canonical transformations.
11. Describe the concepts of displacement and virtual work.
12. Describe the connection between dynamic equations and variational principles.
13. Describe the relationship between symmetry and the law of conservation.
14. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
15. Use variational calculus.
16. Use vector calculus and differential equations.
17. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
18. Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Content

1. *D'Alembert's Formulation:* Constraints. Virtual displacements. D'Alembert's principle. Generalized coordinates. Lagrange's equations.
2. *Lagrange's formulation:* Calculus of variations. Hamilton's principle. Euler-Lagrange's equations. Extension to non-holonomic systems.
3. *Symmetries and conservation laws:* Theorems of conservation: energy conservation, linear and angular momentum. Symmetry test. Noether's theorem. Symmetries in Classical Mechanics: Galileo's group.
4. *Hamilton's formulation:* Phase space. Legendre's transformation.Hamilton's function. Canonical equations. Poisson's brackets.
5. *Hamilton-Jacobi's formulation:* Method of separation of variables. Examples.

6. *Introduction to the Theory of Classical Fields:* Lagrangian and Hamiltonian formulation of a continuous medium. Relativistic Field Theory. Examples. Symmetries and conservation laws in Classical Field Theory: energy-momentum tensor, Noether's theorem, internal and external symmetries. Examples.

Methodology

The work method will be divided between conducted teaching activities and self-teaching activities.

The conducted teaching activities will also be divided between theory classes in front of a blackboard together with tutorials where the students will be able to solve their difficulties, and exercise classes where the students will see how to apply all the concepts previously explained in class.

The self-teaching activities will consist in studying the theory foundations by the student and their application on the different examples, by means of solving exercises both at an individual level and at a group level.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Exercises calsses	16	0.64	1, 4, 5, 3, 2, 6, 9, 8, 11, 12, 13, 10, 14, 17, 18, 15, 16
theory classes	33	1.32	1, 4, 5, 3, 2, 7, 6, 9, 8, 11, 12, 13, 10, 14, 17, 18, 15, 16
Type: Autonomous			
Problem solving	47	1.88	1, 4, 5, 3, 2, 7, 6, 9, 8, 11, 12, 13, 10, 14, 17, 18, 15, 16
Study of the theory fundamentals	48	1.92	1, 4, 5, 3, 2, 7, 6, 9, 8, 11, 12, 13, 10, 14, 17, 18, 15, 16

Assessment

Grading

A) Take-home exercises (20% of the final grade): one or more exercises will be set, periodically, to be solved and handed in at a time that will be eventually established.

B) Mid-semester exam (35% of the final grade): it is a written exam, without any books or student's notes, individual, about the middle of the semester.

C) Final exam (45% of the final grade): it is a written exam, with books and/or student's notes, individual, at the end of the semester. The final grade will be the result of A+B+C.

D) Make-up exam of B+C: this exam is optional, without books or student's notes, at the end of the semester. If the grade achieved from A+B+C > 3.5/10, the student will have the right to take this make-up final exam provided he/she has already taken both exams B+C. The final grade achieved in this exam will replace the previous grade from B+C in all cases.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Delivery of Exercises	20%	1	0.04	1, 4, 5, 3, 2, 7, 6, 9, 8, 11, 12, 13, 10, 14, 17, 18, 15, 16

final exam	45%	1	0.04	1, 4, 5, 3, 2, 7, 9, 8, 11, 12, 13, 10, 15, 16
make-up exam	80%	3	0.12	1, 4, 5, 3, 2, 7, 9, 8, 11, 12, 13, 10, 15, 16
mid-term exam	35%	1	0.04	1, 4, 5, 3, 2, 7, 6, 9, 8, 11, 12, 13, 10, 14, 17, 18, 15, 16

Bibliography

1. Classical Mechanics, H. Goldstein, C. P. Poole i J. L. Safko, Addison Wesley (2002).
2. Classical Mechanics: System of Particles and Hamiltonian Dynamics, W. Greiner, Springer-Verlag (2010).
3. Classical Dynamics of Particles and Systems, J. B. Marion i S. T. Thornton, Brooks Cole (2004).
4. Course in Theoretical Physics Vol. 1: Mechanics, L. D. Landau i E. M. Lifshitz, Butterworth-Heinemann (1995).
5. Lectures in Analytical Mechanics, F. Gantmacher, Mir Publishers Moscow (1975).
6. Mechanics: From Newton's Laws to Deterministic Chaos, F. Scheck, Springer-Verlag (2005).
7. Mathematical Methods of Classical Mechanics, V. I. Arnold, Springer-Verlag (1989).
8. An Introduction to Quantum Field Theory, M. E. Peskin i D. V. Schroeder, Perseus Books (1995).