Universitat Autònoma de Barcelona

2022/2023

Mechanics and Relativity

Code: 100137
ECTS Credits: 6

Degree	Type	Year	Semester
2500097 Physics	FB	1	1

Contact

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Use of Languages

Principal working language: catalan (cat)

Some groups entirely in English: No

Some groups entirely in Catalan: Yes

Some groups entirely in Spanish: Yes

Other comments on languages

Occasionally, at the beginning of the course, Spanish will be used if a non-Catalan-speaking student requests it.

Teachers

Emili Bagan Capella

Eduard Masso Soler

Santiago Llorens Fernandez

Lindber Ivan Salas Escobar

Arnau Riera Graells

Prerequisites

The subject has two sections (about 7 weeks each part). There are no prerequisites, but for each of the sections the following recommendations are important:

For the mechanics section.

Mathematics: have a good knowledge of elementary algebra, including vector algebra; have elementary knowledge of calculus, in particular of derivation, and notions of integration.

Physics: have basic knowledge of mechanics. Specifically: elementary Newtonian kinematics, forces, and dynamics.

Others: students should have good study habits that allow them to keep up with the course.

For the Fluids and Relativity sections.

Mathematics: Have a good knowledge of basic mathematics. Have agility with elementary algebra.

Physics: have basic knowledge of Newtonian kinematics and dynamics.

Others: students should be open-minded and should have good study habits that allow them to keep up with the course.

Objectives and Contextualisation

Expand knowledge of classical mechanics, essential to understand more advanced subjects. Expose students to special relativity, which is an essential part of modern physics.

Help students to undersatnd the fundamental concepts and the formalism of these disciplines. Develop their ability to deal with exercises and problems of an intermediate level and/or that do not fit a specific typology. Develop analytical skills. Prepare students to deepen and expand knowledge in more advanced subjects.

A more specific objective concerning special relativity is training students in the use of Lorentz transformations to describe events from different reference systems and solve the most common paradoxes of special relativity.

Train students in the application of the elementary principles of fluid physics.

Competences

- Act with ethical responsibility and respect for fundamental rights and duties, diversity and democratic values.
- Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals
- 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 strategies for analysis, synthesis and communication that allow the concepts of physics to be transmitted in educational and dissemination-based contexts
- 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
- Make changes to methods and processes in the area of knowledge in order to provide innovative responses to society's needs and demands.
- 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

Learning Outcomes

1. Analyse and interpret the main experiments related to basic physics.
2. Analyse certain open questions in contemporary physics and explain them clearly.
3. Apply Newton's laws to simple problems of particle dynamics and those of fixed-axis rigid bodies.
4. Apply the Bernoulli and Poiseuille equations for fluids.
5. Apply the principles of relativistic conservation to shocks and particle decay.
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. Contrast the sharpness of mathematical results with margins of error in experimental observations.
8. Correctly use principles of conservation.
9. Describe the Bernoulli and Poiseuille equations for fluids.
10. Describe the Lorentz transformations.
11. Describe the basic paradoxes of relativistic kinematics.
12. Describe the use of the Doppler effect in astronomical measurements.

13. Explain the explicit or implicit code of practice of one's own area of knowledge.
14. Identify situations in which a change or improvement is needed.
15. Identify situations in which conservation principles are useful.
16. Interact across diverse areas of basic physics.
17. List and describe Newton's laws.
18. Make mathematical rigor compatible with approximate physical modelling.
19. Outline and resolve the static equilibrium conditions of simple systems.
20. Relate the basic concepts of physics with scientific, industrial and everyday subjects.
21. Select good variables and carry out correct simplifications.
22. Use complex numbers.
23. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
24. Use differential and integral calculus.
25. Use linear transformations and matrix calculus.
26. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
27. Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals

Content

Classical mechanics

Kinematics of the point in one, two and three dimensions. Dynamics of the material point: Newton's laws. Inertial and non-inertial reference frames. Galilean relativity. Dynamics of particle systems. Linear momentum. Center of mass. Conservation of linear momentum. Moment of a force. Angular momentum. Static of solids. Work and energy Conservative forces, potential and mechanical energies. Introduction to the dynamics of rigid bodies (fixed or parallel rotation axes). Moment of inertia.

Fluid mechanics

Perfect fluids. Pressure and density Bernoulli equation. Applications: static and dynamic of perfect fluids.

Viscous fluids Viscosity. Law of Poiseuille. Fluid circuits.

Special relativity

Introduction. Einstein's Principle of Relativity. Principle of the constancy of the speed of light. Relativistic kinematics: Lorentz transformations; relativistic space-time. Paradoxes, applications and tests of relativistic kinematics. Relativistic Doppler effect. Definition of relativistic linear energy and momentum and conservation principles.

The (important) topic relativistic electrodynamics will be taught in the *Electricity and Magnetism* module. Other complementary parts will be taught in *Waves and Optics*.

Methodology

Face-to-face activities (directed and supervised)

Two hours per week of theory lectures and one hour of problem-solving classes will be delivered. Additionally, eight hours of specialized seminars will be held, in which each group will be divided into two subgroups to facilitate interaction between students and the instructors who supervise the activities.

In the lectures, the key points of relativity and Newtonian mechanics will be presented and developed to achieve (at a reasonable level) a consistent and well-structured body of doctrine that will allow studying their applications and solving exercises. These exercises will be solved and discussed in problem-solving classes and specialized seminars.

Non-face-to-face activities (autonomous)

Students will be provided with the content of the lectures and problem-solving classes. In addition to the textbooks (see the bibliography), students will have access (through the Virtual Campus) to the content of the lectures and, concerning the problem-solving classes, they will be provided with the statements of the exercises that will be solved and discussed. Homework assigments will be proposed. They can only increase the final grade.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Problem solving classes	14	0.56	4, 3, 18, 6, 19, 21, 8, 24, 25
Theory classes	28	1.12	4, 3, 12, 9, 11, 10, 17, 16
Type: Supervised			
Specialized seminars	8	0.32	1, 5, 4, 3, 18, 7, 12, 9, 11, 10, 17, 15, 19, 20, 16, 21, 8, 24, 25
Type: Autonomous			
Autonomous Learning	91	3.64	2, 4, 3, 18, 12, 9, 11, 10, 17, 15, 19, 20, 16, 21, 8, 24, 25

Assessment

The evaluation will be done in 3 calls. In each of them an exam with theoretical questions and exercises will be held. In the first two, in addition, a homework assignment to be solved individually or in groups will be also given. A bad grade in these assignments can be improved in the corresponding exam. The first call will include Newtonian mechanics and the second special relativity and fluids. Each part will have the same weight in the final grade. The module is passed if the geometric mean of each part is higher than 5.0. These grades include the corresponding assignment.

The third and last call (make-up exams) consists of two written exams, one for each section of the module. Only students who have failed one or the two sections, and those who want to improve their grade must take these exams. They can only increase their grades (they have no effect if their grades are lower than those obtained in the previous exams). Students that take the two exams will have to answer only a selection of questions, as the time allowed is the same for all students. The final grade will be the geometric mean of the grades of each exam. Only students that have taken the partial exams in the first two calls are allowed to take the make-up exams. There is no minimum grade required to take the make-up exams.

Theoretical questions will be short and will not require complex calculations. They will asses the assimilation of the concepts introduced in the lectures.

The exercises will be longer and will require more complex calculations. They will test the level of comprehension reached by the student, their ability to formulate mathematically the solution of the different sections and also their ability to calculate. These exercises will not necessarily be variations of those solved in the problem-solving classes.

Observation. The two sections of the module are central pillars of the education of a physicist. A good grade in one of the sections can not compensate for a poor grade in the other. That is why when calculating the global note we use the geometric mean instead of the arithmetic. The geometric mean differs little from the arithmetic when the grades of each part are similar, but it penalizes the situations in which the grades are unbalanced, especially when one of them is very low.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Delivery of mechanical problems (recoverable int the written mechanical exam)	10%	0	0	1, 3, 18, 6, 13, 27, 15, 14, 19, 23, 20, 16, 21, 26, 8, 24, 25
Delivery of relativity and fluid problems (recoverable in the written exam of relativity and fluid)	10%	0	0	5, 4, 18, 6, 13, 27, 15, 14, 23, 20, 21, 26, 8, 24, 25
Final written exam or re-validation (optional for those who have the two previous exams approved)	up to 100%	3	0.12	4, 3, 6, 7, 12, 9, 11, 10, 17, 19, 23, 16, 8, 24
Written exam of mechanics (recoverable in the final written exam)	40-50%	3	0.12	1, 3, 18, 6, 7, 27, 15, 19, 23, 20, 21, 8, 24, 22, 25
Written exam of relativity and fluids (recoverable in the final written exam)	40-50%	3	0.12	2, 5, 4, 6, 12, 9, 11, 10, 27, 23, 21

Bibliography

Theory books

M. Alonso i E. J. Finn. *Física. Vol 1, Mecánica.* Addison Wesley Longman; 1 edición (2000) [https://cataleg.uab.cat/iii/encore/record/C__Rb1023008]

Tipler+Mosca, *Física para la ciencia y tecnología,* ed. Reverté, 5a (2003) i 6a (2010) edición [https://cataleg.uab.cat/iii/encore/record/C__Rb1616987]

E. Massó, *Curs de Relativitat Especial*, Manuals de la UAB (1998). Specific for the relativity part [https://cataleg.uab.cat/iii/encore/record/C__Rb1418525]

P. French, *Special Relativity,* CTC Press (2017) [https://cataleg.uab.cat/iii/encore/record/C__Rb1364971] (specifically for special relativity)

Notes of the parts in the VC. Summarized and, therefore, difficult to assimilate if the theory classes have not been followed. They allow for an overview of the subject.

Problems books

Statements of exercises and problems of the course, and solutions of selected problems will be provided through *Campus Virtual*

Tipler+Mosca, *Física para la ciencia y tecnología,* ed. Reverté, 5a (2003) i 6a (2010) edición [https://cataleg.uab.cat/iii/encore/record/C__Rb1616987]

Software

No specific software will be used.