Universitat Autònoma de Barcelona

2022/2023

Classical Mechanics

Code: 100148
ECTS Credits: 10

Degree	Type	Year	Semester
2500097 Physics	OB	2	A

Contact

Name: Emili Bagan Capella
Email: emili.bagan@uab.cat

Use of Languages

Principal working language: catalan (cat)
Some groups entirely in English: No
Some groups entirely in Catalan: No
Some groups entirely in Spanish: No

Teachers

Eduard Masso Soler
Alex Pomarol Clotet

Prerequisites

There are no essential prerequisites, but the following recommendations are useful.

It is very important to have a deep knowledge of the basic concepts of Mechanics and Relativity from the first course.

It is important to master the basic tools of one-variable differential and integral calculus, Taylor series approximations, and elementary integrals. Knowledge of algebra (vector spaces, matrices) is also required.

It is also recommended to know the basic principles of calculus in several variables for analytical mechanics and the diagonalization of matrices for coupled oscillators and the tensor of inertia.

Objectives and Contextualisation

General goals are :

1. Learning more advanced subjects in Newtonian Mechanics;

2. Being able to deal with approximations, mainly by means of Taylor series.

3. Knowing and applying basic concepts of Analytical Mechanics and recognize its importance for the whole of Physics.

Specific goals are :

. Solving central forces problems using rotational symmetry.

. Dealing with particle systems and coupled oscillators.

. Studying rigid body rotations, tensor of inertia and Euler equations.

. In Relativistic Dynamics, a deeper knowledge of relativistic linear momentum and energy and its applications.

. Knowing Lagragian and Hamiltonian formalisms.

Competences

- 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
- 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. Analytically and numerically solve the Newton's equation.
2. Describe conservative forces.
3. Describe motion in one, two and three dimensions.
4. Describe non-inertial reference systems.
5. Describe relativistic kinematics.
6. Describe shocks.
7. Describe the fundamentals of analytical mechanics.
8. Describe the fundamentals of classical mechanics.
9. Describe the kinematics and dynamics of rigid bodies.
10. Formulate and solve the motion of a system using Lagrange's equations.
11. Identify laws of conservation in a system of particles.
12. Identify the concepts of linear and angular momentum and energy.
13. Identify types of oscillators: simple harmonic, buffed and forced.
14. Properly handle the developments in Taylor series, the chain rule, implicit equations, diagonalization, dimensional analysis and vector calculus.
15. Solve movement in the event of variable force or mass.
16. Solve the movement produced by a central force.
17. Translate specific physical problems to a mathematical formulation that allows subsequent resolution, either exact or approximate.
18. Transmit, orally and in written format, physical concepts of a certain complexity, making them understandable to non-specialist settings.
19. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
20. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.

Content

FIRST TERM

1. Review of 1st year mechanics: Newton's laws, conservation theorems, rigid body. collisions.

2. Motion in one dimension: variable forces and variable masses.

3. Oscillations and related problems: simple, damped, forced harmonic oscillator. Fourier series. Green's function. Nonlinear oscillators.

4. Motion under central forces: equation of the trajectory, 1/r potential, Kepler's laws, Bertrand's theorem, stability and perturbation theory. 2 body problem. Scattering. cross section.

5. Coupled oscillations I: simple examples, normal modes, weak coupling.

6. Coupled oscillations II: general theory of oscillations about equilibrium, many oscillators, continium limit and vibrating string. Wave equation.

7. Kinematics of rotations: mathematical foundations, infinitesimal rotations, angular velocity and acceleration, rotating reference frames (Coriolis force), rigid body kinematics.

SECOND TERM

Solid Rigid II

8. Tensor of inertia of a rigid body, rotational kinetic energy, angular momentum, free rotation of the symmetric top.

9. Euler angles, Euler equations, stability around a principal axis.

Relativistic dynamics

10. Relativistic linear momentum, invariants and quadrivectors, relativistic energy.

11. Relativistic particle collisions and decays.

12. Relativistic forces.

Introduction to Mech. Analytics

13. Constraints and generalized coordinates.

14. Calculus of variations. Hamilton's principle. Lagrangian mechanics. Conserved quantities.

15. Poisson brackets. Lagrange multipliers and constraint forces. Liouville and virial theorems.

16. Relativistic analytical mechanics. Motion of charges in electromagnetic fields.

Methodology

Face-to-face lectures and problem-solving classes.

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			
magister lecture	55	2.2	3, 7, 8, 4, 6, 9, 5, 2, 10, 12, 11, 15, 16
problem teaching	28	1.12	10, 14, 19, 15, 16, 1, 17, 18
Type: Supervised			

Supervised tests	2	0.08	7, 8, 19, 16
Type: Autonomous			
Individual work	138	5.52	3, 7, 8, 4, 6, 9, 5, 2, 10, 12, 11, 14, 19, 15, 16, 1, 17, 18
problem resolution	12	0.48	18

Assessment

The course is divided into two parts or terms that are structured in a similar way.

A partial exam will be held in the middle and at the end of each term.

Students will be informed in due time if in some sections of these exams they will be allowed to use a list of formulas, which they will have to prepare in advance.

Homework assignments will be given. They will count up to 10% of the final grade in the first term and exactly 5% in the second term. They will not count towards the grade of the make-up exam.

The grade of a term is defined as the average of the grades of the two partial exams and the corresponding homework assignment.

The course is passed ("by terms") when the geometric mean of the grades of the two terms equals or exceeds 5.

In order to pass the course "by terms", students are required to have taken the four partial exams.

Students who have not passed the course "by terms" may take a make-up exam in July. This exam will have two sections, one for each term, and students will have to take the first, the second, or both sections depending on the terms they have not passed (term grade less than 5). The grade of this exam is 100% of the final grade and has no associated homework assignment.

Students who have passed the course "by terms" but wish to improve their grade can take the make-up exam. The final grade will be the geometric mean of the highest grades between those of each term and those of the corresponding section of the make-up exam.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
1st partial 1st semester (recoverable)	20-25%	3	0.12	3, 8, 6, 2, 12, 13, 11, 19, 1, 18
1st partial 2nd semester (recoverable)	22.5%	3	0.12	4, 9, 5, 19, 17, 18
2nd partial 1st semester (recoverable)	20-25%	3	0.12	6, 11, 14, 19, 15, 16, 1, 17, 18
2nd partial 2nd semester (recoverable)	22.5%	3	0.12	7, 10, 19, 17, 18
Homework assignments	5-15%	0	0	19, 1, 17, 18, 20
Recovery Examination (Optional if "passed by terms")	100%	3	0.12	3, 7, 8, 4, 6, 9, 2, 10, 12, 11, 14, 19, 15, 16, 1, 17, 18

Bibliography

• J.B. Marion, *Dinámica Clásica de las Partículas y Sistemas*, Ed. Reverté.

• T.W.B. Kibble, *Mecánica Clásica*, Ed. Urmo

• A.F. Rañada, *Dinámica Clásica*, Ed. Alianza Universida*d.*

• E. Massó*, Special Relativity. (provided to students through Campus Virtual)*

Software

Python and LTspice 2