UAB
Universitat Autònoma de Barcelona

Classical Mechanics

Code: 100148
ECTS Credits: 10

2024/2025

Degree	Type	Year
2500097 Physics	OB	2

Contact

Name: Eduard Masso Soler

Email: eduard.masso@uab.cat

Teachers

Emili Bagan Capella

Eduard Masso Soler

Marc Manera Miret

Teaching groups languages

You can view this information at the end of this document.

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.

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
magister lecture	55	2.2	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16

problem teaching	28	1.12	1, 10, 14, 15, 16, 17, 18, 19
Type: Supervised			
Supervised tests	2	0.08	7, 8, 16, 19
Type: Autonomous			
Individual work	138	5.52	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19
problem resolution	12	0.48	18

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.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
1st partial 1st semester (recoverable)	22.5%	3	0.12	1, 2, 3, 6, 8, 11, 12, 13, 18, 19
1st partial 2nd semester (recoverable)	22.5%	3	0.12	4, 5, 9, 17, 18, 19
2nd partial 1st semester (recoverable)	22.5%	3	0.12	1, 6, 11, 14, 15, 16, 17, 18, 19
2nd partial 2nd semester (recoverable)	22.5%	3	0.12	7, 10, 17, 18, 19
Homework assignments	10%	0	0	1, 17, 18, 19, 20
Recovery Examination (Optional if "passed by terms")	90%	3	0.12	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19

The course is divided into two parts or semesters (Sem.) that are structured similarly. In the middle and at the end of each Sem. there will be a partial exam. Assignments will be proposed that will count the percentage that is specified later.

The 1st and 2nd Sem. deal with different subjects; a good result in one of them cannot compensate for a bad result in the other. That is why there is a cut-off grade of 4 to be able to do the arithmetic average between the two Sem., both after the partials and after the resit exam.

The notes of Sem. are defined as the weighted average between the two partial exams and the corresponding assignement.

Unique assessment. Students who have accepted the single assessment modality will have to take a single test for each Sem., which will consist of 90% a standard exam and 10% completed exercises, to be handed in at the same time. The single assessment tests will take place on the same day, time and place as the partial second tests of the continuous assessment modality.

The subject is considered approved by partials when the Sem. grades are equal to or greater than 4 and the average of the grades of the two Sem. equals or exceeds 5. There is the possibility of trying to improve the grade in the resit exam.

If the average of the grades of the two Sem. is less than 3, the student fails the subject (no possibility to attend the resit exam).

If the arithmetic average of the grades of the two Sem. is equal to or higher than 3, but the subject has not been approved by partials, you must go to the resit exams for the corresponding parts (Sem. grade lower than 4). There may be students who attend one of the two exams because they have less than 4 and the other to improve their grade.

The resit exam will have two parts, one for each Sem. The assignement is taken into account in the final resit grade.

In all cases, the grade of one Sem. cannot go down, because the maximum grade is taken.

The evaluation will be done as follows.

Let EP11 and EP12 (EP21 and EP22) be the grades -out of 10- of the partial exams of the 1st (2nd) Sem. and E1 (E2) the grade -out of 1- of the assignement of the 1st (2nd) Sem. The grade N1 and N2 of the 1st and 2nd Sem. will be

$Ni=0.45*(EPi1+EPi2)+Ei$ i=1.2

The course grade for partials is $N=(N1+N2)/2$

If $N<3$ the student fails the subject and cannot go to the recovery exams.

If $N>=5$ and $N1>=4$ and $N2>=4$, the subject is approved by partials with a final grade equal to N. The student, if he/she wants, can take the resit exam to try to improve the grade.

If $3<=N<5$ or $N1<4$ or $N2<4$ the student must go to the corresponding resit exam. It is possible to go to the resit exam of a Sem. that has been passed to improve the grade of that Sem.

Let ER1 and ER2 be the grades of the 1st and 2nd Sem resit exams. The corresponding resit grades R1 and R2 are

$Ri=0.9*ERi+Ei.$ i=1.2

Both for students who want to improve their grade and for those who are retaking from a failed exam, the final grades of Sem., F1 and F2, are

$Fi=Max(Ni,Ri)$, i=1,2

The final grade of the course is $F= (F1+F2)/2$

To pass the subject you need $F>=5$ and $F1>=4$ and $F2>=4$, otherwise the student fails the subject.

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 Universidad*.*

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

Software

Python and LTspice 2

Language list

Name	Group	Language	Semester	Turn
(PAUL) Classroom practices	1	Catalan	annual	morning-mixed
(PAUL) Classroom practices	2	Catalan	annual	morning-mixed
(TE) Theory	1	Catalan	annual	morning-mixed
(TE) Theory	2	Catalan	annual	morning-mixed