UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Sistemi Dinamici e Meccanica Classica

2223-2-E3501Q012

Aims

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This course aims to present the basic ideas of Classical mechanics, from the Galielo-Newton formulation to those of Lagrange, Hamilton and Jacobi and to provide the necessary mathematical tools.

The expected learning outcomes include:

- the knowledge and understanding of the basic definitions and statements of different formulations of Classical Mechanics.
- the knowledge and understanding of some key examples (harmonic oscillator, Kepler's problem, Lagrange top).
- the ability to apply the acquired theoretical knowledge to the solution of exercises. In particular the derivation of the Lagrange/Hamilton equations for constrained mechanical systems, the reduction of the degrees of freedom in the presence of symmetries and, in some simple examples, the discussion of the qualitative behaviour of solutions of the equations of motion and/or their reduction to quadrature.

Detailed program

1. A reminder of the theory of ordinary differential equations. Vector fields and systems of first order ODEs. Equilibria and their stability. Lyapounov theorem. Linearization near equilibrium points. Systems with one degrees of freedom: level curves of the energy

2. Lagrangian Mechanics. Euler-Lagrange equations. Particle constrained on a regular curve. Particle constrained on a regular surface. The D'Alembert principle for general holonomic constraints. Equilibrium points and small oscillations. Variational formulation of Euler-Lagrange equations. One-parameter group of diffeomorphisms, symmetries and Noether's theorem. The two-body problem and the Kepler laws.

3. SO(3) and angular velocity. Inertial and non inertial frames. Mechanics of rigid bodies. The inertia operator.

K•oenig's theorem. Euler's equations for rigid bodies. The Euler angles and the Lagrange top.

4. Hamiltonian Mechanics. Legendre transformation. Hamilton's equations. Poisson bracket and Lie bracket. Symmetries and conservation laws in Hamiltonian Mechanics. Variational formulation of Hamilton's equations. Canonical transformations. Equivalent conditions of canonicity. Liouville's theorem.

Prerequisites

Calculus I, Linear Algebra and Geometry, Physics I.

Teaching form

Lectures: 8 CFU

Exercise classes: 4 CFU

Textbook and teaching resource

The course is based on lecture notes provided by the instructor.

The following books are also recommended:

1. V. I. Arnold, Metodi matematici della meccanica classica, Editori Riuniti.
2. S. Benenti, Modelli matematici della Meccanica, Quaderni di matematica per le scienze applicate. Celid
3. A. Fasano e S. Marmi Meccanica Analitica Bollati-Boringhieri 2002.
4. L.D. Landau. E. M. Lifshits, Meccanica, Editori Riuniti.

5 N.M.J. Woodhouse, Introduction to analytical dynamics, Oxford Science Publications. The Clarendon Press, Oxford University Press, New York, 1987.

G.Dell'Antonio, Elementi di Meccanica, Liguori, Napoli (1996)

Semester

Second semester.

Assessment method

The exam consists of two parts: a written test and an oral test.

The written test requires the solution of 3 problems (a dynamical system in the plane, a problem of Lagrangian Mechanics and a problem of Hamiltonian Mechanis). The duration is typically two and half hours. Correct answers without clear explanation will not receive full marks. The minimum grade to pass to the oral part is 15/30.

During the oral exam the students will be asked to state and prove the theorems carried out in class and to illustrate their meaning with significant examples. The oral exam will evaluate the knowledge of the theoretical aspects of the course, as well as the ability to expose it in a well-organized and consistent way.

The written an the oral exams equally contribute to the final grade. The oral examination can be taken in the same session of the written test, as well as in the subsequent one.

During the course, two written partial tests will be offered, each referred to one half of the course. To pass the written examination through the partial tests, the student needs to pass each of them with the minimum grade of 15/30. In this case oral examination must be taken within the exam session of September.

Office hours

By appointment.

Contents

Newtonian Mechanics (a reminder). Ordinary differential equations. Qualitative analysis. The D'Alembert principle and Lagrangian Mechanics. The two-body problem. The rigid body. Hamiltonian mechanics. Canonical transformations.

Detailed program

1. A reminder of the theory of ordinary differential equations. Vector fields and systems of first order ODEs. Equilibria and their stability. Lyapounov theorem. Linearization near equilibrium points. Systems with one degrees of freedom: level curves of the energy

2. Lagrangian Mechanics. Euler-Lagrange equations. Particle constrained on a regular curve. Particle constrained on a regular surface. The D'Alembert principle for general holonomic constraints. Equilibrium points and small oscillations. Variational formulation of Euler-Lagrange equations. One-parameter group of diffeomorphisms, symmetries and Noether's theorem. The two-body problem and the Kepler laws.

3. SO(3) and angular velocity. Inertial and non inertial frames. Mechanics of rigid bodies. The inertia operator. K•oenig's theorem. Euler's equations for rigid bodies. The Euler angles and the Lagrange top.

4. Hamiltonian Mechanics. Legendre transformation. Hamilton's equations. Poisson bracket and Lie bracket. Symmetries and conservation laws in Hamiltonian Mechanics. Variational formulation of Hamilton's equations. Canonical transformations. Liouville's theorem.

Prerequisites

Analysis I, Linear Algebra and Geometry, Physics I.

Teaching form

Lectures: 8 cfu
Exercises class 4 cfu

Textbook and teaching resource

The following books are recommended:

1. V. I. Arnold, Metodi matematici della meccanica classica, Editori Riuniti.

2. A. Fasano e S. Marmi Meccanica Analitica Bollati-Boringhieri 2002.

3. L.D. Landau. E. M. Lifshits, Meccanica, Editori Riuniti.

4. N.M.J. Woodhouse, Introduction to analytical dynamics, Oxford Science Publications. The Clarendon Press, Oxford University Press, New York, 1987.

G.Dell'Antonio, Elementi di Meccanica, Liguori, Napoli (1996)

Lecture notes on special parts will be also provided by the teacher.

Suitable collections of solved exercises are:

1. F. Talamucci, Esercizi svolti sul formalismo lagrangiano e hamiltoniano con brevi richiami di teoria. Edizioni Nuova Cultura, 2014

2. Alessandra Celletti, Esercizi e Complementi di Meccanica Razionale, Aracne Editrice, (2003)

3. Giancarlo Benettin, Eserciziario per il corso di Fisica Matematica, Padova (2017)

(freely downloadable from the webpage of the author:

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Semester

Second semester.

Assessment method

The exam consists of two parts: a written test and an oral test.

The written test requires the solution of 3 problems (a problem of Lagrangian Mechanics and a problem of Hamiltonian Mechanis). The duration is typically three hours. Correct answers without clear explanation will not receive full marks. The minimum grade to pass to the oral part is 15/30.

During the oral exam the students will be asked to state and prove the theorems carried out in class and to illustrate their meaning with significant examples. The oral exam will evaluate the knowledge of the theoretical aspects of the course, as well as the ability to expose it in a well-organized and consistent way.

The written an the oral exams equally contribute to the final grade. The oral examination can be taken in the same session of the written test, as well as in the subsequent one.

During the course, two written partial tests will be offered, each referred to one half of the course. To pass the written examination through the partial tests, the student needs to pass each of them with the minimum grade of 15/30. In this case oral examination must be taken within the exam session of July.

Office hours

By appointment through webex platform or in person if possible.

Sustainable Development Goals

QUALITY EDUCATION