COURSE PROGRAMME

1. Information about the programme

1.1 University	**“Alexandru Ioan Cuza” University of Iaşi**
1.2 Faculty	**Faculty of Mathmatics**
1.3 Department	**Mathematics**
1.4 Domain	**Mathematics**
1.5 Cycle	**Master**
1.6 Programme / Qualification	**Applied Mathematics**

2. Information about the course

2.1 Course Name	**Celestial Mechanics**						
2.2 Course taught by	**Prof. Catalin Gales**						
2.3 Seminary / laboratory taught by	**Prof. Catalin Gales**						
2.4 Year	**1**	**2.6** Semester	**2**	**2.6** Type of evaluation	**E**	**2.7** Course type	**OP**

** OB – Obligatory / OP – Optional / F-Facultative*

3. Total hours (estimated per semester and activities)

3.1 Number of hours per week	**4**	3.2 course	**2**	3.3. seminar/laboratory	**2**
3.4 Total number of hours	**56**	3.5. course	**28**	3.6. seminar/laboratory	**28**

Distribution	hours
Individual study using textbooks, course notes, bibliography items, etc.	**60**
Supplimentary study (library, on-line platforms, etc.)	**30**
Individual study for seminary/laboratory, homeworks, projects, etc.	**29**
Tutoring	
Examination 4	**4**
Other activities..................................	

3.7 Total hours of individual activity	**119**
3.8 Total hours per semester 210	**175**
3.9 Credit points	**7**

4. Pre-requisites

4.1 Curriculum	Mathematical analysis, Differential equations
4.2 Competencies	Use basic notions of real analysis and differential equations

5. Conditions (if necessary)

5.1 Course	Lecture room
5.2 Seminary/Laboratory	Laboratory room

6. Specific competences acquired

Professional competencies	C1 Manipulating notions, methods and mathematical models, specific techniques and technologies in scientific calculus and applications in celestial mechanics and astrodynamics: 1 credit point C3 Being able to develop, test and validate algorithms; implementation in high level programing Languages: 1 credit point C4 Being able to construct and apply mathematical models for analyzing and simulating some dynamical phenomena and processes: 2 credit points C6 Being able to analyze and interpret some dynamical phenomena and processes: 1 credit point
Transversal competencies	CT1 Having a responsible attitude towards scientific research and teaching, being able to fully develop the personal potential in the professional career, respecting the principles of a rigorous and efficient work in order to fulfill complex tasks, respecting the ethical norms and principles in the professional activity: 1 credit point CT4 Being able to make a selection of information resources and to use them efficiently, in Romanian or other language of international circulation, in order to develop the professional activity and adapt it to the demands of a dynamical society: 1 credit point

7. Course objectives

7.1. General objective	1. To model dynamics of space objects; 2. To be able to use analytical and numerical techniques for studying the dynamics of various mathematical models of celestial mechanics and astrodynamics; 3. To provide a qualitative and quantitative description of the dynamical phenomena.
7.2. Specific objectives	At the end of the course, students will be able to: ▪ Provide the ordinary equations describing the motion of a given spatial system; ▪ Describe several mathematical tools able to study a given dynamical model; ▪ Use numerical tools to numerically propagate the orbit of a space object (or system); ▪ Characterize regular, resonant and chaotic orbits by computing chaos indicators; ▪ Use elements of the canonical perturbation theory to analyze long-term dynamics of celestial bodies; ▪ Apply Hamiltonian (analytical and semi-analytical) tools to investigate the dynamics of space objects.

8. Contents

8.1	**Course**	**Teaching methods**	**Remarks** (number of hours and references)
1.	Elements of classical mechanics (kinematics, dynamics, generalized coordinates, Lagrange equations)	Lecture, conversation, proof and problematization	5 hours, reference [1]
2.	Elements of Hamilton mechanics (canonical transformations, conditions of canonicity, first integrals);	Lecture, conversation, proof and problematization	5 hours, references [1], [2], [5], [6]
3.	Numerical methods for ordinary differential equations (Adams-Bashforth-Moulton, Runge-Kutta).	Lecture, conversation, proof and problematization	2 hours, references [7]

4.	The analytical solution of the two body problem. Orbital elements	Lecture, conversation, proof and problematization	3 hours, references [3], [4]
5.	The n body problem (formulation of the problem, first integrals, numerical studies in the case n = 3, the restricted three body problem). Applications to extrasolar systems;	Lecture, conversation, proof and problematization	4 hours, references [2], [3], [4]
6.	Elements of canonical perturbation theory (integrable systems, Liouville's theorem, action-angle variables, quasi-integrable Hamiltonian systems, disturbing functions, expansions)	Lecture, conversation, proof and problematization	5 hours, references [2], [5],[6]
7.	Orbital resonances and spin-orbital resonances	Lecture, conversation, proof and problematization	2 hours, references [1], [2]
8.	Dynamics of space debris	Lecture, conversation, proof and problematization	2 hours, references [4], [7]

Bibliography

Main references:
1. A. Celletti, Stability and Chaos in Celestial Mechanics, Springer-Verlag, Berlin (2010).
2. A. Morbidelli, Modern Celestial Mechanics. Aspects of Solar System Dynamics, Taylor & Francis Scientific Publishers, Cambridge (2011).
3. C. D. Murray, S.F. Dermott, Solar system dynamics, Cambridge University Press, 1999.
4. D.A. Vallado, Fundamentals of astrodynamics and applications, McGraw-Hill 1997.

Additional references:
5. V.I. Arnold. Mathematical methods of Classical Mechanics, second edition translated by K. Vogtmann and A. Weinstein, Springer-Verlag (1989).
6. C. Efthymiopoulos, Canonical perturbation theory, stability and diffusion in Hamiltonian systems: applications in dynamical astronomy, in 3rd La Plata International School on Astronomy and Geophysics “Chaos, Diffusion and Non-integrability in Hamiltonian Systems - Applications to Astronomy” (1st edition), P. Cincotta, C. Giordano, C., Efthymiopoulos, eds., Uni. Nac. de la Plata, La Plata (2011).
7. O. Montenbruck, E. Gill, Satellite orbits, Science (Vol. 134), Springer Berlin Heidelberg, 2000.

8.2	**Seminar / Laborator**	**Metode de predare**	**Observaţii** (ore şi referinţe bibliografice)
1.	Elements of classical mechanics (kinematics, dynamics, generalized coordinates, Lagrange equations)	Exercises, conversations, proofs	5 hours, references [1], [2], [5], [6]
2.	Elements of Hamilton mechanics (canonical transformations, conditions of canonicity, first integrals);	Exercises, conversations, proofs	5 hours, references [1], [2], [5], [6]
3.	Propagation of orbits using single-step and multi-step integrators (Runge-Kutta, Adams-Bashforth-Moulton)	Exercises, conversations, proofs	2 hours, references [7]
4.	Chaos indicators (Lyapunov exponents, the Poincare map). Application the Henon and Heiles system (1964));	Exercises, conversations, proofs	3 hours, references [1], [2]
5.	The analytical solution of the two body problem. Orbital elements	Exercises, conversations, proofs	3 hours, references [3], [4]

6.	The Delaunay variables	Exercises, conversations, proofs	2 hours, references [3], [4]
7.	Elements of canonical perturbation theory	Exercises, conversations, proofs	3 hours, references [2], [5],[6]
8.	Orbital resonances and spin-orbital resonances. Applications: Sun-Jupiter-Asteroid problem	Exercises, conversations, proofs	3 hours, references [1], [2]
9.	Dynamics of space debris (methods to study the dynamics of debris population)	Exercises, conversations, proofs	2 hours, references [4], [7]

Bibliography

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1. A. Celletti, Stability and Chaos in Celestial Mechanics, Springer-Verlag, Berlin (2010).
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3. C. D. Murray, S.F. Dermott, Solar system dynamics, Cambridge University Press, 1999.
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6. C. Efthymiopoulos, Canonical perturbation theory, stability and diffusion in Hamiltonian systems: applications in dynamical astronomy, in 3rd La Plata International School on Astronomy and Geophysics “Chaos, Diffusion and Non-integrability in Hamiltonian Systems - Applications to Astronomy” (1st edition), P. Cincotta, C. Giordano, C., Efthymiopoulos, eds., Uni. Nac. de la Plata, La Plata (2011).
7. O. Montenbruck, E. Gill, Satellite orbits, Science (Vol. 134), Springer Berlin Heidelberg, 2000.

9. Coordination of the contents with the expectations of the community representatives, professional associations and relevant employers in the corresponding domain

The student will be able to apply various tools to study the dynamics of solar-system bodies (planets, asteroids, satellites, spacecraft, space debris). The course offers the support to familiarize students with the problems faced nowadays by the space industry, space agencies and researchers working in space sciences.

10. Assessment and examination

Activity	**10.1 Criteria**	**10.2 Modes**	**10.3 Weight in the final grade (%)**
10.4 Course	To know and correctly use the notions and theories presented at the lectures	Oral examination	50%
10.5 Seminary/ Laboratory	To identify and apply (implement) the methods for solving problems related to the course curricula;	Written exam	50%

10.6 Minimal requirements

1. To identify and select correct methods for approaching a given topic.

2. To know and correctly use the basic notions and mathematical tools studied at this course

Date | Course coordinator Prof. Catalin Gales | Seminary coordinator Prof. Catalin Gales

Approval date in department | Head of the department Prof. dr. Ioan Bucataru