MASTER 'S PROGRAMME
APPLIED MATHEMATICS - IN ENGLISH

1ST YEAR OF STUDY, 2ND SEMESTER

COURSE TITLE	**MATHEMATICAL METHODS IN SPACE SCIENCES**
COURSE CODE	**MA2MMS**
COURSE TYPE	full attendance/ tutorial
COURSE LEVEL	2nd cycle (master's degree)
YEAR OF STUDY, SEMESTER	1st year of study, 2nd semester
NUMBER OF ECTS CREDITS	**7**
NUMBER OF HOURS PER WEEK	4 (2 lecture hours + 2 seminar/laboratory hours)
NAME OF LECTURE HOLDER	Dr. Galeș Cătălin
NAME OF SEMINAR HOLDER	Dr. Galeș Cătălin
PREREQUISITES	Curriculum: Mathematical analysis, Differential equations Competencies: use basic notions of real analysis and differential equations Language: advanced level of English

A GENERAL AND COURSE-SPECIFIC COMPETENCES

General competences:

- ✓ 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
- ✓ Being able to make a selection of information resources and to use them efficiently in order to develop the professional activity and adapt it to the demands of a dynamical society

Course-specific competences:

- ✓ Manipulating notions, methods and mathematical models, specific techniques and technologies in scientific calculus and applications in economy and informatics
- ✓ Being able to develop, test and validate algorithms; implementation in high level programming languages
- ✓ Being able to construct and apply mathematical models for analysing and simulating some phenomena and processes
- ✓ Being able to analyse and interpret some economic processes and phenomena

B LEARNING OUTCOMES

- ✓ To model dynamical phenomena in space sciences
- ✓ To be able to use analytical and numerical techniques for studying the dynamics of various mathematical models of celestial mechanics and astrodynamics
- ✓ To provide a qualitative and quantitative description of the dynamical phenomena
- ✓ After successfully completing this course, the 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 analyse long-term dynamics of celestial bodies
  - ✧ Apply Hamiltonian (analytical and semi-analytical) tools to investigate the dynamics of space objects

C LECTURE CONTENT

1. Elements of Hamilton mechanics (canonical transformations, conditions of canonicity, first integrals)
2. Numerical methods for ordinary differential equations (Adams-Bashforth-Moulton, Runge-Kutta)

3. Chaos indicators (Lyapunov exponents, the Poincare map)
4. The analytical solution of the two body problem. Orbital elements
5. The *n* body problem (formulation of the problem, first integrals, numerical studies in the case *n* = *3*). Application to extrasolar systems
6. The stability of equilibrium points in the restricted three body problem
7. Elements of canonical perturbation theory (quasi-integrable Hamiltonian systems, disturbing functions, normal forms)
8. Orbital resonances and spin-orbital resonances
9. The Hohmann orbit transfer
10. Dynamics of space debris

D RECOMMENDED READING FOR LECTURES

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.
5. V.I. Arnold. Mathematical methods of Classical Mechanics, second edition translated by K. Vogtmann and A. Weinstein, Springer-Verlag (1989).

E SEMINAR CONTENT

1. Elements of Hamilton mechanics (canonical transformations, conditions of canonicity, first integrals)
2. Propagation of satellite orbits using single-step and multi-step integrators (Runge-Kutta, Adams-Bashforth-Moulton)
3. Chaos indicators (Lyapunov exponents, the Poincare map). Application the Henon and Heiles system (1964))
4. The analytical solution of the two body problem. Orbital elements
5. The *n* body problem (formulation of the problem, first integrals, numerical studies in the case *n* = *3*). Application to extrasolar systems
6. The stability of equilibrium points in the restricted three body problem
7. Elements of canonical perturbation theory
8. Orbital resonances and spin-orbital resonances. Applications: Sun-Jupiter-Asteroid problem
9. Orbit transfers and interplanetary trajectories
10. Dynamics of space debris (methods to study the dynamics of debris population)

F RECOMMENDED READING FOR SEMINARS

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.

G EDUCATION STYLE

LEARNING AND TEACHING METHODS	Lectures: lecture, conversation, proof and problematization Seminars/laboratory: exercises, conversations, proofs
ASSESSMENT METHODS	Course: weight in the final grade 50% (written exam, oral examination) Class activity/homework: weight in the final grade 50% (written exam, presentation of a home project) 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 3. To create and present a project on a given theme. 4. Minimum grade 5
LANGUAGE OF INSTRUCTION	English