COURSE DESCRIPTION

Dynamical Systems

Academic year 2026/2027

1. Programme-related data

1.1. Higher Education Institution	Babeş-Bolyai University	
1.2. Faculty	Mathematics and Computer Science	
1.3. Department	Mathematics	
1.4. Field	Computer Science	
1.5. Level of study	Bachelor	
1.6. Degree programme / Qualification	Computer Science (english)	
1.7. Form of education	Full time	

2. Course-related data

2.1. Course title	**Dynamical Systems**			Course code	**MLE0010**
2.2. Course coordinator	Conf. Dr. Adriana Buică				
2.3. Seminar coordinator	Conf. Dr. Adriana Buică				
2.4. Year of study	1	2.5. Semester	2	2.6. Type of assessment	Exam
2.7. Course status	Compulsory			2.8. Course type	Complementary subject

3. Total estimated time (hours per semester of teaching activities)

3.1. Number of hours per week	**4**	of which: 3.2. course	**2**	3.3. seminar/ laboratory/ project	**2**
3.4. Total of hours in the curriculum	56	of which: 3.5. course	28	3.6. seminar/ laboratory	**28**
Time allocation for individual study (IS) and self-taught activities (ST)					**hours**
Learning from textbooks, course materials, bibliography, and notes (IS)					35
Additional research in the library, on subject-specific electronic platforms, and on-site					8
Preparing seminars/ laboratories/ projects, assignments, reports, portfolios, and essays					14
Tutoring (professional guidance)					4
Examinations					6
Other activities					2
3.7. Total hours of individual study (IS) and self-taught activities (ST)				**69**	
3.8. Total hours per semester				**125**	
3.9. Number of credits				**5**	

4. Prerequisites (where applicable)

4.1. curriculum-related	Mathematical Analysis (Derivation and integration, Taylor expansion, properties of real functions), Linear Algebra (eigenvalues and eigenvectors, linear spaces, linear maps), Basics of Geometry (conics), Basics of Physics (the Newton's second law of motion)
4.2 skills-related	Logical thinking

5. Specific conditions (where applicable)

5.1. course-related	blackboard
5.2. seminar/laboratory-related	Blackboard and computers

6.1. Competencies resulting from the completion of the degree programme *(as referred to in the curriculum)*[1]

Professional competencies	
Competency code	**Competency**
PC1	Develop problem-solving strategies
PC5	Synthesize information
PC6	Think abstractly
Transversal competencies	
Competency code	**Competency**
TC4	Solve problems
TC5	Think analytically

6.2. Learning outcomes relevant to the degree programme (as referred to in the curriculum)[2]

Learning outcomes targeted by the subject		
Competency code	**Knowledge and comprehension**	**Specific academic skills**
PC1	1. *The student compares and distinguishes related notions and their properties from the core disciplines of mathematics.*	1. *The student recognizes and analyzes the necessary and/or sufficient conditions in the statements of mathematical assertions and specifies their role in the proof.*
PC5 and PC6	2. *The student defines the fundamental concepts from the core disciplines of mathematics.*	2. *The student provides examples of how fundamental concepts and theoretical results are used in solving exercises and problems related to the topics covered in the curriculum disciplines.*
TC4 and TC5	*3. The student has the knowledge necessary to understand and solve complex problems, and to plan and organize advanced processes in various fields*	*3. The student has the ability to apply general rules to specific problems and produce relevant solutions.*

7. Subject-specific learning outcomes

Knowledge and comprehension
1. The student has acquired the knowledge specific to the discipline studied necessary for solving problems.
2. The student knows fundamental notions and theorems of dynamical systems as well as methods of applying them in fields of science.
Specific academic skills
1. The student is able to construct clear and well-supported mathematical arguments to explain mathematical problems, topics, and ideas in writing.
2. The student is able to solve exercises and problems using theoretical results and will be able to present the solutions both orally and in writing.

[1] The professional and/or transversal skills targeted by the subject for which the course description is prepared will be copied from the curriculum of the degree programme. For each competency, the complete entry, including the competency code, will be copied with the exact wording that appears in the curriculum, without any changes. If no competency is copied from either of the two categories, the row corresponding to that category is deleted from the table.

[2] The learning outcomes relevant for the degree programme and targeted by the subject for which the course description is prepared will be listed. The entries, copied without any changes from the Curriculum by subject type (Core Subject/Specialisation Subject/Complementary Subject), are listed under the corresponding competency.

8. Contents

8.1. Course	**Teaching and learning methods**	**Remarks[3]**
1.Introduction to dynamical systems (examples, notions, initial conditions, boundary conditions, examples, fundamental problems, physical models)	Exposition, proofs, examples	
2.Linear differential equations (existence and uniqueness theorem, fundamental theorems)	Exposition, proofs, examples	
3.Linear differential equations with constant coefficients.	Exposition, proofs, examples	
4.Linear differential equations. Applications (Newton's law of cooling, Pendulum equation, Harmonic oscillations)	Exposition, proofs, examples	
5.Scalar first order linear differential equations	Exposition, proofs, examples	
6.Linear differential systems	Exposition, proofs, examples	
7.The dynamical system generated by a differential equation (main notions and first examples). Phase portraits of scalar equations.	Exposition, proofs, examples	
8.Stability of equilibria (definition, examples, stability of linear systems, the linearization method). The nonlinear pendulum equation.	Exposition, proofs, examples	
9.Phase portraits of planar systems.	Exposition, proofs, examples	
10.Numerical methods for ordinary differential equations (Euler and Runge-Kutta numerical formulas)	Exposition, proofs, examples	
11.Linear recurrences (difference equations) with constant coefficients (fundamental theorems, Fibonacci sequence)	Exposition, proofs, examples	
12.Linear systems of difference equations (convergent matrix, complex notation)	Exposition, proofs, examples	
13.Nonlinear scalar discrete dynamical systems (notions, examples, stability of a fixed point)	Exposition, proofs, examples	
14.The logistic map. Euler numerical formula revisited.	Exposition, proofs, examples	

Bibliography

1. The webpage of the course http://www.math.ubbcluj.ro/~abuica/dynsys.htm
2. A. Buică, Lecture notes on Dynamical Systems uploaded in Teams
3. S.E. Elaydi, Discrete Chaos: with applications in science and engineering, CRC Press, 2008.
4. J. Hale, H. Kocak, Dynamics and Bifurcations, Springer, 1991.
5. M.W. Hirsch, S. Smale, R.L. Devaney, Differential Equations, Dynamical Systems and an Introduction to Chaos, Academic Press, 2004.
6. R.Precup, Ordinary Differential Equations, De Gruyter, 2017.

8.2. Seminar/ laboratory	**Teaching and learning methods**	**Remarks**
Seminar 1. Linear homogeneous differential equations with constant coefficients. General solutions and properties of solutions (periodicity, oscillations, boundedness…)	Examples, dialogue, explanations, proofs, critical thinking	
Laboratory 1. Introduction to Maple. Basic notions.	Examples, dialogue, explanations, critical thinking	
Seminar 2. Linear differential equations (the method of undetermined coefficients, the Lagrange method).	Examples, dialogue, explanations, proofs, critical thinking	
Laboratory 2. The use of Maple to find the general solution of linear differential equations, to solve initial and boundary value problems and to study the properties of solutions	Examples, dialogue, explanations, critical thinking	

[3] For example, organisational aspects, recommendations for students, specific aspects relating to the course/seminar, such as inviting experts in the field, etc.

Seminar 3. Linear differential equations.	Examples, dialogue, explanations, proofs, critical thinking	
Laboratory 3. The use of Maple to find the general solution to Euler equations and to linear systems. Power series method.	Examples, dialogue, explanations, critical thinking	
Seminar 4. Phase portraits of scalar nonlinear dynamical systems and planar linear systems.	Examples, dialogue, explanations, proofs, critical thinking	
Laboratory 4. Orbits and direction fields of planar systems.	Examples, dialogue, explanations, critical thinking	
Seminar 5. Stability of linear systems and of equilibria of nonlinear systems.	Examples, dialogue, explanations, proofs, critical thinking	
Laboratory 5. First integrals of planar systems around equilibria of center type.	Examples, dialogue, explanations, critical thinking	
Seminar 6. Test. Introduction to linear recurrences.	Examples, dialogue, explanations, proofs, critical thinking	
Laboratory 6. Numerical methods. Nonlinear scalar maps.	Examples, dialogue, explanations, critical thinking	
Seminar 7. Linear recurrences. Nonlinear scalar maps.	Examples, dialogue, explanations, proofs, critical thinking	
Laboratory 7. Test.	Evaluation	

Bibliography

1. A. Buică, Pproblems on Dynamical Systems uploaded in Teams
2. S.E. Elaydi, Discrete Chaos: with applications in science and engineering, CRC Press, 2008.
3. J. Hale, H. Kocak, Dynamics and Bifurcations, Springer, 1991.
4. S. Lynch, Dynamical systems with applications using MAPLE, Birkhauser, 2001.

9. Evaluation

Type of activity	9.1 Evaluation criteria[4]	9.2 Evaluation methods[5]	9.3 Percentage in the final grade
9.4. Course	The evaluation of the knowledges and the competencies to apply them	Written exam	70%
9.5. Seminar/ laboratory	Solving problems skills	One test	10%
	Interest and implication in each lab activity. One final test in the last lab.	Dialogue in each lab and one final test	20%

9.6 Minimum standard for passing

- Presence at least at 6 labs and 5 seminars.
- To obtain at least 7 points at the lab test and at least 15 points at the written exam.
- The minimum passing grade is 5.

[4] The evaluation criteria must directly reflect the learning outcomes targeted at the level of the degree programme respectively at the level of the subject. More specifically, the learning outcomes set out in the expected learning outcomes are assessed.

[5] Both final evaluation methods and ongoing evaluation strategies should be established.

10. SDG labels (Sustainable Development Goals)[6]

	○	Sustainable Development Generic Label

								
○	○	○	○	○	○	○	○	X
								No label applies
○	○	○	○	○	○	○	○	○

Date of entry:
11/04/2026

Signature of course coordinator

Conf. dr. Adriana Buică

Signature of seminar coordinator

Conf. dr. Adriana Buică

Date of approval in the department:
26/04/2026

Signature of the head of department

Prof. dr. Andrei Mărcuş

[6] Select a single label which, according to the *Implementation of SDG labels in the academic process*, best matches the subject. If the subject addresses sustainable development in a generic manner (i.e. by presenting/introducing the general framework of sustainable development, etc.), then the Sustainable Development generic label may be applied. If none of the labels describe the subject, select the last option: *"No label applies."*