# COURSE DESCRIPTION

## Qualitative theory of ordinary differential equations

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 | **Mathematics** |
| 1.5. Level of study | **Master** |
| 1.6. Degree programme / Qualification | **Advanced Mathematics** |
| 1.7. Form of education | **Full-time** |

**2. Course-related data**

| | | | | | |
|---|---|---|---|---|---|
| 2.1. Course title | **Qualitative theory of ordinary differential equations** | | | Course code | **MME3109** |
| 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 | 1 | 2.6. Type of assessment | Exam |
| 2.7. Course status | Compulsory | | | 2.8. Course type | Core subject |

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

| | | | | | |
|---|---|---|---|---|---|
| 3.1. Number of hours per week | **3** | of which: 3.2. course | **2** | 3.3. seminar/ laboratory/ project | **1** |
| 3.4. Total of hours in the curriculum | **42** | of which: 3.5. course | **28** | 3.6. seminar/ laboratory | **14** |
| **Time allocation for individual study (IS) and self-taught activities (ST)** | | | | | **hours** |
| Learning from textbooks, course materials, bibliography, and notes (IS) | | | | | 37 |
| Additional research in the library, on subject-specific electronic platforms, and on-site | | | | | 30 |
| Preparing seminars/ laboratories/ projects, assignments, reports, portfolios, and essays | | | | | 36 |
| Tutoring (professional guidance) | | | | | 10 |
| Examinations | | | | | 20 |
| Other activities | | | | | |
| **3.7. Total hours of individual study (IS) and self-taught activities (ST)** | | | | **133** | |
| **3.8. Total hours per semester** | | | | **175** | |
| **3.9. Number of credits** | | | | **7** | |

**4. Prerequisites** (where applicable)

| | |
|---|---|
| 4.1. curriculum-related | Mathematical Analysis, Differential Equations, Linear Algebra |
| 4.2 skills-related | Logical deduction, abstract thinking, critical thinking, ability to operate with mathematical notions and properties |

**5. Specific conditions** (where applicable)

| | |
|---|---|
| 5.1. course-related | blackboard |
| 5.2. seminar/laboratory-related | blackboard |

**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 |
| **PC3** | Perform analytical mathematical calculations |
| **PC6** | Disseminate results among the scientific community |
| **Transversal competencies** | |
| **Competency code** | **Competency** |
| **TC3** | Work independently |
| **TC6** | 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 graduate analyzes the hypotheses and conclusions from mathematical assertions and links them within the demonstration. | 1. The graduate demonstrates the acquisition and use of effective research methods and techniques. |
| **PC3** | 2. The graduate formulates observations and differentiates notions, properties and assertions from advanced disciplines of mathematics through examples and counterexamples. | 2. The graduate verifies, on particular cases or by constructing examples or counterexamples, the validity of mathematical statements. The graduate translates a practical situation into mathematical language, solves the problem obtained and interprets the results obtained. |
| **PC6** | 3. The graduate defines the basic concepts from advanced mathematics disciplines in the curriculum. | 3. The graduate correctly and rigorously formulates the statements of mathematical assertions (lemmas, propositions, theorems) from the disciplines in the curriculum. |
| **TC3** | 4. The graduate compares and distinguishes related notions and their properties from advanced mathematics disciplines in the curriculum. | 4. The graduate is able to identify and formulate significant problems which form the basis for further research. |
| **TC6** | 5. The graduate critically studies the specialized literature, including by using international databases, identifying fundamental concepts. | 5. The graduate applies appropriate techniques for solving advanced problems. |

**7. Subject-specific learning outcomes**

| Knowledge and comprehension |
|---|
| 1. The graduate has acquired the knowledge specific to the discipline studied necessary for solving problems. |
| 2. The graduate knows fundamental notions and theorems of differential equations as well as methods of applying them in fields of science. |

[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.

| Specific academic skills |
|---|
| 1. The graduate is able to construct clear and well-supported mathematical arguments to explain mathematical problems, topics, and ideas in writing. |
| 2. The graduate is able to prove theorems using mathematical language in theoretical courses and will be able to present these results both orally and in writing. |

**8. Contents**

| 8.1. Course | Teaching and learning methods | Remarks[3] |
|---|---|---|
| 1.Linear differential systems. Fundamental theory. | Explanation, dialogue, examples, proofs | |
| 2.Linear differential systems with constant coefficients. The exponential matrix for a diagonalizable matrix. | Explanation, dialogue, examples, proofs | |
| 3.Linear differential systems with constant coefficients. The exponential matrix for a deffective matrix. | Explanation, dialogue, examples, proofs | |
| 4.The asymptotic behaviour of the solutions of linear systems with constant coefficients. Stable, unstable, center manifolds. | Explanation, dialogue, examples, proofs | |
| 5.The fundamental theorems for nonlinear systems: the existence and uniqueness theorem | Explanation, dialogue, examples, proofs | |
| 6.The fundamental theorems for nonlinear systems: maximal interval of existence | Explanation, dialogue, examples, proofs | |
| 7.The fundamental theorems for nonlinear systems: continuity and differentiability with respect to parameters and initial data | Explanation, dialogue, examples, proofs | |
| 8.Stability of equilibria of nonlinear autonomous systems by linearization. | Explanation, dialogue, examples, proofs | |
| 9.Stability of equilibria of nonlinear autonomous systems by the Lyapunov functions method | Explanation, dialogue, examples, proofs | |
| 10.Stability of nonautonomous linear differential systems | Explanation, dialogue, examples, proofs | |
| 11.Stability of periodic linear differential systems. Floquet theory I | Explanation, dialogue, examples, proofs | |
| 12.Stability of periodic linear differential systems. Floquet theory II | Explanation, dialogue, examples, proofs | |
| 13.Periodic solutions of linear periodic systems | Explanation, dialogue, examples, proofs | |
| 14.Stability of periodic solutions of periodic nonlinear systems | Explanation, dialogue, examples, proofs | |

**Bibliography**


1. A. Buică, Periodic solutions for nonlinear systems, Cluj University Press, 2006.
2. A. Buică, Lecture Notes on Qualitative theory of differential equations uploaded in Teams.
3. C. Chicone, Ordinary differential equations with applications, Springer, 2006.
4. E.A. Coddington, N. Levinson, Theory of ordinary differential equations, 1959.
5. P. Hartman, Ordinary differential equations, SIAM, 2002.
6. L. Perko, Differential equations and dynamical systems, Springer, 2001.
7. M. Viana, J.M Espinar, Differential equations: a dynamical systems approach to theory and practice, American Mathematical Society, 2021.


| 8.2. Seminar/ laboratory | Teaching and learning methods | Remarks |
|---|---|---|
| 1.Exercises and problems related to the fundamental theorems for linear differential systems. | dialogue, examples, proofs | |

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

| | | |
|---|---|---|
| 2.Exercises to recognize a diagonalizable matrix over R or over C, the computation of their exponential and the general solution of the corresponding linear differential system. | dialogue, examples, proofs | |
| 3. .Exercises to recognize a deffective matrix, the computation of their exponential and the general solution of the corresponding linear differential system. | dialogue, examples, proofs | |
| 4.Stable, unstable and center manifolds on examples. | dialogue, examples, proofs | |
| 5.The existence and uniqueness theorem on examples and its important consequences. | dialogue, examples, proofs | |
| 6.The maximal interval of existence for the solutions of various equations, including the pendulum equation. | dialogue, examples, proofs | |
| 7.Continuity and differentiability with respect to the initial data and parameters on examples. | dialogue, examples, proofs | |
| 8.The stability by linearization of the equilibria of various differential autonomous systems. | dialogue, examples, proofs | |
| 9. The stability by the direct method of Lyapunov of the equilibria of various differential autonomous systems. | dialogue, examples, proofs | |
| 10.The stability of linear nonautononous systems. Exrcises to understand how to apply the main results. | dialogue, examples, proofs | |
| 11.Applications of the Floquet theory. | dialogue, examples, proofs | |
| 12.The stability of some periodic linear differential equations, including the Hill equation. | dialogue, examples, proofs | |
| 13.The existence of periodic solutions of some periodic differential equations, including the Hill equation. | dialogue, examples, proofs | |
| 14.Discussion on the stability of periodic solutions of autonomous systems. | dialogue, examples, proofs | |

**Bibliography**


1. A. Buică, Periodic solutions for nonlinear systems, Cluj University Press, 2006.
2. A. Buică, Lecture Notes on Qualitative theory of differential equations uploaded in Teams.
3. C. Chicone, Ordinary differential equations with applications, Springer, 2006.
4. E.A. Coddington, N. Levinson, Theory of ordinary differential equations, 1959.
5. P. Hartman, Ordinary differential equations, SIAM, 2002.
6. L. Perko, Differential equations and dynamical systems, Springer, 2001.
7. M. Viana, J.M Espinar, Differential equations: a dynamical systems approach to theory and practice, American Mathematical Society, 2021.


**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 | Knowledge of the notions and their properties by examples or counterexamples. Ability to prove the main theoretical results. | Oral exam | 40 |
| | Development of a specific subject by reading the bibliography. | Report with oral presentation | 20 |
| 9.5. Seminar/ laboratory | Solving problems skills | Written tests and oral presentation | 30 |
| | Active participation in the classroom | | |
| 9.6 Minimum standard for passing | | | |
| At least 20 (/40) at the oral exam and at least 20 (/30) at the seminar evaluation | | | |

[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 |
|  |  |  |
| ○ | ○ | ○ |
|  |  |  |
| ○ | ○ | ○ |
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| ○ | ○ | X |
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| ○ | ○ | ○ |

Date of entry:
12.04.2026

Signature of course coordinator

Conf. Dr. Adriana Buică

Signature of seminar coordinator

Conf. Dr. Adriana Buică

Date of approval in the department:
25.04.2026

Signature of the head of department

Prof. Dr. Andrei Mărcuș

[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."*