SYLLABUS

Complements of Complex Analysis

University year 2025-2026

1. Information regarding the programme

1.1. Higher education institution	Babeş-Bolyai University
1.2. Faculty	Mathematics and Computer Science
1.3. Department	Mathematics
1.4. Field of study	Mathematics
1.5. Study cycle	Bachelor
1.6. Study programme/Qualification	Mathematics
1.7. Form of education	Full time

2. Information regarding the discipline

2.1. Name of the discipline	**Complemente de analiză complexă / Complements of Complex Analysis**					Discipline code	**MLE0036**
2.2. Course coordinator						**Professor PhD Mirela KOHR**	
2.3. Seminar coordinator						**Professor PhD Mirela KOHR**	
2.4. Year of study	**3**	2.5. Semester	**6**	2.6. Type of evaluation	**E**	2.7. Discipline regime	**Optional**

3. Total estimated time (hours/semester of didactic activities)

3.1. Hours per week	**4**	of which: 3.2 course	**2**	3.3 seminar/laboratory	**2 sem**
3.4. Total hours in the curriculum	**48**	of which: 3.5 course	**24**	3.6 seminar/laborator	**24**
Time allotment for individual study (ID) and self-study activities (SA)					**hours**
Learning using manual, course support, bibliography, course notes (SA)					36
Additional documentation (in libraries, on electronic platforms, field documentation)					14
Preparation for seminars/labs, homework, papers, portfolios and essays					20
Tutorship					12
Evaluations					20
Other activities:					-

3.7. Total individual study hours	102
3.8. Total hours per semester	150
3.9. Number of ECTS credits	6

4. Prerequisites (if necessary)

4.1. curriculum	In-depth knowledge of the following disciplines: • Mathematical analysis 2 (Differential and Integral Calculus in $\mathbf{R}^n$); • Complex Analysis; • Real Analysis; • Differential Equations; • Partial Differential Equations.
4.2. competencies	• Ability to use logical thinking and mathematical notions and results from the above-mentioned fields. • Ability to use of concepts and mathematical methods.

5. Conditions (if necessary)

5.1. for the course	Classroom with blackboard, video projector.
5.2. for the seminar /lab activities	Classroom with blackboard, video projector.

6.1. Specific competencies acquired [1]

Professional/essential competencies	• C1.4 Recognizing the main classes/types of mathematical problems and selecting appropriate methods and techniques for solving them. • C5.2 Using mathematical reasoning to prove mathematical results. • The ability to formulate and communicate orally and in writing ideas and concepts from complex analysis. • Ability to use various specific methods of complex analysis to solve problems in other branches of mathematics, mechanics and physics.
Transversal competencies	• CT1 Application of organized and efficient work rules, a responsible attitude towards the didactic-scientific field, to bring creative value to own potential respecting professional ethics principles. • Ability to inform themselves, to work independently or in a team in order to carry out studies and to solve complex problems. • Ability to apply the concepts studied to solve concrete problems that occur in various fields of mathematics and in practice. • Ability for continuous self-perfecting and study.

6.2. Learning outcomes

Knowledge	• The student is able to ensure the formation of skills specific to the Mathematics-related disciplines needed to complete the assignments. • The student knows fundamental notions and advanced results of Complex Analysis as well as methods of applying them to areas of science related to Mathematics, Mechanics, Computer Science and Engineering.
Skills	The student is able to: - construct clear and well-supported mathematical arguments to explain mathematical problems, topics, and ideas in writing. - demonstrate theorems and fundamental results in Complex Analysis using mathematical language in theoretical courses and will be able to present these results both orally and in writing with precision, clarity, and organization.
Responsibility and autonomy:	The student is able to: - explore some mathematical content independently, drawing on ideas and tools from previous coursework to extend their understanding. - extend independently mathematical ideas and arguments from previous coursework to a mathematical topic not previously studied. - work independently and solve problems in Complex Analysis.

7. Objectives of the discipline (outcome of the acquired competencies)

7.1 General objective of the discipline	• Knowledge, understanding and use of main concepts and results of Complex Analysis.

[1] One can choose either competences or learning outcomes, or both. If only one option is chosen, the row related to the other option will be deleted, and the kept one will be numbered 6.

7.2 Specific objective of the discipline	• Acquiring basic and advanced knowledge of the theory of functions of one complex variable. • Understanding the index theory and the theory of uniform branches. • Deep knowkedge of some fundamental results from the theory of holomorphic and meromorphic functions of one complex variable. • Understanding and deep knowledge of the theory of conformal mappings in the complex plane. • The possibility of identifying the conformal representations between various simply connected domains in the complex plane. • Ability to calculate various types of real integrals using methods of complex analysis. • The ability to use various specific methods of complex analysis in addressing problems from other branches of mathematics.

8. Content

8.1 Course	**Teaching methods**	**Remarks**
1. Linear fractional transformations (Möbius transformations). General properties. Special subgroups of linear fractional transformations.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
2. The Schwarz-Pick Lemma. Hyperbolic metric on the unit disk. Applications.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
3. Uniform branches. Uniform branch theorems for the multivalued logarithm and power applications. Examples and applications.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
4. Index. General properties. The index theorem. Cauchy's formulas for contours.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
5. Meromorphic functions. Properties. Calculation of the number of zeros and poles of meromorphic functions. Principle of variation of argument. Rouché's theorem. Domain invariance theorem. Applications.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
6. Decomposition of meromorphic functions into Mittag-Leffler series. Integer functions and products of canonical factors. Examples.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
7. Sets of holomorphic functions. Montel's theorem. Characterization of compact sets of holomorphic functions. Examples and applications.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
8. General properties of univalent functions. Theorems of Alexander, Kaplan and Hurwitz. Special families of univalent functions on the unit disc.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
9. Loewner chains, Herglotz vector fields and the Loewner differential equation. Applications in the theory of univalent functions (I).	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	

10. Loewner chains, Herglotz vector fields and the Loewner differential equation. Applications in the theory of univalent functions (II).	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
11. Conformal representation. Fundamental notions and results. Riemann's theorem. Applications.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
12. Remarkable conformal representations of simply connected domains in **C**.	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	

Bibliography

1. Kohr, G., Mocanu, P.T., *Capitole Speciale de Analizã Complexã*, Presa Universitarã Clujeanã, Cluj-Napoca, 2005.
2. Kohr, G., *Complex Analysis*, Lecture Notes, 2020.
3. Hamburg, P., Mocanu, P.T., Negoescu, N., *Analiză Matematică* (*Funcţii Complexe*), Editura Didacticã şi Pedagogică, Bucureşti, 1982.
4. Graham, I., Kohr, G., *Geometric Function Theory in One and Higher Dimensions*, Marcel Dekker Inc. New York, 2003.
5. Sălăgean, G.S., *Geometria Planului Complex*, Promedia-Plus, Cluj-Napoca, 1997.
6. Gaşpar, D., Suciu, N., *Analiză Complexă*, Editura Academiei Române, Bucureşti, 1999.
7. Bulboacă, T., Joshi, S.B., Goswami, P., *Complex Analysis. Theory and Applications*, de Gruyter, Berlin, Boston, 2019.
8. Krantz, S., *Handbook of Complex Variables*, Birkhäuser Verlag, Boston, Basel, Berlin, 1999.
9. Conway, J.B., *Functions of One Complex Variable,* vol. I, Graduate Texts in Mathematics, 159, Springer Verlag, New York, 1996.
10. Stein, E.M., Shakarchi, R., *Complex Analysis,* Princeton University Press, 2003.
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12. Popa, E., *Introducere în Teoria Funcţiilor de o Variabilã Complexã*, Editura Univ. A.I. Cuza, Iaşi, 2001.
13. Berenstein, C.A., Gay, R., *Complex Variables: An Introduction*, Springer-Verlag New York Inc., 1991.

8.2 Seminar	**Teaching methods**	**Remarks**
1. Möbius transformations. Examples and applications.	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
2. Applications of the residue theorem. Computing real definite integrals using the residue theorem (I).	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
3. Applications of the residue theorem. Computing real definite integrals using the residue theorem (II).	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
4. Harmonic functions. Fundamental properties. Examples. Construction of harmonic conjugates on simply connected domains in **C**.	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
5. Subharmonic functions. Examples.	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	

6. Applications of the Argument Principle and Rouché's Theorem.	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
7. Applications of the Mittag-Leffler Theorem.	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
8. Examples of univalent functions. Sufficient conditions for univalence. Necessary and sufficient conditions for univalence on the unit disk.	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
9. Loewner chains. Loewner differential equation. Applications.	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
10. Examples of classical conformal mappings (I).	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
11. Examples of classical conformal mappings (I).	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
12. Conformal automorphisms of bounded domains in **C**.	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	

Bibliography

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7. Ahlfors, L.V., *Complex Analysis*, 3rd ed., McGraw-Hill Book Co., New York, 1979.
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10. Berenstein, C.A., Gay, R., *Complex Variables: An Introduction*, Springer-Verlag New York Inc., 1991.

9. Corroborating the content of the discipline with the expectations of the epistemic community, professional associations and representative employers within the field of the program

- The content of this discipline is in accordance with the curricula of the most important universities in Romania and abroad.
- This discipline is useful in preparing future teachers and researchers in mathematics, as well as those who use mathematical methods and techniques in other areas (physics, chemistry, engineering, computer science).

10. Evaluation

Activity type	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Percentage of final grade
10.4 Course	Knowledge of concepts and basic results.	Written exam.	60%
	Ability to justify by proofs theoretical results.		
10.5 Seminar/laboratory	Ability to apply concepts and results acquired in the course in solving problems.	Evaluation of student activity at the seminar during the semester: homework, solving problems at the blackboard, and active participation in the seminar activity. A midterm written test.	10% 30%
There are valid the official rules of the faculty concerning the attendance of students at teaching activities.			
10.6 Minimum standard of performance			
• The final grade should be at least 5 (from a scale of 1 to 10) as a result of the evaluation of the written exam, the midterm written test and the seminar activity during the semester, with the indicated percentage.			

11. Labels ODD (Sustainable Development Goals)[2]

	General label for Sustainable Development							
								9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Date: 11.04.2025

Signature of course coordinator
Prof.PhD. Mirela KOHR

Signature of seminar coordinator
Prof.PhD. Mirela KOHR

Date of approval: 25.04.2025

Signature of the head of department
Prof.PhD. Andrei MĂRCUȘ

[2] Keep only the labels that, according to the *Procedure for applying ODD labels in the academic process*, suit the discipline and delete the others, including the general one for *Sustainable Development* – if not applicable. If no label describes the discipline, delete them all and write „*Not applicable*.”.