COURSE DESCRIPTION

Complements of Complex Analysis

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	Bachelor
1.6. Degree programme / Qualification	Mathematics Computer Science (in English)
1.7. Form of education	Full-time

2. Course-related data

2.1. Course title	**Complemente de analiză complexă / Complements of Complex Analysis**				Course code	**MLE0036**
2.2. Course coordinator	**Professor PhD Mirela KOHR**					
2.3. Seminar coordinator	**Professor PhD Mirela KOHR**					
2.4. Year of study	**2**	2.5. Semester	**4**	2.6. Type of assessment	Progress check	
2.7. Course status		Optional		2.8. Course type	Specialisation 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 sem**
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)					36
Additional research in the library, on subject-specific electronic platforms, and on-site					14
Preparing seminars/ laboratories/ projects, assignments, reports, portfolios, and essays					25
Tutoring (professional guidance)					9
Examinations					10
Other activities					-
3.7. Total hours of individual study (IS) and self-taught activities (ST)				94	
3.8. Total hours per semester				150	
3.9. Number of credits				6	

4. Prerequisites (where applicable)

4.1. curriculum-related	In-depth knowledge of the following disciplines: • Calculus 2 (Differential and Integral Calculus in $\mathbf{R}^n$); • Complex Analysis; • Differential Equations.
4.2 skills-related	• Ability to use logical thinking and mathematical notions and results from the above-mentioned fields. • Ability to use of concepts and mathematical methods. • Ability to solve math problems based on acquired notions.

5. Specific conditions (where applicable)

5.1. course-related	Classroom with blackboard, video projector.
5.2. seminar/laboratory-related	Classroom with blackboard, video projector.

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

Professional competencies	
Competency code	**Competency**
PC2	perform analytical mathematical calculations
PC3	conduct quantitative research
PC6	think abstractly
PC8	study relationships between quantities
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**
PC2, PC3	7. The student/graduates selects, explains, and specifies the mathematical foundations applied in computer science, including formal logic, algebra, probability, and statistics.	7. The student/graduates applies, evaluates, and proposes mathematical methods for modeling, simulating, and solving computer science problems.
PC6	4. The student/graduate defines the basic concepts from advanced mathematics disciplines in the curriculum.	4. The student/graduate answers questions and correctly and rigorously formulates the statements of mathematical assertions (lemmas, propositions, theorems) from the disciplines in the curriculum.
PC8	3. The student/graduate formulates observations and differentiates notions, properties, and assertions from the core disciplines of mathematics through examples and counterexamples.	3. The student/graduate identifies and describes the essential elements in the construction of proofs of mathematical assertions (lemmas, propositions, theorems), recognizes errors in reasoning, and corrects them.
TC4, TC5	2. The student/graduate compares and distinguishes related notions and their properties from the core disciplines of mathematics.	2. The student/graduate recognizes and analyzes the necessary and/or sufficient conditions in the statements of mathematical assertions and specifies their role in the proof.

7. Subject-specific learning outcomes

	Knowledge and comprehension
1.	The student is able to ensure the formation of skills specific to the Mathematics-related disciplines needed to complete the assignments.
2.	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.

[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 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. - work independently or in a team and solve complex problems in Complex Analysis. - extend independently mathematical ideas and arguments from previous coursework to a mathematical topic not previously studied.
2. The student is able to introduce new and innovative elements in the instructive-educational process of the field Mathematics, if it is considered necessary/useful.

8. Contents

8.1. Course	Teaching and learning methods	Remarks[3]
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** (I).	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	
13. Remarkable conformal representations of simply connected domains in **C** (II).	Lectures, modeling, didactical demonstration, conversation. Presentation of examples and alternative explanations.	

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

14. Applications in Fluid Dynamics.	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.
11. Narasimhan, R., Nievergelt, Y., *Complex Analysis in One Variable*, Second Edition, Birkhäuser, 1985.
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 and learning 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** (I).	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
13. Conformal automorphisms of bounded domains in **C** (II).	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	
14. Applications in Fluid Dynamics.	Description of arguments and proof for solving problems. Examples, dialogue, explanation, direct answers to students' questions. Homework assignments.	

Bibliography

1. Kohr, G., Mocanu, P.T., *Capitole Speciale de Analiză Complexã*, Presa Universitarã Clujeanã, Cluj-Napoca, 2005.
2. Kohr, G., *Complex Analysis*, Seminar Notes, 2020.
3. Hamburg, P., Mocanu, P.T., Negoescu, N., *Analiză Matematică* (*Funcţii Complexe*), Editura Didacticã şi Pedagogică, Bucureşti, 1982.
4. Gaşpar, D., Suciu, N., *Analiză Complexă*, Editura Academiei Române, Bucureşti, 1999.
5. Bulboacă, T., Joshi, S.B., Goswami, P., *Complex Analysis. Theory and Applications*, de Gruyter, Berlin, Boston, 2019.
6. Conway, J.B., *Functions of One Complex Variable,* vol. I, Graduate Texts in Mathematics, 159, Springer Verlag, New York, 1996.
7. Ahlfors, L.V., *Complex Analysis*, 3rd ed., McGraw-Hill Book Co., New York, 1979.
8. Rudin, W., *Real and Complex Analysis*, 3nd ed., Mc. Graw-Hill, 1987.
9. Popa, E., *Introducere în Teoria Funcţiilor de o Variabilã Complexã*, Editura Univ. A.I. Cuza, Iaşi, 2001.
10. Berenstein, C.A., Gay, R., *Complex Variables: An Introduction*, Springer-Verlag New York Inc., 1991.

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 concepts and basic results.	Middle term written test.	40%

[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.

	Ability to justify by proofs theoretical results.	Final Written Test.	40%
9.5. Seminar	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.	20%
There are valid the official rules of the faculty concerning the attendance of students at teaching activities.			
9.6 Minimum standard for passing			
• 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.			

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

	○	Sustainable Development Generic Label						
1 FĂRĂ SĂRĂCIE	2 FOAMETE „ZERO”	3 SĂNĂTATE ȘI BUNĂSTARE	4 EDUCAȚIE DE CALITATE	5 EGALITATE DE GEN	6 APĂ CURATĂ ȘI SANITAȚIE	7 ENERGIE CURATĂ ȘI LA PREȚURI ACCESIBILE	8 MUNCĂ DECENTĂ ȘI CREȘTERE ECONOMICĂ	9 INDUSTRIE, INOVAȚIE ȘI INFRASTRUCTURĂ
○	○	○	○	○	○	○	○	X
10 INEGALITĂȚI REDUSE	11 ORAȘE ȘI COMUNITĂȚI DURABILE	12 CONSUM ȘI PRODUCȚIE RESPONSABILE	13 ACȚIUNE CLIMATICĂ	14 VIAȚA ACVATICĂ	15 VIAȚA TERESTRĂ	16 PACE, JUSTIȚIE ȘI INSTITUȚII EFICIENTE	17 PARTENERIATE PENTRU REALIZAREA OBIECTIVELOR	No label applies
○	○	○	○	○	○	○	○	○

Date of entry: 10.04.2026

Signature of course coordinator
Prof.PhD. Mirela KOHR

Signature of seminar coordinator
Prof.PhD. Mirela KOHR

Date of approval in the department: 24.04.2026

Signature of the head of department
Prof.PhD. 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."*