University of Gdańsk

Subject card

Subject name and code	Computational Mathematics Methods, PG_00179327		
Field of study	Mathematical Modeling and Data Analysis		
Date of commencement of studies	October 2025	Academic year of realisation of subject	2025/2026
Education level	Master's studies	Subject group	Obligatory subject group in the field of study Optional subject group
Mode of study	full-time studies	Mode of delivery	at the university
Year of study	1	Language of instruction	Polish If students express their willingness, we can conduct the classes in English to enhance their language skills.
Semester of study	2	ECTS credits	5.0
Learning profile	academic	Assessment form	credit
Conducting unit			
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. Karolina Kropielnicka	
	Teachers		

Lesson types							
	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	0.0	0.0	0.0	0.0	30.0	30
	E-learning hours included: 0.0						

Learning activity and number of study hours					
	Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
	Number of study hours	30	5.0	90.0	125

Subject objectives	The objective of the seminar is to deepen knowledge and skills in computational mathematics, with a particular focus on numerical methods for solving differential equations. Students will learn both the theoretical foundations and practical techniques for designing, analyzing, and implementing numerical algorithms. The seminar prepares students for independent research work and creative problem-solving in mathematics using computational tools.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[MMiADMU2_K04] is ready to understand and appreciate the importance of intellectual honesty in the actions of himself and others; is ready to act ethically	The student is prepared to understand and appreciate the importance of intellectual honesty in their own actions and those of others, as well as to adhere to ethical conduct.	[SK8] observation of student's independent or team work
[MMiADMU2_W03] knows and understands in-depth a selected field of theoretical or applied mathematics and is able to understand the formulations of issues in this field that are still being researched and knows the links between the issues of this field and other branches of mathematics	The student has an in-depth knowledge and understanding of a selected area of theoretical or applied mathematics, is able to interpret and analyze research-level problem formulations, and understands the connections of this area with other branches of mathematics.	[SW1] oral statement/ conversation/discussion
[MMiADMU2_U03] can understand mathematical texts from selected areas of mathematics	The student is able to understand mathematical texts of varying nature and complexity from selected areas of mathematics.	[SU8] observation of student's independent or team work
[MMiADMU2_W07] knows and understands the basic legal and ethical conditions related to research and teaching	The student knows and understands the basic legal and ethical conditions related to scientific and teaching activities and is able to apply them in practice.	[SW5] implementation of a problem task
[MMiADMU2_K02] is ready to precisely formulate questions to deepen his own understanding of a given topic or to find missing elements of reasoning	The student is prepared to formulate precise questions aimed at deepening their understanding of a given topic and identifying missing elements in the reasoning.	[SK1] oral statement/conversation/ discussion
[MMiADMU2_U08] is able to in-depth preparation of texts in Polish and at least one foreign language, in a selected field of mathematics	The student is capable of preparing in-depth written works in Polish and at least one foreign language on selected topics in mathematics, demonstrating precision and substantive accuracy.	[SU8] observation of student's independent or team work
[MMiADMU2_K06] is ready to form an opinion on basic mathematical issues	The student is able to formulate and express opinions on fundamental mathematical issues, demonstrating the ability to argue and justify their viewpoints.	[SK1] oral statement/conversation/ discussion
[MMiADMU2_K01] is ready to recognize the limitations of his own knowledge and is ready to continue his education	The student is aware of the limitations of their own knowledge and is prepared for continued independent learning and academic development.	[SK8] observation of student's independent or team work
[MMiADMU2_U05] is able to make proofs and analyzes in a given field, in which, if necessary, he also uses tools from other areas of mathematics	The student is able to carry out rigorous proofs and analyses in a selected area of mathematics, employing tools and methods from other branches of mathematics when necessary.	[SU8] observation of student's independent or team work
[MMiADMU2_U04] can, at an advanced level and including modern mathematics, apply and present in speech and in writing the methods of at least one selected branch of mathematics	The student is able, at an advanced level including modern mathematical approaches, to apply and clearly present in both oral and written form methods from at least one selected branch of mathematics.	[SU8] observation of student's independent or team work
[MMiADMU2_U09] can prepare in-depth oral presentations in Polish and at least in one foreign language in a selected field of mathematics	The student is able to prepare and deliver in-depth oral presentations in Polish and at least one foreign language on topics from a selected area of mathematics, presenting knowledge clearly and convincingly.	[SU5] implementation of a problem task
[MMiADMU2_K05] is ready to independently search for information in literature, also in foreign languages	The student is prepared to independently search for and analyze information in professional literature, including sources in foreign languages.	[SK8] observation of student's independent or team work
[MMiADMU2_U02] can express mathematical content in speech and in writing, in mathematical texts of various nature	The student is able to clearly and accurately communicate mathematical content both orally and in writing, handling mathematical texts of varying complexity.	[SU6] demonstration of practical skills

Course outcome	Subject outcome	Method of verification
[MMiADMU2_U07] is able to define his interests and develop them; in particular, is able to establish contact with specialists in their field, e.g. understand their lectures intended for young mathematicians	The student is able to identify and develop their scientific interests systematically. They are capable of establishing contact with specialists in their field and understanding lectures and materials aimed at young mathematicians.	[SU8] observation of student's independent or team work

Subject contents

1. **Introduction to Computational Mathematics:**
   - Role and importance of numerical methods in solving differential equations.
   - Overview of fundamental computational tools and techniques.
2. **Discretization of Mathematical Problems:**
   - Finite Differences methods.
   - Finite Elements methods.
   - Spectral methods (Galerkin, Fourier).
3. **Numerical Methods for Evolutionary Equations:**
   - Temporal and spatial discretization of equations.
   - Implementation and analysis of numerical algorithms.
4. **Numerical Linear Algebra:**
   - Matrix factorizations (QR, LU).
   - Krylov subspace methods.
5. **Numerical Integration Methods (Quadratures):**
   - Gaussian, Newton-Cotes, Filon quadratures.
6. **Applications and Case Studies:**
   - Solving wave, heat, and Schrödinger equations.
   - Visualization and analysis of results.
7. **Programming and Implementation:**
   - Practical use of Python for implementing numerical methods.
   - Analysis of algorithm efficiency, stability, and accuracy.

Prerequisites and co-requisites

Prerequisites

- Basic knowledge of mathematical analysis and linear algebra.
- Basic programming skills in Python.
- Familiarity with fundamental numerical methods and computational techniques.
- Ability to read and understand scientific texts in English.

Additional requirements

- Experience with solving differential equations and analyzing their solutions.
- Knowledge of discretization methods such as finite difference or finite element methods.
- Ability to use numerical libraries in Python (e.g., NumPy, SciPy).
- Interest in advanced topics in computational mathematics and programming.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Oral presentations and written reports	51.0%	70.0%
Participation and activity during classes (discussions, questions, exercises)	51.0%	30.0%

Recommended reading

Basic literature

1. A. Iserles, *A First Course in the Numerical Analysis of Differential Equations*, Cambridge University Press, 2009.
2. P. Deuflhard, F. Bornemann, *Scientific Computing with Ordinary Differential Equations*, Springer, 2002.
3. E. Hairer, G. Wanner, *Solving Ordinary Differential Equations II*, 2nd edition, Springer, 1996.
4. P. Deuflhard, M. Weiser, *Adaptive Numerical Solution of PDEs*, DeGruyter, 2012.
5. C. Lubich, *From Quantum to Classical Molecular Dynamics: Reduced Models and Numerical Analysis*, EMS, 2008.

	Supplementary literature	1. B. Fornberg, D.M. Sloan, *A Review of Pseudospectral Methods for Solving Partial Differential Equations*, Acta Numerica, 1994, 203267 Cambridge University Press 2. W. Arendt, K. Urban, *Partial Differential Equations An Introduction to Analytical and Numerical Methods*, Springer, 2023 SpringerLink 3. A.J. Salgado, S.M. Wise, *Classical Numerical Analysis A Comprehensive Course*, Cambridge University Press, 2023 Cambridge University Press 4. J. Stoer, R. Bulirsch, *Introduction to Numerical Analysis*, Springer, 2002 SpringerLink 5. G. Strang, *Computational Science and Engineering*, Wellesley-Cambridge Press, 2007 MIT OpenCourseWare
	eResources addresses	
Example issues/ example questions/ tasks being completed	• Discretization of differential equations: finite difference, finite element, and spectral methods • Stability and accuracy analysis of selected numerical methods • Implementation of numerical algorithms (e.g., Euler, Runge-Kutta) in Python • Solving evolutionary equations: wave, heat, and Schrödinger equations • Practical use of matrix decompositions: LU, QR, Krylov subspace methods • Numerical integration (quadrature): Gaussian, Newton-Cotes, Filon methods • Project tasks: implementing and analyzing a chosen numerical method for a specific mathematical model • Discussions on numerical limitations and challenges in solving differential equations • Literature review and independent research on advanced computational methods	
Work placement	Not applicable	

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