List of modules for the
Master's degree programme
Computational and Applied Mathematics

for the wintersemester 2021/22

Department of Mathematics
Friedrich-Alexander-Universität Erlangen-Nürnberg

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FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG

NATURWISSENSCHAFTLICHE
FAKULTÄT

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1	**Module name**	**Module 9:** **AdDiscTech: Advanced Discretization Techniques**	**ECTS 10**
2	**Courses/lectures**	a) Lecture: 4 semester hrs/week b) Practical: 1 semester hr/week	
3	**Lecturers**	Prof. Dr. Eberhard Bänsch baensch@math.fau.de	
4	**Module coordinator**	Prof. Dr. Eberhard Bänsch baensch@math.fau.de	
5	**Content**	conforming and non-conforming finite element methods saddle point problems in Hilbert spaces mixed finite element methods for saddle point problems, in particular for Darcy and Stokes Streamline-Upwind Petrov-Galerkin (SUPG) and discontinuous Galerkin (dG) finite element methods (FEM) for convection dominated problems Finite Volume (FV) methods and their relation to FEM a posteriori error control and adaptive methods	
6	**Learning objectives and skills**	Students have a discriminating understanding, both theoretically and computationally of FE as well as FV methods for the numerical solution of partial differential equations (pde) (in particular of saddle point problems), are capable of developing problem dependent FE or FV methods and judge on their properties regarding stability and effectiveness, are familiar with a broad spectrum of pde problems and their computational solutions, are capable of designing algorithms for adaptive mesh control.	
7	**Prerequisites**	Recommended: Introduction to numerical methods for pdes, functional analysis	
8	**Integration into curriculum**	1st semester	
9	**Module compatibility**	Mandatory elective module for MSc in Computational and Applied Mathematics Compulsory elective module for MSc in Mathematics	
10	**Method of examination**	oral exam (15 minutes)	
11	**Grading Procedure**	100% based on oral exam	
12	**Module frequency**	Winter semester (annually)	
13	**Workload**	Contact hours: 75 hrs Independent study: 225 hrs Total: 300 hrs, corresponding to 10 ECTS credits	
14	**Module duration**	One semester	
15	**Teaching and examination language**	English	

16	**Recommended reading**	• A. Ern, J.-L. Guermond: Theory and Practice of Finite Elements • A. Quarteroni & A. Valli: Numerical Approximation of Partial Differential Equations • P. Knabner & L. Angermann: Numerical Methods for Elliptic and Parabolic Differential Equations, Springer • D. A. Di Piettro & A. Ern: Mathematical aspects of discontinuous Galerkin methods. Springer 2012

1	**Module name**	**Module 10a:** **MaSe: Master's seminar MApA**	**ECTS 5**
2	**Courses/lectures**	Masterseminar	
3	**Lecturers**	Prof. Dr. Martin Burger martin.burger@fau.de	
4	**Module coordinator**	Prof. Dr. Günther Grün gruen@math.fau.de	
5	**Content**	A topic from MApA that relates to the compulsory elective modules offered.	
6	**Learning objectives and skills**	Students can use original literature to familiarise themselves with a current research topic, can structure the content acquired both verbally and in writing and make their own contributions to its presentation and/or substance, learn scientific content on the basis of academic lectures and actively discuss it at a plenary session. For the MApA specialisation: make use of analytical techniques to rigorously prove the qualitative characteristics of solutions to mathematical models in applied sciences.	
7	**Prerequisites**	All compulsory modules for the MSc in Computational and Applied Mathematics recommended	
8	**Integration into curriculum**	3rd semester	
9	**Module compatibility**	Compulsory module for MSc in Computational and Applied Mathematics Compulsory module for MSc in Mathematics Compulsory module for MSc in Mathematics and Economics	
10	**Method of examination**	talk/presentation (90 minutes) and handout (5-10 pages)	
11	**Grading Procedure**	talk/presentation 75% handout 25%	
12	**Module frequency**	Winter semester (annually)	
13	**Workload**	Contact hours: 30 hrs Independent study: 120 hrs Total: 150 hrs, corresponding to 5 ECTS credits	
14	**Module duration**	One semester	
15	**Teaching and examination language**	English	
16	**Recommended reading**	Depending on topic. Will be published on StudOn at the beginning of the semester.	

1	**Module name**	**Module 10b:** **MaSe: Master's seminar NASi**	**ECTS 5**
2	**Courses/lectures**	Masterseminar	
3	**Lecturers**	Prof. Dr. Martin Burger martin.burger@fau.de	
4	**Module coordinator**	Prof. Dr. Eberhard Bänsch baensch@math.fau.de	
5	**Content**	A topic from NASi that relates to the compulsory elective modules offered.	
6	**Learning objectives and skills**	Students can structure the content acquired both verbally and in writing and make their own contributions to its presentation and/or substance, learn scientific content on the basis of academic lectures and actively discuss it at a plenary session. For the NASi specification: can solve exemplary computational problems with given or self-developed software in order to illustrate or verify numerical methods under consideration.	
7	**Prerequisites**	All compulsory modules for the MSc in Computational and Applied Mathematics recommended	
8	**Integration into curriculum**	3rd semester	
9	**Module compatibility**	Compulsory module for MSc in Computational and Applied Mathematics Compulsory module for MSc in Mathematics Compulsory module for Msc in Mathematics and Economics	
10	**Method of examination**	talk/presentation (90 minutes) and handout (5-10 pages)	
11	**Grading Procedure**	talk/presentation 75% handout 25%	
12	**Module frequency**	Winter semester (annually)	
13	**Workload**	Contact hours: 30 hrs Independent study: 120 hrs Total: 150 hrs, corresponding to 5 ECTS credits	
14	**Module duration**	One semester	
15	**Teaching and examination language**	English	
16	**Recommended reading**	Depending on topic. Will be published on StudOn at the beginning of the semester.	

1	**Module name**	**Module 10c:** **MaSe: Master's seminar Opti**	**ECTS 5**
2	**Courses/lectures**	Masterseminar	
3	**Lecturers**	Prof. Dr. Martin Burger martin.burger@fau.de	
4	**Module coordinator**	Prof. Dr. Michael Stingl michael.stingl@fau.de	
5	**Content**	A topic from Opti that relates to the compulsory elective modules offered.	
6	**Learning objectives and skills**	Students can use original literature to familiarise themselves with a current research topic, can structure the content acquired both verbally and in writing and make their own contributions to its presentation and/or substance, learn scientific content on the basis of academic lectures and actively discuss it at a plenary session. For the Opti specialisation: model theoretical and applied tasks as optimization problems and/or develop optimization algorithms for their solution and/or put these into practice.	
7	**Prerequisites**	All compulsory modules for the MSc in Computational and Applied Mathematics recommended	
8	**Integration into curriculum**	3rd semester	
9	**Module compatibility**	Compulsory module for MSc in Computational and Applied Mathematics Compulsory module for MSc in Mathematics Compulsory module for MSc in Mathematics and Economics	
10	**Method of examination**	talk/presentation (90 minutes) and handout (5-10 pages)	
11	**Grading Procedure**	talk/presentation 75% handout 25%	
12	**Module frequency**	Winter semester (annually)	
13	**Workload**	Contact hours: 30 hrs Independent study: 120 hrs Total: 150 hrs, corresponding to 5 ECTS credits	
14	**Module duration**	One semester	
15	**Teaching and examination language**	English	
16	**Recommended reading**	Depending on topic. Will be published on StudOn at the beginning of the semester.	

1	**Module name**	**Module 11:** **Master's Thesis**	**ECTS 25**
2	**Courses/lectures**	Oral examination Master's Thesis	
3	**Lectures**	The lecturers for the degree programme in Computational and Applied Mathematics	MaPA/NASI/Opti
4	**Module coordinator**	Prof. Dr. Günther Grün gruen@math.fau.de	
5	**Content**	The master's thesis is in the field of Modelling and Analysis, or Numerical Analysis and Simulation, or Optimization, and deals with a current research topic.	
6	**Learning objectives and skills**	Students are capable of independently follow up a scientific question in the fields of "Modelling and Analysis", "Numerical Analysis and Simulation" or "Optimization" over an extended, specified period, develop original ideas and concepts for solving scientific problems in these fields, apply and improve mathematical methods rather independently - also in unfamiliar and interdisciplinary contexts, present and explain mathematical or interdisciplinary contents clearly in a manner appropriate for the target audience, both in writing and orally, improve their ability to plan and structure by implementing a thematic project.	
7	**Prerequisites**	Successful participation in all mandatory modules (35 ECTS) and at least 20 ECTS from mandatory elective modules	
8	**Integration into curriculum**	4th semester	
9	**Module compatibility**	Master's degree programme in Computational and Applied Mathematics	
10	**Method of examination**	Master's thesis (scope according to examination regulations) Oral exam (15 minutes)	
11	**Grading Procedure**	90% Master's thesis 10% Oral exam	
12	**Module frequency**	Summer semester (annually)	
13	**Workload**	Contact hours: 15 hrs Independent study: 735 hrs Total: 750 hrs, corresponding to 25 ECTS credits	
14	**Module duration**	One semester	
15	**Teaching and examination language**	English	
16	**Recommended reading**	Individual, depending on topic of Master's Thesis.	

1	**Module name**	**Module 15:** **IPReg: Inverse Problems and their Regularizations**	**ECTS 5**
2	**Courses/lectures**	a) Lectures: 2 semester hrs/week b) Practical: 0.5 semester hrs/week	
3	**Lecturers**	Prof. Dr. Martin Burger martin.burger@math.fau.de	
4	**Module coordinator**	Prof. Dr. Martin Burger martin.burger@math.fau.de	
5	**Content**	Examples of inverse and ill-posed problems in engineering and medical imaging Linear regularization methods in Hilbert spaces and singular value decomposition Variational methods for regularization and image reconstruction problems Tomographic reconstruction and Radon transforms	
6	**Learning objectives and skills**	Students develop understanding for special aspects of inverse problems and ill-posedness, apply regularization methods to inverse problems and develop a basic understanding of their properties, derive and solve inverse problems arising from technical and biomedical applications.	
7	**Prerequisites**	Recommended: basic knowledge in functional analysis	
8	**Integration into curriculum**	1st or 3rd semester	
9	**Module compatibility**	Mandatory elective module for MSc in Computational and Applied Mathematics Elective module for MSc in Mathematics Elective module for MSc in Mathematics and Economics	
10	**Method of examination**	Oral exam (15 minutes)	
11	**Grading Procedure**	100% Oral exam	
12	**Module frequency**	Winter semester (not annually) To check whether the course is offered in the current semester, see UnivIS univis.fau.de or module handbook of current semester	
13	**Workload**	Contact hours: 37,5 hrs Independent study: 112,5 hrs Total: 150 hrs, corresponding to 5 ECTS credits	
14	**Module duration**	One semester	
15	**Teaching and examination language**	English	
16	**Recommended reading**	H. Engl, M. Hanke, A. Neubauer: Regularization Methods for Inverse Problems, Kluwer 1996 M. Benning, M. Burger: Modern Regularization Methods for Inverse Problems, Acta Numerica 2018	

1	**Module name**	**Module 23:** **MaMoLS: Mathematical Modeling in the Life Sciences**	**ECTS 5**
2	**Courses/lectures**	a) Lectures: 2 semester hrs/week b) Practical: 0,5 semester hrs/week	
3	**Lecturers**	Dr. Maria Neuss-Radu maria.neuss-radu@math.fau.de	**MApA**
4	**Module coordinator**	Dr. Maria Neuss-Radu maria.neuss-radu@math.fau.de	
5	**Content**	• Biochemical reaction networks, enzyme kinetics • Models for interacting populations (Predator-prey, competition, symbiosis) • Diffusion, reactions, and transport in biological cell tissues and vessels • Structured population models	
6	**Learning objectives and skills**	Students • have profound knowledge in the area of mathematical modeling of processes in the life sciences • are able to identify significant mechanisms and to apply suitable analytical and numerical methods for their analysis • are able to work interdisciplinary and problem-oriented.	
7	**Prerequisites**	Recommended: Modeling and Analysis in Continuum Mechanics I	
8	**Integration into curriculum**	3rd semester	
9	**Module compatibility**	• Mandatory elective module for MSc in Computational and Applied Mathematics • Mandatory elective module for MSc in Mathematics in the field of study “Modelling, Analysis and Optimization”	
10	**Method of examination**	Oral exam (15 minutes)	
11	**Grading Procedure**	100% Oral exam	
12	**Module frequency**	Winter semester (annually)	
13	**Workload**	Contact hours: 37.5 hrs Independent study: 112.5 hrs Total: 150 hrs, corresponding to 5 ECTS credits	
14	**Module duration**	One semester	

15	**Teaching and examination language**	English
16	**Recommended reading**	• J. D. Murray: Mathematical Biology I: An Introduction, Mathematical Biology II: Spatial Models and Biomedical Applications • G. de Vries, T. Hillen, et al.: A course in Mathematical Biology • J. Prüss: Mathematische Modelle in der Biologie: Deterministische homogene Systeme

1	**Module name**	**Module 29:** **DiscOpt I: Discrete Optimization I**	**ECTS 5**
2	**Courses/lectures**	a) Lectures: 2 weekly lecture hours b) Practical: 1 weekly lecture hour	
3	**Lecturers**	Dr. Andreas Bärmann andreas.baermann@math.uni-erlangen.de	Opti
4	**Module coordinator**	Prof. Dr. Alexander Martin alexander.martin@fau.de	
5	**Content**	Theoretical and practical fundamentals of solving difficult mixed-integer linear optimization problems (MIPs) constitute the main focus of this lecture. At first, the concept of NP-completeness and a selection of common NP-complete problems will be presented. As for polyhedral theory, fundamentals concerning the structure of faces of convex polyhedra will be covered. Building upon these fundamentals, cutting plane algorithms as well as branch-and-cut algorithms for solving MIPs will be taught. Finally, some typical problems of discrete optimization, e.g., the knapsack problem, the traveling salesman problem or the set packing problem will be discussed.	
6	**Learning objectives and skills**	Students will gain basic theoretical knowledge of solving mixed-integer linear optimization problems (MIPs), are able to solve MIPs with the help of state-of-the-art optimization software.	
7	**Prerequisites**	Recommended: Linear and Combinatorial Optimization	
8	**Integration into curriculum**	1st or 3rd semester	
9	**Module compatibility**	Mandatory elective module for MSc Computational and Applied Mathematics, Elective module for MSc in Mathematics, Elective module for MSc in Mathematics and Economics, Core/research module MSc Mathematics within “Modeling, simulation, optimization”, MSc Mathematics and Economics within “Optimization and process management”	
10	**Method of examination**	oral exam (15 minutes)	
11	**Grading Procedure**	100% based on oral exam	
12	**Module frequency**	Winter semester (not annually) To check whether the course is offered, see UnivIS: univis.fau.de	
13	**Workload**	Attendance: 45 h Self-study: 105 h	
14	**Module duration**	one semester	
15	**Teaching and examination language**	English	

16	**Recommended reading**	Lecture notes Conforti, Cornuéjols & Zambelli: Integer Programming, Springer 2014 B. Grünbaum: Convex Polytopes, Springer, 2003 B. Korte & J. Vygen: Combinatorial Optimization, Springer 2005 G. L. Nemhauser & L.A. Wolsey: Integer and Combinatorial Optimization, Wiley 1994 A. Schrijver: Theory of Linear and Integer Programming, Wiley 1986 L.A. Wolsey: Integer Programming, Wiley 1998 G. Ziegler: Lectures on Polytopes, Springer, 1995

1	**Module name**	**Module xx: EffDisc: Efficient discretization of two-phase flow**	**5 ECTS**
2	**Courses/lectures**	Seminar: 2 semester hrs/week	
3	**Lecturers**	Dr. Stefan Metzger stefan.metzger@fau.de	MApA NASi
4	**Module coordinator**	Dr. Stefan Metzger stefan.metzger@fau.de	
5	**Content**	Based on recent scientific publications, different discretization approaches for two-phase flow are discussed.	
6	**Learning objectives and skills**	Students • can use original literature to familiarise themselves with a current research topic, • can structure the content acquired both verbally and in writing and make their own contributions to its presentation and/or substance, • learn scientific content on the basis of academic lectures and actively discuss it at a plenary session, • learn to compare different discretization methods regarding their specific advantages and disadvantages.	
7	**Prerequisites**	Recommended: Numerics of Partial Differential Equations I	
8	**Integration into curriculum**	1st or 3rd semester	
9	**Module compatibility**	• Mandatory elective module for BSc in Mathematics • Mandatory elective module for BSc in Technomathematics • Mandatory elective module for MSc in Computational and Applied Mathematics • Mandatory elective module for MSc in Mathematics in the field of study “Modeling, Simulation and Optimization”	
10	**Method of examination**	Talk/presentation (60-80 minutes) with handout (5-10 pages)	
11	**Grading Procedure**	100% talk/presentation with handout	
12	**Module frequency**	Winter semester (not annually)	
13	**Workload**	Contact hours: 30 hrs Independent study: 120 hrs Total: 150 hrs, corresponding to 5 ECTS credits	
14	**Module duration**	One semester	
15	**Teaching and examination language**	English	
16	**Recommended reading**	Depending on topic. Will be published on StudOn at the beginning of the semester.	