FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE
FAKULTÄT

Module handbook for the Master's degree programme Computational and Applied Mathematics

for the winter semester 2018/19

In the following you find only those modules which are offered in the winter semester 2018/19.

Department of Mathematics
Friedrich-Alexander-Universität Erlangen-Nürnberg

Last updated: June 28, 2018
Reference: Examination regulations dated Feb 27, 2017

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Table of contents

Last updated: 28 June 2018

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FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE FAKULTÄT

1	**Module name**	**Module 1: ModAna1: Modeling and Analysis in Continuum Mechanics I**	**10 ECTS credits**
2	**Courses/lectures**	a) Lectures: 4 semester hrs/week b) Practical: 1 semester hr/week	
3	**Lecturers**	**Prof. Dr. G. Grün**	

4	**Module coordinator**	**Prof. Dr. G. Grün**
5	**Content**	• Theory of elasticity (geometrical non-linear modelling, objectivity and isotropy of energy functionals, linearised elasticity, polyconvexity, existence according to J. Ball) • Non-equilibrium thermodynamics and modelling in hydrodynamics (basic concepts in thermodynamics, balance equations, constitutive relations) • Parabolic function spaces and the Aubin-Lions lemma • Weak solution theory for incompressible Navier-Stokes equations
6	**Learning objectives and skills**	Students • derive mathematical models for fluid mechanics and elasticity theory, • evaluate the predictive power of models using physical modelling assumptions and the qualitative characteristics of solutions, • apply analytical techniques to rigorously prove qualitative properties of solutions.
7	**Prerequisites**	Basic knowledge in functional analysis and modelling is recommended.
8	**Integration into curriculum**	1st semester
9	**Module compatibility**	Compulsory module for MSc in Computational and Applied Mathematics Compulsory elective module for MSc in Mathematics
10	**Method of examination**	oral exam (20 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**	• P.G. Ciarlet: Mathematical elasticity, North-Holland, • S.R. De Groot & P. Mazur: Non-equilibrium thermodynamics, Dover, • C. Eck, H. Garcke & P. Knabner: Mathematical Modeling, Springer, • L.C. Evans: Partial differential equations, AMS, • I. Liu: Continuum mechanics, Springer, • R. Temam: The Navier-Stokes equations, AMS Chelsea Publishing.

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NATURWISSENSCHAFTLICHE FAKULTÄT

1	**Module name**	**Module 5: ArchSup: Architectures of Supercomputers**	**5 ECTS credits**
2	**Courses/lectures**	a) Lectures: 2 semester hrs/week b) Practical: 2 semester hrs/week	
3	**Lecturers**	**Prof. Dr. Dietmar Fey, Dr. Andreas Schäfer**	
4	**Module coordinator**	**Prof. Dr. Dietmar Fey**	
5	**Content**	• Principles of computer and processor architectures • Modern processor architectures • Homogeneous and heterogeneous multi/many-core processors • Parallel computer architectures • Classification and principles of coupling parallel computers • High speed networks in supercomputers • Examples of supercomputers • Programming of supercomputers	
6	**Learning objectives and skills**	Students • can explain the functionality of modern processors used in supercomputers, • recognise the special problems associated with energy consumption and programming in supercomputers, • can explain the different ways of interconnecting parallel processes, • can classify parallel computers with regard to their storage connection and basic processing principles, • are able to make use of and run a supercomputer to solve their own technical or mathematical problem. Based on the examples demonstrated during the lecture, they are able to generalise challenges associated with the discovery of bottlenecks and use them to solve their specific problem, • are able to characterise their problems (e.g. scientific or technical simulation experiments) with regard to the computing and memory requirements for a supercomputer in a way that is appropriate for the architecture, • can make use of the performance-measuring methods for parallel computers to evaluate various computer architectures and select the appropriate architecture for their problem.	
7	**Prerequisites**	None	
8	**Integration into curriculum**	3rd semester	
9	**Module compatibility**	Compulsory module for MSc Computation and Applied Mathematics, Computational Engineering degree programmes (Computer-Assisted Engineering) (Master of Science) and Information Technology (Master of Science)	
10	**Method of examination**	oral exam (30 minutes):	
11	**Grading procedure**	100% based on oral exam	
12	**Module frequency**	Winter semester (annually)	
13	**Workload**	Contact hours: 60 hrs Independent study: 90 hrs Total: 150 hrs, corresponding to 5 ECTS credits	
14	**Module duration**	One semester	
15	**Teaching and examination language**	English	
16	**Recommended reading**	• Quinn: Parallel Programming in C with MPI and OpenMP, McGraw-Hill • Hennessy/Patterson: Computer Architecture - A Quantitative Approach, Morgen&Kaufmann	

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE FAKULTÄT

1	**Module name**	**Module 6a: MaSe: Master's seminar MApA**	**5 ECTS credits**
2	**Courses/lectures**	Seminar: 2 semester hrs/week	
3	**Lecturers**	**Prof. Dr. G. Leugering, N.N.**	

4	**Module coordinator**	**Prof. Dr. G. Grün**
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.

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE FAKULTÄT

1	Module name	Module 6b: MaSe: Master's seminar NASi	5 ECTS credits
2	Courses/lectures	Seminar: 2 semester hrs/week	
3	Lecturers	Prof. Dr. G. Leugering, N.N.	

4	**Module coordinator**	**Prof. Dr. E. Bänsch**
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.

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE FAKULTÄT

1	**Module name**	**Module 6c: MaSe: Master's seminar Opti**	**5 ECTS credits**
2	**Courses/lectures**	Seminar: 2 semester hrs/week	
3	**Lecturers**	**Prof. Dr. G. Leugering, N.N.**	

4	**Module coordinator**	**Prof. Dr. M. Stingl**
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.

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NATURWISSENSCHAFTLICHE FAKULTÄT

1	**Module name**	**Module 8: AdDiscTech: Advanced Discretization Techniques**	**10 ECTS credits**
2	**Courses/lectures**	a) Lecture: 4 semester hrs/week b) Practical: 1 semester hr/week	
3	**Lecturers**	**Prof. Dr. F. Frank**	

4	**Module coordinator**	**Prof. Dr. E. Bänsch**
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 (20 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 Pietro & A. Ern: Mathematical aspects of discontinuous Galerkin methods. Springer 2012

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1	**Module name**	**Module 11: RTpMNum: Transport and Reaction in Porous Media: Simulation**	**5 ECTS-Punkte**
2	**Courses/lectures**	a) Lectures: 2 semester hrs/week b) Practical: 0,5 semester hrs/week	
3	**Lecturers**	**Profs. Drs. P. Knabner, F. Frank**	

4	**Module coordinator**	**Prof. Dr. P. Knabner**
5	**Content**	• Degenerate parabolic differential equations as multiphase flow models: formulation, nonlinear solution methods, discretization methods • Models for transport and reactions in porous media, consisting of coupled PDEs and ODEs, if necessary coupled to algebraic equations (AEs) and inequalities for the description of local equilibria (differential-algebraic system) • Different formulations of the system (operator splitting, change of variables, combination of the equations, elimination of AEs), as a basis for different software packages for numerical simulations, connection to optimisation (Gibbs energy) • Treatment of numerical difficulties (Guarantee of nonnegativity of numerical solutions of the (nonlinear) problems, scaling problems, convection dominated problems
6	**Learning objectives and skills**	Students • use methods for the numerical solving of a class of problems whose complexity goes significantly beyond standard problems (Poisson and heat equation): coupled nonlinear partial and ordinary differential equations (PDEs, ODEs) and algebraic equations (AEs), • put strategies for the treatment of possible difficulties during the numerical solving into practice.
7	**Prerequisites**	Recommended: Basic knowledge in differential equations, Transport and Reaction in Porous Media: Modeling
8	**Integration into curriculum**	3rd semester
9	**Module compatibility**	• Mandatory elective module for MSc in Computational and Applied Mathematics • Research module for MSc in Mathematics with field of "Modeling, Simulation, and Optimisation" • Mathematical elective module in all other fields of study in MSc Mathematics and in MSc Mathematics and Economics • Master Physics, non-physical elective module
10	**Method of examination**	Oral exam (20 minutes)
11	**Grading procedure**	100% based on 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**	- P. Knabner & L. Angermann: Numerical Methods for Elliptic and Parabolic Partial Differential Equations, Springer - Handbooks of Software Packages, www.mso.math.fau.de/applied-mathematics-1/research/software

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NATURWISSENSCHAFTLICHE FAKULTÄT

1	**Module name**	**Module 25:** **AlgNLOpt: Advanced Algorithms for Nonlinear Optimization**	**5 ECTS credits**
2	**Courses/lectures**	a) Lectures: 2 semester hrs/week b) Practical: 0.5 semester hrs/week	
3	**Lecturers**	**Prof. Dr. M. Stingl**	

4	**Module coordinator**	**Prof. Dr. M. Stingl**
5	**Content**	Several of the following topics: • Trust region methods • Iterative methods in the presence of noisy data • Interior point methods for nonlinear problems • Modified barrier and augmented Lagrangian methods • Local and global convergence analysis
6	**Learning objectives and skills**	Students • use methods of nonlinear constrained optimization in finite dimensional spaces, • analyse convergence behaviour of these methods and derive robust and efficient realisations, • apply these abilities to technical and economic applications.
7	**Prerequisites**	Basic knowledge in nonlinear optimization is recommended.
8	**Integration into curriculum**	1st semester
9	**Module compatibility**	• Mandatory elective module for MSc in Computational and Applied Mathematics • Elective module for MSc in Mathematics
10	**Method of examination**	oral exam (20 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**	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**	• C.T. Kelley: Iterative Methods for Optimization, SIAM, • J. Nocedal & S. Wright: Numerical Optimization, Springer.

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
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1	**Module name**	**Module 26: DiscOpt I: Discrete Optimization I**	**5 ECTS credits**
2	**Courses/lectures**	a) Lectures: 2 weekly lecture hours b) Practical: 1 weekly lecture hour	
3	**Lecturers**	**Prof. Dr. F. Liers, Dr. L. Schewe**	

4	**Module coordinator**	**Prof. Dr. A. Martin**
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 32: OptIE: Optimization in Industry and Economy**	**5 ECTS credits**
2	**Courses/lectures**	a) Lectures: 2 weekly lecture hours b) Practical: 1 weekly lecture hour	
3	**Lecturers**	**Prof. Dr. M. Schmidt**	

4	**Module coordinator**	**Prof. Dr. F. Liers**
5	**Content**	This course focuses on modeling and solving real-world optimization problems occurring in industry and economics. Advantages and disadvantages of different modeling techniques will be outlined. In order to achieve efficient solution approaches, different reformulations and their numerical results will be discussed. Students will learn how to present optimization results properly as well as how to interpret and evaluate these results for practical applications. The latter may include but is not limited to the optimization of transport networks (gas, water, energy), air traffic management and mathematical modeling/optimization of market mechanisms in the energy sector.
6	**Learning objectives and skills**	Students • model complex real-world optimization problems with respect to efficient solvability, • classify the models and use appropriate solution strategies, • evaluate the achieved computational results.
7	**Prerequisites**	Recommended: Knowledge in linear and combinatorial optimization
8	**Integration into curriculum**	1st or 3rd semester
9	**Module compatibility**	• Mandatory elective module for MSc Computational and Applied Mathematics, MSc Mathematics, and MSc Mathematics and Economics, • Core/research module for MSc in 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 (annually)
13	**Workload**	Attendance: 45 h Self-study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	English
16	**Recommended reading**	• Lecture notes (will be published on StudOn at the beginning of the semester) • Up-to-date research literature (will be published on StudOn at the beginning of the semester)