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

for the wintersemester 2020/21

Department of Mathematics
Friedrich-Alexander-Universität Erlangen-Nürnberg

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FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
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1	**Module name**	**Module 1:** **ModAna1: Modeling and Analysis in Continuum Mechanics I**	**ECTS 10**
2	**Courses/lectures**	a) Lectures: 4 semester hrs/week b) Practical: 1 semester hr/week	
3	**Lecturers**	Prof. Dr. Enrique Zuazua enrique.zuazua@fau.de	MApA
4	**Module coordinator**	Prof. Dr. Günther Grün gruen@math.fau.de	
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.	

1	**Module name**	**Module 8:** **NumPDE: Numerics of Partial Differential Equations**	**ECTS 10**
2	**Courses/lectures**	a) Lecture: 4 semester hrs/week b) Practical: 2 semester hr/week	
3	**Lecturers**	Prof. Dr. Eberhard Bänsch baensch@math.fau.de	NASi
4	**Module coordinator**	Prof. Dr. Eberhard Bänsch baensch@math.fau.de	
5	**Content**	Classical theory of linear elliptic boundary value problems (outline) Finite difference method (FDM) for Poisson's equation in two dimensions (including stability via inverse monotonicity) Finite element method (FEM) for Poisson's equation in two dimensions (stability and convergence, example: linear finite elements, implementation) Variational theory of linear elliptic boundary value problems (outline) FEM for linear elliptic boundary value problems (2^{nd} order) (types of elements, affin-equivalent triangulations, order of convergence, maximum principle) Iterative methods for large sparse linear systems of equations (condition number of finite element matrices, linear stationary methods (recall), cg method (recall), preconditioning, Krylov subspace methods	
6	**Learning objectives and skills**	Students apply algorithmic approaches for models with partial differential equations and explain and evaluate them, are capable to judge on a numerical method's properties regarding stability and efficiency, implement (with own or given software) numerical methods and critically evaluate the results, explain and apply a broad spectrum of problems and methods with a focus on conforming finite element methods for linear elliptic problems, collect and evaluate relevant information and realize relationships.	
7	**Prerequisites**	Recommended: basic knowledge in numerics, discretization, and optimization	
8	**Integration into curriculum**	1st semester	
9	**Module compatibility**	Mandatory elective module for MSc in Computational and Applied Mathematics Mandatory elective module for BSc Mathematics mandatory module for BSc Technomathematik Non-Physics elective module for MSc Physics	
10	**Method of examination**	written exam (90 minutes) with exercises	
11	**Grading Procedure**	100% based on written exam	
12	**Module frequency**	Winter semester (annually)	
13	**Workload**	Contact hours: 90 hrs Independent study: 210 hrs Total: 300 hrs, corresponding to 10 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 Differential Equations, Springer 2003 • S. Larssen & V. Thomee: Partial Differential Equations with Numerical Methods. Springer 2005 • D. Braess: Finite Elements. Cambridge University Press 2010 • lecture scripts on the homepage of the domain Modeling, Simulation, and Optimization of the department Mathematics, frequently updated

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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	NASi
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**	Seminar: "Topics on control and numerics of Partial Differential Equations (PDE)"	
3	**Lecturers**	Prof. Dr. Enrique Zuazua enrique.zuazua@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**	Seminar: "Topics on control and numerics of Partial Differential Equations (PDE)"	
3	**Lecturers**	Prof. Dr. Enrique Zuazua enrique.zuazua@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**	Seminar: "Topics on control and numerics of Partial Differential Equations (PDE)"	
3	**Lecturers**	Prof. Dr. Enrique Zuazua enrique.zuazua@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 14:** **NuIF2: Numerics of Incompressible Flows II**	**ECTS 5**
2	**Courses/lectures**	a) Lecture: 2 semester hrs/week b) Practical: 0.5 semester hrs/week	
3	**Lecturers**	Prof. Dr. Eberhard Bänsch baensch@math.fau.de	NASi
4	**Module coordinator**	Prof. Dr. Eberhard Bänsch baensch@math.fau.de	
5	**Content**	• Variational formulation of the instationary Stokes and Navier-Stokes (NVS) equations • Existence and uniqueness of solutions to the instationary Stokes and NVS equations • Time discretisation methods • Fully discrete equations and error estimates • Solution techniques • Operator splitting, projection methods • More general boundary conditions • Coupling of NVS with temperature equation • Computational experiments with academic or commercial codes	
6	**Learning objectives and skills**	Students • discretize the instationary NVS equations in time and space, • explain and analyse discretisation schemes and operator splitting techniques, • choose appropriate algorithms for given flow problems and solve them with academic or commercial software.	
7	**Prerequisites**	Recommended: Advanced discretization techniques, Numerics of incompressible flows 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 “Modeling, Simulation and Optimization”	
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: 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**	• V. Girault & P.-A. Raviart: Finite element methods for the Navier-Stokes equations. Theory and algorithms. Springer 1986 • H. Elman, D. Silvester & A. Rathen: Finite elements and fast iterative solvers: with applications in incompressible fluid dynamics. Oxford University Press 2014 • R. Glowinski: Finite Element Methods for Incompressible Viscous Flow, in : Handbook of Numerical Analysis vol. IX • R. Temam: Navier-Stokes equations. Theory and numerical analysis. North Holland

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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 25:** **AnFBP: Analysis of free-boundary problems in continuum mechanics**	**ECTS 5**
2	**Courses/lectures**	Lecture: 2 semester hrs/week Practical: 0.5 semester hrs/week	
3	**Lecturers**	Prof. Dr. Günther Grün gruen@math.fau.de	MapA
4	**Module coordinator**	Prof. Dr. Günther Grün gruen@math.fau.de	
5	**Content**	Derivation of time-dependent free boundary problems in continuum mechanics, Basic results on existence and qualitative behaviour, Optimal estimates on the propagation of free boundaries, Other approaches, e.g. relaxation by phase-field models.	
6	**Learning objectives and skills**	Students • formulate free-boundary problems in hydrodynamics and in porousmedia flow • explain analytical concepts for existence and nonnegativity results for degenerate parabolic equations as well as techniques for optimal estimates on spreading rates • validate different modeling approaches in a critical way.	
7	**Prerequisites**	Recommended: Basic knowledge of analysis of partial differential equations, corresponding to the syllabus of "Modeling and applied analysis in continuum mechanics" or that one of other pde-lectures.	
8	**Integration into curriculum**	3rd semester	
9	**Module compatibility**	Mandatory elective module MSc Computational and Applied Mathematics, Elective module MSc Mathematics (Analysis and Stochastics)	
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 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	
14	**Module duration**	One semester	
15	**Teaching and examination language**	English	
16	**Recommended reading**	L.C. Evans: Partial Differential Equations, AMS, Original journal articles.	

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1	**Module name**	Module 28: AlgNLOpt: Advanced Algorithms for Nonlinear Optimization	**ECTS 5**
2	**Courses/lectures**	a) Lectures: 2 semester hrs/week b) Practical: 0.5 semester hrs/week	
3	**Lecturers**	Prof. Dr. Michael Stingl michael.stingl@fau.de	Opti
4	**Module coordinator**	Prof. Dr. Michael Stingl michael.stingl@fau.de	
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 • Mandatory elective module for MSc in Mathematics in the field of study “Modelling, Simulation and Optimization” • Mandatory elective module for the MSc in Mathematics and Economics in the field of study “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 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**	• C.T. Kelley: Iterative Methods for Optimization, SIAM, • J. Nocedal & S. Wright: Numerical Optimization, Springer.	

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**	Prof. Dr. Alexander Martin alexander.martin@fau.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 33:** **OptPDE: Optimization with Partial Differential Equations**	**ECTS 5**
2	**Courses/lectures**	a) Lectures: 2 semester hrs/week b) Practical: 0.5 semester hrs/week	
3	**Lecturers**	Prof. Dr. Günter Leugering guenter.leugering@fau.de	Opti
4	**Module coordinator**	Prof. Dr. Michael Stingl michael.stingl@fau.de	
5	**Content**	Several of the following topics: Optimization and control in Banach spaces Concepts of controllability and stabilization Optimal control of Partial differential equations Singular Perturbations and asymptotic analysis Numerical realizations of optimal controls Technical, medical and economic applications	
6	**Learning objectives and skills**	Students explain and use theory as well as numerical methods for optimization, control and stabilization in the context of partial differential equations, apply these abilities to technical and economic applications.	
7	**Prerequisites**	Basic knowledge in numerics, partial differential equations, and nonlinear optimization is recommended.	
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% based on oral exam	
12	**Module frequency**	Winter semester (not annually) To check whether the course is offered, 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**	- F. Tröltzsch: Optimal Control of Partial Differential Equations, AMS, - G. Leugering & P. Kogut: Optimal Control of PDEs in Reticulated Domains, Birkhäuser.	

1	**Module name**	**Module 35: OptIE: Optimization in Industry and Economy**	**ECTS 5**
2	**Courses/lectures**	Lecture: Optimization in Industry and Economy Exercises: Optimization in Industry and Economy	
3	**Lecturers**	Prof. Dr. Frauke Liers frauke.liers@math.uni-erlangen.de	Opti
4	**Module coordinator**	Prof. Dr. Alexander Martin alexander.martin@fau.de	
5	**Content**	Graph routing problems consist usually of an agent that must achieve a certain goal while traversing the arcs or vertices of a graph. Practical applications of graph routing include vehicle routing, pick-up and delivery services, mail delivery, meter reading, snow plowing, waste collection, and many others. Perhaps the simplest graph routing problems are the postman problem and the traveling salesman problem (covered in "Graph routing and applications"). In this course we are going to present some more complicated graph routing problems with practical applications, we are going to cover the mathematical programming techniques used to model these problems (usually as integer programs), and we are going to describe algorithmic methods of solution for some of them.	
6	**Learning objectives and skills**	At the end of this course, students should be able to (a) recognize the basic arc and edge graph routing problems, (b) solve graph routing problems using well-known combinatorial algorithms, (c) model more complex graph routing problems using integer programming, (d) apply mathematical programming techniques to solve practical graph routing problems.	
7	**Prerequisites**	Recommended: Modul LKOpt: Linear and combinatorial optimization	
8	**Integration into curriculum**	Master: 1st semester or later	
9	**Module compatibility**	Master elective modul (M-MA, TM-MA, WM-MA, CAM-MA-NASi, CAM-MA-Opti, CAM-MA-MApA)	
10	**Method of examination**	Oral exam (15 min)	
11	**Grading Procedure**	100% based on oral exam	
12	**Module frequency**	Winter semester (2019/2020)	
13	**Workload**	150 hr as follows: Lecture: 4 SWS x 7.5 = 30 hr Exercises: 2 SWS x 7.5 = 15 hr Self-study: 105 hr	
14	**Module duration**	Half a semester	
15	**Teaching and examination language**	English	
16	**Recommended reading**	There is a script prepared by the lecturer which will be available on StudOn	

1	**Module name**	**Module 37: Conic Optimization and Applications**	**ECTS 10**
2	**Courses/lectures**	a) Lectures: 2 semester hrs/week b) Practical: 1 semester hr/week	
3	**Lecturers**	Dr. Jan Rolfes jan.rolfes@fau.de	Opti
4	**Module coordinator**	Dr. Jan Rolfes jan.rolfes@fau.de	
5	**Content**	In modern „Convex Optimization“ the theory of semidefinite optimization plays a central role. Semidefinite optimization is a generalization of linear optimization, where one wants to optimize linear functions over positive semidefinite matrices restricted by linear constraints. A wide class of convex optimization problems can be modeled using semidefinite optimization. On the one hand, there are algorithms to solve semidefinite optimization problems, which are efficient in theory and practice. On the other hand, semidefinite optimization is a tool of particular usefulness and elegance. Overview of topics: - Topological properties of cones - Foundations of conic optimization, theorems of the alternative, duality - Applications in Eigenvalue optimization and robust optimization - Approximations of combinatorial optimization problems such as MAXCUT, packing problems, coloring problems, Shannon capacity - Symmetry reduction of optimization	
6	**Learning objectives and skills**	Students - gain insight of the fundamental concepts in conic optimization - apply algorithmic techniques to problems in the fields of combinatorics, geometry and algebra - extend their expertise in geometry, in particular about the interplay between the fields of geometry and optimization	
7	**Prerequisites**	Recommended: at least one of the modules “Linear and combinatorial optimization”, “robust optimization”, “discrete optimization”	
8	**Integration into curriculum**	1st or 3rd semester	
9	**Module compatibility**	- Mandatory elective module for MSc Computational and Applied – - Mathematics•Mandatory elective module for MSc Mathematics in the field of “Modeling, Simulation and Optimization” - Mandatory elective module for MSc Mathematics and Economics in the fields of “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 in the current semester, see UnivISunivis.fau.de or module handbook of current semester
13	**Workload**	Contact hours: 45 hrs Independent study: 105 hrs Total: 150 hrs, corresponding to 5 ECTS credits
14	**Module duration**	One semester
15	**Teaching and examination language**	English
16	**Recommended reading**	- M. Laurent, F. Vallentin: lecture notes - http://www.mi.uni-koeln.de/opt/wp-content/uploads/2015/10/laurent_vallentin_sdo_2012_05.pdf - Further literature and scientific publications are announced during the lectures