Module Guide for the Study Path

Master MES
# Module Guide

## Mathematics

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## CS3120 - Electronics and Microsystems (ElMi)

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<td>Turnus of offer:</td>
<td>Each winter semester</td>
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<td>Credit points:</td>
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### Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics, 1. Term
- Master MES (Consolidating), 1. Term
- Bachelor Computer Science (Optional Subject), Informatics central topics, 5. or 6. term
- Bachelor MES (Optional Subject), Medical Engineering Sciences
- Bachelor Computer Science (compulsory), Enhanced course robotics and automation, 5. Term

### Classes and lectures:
- Electronics and Microsystems (Lecture, 2 SWS)
- Electronics and Microsystems (Exercise, 1 SWS)
- Workload:
  - 55 Hours Private studies
  - 45 Hours Presence studies
  - 20 Hours Test preparation

### Contents of teaching:
- Analysis of DC-networks
- Transient analysis in the time-domain
- Network analysis in the frequency domain
- Passive filters
- Oscillator circuits
- Bipolar transistors
- Field-effect transistors
- Amplifiers
- Operational amplifiers
- Active filters
- Digital-analog converters
- Analog-digital converters
- Phase-locked loops
- Introduction to Microsystems engineering
- Materials used in Microsystems
- Manufacturing technologies

### Qualification-goals/Competencies:
- Students know the most important electronic components and corresponding basic circuits
- They are qualified to design and analyse basic active and passive electronic circuits
- They have basic knowledge about the methods of Microsystems engineering and its application areas

### Grading through:
- Exercises
- Test

### Requires:
- Fundamentals of Computer Engineering (CS1200)

### Teacher:
- Institute of Computer Engineering
- Prof. Dr.-Ing. Erik Maehle

### Literature:
- Tietze, U.; Schenk, Ch.; Gamm, E.: Halbleiter-Schaltungstechnik - Berlin: Springer 2012

### Language:
• Offered only in German
| Duration: | 1 Semester |
| Turnus of offer: | Each winter semester |
| Credit points: | 4 |

### Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics, 1. Term
- Master MML (compulsory), Mathematics, 1st or 3rd term
- Master MES (Consolidating), 1. Term
- Master Computer Science (compulsory), Computer Science Mandatory Courses, 1. Term

### Classes and lectures:
- Pattern Recognition (Lecture, 2 SWS)
- Pattern Recognition (Exercise, 1 SWS)

### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- Introduction to probability theory
- Principles of feature extraction and pattern recognition
- Bayes decision theory
- Discriminance functions
- Neyman-Pearson test
- Receiver Operating Characteristic
- Parametric and nonparametric density estimation
- kNN classifiers
- Linear classifiers
- Support vector machines and kernel trick
- Feature reduction and feature transforms
- Validation of classifiers

### Qualification-goals/Competencies:
- Students will know the main elements of feature extraction and pattern recognition.
- They will know the basic elements of statistical modeling.
- They will be able to use feature extraction, feature reduction and pattern classification techniques in practice.
- They will be aware of interrelationships between pattern recognition, signal processing, and data representation.

### Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

### Responsible for this module:
- Prof. Dr.-Ing. Alfred Mertins

### Teacher:
- Institute for Signal Processing
- Prof. Dr.-Ing. Alfred Mertins

### Literature:
- C. M. Bishop: Pattern Recognition and Machine Learning - Springer 2009

### Language:
- Offered only in German
| Duration: | 1 Semester |
| Turnus of offer: | Each summer semester |
| Credit points: | 4 |

### Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics, 2. Term
- Bachelor MES (Optional Subject), 6. Term
- Master Computer Science (Optional Subject), advanced curriculum Organic Computing, 2. or 3. term
- Master MES (Consolidating), 2. Term
- Master Computer Science (Optional Subject), advanced curriculum Intelligent Embedded Systems, 2. or 3. term
- Master Computer Science (compulsory), Enhanced course robotics and automation, 2. Term
- Master Computer Science (compulsory), Enhanced course Biology & IT, 2. Term
- Master MML (compulsory), 2. Term

### Classes and lectures:
- Neuro-informatics (Lecture, 2 SWS)
- Neuro-informatics (Exercise, 1 SWS)

### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- The human brain
- Neural networks
- Learning (in neural networks)
- Perceptrons
- Sparse coding
- Boltzmann machines
- Associative memories
- Self-organising maps
- Deep learning

### Qualification-goals/Competencies:
- Principles of the human nervous system
- Insides into the information processing in the nervous system
- Derivation of learning rules
- Principles of the information processing and corresponding neural architectures
- Knowledge of principal neural network architectures
- Practical experience with common methods using supervised and unsupervised learning

### Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

### Teacher:
- Institute for Neuro- and Bioinformatics
- Prof. Dr. rer. nat. Thomas Martinetz

### Literature:

### Language:
- Offered only in German
# MA3110 - Numerics 1 (Num1)

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<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
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<td>1 Semester</td>
<td>Each winter semester</td>
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## Course of study, specific field and term:
- (Optional Subject)
- Bachelor Computer Science (Optional Subject), Informatics central topics, 5. Term
- Master MES (Optional Subject), Mathematics, 1. Term
- Bachelor MES (Optional Subject), Mathematics, 3. Term
- Bachelor Computer Science (Optional Subject), Mathematics, 5. or 6. term
- Bachelor Medical Informatics SJ14 (Optional Subject), Mathematics, 5. or 6. term

## Classes and lectures:
- Numerics 1 (Lecture, 2 SWS)
- Numerics 1 (Exercise, 1 SWS)

## Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

## Contents of teaching:
- Round-off errors and condition
- Direct solvers for linear equations
- LR decomposition
- Perturbation theory
- Cholesky decomposition
- QR decomposition, least squares fit

## Qualification-goals/Competencies:
- Basic understanding of numeric tasks
- Mastering the modern programming language MATLAB
- Experience in the implementation of theoretical algorithms
- Ability to judge the quality of a method (accuracy, stability, complexity)

## Grading through:
- Exercises
- Programming exercises
- Test

## Requires:
- Linear Algebra and Discrete Structures 2 (MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000)
- Analysis 2 (MA2500)
- Analysis 1 (MA2000)

## Responsible for this module:
- Prof. Dr. Andreas Rößler

## Teacher:
- Institute for Mathematics
- Prof. Dr. Andreas Rößler

## Literature:
<table>
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| Notes: | The lecture is identical to that in module MA3110-MML/Numerics 1 |
## MA3400 - Biomathematics (Biomathe)

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### Course of study, specific field and term:
- Bachelor Medical Informatics SJ14 (Optional Subject), medical computer science, 5. or 6. term
- Bachelor Computer Science (compulsory), Enhanced course Biology & IT, 5. Term
- Master MES (Optional Subject), Mathematics, 1. Term
- Bachelor Medical Informatics (Optional Subject), Biology & IT
- Master Computer Science (Optional Subject), Enhanced course medical computer science, 3. Term
- Bachelor MES (Optional Subject), Mathematics, 5. Term
- Bachelor Computer Science (compulsory), Enhanced course Biology & IT, 5. Term

### Classes and lectures:
- Biomathematics (Lecture, 2 SWS)
- Biomathematics (Exercise, 1 SWS)

### Workload:
- 55 Hours Self studies and exercises
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- Basics of differential equations
- Differential equations of first order
- Linear differential equations of n-th order
- Systems of linear differential equations with constant coefficients
- Notes on numerics and qualitative analysis; the prey-predator model

### Qualification-goals/Competencies:
- Learning the basics of ordinary differential equations
- Ability to apply differential equations
- Learning by means of examples how to use differential equations for models in biology, chemistry and medicine
- Basic understanding of simple numerical methods

### Grading through:
- Exercises
- Test

### Responsible for this module:
- Prof. Dr. rer. nat. Jürgen Prestin
- PD Dr. rer. nat. Hanns-Martin Teichert

### Teacher:
- Institute for Mathematics
- PD Dr. rer. nat. Hanns-Martin Teichert

### Literature:
- J. D. Murray: Mathematical Biology - Springer
- R. Schuster: Biomathematik - Vieweg + Teubner Studienbücher 2009

### Language:
- Offered only in German
# MA3445 - Graph Theory (Graphen)

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<th><strong>Duration:</strong></th>
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<td><strong>Credit points:</strong></td>
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**Course of study, specific field and term:**
- (Optional Subject)
- Bachelor Computer Science (Optional Subject), Informatics central topics, 5. or 6. term
- Master MML (choice), Mathematics, Arbitrary semester
- Master MES (Optional Subject), Mathematics
- Bachelor MML (choice), Mathematics, 5. or 6. term
- Bachelor Medical Informatics SJ14 (Optional Subject), Mathematics, 5. or 6. term

**Classes and lectures:**
- Graph theory (Lecture, 2 SWS)
- Graph theory (Exercise, 1 SWS)
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**
- Hamiltonian graphs and degree sequences
- Menger's theorem - new proofs
- Matchings and decompositions of graphs
- The theorems of Turan and Ramsey
- Vertex and edge colourings
- The four colour theorem

**Qualification-goals/Competencies:**
- Ability to solve discrete problems using graph theoretical methods
- Knowledge of proof techniques and ideas of discrete mathematics
- Knowledge of fundamental and selected recent research results

**Grading through:**
- Exercises
- Viva Voce

**Requires:**
- Linear Algebra and Discrete Structures 2 (MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000)

**Responsible for this module:**
- PD Dr. rer. nat. Hanns-Martin Teichert

**Teacher:**
- Institute for Mathematics
- PD Dr. rer. nat. Hanns-Martin Teichert

**Literature:**
- F. Harary: Graph Theory - Reading, MA:.Addison-Wesley 1969
- R. Diestel: Graphentheorie - Berlin: Springer 2000
- B. Bollobas: Modern Graph Theory - Berlin: Springer 1998

**Language:**
- Offered only in German
## MA4020 - Stochastics 2 (Stoch2)

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### Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics, 1. Term
- Master Computer Science (Optional Subject), Enhanced course Biology & IT, 3. Term
- Master Computer Science (compulsory), advanced curriculum Stochastics, 3. Term
- Master Computer Science (Optional Subject), advanced curriculum Analysis, 3. Term
- Bachelor MES (Optional Subject), Mathematics, 5. Term

### Classes and lectures:
- Stochastics 2 (Lecture, 2 SWS)
- Stochastics 2 (Exercise, 1 SWS)

### Workload:
- 65 Hours Self studies and exercises
- 45 Hours Presence studies
- 10 Hours Test preparation

### Contents of teaching:
- Lebesgue integral and Riemann integral
- Transformations of measures and integrals
- Product measures and Fubini’s theorem
- Moments and dependency measures
- Normally distributed random vectors and distributions closely related to the normal distribution

### Qualification-goals/Competencies:
- Insight into basic aspects of measure and integration theory
- Mastery of techniques of integration being relevant to stochastics and of techniques for the treatment of (particularly normally distributed) random vectors and their distributions

### Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

### Is requisite for:
- Modeling Biological Systems (MA4450)
- Stochastic processes and modeling (MA4610)

### Requires:
- Stochastics 1 (MA2510)
- Linear Algebra and Discrete Structures 2 (MA1500)
- Analysis 2 (MA2500)

### Responsible for this module:
- Prof. Dr. Karsten Keller

### Teacher:
- Institute for Mathematics
- Prof. Dr. Karsten Keller

### Literature:
- J. Elstrodt: Maß- und Integrationstheorie - Springer
- M. Fisz: Wahrscheinlichkeitsrechnung und mathematische Statistik - Deutscher Verlag der Wissenschaften

### Language:
- Offered only in German

### Notes:
The lecture is identical to that in module MA4020-MML.
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<th>Duration: 1 Semester</th>
<th>Turnus of offer: Each summer semester</th>
<th>Credit points: 8</th>
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Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics, 2. Term
- Master Computer Science (Optional Subject), advanced curriculum Numerical Image Processing, 2. or 3. term
- Bachelor MES (Optional Subject), Medical Engineering Sciences, 6. Term
- Master Computer Science (Optional Subject), advanced curriculum Analysis, 2. or 3. term
- Bachelor MML (compulsory), Mathematics, 4. Term

Classes and lectures:
- Optimization (Lecture, 4 SWS)
- Optimization (Exercise, 2 SWS)

Workload:
- 130 Hours Self studies and exercises
- 90 Hours Presence studies
- 20 Hours Test preparation

Contents of teaching:
- Linear optimization
- Unconstrained and constrained nonlinear optimization
- Discrete optimization

Qualification-goals/Competencies:
- Fundamental knowledge and understanding of general optimization strategies
- Experience in realization of practical problems within the field of life sciences
- Experience in realization of theoretical concepts
- Competence and understanding of numerical results and simulations

Grading through:
- Exercises
- Test

Requires:
- Analysis 2 (MA2500)

Responsible for this module:
- Prof. Dr. Jan Modersitzki

Teacher:
- Institute of Mathematics and Image Computing
- Prof. Dr. Jan Modersitzki

Literature:
- J. Nocedal, S. Wright: Numerical Optimization - Springer

Language:
- Offered only in German
# MA4040 - Numerics 2 (Num2)

<table>
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<th>Duration:</th>
<th>1 Semester</th>
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<td>Turnus of offer:</td>
<td>Each summer semester</td>
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<td>Credit points:</td>
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## Course of study, specific field and term:
- (Optional Subject)
- Master MES (Optional Subject), Mathematics, 2. Term
- Bachelor MES (Optional Subject), Medical Engineering Sciences, 6. Term
- Master Computer Science (Optional Subject), advanced curriculum Analysis, 2. or 3. term

## Classes and lectures:
- Numerics 2 (Lecture, 2 SWS)
- Numerics 2 (Exercise, 1 SWS)

## Workload:
- 60 Hours Self studies and exercises
- 45 Hours Presence studies
- 15 Hours Test preparation

## Contents of teaching:
- Polynomial interpolation
- Hermite interpolation
- Approximation
- Numerical quadrature

## Qualification-goals/Competencies:
- Becoming acquainted with fundamental numerical methods
- Understanding the transformation of a continuous problem into a discrete one
- Secure competencies in using both stable and robust numeric algorithms
- Experience in the implementation of practical tasks

## Grading through:
- Exercises
- Programming exercises
- Test

## Requires:
- Numerics 1 (MA3110)
- Linear Algebra and Discrete Structures 2 (MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000)
- Analysis 2 (MA2500)
- Analysis 1 (MA2000)

## Responsible for this module:
- Prof. Dr. Andreas Rößler

## Teacher:
- Institute for Mathematics
- Prof. Dr. Andreas Rößler

## Literature:
- P. Deuflhard, A. Hohmann: Numerische Mathematik I

## Language:
- Offered only in German

Notes:
The lecture is identical to that in module MA4040-MML/Numerics 2
### MA4330 - Biosignal analysis (BioSA)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each summer semester</td>
<td>4</td>
</tr>
</tbody>
</table>

**Course of study, specific field and term:**
- Master MES (Optional Subject), Mathematics, 2. Term
- Master Computer Science (compulsory), advanced curriculum Analysis, 2. Term
- Master MML (compulsory), Mathematics, 2. Term

**Classes and lectures:**
- Biosignal analysis (Lecture, 2 SWS)
- Biosignal analysis (Exercise, 1 SWS)

**Contents of teaching:**
- Hilbert spaces
- Fourier series and Fourier transformation
- generalized functions
- discrete wavelet transformation
- least square techniques
- application to biological and medical data

**Contents of teaching:**
- deepened knowledges of the mathematical background of signal analysis
- mastery of different methods for one-dimensional and multidimensional signal analysis
- practical skills in the application of these methods

**Qualification-goals/Competencies:**
- Exercises
- Test or Viva voce, made available by the lecturer

**Grading through:**
- Analysis 2 (MA2500)

**Responsible for this module:**
- Prof. Dr. Karsten Keller

**Teacher:**
- Institute for Mathematics
- Prof. Dr. Karsten Keller
- Prof. Dr. rer. nat. Jürgen Prestin

**Literature:**
- A. N. Kolmogorov, S.V. Fomin: Reelle Funktionen und Funktionalanalyse - Deutscher Verlag der Wissenschaften 1975

**Language:**
- Offered only in German

**Workload:**
- 65 Hours Private studies
- 45 Hours Presence studies
- 10 Hours Test preparation
# MA4400 - Chaos and Complexity of Biological Systems (CKBS)

## Duration:
1 Semester

## Turnus of offer:
Irregular

## Credit points:
4

## Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics
- Master Computer Science (Optional Subject), Enhanced course Biology & IT, 2. or 3. term
- Master MES (Consolidating)
- Master MML (choice), Mathematics, Arbitrary semester

## Classes and lectures:
- Chaos and Complexity of Biological Systems (Lecture, 2 SWS)
- Chaos and Complexity of Biological Systems (Exercise, 1 SWS)

## Workload:
- 65 Hours Private studies
- 45 Hours Presence studies
- 10 Hours Test preparation

## Contents of teaching:
- Time-discrete dynamical systems and stochastic processes
- Nonlinearity and chaos
- Ergodicity
- Lyapunov exponents and fractal dimensions
- Symbolic dynamics
- Information-theoretic complexity measures
- Biological and medical applications, in particular EEG analysis

## Qualification-goals/Competencies:
- Insight into concepts of nonlinear dynamics
- Skills in analyzing and modeling complex data and time series

## Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

## Requires:
- Stochastics 1 (MA2510)
- Analysis 1 (MA2000)

## Responsible for this module:
- Prof. Dr. Karsten Keller

## Teacher:
- Institute for Mathematics
- Prof. Dr. Karsten Keller

## Literature:
- M. Brin, G. Stuck: Introduction to Dynamical Systems - Cambridge University Press 2002
- J. M. Amigó: Permutation Complexity in Dynamical Systems - Springer 2010

## Language:
- Offered only in English

## Notes:
Lecture and tutorial in English (in German only if desired by all students), lecture notes in English, exam can be taken either in English or German language
# MA4450 - Modeling Biological Systems (MoBS)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each winter semester</td>
<td>4</td>
</tr>
</tbody>
</table>

## Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics, 1. Term
- Master MES (Consolidating), 1. Term
- Master Computer Science (compulsory), Enhanced course Biology & IT, 1. Term
- Master Computer Science (Optional Subject), advanced curriculum Organic Computing, 2. or 3. term

## Classes and lectures:
- Modeling Biological Systems (Lecture, 2 SWS)
- Modeling Biological Systems (Exercise, 1 SWS)

## Workload:
- 65 Hours Self studies and exercises
- 45 Hours Presence studies
- 10 Hours Test preparation

## Contents of teaching:
- Elementary time-discrete deterministic models
- Structured time-discrete population dynamics
- Generating functions, Galton-Watson-processes
- Markov chains with applications
- Modeling of data and data analysis

## Qualification-goals/Competencies:
- Knowledge of elementary time-discrete models for modeling biological processes
- Development of skills in connecting ideas from different fields of mathematics
- Competencies in data analysis and modelling
- Interdisciplinary competencies

## Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

## Requires:
- Stochastics 1 (MA2510)
- Analysis 2 (MA2500)
- Linear Algebra and Discrete Structures 2 (MA1500)

## Responsible for this module:
- Prof. Dr. Karsten Keller

## Teacher:
- Institute for Mathematics
- Prof. Dr. Karsten Keller

## Literature:
- S. N. Elaydi: An Introduction to Difference Equations - New York: Springer 1999
- B. Huppert: Angewandte Lineare Algebra - Berlin: de Gruyter 1990

## Language:
- Offered only in German

## Notes:
The lecture is identical to that in module MA4450-MML. For students in the master Infection Biology programme, this is not a stand-alone module, but rather part of module CS4011.
# MA4450-MML - Modeling Biological Systems (MoBS)

<table>
<thead>
<tr>
<th>Duration:</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Each winter semester</td>
</tr>
<tr>
<td>Credit points:</td>
<td>8 (CLS 5.5)</td>
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</tbody>
</table>

## Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics, 1st or 3rd term
- Bachelor MML (compulsory), Mathematics, 5. Term

## Classes and lectures:
- Modeling Biological Systems (Lecture, 2 SWS)
- Modeling Biological Systems (Exercise, 2 SWS)

## Workload:
- 160 Hours Self studies and exercises
- 60 Hours Presence studies
- 20 Hours Test preparation

## Contents of teaching:
- Elementary time-discrete deterministic models
- Structured time-discrete population dynamics
- Generating functions, Galton-Watson processes
- Markov chains with applications
- Modeling of data and data analysis

## Qualification-goals/Competencies:
- Knowledge of elementary time-discrete models for modeling biological processes
- Development of skills in connecting ideas from different fields of mathematics
- Competencies in data analysis and modelling
- Interdisciplinary competencies

## Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

## Requires:
- Linear Algebra and Discrete Structures 2 (MA1500)
- Stochastics 1 (MA2510)
- Analysis 2 (MA2500-MML)

## Responsible for this module:
- Prof. Dr. Karsten Keller

## Teacher:
- Institute for Mathematics
- Prof. Dr. Karsten Keller

## Literature:
- S. N. Elaydi: An Introduction to Difference Equations - New York: Springer 1999
- B. Huppert: Angewandte Lineare Algebra - Berlin: de Gruyter 1990

## Language:
- Offered only in German

## Notes:
The lecture is identical to that in module MA4450.
### MA4500 - Mathematical Methods in Image Processing (MatheBildv)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Every second winter semester</td>
<td>4</td>
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</tbody>
</table>

**Course of study, specific field and term:**
- Master Medical Informatics SJ14 (Optional Subject), medical computer science
- (Optional Subject)
- Master MES (Optional Subject), Mathematics, 1st or 3rd term
- Master Computer Science (Optional Subject), advanced curriculum Imaging Systems, 2. or 3. term
- Master MES (Consolidating), 1st or 3rd term
- Master Computer Science (compulsory), advanced curriculum Numerical Image Processing, 2. or 3. term
- Master MML (compulsory), Mathematics, 1st or 3rd term

**Classes and lectures:**
- Mathematical Methods in Image Processing (Lecture, 2 SWS)
- Mathematical Methods in Image Processing (Exercise, 1 SWS)

**Workload:**
- 65 Hours Self studies and exercises
- 45 Hours Presence studies
- 10 Hours Test preparation

**Contents of teaching:**
- Image processing
- Digital images
- Operators in the spatial domain
- Operators in the Fourier domain
- Deblurring
- Methods of total variation
- Segmentation
- Level set methods

**Qualification-goals/Competencies:**
- Introduction to fundamental mathematical concepts in image processing
- Understanding of important operators in spatial domain
- Acquisition of fundamental discretization techniques
- Acquisition of typical numerical methods in images processing

**Grading through:**
- Test or Viva voce, made available by the lecturer

**Is requisite for:**
- Calculus of Variations and Partial Differential Equations (MA5034)

**Requires:**
- Linear Algebra and Discrete Structures 1 (MA1000)
- Analysis 1 (MA2000)

**Responsible for this module:**
- Prof. Dr. Jan Modersitzki

**Teacher:**
- Institute of Mathematics and Image Computing
- Prof. Dr. Jan Modersitzki

**Literature:**
<table>
<thead>
<tr>
<th>MA4612 - Numerik dynamischer Systeme</th>
</tr>
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<tbody>
<tr>
<td><strong>Duration:</strong> 1 Semester</td>
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<tr>
<td><strong>Turnus of offer:</strong> Every third semester</td>
</tr>
<tr>
<td><strong>Credit points:</strong> 4</td>
</tr>
</tbody>
</table>

**Course of study, specific field and term:**
- Master MML (choice), Mathematics, Arbitrary semester
- Master MES (Optional Subject), Mathematics
- Bachelor MML (choice), Mathematics, 6. Term

**Classes and lectures:**
- Numerik dynamischer Systeme (Lecture, 2 SWS)
- Numerik dynamischer Systeme (Exercise, 1 SWS)

**Contents of teaching:**
- Diskrete dynamische Systeme
- Kontinuierliche dynamische Systeme (Systeme gewöhnlicher Differentialgleichungen)
- Modellierungsaspekte

**Qualification-goals/Competencies:**
- Modellierung, Simulation und Analyse lebender Systeme
- Numerische Umsetzung der einzelnen Ansätze
- Anwendung auf praxisrelevante Fragestellungen

**Grading through:**
- Exercises
- Test

**Workload:**
- 65 Hours Private studies
- 45 Hours Presence studies
- 10 Hours Test preparation

**Requires:**
- Linear Algebra and Discrete Structures 1 (MA1000)

**Teacher:**
- Institute for Mathematics
- Prof. Dr. Jan Modersitzki

**Language:**
- Offered only in German
<table>
<thead>
<tr>
<th><strong>MA4615 - Numerical methods for stochastic processes (NumStochPr)</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Duration:</strong> 1 Semester</td>
</tr>
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</table>

**Course of study, specific field and term:**
- Master MES (Optional Subject), Mathematics
- Bachelor MML (Optional Subject), Mathematics, 5. or 6. term
- Master MML (Optional Subject), Mathematics, Arbitrary semester

**Classes and lectures:**
- Numerical methods for stochastic processes (Lecture, 2 SWS)
- Numerical methods for stochastic processes (Exercise, 1 SWS)

**Workload:**
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**
- Basic principles of stochastic processes in continuous time
- Stochastic differential equations
- Discrete time approximations for solutions of stochastic differential equations
- Numerical schemes for strong and weak approximations

**Qualification-goals/Competencies:**
- To impart basic principles of stochastic processes and of some numerical schemes
- To learn methods of proof as well as the application of algorithms
- Accomplished handling of essential concepts and results as well as of selected advanced topics

**Grading through:**
- Exercises
- Test or Viva voce, made available by the lecturer

**Requires:**
- Stochastics 2 (MA4020)
- Stochastics 1 (MA2510)

**Responsible for this module:**
- Prof. Dr. Andreas Rößler

**Teacher:**
- Institute for Mathematics
- Prof. Dr. Andreas Rößler

**Literature:**

**Language:**
- Offered only in German

**Notes:**
Criteria for admission to the examination will be established by the lecturer.
### MA4616 - Advanced Numerics (HoehereNum)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>1 Semester</th>
</tr>
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<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Irregular</td>
</tr>
<tr>
<td>Credit points:</td>
<td>4</td>
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</tbody>
</table>

#### Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics, Arbitrary semester
- Bachelor MML (Optional Subject), Mathematics, S. or 6. term
- Master MML (Optional Subject), Mathematics, Arbitrary semester

#### Classes and lectures:
- Advanced Numerics (Lecture, 2 SWS)
- Advanced Numerics (Exercise, 1 SWS)

#### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

#### Contents of teaching:
- Numerics for ordinary differential equations
- One-step methods, local and global error analysis
- Orders of consistence and convergence
- Stiff differential equations, implicit schemes, stability

#### Qualification-goals/Competencies:
- To impart basic principles of numerics for differential equations
- To learn methods of proofs as well as the application of results from numerics for differential equations
- Accomplished handling of essential concepts and results as well as of selected advanced topics

#### Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

#### Requires:
- Numerics 2 (MA4040-MML)
- Numerics 2 (MA4040)
- Numerics 1 (MA3110-MML)
- Numerics 1 (MA3110)

#### Responsible for this module:
- Prof. Dr. Andreas Rößler

#### Teacher:
- Institute for Mathematics
- Prof. Dr. Andreas Rößler

#### Language:
- Offered only in German

#### Notes:
- Literature will be announced in the lecture.
- Criteria for admission to the examination will be established by the lecturer.
### MA4620 - Statistische Versuchsplanung

<table>
<thead>
<tr>
<th>Duration:</th>
<th>1 Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Every third semester</td>
</tr>
<tr>
<td>Credit points:</td>
<td>4</td>
</tr>
</tbody>
</table>

#### Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics

#### Classes and lectures:
- Statistische Versuchsplanung (Lecture, 2 SWS)
- Statistische Versuchsplanung (Exercise, 1 SWS)

#### Workload:
- 60 Hours Private studies
- 45 Hours Presence studies
- 15 Hours Test preparation

#### Contents of teaching:
- Lineare Modelle und Stichprobenzahlplanung (Wiederholung)
- Randomisierte (Block-)Pläne, Lateinische Quadrate, Faktorielle Versuchsplanung, Balanzierte und unvollständige Blockpläne
- Response Surface Exploration
- Optimale Versuchspläne in Regressionsproblemen
- Ausgewählte Beispiele aus den Life Sciences

#### Qualification-goals/Competencies:
- Verständnis der grundsätzlichen Bedeutung und Möglichkeiten der Versuchsplanung
- Überblick wichtiger Fragestellungen und Methoden
- Detailkenntnisse in ausgewählten Bereichen

#### Grading through:
- Exercises
- Viva Voce
- Test

#### Requires:
- Stochastics 2 (MA4020)
- Stochastics 1 (MA2510)
- Biostatistics 2 (MA2600)
- Biostatistics 1 (MA1600)

#### Teacher:
- Institute for Mathematics
- Prof. Dr. Karsten Keller

#### Language:
- Offered only in German
<table>
<thead>
<tr>
<th>MA4630 - Fourier Analysis (FourierAna)</th>
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</thead>
<tbody>
<tr>
<td><strong>Duration:</strong> 1 Semester</td>
</tr>
<tr>
<td><strong>Turnus of offer:</strong> Irregular</td>
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<tr>
<td><strong>Credit points:</strong> 4</td>
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</table>

<table>
<thead>
<tr>
<th>Course of study, specific field and term:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Bachelor MML (choice), Mathematics, 5. or 6. term</td>
</tr>
<tr>
<td>• Master MES (Optional Subject), Mathematics</td>
</tr>
<tr>
<td>• Master MML (choice), Mathematics, Arbitrary semester</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classes and lectures:</th>
<th>Workload:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fourier Analysis (Lecture, 2 SWS)</td>
<td>• 65 Hours Private studies</td>
</tr>
<tr>
<td>• Fourier Analysis (Exercise, 1 SWS)</td>
<td>• 45 Hours Presence studies</td>
</tr>
<tr>
<td>• 65 Hours Private studies</td>
<td>• 10 Hours Test preparation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contents of teaching:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Theory of the Fourier transform</td>
</tr>
<tr>
<td>• Fourier transform in the Hilbert space</td>
</tr>
<tr>
<td>• Summability methods</td>
</tr>
<tr>
<td>• Applying Fourier transforms in solving differential equations</td>
</tr>
<tr>
<td>• Laplace and Mellin transforms</td>
</tr>
<tr>
<td>• Numerical aspects and relation to discrete Fourier transforms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Qualification-goals/Competencies:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Knowledge of integral transforms</td>
</tr>
<tr>
<td>• A comprehensive understanding for the Fourier transform</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grading through:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Exercises</td>
</tr>
<tr>
<td>• Test</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Responsible for this module:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Prof. Dr. rer. nat. Jürgen Prestin</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teacher:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Institute for Mathematics</td>
</tr>
<tr>
<td>• Prof. Dr. rer. nat. Jürgen Prestin</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literature:</th>
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</thead>
<tbody>
<tr>
<td>• Chandrasekharan, K.: Classical Fourier Transforms - Springer 1989</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Language:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Offered only in German</td>
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<tr>
<td>MA4640 - Sampling in der Signalanalyse</td>
</tr>
<tr>
<td>---------------------------------------</td>
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<tr>
<td><strong>Duration:</strong> 1 Semester</td>
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**Course of study, specific field and term:**
- Bachelor MML (choice), Mathematics, 5. or 6. term
- Master MES (Optional Subject), Mathematics
- Master MML (choice), Arbitrary semester

**Classes and lectures:**
- Sampling-Verfahren in der Signalanalyse (Seminar, 2 SWS)

**Workload:**
- 70 Hours Private studies
- 30 Hours Presence studies
- 20 Hours

**Contents of teaching:**
- Hilberträume, Basen und Frames
- Endliches und Unendliches Sampling
- Anwendungen auf lineare gewöhnliche Differentialgleichungen
- Multi-band und Multi-channel Sampling
- Sampling und Eigenwert-Probleme

**Qualification-goals/Competencies:**
- 
- 
- 

**Grading through:**
- Recitation
- Written elaboration
- Participation on discussions

**Teacher:**
- Institute for Mathematics
- Prof. Dr. rer. nat. Jürgen Prestin

**Language:**
- Offered only in German
<table>
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<tr>
<th>MA4650 - Matrix algebra (MatrixAlg)</th>
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<td><strong>Duration:</strong> 1 Semester</td>
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<tr>
<td><strong>Turnus of offer:</strong> Each semester</td>
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<td><strong>Credit points:</strong> 4</td>
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<tr>
<td><strong>Max. group size:</strong> 20</td>
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**Course of study, specific field and term:**
- Master MML (Optional Subject), Mathematics, Arbitrary semester
- Master MES (Optional Subject), Mathematics, 1. Term
- Bachelor MML (Optional Subject), Mathematics, 6. Term

**Classes and lectures:**
- Matrix algebra (Lecture, 2 SWS)
- Matrix algebra (Exercise, 1 SWS)

**Workload:**
- 60 Hours Self studies and exercises
- 45 Hours Presence studies
- 15 Hours Test preparation

**Contents of teaching:**
- Properties of matrices
- Special matrices
- Quadratic forms
- Decompositions
- Generalized inverses
- Differentiation
- Probability calculation
- Derivation and calculation of estimators
- Design matrices
- Linear hypotheses
- Examples: multiple linear regression, weighted least-squares estimation, shrinkage estimation

**Qualification-goals/Competencies:**
- Understanding of typical derivation techniques needed for generalized linear models and multivariate methods
- Command of matrix algebra
- Application of linear algebra to linear models
- Ability to work on practical statistical problems using matrix algebra

**Grading through:**
- Test

**Requires:**
- Biostatistics 1 (MA1600)
- Analysis 2 (MA2500-MML)

**Responsible for this module:**
- Prof. Dr. rer. nat. Andreas Ziegler

**Teacher:**
- Institute of Medical Biometry and Statistics
- Prof. Dr. rer. nat. Andreas Ziegler
- Dr. Reinhard Vonthein

**Literature:**

**Language:**
- Offered only in German
# MA4660 - Prognostic models (PM)

<table>
<thead>
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<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
<th>Max. group size:</th>
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</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Irregular</td>
<td>4</td>
<td>20</td>
</tr>
</tbody>
</table>

## Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics
- Master MML (choice), Mathematics, Arbitrary semester

## Classes and lectures:
- Prognostic models (Lecture, 2 SWS)
- Prognostic models (Exercise, 1 SWS)

## Workload:
- 60 Hours Private studies
- 45 Hours Presence studies
- 15 Hours Test preparation

## Contents of teaching:
- Aims and applications of prognostic models
- General approach to develop valid prognostic models
- Classical statistical approaches to develop prognostic models
- Approaches to validate prognostic models
- Alternative approaches to develop prognostic models: Classification and Regression Trees, ensemble methods, support vector machines

## Qualification-goals/Competencies:
- Understanding the application as well as the general approach to develop valid prognostic models
- Mastering the most important classical statistical approaches to develop prognostic models
- Mastering the most important alternative approaches to develop prognostic models
- Mastering different methods to validate prognostic models
- Applying basic approaches by hand and more complex approaches computer-based

## Grading through:
- Test

## Requires:
- Biostatistics 2 (MA2600)
- Statistics - Practical Course (MA3210)

## Responsible for this module:
- Prof. Dr. rer. biol. hum. Inke R. König
- Prof. Dr. rer. nat. Andreas Ziegler

## Teacher:
- Institute of Medical Biometry and Statistics
- Prof. Dr. rer. biol. hum. Inke R. König
- Prof. Dr. rer. nat. Andreas Ziegler

## Language:
- Offered only in German
### MA4670 - Combinatorics (Kombi)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Irregular</td>
<td>4</td>
</tr>
</tbody>
</table>

#### Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics
- Master MML (choice), Mathematics, Arbitrary semester
- Bachelor MML (choice), Mathematics, 5. or 6. term

#### Classes and lectures:
- combinatorics (Lecture, 2 SWS)
- combinatorics (Exercise, 1 SWS)

#### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

#### Contents of teaching:
- Permutations, combinations, variations
- Partitions
- Generating functions
- Recurrence equations
- Sums and differences
- Inclusion - exclusion

#### Qualification-goals/Competencies:
- Learning the basics of combinatorics
- Knowledge of different proof techniques and combinatorial approaches
- Teaching fundamental results and deepening some selected aspects of combinatorics

#### Grading through:
- Exercises
- Viva Voce

#### Requires:
- Analysis 1 (MA2000)
- Linear Algebra and Discrete Structures 2 (MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000)

#### Responsible for this module:
- PD Dr. rer. nat. Hanns-Martin Teichert

#### Teacher:
- Institute for Mathematics
- PD Dr. rer. nat. Hanns-Martin Teichert

#### Literature:
- Peter Tittmann: Einführung in die Kombinatorik - Spektrum Akademischer Verlag 2000
- Richard A. Brualdi: Introductory Combinatorics - Pearson Prentice Hall 2004

#### Language:
- Offered only in German
### MA4700 - Angewandte Analysis

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each winter semester</td>
<td>4</td>
</tr>
</tbody>
</table>

**Course of study, specific field and term:**
- Master MES (Optional Subject), Mathematics, 1. Term
- Master MML (choice), Mathematics, Arbitrary semester
- Bachelor MML (choice), Mathematics, 6. Term

**Classes and lectures:**
- Angewandte Analysis (Vertiefungsveranstaltung) (Lecture, 2 SWS)
- Angewandte Analysis (Vertiefungsveranstaltung) (Exercise, 1 SWS)

**Workload:**
- 60 Hours Private studies
- 45 Hours Presence studies
- 15 Hours Test preparation

**Contents of teaching:**
- Maße und ihre Konstruktion
- Messbare Funktionen, Integration, Konvergenzsätze
- Produktmaße, Fubini
- Satz von Radon-Nikodym
- Lebesgue-Maße, Transformationsformel
- Kurven- und Oberflächenintegrale
- Integralsätze
- Partielle Differentialgleichungen erster Ordnung (Zusammenhang mit Systemen gewöhnlicher Differentialgleichungen)
- Klassifikation von Gleichungen zweiter Ordnung
- Beispielhafte Behandlung der drei Grundtypen

**Qualification-goals/Competencies:**
- Anwendungsbereites Verständnis der abstrakten Maß- und Integrationstheorie und ihrer konkreten Anwendungen in euklidischen Räumen
- Einführung in die Theorie partieller Differentialgleichungen
- Erlernen hierzu grundlegender analytischer Hilfsmittel
- Stärkung des Verständnisses für Modellierung

**Grading through:**
- Exercises
- Test

**Teacher:**
- Institute for Mathematics
- Prof. Dr. rer. nat. Jürgen Prestin

**Language:**
- Offered only in German
## MA4710 - Functional Analysis (FunkAna)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
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<tbody>
<tr>
<td>1 Semester</td>
<td>Irregular</td>
<td>4</td>
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</table>

### Course of study, specific field and term:
- Master MES (Optional Subject), Mathematics
- Master MML (choice), Mathematics, Arbitrary semester
- Bachelor MML (choice), Mathematics, 5. or 6. term

### Classes and lectures:
- Functional Analysis (Lecture, 2 SWS)
- Functional Analysis (Exercise, 1 SWS)

### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- Metric spaces and their topology
- Banach spaces, Hilbert spaces and their geometry
- Duality, Hahn-Banach theorems
- Bounded linear operators, open mapping principle
- $L^p$-spaces and the theorem of Riesz-Fischer
- Weak topologies and reflexive spaces

### Qualification-goals/Competencies:
- Learning the basic techniques for the analysis of linear functionals and operators on Banach and Hilbert spaces
- Study of the fundamental principles of functional analysis

### Grading through:
- Exercises
- Viva Voce

### Responsible for this module:
- Dr. rer. nat. Wolfgang Erb

### Teacher:
- Institute for Mathematics
- Dr. rer. nat. Wolfgang Erb

### Literature:

### Language:
- Offered only in German
<table>
<thead>
<tr>
<th>MA4800 - Differenzialgeometrie</th>
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<tbody>
<tr>
<td><strong>Duration:</strong> 1 Semester</td>
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<tr>
<td><strong>Turnus of offer:</strong> Every second year</td>
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<tr>
<td><strong>Credit points:</strong> 4</td>
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</table>

**Course of study, specific field and term:**
- Master MES (Optional Subject), Mathematics
- Master MML (choice), Mathematics, Arbitrary semester
- Bachelor MML (choice), Mathematics, 6. Term

**Classes and lectures:**
- Differenzialgeometrie (Lecture, 2 SWS)
- Differenzialgeometrie (Exercise, 1 SWS)

**Workload:**
- 60 Hours Private studies
- 45 Hours Presence studies
- 15 Hours Test preparation

**Contents of teaching:**

**Qualification-goals/Competencies:**

**Grading through:**
- Exercises
- Test or Viva voce, made available by the lecturer

**Teacher:**
- Institute for Mathematics
- Prof. Dr. Reinhard Schuster

**Language:**
- Offered only in German
<table>
<thead>
<tr>
<th>Module Guide</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA4802 - Spezielle und allgemeine Relativitätstheorie</td>
</tr>
</tbody>
</table>

**Duration:** 1 Semester  
**Turnus of offer:** Every second year  
**Credit points:** 4

**Course of study, specific field and term:***
- Master MES (Optional Subject), Mathematics
- Master MML (choice), Mathematics, Arbitrary semester
- Bachelor MML (choice), Mathematics, 5. or 6. term

**Classes and lectures:**
- Spezielle und allgemeine Relativitätstheorie (Lecture, 2 SWS)
- Spezielle und allgemeine Relativitätstheorie (Exercise, 1 SWS)

**Workload:**
- 60 Hours Private studies
- 45 Hours Presence studies
- 15 Hours Test preparation

**Contents of teaching:**

**Grading through:**
- Exercises
- Test or Viva voce, made available by the lecturer

**Teacher:**
- Institute for Mathematics
- Prof. Dr. Reinhard Schuster

**Language:**
- Offered only in German
### MA5030 - Image Registration (Bildregist)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
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</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Every second winter semester</td>
<td>4</td>
</tr>
</tbody>
</table>

**Course of study, specific field and term:**
- Master Medical Informatics SJ14 (Optional Subject), medical computer science
- (Optional Subject), 1. Term
- Master Computer Science (Optional Subject), advanced curriculum Imaging Systems, 2. or 3. term
- Master MES (Optional Subject), Mathematics, 1st or 3rd term
- Master MES (Consolidating), 1st or 3rd term
- Master MML (Optional Subject), Mathematics, 1st or 3rd term
- Master Computer Science (Optional Subject), advanced curriculum Numerical Image Processing, 2. or 3. term

**Classes and lectures:**
- Image Registration (Lecture, 2 SWS)
- Image Registration (Exercise, 1 SWS)

**Workload:**
- 65 Hours Self studies and exercises
- 45 Hours Presence studies
- 10 Hours Test preparation

**Contents of teaching:**
- Introduction and foundation
- Interpolation
- Models for transformations
- Landmark-based registration
- Parametric registration
- Elastic registration
- Constrained registration

**Qualification-goals/Competencies:**
- Knowledge of fundamental concepts for image registration
- Translation of concrete problems into adequate models
- Handling of parametric and non-parametric registration problems

**Grading through:**
- Test or Viva voce, made available by the lecturer

**Is requisite for:**
- Numerical Methods for Image Computing (MA5032)

**Requires:**
- Linear Algebra and Discrete Structures 1 (MA1000)
- Analysis 1 (MA2000)

**Responsible for this module:**
- Prof. Dr. Jan Modersitzki

**Teacher:**
- Institute of Mathematics and Image Computing
- N.N.
  - Prof. Dr. Jan Modersitzki

**Literature:**
- Goshtasby: 2D and 3D Image Registration - Wiley 2005
- Rohr: Landmark-Based Image Analysis - Kluwer 2001
## MA5034 - Calculus of Variations and Partial Differential Equations (VariPDE)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
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<tbody>
<tr>
<td>1 Semester</td>
<td>Every second summer semester</td>
<td>4</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Master Medical Informatics SJ14 (Optional Subject)
- Master MES (Optional Subject), Mathematics, 2nd or 4th term
- Master Computer Science (Optional Subject), advanced curriculum Numerical Image Processing, 2. or 3. term
- Master MES (Consolidating), 2nd or 4th term
- Master MML (choice), Mathematics, 2nd or 4th term
- Bachelor MML (Optional Subject), Mathematics

### Classes and lectures:
- Calculus of Variations and Partial Differential Equations (Lecture, 2 SWS)
- Calculus of Variations and Partial Differential Equations (Exercise, 1 SWS)

### Workload:
- 65 Hours Private studies
- 45 Hours Presence studies
- 10 Hours Test preparation

### Contents of teaching:
- Introduction to the calculus of variations
- Introduction to partial differential equations
- Application to deblurring
- Application to segmentation
- Application to registration

### Qualification-goals/Competencies:
- Acquisition of state-of-the-art mathematical methods for imaging
- Transfer of knowledge to current and practice-relevant problems in image processing
- Numerical realization of selected approaches

### Grading through:
- Test or Viva voce, made available by the lecturer

### Requires:
- Linear Algebra and Discrete Structures 1 (MA1000)
- Analysis 1 (MA2000)
- Mathematical Methods in Image Processing (MA4500)

### Responsible for this module:
- Prof. Dr. Jan Modersitzki

### Teacher:
- Institute of Mathematics and Image Computing
- Prof. Dr. Jan Modersitzki

### Literature:
- Chan & Shen: Image Processing and Analysis - SIAM 2005
- Vogel: Computational Methods for Inverse Methods - SIAM 2002

### Language:
<table>
<thead>
<tr>
<th><strong>ME4030 - Inverse Probleme bei der Bildgebung (InversProb)</strong></th>
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<tbody>
<tr>
<td><strong>Duration:</strong> 1 Semester</td>
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<tr>
<td><strong>Turnus of offer:</strong> Irregular</td>
</tr>
<tr>
<td><strong>Credit points:</strong> 4</td>
</tr>
</tbody>
</table>

**Course of study, specific field and term:**
- (Optional Subject), Medical Engineering Sciences
- Master MES (Optional Subject), Mathematics
- Master Computer Science (Optional Subject), advanced curriculum Signal and Image Processing, 2. or 3. term
- Master Computer Science (Optional Subject), Enhanced course robotics and automation, 3. Term
- Master Computer Science (Optional Subject), Enhanced course medical computer science, 3. Term
- Master Computer Science (Optional Subject), advanced curriculum Imaging Systems, 2. or 3. term
- Master MES (Consolidating)
- Master MML (choice), Mathematics, 1. and 2. term

**Classes and lectures:**
- Tomographische Verfahren II: Inverse Probleme bei der Bildgebung (Lecture, 2 SWS)
- Tomographische Verfahren II: Inverse Probleme bei der Bildgebung (Exercise, 1 SWS)

**Contents of teaching:**
- Introduction to inverse and ill-posed problems (e.g. seismology, impedance tomography, heat equation)
- Hadamard and ill-conditioned problems
- SVD and Fourier-based methods in imaging
- Out-of-focus effects due to movement
- Image-deconvolution
- Regularisation methods
- Iterative regularisation methods, e.g. Landweber
- Statistical methods as Bayes and Maximum Likelihood
- Computed Tomography, Magnetic Particle Imaging, Modelling of tumour progression

**Qualification-goals/Competencies:**
- Ability to use regularisation methods for ill-posed problems
- Learn about the connection of physical acquisitions and quality of the signal
- Ability to apply the learned methods to real data

**Grading through:**
- Test or Viva voce, made available by the lecturer

**Responsible for this module:**
- Prof. Dr. rer. nat. Thorsten Buzug

**Teacher:**
- Institute of Medical Engineering
- Prof. Dr. rer. nat. Thorsten Buzug

**Literature:**
- Andreas Rieder: Keine Probleme mit inversen Problemen - Vieweg, Wiesbaden, 2003

**Language:**
- Offered only in German
# PS4620 - Ethics in Science (EthikMIW)

## Duration:
- 1 Semester
- Each summer semester

## Turnus of offer:
- Each summer semester

## Credit points:
- 3

## Course of study, specific field and term:
- Master MES (compulsory), Interdisciplinary competence, 2. Term

## Classes and lectures:
- PS4620: Ethics in Sciences (Lecture with exercises or seminar, 2 SWS)

## Workload:
- 40 Hours Private studies
- 30 Hours Presence studies
- 20 Hours Test preparation

## Contents of teaching:
- Societal and ethical implications of research in biomedical sciences and technologies
- Basics of philosophy and sociology of science
- Good scientific practice
- Basics of bioethics: duties of investigators, obligations to colleagues,
- Use and implications of images in science

## Qualification-goals/Competencies:
- Understanding of basic ethical implications of human actions and decisions
- Understanding of ethical implication of experimental scientific research
- Understanding of basic dimensions of philosophy and sociology of science and technology
- Knowledge of relevant legal regulations in Germany and internationally
- Knowledge of key debates in bioethics and research ethics
- Basic skills for an autonomous ethical reflection about issues in biomedical sciences

## Grading through:
- Test

## Responsible for this module:
- Prof. Dr. phil. Christoph Rehmann-Sutter

## Teacher:
- Institute for the History of Medicine and Science Studies
- Prof. Dr. phil. Christoph Rehmann-Sutter
- Prof. Dr. med. Cornelius Borck
- Prof. Dr. rer. nat. Burghard Weiss

## Literature:
- Daniel A. Vallero: Biomedical Ethics for Engineers. Ethics and Decision Making in Biomedical and Biosystem Engineering - Amsterdam: Elsevier 2007
- Sergio Sismondo: An introduction to science and technology studies - Chichester: Wiley-Blackwell 2010

## Language:
- German and English skills required
# LS4600 C - Biophysik und Biomedizinische Optik: Modulteil C: Biophysik 1 (BiPh1)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each winter semester</td>
<td>4</td>
</tr>
</tbody>
</table>

## Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 1. Term

## Classes and lectures:
- Biophysik I (Lecture, 2 SWS)
- Biophysik I (Exercise, 1 SWS)

## Workload:
- 55 Hours Self studies and exercises
- 45 Hours Presence studies
- 20 Hours Test preparation

## Contents of teaching:
- Einführung: Biomoleküle und molekulare Prozesse
- Physikalische Wechselwirkungen bestimmen die Struktur von Proteinen: Coulomb- und van-der-Waals-Wechselwirkung
- Grundlagen der Proteindynamik
- Einführung in die Quantenmechanik anhand von Beispielen aus der Biophysik
- Methoden zur Charakterisierung von Biomolekülen - Optische Spektroskopie (UV-Vis) - Infrarot-Spektroskopie (IR) - Elektronparamagnetische Resonanz (EPR) - Mössbauer Spektroskopie - Elektronenmikroskopie - Kraftmikroskopie - Proteinkristallographie (Röntgenstrukturanalyse) - Röntgenabsorptionspektroskopie (EXAFS, XANES) - Röntgenkleinwinkelstreueung

## Qualification-goals/Competencies:
- Erkennen und Verstehen von physikalischen Phänomene in der Biologie
- Beherrschen von grundlegenden Methoden zur Charakterisierung von Biomolekülen
- Anwenden der Methoden durch selbstständige Vertiefung auf biologische Fragestellungen

## Grading through:
- Viva Voce
- Exercises

## Teacher:
- Institute of Physics
  - Prof. Dr. rer. nat. Holger Notbohm
  - PD Dr. rer. nat. Hauke Paulsen
  - Prof. Dr. rer. nat. Christian Hübner

## Literature:
- :
- :

## Language:
- Offered only in German
### LS4600 D - Biophysik und Biomedizinische Optik: Modulteil D: Biophysik 2, Instrumentierung in der Biophysik (BioPh2)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>1 Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Each summer semester</td>
</tr>
<tr>
<td>Credit points:</td>
<td>4</td>
</tr>
</tbody>
</table>

**Course of study, specific field and term:**
- Master MES (compulsory), Medical Engineering Sciences, 2. Term

**Classes and lectures:**
- Biophysik 2, Instrumentierung in der Biophysik (Lecture with Exercises, 3 SWS)

**Workload:**
- 135 Hours Private studies
- 75 Hours Presence studies

**Contents of teaching:**

**Grading through:**
- Test

**Responsible for this module:**
- Prof. Dr. rer. nat. Thomas Gutsmann

**Teacher:**
- Research Center Borstel
- Prof. Dr. rer. nat. Thomas Gutsmann

**Language:**
- English, except in case of only German-speaking participants
### ME4400 - Bildgebende Systeme, Signal- und Bildverarbeitung (BSSB)

<table>
<thead>
<tr>
<th>Duration: 2 Semester</th>
<th>Turnus of offer: Each winter semester</th>
<th>Credit points: 16</th>
</tr>
</thead>
</table>

**Course of study, specific field and term:**
- Master MES (compulsory), Medical Engineering Sciences, 1. and 2. term

**Classes and lectures:**
- ME4000 - Bildgebende Systeme 1 (Lecture with Exercises, 3 SWS)
- ME4020 - Bildgebende Systeme 2 (Lecture with Exercises, 3 SWS)
- CS3100 - Signalverarbeitung (Lecture with Exercises, 3 SWS)
- CS3203 - Bildverarbeitung (Lecture with Exercises, 3 SWS)

**Workload:**
- 220 Hours Private studies
- 180 Hours Presence studies
- 80 Hours Test preparation

**Contents of teaching:**

**Qualification-goals/Competencies:**

**Grading through:**
- Test or Viva voce, made available by the lecturer

**Responsible for this module:**
- Prof. Dr. rer. nat. Thorsten Buzug
- Prof. Dr.-Ing. Alfred Mertins
- Prof. Dr. rer. nat. Martin Koch

**Teacher:**
- Institute for Signal Processing
- Institute of Medical Engineering

**Language:**
- German and English skills required
ME4400 A - Module Part A: Imaging Systems 1 (BS1)

**Duration:** 1 Semester
**Turnus of offer:** Each winter semester
**Credit points:** 4

**Course of study, specific field and term:**
- Master MES (compulsory), Medical Engineering Sciences, 1. Term

**Classes and lectures:**
- Imaging Systems 1 (Lecture, 2 SWS)
- Imaging Systems 1 (Exercise, 1 SWS)

**Workload:**
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**
- Signal processing (recapitulation of fundamental principles in signal processing)
- Mathematical methods in image reconstruction and signal processing
- X-Ray (fundamental principles, quantum statistics)

**Qualification-goals/Competencies:**
- This lecture gives a comprehensive overview of the main signal processing and system analysis methods in medical imaging. The basis of the reconstruction is undoubtedly mathematics. However, the beauty of e.g. computed tomography cannot be understood without a basic knowledge of X-ray physics, signal processing concepts and measurement systems. Therefore, students will be provided with a number of references to these basic disciplines as well as a brief introduction to many of the underlying principles. The main application focus of the lecture is given to computed tomography. The lecture is structured to cover the basics of signals and systems within CT, from photon statistics to modern cone-beam systems. However, without an elementary knowledge of X-ray physics, a number of the described imaging effects and artifacts cannot readily be understood. In the main part of the lecture the principles of signal processing are reviewed. This part focuses on the necessary background of computed tomography and, consequently, introducing the Fourier transform. Subsequently, a detailed overview of two-dimensional reconstruction mathematics is given as a straightforward application of the Fourier principles. Then, algebraic and statistical approaches are explained as a general tool for signal analysis and over-determined system solution. In the last lessons three-dimensional methods of CT image or volume reconstruction are reviewed. It is shown that some of the ideas are consequent extensions of the methods discussed at the beginning of the lecture. The methods described here represent the basis of a highly active field of research.

**Grading through:**
- Viva Voce

**Responsible for this module:**
- Prof. Dr. rer. nat. Thorsten Buzug

**Teacher:**
- Institute of Medical Engineering
- Prof. Dr. rer. nat. Thorsten Buzug

**Literature:**
- T. M. Buzug: Einführung in die Computertomographie, Mathematisch-physikalische Grundlagen der Bildrekonstruktion - Springer-Verlag, Berlin/Heidelberg, 2004

**Language:**
- Offered only in English
# Module Guide

## ME4400 B - Module Part B: Imaging Systems 2 (BS2)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
<th>Max. group size:</th>
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</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each summer semester</td>
<td>4</td>
<td>99</td>
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</tbody>
</table>

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 2. Term

### Classes and lectures:
- Imaging Systems II (Lecture, 2 SWS)
- Imaging Systems II (Exercise, 1 SWS)

### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- Fundamentals of magnetic resonance imaging (nuclear magnetic resonance, principles of spatial encoding, relaxation)
- Description of the measurement in k-space
- Basic pulse sequences
- Hardware components of an MR imaging system, influence of experimental parameters on the signal-to-noise ratio in an image, image artefact mechanisms
- Functional and diffusion weighted MR imaging, angiography, and spectroscopy
- Clinical applications of MR imaging

### Qualification-goals/Competencies:
- Knowledge of physical principles behind MR imaging
- Knowing how important pulse sequences work
- Being able to trace down the origin of image artefacts
- Having a basic overview of the pros and cons of MR imaging

### Grading through:
- Test or Viva voce, made available by the lecturer

### Responsible for this module:
- Prof. Dr. rer. nat. Martin Koch

### Teacher:
- Institute of Medical Engineering
- Prof. Dr. rer. nat. Martin Koch

### Literature:

### Language:
- German and English skills required
### ME4400 C - Module Part C: Signal processing (SV)

**Duration:** 1 Semester  
**Turnus of offer:** Each winter semester  
**Credit points:** 4

**Course of study, specific field and term:**  
● Master MES (compulsory), Medical Engineering Sciences, 1. Term

**Classes and lectures:**  
- Signal processing (Lecture, 2 SWS)  
- Signal processing (Exercise, 1 SWS)

**Contents of teaching:**  
- Linear time-invariant systems  
- Impulse response  
- Convolution  
- Fourier transform  
- Transfer function  
- Correlation and energy density of deterministic signals  
- Sampling  
- Discrete-time signals and systems  
- Discrete-time Fourier transform  
- z-Transform  
- FIR and IIR filters  
- Block diagrams  
- FIR filter design  
- Discrete Fourier transform (DFT)  
- Fast Fourier transform (FFT)  
- Characterization and processing of random signals

**Workload:**  
- 55 Hours Private studies  
- 45 Hours Presence studies  
- 20 Hours Test preparation

**Qualification-goals/Competencies:**  
- Students will know the basic elements of linear system theory and signal processing  
- They will have a command of methods for the description and analysis of continuous-time and discrete-time signals and systems  
- They are able to designs digital filters and know various structures for their implementation  
- They will know the basic techniques for describing and processing of random signals

**Grading through:**  
- Exercises  
- Test or Viva voce, made available by the lecturer

**Is requisite for:**  
- Image processing (CS3203)

**Requires:**  
- Analysis 1 (MA2000)

**Teacher:**  
- Institute for Signal Processing  
- Prof. Dr.-Ing. Alfred Mertins

**Literature:**  
- B. Girod, R. Rabenstein, and A. Stenger: Einführung in die Systemtheorie - Teubner, 3. Auflage, 2005  
<table>
<thead>
<tr>
<th>Language:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offered only in German</td>
</tr>
</tbody>
</table>
# ME4400 D - Module Part D: Image processing (BV)

### Duration:
1 Semester

### Turnus of offer:
Each summer semester

### Credit points:
4

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 2. Term

### Classes and lectures:
- Image processing (Lecture, 2 SWS)
- Image processing (Exercise, 1 SWS)

### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- Introduction, meaning of visual information
- Fourier Transformation
- Sampling and sampling theorem
- Filtering
- Image enhancement
- Edge detection
- Multiresolution concepts: Gaussian and Laplacian Pyramid, Wavelets
- Principles of image compression
- Segmentation
- Morphological image processing

### Qualification-goals/Competencies:
- Students will have basic knowledge of the two-dimensional system theory
- They will know the main techniques for image analysis and image enhancement
- They will be able to use the learned principles in practice

### Grading through:
- Exercises
- Programming project
- Test or Viva voce, made available by the lecturer

### Requires:
- Signal processing (CS3100)
- Analysis 1 (MA2000)

### Teacher:
- Institute for Signal Processing
- Prof. Dr.-Ing. Alfred Mertins

### Literature:
- Bernd Jähne: Digitale Bildverarbeitung - Springer, Berlin 2005

### Language:
- Offered only in German
## ME4600 - Biophysik und Biomedizinische Optik (BBO)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>2 Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Each winter semester</td>
</tr>
<tr>
<td>Credit points:</td>
<td>16</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 1. and 2. term

### Classes and lectures:
- ME4100 - Biomedizinische Optik 1 (Lecture with Exercises, 3 SWS)
- ME4120 - Biomedizinische Optik 2 (Lecture with Exercises, 3 SWS)
- LS4125 - Biophysik 1 (Lecture with Exercises, 3 SWS)
- LS4130 - Biophysik 2 (Lecture with Exercises, 3 SWS)

### Workload:
- 220 Hours Private studies
- 180 Hours Presence studies
- 80 Hours Test preparation

### Contents of teaching:

### Qualification-goals/Competencies:

### Grading through:
- Test or Viva voce, made available by the lecturer

### Responsible for this module:
- Prof. Dr. rer. nat. Christian Hübner

### Teacher:
- Research Center Borstel
- Institute of Physics
- Institute of Biomedical Optics
- Prof. Dr. rer. nat. Alfred Vogel
- PD Dr. rer. nat. Gereon Hüttmann
- Prof. Dr. rer. nat. Christian Hübner
- PD Dr. rer. nat. Hauke Paulsen
- Prof. Dr. rer. nat. Holger Notbohm
- Prof. Dr. rer. nat. Thomas Gutschmann

### Language:
- Offered only in German
# ME4600 A - Biophysik und Biomedizinische Optik: Modulteil A: Biomedizinische Optik 1 (BMO1)

| Duration: | 1 Semester |
| Turnus of offer: | Each winter semester |
| Credit points: | 4 |

**Course of study, specific field and term:**
- Master MES (compulsory), Medical Engineering Sciences, 1. Term

**Classes and lectures:**
- Lecture Biomedical Optics 1 (Lecture, 2 SWS)
- Exercise Biomedical Optics 1 (Exercise, 1 SWS)

**Workload:**
- 55 Hours Self studies and exercises
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**

**Qualification-goals/Competencies:**

**Grading through:**
- Test or Viva voce, made available by the lecturer

**Is requisite for:**
- Moderne Techniken der biomedizinischen Optik 2 (ME4120)

**Teacher:**
- Institute of Biomedical Optics
- Prof. Dr. rer. nat. Alfred Vogel
- PD Dr. rer. nat. Gereon Hüttmann

**Language:**
- Offered only in German
<table>
<thead>
<tr>
<th>Duration:</th>
<th>1 Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Each summer semester</td>
</tr>
<tr>
<td>Credit points:</td>
<td>4</td>
</tr>
</tbody>
</table>

**Course of study, specific field and term:**
- Master MES (compulsory), Medical Engineering Sciences, 2. Term

**Classes and lectures:**
- Moderne Techniken der biomedizinischen Optik II (Lecture, 2 SWS)
- Moderne Techniken der biomedizinischen Optik II (Exercise, 1 SWS)

**Workload:**
- 45 Hours Presence studies
- 40 Hours Private studies
- 20 Hours Test preparation
- 15 Hours Presentation (including preparation)

**Contents of teaching:**

**Qualification-goals/Competencies:**

**Grading through:**
- Participation on discussions
- Test or Viva voce, made available by the lecturer
- Recitation

**Requires:**
- Moderne Techniken der biomedizinischen Optik 1 (ME4100)

**Teacher:**
- Institute of Biomedical Optics
- Prof. Dr. rer. nat. Alfred Vogel
- PD Dr. rer. nat. Gereon Hüttmann

**Language:**
- Offered only in German
<table>
<thead>
<tr>
<th><strong>ME5500 - Internship 1 (ProjPrak1)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration:</strong> 1 Semester</td>
</tr>
<tr>
<td><strong>Course of study, specific field and term:</strong></td>
</tr>
<tr>
<td>● (compulsory), Medical Engineering Sciences, 3. Term</td>
</tr>
<tr>
<td>● Master MES (compulsory), Medical Engineering Sciences, 3. Term</td>
</tr>
<tr>
<td><strong>Classes and lectures:</strong></td>
</tr>
<tr>
<td>● Internship I (September-November) (project work, 9 SWS)</td>
</tr>
<tr>
<td><strong>Workload:</strong></td>
</tr>
<tr>
<td>● 280 Hours Work on project</td>
</tr>
<tr>
<td>● 60 Hours Self studies and exercises</td>
</tr>
<tr>
<td>● 20 Hours Written Presentation</td>
</tr>
<tr>
<td><strong>Contents of teaching:</strong></td>
</tr>
<tr>
<td>● Project task in a concrete application scenario</td>
</tr>
<tr>
<td>● Documentation, presentation, motivation in heterogeneous environments</td>
</tr>
<tr>
<td>● The project task is always embedded in heterogeneous and vivid environments with significant demands on communication integration, planning, interfaces, resources, etc.</td>
</tr>
<tr>
<td><strong>Qualification-goals/Competencies:</strong></td>
</tr>
<tr>
<td>● In-depth understanding and implementation of selected aspects of Medical Engineering</td>
</tr>
<tr>
<td>● Ability to document and present project results</td>
</tr>
<tr>
<td>● Ability to respond in a presentation to particular audiences or time restrictions (eg elevator pitch, etc.)</td>
</tr>
<tr>
<td>● Project experience in concrete application scenarios</td>
</tr>
<tr>
<td>● Development of project management skills</td>
</tr>
<tr>
<td><strong>Grading through:</strong></td>
</tr>
<tr>
<td>● Written elaboration</td>
</tr>
<tr>
<td>● Regular and successful participation in the practical course, min. 80%</td>
</tr>
<tr>
<td>● Documentation</td>
</tr>
<tr>
<td><strong>Teacher:</strong></td>
</tr>
<tr>
<td>● Medical technology companies at the Universität zu Lübeck or abroad with mandatory supervision by an university lecturer</td>
</tr>
<tr>
<td>● Scientific facilities at the Universität zu Lübeck or abroad with mandatory supervision by an university lecturer</td>
</tr>
<tr>
<td>● Clinics and institutes of the department of medicine</td>
</tr>
<tr>
<td>● Institutes of the department of natural science/computer science/engineering</td>
</tr>
<tr>
<td><strong>Language:</strong></td>
</tr>
<tr>
<td>● English, except in case of only German-speaking participants</td>
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# ME5510 - Internship 2 (ProjPrak2)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
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</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each winter semester</td>
<td>12 (Typ B)</td>
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</tbody>
</table>

### Course of study, specific field and term:
- (compulsory), Medical Engineering Sciences, 3. Term
- Master MES (compulsory), Medical Engineering Sciences, 3. Term

### Classes and lectures:
- Internship II (December-February) (project work, 9 SWS)

### Workload:
- 280 Hours Work on project
- 60 Hours Self studies and exercises
- 20 Hours Written Presentation

### Contents of teaching:
- Project task in a concrete application scenario
- Documentation, presentation, motivation in heterogeneous environments
- The project task is always embedded in heterogeneous and vivid environments with significant demands on communication integration, planning, interfaces, resources, etc.

### Qualification-goals/Competencies:
- In-depth understanding and implementation of selected aspects of Medical Engineering
- Ability to document and present project results
- Ability to respond in a presentation to particular audiences or time restrictions (e.g., elevator pitch, etc.)
- Project experience in concrete application scenarios
- Development of project management skills

### Grading through:
- Written elaboration
- Regular and successful participation in the practical course, min. 80%
- Documentation

### Teacher:
- Medical technology companies at the Universität zu Lübeck or abroad with mandatory supervision by an university lecturer
- Scientific facilities at the Universität zu Lübeck or abroad with mandatory supervision by an university lecturer
- Clinics and institutes of the department of medicine
- Institutes of the department of natural science/computer science/engineering

### Language:
- English, except in case of only German-speaking participants
<table>
<thead>
<tr>
<th><strong>ME5530 - Master-Seminar Medical Engineering Science (MSMIW)</strong></th>
</tr>
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<tbody>
<tr>
<td><strong>Duration:</strong> 1 Semester</td>
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<tr>
<td><strong>Course of study, specific field and term:</strong></td>
</tr>
<tr>
<td>● Master MES (compulsory), Medical Engineering Sciences, 3. Term</td>
</tr>
<tr>
<td><strong>Classes and lectures:</strong></td>
</tr>
<tr>
<td>● Active participation (with presentation) at the Student Conference (Course, 2 SWS)</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>Contents of teaching:</strong></td>
</tr>
<tr>
<td>● The Master Seminar comprises compulsory attendance at the student conference at which each student will give a presentation in English about the completed project internship. Active participation of all students at the scientific discussion is required.</td>
</tr>
<tr>
<td>● Because the content of the presentation should reflect the results of at least one of the project internships, the student is attended by the issuing supervisor of the respective internship project.</td>
</tr>
<tr>
<td><strong>Qualification-goals/Competencies:</strong></td>
</tr>
<tr>
<td>● Experience in a comprehensive review of a scientific topic.</td>
</tr>
<tr>
<td>● Students are able to get an extensive overview of a complex scientific area.</td>
</tr>
<tr>
<td>● Experience and ability to take an active part in scientific discussions.</td>
</tr>
<tr>
<td><strong>Grading through:</strong></td>
</tr>
<tr>
<td>● Recitation</td>
</tr>
<tr>
<td>● Seminar work</td>
</tr>
<tr>
<td><strong>Responsible for this module:</strong></td>
</tr>
<tr>
<td>● Prof. Dr. rer. nat. Thorsten Buzug</td>
</tr>
<tr>
<td><strong>Teacher:</strong></td>
</tr>
<tr>
<td>● Institutes of natural science</td>
</tr>
<tr>
<td>● Clinics and institutes of the department of medicine</td>
</tr>
<tr>
<td>● Informatic Institutes</td>
</tr>
<tr>
<td><strong>Language:</strong></td>
</tr>
<tr>
<td>● Offered only in English</td>
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</table>
### ME5990 - Master Thesis Medical Engineering (MAMIW)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
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<tbody>
<tr>
<td>1 Semester</td>
<td>Each semester</td>
<td>30</td>
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</tbody>
</table>

#### Course of study, specific field and term:
- (compulsory), Medical Engineering Sciences, 4. Term
- Master MES (compulsory), Medical Engineering Sciences, 4. Term

#### Classes and lectures:
- Colloquium (team work, 1 SWS)

#### Workload:
- 870 Hours Private studies
- 30 Hours Presentation (including preparation)

#### Contents of teaching:
- Required immersion on the chosen subject must be carried out in self-study.

#### Qualification-goals/Competencies:
- Students are able to solve a complex scientific problem by the means of their discipline.
- Experience in creating a challenging academic work in a given time
- Expert in a specialized field
- Experience in the study of scientific original literature
- Lecturing experience

#### Grading through:
- Recitation
- Written elaboration

#### Teacher:
- Institutes and hospitals of the University of Lübeck

#### Literature:
- :

#### Language:
- Thesis possible in German or English
## MZ4300 - Klinische Medizin 1 (KM1)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>1 Semester</th>
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<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Each winter semester</td>
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<tr>
<td>Credit points:</td>
<td>3</td>
</tr>
<tr>
<td>Max. group size:</td>
<td>40</td>
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</tbody>
</table>

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 1. Term

### Classes and lectures:
- Klinische Medizin 1 (Lecture, 2 SWS)

### Workload:
- 40 Hours Private studies
- 30 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:

### Qualification-goals/Competencies:

### Grading through:
- Test or Viva voce, made available by the lecturer

### Responsible for this module:
- PD Dr. med. Markus Kleemann
- PD Dr. med. Arndt P. Schulz
- PD Dr. med. Martin Kaiser
- Dr. med. Jens Cordes
- Prof. Dr. med. Martin Russlies

### Teacher:

### Literature:

### Language:
- Offered only in German
# MZ4320 - Klinische Medizin 2 (MZ2)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>1 Semester</th>
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<tbody>
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<td>Turnus of offer:</td>
<td>Each winter semester</td>
</tr>
<tr>
<td>Credit points:</td>
<td>3</td>
</tr>
<tr>
<td>Max. group size:</td>
<td>40</td>
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</tbody>
</table>

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 1. Term

### Classes and lectures:
- **HNO, Neurochirurgie, Augenheilkunde, Kieferchirurgie** (Lecture, 2 SWS)
- **MZ4320 A - Berufsfelderkundung Medizin 1** (Lecture, 1 SWS)

### Workload:
- 40 Hours Private studies
- 30 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- Practical implementation of medical technology in ophthalmology, ENT, oral and maxillofacial surgery as well as neurosurgery
- Application of medical technology procedures and their interaction with the patient
- Implementation of medical technology procedures in clinical processes of diagnostics and therapy

### Qualification-goals/Competencies:
- Knowledge of essential diseases in the fields of ophthalmology, ENT, oral and maxillofacial surgery and neurosurgery as well as surgical treatment principles
- Knowledge of the interaction between medical technology procedures and patient-oriented application

### Grading through:
- Test or Viva voce, made available by the lecturer

### Responsible for this module:
- Dr. med. Sabrina Heinrichs

### Teacher:
- Institute of Anatomy
- Department of Neurosurgery
- Prof. Dr. med. Jürgen Westermann

### Literature:
- Berghaus: Duale Reihe HNO
- Theissing: Praktische HNO-Lehre, Thieme-Verlag
- Howaldt/Schmelzeisen: Einführung in die Mund-, Kiefer-, Gesichtschirurgie - Verlag Urban und Fischer
- Schwenzer/Ehrenfeld: Zahn-Mund-Kiefer-Heilkunde - Thieme-Verlag, Stuttgart
- Moskopp/Wassmann: Neurochirurgie - Schattauer-Verlag
- Kampik: Laserjahrbuch der Augenheilkunde - Biermann-Verlag
- Lang: Augenheilkunde verstehen, lernen und anwenden - Thieme-Verlag

### Language:
- Offered only in German
## MZ4320 A - Module Part: Course Survey of Medical Professions 1 (Erkundung1)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each winter semester</td>
<td>1</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 1. Term

### Classes and lectures:
- Survey of Medical Professions 1 (Lecture, 1 SWS)
- 25 Hours Presence studies

### Workload:
- 25 Hours Presence studies

### Contents of teaching:
- Overview of the different clinics on the campus
- Basics of clinical examination
- Importance of teamwork: Doctors and physiotherapists
- Clinic from a surgical perspective

### Qualification-goals/Competencies:
- Knowledge concerning organizational structures and duties in the clinics
- Understanding of requirements in medical technology

### Grading through:
- Test or Viva voce, made available by the lecturer

### Teacher:
- Institute of Anatomy
- Prof. Dr. med. Jürgen Westermann

### Language:
- Offered only in German
# MZ4340 - Klinische Medizin 3 (MZ3)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
<th>Max. group size:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each summer semester</td>
<td>3</td>
<td>40</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 2. Term

### Classes and lectures:
- Herzchirurgie, Kardiologie, Nephrologie (Lecture, 2 SWS)
- MZ4340 A - Modulteil: Veranstaltung Berufsfelderkundung Medizin 2 (Lecture, 1 SWS)

### Workload:
- 40 Hours Private studies
- 30 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- ...

### Qualification-goals/Competencies:
- ...

### Grading through:
- Test or Viva voce, made available by the lecturer

### Responsible for this module:
- Dr. med. Daniel Drömann

### Teacher:
- Dr. med. Daniel Drömann
- Dr. med. Henning Jansen
- PD Dr. med. Kai Mortensen
- PD Dr. med. Michael Reppel
- PD Dr. med. Markus Meier
- Dr. med. Jan Ketel
- PD Dr. med. Thorsten Hanke
- Prof. Dr. med. Stefan Klotz
- Dr. rer. hum. biol. Michael Scharfschwerdt

### Language:
- Offered only in German
## MZ4340 A - Module Part: Course Survey of Medical Professions 2 (Erkundung2)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>1 Semester</th>
<th>Turnus of offer:</th>
<th>Each summer semester</th>
<th>Credit points:</th>
<th>1</th>
</tr>
</thead>
</table>

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 2. Term

### Classes and lectures:
- Survey of Medical Professions 2 (Lecture, 1 SWS)
- 0 Hours

### Contents of teaching:
- Clinic from the perspective of internal medicine
- Clinic and pathology
- Clinic and microbiology

### Qualification-goals/Competencies:
- Understanding of pathways in clinical medicine

### Grading through:
- Test or Viva voce, made available by the lecturer

### Responsible for this module:
- Prof. Dr. med. Jürgen Westermann

### Teacher:
- Institute of Anatomy

### Language:
- Offered only in German
## PS5520 - Scientific Writing (WP)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>1 Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Each winter semester</td>
</tr>
<tr>
<td>Credit points:</td>
<td>3</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Sciences, 3. Term

### Classes and lectures:
- Theoretical part (Lecture, 1 SWS)
- Practical part (as Student Conference) (Course, 1 SWS)

### Workload:
- 60 Hours
- 30 Hours Presence studies

### Contents of teaching:
- Analysis of scientific texts and guidance to their presentation
- Planning, design, and production of extensive scientific work (master's thesis, etc.)
- Preparation and presentation of a scientific poster in English based on the results of the project internships (in context of the Student Conference)
- Preparation of a scientific publication in English based on the results of the project internships (in context of the Student Conference)

### Qualification-goals/Competencies:
- Understanding and analyzing the logical and formal structure of scientific publications. Analysis of a given original publication. Knowledge of the "peer review process" of publications.
- Competence to draw up extensive scientific work: planning, construction, implementation.
- Format and didactic criteria of scientific posters. Experience in a poster presentation on the basis of given data.
- Knowledge of the preparation of project proposals and in the fund raising for research. Experience by preparing a fictitious external funding application to given preliminary work and a research objective.

### Grading through:
- Scientific paper
- Recitation
- Seminar work
- Poster
- Test or Viva voce, made available by the lecturer
- Participation on discussions

### Teacher:
- Institute of Molecular Medicine
- Institute of Medical Engineering
- Prof. Dr. rer. nat. Thorsten Buzug
- Prof. Dr. rer. nat. Georg Sczakiel

### Language:
- English, except in case of only German-speaking participants

### Notes:
The practical part of this course takes place in form of the Student Conference, which is organized by the Universität zu Lübeck. The issuing lecturer of the respective project internship supervises the work of the practical part as part of the Student Conference. The participation in the theoretical part of this course is not mandatory for students of MES.
## CS4250 - Computer Vision (CompVision)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each summer semester</td>
<td>4</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- (Optional Subject)
- Master Media Informatics SJ14 (Optional Subject), Arbitrary semester
- Master Computer Science (Optional Subject), advanced curriculum Imaging Systems, 2. or 3. term
- Master MML (compulsory), 2. Term
- Master MES (Consolidating), 2. Term
- Master Computer Science (Optional Subject), advanced curriculum Signal and Image Processing, 2. or 3. term
- Master Computer Science (compulsory), Enhanced course robotics and automation, 2. Term
- Master Computer Science (compulsory), Enhanced course Biology & IT, 2. Term
- Master Computer Science (Optional Subject), advanced curriculum Intelligent Embedded Systems, 2. Term

### Classes and lectures:
- Computer Vision (Lecture, 2 SWS)
- Computer Vision (Exercise, 1 SWS)

### Contents of teaching:
- Introduction to human and computer vision
- Sensors, cameras, optics and projections
- Camera calibration
- Range imaging and stereo vision, 3-D cameras
- Image features: edges, intrinsic dimension, Hough transform, Fourier descriptors, snakes
- Motion and optical flow
- Object recognition
- Example applications

### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

### Qualification-goals/Competencies:
- Understand the basic issues in computer vision
- Know how to set up and calibrate cameras
- Know how to extract features and estimate motion
- Know what kind of problems can be solved with computer vision

### Grading through:
- Exercises
- Viva Voce

### Responsible for this module:
- Prof. Dr.-Ing. Erhardt Barth

### Teacher:
- Institute for Neuro- and Bioinformatics
- Prof. Dr.-Ing. Erhardt Barth

### Literature:

### Language:
- English, except in case of only German-speaking participants
<table>
<thead>
<tr>
<th>CS4270 - Medical Robotics (MedRob)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration:</strong></td>
</tr>
<tr>
<td>1 Semester</td>
</tr>
</tbody>
</table>

**Course of study, specific field and term:**
- Master Computer Science (Optional Subject), advanced curriculum Imaging Systems, 2. or 3. term
- Master Computer Science (Optional Subject), advanced curriculum Signal and Image Processing, 2. or 3. term
- Master MES (Consolidating), 2. Term
- Master Computer Science (compulsory), Enhanced course robotics and automation, 2. Term
- Master Computer Science (Optional Subject), Enhanced course medical computer science, 2. or 3. term

**Classes and lectures:**
- Medical Robotics (Lecture, 2 SWS)
- Medical Robotics Exercise (Exercise, 1 SWS)

**Workload:**
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**
- 

**Qualification-goals/Competencies:**
- 

**Grading through:**
- Viva Voce

**Teacher:**
- Institute for Robotics and Cognitive Systems
- Prof. Dr.-Ing. Achim Schweikard

**Literature:**

**Language:**
- Offered only in English
## CS4330 - Image Analysis and Visualization in Diagnostics and Therapy (BAVIS)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
<th>Max. group size:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Each summer semester</td>
<td>4</td>
<td>99</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Master MES (Consolidating), 2. Term
- Master MML (choice), Arbitrary semester
- Master Computer Science (compulsory), Enhanced course medical computer science, 2. Term

### Classes and lectures:
- **Image Analysis and Visualization Systems in Diagnostics and Therapy (Lecture, 2 SWS)**
- **Image Analysis and Visualization Systems in Diagnostics and Therapy (Exercise, 1 SWS)**

### Workload:
- 55 Hours Self studies and exercises
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- Methods and algorithms for the analysis and visualization of medical images including current research activities in the field of medical image computing. The following methods and algorithms are explained:
- segmentation of multispectral image data
- live wire segmentation
- segmentation with active contour models and deformable models
- level set segmentation
- statistical shape models
- image registration
- atlas-based segmentation and motion field estimation using non-linear registration
- visualization techniques in medicine
- 3D-Visualisierungsverfahren: Ray Casting, Volume Rendering etc.
- haptic 3D interactions in virtual bodies
- virtual reality techniques in medical applications

### Qualification-goals/Competencies:
- Increase knowledge in medical image processing and visualization
- Knowledge of the individual steps of pattern recognition
- Understanding of the underlying algorithms
- Ability to select appropriate methods for a given problem
- Implementation of the methods
- Application to practical problems
- Overview of medical image processing techniques with many examples
- Capability to communicate and process medical image data

### Grading through:
- Test or Viva voce, made available by the lecturer

### Requires:
- Image and Signal Processing in Medicine 1 (CS3310-INF)

### Responsible for this module:
- Prof. Dr. rer. nat. habil. Heinz Handels

### Teacher:
- Institute of Medical Informatics
  - Prof. Dr. rer. nat. habil. Heinz Handels

### Literature:
Module Guide


**Language:**
- Offered only in German
<table>
<thead>
<tr>
<th>CS5170 - Hardware/Software Co-Design (HWSWCod)</th>
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<tbody>
<tr>
<td><strong>Duration:</strong> 1 Semester</td>
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<tr>
<td><strong>Turnus of offer:</strong> Each summer semester</td>
</tr>
<tr>
<td><strong>Credit points:</strong> 4</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Master Computer Science (compulsory), Schwerpunktfach Software Systems Engineering, 1. Term
- Master MES (Consolidating)
- Master Media Informatics SJ14 (Optional Subject), Arbitrary semester
- Master Computer Science (Optional Subject), Enhanced course robotics and automation, 2. or 3. term
- Master Computer Science (Optional Subject), advanced curriculum Parallel and Distributed System Architecture, 2. or 3. term
- Master Computer Science (Optional Subject), advanced curriculum Intelligent Embedded Systems, 2. or 3. term
- Master Computer Science (compulsory), Schwerpunktfach Software Systems Engineering, 2. Term

### Classes and lectures:
- Hardware/Software Co-Design (Lecture, 2 SWS)
- Hardware/Software Co-Design (Exercise, 1 SWS)

### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- System design flow
- Basic architectures for HW/SW systems
- System design and modelling
- System synthesis
- Algorithms for scheduling
- System partitioning
- Algorithms for system partitioning
- Design systems
- Performance analysis
- System design and specification with SystemC
- Application examples

### Qualification-goals/Competencies:
- Capability to design and partition an application for a given hardware-software platform
- Skills about methods and algorithms for automatic system partitioning
- Knowledge about performance metrics for the analysis of hardware and software components
- Basic knowledge of system modelling and simulation with SystemC

### Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

### Teacher:
- Institute of Computer Engineering
- Prof. Dr.-Ing. Erik Maehle

### Literature:

### Language:
- Offered only in German
# Module Guide

## CS5260 - Digital Speech and Audio Signal Processing (SprachAudi)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
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</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Irregular</td>
<td>4</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Master Computer Science (Optional Subject), advanced curriculum Signal and Image Processing, 2. or 3. term
- Master MML (choice), Arbitrary semester
- Master MES (Consolidating)
- Master Computer Science (Optional Subject), advanced curriculum Intelligent Embedded Systems, 2. or 3. term
- Master Computer Science (Optional Subject), Enhanced course robotics and automation, 3. Term
- Master Computer Science (Optional Subject), Enhanced course Media Informatics, 2. or 3. term

### Classes and lectures:
- Digital Speech and Audio Signal Processing (Lecture, 2 SWS)
- Digital Speech and Audio Signal Processing (Exercise, 1 SWS)

### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- Speech production and human hearing
- Spectral analysis
- Vocal tract models
- Linear prediction
- Coding in time and frequency domains
- Speech synthesis
- Noise reduction and echo compensation
- Source localization and spatial reproduction
- Basics of automatic speech recognition

### Qualification-goals/Competencies:
- Students will have good knowledge of the theoretical basics of speech production, filtering and recognition.
- They will have basic knowledge in the field of statistical modeling.
- They will know the principles of speech coding.
- They will be able to understand the relations between speech signal analysis, signal processing and acoustic perception.

### Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

### Responsible for this module:
- Prof. Dr.-Ing. Alfred Mertins

### Teacher:
- Institute for Signal Processing
- Prof. Dr.-Ing. Alfred Mertins

### Literature:

### Language:
- Offered only in German
### CSS275 - Selected Topics of Signal Analysis and Enhancement (AMSAV)

<table>
<thead>
<tr>
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<tbody>
<tr>
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<td>4</td>
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</tbody>
</table>

#### Course of study, specific field and term:
- Master Medical Informatics SJ14 (Optional Subject)
- Master MML (choice), Arbitrary semester
- Master Computer Science (Optional Subject), Enhanced course Biology & IT, 3. Term
- Master MES (Consolidating)
- Master Computer Science (Optional Subject), advanced curriculum Signal and Image Processing, 2. or 3. term
- Master Computer Science (Optional Subject), Enhanced course robotics and automation, 3. Term
- Master Computer Science (Optional Subject), advanced curriculum Intelligent Embedded Systems, 2. or 3. term

#### Classes and lectures:
- Selected Topics of Signal Analysis and Enhancement (Lecture, 2 SWS)
- Selected Topics of Signal Analysis and Enhancement (Exercise, 1 SWS)

#### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

#### Contents of teaching:
- Introduction to statistical signal analysis and linear optimum filters
- Adaptive filters
- Basic concepts of multirate signal processing
- Applications in enhancement/restauration of one- and two-dimensional signals

#### Qualification-goals/Competencies:
- Students will know the basic elements of stochastic signal processing and optimum filtering.
- Students will know concepts of adaptive signal processing.
- They will be able to analyze and design multirate systems.
- Students will be aware of various applications of nonlinear and adaptive signal processing.
- Students will be able to describe and process stochastic signals on their own.
- They will be able to create and implement linear optimum filters and nonlinear signal enhancement techniques on their own.

#### Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

#### Responsible for this module:
- Prof. Dr.-Ing. Alfred Mertins

#### Teacher:
- Institute for Signal Processing
- Prof. Dr.-Ing. Alfred Mertins

#### Literature:

#### Language:
<table>
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<th>Duration:</th>
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<th>Irregular</th>
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<th>4</th>
</tr>
</thead>
</table>

**Course of study, specific field and term:**
- (Optional Subject), Medical Engineering Sciences
- Master MES (Consolidating)
- Master MML (choice), Mathematics, 2. or 3. term

**Classes and lectures:**
- Quantenphysik der medizinischen Diagnostik und Therapie (Lecture, 2 SWS)
- Quantenphysik der medizinischen Diagnostik und Therapie (Exercise, 1 SWS)

**Workload:**
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**

**Qualification-goals/Competencies:**
- Erlernen grundlegender quantenmechanischer Prinzipien
- Vertiefung in der Anwendung der Fouriertransformation
- Verständnis quantenmechanischer Prozesse in Anwendungen der Medizintechnik

**Grading through:**
- Test or Viva voce, made available by the lecturer

**Responsible for this module:**
- Prof. Dr. rer. nat. Thorsten Buzug

**Teacher:**
- Institute of Medical Engineering
- Prof. Dr. rer. nat. Thorsten Buzug
- Prof. Dr. rer. nat. Martin Koch

**Language:**
- Offered only in German
## ME5050 - Biophysics of Ionizing Radiation and Radiation Safety (StrahlenS)

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<tr>
<th>Duration:</th>
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<tbody>
<tr>
<td>1 Semester</td>
<td>Each winter semester</td>
<td>4</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Master MES (Consolidating)
- Master MLS (compulsory), Life Sciences
- (compulsory), Medical Engineering Sciences, 5. Term

### Classes and lectures:
- Biophysics of Ionizing Radiation and Radiation Safety (Lecture, 2 SWS)
- Biophysics of Ionizing Radiation and Radiation Safety (practical course, 1 SWS)

### Workload:
- 55 Hours Presence studies
- 45 Hours Private studies
- 20 Hours Test preparation

### Contents of teaching:
- Physics of ionizing radiation
- Basic principles of dosimetry
- Introduction to methods of radiation measurement
- Radiation biology: principles of radiation damage, deterministic and stochastic effects, health risks caused by ionizing radiation
- Radiation chemistry, handling of radioactive materials
- Safety requirements in radionuclide laboratories
- Application of radionuclides in biochemistry and molecular biology
- Laws and regulations dealing with radiation safety

### Qualification-goals/Competencies:
- Certificate in radiation safety according to German law (StrSchV, RöV)
- Acquisition of basic skills in handling of radioactive materials and sources
- Knowledge of ethical and socio-political aspects of applying ionizing radiation

### Grading through:
- Regular and successful participation in lecture and practical course, each with min. 90%
- Test

### Responsible for this module:
- Prof. Dr. rer. nat. Christian Schmidt

### Teacher:
- Isotopes laboratory
- Prof. Dr. rer. nat. Christian Schmidt
- Prof. Dr. rer. nat. Christian Hübner
- Dipl.-Ing. Henning Schönwald
- N.N.

### Language:
- Offered only in German
### CS4440 - Molecular Bioinformatics (MolBioInfo)

<table>
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<tr>
<th><strong>Duration:</strong></th>
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</tbody>
</table>

#### Course of study, specific field and term:
- Master MES (Consolidating), 2. Term
- Master MLS (Optional Subject), Interdisciplinary competence, 1. Term
- Master MML (choice), 1st or 3rd term
- Master Computer Science (compulsory), Enhanced course Biology & IT, 1. Term

#### Classes and lectures:
- Molecular Bioinformatics (Lecture, 2 SWS)
- Molecular Bioinformatics (Exercise, 1 SWS)

#### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

#### Contents of teaching:
- Analysis of data describing gene expression profiles and sequence variation
- Advanced usage of biological databases (for sequences, motifs, structures, gene regulation and interactions)
- Selection and use of software in bioinformatics
- phylogenetic trees
- motif finding

#### Qualification-goals/Competencies:
- Understanding of probabilistic modelling and its algorithmic application
- Use and design of databases for molecular-biological research
- Collaboration between Life- and Computer Scientists

#### Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

#### Requires:
- Introduction to Bioinformatics (CS1400)

#### Responsible for this module:
- Prof. Dr. rer. nat. Thomas Martinetz

#### Teacher:
- Institute for Neuro- and Bioinformatics
- Prof. Dr. rer. nat. Thomas Martinetz
- MitarbeiterInnen des Instituts

#### Literature:
- D. M. Mount: Bioinformatics - Sequence and Genome - New York: Cold Spring Harbor Press

#### Language:
- Offered only in German

#### Notes:
This modul is for Master MLS the Modulpart B of Modul LS4060 with 5 credit points.
<table>
<thead>
<tr>
<th>Duration:</th>
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</table>

**Course of study, specific field and term:**
- (Optional Subject), 1. Term
- Master MES (Consolidating), 1. Term

**Classes and lectures:**
- Molecular Dynamics (Lecture, 2 SWS)
- Molecular Dynamics Exercises (Exercise, 1 SWS)

**Workload:**
- 45 Hours Self studies and exercises
- 35 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**

**Qualification-goals/Competencies:**

**Grading through:**
- Test or Viva voce, made available by the lecturer

**Requires:**
- Biophysik 1 (LS4700)

**Responsible for this module:**
- Prof. Dr. rer. nat. Christian Hübner

**Teacher:**
- Institute of Physics
- PD Dr. rer. nat. Hauke Paulsen
- Prof. Dr. rer. nat. Christian Hübner

**Literature:**
- :

**Language:**
- English, except in case of only German-speaking participants
<table>
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<th><strong>LS5720 - Single molecule methods (EinzelStr)</strong></th>
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<tr>
<td><strong>Classes and lectures:</strong></td>
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<tr>
<td>● Single molecule methods (Lecture, 2 SWS)</td>
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<tr>
<td>● Seminar Single molecule methods (Seminar, 1 SWS)</td>
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<tr>
<td><strong>Requires:</strong></td>
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<tr>
<td>● Introduction into Biophysics (LS2200)</td>
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<td><strong>Teacher:</strong></td>
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<tr>
<td>● Institute of Physics</td>
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<tr>
<td>● Prof. Dr. rer. nat. Christian Hübner</td>
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<tr>
<td><strong>Language:</strong></td>
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<tr>
<td>● English, except in case of only German-speaking participants</td>
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<td>Module Guide</td>
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**MA1600 - Biostatistics 1 (BioStat1)**

**Duration:** 1 Semester  
**Turnus of offer:** Each summer semester  
**Credit points:** 4

**Course of study, specific field and term:**
- Bachelor Computer Science (compulsory), Enhanced course Biology & IT, 6. Term  
- Master MES (Consolidating), 2. Term  
- Bachelor Medical Informatics (compulsory), medical computer science, 4. Term  
- Master Computer Science (Optional Subject), Enhanced course Biology & IT, 2. or 3. term  
- Master Computer Science (compulsory), advanced curriculum Stochastics, 2. Term  
- Bachelor Computer Science (Optional Subject), Enhanced course Biology & IT, 6. Term  
- Bachelor MES (compulsory), Life Sciences, 6. Term  
- Bachelor MES (Optional Subject), Medical Engineering Sciences, 6. Term  
- Bachelor Computer Science (compulsory), Enhanced course medical computer science, 6. Term  
- Bachelor Medical Informatics SJ14 (compulsory), medical computer science, 4. Term

**Classes and lectures:**
- Biostatistics 1 (Lecture, 2 SWS)  
- Biostatistics 1 (Exercise, 1 SWS)

**Workload:**
- 60 Hours Private studies  
- 45 Hours Presence studies  
- 15 Hours Test preparation

**Contents of teaching:**
- Descriptive statistics  
- Probability theory, including random variables, density, and cumulative distribution function  
- Normal distribution  
- Diagnostic tests, reference range, normal range, coefficient of variation  
- Statistical testing  
- Sample size calculations  
- Confidence intervals  
- Selected statistical tests I  
- Selected statistical tests I  
- Analysis of variance (one-way-classification)  
- Simple linear regression  
- Clinical trials

**Qualification-goals/Competencies:**
- Knowledge of the most important methods of descriptive statistics  
- Basic understanding of the approach to testing and estimation  
- Practice in basic statistical test and estimation methods

**Grading through:**
- Test

**Is requisite for:**
- Biostatistics 2 (MA2600)

**Responsible for this module:**
- Prof. Dr. rer. nat. Andreas Ziegler

**Teacher:**
- Institute of Medical Biometry and Statistics  
- Prof. Dr. rer. nat. Andreas Ziegler

**Literature:**

**Language:**
- Offered only in German
## MA5630 - Systems Biology (SysBio)

<table>
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<td>Turnus of offer:</td>
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<tr>
<td>Credit points:</td>
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</tbody>
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### Course of study, specific field and term:
- Master MES (Consolidating), 1. Term
- Master Computer Science (choice), Enhanced course Biology & IT, Arbitrary semester
- Master MML (choice), Arbitrary semester
- Master MML (choice), Life Sciences, Arbitrary semester
- Master MML (choice), Mathematics, Arbitrary semester

### Classes and lectures:
- Systems Biology (Lecture, 2 SWS)
- Systems Biology (Exercise, 1 SWS)

### Workload:
- 60 Hours Private studies
- 45 Hours Presence studies
- 15 Hours Test preparation

### Contents of teaching:
- Kinetic modeling of enzymatic and metabolic reactions
- Signal transduction and regulatory motifs
- Biological oscillators and cell cycle
- Gene expression and modeling approaches
- Regulatory motifs and complex graphs
- Stochastic systems and variability
- Quasispecies and hypercycles
- Boolean and NK models, robustness
- Basic statistical physics and thermodynamics
- Evolutionary dynamics and optimality
- Structure of experimental approaches and data
- Parameter estimation and observability
- Drug discovery and systems medicine

### Qualification-goals/Competencies:
- Comprehension of the objectives of systems biology
- Competent knowledge of the basic mathematical methods
- Overall view of advanced model approaches
- Critical reflection of the methodological limits of systems biology

### Grading through:
- Exercises
- Viva Voce

### Responsible for this module:
- PD Dr. rer. nat. Jens Christian Claussen

### Teacher:
- Institute for Neuro- and Bioinformatics
- PD Dr. rer. nat. Jens Christian Claussen

### Literature:
- Uri Alon: An Introduction to Systems Biology - Chapman and Hall 2003

### Language:
- English, except in case of only German-speaking participants
# ME4130 - Laserphysik (LaPhy)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
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<tbody>
<tr>
<td>1 Semester</td>
<td>Each semester</td>
<td>4</td>
</tr>
</tbody>
</table>

## Course of study, specific field and term:
- Master MES (Consolidating)

## Classes and lectures:
- Lecture laser physics (Lecture, 2 SWS)
- Exercise laser physics (Exercise, 1 SWS)

## Workload:
- 55 Hours Self studies and exercises
- 45 Hours Presence studies
- 20 Hours Test preparation

## Contents of teaching:
- Absorption, spontaneous and stimulated emission, saturable absorption
- Principle of laser emission and optical resonators
- Kinetics of the laser process, laser rate equations
- Relaxations oscillations, Q-switching, modelocking
- Gas and semiconductor lasers
- Solid state lasers, fiber laser, disc laser
- Tunable lasers (vibronic state laser, dye laser)
- Fs-ultra short pulsed lasers
- Nonlinear frequency conversion, photonic crystals, raman effects

## Qualification-goals/Competencies:
- Understanding the physics of the laser process, the main laser types and applications

## Grading through:
- Test or Viva voce, made available by the lecturer

## Teacher:
- Institute of Biomedical Optics
- Dr. rer. nat. Ralf Brinkmann

## Language:
- Offered only in German
<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
<th>Max. group size:</th>
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<tbody>
<tr>
<td>1 Semester</td>
<td>Each winter semester</td>
<td>4</td>
<td>8</td>
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</tbody>
</table>

**Course of study, specific field and term:**
- (Optional Subject)
- Master MES (Consolidating), 1. Term

**Classes and lectures:**
- Mechanismen der Photobiologie und Photomedizin (Lecture, 2 SWS)
- Mechanismen der Photobiologie und Photomedizin (Exercise, 1 SWS)

**Workload:**
- 60 Hours Presence studies
- 35 Hours Presentation (including preparation)
- 25 Hours Written Presentation

**Contents of teaching:**

**Qualification-goals/Competencies:**

**Grading through:**
- Recitation
- Test or Viva voce, made available by the lecturer

**Responsible for this module:**
- Dr. rer. nat. Heyke Diddens-Tschoeke

**Teacher:**
- Institute of Biomedical Optics
- Dr. rer. nat. Heyke Diddens-Tschoeke

**Language:**
- Offered only in German
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</tbody>
</table>

**Course of study, specific field and term:**
- Master MES (Consolidating), 1. Term
- (Optional Subject), Medical Engineering Sciences

**Classes and lectures:**
- Human ophthalmic system (Lecture, 1 SWS)
- Construction and function of optical ophthalmic instruments (Exercise, 2 SWS)

**Workload:**
- 50 Hours Private studies
- 40 Hours Presence studies
- 30 Hours Test preparation

**Contents of teaching:**
- Fundamentals of geometric and wave optical processes within the human ocular system
- Demonstrations and laboratory exercises using optical experimental set-ups and ophthalmic instruments

**Qualification-goals/Competencies:**
- Understanding of fundamental optical principles for image formation and visual process in the human eye
- Knowledge on capabilities and applications of optical systems and instruments for diagnostics and therapeutics in ophthalmology
- Practical skills in the area of bio-optical imaging techniques, anterior chamber microscopy, and ophthalmoscopy

**Grading through:**
- Oral presentation and written report
- Regular and successful participation in the course

**Responsible for this module:**
- Dr. rer. nat. Fred Reinholz

**Teacher:**
- Institute of Biomedical Optics
- Dr. rer. nat. Fred Reinholz

**Language:**

**Notes:**
- Block scheduling
- Held as a one-week intensive course
### ME4150 - Moderne Optische Verfahren 1 (ModOptVer1)

| Duration: | 1 Semester | Turnus of offer: | Each winter semester | Credit points: | 4 | Max. group size: | 12 |

#### Course of study, specific field and term:
- Master MES (Consolidating), 1. Term

#### Classes and lectures:
- Moderne Optische Verfahren 1 (Lecture, 2 SWS)
- Moderne Optische Verfahren 1 (practical course, 1 SWS)

#### Workload:
- 45 Hours Written Presentation
- 30 Hours Private studies
- 30 Hours Presence studies
- 15 Hours group work

#### Contents of teaching:
- ...

#### Qualification-goals/Competencies:
- ...

#### Grading through:
- Written elaboration

#### Teacher:
- Institute of Anatomy
- Institute of Biomedical Optics
- Prof. Dr. rer. nat. Alfred Vogel
- Prof. Dr. med. Andreas Gebert
- PD Dr. rer. nat. Gereon Hüttmann

#### Language:
- Offered only in German
# ME4160 - Moderne Optische Verfahren 2 (ModOptVer2)

<table>
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<tr>
<td>1 Semester</td>
<td>Each summer semester</td>
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</table>

**Course of study, specific field and term:**
- Master MES (Consolidating), 2. Term

**Classes and lectures:**
- Moderne Optische Verfahren 2 (Lecture, 3 SWS)

**Workload:**
- 55 Hours Self studies and exercises
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**
- ...
- ...
- ...
- ...
- ...
- ...
- ...

**Qualification-goals/Competencies:**
- ...

**Grading through:**
- Test or Viva voce, made available by the lecturer

**Teacher:**
- Institute of Anatomy
- Institute of Biomedical Optics
- PD Dr. rer. nat. Gereon Hüttmann
- Prof. Dr. med. Andreas Gebert
- Prof. Dr. rer. nat. Alfred Vogel

**Language:**
- Offered only in German
### ME4170 - Mechanismen laserinduzierter Gewebseffekte (MechLasGew)

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<td>1 Semester</td>
<td>Each winter semester</td>
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</tbody>
</table>

#### Course of study, specific field and term:
- (Optional Subject), Medical Engineering Sciences
- Master MES (Consolidating), 1. Term

#### Classes and lectures:
- Physical Mechanisms of Pulsed Laser Surgery of Cells and Tissues (Lecture, 2 SWS)
- Physical Mechanisms of Pulsed Laser Surgery of Cells and Tissues/Exercises (Exercise, 1 SWS)

#### Workload:
- 55 Hours Self studies and exercises
- 45 Hours Presence studies
- 20 Hours Test preparation

#### Contents of teaching:

#### Qualification-goals/Competencies:

#### Grading through:
- Test or Viva voce, made available by the lecturer

#### Responsible for this module:
- Prof. Dr. rer. nat. Alfred Vogel

#### Teacher:
- Institute of Biomedical Optics
- Prof. Dr. rer. nat. Alfred Vogel

#### Language:
- Offered only in German
# Module Guide

**ME4180 - Bildgebende optische Diagnostik (BOD)**

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<td>4</td>
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</tbody>
</table>

**Course of study, specific field and term:**
- (Optional Subject)
- Master MES (Consolidating), 2. Term

**Classes and lectures:**
- Lecture Bildgebende optische Diagnostik (Lecture, 2 SWS)
- Seminar Bildgebende optische Diagnostik (Seminar, 1 SWS)

**Workload:**
- 75 Hours
- 45 Hours Presence studies

**Contents of teaching:**

**Qualification-goals/Competencies:**

**Grading through:**
- Recitation
- Written elaboration
- Participation on discussions

**Requires:**
- Moderne Techniken der biomedizinischen Optik 1 (ME4100)

**Responsible for this module:**
- PD rer. nat. Gereon Hüttmann

**Teacher:**
- Institute of Biomedical Optics
- PD Dr. rer. nat. Gereon Hüttmann

**Language:**
- English, except in case of only German-speaking participants
### Module Guide

#### ME4190 - Zellmanipulation mit optischen Methoden (ZOM)

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</table>

**Course of study, specific field and term:**
- Master MES (Consolidating), 1. Term
- (Optional Subject)

**Classes and lectures:**
- Zellmanipulation mit optischen Methoden (Lecture, 2 SWS)
- Zellmanipulation mit optischen Methoden (Exercise, 1 SWS)

**Workload:**
- 50 Hours Private studies
- 40 Hours Presence studies
- 30 Hours Test preparation

**Contents of teaching:**

**Qualification-goals/Competencies:**

**Grading through:**
- Oral presentation and written report
- Regular and successful participation in the course

**Responsible for this module:**
- Dr. rer. nat. Ramtin Rahmanzadeh

**Teacher:**
- Institute of Biomedical Optics

**Language:**
- Offered only in German
# MA5032 - Numerical Methods for Image Computing (NumerikBV)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
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</thead>
<tbody>
<tr>
<td>1 Semester</td>
<td>Every second summer semester</td>
<td>4</td>
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</tbody>
</table>

## Course of study, specific field and term:
- Master Medical Informatics SJ14 (Optional Subject), medical computer science
- Master MES (Optional Subject), advanced curriculum Imaging Systems, 2nd or 4th term
- Master Computer Science (Optional Subject), advanced curriculum Numerical Image Processing, 2. or 3. term
- Master MML (Optional Subject), Mathematics, 2nd or 4th term

## Classes and lectures:
- Numerical Methods for Image Computing (Lecture, 2 SWS)
- Numerical Methods for Image Computing (Exercise, 1 SWS)

## Workload:
- 65 Hours Self studies and exercises
- 45 Hours Presence studies
- 10 Hours Test preparation

## Contents of teaching:
- Modeling
- Discretization
- Numerical methods for partial differential equations
- Multilevel and multiscale approaches
- Optimization methods
- Multigrid methods
- Operator splitting

## Qualification-goals/Competencies:
- Acquisition of fundamental numerical concepts
- Experience in realization of practical solutions

## Grading through:
- Test or Viva voce, made available by the lecturer

## Requires:
- Linear Algebra and Discrete Structures 1 (MA1000)
- Analysis 1 (MA2000)
- Image Registration (MA5030)

## Responsible for this module:
- Prof. Dr. Jan Modersitzki

## Teacher:
- Institute of Mathematics and Image Computing
- Prof. Dr. Jan Modersitzki

## Literature:
- Nocedal Wright: Numerical Optimization - Springer 2000

## Language:
# Module Guide

## CS3100 - Signal processing (SignalV)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>1 Semester</th>
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</thead>
<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Each winter semester</td>
</tr>
<tr>
<td>Credit points:</td>
<td>4</td>
</tr>
</tbody>
</table>

### Course of study, specific field and term:
- Bachelor Medical Informatics (compulsory), 5. Term
- Master MES (compulsory), Medical Engineering Science (expiring), 1. Term
- Master MML (compulsory), Mathematics, 1. Term
- Bachelor Computer Science (compulsory), Computer Science Basics, 5. Term

### Classes and lectures:
- Signal processing (Lecture, 2 SWS)
- Signal processing (Exercise, 1 SWS)

### Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

### Contents of teaching:
- Linear time-invariant systems
- Impulse response
- Convolution
- Fourier transform
- Transfer function
- Correlation and energy density of deterministic signals
- Sampling
- Discrete-time signals and systems
- Discrete-time Fourier transform
- z-Transform
- FIR and IIR filters
- Block diagrams
- FIR filter design
- Discrete Fourier transform (DFT)
- Fast Fourier transform (FFT)
- Characterization and processing of random signals

### Qualification-goals/Competencies:
- Students will know the fundamentals of linear system theory.
- They will know the basic elements of signal processing.
- They will have a command of methods for the description and analysis of continuous-time and discrete-time signals and systems.
- They are able to design digital filters and know various structures for their implementation.
- They will know the basic techniques for describing and processing of random signals.

### Grading through:
- Exercises
- Test or Viva voce, made available by the lecturer

### Is requisite for:
- Image processing (CS3203)

### Requires:
- Analysis 1 (MA2000)

### Responsible for this module:
- Prof. Dr.-Ing. Alfred Mertins

### Teacher:
- Institute for Signal Processing
- Prof. Dr.-Ing. Alfred Mertins
Literature:

- B. Girod, R. Rabenstein und A. Stenger: Einführung in die Systemtheorie - Teubner, 3. Auflage, 2005
- V. Oppenheim, R. W. Schafer, and J. R. Buck: Discrete-time signal processing - Prentice Hall, 1999

Language:

- Offered only in German
# CS3203 - Image processing (Bildverarbeitung)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
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<tbody>
<tr>
<td>1 Semester</td>
<td>Each summer semester</td>
<td>4</td>
</tr>
</tbody>
</table>

## Course of study, specific field and term:
- Bachelor Computer Science (Optional Subject), Enhanced course Biology & IT, 6. Term
- Bachelor Medical Informatics (compulsory), 6. Term
- Master MES (compulsory), Medical Engineering Science (expiring), 2. Term
- Master MML (compulsory), Mathematics, 2. Term
- Bachelor Computer Science (compulsory), Enhanced course robotics and automation, 6. Term
- Bachelor Computer Science (Optional Subject), Informatics central topics, 5. or 6. term

## Classes and lectures:
- Image processing (Lecture, 2 SWS)
- Image processing (Exercise, 1 SWS)

## Workload:
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

## Contents of teaching:
- Introduction, interest of visual information
- Fourier transformation
- Sampling and sampling theorem
- Filtering
- Image enhancement
- Edge detection
- Multiresolution concepts: Gaussian and Laplacian Pyramid, wavelets
- Principles of image compression
- Segmentation
- Morphological image processing

## Qualification-goals/Competencies:
- Students will have basic knowledge of the two-dimensional system theory.
- They will know the main techniques for image analysis and image enhancement.
- They will be able to use the learned principles in practice.

## Grading through:
- Exercises
- Programming project
- Test or Viva voce, made available by the lecturer

## Requires:
- Signal processing (CS3100)
- Analysis 1 (MA2000)

## Responsible for this module:
- Prof. Dr.-Ing. Alfred Mertins

## Teacher:
- Institute for Signal Processing
- Prof. Dr.-Ing. Alfred Mertins

## Literature:
- Jae S. Lim: Two-Dimensional Signal and Image Processing - Prentice Hall, 1990
- Bernd Jähne: Digitale Bildverarbeitung - Springer, Berlin 2005

## Language:
• Offered only in German
# LS4700 - Biophysik 1 (Biophy1)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Turnus of offer:</th>
<th>Credit points:</th>
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<tbody>
<tr>
<td>1 Semester</td>
<td>Each winter semester</td>
<td>4</td>
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</tbody>
</table>

## Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Science (expiring), 1. Term

## Classes and lectures:
- Biophysik I (Lecture, 2 SWS)
- Biophysik I (Exercise, 1 SWS)

## Workload:
- 55 Hours Self studies and exercises
- 45 Hours Presence studies
- 20 Hours Test preparation

## Contents of teaching:
- Einführung: Biomoleküle und molekulare Prozesse
- Physikalische Wechselwirkungen bestimmen die Struktur von Proteinen: Coulomb- und van-der-Waals-Wechselwirkung
- Grundlagen der Proteindynamik
- Einführung in die Quantenmechanik anhand von Beispielen aus der Biophysik
- Methoden zur Charakterisierung von Biomolekülen - Optische Spektroskopie (UV-Vis) - Infrarot-Spektroskopie (IR) - Elektron Paramagnetische Resonanz (EPR) - Mössbauer Spektroskopie - Elektronenmikroskopie - Protein kristallographie (Röntgenstrukturanalyse) - Röntgenabsorptionspektroskopie (EXAFS, XANES) - Röntgenkleinwinkelstreuung

## Qualification-goals/Competencies:
- Erkennen und Verstehen von physikalischen Phänomenen in der Biologie
- Beherrschen von grundlegenden Methoden zur Charakterisierung von Biomolekülen
- Anwenden der Methoden durch selbstständige Vertiefung auf biologische Fragestellungen

## Grading through:
- Exercises
- Viva Voce

## Teacher:
- Institute of Physics
- Prof. Dr. rer. nat. Holger Notbohm
- PD Dr. rer. nat. Hauke Paulsen
- Prof. Dr. rer. nat. Christian Hübner

## Literature:
- :
- :

## Language:
- Offered only in German
### LS4720 - Biophysics 2 (BiPh2)

<table>
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<tr>
<th>Duration:</th>
<th>1 Semester</th>
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<tbody>
<tr>
<td>Turnus of offer:</td>
<td>Each summer semester</td>
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<tr>
<td>Credit points:</td>
<td>4</td>
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#### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Science (expiring), 2. Term

#### Classes and lectures:
- module parts A: Membranbiophysics or B: Proteinbiophysics (Lecture with Exercises, 3 SWS)

#### Workload:
- 135 Hours Private studies
- 75 Hours Presence studies

#### Contents of teaching:
- See part of the module LS4130 A and B

#### Qualification-goals/Competencies:
- See part of the module LS4130 A and B

#### Grading through:
- Test

#### Responsible for this module:
- Prof. Dr. rer. nat. Christian Hübner

#### Teacher:
- Research Center Borstel
- Institute of Physics
  - Prof. Dr. rer. nat. Christian Hübner
  - Prof. Dr. rer. nat. Thomas Gutsmann

#### Language:
- English, except in case of only German-speaking participants
### Module Guide

**ME4000 - Imaging Systems 1 (BildgbSys1)**

<table>
<thead>
<tr>
<th><strong>Duration:</strong></th>
<th>1 Semester</th>
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<tbody>
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<td><strong>Turnus of offer:</strong></td>
<td>Each winter semester</td>
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<tr>
<td><strong>Credit points:</strong></td>
<td>4</td>
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</tbody>
</table>

**Course of study, specific field and term:**
- Master Computer Science (compulsory), Enhanced course robotics and automation, 1. Term
- Master Computer Science (Optional Subject), advanced curriculum Signal and Image Processing, 2. or 3. term
- Master Computer Science (Optional Subject), Enhanced course medical computer science, 3. Term
- Master Computer Science (Optional Subject), advanced curriculum Imaging Systems, 2. or 3. term
- Master MML (compulsory), 1. Term
- Master MES (compulsory), Medical Engineering Science (expiring), 1. Term

**Classes and lectures:**
- Imaging Systems 1 (Lecture, 2 SWS)
- Imaging Systems 1 (Exercise, 1 SWS)

**Workload:**
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**
- Signal processing (recapitulation of fundamental principles in signal processing)
- Mathematical methods in image reconstruction and signal processing
- X-Ray (fundamental principles, quantum statistics)

**Qualification-goals/Competencies:**
- This lecture gives a comprehensive overview of the main signal processing and system analysis methods in medical imaging. The basis of the reconstruction is undoubtedly mathematics. However, the beauty of e.g. computed tomography cannot be understood without a basic knowledge of X-ray physics, signal processing concepts and measurement systems. Therefore, students will be provided with a number of references to these basic disciplines as well as a brief introduction to many of the underlying principles. The main application focus of the lecture is given to computed tomography. The lecture is structured to cover the basics of signals and systems within CT, from photon statistics to modern cone-beam systems. However, without an elementary knowledge of X-ray physics, a number of the described imaging effects and artifacts cannot readily be understood. In the main part of the lecture the principles of signal processing are reviewed. This part focuses on the necessary background of computed tomography and, consequently, introducing the Fourier transform. Subsequently, a detailed overview of two-dimensional reconstruction mathematics is given as a straight forward application of the Fourier principles. Then, algebraic and statistical approaches are explained as a general tool for signal analysis and over- determined system solution. In the last lessons three-dimensional methods of CT image or volume reconstruction are reviewed. It is shown that some of the ideas are consequent extensions of the methods discussed at the beginning of the lecture. The methods described here represent the basis of a highly active field of research.

**Grading through:**
- Viva Voce

**Responsible for this module:**
- Prof. Dr. rer. nat. Thorsten Buzug

**Teacher:**
- Institute of Medical Engineering
- Prof. Dr. rer. nat. Thorsten Buzug

**Literature:**
- T. M. Buzug: Einführung in die Computertomographie, Mathematisch-physikalische Grundlagen der Bildrekonstruktion - Springer-Verlag, Berlin/Heidelberg, 2004

**Language:**
- Offered only in English
### ME4020 - Imaging Systems 2 (BildgbSys2)

<table>
<thead>
<tr>
<th>Duration:</th>
<th>Credit points:</th>
<th>Max. group size:</th>
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</thead>
<tbody>
<tr>
<td>1 Semester</td>
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<td>99</td>
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</tbody>
</table>

**Turnus of offer:** Each summer semester

**Course of study, specific field and term:**
- Master Computer Science (Optional Subject), advanced curriculum Imaging Systems, 2. or 3. term
- Master MML (compulsory), 2. Term
- Master MES (compulsory), Medical Engineering Science (expiring), 2. Term

**Classes and lectures:**
- Imaging Systems 2 (Lecture, 2 SWS)
- Imaging Systems 2 (Exercise, 1 SWS)

**Contents of teaching:**
- Fundamentals of magnetic resonance imaging (nuclear magnetic resonance, principles of spatial encoding, relaxation)
- Description of the measurement in k-space
- Basic pulse sequences
- Hardware components of an MR imaging system, influence of experimental parameters on the signal-to-noise ratio in an image, image artefact mechanisms
- Functional and diffusion weighted MR imaging, angiography, and spectroscopy
- Clinical applications of MR imaging

**Workload:**
- 55 Hours Private studies
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents:**
- Knowledge of physical principles behind MR imaging
- Knowing how important pulse sequences work
- Being able to trace down the origin of image artefacts
- Having a basic overview of the pros and cons of MR imaging

**Grading through:**
- Viva Voce

**Responsible for this module:**
- Prof. Dr. rer. nat. Martin Koch

**Teacher:**
- Institute of Medical Engineering
- Prof. Dr. rer. nat. Martin Koch

**Literature:**

**Language:**
- German and English skills required
<table>
<thead>
<tr>
<th>Duration:</th>
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<tbody>
<tr>
<td>1 Semester</td>
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<td>4</td>
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</tbody>
</table>

**Course of study, specific field and term:**
- Master MES (compulsory), Medical Engineering Science (expiring), 1. Term

**Classes and lectures:**
- Lecture Biomedical Optics 1 (Lecture, 2 SWS)
- Exercise Biomedical Optics 1 (Exercise, 1 SWS)

**Workload:**
- 55 Hours Self studies and exercises
- 45 Hours Presence studies
- 20 Hours Test preparation

**Contents of teaching:**

**Qualification-goals/Competencies:**

**Grading through:**
- Test or Viva voce, made available by the lecturer

**Is requisite for:**
- Moderne Techniken der biomedizinischen Optik 2 (ME4120)

**Teacher:**
- Institute of Biomedical Optics
- Prof. Dr. rer. nat. Alfred Vogel
- PD Dr. rer. nat. Gereon Hüttmann

**Language:**
- Offered only in German
## ME4120 - Moderne Techniken der biomedizinischen Optik 2 (MTBMO2)

<table>
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<td>Each summer semester</td>
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<tr>
<td>Credit points:</td>
<td>4</td>
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</tbody>
</table>

### Course of study, specific field and term:
- Master MES (compulsory), Medical Engineering Science (expiring), 2. Term

### Classes and lectures:
- Moderne Techniken der biomedizinischen Optik II (Lecture, 2 SWS)
- Moderne Techniken der biomedizinischen Optik II (Exercise, 1 SWS)

### Workload:
- 45 Hours Presence studies
- 40 Hours Private studies
- 20 Hours Test preparation
- 15 Hours Presentation (including preparation)

### Contents of teaching:
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### Qualification-goals/Competencies:
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### Grading through:
- Recitation
- Test or Viva voce, made available by the lecturer
- Participation on discussions

### Requires:
- Moderne Techniken der biomedizinischen Optik 1 (ME4100)

### Teacher:
- Institute of Biomedical Optics
- Prof. Dr. rer. nat. Alfred Vogel
- PD Dr. rer. nat. Gereon Hüttmann

### Language:
- Offered only in German