## Advanced Engineering Mathematics

<table>
<thead>
<tr>
<th>Rota annually</th>
<th>Duration</th>
<th>Semester</th>
<th>SWS</th>
<th>Credit Points</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Semester</td>
<td>1st (Semester)</td>
<td>5 SWS</td>
<td>7</td>
<td>210 h</td>
</tr>
</tbody>
</table>

### 1 Modul Structure

<table>
<thead>
<tr>
<th>Course (Abbreviation)</th>
<th>Type/ SWS</th>
<th>Presence</th>
<th>Self study</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Advanced Engineering Mathematics (AEM)</td>
<td>Lecture/ 3 SWS</td>
<td>45 h</td>
<td>90 h</td>
<td>4</td>
</tr>
<tr>
<td>b) Advanced Engineering Mathematics (AEM)</td>
<td>Tutorial/ 2 SWS</td>
<td>30 h</td>
<td>45 h</td>
<td>3</td>
</tr>
</tbody>
</table>

### 2 Language
- English

### 3 Content
1. **Linear Algebra**: Vector spaces, matrices and equation systems, linear maps, Jordan-, LU-, QR-, and singular value decomposition, numerical aspects.
2. **Differential Equation**: Linear systems, differential equations with constant coefficients.
3. **Laplace-Transform**: Definition, convolution and application to differential equations.
4. **Differential Calculus with several variables**: Derivatives, inverse and implicit functions, Taylor expansion and extreme values.
6. **Variational Calculus**

### Literature:
- Bajpai, Avinash C., Mathematics for engineers and scientists
- Meyer, R.M., Essential mathematics for applied fields
- Lancaster, P., Tismenetsky, M., The theory of matrices
- Lang, S., Linear algebra
- Slides

### 4 Goals
The course gives an introduction to fundamental mathematical techniques used in almost every course. Attention is given to the underlying mathematical structure.

### 5 Examination Requirements
The final exam will be a written (2 hours) exam.

### 6 Formality of Examination
- Module Finals
- Accumulated Grade

### 7 Module Requirements (Prerequisites)

### 8 Allocation to Curriculum:
- Mandatory Course
- Program: Automation & Robotics

### 9 Responsibility/ Lecturer
Dr. P. Furlan/ Dr. P. Furlan
## Aspects of Mathematical Modeling

<table>
<thead>
<tr>
<th>Rota</th>
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<th>Workload</th>
</tr>
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<tbody>
<tr>
<td>annually WS or SS</td>
<td>1 Semester</td>
<td>2nd/3rd (Semester)</td>
<td>3 SWS</td>
<td>5</td>
<td>150 h</td>
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<td>Self study</td>
<td>Credits</td>
<td></td>
</tr>
<tr>
<td>a) Aspects of Mathematical Modeling (AMM)</td>
<td>Lecture/ 2 SWS</td>
<td>30 h</td>
<td>70 h</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>b) Aspects of Mathematical Modeling (AMM)</td>
<td>Tutorial/ 1 SWS</td>
<td>15 h</td>
<td>35 h</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

| 2 Language: | English |

### Content

Different directions of mathematical modeling techniques are introduced that build on the course Advanced Engineering Mathematics and assume a solid background in mathematics. Among the subjects are the following:

1. **Optimization**: Theoretical and practical aspects of optimization problems, formulation, optimality conditions, linear programming, discrete optimization.

2. **Applied partial differential equations**: Prototypes, representation formulae, qualitative and quantitative behavior, conservation laws, elliptic, parabolic and hyperbolic equations, convection-diffusion-reaction systems.

3. **Continuum mechanics**: Inertia and momentum, equations of motion, external forces, conservation laws, deformations.


### Literature:

References will be given in the courses.

### Goals

This course offers an introduction to different fundamental techniques of mathematical modeling and analysis that are useful for the dynamics and control of robotic devices. Tools that allow for the description and control of movement and the interaction with the environment are introduced. The ability to create and use models to estimate qualitatively and quantitatively the behavior of dynamic systems will be trained.

### Examination Requirements

The final exam will be an oral (20 minutes) or written (1.5 hours) exam, depending on the number of participants (form will be announced in the second week of the course).

### Formality of Examination

- Module Finals
- Accumulated Grade

### Module Requirements (Prerequisites)

Course: “Advanced Engineering Mathematics”

### Allocation to Curriculum:


### Responsibility/ Lecturer

Dean of the Mathematics faculty / Lecturers of the Mathematics faculty
## Mathematical Simulation Techniques

<table>
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<tbody>
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<td>Lecture/ 2 SWS</td>
<td>30 h</td>
<td>70 h</td>
<td>3</td>
</tr>
<tr>
<td>b) Mathematical Simula- tion Techniques (MST)</td>
<td>Tutorial/ 1 SWS</td>
<td>15 h</td>
<td>35 h</td>
<td>2</td>
</tr>
</tbody>
</table>

### 2 Language: English

### 3 Content: Discretization and solution techniques for the numerical simulation of problems in continuum mechanics, as well as their efficient treatment on computer systems are introduced. The course Advanced Engineering Mathematics, a solid background in mathematics, and solid programming skills are assumed. Among the subjects are the following:

1. **Practical finite elements:** Variational formulation of partial differential equations, weak solutions, Ritz-Galerkin techniques, finite element approximation and analysis, numerical integration, boundary approximation, mesh generation, error control and reliability, solution of linear systems.

2. **Computational aspects of fluid dynamics:** Conservation laws, compressible and incompressible fluids, spatial discretization (FD, FV, FEM), stabilization techniques, explicit and implicit time stepping schemes, treatment of boundary conditions, projection- and operator-splitting techniques.

3. **High performance computing:** Parallel computer architecture, performance-oriented programming, sparse numerical linear algebra, Krylov-subspace and multigrid solvers, preconditioning strategies, domain decomposition methods, shared and distributed memory parallelization with OpenMP and MPI, GPU Computing.

4. **Approximation theory:** Interpolation and approximation, polynomial spaces, splines and Bézier curves, existence and uniqueness, best-approximation properties, quasi-interpolation, quality assessment and error analysis.

### Literature: References will be given in the courses.

### 4 Goals

This course provides students with fundamental mathematical simulation techniques that are essential to solve automation problems in robotics as well as in production and engineering processes of all kinds. The entire simulation pipeline is covered in theory and practice. Students are trained to solve real-life complex problems in “Numerics Labs”.

### 5 Examination Requirements

The final exam will be an oral (20 minutes) or written (1.5 hours) exam, depending on the number of participants (form will be announced in the second week of the course).

### 6 Formality of Examination

- Module Finals
- Accumulated Grade

### 7 Module Requirements (Prerequisites)

Course: “Advanced Engineering Mathematics”, solid programming skills

### 8 Allocation to Curriculum:


### 9 Responsibility/ Lecturer

*Dean of the Mathematics faculty / Lecturers of the Mathematics faculty*