TUM. Milestones

1868: King Ludwig II founded the “Polytechnic School“ organized like a university
1877: Awarded the designation "Technical University"
1901: Granted the right to award doctorates
1905: First female students
   First Female Doctoral Candidate: Amalie Baur
1930: Integration of the College of Agriculture and Brewing in Weihenstephan
1957: First Neutron Research Reactor in Germany
1967: Department of Medicine, University Hospital
1970: Presidential Constitution, renamed to "Technische Universität München - TUM"
TUM. Milestones

1999: TUM’s University Reform started
Entrepreneurial University Constitution

2000: Center of Life and Food Science
Weihenstephan (Matrix Structure)

2002: TUM Branch in Singapore (TUM. Asia)
TUM School of Management
Department of Sports Science

2004: High-Flux Research Neutron Source Heinz
Maier-Leibnitz

2005: Institute for Advanced Study (IAS)

2006: TUM elected “University of Excellence”

2009: TUM SCHOOL OF EDUCATION
TUM GRADUATE SCHOOL

2010: TUM University Foundation

2012: TUM elected “University of Excellence”
TUM. Selected Nobel Laureates

- Heinrich O. Wieland 1927, Chemistry
- Hans Fischer 1930, Chemistry
- Rudolf L. Mößbauer 1961, Physics
- Ernst Otto Fischer 1973, Chemistry
- Klaus von Klitzing 1985, Physics
- Robert Huber 1988, Chemistry
TUM. Selected Inventors, Engineers, Entrepreneurs

- Oskar von Miller
  Storage Power Plants
  Walchensee Power Plant
  German Museum

- Carl von Linde
  Refrigeration Engineering
  Linde’s Refrigeration Machines
  Air Liquefaction

- Rudolf Diesel
  Combustion Engine Development
  Diesel Engine (MAN)

- Claude Dornier
  Aircraft Construction
  Water Planes

- Willy Messerschmitt
  Aircraft Construction
  First Jet Plane Engine

- Heinz Maier-Leibnitz
  Neutron Research
  "Atom Ei"
TUM. Science Capital, Greater Munich.

- Garching
- Munich, Olympic Park
- Munich, Downtown
- Freising-Weihenstephan
- Munich, TUM Hospital
TUM. Locations in Bavaria

Iffeldorf

Obernach

Ingolstadt

Augsburg

Garching

Freising-Weihenstephan

Augsburg

Ingolstadt

Raitenhaslach

Freyung-Grafenau

Wettzell

MÜNCHEN

Rosenheim

Obernach/Walchensee

TUM Locations

Scientific Networks
Munich Metropolitan Region
Munich Metropolitan Region
TUM. Dimensions 2013/14

13 Departments
411 Buildings
154 Degree Courses

~ 36 000 Students, 33% Female Students, 20% Internat’l Students
~ 12 000 First-year Students
~ 7 113 Graduates
964 Doctorates completed

~ 5 000 Publications in peer-reviewed journals
501 Professors (incl. hospital)

~ 6 168 Scientific Staff Members (incl. hospital)
~ 3 232 Non-Scientific Staff Members (not incl. hospital)

19 ERC Grants 2008-11
48 Humboldt Laureates 2006-11
13 Nobel Prize Laureates
13 Leibniz Laureates (DFG) since 1986
4 Humboldt Professors

981 Research Agreements with Industry
Shanghai Ranking: 13th place in chemistry worldwide

TUM is Germany’s best technical university

16.08.2014, TUM in Rankings

In the new edition of the renowned Academic Ranking of World Universities ("Shanghai Ranking"), the Technische Universität München (TUM) occupies 53rd place. This positions TUM as Germany’s best technical university by far, and among the top four technical universities in Europe. In the rankings of individual subjects, TUM attained 13th place in chemistry and 30th place in computer science worldwide, ahead of all other German universities.

TUM is Germany’s best technical university. (Photo: A. Scharger/ TUM)

Nobel Prize or the Fields Medal.

The well respected ranking by Shanghai Jiao Tong University assesses the research performance of universities worldwide. The evaluation is based mainly on factors such as publications in important journals, scientists’ citation rates, and alumni who have won the...
TUM. Elite University

We aim for
Top-Level Research + Excellent Teaching

1. International top level research
2. Education focusing on specific scientific topics
3. Responsible for scientific advancements
4. Science and technology for people
5. Cosmopolitan attitude and global cooperation
TUM. Faculty of Civil, Geo and Environmental Engineering – Courses

Admission criteria

+ external applicants

Non-consecutive Master: program dependent admission criteria

Consecutive Master: program dependent admission criteria

Bachelor: Joint courses with other faculties

Bachelor: program dependent admission criteria
TUM. M.Sc. Computational Mechanics

- The M.Sc. *Computational Mechanics* was founded in 2000 by the Faculty Civil, Geo and Environmental Engineering.

- It aims for educating experts for industry and academia in the field of computational methods in mechanics for all areas of engineering.

- [http://www.come.tum.de](http://www.come.tum.de)
Generally, the lectures are offered at the central campus.

The main chairs involved are:

- Chair of Structural Mechanics, Prof. Gerhard MÜLLER
- Chair of Structural Analysis, Prof. Kai-Uwe BLETZINGER
- Chair of Computation in Engineering, Prof. Ernst RANK
- Chair of Hydromechanics, Prof. Michael MANHART
- Chair of Computational Mechanics, Prof. Fabian DUDDECK
Curriculum of the COME.tum program

- **Two years master program**
- **In total 120 ECTS credits**
  - 36 ECTS credits compulsory courses
  - 24 ECTS credits compulsory elective courses
  - 30 ECTS credits elective courses
  - 30 ECTS credits master’s thesis
- **TOTAL**
  - 120 ECTS

- **Additional qualification during your COME studies possible**
  - BGCE - Bavarian Graduate School of Computational Engineering
  - Selection process at the end of the first semester.
## Compulsory Modules

### Semester 1

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computation in Engineering 1</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Fluid Mechanics &amp; Turbulence</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Introduction into Finite Element Methods</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Computational Material Modelling I</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Continuum Mechanics</td>
<td>6 ECTS</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>30/120 ECTS</strong></td>
</tr>
</tbody>
</table>

### Semester 3

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Lab</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Project with focus on one of the specialisations</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>6/120 ECTS</strong></td>
</tr>
</tbody>
</table>

### Semester 4

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master Thesis</td>
<td>30 ECTS</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>30/120 ECTS</strong></td>
</tr>
</tbody>
</table>
Compulsory Modules – Computation in Engineering 1

CONTENT

• Object oriented modeling and programming (C++)
• Data structures
• Algorithms
• Finding roots, sorting
• Numerical integration
• Least squares method
• Conjugated Gradient method
• Quadtree/Octree structures
• Radiosity method
• Mesh generation

Quadtree for discretisation of a 2D region.

Stefanie Schraufstetter, André Borrmann, Ernst Rank
Compulsory Modules – Computation in Engineering 1
Introduction to Programming in C++

This module is running in the context of Comput. In Engrg 1

CONTENT
• Introduction into IDE (Integrated Development Environment)
• Expressions in C++
• Data types
• Control structures
• Functions
• Arrays
• Pointers & references, files
• Elementary algorithms
Compulsory Modules – Fluid Mechanics & Turbulence

CONTENT

• Kinematics
• Kinetics – Navier-Stokes equations
• Pipe flow, free surface flow
• Dimensional analysis
• Turbulent flows

APPLICATIONS

• Hydraulic, river and environmental engineering
• Building aerodynamics
• Process and mechanical engineering
Compulsory Modules – Introduction into Finite Element Methods

CONTENT

• Direct Stiffness Method
• Finite Element Modeling
• Variational Formulation
• Plane Stress Elements
• Beam and Plate Elements
• Convergence Requirements
• Locking and FE Technology
• Implementation
• Applications
• Complemented with the course on Modelling & Simulation (FE tutorials)

\[ K = \int_{-1}^{1} \int_{-1}^{1} t B^T \cdot C \cdot B |J| \, d\xi d\eta \]
Compulsory Modules – Introduction into Finite Element Methods
Tutorials on Modeling and Simulation

CONTENT

• Introduction to a commercial FE software
• Computer science and data management
• Mechanical modeling of structures
• Simulation of linear and first non-linear and/or dynamic processes
• Applications
• Validations
COMPULSORY MODULES – COMPUTATIONAL MATERIAL MODELLING I

CONTENT

• Computational descriptions for material behaviour (micro, meso & macro levels)

• Elasticity, visco-elasticity, plasticity, visco-plasticity, etc.

• Computational modeling of
  - Metals
  - Polymers
  - Composites
  - Ceramics
  - Foams
  - Biomaterials
  - Geomaterials
  - Others
Compulsory Modules – Continuum Mechanics

CONTENT

• Introduction into tensor analysis
• Description of stress states in arbitrary, curvilinear coordinates
• Lagrangian description of strain states
• Conservation of energy
• Conservation of mass
• Constitutive relations
• General treatment of continuum mechanical knowledge in order to solve non-linear problems
• References to approaches of Technical Mechanics (Torsion, Bending, Plates, Dynamics)

\[ \tau^{im} \|_i + Q^m - \rho b^m = 0 \]
Compulsory Modules – Software Lab (2\textsuperscript{nd} + 3\textsuperscript{rd} semester)

CONTENT

• Group work on software development.
• Engineering problems from different application fields.
• Collaboration with industry and academia
## Compulsory Elective Modules

### Semester 2 (Summer)
Choose 2 out of 4 modules

<table>
<thead>
<tr>
<th>Nonlinear Finite Element Methods</th>
<th>Computational Fluid Dynamics</th>
<th>Theory of Plates* and Shells</th>
<th>Structural Dynamics</th>
</tr>
</thead>
</table>

* The “plates lecture” as a part of the lecture (plates & shells) is given in the winter and it is recommended to take it already in the first semester.

**TOTAL: 12/120 ECTS**

Recommended: add elective modules **18/120 ECTS**

### Semester 3 (Winter)
Choose 2 out of 4 modules

|-------------------------------------------|-------------------|------------------------------------|-------------------------|

**TOTAL: 12/120 ECTS**

Recommended: add elective modules **12/120 ECTS**
Some Elective Modules (Semester 2 / Summer)

### 6 ECTS Modules

<table>
<thead>
<tr>
<th>Module</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Order &amp; Isogeom. Element Meth*</td>
<td></td>
</tr>
<tr>
<td>Isogeometric Structural Analysis &amp; Design*</td>
<td></td>
</tr>
<tr>
<td>Risk Analysis I</td>
<td></td>
</tr>
<tr>
<td>Vehicular Crash-worthiness*</td>
<td></td>
</tr>
<tr>
<td>Explicit FEM and Transient Analysis*</td>
<td></td>
</tr>
<tr>
<td>Turbulence modelling &amp; Turbulence Simulation Lab</td>
<td></td>
</tr>
<tr>
<td>Computation in Engineering II</td>
<td></td>
</tr>
<tr>
<td>Signal Proc. &amp; Measurem. 1*</td>
<td></td>
</tr>
<tr>
<td>Technical Acoustics I*</td>
<td></td>
</tr>
<tr>
<td>Technical Acoustics II (Sem 3)</td>
<td></td>
</tr>
</tbody>
</table>

Remarks: The parts marked with (.)* of these modules can also be taken as a small module (3 ECTS). The compulsory elective modules can be also chosen as electives if taken additionally.

### 3 ECTS Modules

<table>
<thead>
<tr>
<th>Module</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithms &amp; Data Structures</td>
<td></td>
</tr>
<tr>
<td>Biofluid Mechanics</td>
<td></td>
</tr>
<tr>
<td>Boundary Element Methods</td>
<td></td>
</tr>
<tr>
<td>Structural Reliability</td>
<td></td>
</tr>
<tr>
<td>Industrial Appl. of Structural Mechanics I</td>
<td></td>
</tr>
<tr>
<td>Comput Meth in Stochastic Dynamics</td>
<td></td>
</tr>
<tr>
<td>Building Energy Simulation</td>
<td></td>
</tr>
<tr>
<td>Advanced FEM</td>
<td></td>
</tr>
<tr>
<td>Integral Transform Methods</td>
<td></td>
</tr>
<tr>
<td>Contact Mechanics</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL: 18/120 ECTS

Complete list at TUMonline
Some Elective Modules (Semester 3 / Winter)

<table>
<thead>
<tr>
<th>6 ECTS Modules</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Non-destructive Testing I</td>
<td>Risk Analysis II</td>
</tr>
</tbody>
</table>

Remarks: The parts marked with (*) of these modules can also be taken as a small module (3 ECTS)

<table>
<thead>
<tr>
<th>3 ECTS Modules</th>
<th>3 ECTS Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computational Visualisation</td>
<td>Soil Dynamics</td>
</tr>
<tr>
<td>Engineering Databases</td>
<td>Industrial Applications if Struct Mech II</td>
</tr>
<tr>
<td>Stability of Structures</td>
<td>CFD Lab</td>
</tr>
<tr>
<td>Stochastic Finite Element Methods</td>
<td>Introduction to Random Vibrations</td>
</tr>
<tr>
<td>Modeling in Struct Dyn &amp; Vibroacoustics</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL: 12/120 ECTS**
**Elective Modules from other Programs**

- Among the 30 credits for elective modules, 21 ECTS have to be chosen from courses defined in the official curriculum (TUMonline).
- That means a maximum of 9 credits can be taken from other programs, for example:
  - Modules from other faculties (e.g. Mechanical Engineering)
  - Modules from the international ATHENS program
    http://www.athensprogramme.com/catalog
    http://www.international.tum.de/
  - Courses offered by the language center of the TUM
    German language is strongly recommended for international students
  - Courses from other master programs of the BGCE, mainly CSE (Computational Science and Engineering)
    www.cse.tum.de
Examinations (recommended 6 exams à 6 ECTS per semester)

<table>
<thead>
<tr>
<th>Semester 1 = 30 ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computation in Engineering I (6 ECTS)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semester 2 = 30 ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory Elective I (6 ECTS)</td>
</tr>
<tr>
<td>Compulsory Elective II (6 ECTS)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semester 3 = 30 ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Lab (6 ECTS)</td>
</tr>
<tr>
<td>Compulsory Elective IV (6 ECTS)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semester 4 = 30 ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master thesis (30 ECTS)</td>
</tr>
</tbody>
</table>

TOTAL: 120/120 ECTS
Compulsory Elective: Nonlinear Finite Element Methods

CONTENT

• Large deformations
• Instability
• Ultimate load analysis
• Element formulation
• Green Lagrange strain
  Piola Kirchhoff stresses
• Numerical methods
• Bifurcations, limit points
  path following algorithms
• Applications
Compulsory Elective: Computational Fluid Dynamics (CFD)

CONTENT
• Finite differences, finite volume method of weighted residuals
• Time integration
• Stability and accuracy analysis
• Solution of Navier-Stokes equations

APPLICATIONS
• Hydraulic, river and environmental engineering
• Building aerodynamics
• Process and mechanical engineering
Compulsory Elective: Theory of Plates and Shells

CONTENT

- Plane stress / plane strain
- Membranes, strut & tie models
- FE formulation
- Plates in bending
- Kirchhoff / Reissner-Mindlin

- Differential geometry
- Membrane theory
- Kirchhoff-Love theory
- Shells of revolution
- Force method
- Applications
Compulsory Elective: Structural Dynamics

CONTENT
Solution techniques for structures under the action of dynamic loads

- Single and multi degrees of freedom systems (SDOF and MDOF)
- Modal Analysis
- Statistical Energy Analysis
- Linear and non-linear systems
- Structures under seismic loads
- Structures under wind loads
- Machine foundations
Compulsory Elective: Functional Analysis & Linear Algebra

CONTENT

• Mathematical foundation for numerical methods
• Error analysis and convergence
• Hilbert, Sobolev and Banach spaces

• Vector and matrix algebra
• Solution methods for large systems
Compulsory Elective: Parallel Computing

CONTENT

• Introduction, hardware development
• Hardware: parallel and vector computers
• Basic concepts of parallel computing
• Performance measuring
• Message passing, the MPI library
• Blocking / non-blocking communication
• Domain decomposition techniques

Different domain decompositions of a FEM model
Compulsory Elective: Computational Material Modelling 2

CONTENT

• Algorithms for plasticity
• Advanced plasticity models
• Damage
• Fracture
• Creep
• Fatigue
Compulsory Elective: Structural Optimization 1 & 2

CONTENT

• Mathematical basics, basic algorithms
• Gradient-based methods
• Sizing optimization
• Shape and topology optimization
• Sensitivity analysis
• Design of Experiments
• Robustness
• Evolutionary/Genetic algorithms
• Swarm methods, ant colony
• Multi-criteria optimization
• Applications
The Bavarian Graduate School ... of Computational Engineering is an association of three Master programs:

1. **Computational Engineering (CE)** at the Friedrich-Alexander-Universität Erlangen-Nürnberg,

2. **Computational Mechanics (COME)**, and

3. **Computational Science and Engineering (CSE)** at the Technische Universität München.

Master of Science with Honours

- Students who master the regular program with an above-average grade, and are still able to complete the Honours program, as well, will earn an adequate degree for their outstanding performance - the "Master of Science with Honours".

http://www.bgsce.de/
Technische Universität München

Contact Address

Prof. Fabian DUDDECK
duddeck@tum.de
Tel.: 089 – 289-28656

Q&A TODAY: 5-6pm
Thanks for coming to TUM / COME