Module Catalog

B.Sc.
TUM Department of Aerospace and Geodesy
Technische Universität München

www.tum.de/
www.lrg.tum.de
Module Catalog: General Information and Notes to the Reader

What is the module catalog?
One of the central components of the Bologna Process consists in the modularization of university curricula, that is, the transition of universities away from earlier seminar/lecture systems to a modular system in which thematically-related courses are bundled together into blocks, or modules.
This module catalog contains descriptions of all modules offered in the course of study.
Serving the goal of transparency in higher education, it provides students, potential students and other internal and external parties with information on the content of individual modules, the goals of academic qualification targeted in each module, as well as their qualitative and quantitative requirements.

Notes to the reader:

Updated Information
An updated module catalog reflecting the current status of module contents and requirements is published every semester. The date on which the module catalog was generated in TUMonline is printed in the footer.

Non-binding Information
Module descriptions serve to increase transparency and improve student orientation with respect to course offerings. They are not legally-binding. Individual modifications of described contents may occur in praxis.
Legally-binding information on all questions concerning the study program and examinations can be found in the subject-specific academic and examination regulations (FPSO) of individual programs, as well as in the general academic and examination regulations of TUM (APSO).

Elective modules
Please note that generally not all elective modules offered within the study program are listed in the module catalog.
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[LRG0005] Bachelor's Thesis | Bachelor's Thesis

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[LRG0060] Computational Foundations I | Computational Foundations I
[CF1]
[LRG0020] CAD/TD for Aerospace Engineers | CAD/TD for Aerospace Engineers
[LRG0040] Aerospace Materials Science and Processing | Aerospace Materials Science and Processing
[LRG0080] Electrical Engineering | Electrical Engineering
[MA9802] Differential and Integral Calculus (MSE) | Differential- und Integralrechnung (MSE)

**[LRG0061] Computational Foundations II** | Computational Foundations II
**[LRG0030] Thermodynamics I** | Thermodynamics I
**[MA9803] Modeling and Simulation with Ordinary Differential Equations (MSE)** | Modellierung und Simulation mit gewöhnlichen Differentialgleichungen (MSE)
**[LRG0031] Thermodynamics II** | Thermodynamics II
**[LRG0070] Fluid Mechanics I** | Fluid Mechanics I
**[LRG0050] Aerospace Structures and Elements** | Aerospace Structures and Elements
**[MW1410] Heat Transfer (MSE)** | Heat Transfer (MSE)
**[LRG0071] Fluid Mechanics II** | Fluid Mechanics II
**[LRG0081] Automatic Control Engineering** | Automatic Control Engineering
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Bachelor's Thesis | Bachelor's Thesis

Module Description

LRG0005: Bachelor's Thesis | Bachelor's Thesis

Version of module description: Gültig ab winterterm 2023/24

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<tbody>
<tr>
<td>Bachelor</td>
<td>German/English</td>
<td>one semester</td>
<td>winter/summer semester</td>
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Credits:* 12

Total Hours: 360

Self-study Hours: 360

Contact Hours: 

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

The examination consists of the scientific elaboration of a Bachelor's Thesis in English, which is handed out and supervised by a university lecturer of the departments involved in the program (topic issuer). The thesis can be submitted in German upon application to the examination board, given the approval of the topic issuer.

Students apply the technical and methodological knowledge acquired during their studies to a scientific, specifically engineering or applied scientific question in the field of aerospace.

In doing so, the formal requirements of the respective chair as well as the "Guidelines for Ensuring Good Scientific Practice" of the TU Munich must be observed: Guidelines: https://portal.mytum.de/archiv/kompendium_rechtsangelegenheiten/sonstiges/wiss_Fehlverh.pdf/view

The processing time is 6 months. The written elaboration should normally contain the following sections: Introduction, problem definition and objectives, theoretical foundations, methods, results, summary, and appendix with bibliography. Details of the thematic orientation and structure should be clarified with the topic issuer prior to submission.

The submission of the scientific paper will be supplemented by an oral presentation, which will not be graded separately.

Repeat Examination:

Next semester

(Recommended) Prerequisites:

The completion of the bachelor's thesis module is meant to be the last exam students take in the program. A student can be accepted for the bachelor's thesis ahead of schedule upon application to the board of examiners, provided that the prerequisites defined in the statute (FPSO) are met.

Knowledge of the following code of conduct and citation guide are a required:
Content:
The module introduces the students to the scientific working method on the basis of a question defined by a university lecturer from the aerospace engineering field. They are instructed to use independent scientific work using the methods of engineering science. The independent written work of the students summarizes the essential aspects as well as the current state of knowledge/research of the subject area covered, discusses the developed solution approach and describes and discusses the scientific solution developed by the students.

Intended Learning Outcomes:
With the completion of their bachelor's thesis, students are able to quickly familiarize themselves with engineering-related topics and to independently and systematically apply solutions to scientific problems within a specified period. They have learned how to deal with concrete issues and to understand, describe and implement their solution in relation to the issue. In addition, participants are qualified to independently present, classify and professionally discuss facts and findings, based on scientific research. They are familiar with the principles of scientific writing and are in a position, based on the skills they have acquired, to work largely autonomously in the aerospace engineering field.

Teaching and Learning Methods:
The fundamental teaching and learning methods involved in preparing the bachelor's thesis are: conducting literature review and research, engaging in scientific reading, analyzing and describing a problem and finding solutions. Also included are the written and, if applicable, computer-based preparation of the issue and the solution. Under the guidance of the supervisor (topic issuer), the methodological principles for finding solutions are independently elaborated (methods of measurement and the setting up of testing facilities for practical work, as well as specific theoretical principles and software for theoretical work). By researching materials and literature the participants learn how to independently find the information they need to develop their thesis. The students are taught how to break down their scientific topic into individual tasks in order to be able to achieve their objective within the specified time frame and structural conditions.

Media:
While writing the bachelor's thesis, students have access to all the relevant aids that they may need for their respective thesis (subject-related literature, measuring instruments and testing facilities in labs and technical centers, computers and software).

Reading List:
Literature sources depending on topic area; individual research; Code of conduct for safeguarding good academic practice: https://portal.mytum.de/archiv/kompendium_rechtsangelegenheiten/sonstiges/wiss_Fehlverh.pdf/view
TUM Citation Guide produced by the University Library: https://mediatum.ub.tum.de/?id=1225458

**Responsible for Module:**
Studiendekan LRG | studiendekanat@lrg.tum.de

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click campus.tum.de or here.
Required Modules | Pflichtmodule

Module Description

MA9801: Basic Mathematics (MSE) | Mathematische Grundlagen (MSE)

Version of module description: Gültig ab summerterm 2021

<table>
<thead>
<tr>
<th>Module Level:</th>
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<tbody>
<tr>
<td>Bachelor</td>
<td>English</td>
<td>one semester</td>
<td>winter semester</td>
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</table>

Credits:* 8

Total Hours: 240
Self-study Hours: 135
Contact Hours: 105

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The final exam consists in a 90-min written test (A4 cheat sheet allowed). During the exam it will be proved whether the students have learnt the basics of Analysis in R (Real numbers) and of linear Algebra and are able to apply them to solve simple problems.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
None

Content:
Basics and Notation in Linear Algebra and Analysis in R (Real numbers).
- Linear Algebra: Systems of linear equations, matrix factorization, eigenvalues, linear least squares, with emphasis on numerical algorithms and their implementation
- Analysis in R (Real numbers): limits, continuity, differentiation; Newton's method and further applications
- Numerical methods: polynomials and polynomial interpolation

Intended Learning Outcomes:
At the end of the module, the students are able to
- understand basic one dimensional optimization problems using tools like first and second order optimality conditions, monotonicity and convexity
- analyze fundamental concepts in Linear Algebra and Analysis in R (Real numbers),
- apply the basic vector and matrix calculus for solution of problems arising in applications like network analysis or curve fitting
- implement and test numerical algorithms for the solution of simple engineering problems in MATLAB or similar software.

**Teaching and Learning Methods:**
The module consists of a lecture where the content is taught by a presentation and using the blackboard. The lecture is accompanied by exercises with individual- and team-work to improve and apply the theoretical knowledge.

**Media:**
Homework assignments;
Presentation of exercises;
Programming with MATLAB.
Solutions of the homework assignments are provided online.

**Reading List:**

**Responsible for Module:**
Wohlmuth, Barbara; Prof. Dr. rer. nat.

**Courses (Type of course, Weekly hours per semester), Instructor:**
Mathematische Grundlagen (MSE) [MA9801] (Vorlesung, 5 SWS)
Cicalese M, Forster M

Übungen zu Mathematische Grundlagen (MSE) [MA9801] (Übung, 2 SWS)
Cicalese M, Forster M

For further information in this module, please click campus.tum.de or here.
Module Description

Statics

Version of module description: Gültig ab winterterm 2021/22

<table>
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<tbody>
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<td>Bachelor</td>
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<table>
<thead>
<tr>
<th>Credits:*</th>
<th>Total Hours:</th>
<th>Self-study Hours:</th>
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<tbody>
<tr>
<td>6</td>
<td>180</td>
<td>75</td>
<td>105</td>
</tr>
</tbody>
</table>

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Accompanying the lecture, exercise and groupd exercise in this module, homework assignments on the current topic are offered at intervals of about two weeks. They are of small size and serve as feedback for the student on his progressing knowledge of the mechanics of rigid and elastic bodies.
At the end of the semester, a written exam (90 minutes) is held to test whether the students can identify problems concerning bodies at rest and find ways to solve them within a limited period of time using the given methods and defined aids. In particular, it is tested to what extent the students can remember, classify and calculate static structures, mechanical models and different systems.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basic knowledge of mathematics (Differentiation, Integration,...) and physics (forces, law of levers, ...)

Content:
Mechanics as a branch of physics is a fundamental discipline in the engineering sciences.
It deals with the description and predetermination of the movements of bodies and with the associated forces. Bodies at rest as a subfield of mechanics are described in (elasto-)statics, the fundamentals of which are taught in this module. This is mainly done for rigid bodies, but towards the end of the courses also for elastic bodies.
The main topics are:
modeling in mechanics, general plane and spatial structures, trusses, beams, frame and arch beams, principle of virtual work, friction, rope statics, Elastostatics of small distortions (expansion bar), work and energy methods

**Intended Learning Outcomes:**
After successful participation in the module course Engineering Mechanics 1, students are able to recognize static load-bearing structures in nature and technology. They can extract mechanical models from reality, classify them in terms of analysis and calculate statically determinate as well as statically indeterminate systems using the methods they have learned. This is done above all with regard to forces occurring between and within rigid bodies. They are also able to recognize relationships in elastostatics, i.e. between forces and deformations, and to calculate these for simple types of structures. The basic methods learned contribute to the development of the ability to formulate mechanical issues in engineering problems and to solve them independently.

**Teaching and Learning Methods:**

**Media:**
Lecture, presentation with tablet PC, gap script in lecture, learning materials on learning platform, homework on learning platform.

**Reading List:**

**Responsible for Module:**
Prof. Markus Ryll

**Courses (Type of course, Weekly hours per semester), Instructor:**
For further information in this module, please click campus.tum.de or here.
Module Description

LRG0060: Computational Foundations I | Computational Foundations I [CF1]
Computational Foundations I

Version of module description: Gültig ab winterterm 2021/22

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<tbody>
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<td>Bachelor</td>
<td>English</td>
<td>one semester</td>
<td>winter semester</td>
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<tr>
<th>Credits:*</th>
<th>Total Hours:</th>
<th>Self-study Hours:</th>
<th>Contact Hours:</th>
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<tbody>
<tr>
<td>5</td>
<td>150</td>
<td>105</td>
<td>45</td>
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</table>

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The successful completion of this module is checked in a written examination (90 minutes) in which the students have to prove that they are able to solve problems using techniques from computer science and informatics in limited time. The answers involve free formulations as well as multiple-choice questions.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
one

Content:
This lecture introduces basic program elements like machine models, variables, pointers, objects, and control structures with very basic programming exercises in C/C++ and MATLAB. It includes very basic exposition to recursion, event-driven programming (interrupts, event queue, etc.), and functional programming as well. We will introduce algorithms as examples covering Part I Foundations from the seminal book "Introduction to Algorithms" (Cormen et al.). Then, C++ +11 data structures (map, queue, list, set, unordered sets, priority queue, tree) are introduced together with their algorithms (linear search, binary search, sorting, min-hash, balanced trees). as well as modern C++ control structures and their use (e.g., unique_ptr, shared_ptr, unique_lock, scoped_lock, counting_semaphore, latches, barriers etc.).
In this way, a clear introduction to core principles of programming and common pitfalls is ensured as all these advanced structures have been introduced to avoid common pitfalls and inefficiencies.
Reference literature includes parts of Bjarne Stroustrup’s book “Programming”. In the tutorials, we will introduce selected algorithmic patterns (e.g., dynamic programming, integer programming, shortest paths, divide & conquer) as they are only to be understood by applying them to toy problems.

Then we increase the versatility of students in computational engineering problems by introducing selected non-trivial algorithms.

A chapter on correctness including treatment of rounding errors, infinite precision computation, and the Hoare calculus complete the lectures core exposition.

Finally, students will get an overview (partly simplified) to the real world including special situations including embedded, GPU, FPGA, Supercomputer, and other challenging computational environments and what they imply for programming and software design.

**Intended Learning Outcomes:**

By completing this module, students will have had a detailed exposition to two (mainly) imperative programming environments MATLAB and C/C++. They have learned the core language. Furthermore, students have understood a selection of data structures (arrays, trees, maps, hash tables, priority queues, sets), programming patterns, and core algorithms.

**Teaching and Learning Methods:**

Lecture and presentation, exercises

**Media:**

slides, handout, script, literature, whiteboard, screencasts, examples

**Reading List:**

Cormen et al. "Introduction to Algorithms"; Bjarne Stroustrup’s “Programming” (2nd edition)

**Responsible for Module:**

Prof. Martin Werner

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0020: CAD/TD for Aerospace Engineers | CAD/TD for Aerospace Engineers

Version of module description: Gültig ab winterterm 2021/22

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<tbody>
<tr>
<td>Bachelor</td>
<td>English</td>
<td>one semester</td>
<td>winter semester</td>
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<thead>
<tr>
<th>Credits:*</th>
<th>Total Hours:</th>
<th>Self-study Hours:</th>
<th>Contact Hours:</th>
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<tr>
<td>3</td>
<td>90</td>
<td>45</td>
<td>45</td>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The learning outcomes are tested by a total of two achievements and one assessment method. The assessment method is a written exam with a duration of 90 minutes at the end of the semester. This exam examines the student's ability to produce their own component drawings, to master modern CAD systems and their modelling approaches independently of software, and to answer questions regarding the design of constructions using examples. In addition to the usual writing material, drawing pens, pencils, compasses, rulers, and the circle template are permitted as aids during the exam. The written exam ensures a practical examination of the skills learned. The mark of the exam is considered as the module mark.

The first achievement is the submission of a component drawing done by hand in the middle of the semester. To complete this achievement successfully, the fundamentals of engineering drawings, which were part of the lectures up to this point, have to be applied correctly.

The second achievement is the submission of a complex component drawing done by CAD. For the successful completion, the drawing has to be complete and conform with standards. The submission is due to the end of the semester.

The final grade is an averaged grade from the written exam (60 %) and from the submissions of the component drawings (40 %).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none
Content:
The course covers the basic principles of technical drawing, CAD, and design theory:

Content technical drawing:
- Fundamentals of engineering drawings (drawing types, scale, line types, lettering)
- Drawing of engineering components (views, rules view projection, hatching, section views, rules for marking)
- Dimensioning of engineering components (fundamentals of dimensioning, drawing and dimensioning of threads, dimensioning for manufacture)
- Surface specifications (surface roughness, edge specifications, hardness, knurls)
- Tolerances (fundamentals of tolerances, tolerances of dimensions, positional and shape tolerances)
- Fits (basic concept of fits, ISO tolerance fields, fit selection with standard bore/shaft)
- Joint connections (types of seams/joints and their drawing/dimensioning)
- Standard Parts (drawing of commonly used standard parts, shaft-hub connections, bearings, and gears)

Content CAD:
- Basic principles (history, classification within CAE, differences 2D/2.5D/3D)
- Models (wireframe, surface, volume)
- Elements (points, lines, splines, planes, sketches, surfaces, bodies/solids)
- Operations (block/extrusion, rotation, boolean operators)

Content design theory:
- Basic rules (straightforward, simple, safe)
- Approach (integral/differential, top down-/bottom up-principle)
- Production oriented design (design for welding, casting, forging, and cutting manufacturing)
- Load compliant design (force transmission, basic rules)

Intended Learning Outcomes:
Upon completion of the module, students are able to:
- analyse a complex component drawing of an engineering component.
- analyse the connection between component and assembly drawings.
- create a component drawing of an engineering component.
- describe important basic terms of CAD systems and explain their differences.
- evaluate different engineering components regarding their design strategy.

Teaching and Learning Methods:
lecture + exercise

Media:
- Scripts
- Presentations
- Exercise Sheets
- Additional exercises and solutions

**Reading List:**
- Scripts of the Chair
- Documents on the moodle platform

**Responsible for Module:**
Prof. Mirko Hornung

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click [campus.tum.de](http://campus.tum.de) or [here](http://example.com).
Module Description

LRG0040: Aerospace Materials Science and Processing

Version of module description: Gültig ab winterterm 2021/22

<table>
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<th>Module Level: Bachelor</th>
<th>Language: English</th>
<th>Duration: two semesters</th>
<th>Frequency: winter/summer semester</th>
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<tbody>
<tr>
<td>Credits:* 8</td>
<td>Total Hours: 210</td>
<td>Self-study Hours: 120</td>
<td>Contact Hours: 90</td>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written examination is taken.
The duration of the exam is 90 minutes. A programmable calculator is permitted for the examination. Students demonstrate in the exam that they have mastered the vocabulary of materials engineering and know the requirements, properties and applications of various materials in aerospace.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
It is recommended to have heard the lecture "Introduction into Aerospace".

Content:
- Fundamentals of materials science for polymers and metals
- Material properties (stiffness, strength, failure mechanisms)
- Metallic materials
- Fiber composites
- High temperature materials
- Functional materials
- Sandwich structures
- Joining technology
- Additive manufacturing
- materials testing
- NDT
- Digitization in materials engineering and manufacturing
- Exemplary application in aircraft construction and space technology
- Life cycle considerations

**Intended Learning Outcomes:**
The following learning outcomes are intended:
- Students have achieved a basic understanding of materials.
- Students will be able to apply the vocabulary of materials engineering.
- Students are familiar with essential materials in the aerospace industry and their properties.
- Students can select the appropriate materials according to the requirements for an application.

**Teaching and Learning Methods:**
The following learning methods are used:
- Teaching content by means of lectures and case studies
- Open discussion with the students during the lecture and in the exercises.
- Through self-study or individual note-taking in the lecture, students learn to elaborate essential content.
- Deepening of understanding through laboratory exercises.

**Media:**
PowerPoint
Whiteboard / Flip chart

**Reading List:**
Hornbogen, Eggeler, Werner: Werkstoffe. Aufbau und Eigenschaften, Springer
Werner, Hornbogen, Jost, Eggeler: Fragen und Antworten zu Werkstoffe, Springer
N. Eswara Prasad , Aerospace Materials and Material Technologies, Springer
Sohel Rana, Advanced Composite Materials for Aerospace Engineering: Processing, Properties and Applications, Elsevier

**Responsible for Module:**
Prof. Klaus Drechsler

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0080: Electrical Engineering | Electrical Engineering

Version of module description: Gültig ab winterterm 2021/22

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<th>Module Level:</th>
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<th>Duration:</th>
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<tbody>
<tr>
<td>Bachelor</td>
<td>English</td>
<td>two semesters</td>
<td>winter/summer semester</td>
</tr>
</tbody>
</table>

Credits:* 8

Total Hours: 240
Self-study Hours: 150
Contact Hours: 90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination consists of a written exam (90 minutes), for which only a non-programmable calculator is permitted as an aid. In the written exam, the students are to demonstrate their understanding of fundamental technical terms such as voltage, current, electric and magnetic fields as well as their knowledge of technical components of electric drive systems and their application in the aerospace sector by means of examples using knowledge and transfer questions.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
No prior knowledge is required to attend the module

Content:
Electric circuits (key terms: electric voltage and current, resistance, electric circuits, Kirchhoff’s laws); Electric field (electrical potential, electric field strength, electric flux density, material equation, electrical induction, capacitor, charging and discharging); Magnetic field (magnetic field strength, magnetic flux density, material equation, voltage induction, coil arrangements and inductance, charging and discharging); DC voltage, AC voltage, voltage sources (ideal, real), soft and hard magnetic materials; DC machines (design and basic principle, balance of electrical and mechanical power flow, DC shunt wound machine, DC series-wound machine, losses and power efficiency); fundamentals of power electronic components (materials and basic effects, switching elements, applications); DC/DC converters (buck, boost); exemplary drive system; outlook on further drive systems

Intended Learning Outcomes:
By taking the module course, students gain a basic understanding of the electrical engineering methods used in aerospace engineering. They understand the physical effects of voltage, current,
electric and magnetic fields. In addition, students master the analysis of linear electrical networks and are able to apply this knowledge to AC and three-phase systems. In addition, students gain a basic understanding of the physical operation and torque generation in electrical machine and know their structure as well as their fundamental function. Students will be familiar with the operation of semiconductor devices and their application to the control (open/closed loop) of electrical machines and converters.

**Teaching and Learning Methods:**
As a learning method, in addition to the students' individual methods, a deepening knowledge formation is aimed at through repeated task calculation in exercises. The teaching method in the lectures and exercises is frontal teaching, in the exercises also working lessons (calculating tasks). During the lecture, the theoretical fundamentals are taught by means of presentations. Important correlations are derived. A collection of slides and a collection of exercises are made available to the students online. Furthermore, lecture notes are available to the students. Students are encouraged to solve the exercises independently. The corresponding solutions are presented in the exercise and discussed in the context of the theoretical foundations from the lecture.

**Media:**
The following media Forms are used:
- slide presentations
- script
- exercises with solutions as downloads

**Reading List:**
to be announced during the course

**Responsible for Module:**
Prof. Hans-Georg Herzog

**Courses (Type of course, Weekly hours per semester), Instructor:**
For further information in this module, please click [campus.tum.de](http://campus.tum.de) or here.
Module Description

MA9802: Differential and Integral Calculus (MSE) | Differential- und Integralrechnung (MSE)

Version of module description: Gültig ab winterterm 2021/22

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The final exam consists in a 90-min written test (A4 cheat sheet allowed). During the exam it will be
proved whether the students have learnt the basics of Calculus and Analysis in more dimensions
and of simple ordinary differential equations and are able to apply them to solve simple problems.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
MA9801 Basic Mathematics

Content:
Analysis in R (Real numbers) and Rn (Euclidean space)
- Analysis in R (Real numbers): Riemann quadrature; main theorem of integral and differential
calculus, Laplace and Fourier transformation, Fast Fourier Transform (FFT)
- Analysis in Rn (Euclidean space): partial and total derivative, mean value theorem, Taylor
expansion, Gradient, Hessian matrix, Extremal problems, Newton's Method in Rn (Euclidean
Space)
- Integration in Rn (Euclidean Space): Vector Analysis
- linear o. d. e.’s with constant coefficients and source terms

Intended Learning Outcomes:
At the end of the module students
- understand the essential concepts of one - and multidimensional calculus
- are able to apply analytical methods and concepts like first and second order optimality
conditions for functions of more than one variable, Taylor series expansions or integration in higher
dimensions
- have the basic tools listed above to the treatment of advanced engineering problems like higher
dimensional constrained optimization problems or first and second order linear ODEs

Teaching and Learning Methods:
The module consists of a lecture where the content is taught by a presentation and using the
blackboard. The lecture is accompanied by exercises with individual- and team-work to improve
and apply the theoretical knowledge.

Media:
Presentation of exercises; Solution of exercises;
Programming with MATLAB.
Solutions of exercises can be found in the Internet.

Reading List:
Ansorge, R./Oberle, H. J.: Mathematik für Ingenieure 1 Lineare Algebra und analytische
Ansorge, R./Oberle, H. J.: Mathematik für Ingenieure 2 Differential- und Integralrechnung mehrerer
Variabler, gewöhnliche und partielle Differentialgleichungen, Integraltransformationen,..., Wiley-
VCH Verlag (2003).
Dahmen, W./Reusken, A.: Numerik für Ingenieure und Naturwissenschaftler, Springer Verlag
J. Stewart: Essential Calculus, Cengage Learning Services;

Responsible for Module:
Wohlmuth, Barbara; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Übungen zu Differential- und Integralrechnung (MSE) [MA9802] (Übung, 2 SWS)
Flad H

Differential- und Integralrechnung (MSE) [MA9802] (Vorlesung, 5 SWS)
Flad H

For further information in this module, please click campus.tum.de or here.
Module Description


Structural Mechanics Modeling

Version of module description: Gültig ab summerterm 2022

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
There will be an 90 min written exam at the end of the semester. The examination consists of small examples to the main topics of the lecture and exercise. Students should demonstrate that they are able to classify structures, describe them in terms of mathematical models and that they are able to understand the principal mechanical behavior of trusses, beams, plates and so on.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Engineering Mechanics I - Statics

Content:
Modeling is the process of describing physical and engineering systems in terms of mathematical equations which can be solved analytically or numerically. Model selection is determined by the mechanical characteristics of the system as well as by the analysis' objectives. This course provides an overview over widely used models in structural mechanics. The corresponding differential equations are derived from a continuum approach by applying dimensional reduction and incorporating mechanical assumptions.

Specifically the following topics will be addressed:
- basics of continuum mechanics
- basics of tensor algebra calculus
- dimensional reduction
- classification of structures
- differential geometry, governing equations, assumptions and structural behaviour of various structural models: truss, beams (Timoshenko beam, Bernoulli beam), in
- plane loaded plates, plates in bending (Reissner-Mindlin plate, Kirchhoff plate) and shells
- principle of virtual work
- derivation of the weak form of the governing differential equations

**Intended Learning Outcomes:**
Upon successful completion of the module, the students have the capabilities to
- extract mechanical models based on reality
- classify structures
- describe structures in terms of mathematical models
- understand the principal mechanical behaviour of trusses, beams, plates and shells

**Teaching and Learning Methods:**
The lecture is given in the form of a talk. Important contents, mathematical equations and
correlations for a better understanding of structural mechanics modeling are written on the tablet-
PC to enable the students to write them in the gaps in the script. Important contents (classification
of structures, extraction of mechanical models based on reality) are pointed out and presented in
detail. In the exercise courses, problems are solved as examples and additional exercises are
distributed for a better understanding of the principal mechanical behaviour of trusses, beams,
plates and so on. Doing these exercises is a voluntary offer to the students.

**Media:**
Presentation with tablet-PC; Script with gaps that have to be filled during the lectures; Whiteboard;
Learning materials on the learning platform

**Reading List:**
M. Bischoff, W. A. Wall, K.-U. Bletzinger, E. Ramm, Models and Finite Elements for Thin-Walled
Szilard, Theories and Application of Plate Analysis, Wiley, 2004a

**Responsible for Module:**
Prof. Michael Gee

**Courses (Type of course, Weekly hours per semester), Instructor:**
For further information in this module, please click [campus.tum.de](http://campus.tum.de) or [here](http://example.com).
Module Description

LRG0061: Computational Foundations II | Computational Foundations II

Version of module description: Gültig ab summerterm 2022

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The successful completion of this module is checked in a written examination (60 minutes) in which the students have to prove that they are able to solve problems using techniques from computer science and informatics in limited time. The answers involve free formulations as well as multiple-choice questions.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Knowledge of theory and practice as is available from the module Computational Foundations I

Content:
This lecture introduces computers from the lowest sensible level by introducing some theory and practice of electronic digital circuits including the basic building blocks of digital computers (clocks, flip-flops, half- and full-adder). On this basement, very simple computers are discussed in some detail based on the Atmel family of microcontrollers (Arduino and others) and basic bus systems (I2C, SPI, etc.) are sketched. On this basement, we explore the field of low-level programming including applications such as real-time software, embedded software, distributed systems, and edge computing using FPGAs and GPUs switching to higher level programming languages (Arduino C, C++11 for NVIDIA GPUs, C++20 for cooperative multitasking) where appropriate. Finally, we show how concepts from distributed systems (client-server, publish-subscribe, etc.), object orientation (inheritance), garbage collection (reference counting), and software engineering can help structuring programs even in those environments where language support is infeasible. The lecture closes with a short overview on software quality aspects including performance optimization, resource sharing, security, safety and proof of correctness, error tolerance and others.
Intended Learning Outcomes:
By completing this module, students will have had a detailed exposition to special programming environments including both realtime and embedded domains and specialized hardware such as GPUs or FPGAs. In addition, they know advanced patterns of software development and software design, which helps them in planning and writing high-quality software even when language support structures such as constructors, exceptions, user interface, debuggers, and IDEs are unavailable.

Teaching and Learning Methods:
Lecture, presentation, discussion, exercises

Media:
slides, handout, script, literature, whiteboard, screencasts, examples

Reading List:

Responsible for Module:
Prof. Martin Werner

Courses (Type of course, Weekly hours per semester), Instructor:
For further information in this module, please click campus.tum.de or here.
Module Description

LRG0030: Thermodynamics I | Thermodynamics I

Version of module description: Gültig ab summerterm 2022

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Being able to think, clearly and logically under pressure is an important skill for an engineer. To test this skill, an exam of 90 min duration in written form must be passed in this module.

The first part of the examination (question and answers section) will give you the opportunity to demonstrate your understanding of the module material by answering comprehension questions on the material covered in the lectures, in particular on basic thermodynamic concepts, material behaviour and balance equations. Further, you will be asked to reproduce relevant formulas of fundamental importance for simple cases as well as explain thermodynamic terms and outline selected thermodynamic processes.

In the second part of the examination (calculation part), you are asked to prepare mass, energy, and entropy balances for propulsion systems, machines, and plants within the broader aerospace context. A special focus is placed on developing the right solution for complex problems. You will have to apply thermal, energetic and entropic equations of state using the equations and given data in order to calculate various technically relevant quantities and parameters for the respective problems.

No aids are permitted in the question and answers section, not even a calculator. In the calculation part, all aids except electronic devices may be used, the use of a calculator is permitted.

Note in view of the limitations on university operations as a result of the CoViD19 pandemic: If the basic conditions (hygiene, physical distance rules, etc.) for a classroom-based examination cannot be met, the planned form of examination can be changed to a written online examination in accordance with §13a APSO. The decision about this change will be announced as soon as possible, but at least 14 days before the date of the examination by the examiner after consultation with the board of examiners of the respective study program.

Repeat Examination:

Next semester
(Recommended) Prerequisites:

Content:
The big idea in thermodynamics - and in this module is that energy is conserved and minimized at equilibrium. Aerospace engineers and scientists must be able to apply thermodynamics in order to understand and control the structure-properties-processing relationships that exist in physical systems. In this module "Thermodynamics 1" you will learn how to effectively, and accurately manipulate the thermodynamic formalism to mathematically describe the behavior of propulsion systems, machines, and plants at equilibrium. In addition, you will learn how to utilize thermodynamic data to predict and optimize the behavior of complex physical systems.

The following topics are covered:

Basic concepts
- Phase and aggregate state
- Thermodynamic systems
- Thermodynamic state and state variables
- Process and process variables

Properties of matter
- Thermal behaviour (pressure, temperature and specific volume)
- Energetic behaviour (inner energy and enthalpy)
- Entropic behavior (entropy)
- Exergetic behaviour (exergy and anergy)
- Ideal gas mixtures
- Canonical state equation (fundamental equation)

Work, heat, potential and kinetic energy

Balance equations
- Mass balances
- Energy balances
- Entropy balances
- Exergy balances

Simple state changes
- Ideal gases (work and heat, efficiencies)
- Real fluids in single-phase and two-phase areas (p-v diagram, T-s diagram, h-s diagram, p-h diagram)

Thermodynamic cycles (heat – work)
- Ideal gases
- Real fluids with phase transitions
Intended Learning Outcomes:
Upon successful completion of this module, you are able to describe the fundamental quantities, relationships and laws of thermodynamics.

Specifically, you are able to ...
- explain the physical assumptions behind thermal, energetic and entropic state descriptions for technically relevant model substances, i.e., ideal gas, gas mixtures, incompressible liquids and solids, as well as for real fluids in the single- and multi-phase range,
- apply analytical equations of state,
- obtain and use data on thermodynamic properties,
- describe the functionality and thermodynamic implications of typical technical propulsion systems, machines, and plants, and
- list and explain thermodynamic cycles of high technical relevance.

In addition, you will be able to grasp the possibilities and limits of analytical mathematical descriptions and you are able to simplify complex problems in such a way that they can be solved analytically or at least semi-analytically by means of balancing using the thermodynamic state equations and data.

Teaching and Learning Methods:
The module consists of a series of lectures, guided exercises, and tutor exercises.
In the lectures you will learn the basics of thermodynamics by listening to and actively following the presentation of the lecturer. The explanations are supported by examples and active learning techniques such as turn-to-your-partner exercises, muddiest part of the lecture, and ungraded concept quizzes, that are interspersed in the presentation. To support your learning outcome, a lecture script and a collection of formulas are made available both online and in printed form. The presentation slides are also available online.
In the guided exercises, the problem sets will give you the opportunity to apply what we have been discussing each week in the lecture. The solution of problems from the exercise script is derived and the theoretical background necessary for solving the problem is repeated in compact form. The teacher presents and explains important formulas and tips for solving problems typical for the exam.
In a voluntary tutor exercise, you can independently solve further problem sets from the exercise script as well as selected old exams. Tutors are available to support you. All exercises and further information are made available online. Old examination questions can be downloaded or obtained from the student council to prepare for the exam.
In the lectures, guided exercises, and tutor exercises, you should make notes of areas/topics/problems that give you particular difficulty, and make sure to speak to the lecturer, tutors, or your peers about them. Individual help can be given during assistant consultation hours and special tutor consultation hours if required.

Media:
lecture notes, collection of formulas, slides, exercise notes
Reading List:


Responsible for Module:
Prof. Agnes Jocher

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Module Description

MA9803: Modeling and Simulation with Ordinary Differential Equations (MSE) | Modellierung und Simulation mit gewöhnlichen Differentialgleichungen (MSE)

Version of module description: Gültig ab summerterm 2021

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The assessment method is a written exam of 60 minutes duration. Students may use one DIN-A4 sheet of handwritten notes (double-sided) during the examination. No other learning aids are permitted. In the exam students should identify mathematical models and ODEs for basic processes in science and engineering, examine the qualitative properties of the ODEs and select and apply suitable analytical and numerical solution methods.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
MA9801 Basic Mathematics,
MA9802 Differential and Integral Calculus

Content:
Initial value problems for ordinary differential equations (ODEs):
- Analysis: existence, uniqueness, stability.
- Modeling and simulation with ODEs: Mathematical modeling of engineering problems with ODEs, numerical simulation, introduction to MATLAB ODE solvers

Intended Learning Outcomes:
At the end of the module students
i) understand the essential concepts in mathematical modeling with ODEs,
ii) are able to formulate initial value problems and solve them by numerical methods,
iii) can visualize parameter dependent solutions.
Teaching and Learning Methods:
The Lecture is presented on blackboard, overhead or tablet. In tutorials, students solve exercises by themselves with support by a tutor. To deepen the mathematical intuition, students work in teams on the solution of small problems using MATLAB or similar software packages. In the tutorials the students apply the analytical and numerical methods presented in the lecture to the solution of small model problems inspired by engineering practise.

Media:
Presentation of exercises; Solution of exercises; Programming with MATLAB; Solutions of exercises can be found in the Internet.

Reading List:

Responsible for Module:
Wohlmuth, Barbara; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Übungen zu Modellierung und Simulation mit gewöhnlichen Differentialgleichungen (MSE) [MA9803] (Übung, 2 SWS)
Ullmann E, Wagner F

Modellierung und Simulation mit gewöhnlichen Differentialgleichungen (MSE) [MA9803] (Vorlesung, 2 SWS)
Ullmann E, Wagner F

For further information in this module, please click campus.tum.de or here.
Module Description


Dynamics

Version of module description: Gültig ab winterterm 2022/23

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Accompanying the lecture, exercise and group exercise in this module, homework assignments on the current topic are offered at intervals of about two weeks. They are of small size and serve as feedback for the student on his progressing knowledge of bodies at rest and bodies moving in time. At the end of the semester, a written exam (90 minutes) is held to test whether the students can identify problems concerning moving bodies and find ways to solve them in a limited amount of time using the given methods and defined aids. In particular, it is tested, for example, to what extent the students can remember, analyze and calculate mechanical problems concerning forces, movements and oscillation systems.

Repeat Examination:
Next semester

(Recommended) Prerequisites:

Content:
Mechanics as a branch of physics is a fundamental discipline in the engineering sciences. It deals with the description and predetermination of the movements of bodies and the associated forces. In the Engineering Mechanics I module, time-independent forces and deformations were considered (bodies at rest); Engineering Mechanics II is now about bodies moving in time. The main topics are: Kinematics of points and rigid bodies in fixed and also in moving coordinate systems (relative kinematics), kinetics of point masses and rigid bodies, impact phenomena, oscillations.
Intended Learning Outcomes:
After successful participation in the module course Engineering Mechanics II, students are able to describe occurring movements in nature and technology geometrically (kinematically). They further understand the interaction of forces and motions and can analyze and calculate this with the methods learned. They are also able to calculate oscillation systems. The basic methods learned contribute to the development of the ability to formulate mechanical issues in engineering problems and to solve them independently.

Teaching and Learning Methods:
The lecture takes place as a lecture in which the theoretical basics of temporally moving bodies are conveyed. Important contents of the lecture are written on the tablet PC, which the students can transfer to their cloze script. In the exercises, example problems will be precalculated and further, weekly exercise problems will be distributed. The completion of these exercises is voluntary. Questions about these assignments, in addition to other general questions, may be asked in small group tutorials. Written homework assignments are provided on the learning platform approximately every two weeks. They can be worked on at home and then handed in. Students will receive feedback on their assessment once it has been corrected.

Media:
Lecture, presentation with tablet PC, gap script in lecture, learning materials on learning platform, homework on learning platform.

Reading List:

Responsible for Module:
Prof. Michael Gee

Courses (Type of course, Weekly hours per semester), Instructor:
For further information in this module, please click campus.tum.de or here.
Module Description

LRG0031: Thermodynamics II | Thermodynamics II

Version of module description: Gültig ab winterterm 2022/23

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Competences are assessed in a 90 minutes written examination. The examn comprises two blocks, a questions block and a calculation block. The exam is conducted without any auxiliary measures, only in the calculation block a calculator can be used. The first block of the examination students are to answer comprehension questions with respect to the content taught and have to be able to reproduce essential formula, explain specific terms and sketch out thermodynamic processes. In the second block of the examination students are to solve a structured set of calculation tasks concerning thermodynamic processes with specific aerospace relevance.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Advanced Mathematics 1+2, Thermodynamics 1, Fluid Mechanics 1

Content:
Chapter 1: Thermodynamics processes of aerospace engines and components
1.1 Basic thermodynamic cycles  --  1.2 Component thermodynamic process basics  --  1.3 Thermodynamic challenges

Chapter 2: Specific thermo-physical properties and thermodynamic phenomena:
2.1 Near critical point phenomena  --  2.2 Cavitation  --  2.3 Flashing  --  2.4 Near-triple-point phenomena

Chapter 3: Thermodynamics of high-speed fluid flow
3.1 Velocity of sound and Mach number  --  3.2 Conservation equations of compressible flow (mass, momentum and energy)  --  3.3 Normal compression shocks  --  3.4 Sub- and supersonic
nozzle flow -- 3.5 Diabatic flow through a pipe -- 3.6 Characteristics of Fanno flow and Rayleigh flow

Chapter 4: Combustion
4.1 Introduction to combustion -- 4.2 Mixing -- 4.3 Ignition Mechanisms -- 4.4 Flame propagation -- 4.5 Flame stabilisation and reaction sequence -- 4.6 Mixture preparation -- 4.7 Global and elementary reactions -- 4.8 Reaction schemes, reaction rates, chemical equilibrium -- 4.9 Lean and rich burn combustion -- 4.10 Emissions -- 4.11 Systems with conversion of species

Intended Learning Outcomes:
After a successful participation to this module the students know key devices of aerospace systems such as jet or rocket engines, compressors and turbines and the phenomena which drive the design of these components and subsystems. They will be able to analyze thermodynamic processes relevant to aerospace applications and apply the learnt skills in thermo-physical properties of species, gas dynamics and combustion for classical problems in aerospace engineering. Finally, the students will have the competence to analyze complex thermo-physical systems and sub-systems, identify and judge phenomena upon their importance.

Teaching and Learning Methods:
The module consists of a series of lectures and exercises.
In the lectures students acquire competences by listening to and actively following the presentation of the lecturer. To support your learning outcome, lecturing presentation slides and a collection of formulas are made available online. In the exercises, the problem sets will give you the opportunity to apply what we have been discussing each week in the lecture. The solution of problems are derived and the theoretical background necessary for solving the problem is repeated in compact form.
In the lectures and exercises students should make notes of areas/topics/problems that give you particular difficulty, and make sure to speak to the lecturer, tutors, or your peers about them. Individual help can be given during assistant consultation hours and special tutor consultation hours if required.

Media:
Presentation, Exercises

Reading List:
Responsible for Module:
Prof. Volker Gümmer

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0070: Fluid Mechanics I | Fluid Mechanics I

Version of module description: Gültig ab winterterm 2022/23

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
An exam of 90 min duration in written form must be passed.
In the first part of the examination (question & answers section), students answer comprehension questions on the material covered in the lectures. They reproduce relevant formulas of fundamental importance for simple cases. They explain technical terms and outline selected fluidmechanic practices. No aids are permitted in the question & answers section, not even a calculator.
In the second part of the examination (calculation part), the students perform calculations of the covered topics. A special focus is on developing the right solution for complex problems. In the calculation section, all aids except electronic devices may be used, use of a calculator is permitted.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Advanced Mathematics I, II, III; Engineering Mechanics I, II; Thermodynamics I

Content:
- Physics of fluids
- Kinematics of flows
- Conservation laws of fluid mechanics
- Law of Bernoulli
- Wave propagation and gas dynamics
- Viscous flows
- Technical flows

Intended Learning Outcomes:
After successful participation in this module, the students possess knowledge in:
(1) the fundamental behavior of liquid and gaseous fluids,
(2) the capability for cinematic descriptions of flows,
(3) the capability for dynamic analysis of fluids with the conservation laws of mass, momentum and energy,
(4) the capability for describing and analyzing simple compressible flows,
(5) the capability for determining simple exact solutions of the Navier-Stokes formulas,
(6) the phenomenological understanding of the effects of friction and turbulence,
(7) the capability for analyzing technical flows.

Teaching and Learning Methods:
In the lectures the teaching contents are mediated by means of speech and presentation. Examples for explanation are interspersed in the presentation. For this purpose, a lecture script and a collection of formulas are made available both online and in printed form. The presentation slides are also available online.
In the exercises, the solution of problems from the exercise script are derived and the theoretical background necessary for the solutions is repeated in compact form. The lecturer presents and explains important formulas and tips for solving problems typical for the exam. In a voluntary tutorial exercise group the students can independently solve further problems. Tutors are available to support the students. All exercises and further information are made available online.

Media:
Script, presentation slides, exercises

Reading List:
Kundu & Cohen "Fluid Mechanics"

Responsible for Module:
Prof. Christian Breitsamter / Prof. Nikolaus Adams

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0050: Aerospace Structures and Elements | Aerospace Structures and Elements

Version of module description: Gültig ab winterterm 2022/23

<table>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination of this course is conducted in written form (Duration 90 min). The students shall find ways to solve problems in limited time with the allowed aids. By answering questions, solving calculation tasks, drawing sketches and diagrams it is examined, if the students achieved the intended learning outcomes. The students shall be able to answer questions about materials, design principles and components in aerospace as well as about effects of elastostability, fatigue, loads and aeroelasticity. They shall show their understanding of the topics mentioned above and that they can apply calculation methods to typical problems by solving calculation tasks which includes transfer of learning. Allowed aids are: writing utensils, ruler, calculator (non-programmable) A formulary will be provided during the exam. It will also be provided before the exam for preparation.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
- Engineering Mechanics
- Advanced Mathematics I-II
- Aerospace Materials Science and Processing

Content:
The contents are:
- Aerospace Materials and Elements
- Lightweight Structure Components
- Fundamental of Finite Element Method
- Structural Dynamics
- Elastostability and Buckling
- Strength and Fatigue
- Aircraft Loads
- Aeroelasticity
- Wing Structures
- Fuselage Structures
- Launcher and Satellite Structures
- Testing Procedures and Certification

Intended Learning Outcomes:
At the end of the course, the students are able to:
- compare current technologies and structural concepts in aerospace in the context of physical technological and economical aspects
- name the basic materials in aerospace with their properties, to evaluate them and to select them depending on the requirements.
- distinguish the main components and design principles in aerospace and to perform evaluations by consideration and calculation.
- explain effects of elasto-stability and fatigue and to perform evaluations about stability and fatigue-strength of aerospace components.
- explain outer- and inner loads on aircraft and to calculate example loads to perform a rough structural sizing of components.
- explain effects of aeroelasticity and to perform example calculations to determine static- and dynamic aeroelastic stability of aircraft structures.
- distinguish and evaluate different wing- and fuselage structures.
- distinguish and evaluate different launcher- and satellite structures.
- name and distinguish the main testing procedures for aerospace structures.

Teaching and Learning Methods:
In the lecture, the contents are taught in form of lecture and presentation. Theoretical basics of aerospace structures are explained and illustrated. The presentation slides are provided to the students beforehand to allow them to take notes during the lecture. Besides that, the students are encouraged to further study relevant technical terms and general correlations by using lecture notes and relevant literature. If needed, students shall repeat content of their basic studies on their own initiative, as the calculation methods in this course are based on that content.
In the tutorial course, exercises are presented by explaining the solutions on a tablet PC. The exercise instructions are provided to the students beforehand and the results are evaluated and discussed with the students during the course. Discussions of real-live examples and demonstration samples are used to further illustrate contents of the lecture. Exemplary evaluations and calculations for structural sizing of aerospace structures are performed. The students are encouraged to solve the presented exercises on their own subsequent to the tutorial course and to compare the solutions.
For selected topics, further exercises including solutions are provided to the students for voluntary homework.
Media:
- Presentation slides lecture
- Presentations slides tutorial, with blank spaces and calculation tasks that shall be filled in and solved
- Presentation slides tutorial, example solutions
- Presentation slides with further calculation tasks to solve in self-study
- Extra examples like animations, videos and numerical calculations
- All media are provided beforehand on moodle

Reading List:
Niu, Chunyun, Airframe Structural Design, Hong Kong [u.a.], Conmilit Press [u.a.], 2006
Niu, Chunyun, Airframe Stress Analysis and Sizing, Hong Kong, Conmilit Press [u.a.], 2011
Bruhn, Elmer F., Analysis and Design of Flight Vehicle Structures, Cincinnati/Ohio, Tri-state Offset Comp., 1973
Wright, Jan R., Introduction to Aircraft Aeroelasticity and Loads, Chichester, Wiley, 2015
Wiedemann, Johannes, Leichtbau, Berlin [u.a.], Springer, 1996

Responsible for Module:
Prof. Mirko Hornung / Prof. Markus Ryll

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Module Description

MW1410: Heat Transfer (MSE) | Heat Transfer (MSE)

Version of module description: Gültig ab summerterm 2020

<table>
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<tr>
<th>Module Level: Bachelor</th>
<th>Language: English</th>
<th>Duration: one semester</th>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Written final examination, aids will be provided (formulary). Duration 90 minutes.
The students should prove in the examination that they understand the basic principles of the stationary and transient processes of conduction, convection and radiation.

Note in view of the limitations on university operations as a result of the CoViD19 pandemic: If the basic conditions (hygiene, physical distance rules, etc.) for a classroom-based examination cannot be met, the planned form of examination can be changed to a written or oral online examination in accordance with §13a APSO. The decision about this change will be announced as soon as possible, but at least 14 days before the date of the examination by the examiner after consultation with the board of examiners of the respective study program.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Thermodynamics, fluid and solid mechanics

Content:
Introduction to heat transfer
Fundamentals of conduction: Fourier's law; Fourier ODE; Boundary Conditions
Stationary conduction: Péclet equation for plane walls, cylinders and spheres; 2D heat conduction
Heat transfer by radiation: black body radiation; emissivity and absorptivity of grey, black and real bodies; Kirchoff's law; spectral properties
Heat exchanger: NTU-efficiency & Log-averaged temperature methods
Convective Heat Transfer: physical phenomena of convective heat transfer; similarity theory and dimensionless groups; correlations for the Nußelt-numbers in configurations of applied interest
Natural convection: laminar convection for isothermal, vertical surfaces, Boussinesq approximation of the boundary layer equations; dimensionless groups; Nußelt correlations for isothermal walls
Transient heat conduction: Biot number, semi-infinite bodies; Fourier series for plane wall, cylinder and sphere; similarity approaches

**Intended Learning Outcomes:**
After successfully passing the Heat Transfer module, students are able to describe heat transport processes. In particular, they understand the basic principles of stationary and transient processes of conduction, convection and radiation and are able to analyse and calculate systems accordingly. The learned basic methods contribute to the development of the ability to identify thermal engineering problems and to solve them independently.

**Teaching and Learning Methods:**
The lecturer presents the topics via lecture and presentation. Terms and fundamentals are introduces and the exercise lecture applies them to real world problems. The slides of the lecture, a collection of exercises and the corresponding solutions are made available to the students via the TUMs e-learning platform.

Individual questions can be discussed directly after the lecture with the lecturer and his assistants or in a personal meeting (with appointment only).

**Media:**
Slides, writing on the board

**Reading List:**
**Responsible for Module:**
Haidn, Oskar; Prof. Dr.-Ing.

**Courses (Type of course, Weekly hours per semester), Instructor:**
Heat Transfer (MSE) (MW1410) (Vorlesung, 2 SWS)
Haidn O [L], Haidn O (von Sethe C), Martinez Sanchis D, Sternin A

Tutorium Heat Transfer (MSE) (MW1410) (Tutorium, 1 SWS)
Haidn O [L], Martinez Sanchis D, Sternin A

ZÜ Heat Transfer (MSE) (MW1410) (Vorlesung, 1 SWS)
Haidn O [L], Martinez Sanchis D, Sternin A

For further information in this module, please click [campus.tum.de](http://campus.tum.de) or [here](http://here).
Module Description

LRG0071: Fluid Mechanics II | Fluid Mechanics II

Version of module description: Gültig ab summerterm 2023

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

An exam of 90 min duration in written form must be passed.

In the first part of the examination (question & answers section), students answer comprehension questions on the material covered in the lectures. They reproduce relevant formulas of fundamental importance for simple cases. They explain technical terms and outline selected fluidmechanic practices. No aids are permitted in the question & answers section, not even a calculator.

In the second part of the examination (calculation part), the students perform calculations of the covered topics. A special focus is on developing the right solution for complex problems. In the calculation section, all aids except electronic devices may be used, use of a calculator is permitted.

Repeat Examination:

Next semester

(Recommended) Prerequisites:

Advanced Mathematics I, II, III; Engineering Mechanics I, II; Thermodynamics I; Fluid Mechanics I

Content:

The module conveys further fundamentals of fluid mechanics and is therefore part of the fundamental engineering education of classical mechanics. Topics are:

1. Vortex flows,
2. Potential flows,

(Recommended) Prerequisites:

Advanced Mathematics I, II, III; Engineering Mechanics I, II; Thermodynamics I; Fluid Mechanics I

Content:

The module conveys further fundamentals of fluid mechanics and is therefore part of the fundamental engineering education of classical mechanics. Topics are:

1. Vortex flows,
2. Potential flows,
Intended Learning Outcomes:
After successful participation in this module, the students possess knowledge in:
(1) describing and analyzing of vortex flows,
(2) the capability to model simple flows with elementary vortices,
(3) describing and analyzing irrotational flows (Potential flows),
(4) modelling two-dimensional potential flows with elementary potential flows,
(5) the theory of boundary layer flows,
(6) the exact and approximated solution of the boundary layer equations,
(7) the phenomenological description of separated flows,
(8) the phenomenological description of the laminar-turbulent transition.

Teaching and Learning Methods:
In the lectures the teaching contents are conveyed by speech and presentation. Examples for explanation are interspersed in the presentation. For this purpose, a lecture script and a collection of formulas are made available both online and in printed form. The presentation slides are also available online. In the exercises, the solution of problems from the exercise script are derived and the theoretical background necessary for the solutions is repeated in compact form. The teacher presents and explains important formulas and tips for solving problems typical for the exam. In a voluntary tutor exercise the students can independently solve further problems. Tutors are available to support the students. All exercises and further information are made available online.

Media:
Script, presentation slides, exercises

Reading List:
Kundu & Cohen "Fluid Mechanics

Responsible for Module:
Prof. Christian Breitsamter / Prof. Nikolaus Adams

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0081: Automatic Control Engineering | Automatic Control Engineering

Version of module description: Gültig ab summerterm 2023

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
At the end of the semester a written exam (90 min) will be conducted. Students are allowed to bring one sheet of paper (DIN-A4) with handwritten equations, text and sketches (both sides of the paper) and bring writing and drawing materials.

During the exam the students shall demonstrate that they are able to:
- model simple mechanical and electrical systems in time and frequency domain
- linearize differential equations and characteristic graphs
- analyse system characteristics such as stability, transfer functions, linearity, etc...
- compute system responses using Laplace transformation
- apply and evaluate Bode and Nyquist diagrams
- design basic controllers in the time and frequency domain and apply stability criteria
- design advanced control strategies encompassing disturbance rejection, feedforward control and cascaded control loops
- develop and evaluate state feedback controllers and state observers
- apply linearized input/output feedback control of nonlinear single-input-single-output (SISO) systems
- discretize continuous controllers for digital computers

Repeat Examination:  
Next semester

(Recommended) Prerequisites:  
Recommended prerequisites are the contents of the following lectures:
- Applied mathematics for engineers I-III, particularly good knowledge about complex numbers and laplace-transformation.
- Mechanical Engineering I-III, particularly good knowledge about modeling of mechanical systems.
- Basics to technical electricity, particularly good knowledge about electrical circuits.

Content:
Automatic control deals with the specific manipulation of technical systems. The considered systems are in relation with the outside world by specified in- and output signals. The design of technologies, which generate input signals to achieve desired responses of the output signals, is the focus of automatic control.

Content:
1. Basic concept of automatic control
2. Modeling
3. Laplace transformation
4. Analysis of dynamic systems
5. Closed-loop systems and stability
6. Control design
7. Advanced control strategies and state feedback control
8. Digital realization of controllers

The content is based on the German lecture "Regelungstechnik" by Prof. B. Lohmann.

Intended Learning Outcomes:
Upon successful completion of the module, students are able to:
- model simple mechanical and electrical systems in time and frequency domain
- linearize differential equations and characteristic graphs
- analyse system characteristics such as stability, transfer functions, linearity, etc.
- compute system responses using Laplace transformation
- apply and evaluate Bode and Nyquist diagrams
- design basic controllers in the time and frequency domain and to apply stability criteria
- design advanced control strategies encompassing disturbance rejection, feedforward control and cascaded control loops
- develop and evaluate state feedback controllers and state observers
- apply linearized input-/ output feedback control of nonlinear single-input-single output systems
- discretize continuous controllers for digital computers

Teaching and Learning Methods:
Within the lecture, the theoretical principles of automatic control will be derived by presentations and writing on the board. A script will be available for the students.
Exercise sheets will be provided to the students and solved within dedicated exercise courses. The active participation of the students by questions and comments within these exercise courses is desired.
Complete solutions of the exercise sheets will be provided. The lectures and the exercise courses encompass the relevant content of the exam.
Media:
Presentation, blackboard, script, supplementary material, exercises

Reading List:
Reference literature for the lecture automatic control:


Responsible for Module:
Prof. Florian Holzapfel (Prof. Boris Lohmann)

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0090: Test, Analysis, and Simulation | Test, Analysis, and Simulation

Version of module description: Gültig ab summerterm 2023

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The course will be assessed through a 90 minute written examination, including both theoretical questions and simple calculation problems. Students should demonstrate an understanding of probability and statistics theory, and be able to explain basic concepts of modelling, design of experiments and simulation discussed in the lecture (e.g. estimation, validation, noise, variance, etc.). Problems may for example include simple data analysis, model construction, estimator application, regression, statistical test application, etc. Additionally, homework projects assigned during the term will flow towards the final mark.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Advanced mathematics I, II, III

Content:
1. Statistics
   a. Basic probability theory (random variables, distributions, etc.)
   b. Descriptive statistics
   c. Statistical tests (t-test, chi-square test, etc.) and figures of merit (accuracy, precision, p-value, etc.)
   d. Parameter estimation
   e. Maximum likelihood
   f. Regression methods
   g. Correlation and causality
2. Design of Experiments (DoE)
   a. Need for DoE
b. Experiment design  
c. Error propagation and error sources (noise, bias, quantification)  
d. Parameter analysis  
e. Time series analysis and overfitting  
3. Mathematical modelling  
a. Modelling of systems  
b. Degree of abstraction and complexity  
c. Model structures (ODE, PDE, etc.) and model types (black-box, white-box, etc.)  
d. System identification  
e. Model quality assessment (variance, bias, correlation)  
f. Sensitivity analysis  
g. Uncertainty analysis  
4. Simulation  
a. Types of simulations / systems  
b. Numerical methods for simulation  
c. Monte-Carlo simulations  
d. Validation and verification  
e. Overview of available modelling software and respective features  

**Intended Learning Outcomes:**  
This module provides an introduction to testing and the underlying statistics theory, with particular focus on aerospace applications. The course will begin with an introduction to statistics. Concepts of probability and estimation theory will be discussed, as well as the most commonly used statistical tests. The concept of parameter estimation will be introduced, based on simple fitting and estimation methods. Building on the theory, we will then discuss design of experiments and time series analysis. The final part of the lecture will focus on modelling and simulation. Students will become familiar with different types of models, key criteria to assess model quality and validity, and the main elements of simulation development. An overview of the most widely-used modelling software will also be given to better equip students for practical applications in their further studies.

**Teaching and Learning Methods:**  
This module will include a lecture and a tutorial. The lecture will involve presentations, accompanied by slides and blackboard writing, and will cover the fundamental theory as well as put it into context in an aerospace perspective. The tutorial will involve working through simple problems to demonstrate how the studied theory is applied. In addition to simple generic problems, examples will be drawn from the aerospace domain. Exercise sheets will be provided to the students.

**Media:**  
Presentation slides, lecture notes, tutorial problems, programming examples

**Reading List:**  
Vorlesungsskripte werden zur Verfügung gestellt; für einen detaillierteren Einblick werden Lehrbücher empfohlen
Responsible for Module:
Prof. Sophie Armanini

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Electives | Wahlmodule

System Elective | System Elective

Module Description

LRG0100: Aircraft Design Basics | Aircraft Design Basics

Version of module description: Gültig ab summerterm 2023

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<th>Module Level: Bachelor</th>
<th>Language: English</th>
<th>Duration: one semester</th>
<th>Frequency: summer semester</th>
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<td>Self-study Hours: 105</td>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The module exam is conducted in the form of a written examination (90 min). Allowed aids are a non-programmable calculator and a ruler. Based on short questions and calculation tasks, the students prove that they are able to design aircraft assemblies and define an aircraft configuration, in a way that customer regulations and the latest regulatory requirements are fulfilled.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basic Mathematics, Differential and Integral Calculus, CAD/TD for Aerospace Engineers, Aerospace Structures and Elements

Content:
1. Introduction
   Historic evolution
   Design process

2. Aerodynamics
   Lift
   Drag
   Airfoil design
   High-lift devices
   Drag reduction
   Stability and trim
3. Structure and mass
   Main assemblies
   Mass estimation for transport aircraft
   Growth factors
   V-n diagram
   Centre of gravity estimation

4. Propulsion design
   Classification
   Engine thrust
   Fuel consumption
   Engine sizing
   Novel propulsion concepts

5. Point performance
   Specific Excess Power
   Turning flight

6. Mission performance
   Mission segments
   Take-off
   Cruise
   Landing
   Mission fuel assessment

7. Design chart
   Basic concepts
   Constraint curves
   Parameter sensitivity

8. Configuration and assemblies
   Main modules
   Integrative aspects
   Design guidelines

9. Electric aircraft technologies
   Potentials and concepts
   Hybrid propulsion concepts
   Operational impact

**Intended Learning Outcomes:**
After successfully participating at the module, students are able to:
- Implement various modern design methods, design tools and analysis models for the applied design of fixed-wing aircraft.
- Design individual assemblies of the aircraft with a view to the aircraft at its entirety.
- Quantify the financial and ecological efficiency along a typical flight mission.

**Teaching and Learning Methods:**
The lecture conveys the theoretic fundamentals of aircraft design by means of presentation and blackboard. Participants are provided with access to a complete scriptum (as Pdf or printed). The students make use of this in order to understand the basics of the aircraft design process. In the exercise, the acquired knowledge is applied via practical calculation tasks. Information to the exercise tasks is provided to the students a priori. Individual transcript by the students during the exercise is expected however. Personal help and consultation is offered in the associated office hours. Thereby, the students learn to implement various design methods and relevant design tools for the applied design of fixed-wing aircraft, to lay out assemblies of the aircraft with regard to the entire aircraft and to define the aircraft configuration in its entirety, so that the latest safety, economic, comfort, ecologic and performance requirements are met.

**Media:**
Presentation, blackboard, tablet-PC with monitor, online teaching material, quizzes, scriptum

**Reading List:**


**Responsible for Module:**
Prof. Mirko Hornung

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click [campus.tum.de](http://campus.tum.de) or [here](http://here).
Module Description

LRG0101: Rotorcraft and VTOL Design Basics | Rotorcraft and VTOL Design Basics

Version of module description: Gültig ab summerterm 2023

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<th>Duration:</th>
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<tr>
<td>Bachelor</td>
<td>English</td>
<td>one semester</td>
<td>summer semester</td>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The module exam is conducted in the form of a written examination (90 min). Allowed aids are a non-programmable calculator and a ruler. Based on short questions and calculation tasks, the students prove that they are able to design Rotorcraft and VTOL assemblies and define an Rotorcraft and VTOL configurations in a way that customer requirements and the applicable certification specifications are fulfilled.

Repeat Examination:
Next semester

(Recommended) Prerequisites:

Content:
1. Introduction
   Historic evolution
   Configurations, models
   Typical missions

2. Aeromechanics
   Introduction to momentum theory
   Hover
   Climb
   Forward Flight
   Autorotation
   Ground effect
   Blade element theory basics
3. Sizing
   Empty mass estimation
   Center of gravity
   Major sub-systems
   MTOW estimation

4. Rotor sizing
   Rotor types
   Sizing parameters
   Rotor limits
   Rotor controls

5. Dynamic system
   Main gearbox
   Turbine engines
   Electrical engines

6. Required power
   Hover
   Forward flight
   Correction factors

7. Mission consumption
   Norm atmosphere
   Specific fuel consumption
   Electric energy
   Mission energy consumption

8. Sizing for missions
   Sizing cycle
   MTOW loop
   Parameter studies, carpet plots

9. Typical sub systems
   Cargo
   Flight over sea
   Sensors

**Intended Learning Outcomes:**
After successfully participating at the module, students are able to:
- Apply various sizing methods and modeling approaches for the applied design of Rotorcraft and VTOL.
-Define major sub-systems of rotorcraft and VTOL aircraft with regard to the overall system performance.
-Evaluate and eventually optimize the defined configurations under consideration of typical mission profiles.

**Teaching and Learning Methods:**
The lecture conveys the theoretic fundamentals of Rotorcraft and VTOL design by means of presentation and blackboard. Participants are provided with access to a complete scriptum (as Pdf or printed). The students make use of this in order to understand the basics of the Rotorcraft and VTOL design process. In the exercise, the acquired knowledge is applied via practical calculation tasks. Information to the exercise tasks is provided to the students a priori. Individual transcript by the students during the exercise is expected however. Personal help and consultation is offered in the associated office hours. Thereby, the students learn to implement various design methods and relevant design tools for the applied design of fixed-wing Rotorcraft and VTOL, to lay out assemblies of the Rotorcraft and VTOL with regard to the entire Rotorcraft and VTOL and to define the Rotorcraft and VTOL configuration in its entirety, so that the latest safety, economic, comfort, ecologic and performance requirements are met.

**Media:**
Presentation, blackboard, tablet-PC with monitor, online teaching material, quizzes, scriptum

**Reading List:**

**Responsible for Module:**
Prof. Manfred Hajek

**Courses (Type of course, Weekly hours per semester), Instructor:**
For further information in this module, please click campus.tum.de or here.
Module Description

LRG0102: Basics of Propulsion Systems | Basics of Propulsion Systems

Version of module description: Gültig ab summerterm 2023

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Competences are assessed in a 90 minutes written examination. The examn comprises two blocks, a questions block and a calculation block. The examn is conducted without any auxiliary measures, only in the calculation block a calculator can be used. The first block of the examination students are to answer comprehension questions with respect to the content taught and have to be able to reproduce essential formula, explain specific terms and sketch out relevant processes. In the second block of the examination students are to solve a structured set of calculation tasks concerning propulsion system processes with specific aerospace relevance.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Thermodynamics 1+2, Fluid Mechanics 1

Content:
Chapter 1 (AP, SP): Overview and classification of propulsion solutions -/-/ Chapter 2 (AP): Air-breathing engines: requirements, role of Mach number, mission profile, architecture, components -/-/ Chapter 3 (AP): Fundamental fluid-mechanical and thermodynamic basics: Bernoulli, isentropic relationships, 1st law thermodynamics, engine thermodynamic cycle -/-/ Chapter 4 (AP): Working principle of turbomachinery: compressors, turbines, velocity diagrams, Euler-equation -/-/ Chapter 5 (AP): Turbomachinery similitude: geometric and kinematic similitude, stage characteristics, characteristic parameters -/-/ Chapter 6 (AP): Basics of turbomachinery operational behavior -/-/ Chapter 7 (SP): Different space missions and according launcher design requirements -/-/ Chapter 8 (SP): Launcher and stage architecture, propulsion system components, engine thrust levels, propellant choice (solid/liquid), burn times and tank dimensions -/-/ Chapter 9 (SP): Engine cycle (staged combustion, gas generator, expander), propellant feed system (pump-fed, pressure-fed)
Chapter 10 (SP): Key components of most severe loads (thrust chamber assembly, turbo-pumps, thrust nozzle)  
Chapter 11 (SP): Relevant subsystems for ignition, propellant injection and combustion chamber cooling  
Chapter 12 (SP): Materials and manufacturing techniques

Intended Learning Outcomes:
This lecture addresses fundamentals of the role of flight mission and payload imposed on aerospace propulsion units. Students learn about key design drivers for the definition of propulsion units for aeronautic and space transport, as well as the propulsion system performance and life requirements, which are strongly dependent on the aircraft or launcher system. Students will know about the different types, applications and architectures of propulsion systems from a transport system design perspective. With the knowledge provided students can judge the impact of the flight mission in terms of requirements and constraints on propulsion system and component level. For aeronautical applications the propulsion unit is rather a system in its own right, imposing aerodynamic, thermal and design challenges, whereas for space applications the propulsion system is extremely important, i.e. for launchers more than 80% of gross lift-off-weight is propellant. The key aspects of aeronautic propulsion (AP) and space propulsion (SP) are covered in the individual sections of this lecture.

Teaching and Learning Methods:
The module consists of a series of lectures and tutorials. In the lectures students acquire competences by listening to and actively following the presentation of the lecturer. To support your learning outcome, lecturing presentation slides and a collection of formulas are made available online. In the tutorials, the problem sets will give you the opportunity to apply what we have been discussing each week in the lecture. The solution of problems are derived and the theoretical background necessary for solving the problem is repeated in compact form.
In the lectures and tutorials students should make notes of areas/topics/problems that give you particular difficulty, and make sure to speak to the lecturer, tutors, or your peers about them. Individual help can be given during assistant consultation hours and special tutor consultation hours if required.

Media:
Presentation, Exercises

Reading List:

Responsible for Module:
Prof. Volker Gümmer

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0103: Basics in Space Technology | Basics in Space Technology

Version of module description: Gültig ab summerterm 2023

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
- Fundamentals of rocket propulsion: rocket principle; basic rocket equation; recoil thrust & pressure thrust; specific impulse; special solutions to rocket equation; propulsion and propellant requirements; efficiency; trade offs structure vs. payload; staging; staging types; payload & propulsion effort optimization.
- Propulsion Systems: Propulsion concepts; Thermodynamic considerations; Flow conditions; Combustion chamber and nozzle geometry; Nozzle matching; Engine design; Thrust coefficient; Expansion ratio; Overexpansion/underexpansion; Propulsion cooling; Monoergole propulsion systems; Diergole propulsion systems; Cold gas; Propellants; Conveying systems; Off-flow
propulsion systems; Main-flow propulsion systems; Solid propulsion systems; Electric propulsion systems; Exotic propulsion systems.
- Launch systems: performance characteristics; selection criteria; launch loads; payload capacity; cost; reliability; overview of available systems; launch sites; satellite market; future projections
- Environmental Impacts: Environmental influences on orbits; atmosphere; atmospheric stratification; atmospheric physics; density distribution; chemical composition & temperature; electromagnetic properties; solar influence; solar flares; solar constant; Earth's magnetic field; solar radiation; Van Allen Belt; Galactic Cosmic Radiation; radiation effects (SEUs); space debris; protective shields.
- Ascent Trajectories: Equations of motion & coordinate systems; Ascension trajectories; Ascension phases; Gravity turn; Pitch maneuver. — Astrodynamics I: Newton's equation of motion; conservation laws; conservation of angular momentum; conservation of energy; two-body problem; conic sections
- Astrodynamics II: Orbital elements; Kepler's laws; Orbital curves; Vis-Viva; Cosmic velocity; Solutions of the equations of motion; 2-momentum orbital transfers; Hohmann transitions; Target errors
- Interplanetary flights: trajectories to planets & moon; concept of spheres of influence; transfer times; launch windows; flyby maneuvers; weak stability boundary transfers; libration points - Re-entry: thermal problem of re-entry; equations of motion; Re-entry at high altitudes; Ballistic entry; Skip re-entry; Thermal loads; Critical acceleration; Protective measures; Apollo and Shuttle examples.

**Intended Learning Outcomes:**
After participating in the module course, students will be able to understand the relevant fundamentals of rocketry, astrodynamics and environmental effects and identify their impact on space technology systems. Based on this knowledge, they are able to analyze existing missions and question selected solutions. Upon completion of the course, you will have all the necessary knowledge to have a say in mission assessments and make a relevant contribution.

**Teaching and Learning Methods:**
In the lecture, the course content is taught by means of lecture, presentation and blackboard writing. The book on the lecture is recommended as a supplement and follow-up. In the accompanying exercise, important key points are repeated and dealt with in greater depth. Students learn to perform system evaluations using rough calculations and estimations. The exercise also provides examples and information on current issues in spaceflight.

**Media:**
Lecture, Tablet-Presentation, Blackboard, Online Teaching Material, Online Quizzes

**Reading List:**

**Responsible for Module:**
Prof. Ulrich Walter
Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Modeling Elective | Modeling Elective

Module Description

LRG0110: Computational Aerodynamics | Computational Aerodynamics

Version of module description: Gültig ab winterterm 2023/24

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
An exam of 90 min duration in written form must be passed.
In the first part of the examination (question & answers section), students answer comprehension questions on the material covered in the lectures. They reproduce relevant formulas of fundamental importance for simple cases. They explain technical terms and outline selected computational aerodynamics practices. No aids are permitted in the question & answers section.
In the second part of the examination (calculation part), the students perform calculations of the covered topics. A special focus is on developing the right solution for complex problems. In the calculation section, all aids except electronic devices may be used; use of a calculator is permitted.

Repeat Examination:
Next semester

(Recommended) Prerequisites:

Content:
The module conveys further fundamentals of computational aerodynamics. Topics are:
- Introduction to Computational Fluid Dynamics (CFD)
- Navier-Stokes equations – numerical solutions
- Finite-volume methods
- Overview on turbulence models
- Boundary conditions
- Mesh generation
- Analysis and visualization
- Example aerodynamic problems
Intended Learning Outcomes:
After successful participation in this module, the students possess knowledge in:
1. understanding of fundamental modeling concepts,
2. understanding of methods available in state-of-the-art flow simulation tools,
3. setting up and conducting flow simulations,
4. analyzing and evaluating simulation results,
5. critical analysis of key numbers.

Teaching and Learning Methods:
In the lectures the teaching contents are mediated by means of speech and presentation. Examples for explanation are interspersed in the presentation. For this purpose, a lecture script and a collection of formulas are made available both online and in printed form. The presentation slides are also available online. In the exercises, the solution of problems from the exercise script are derived and the theoretical background necessary for the solutions is repeated in compact form. The teacher presents and explains important formulas and tips for solving problems typical for the exam. In a voluntary tutor exercise the students can independently solve further problems. Tutors are available to support the students. All exercises and further information are made available online.

Media:
Script, presentation slides, exercises

Reading List:
Anderson "Computational Fluid Dynamics"
Warsi "Fluid Dynamics"

Responsible for Module:
Prof. Christian Breitsamter

Courses (Type of course, Weekly hours per semester), Instructor:
For further information in this module, please click campus.tum.de or here.
Module Description

LRG0111: Computational Solid Mechanics in Aerospace

Version of module description: Gültig ab winterterm 2023/24

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Examination is in the form of a written exam (duration 90min). A mixture of knowledge questions and calculations problems on modeling of structures with space and time discretization methods, in particular finite elements, is intended to test the understanding of phenomena and application of numerical techniques as well as the overall concept of modeling, discretization and solution. Exam questions will cover the entire course.
Permitted aids are a collection of formulas limited in size and a non-programmable calculator.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Knowledge of Engineering Mechanics I, II, and III for Aerospace Engineering is helpful. In particular, this module builds on the linear continuum mechanics presented in EM II as well as the truss, beam, plate, and shell formulation.

Content:
Content of this module is the methodology of discretization and solution of continuum mechanical and structural mechanical models as introduced in the previous compulsory course Engineering Mechanics II for Aerospace Engineers. The content ranges from a brief review of continuous models to the theory and functionality of discretization and solution methods.

Content:
(1) Introduction and review of basic concepts of continuum mechanics.
(2) Interaction of model, discretization and solution of structural mechanics problems
(3) 3D/2D solids: conservation equations, discretization with the finite element method, variational principles, algorithmic solution components, and applications.
(4) "Locking" phenomena of the finite element method
(5) Finite elements for structures such as beam, bar, plate and shell models
(6) Software engineering and introduction to parallel algorithms
(7) Introduction to time discretization methods and numerical dynamics.

**Intended Learning Outcomes:**
After successful participation, students are able to create and solve discrete models of continuum mechanics and structural mechanics problems and to evaluate results. In doing so, they will be able to select suitable models for a given problem from various theories.

**Teaching and Learning Methods:**
The lecture takes place as a presentation. Important content of the lecture will be written on tablet PC, which the students can transfer to their cloze script. In addition to the lecture (2 SWS), exercises (2 SWS) are offered. In the exercises, sample problems are calculated and working techniques are demonstrated, and the most important aspects of the lecture are clarified once again. Furthermore, solutions to additional voluntary homework problems are discussed in the exercises. Some of the exercises are held in the style of a practical course. Here, students have the opportunity to apply their knowledge using a software tool provided. All contents from lecture and exercise are also made available on the learning platform Moodle.

**Media:**
Presentation with tabloid, manuscript, practical course using student's own laptop, all materials provided on online platform (moodle)

**Reading List:**
Manuscript. Further reading is cited in this manuscript.

**Responsible for Module:**
Prof. Michael Gee

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0112: Dynamic simulation for vehicles, machines, and mechanisms
| Dynamic simulation for vehicles, machines, and mechanisms

Version of module description: Gültig ab winterterm 2023/24

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| Credits:* | 5 |
| Total Hours: | 150 |
| Self-study Hours: | 105 |
| Contact Hours: | 45 |

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
After the lecture period, there will be, depending on the number of students, a written (duration 60 min) or oral (one-on-one interview, duration 30 min) final exam (2/3 of overall grade), where the students have to show, that they know how to describe and simulate the dynamics of vehicles, machines, and mechanisms. Special attention is paid to the understanding of the fundamental relations and principles. Case studies are used to verify, if the students are able to apply the learned methods.

There will also be a computer project (1/3 of overall grade), where the students have to implement the discussed formulations and analyze the dynamics of a vehicle, aircraft, machine, or mechanism.

Two separate assessment formats are necessary, since one part of the intended learning outcomes (“The students can apply the basic formalisms for setting up, analysing and solving the equations of motion of rigid multibody systems and implement them on the computer”) cannot be ascertained by a written or oral examination alone. These central points of application and computer implementation of the formulations, which permeate the listed content, must be demonstrated in the course of a second examination assignment; the aforementioned computer project is a format suited to this purpose.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Understanding of the basic kinetic equations and the kinematic relationships. Application of basic methods of differential and integral calculus as well as linear algebra. Solving linear initial value problems. Basic knowledge of a higher programming language, such as MATLAB or Python.
Content:
The lecture is a blend between multibody and classical machine dynamics; branches of engineering devoted to the simulation of vehicles, aircraft, machines, and mechanisms. The following topics provide the basis for these kind of simulation environments:
• Kinematics and dynamics of rigid body systems with localized elasticities (bushings, etc.) and constraints/joints (revolute, prismatic, etc.) as well as simple drives/actuators
• Linearized equations of motion for rigid bodies with flexible supports (Rotor dynamics, machinery vibration analysis, etc.)
• Time integration (tailor-made schemes for multibody systems, e.g. HHT method, etc.)
• Basic computer implementation considerations

Intended Learning Outcomes:
The students can apply the basic formalisms for setting up, analysing and solving the equations of motion of rigid multibody systems and implement them on the computer. Furthermore, the students are able to apply linearisation methods in order to analyse classical (simple) machine dynamics problems starting from the generic multibody equations.

Teaching and Learning Methods:
Lectures and computer project

Media:
Presentation, script, animations, exercises with sample solutions, digital media

Reading List:


Responsible for Module:
Prof. Daniel Rixen, Dr. Andreas Zwölfer

Courses (Type of course, Weekly hours per semester), Instructor:
For further information in this module, please click campus.tum.de or here.
Module Description


Version of module description: Gültig ab winterterm 2023/24

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The written exam (90 min) covers the topics of the module in relation to their coverage in the lecture. Based on theoretical questions, the students show their knowledge concerning modeling approaches, system theoretic properties of state space models, structure-preserving integration methods and their properties as well as functional analytic basics for infinite-dimensional systems.

Moreover, the students are expected to solve tasks in the style of the exercises and in the frame of the module's content, where they prove their ability to apply the learned methods to problems that are representative for typical questions of control-related system modeling and analysis.

Up to 20% of the achievable credits can be obtained by the solution of “single choice” questions according to the examination rules.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Advanced mathematics and basic engineering courses.

Content:
The content is divided into four parts on modeling and systems theoretic analysis of dynamical systems. A "classical" focus is on linear finite-dimensional state space models in continuous time. In addition, concepts of energy-based modeling, structure-preserving integration, and the state representation of infinite-dimensional systems are introduced. These are foundations for a "modern" computational and control-oriented treatment of multi-domain physical systems.
In the first part we summarize modeling principles that lead to state space models in finite and infinite dimension in terms of ordinary and partial differential equations. For lumped parameter systems, we focus on energy- and network-based modeling. For distributed parameter systems, we restrict our attention to the one-dimensional case, and we give examples from structural mechanics and fluid- or thermodynamics that result from the application of variational principles and conservation laws. We emphasize the role of boundary variables as system in- and outputs.

In the second part, we introduce linearization of finite-dimensional state space models at an equilibrium and revisit the necessary concepts from linear algebra and differential equations to discuss the solutions of the linear state space models. Based thereon, and with the help of canonical state transformations, we analyze their fundamental properties like stability, controllability and observability, which are relevant for system design and control.

The third part of the lecture is devoted to numerical integration of state space models. We focus on structure-preserving integration schemes, which enforce conservation properties, and which can be derived from discrete variational principles. We highlight their importance in terms of the power-consistent simulation of interconnected systems.

Finally, we give a brief introduction to the most fundamental notions from functional analysis for infinite-dimensional state space models, such as functional spaces, boundary conditions and domains of differential operators. Based on the 1D modeling examples from the first part, we illustrate these concepts, which are instrumental for the analysis and numerical approximation of infinite-dimensional systems.

**Intended Learning Outcomes:**

Upon successful completion of the module the students
- know important modeling principles for finite- and infinite-dimensional systems,
- are able to establish state space models for lumped parameter systems based on their element equations and the network structure of their interconnections,
- understand the roles of power and energy for the modeling of multi-physical systems,
- can determine equilibria of finite-dimensional systems, linearize state space models, and compute their solutions,
- can analyze system theoretic properties of linear systems and assess their implications for state feedback control,
- can reproduce important structure-preserving integration methods with their properties and apply them to initial value problems,
- are familiar with the presented one-dimensional examples of distributed parameter systems and
- understand basic concepts from functional analysis for infinite-dimensional state space models.

**Teaching and Learning Methods:**

In the module all presented methods are derived systematically and consecutively on the blackboard and illustrated by examples. Lecture notes are available for preparation and self-study, as well as supplementary material (download).
Problems can be downloaded and a part of the solutions will be presented in the exercise. Active participation of the students (questions, comments) is desired. Problems whose solutions are not discussed in detail in the exercise are for self-study. Solutions to all problems are available for download.

Lecture (90 min) and exercise (45 min) cover all topics relevant for the exam. Additionally, a revision course (60 min) is offered on a voluntary basis. It is meant to be attended based on the individual needs and interests of the course participants. As a discussion group with only a small number of participants, this additional exercise serves a) to discuss and deepen the lecture topics and exercise problems, and b) to support the preparation of the exam.

**Media:**
Lectures with mainly blackboard notes, in parts presentation with beamer. Lecture and exercises are complemented by some Matlab and python examples. The lecture notes and supplementary material/slides as well as exercises with solutions are available for download under www.moodle.tum.de.

**Reading List:**
The lecture notes are self-contained. For interested students, the following books are recommended for further reading on the topics of multi-physics modeling [1], linear systems' analysis [2], structure-preserving integration [3] and infinite-dimensional systems from a functional analytic point of view [4]:


**Responsible for Module:**
PD Dr.-Ing. Paul Kotyczka

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click campus.tum.de or here.
Optional Engineering Elective | Optional Engineering Elective

Module Description

MW2462: Basics of Additive Manufacturing | Grundlagen der Additiven Fertigung

Version of module description: Gültig ab winterterm 2020/21

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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Die vermittelten Kompetenzen werden in einer schriftlichen Klausur (Bearbeitungsdauer 90 min), die sowohl aus Wissensfragen und Anwendungsaufgaben besteht, abgefragt. Dabei wird beispielsweise überprüft, inwieweit die Studierenden die Grundlagen der Additiven Fertigung hinsichtlich der Datenvorbereitung, der verschiedenen Fertigungstechnologien und der Nachbearbeitung der Bauteile verstanden haben. Zudem soll das erlernte Wissen auf einen spezifischen Anwendungsfall bzw. ein bestimmtes Bauteil übertragen werden. Für die Bearbeitung der Prüfung sind keine Hilfsmittel außer Schreibmaterialien erlaubt.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Grundlagenstudium im Bachelorstudiengang Maschinenwesen

Content:
Intended Learning Outcomes:
Nach der Teilnahme am Modul Grundlagen der Additiven Fertigung sind die Studierenden in der Lage die unterschiedlichen Additiven Fertigungsverfahren zu verstehen und bezogen auf die technische Anwendung das passende additive Fertigungsverfahren anzuwenden. Zudem sind die Studierenden in der Lage die Prozessschritte zur Herstellung von Bauteilen, beginnend bei der Datenaufbereitung, über den Bauprozess bis hin zur Nachbearbeitung der Bauteile zu beurteilen.

Teaching and Learning Methods:

Media:
Vortrag, Präsentation, Tablet-PC mit Beamer

Reading List:

Responsible for Module:
Wudy, Katrin; Prof. Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Grundlagen der Additiven Fertigung (Übung, 1 SWS)
Grünewald J, Setter R, Wudy K (Wudy K)

Grundlagen der Additiven Fertigung (Vorlesung, 2 SWS)
Setter R, Wudy K

For further information in this module, please click campus.tum.de or here.
Supplementary Courses | Supplementary Courses

Module Description

MW2445: Machine Learning Based Modeling in Structural Dynamics | Machine-Learning-basierte Modellierung in der Strukturodynamik
Module Description

MW2461: Machine Learning and Uncertainty Quantification for Physics-Based Models | Machine Learning and Uncertainty Quantification for Physics-Based Models [MLUQPBM]

Version of module description: Gültig ab winterterm 2020/21

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</table>

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The final grade is based on a presentation (60min + discussion, PowerPoint or similar). By means of a selected paper, the students should demonstrate their understanding of key theoretical concepts of various Machine Learning methods. They should be able to critically evaluate the presented results and be able to discuss the paper’s main idea in a broader content by commenting on the methodological advantages/disadvantages, limitations and transferability to other problems. In addition, the students are expected to demonstrate that they are able to respond competently to any questions, suggestions or discussions brought by the audience and relating to their subject area.

Repeat Examination:

(Recommended) Prerequisites:
Advanced topics in Machine Learning, Statistics, and Numerics of PDEs are covered, thus, basic knowledge in these areas is required, e.g. courses MA1401, MA3303, IN2346. Ideally, participants have prior knowledge covered in the following courses:
- Numerical methods for Uncertainty Quantification (MA5348)
- Physics-based Machine Learning (MW2450)

Content:
Machine learning and uncertainty quantification (UQ) are ubiquitous in modern science and engineering applications. In the last two decades, UQ for complex physical processes has been developed rapidly with a focus on grid-based process models such as finite element models which are well established in engineering applications. On the other hand, machine learning techniques have not traditionally been applied to physics-based models. The recent surge in
data-driven models based on machine learning techniques such as deep learning is changing the computational science and engineering landscape. Novel hybrid models based on neural networks are emerging and are already enhancing traditional methods. In this seminar, we discuss theoretical and computational aspects that arise from combining PDE-based models and neural networks, in particular, physics-informed neural networks (PINNs), neural networks for PDE approximation, and applications in UQ and turbulence models.

**Intended Learning Outcomes:**
Upon successful completion of the module, students will:
- be able to demonstrate the recent advances in the area of Machine Learning and Uncertainty Quantification for Physics-Based Models
- be able to understand the main ideas of various Machine Learning methods
- be able to compare and evaluate different methods in terms of their area of application, advantages/disadvantages, limitations, etc.
- be able to present with rhetorical confidence scientific topics

**Teaching and Learning Methods:**
Each week a different paper will be discussed during the course. After the presentation given by the students we will have a group discussion moderated by the lecturers. The students will therefore learn not only the recent developments in the field of machine learning but also how to successfully present a scientific research. During discussions we will draw connections to other methods and give a critical comparison. Possible improvements and other areas of application will also be discussed. So the students shall for example learn to understand the main ideas of various Machine Learning methods as well as to compare and evaluate different methods in terms of their area of application, advantages/disadvantages, limitations, etc.

**Media:**
The list of papers discussed during the seminar.

**Reading List:**
The material discussed in the seminar is based on recent research papers that will be published online on Moodle.

**Responsible for Module:**
Zavadlav, Julija; Prof. Dr.

**Courses (Type of course, Weekly hours per semester), Instructor:**
Machine Learning and Uncertainty Quantification for Physics-Based Models (Seminar, 2 SWS)
Zavadlav J, Ullmann E
For further information in this module, please click campus.tum.de or here.
Study Requirements | Studienleistungen

Module Description

LRG0200: Introduction to Aerospace | Introduction to Aerospace

Version of module description: Gültig ab winterterm 2021/22

<table>
<thead>
<tr>
<th>Module Level:</th>
<th>Language:</th>
<th>Duration:</th>
<th>Frequency:</th>
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<tbody>
<tr>
<td>Bachelor</td>
<td>English</td>
<td>one semester</td>
<td>winter semester</td>
</tr>
</tbody>
</table>

Credits:* 3

Total Hours: Self-study Hours: Contact Hours:

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The intended learning outcomes are checked with a course work in form of a report on 3-4 topics covered in the course (1-2 pages per topic). The preparation of this report will be used to assess whether the students are able to reproduce in their own words the acquired competencies and basic concepts from various fields of aerospace. In the report, problems addressed in the lecture are to be discussed in an informed written manner.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
The world of ..
1. Aircraft:
   - Aircraft types and their general characteristics (transport, fighter, special purpose)
   - Fundamentals of aerodynamic flight (lift, drag, thrust, weight), force equilibrium, energy and power balance
2. Helicopters:
   - VTOL types (helicopter, eVTOL) and their general characteristics
   - Fundamentals of rotary lift generation and basic equations of light (momentum theory?)
3. Unmanned Aerial Systems (UAV, UAS) / drones:
   - Elements of an unmanned aerial system, system of system approach (air vehicle, payloads, ground control, communications)
   - operational challenges, autonomy vs automation
4. Introduction to Launchers:
- Launcher types (expendable/reusable, solid / liquid propellants), staging principles
- Basic force equilibrium, performance criteria (target orbits, staging concepts)

5. Introduction to Manned Spaceflight:
- Operational challenges for manned spaceflight
- Introduction to previous missions and their specifics

6. Satellites and payloads

7. Space Applications

**Intended Learning Outcomes:**
After attending the module, students will be familiar with basic concepts and issues from the entire spectrum of aerospace. They will have a sound insight into the main achievements, current developments and future problems and challenges of each of the disciplines covered:
- Aircraft, Vertical Launch Vehicles, Spacecraft
- Unmanned flying objects
- Manned space flight and space applications
- Satellite and rocket technology

**Teaching and Learning Methods:**
Lecture series with 2 lecture units per focus topic

**Media:**
Slide presentation, lecture

**Reading List:**
topic-specific literature recommendations will be given in the lectures

**Responsible for Module:**
Studiendekanat LRG // Ringvorlesung

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0201: Introduction to Geodesy and Geoinformation | Introduction to Geodesy and Geoinformation

Version of module description: Gültig ab winterterm 2022/23

<table>
<thead>
<tr>
<th>Module Level: Bachelor</th>
<th>Language: English</th>
<th>Duration: one semester</th>
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<tr>
<td>Credits:* 3</td>
<td>Total Hours: 90</td>
<td>Self-study Hours: 60</td>
<td>Contact Hours: 30</td>
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</table>

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The expected learning outcomes are verified with course work in the form of a report about 3-4 topics treated in the course, which have to be provided as pass/fail credit requirements. By means of the elaboration of this report, it shall be verified if the students are able to apply the acquired competencies and basic concepts of geodesy to practical problems, with a strong focus on and link to applications in aerospace engineering.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Knowledge of fundamentals in mathematics, physics and programming.

Content:
In a lecture series of several disciplines of geodesy, the following contents will be presented and discussed:
- overview on geodesy for observing Earth on all spatial and temporal scales
- components of the Earth System and geodynamic processes
  – Earth’s energy budget and its role for climate
- engineering geodesy, photogrammetry and industrial applications
- remote sensing and Earth observation applications
  – satellite geodesy and geodetic space techniques
- navigation and GNSS
- (global) reference frames and height systems
- gravity field satellites for monitoring mass transport from space
- geoinformatics and big data
- cartography
Intended Learning Outcomes:
Upon successful completion of the module, students are able
- to understand the fundamental principles of geodesy
- to understand geodetic measuring and modelling methods
- to apply these geodetic measuring and modelling methods to basic practical problems, which are relevant for applications in aerospace engineering
- to understand the role of satellite observations for the monitoring of geodynamic processes in the Earth system,
- to develop ideas and concepts for the application of geodetic methods in aerospace engineering,
- to communicate on a technical level with experts from different disciplines of aerospace and geodesy.

Teaching and Learning Methods:
The contents of the lectures are communicated by oral presentations, including interactive discussions with the students. Selected problems to be solved as homework shall deepen the understanding of the theoretical basics presented in the lectures, and shall support the students to apply methods for problem solution in a self-contained manner.

Media:
- Blackboard
- Lecture notes
- Presentations in electronic form

Reading List:

Responsible for Module:
Prof. Roland Pail // Studiendekanat LRG

Courses (Type of course, Weekly hours per semester), Instructor:
For further information in this module, please click campus.tum.de or here.
Module Description
LRG0202: Engineering Project | Engineering Project
Version of module description: Gültig ab winterterm 2023/24

<table>
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<tr>
<th>Module Level</th>
<th>Language</th>
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<td>120</td>
<td>30</td>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Für eine erfolgreiche Teilnahme sind als Grundlage die Inhalte der ersten 4 Semester des Bachelor Aerospace empfohlen. Teilnehmende sollten in der Lage sein, selbstständig alle bis dahin vermittelten Grundlagenkenntnisse, u.a. in Höherer Mathematik, Elektrotechnik, Materialwissenschaften, Informatik/Programmierung, Technischer Mechanik, Aerosdynamik, Fluidmechanik und Technischem Design anwenden zu können.

Content:
Das Modul verbindet die praktische Anwendung von ingenieurwissenschaftlichen Kenntnissen und Methoden mit fachübergreifenden und interdisziplinären Schlüsselkompetenzen wie Projektmanagement und Teamkompetenzen, insbesondere Kommunikations- und Konfliktfähigkeit.

**Intended Learning Outcomes:**

**Teaching and Learning Methods:**
Schulung, betreute Team-/Projektarbeit, interaktives Arbeiten

**Media:**

**Reading List:**

**Responsible for Module:**
Prof. Markus Ryll

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click [campus.tum.de](https://campus.tum.de)
Aerospace Lab Courses | Forschungspraxis

Aerospace Lab Course I | Aerospace Lab Course I

Module Description

LRG0120: Design / Build / Fly | Design / Build / Fly

Version of module description: Gültig ab winterterm 2023/24

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<td>150</td>
<td>90</td>
<td>60</td>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The grading consists of the following items:
- Participation (50%): Presentation of the initial concept and at least two status presentations during the semester, general contribution to the teamwork (individual assessment)
- Written paper (40%): submission of two design reports during the semester (assessment of the treated sub-discipline of the aircraft design)
- Final presentation (10%): presentation of the entire aircraft design process and its results at the end of the semester (assessment on team level)

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Aircraft Design Basics (recommended)

Content:
To kick off the course, a short exercise will guide each student in using simple historical and zero-order methods to create a first shot sized aircraft design of his/her own. The rest of the semester will be dedicated to developing a design concept as part of a multidisciplinary team. Along the way, teams will have opportunity to present their designs and gather valuable feedback. The first of two design reviews will occur near the middle of the semester, and will focus on configuration downselect, qualitative trade studies, and rough top-down sizing. At the second and final design review, teams will be able to present an aircraft conceptual design of relative maturity that incorporates the results of quantitative trade studies, numerical mission simulations (with the assistance of provided software), and approximate bottom-up analyses. The result should be the
Design of a UAV that will be manufactured using Rapid Prototyping. The final aircraft will be flown to evaluate its performance.

**Intended Learning Outcomes:**
After successfully participating at the module, students have practical knowledge on:
- performing a complete aircraft design process
- application of theoretical knowledge
- multidisciplinary optimization
- important subdisciplines of aircraft design
- iterative nature of aircraft design process
- role of requirements
- creative problem solving and decision making
- simplification and solving of complex problems
- importance of efficient communication
- multidisciplinary teamwork

**Teaching and Learning Methods:**
The course follows a project- and team-based learning philosophy. As such, the course seeks to simulate an aircraft conceptual design project as would be encountered in industry. The instructor's role is to convey the necessary ground knowledge to get started, facilitate students access to the appropriate literary and software resources, and provide technical and organizational guidance.

**Media:**
Präsentationen, Tafelanschriebe, Tutorials

**Reading List:**

**Responsible for Module:**
Prof. Mirko Hornung

**Courses (Type of course, Weekly hours per semester), Instructor:**

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0122: Testing of UAV Systems | Testing of UAV Systems
Aerospace Lab Course II | Aerospace Lab Course II

Module Description

LRG0121: Helicopter (Lab Course) | Helicopter (Lab Course)
Module Description

MW1068: Practical Training in Materials and Process Technologies for Carbon Composites | Composite-Bauweisen - Praktikum

Version of module description: Gültig ab summerterm 2020

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<th>Module Level:</th>
<th>Language:</th>
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<td>70</td>
<td>50</td>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The achievement of the targeted learning content is checked in a written examination.

Current note in view of the restricted face-to-face operation due to the CoViD19 pandemic:
If the framework conditions (hygiene, distance rules, etc.) for a face-to-face examination are not available, the planned examination form can be changed to an online-based written or oral distance examination in accordance with §13a APSO. The decision on this change will be announced as soon as possible, but no later than 14 days before the examination date by the examiner after consultation with the responsible examination board.

Repeat Examination:

(Recommended) Prerequisites:
Fiber, matrix, and composite materials with their properties
Manufacturing processes for composite components
Design and construction methods of composite structures

Content:
Material selection, manufacturing technologies and design specifications for fiber composite design are discussed using concrete components from various application industries. In addition to the technological requirements, the focus is also on the economic aspects. Excursions to companies with visits to the series production of fiber composite components round off the practical course.

Intended Learning Outcomes:
After participating in the module course, students are able to select materials and manufacturing technologies according to appropriate specifications for a concrete application. They are able
to analyze and evaluate the influencing variables in the design of component parts according to economic and technological aspects. The students are able to apply new findings from research to practical applications.

**Teaching and Learning Methods:**
The practical sessions are divided into theoretical and excursion sessions. During the theoretical sessions, questions are presented using Power Point slides and then discussed in the group. Afterwards, specific tasks are worked out in small groups and then presented. During the excursion dates, the companies are presented by company representatives and the production is visited in tours.

**Media:**
Lecture, presentation with PowerPoint slides, blackboard, projector

**Reading List:**
Neitzel Manfred; Mitschang, Peter; Handbuch Verbundwerkstoffe: Werkstoffe, Verarbeitung, Anwendung (3-446-22041-0); Faserverbundbauweisen Eigenschaften Mechanische, konstruktive, thermische, elektrische, ökologische, wirtschaftliche Aspekte (3-540-00636-2)

**Responsible for Module:**
Drechsler, Klaus; Prof. Dr.-Ing.

**Courses (Type of course, Weekly hours per semester), Instructor:**
Praktikum zu Composite-Bauweisen (Praktikum, 4 SWS)
Drechsler K [L], Zaremba S

For further information in this module, please click [campus.tum.de](http://campus.tum.de) or here.
Module Description

MW2381: Practical Course on Space Electronics | Praktikum Raumfahrtelektronik

Version of module description: Gültig ab summerterm 2020

<table>
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<tr>
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<th>Language: German</th>
<th>Duration: one semester</th>
<th>Frequency: winter semester</th>
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<td>Credits:*</td>
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<td>Self-study Hours: 60</td>
<td>Contact Hours: 60</td>
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Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Der Erfolg des Praktikums wird als eine Laborleistung bestehend aus den beiden Praktikumsabschnitten (Grundlagen und Praxisteil) benotet.
Die Beurteilung der Leistungen im Praxisteil erfolgt durch die Bewertung einer Abschlusspräsentation (ca. 10 Minuten pro Person) von den Teilnehmern. Dabei sollen die Studierenden demonstrieren, dass sie elektronische Systeme selbst entwerfen und implementieren können und diese Kenntnisse einem Fachpublikum verständlich präsentieren und vor diesem rhetorisch gekonnt rechtfertigen können.
Beide Abschnitte werden entsprechend des Zeitaufwands (60% Testate, 40% Laborleistung) gewichtet.

Aktueller Hinweis angesichts des eingeschränkten Präsenzbetriebs auf Grund der CoViD19-Pandemie: Sofern die Rahmenbedingungen (Hygiene-, Abstandsregeln etc.) für eine Präsenzprüfung nicht vorliegen, kann gemäß §13a APSO die geplante Prüfungsform auf eine online-gestützte schriftliche oder mündliche Fernprüfung umgestellt werden. Die Entscheidung über diesen Wechsel wird möglichst zeitnah, spätestens jedoch 14 Tage vor dem Prüfungstermin durch die Prüfungsperson nach Abstimmung mit dem zuständigen Prüfungsausschuss bekannt gegeben.

Repeat Examination:
(Recommended) Prerequisites:
Das Praktikum Raumfahrtelektronik baut inhaltlich auf den im Bachelorstudium der Fakultät Maschinenwesen vermittelten Kenntnissen zur Elektrotechnik (Modul „Grundlagen der Technischen Elektrizitätslehre für MW“) auf und setzt diese als theoretische Grundlage voraus.

Content:
Im Praktikum werden neben einem breiten Systemverständnis und der interdisziplinären Praxiserfahrung insbesondere folgende spezifische Inhalte in separaten und aufeinander aufbauenden Lerneinheiten vermittelt:
- Grundlagen und Messtechnik: Auffrischung der Elektronikgrundlagen, elektronische Standardbauteile, Potentiale und Erdung von elektrischen Systemen, korrekte Anwendung branchenüblicher Messwerkzeuge
- Handwerkliche Fähigkeiten: Elektroniklöten, Herstellung von Kabeln und Steckverbindern, Schutzvorkehrungen gegen elektrostatische Entladungen (ESD), Bedienung eines Oszilloskops
- Energieversorgung: Varianten Strom- und Spannungsquellen in Laborumgebungen sowie auf Raumfahrzeugen, Arten von Strom- und Spannungswandlern, Schutzmechanismen
- Analoges Sensoren: Auslesen analoger Sensoren, Messverstärkerschaltungen
- Digitale Sensoren: Einführung in Anwendung und Programmierung von Mikrocontrollern, Digitalisierung analoger Signale, digitale Sensordatenverarbeitung
- Digitale Kommunikation: digitale Protokolle zur Chip-to-Chip und Board-to-Board-Kommunikation (UART, SPI, I²C, …)
- Aktuatoren: Verschaltung und elektrische Ansteuerung von Aktuatoren
- Platinendesign- und Herstellung: Verwenden von Bauteilbibliotheken, zeichnen von Schaltplänen, Erstellung von Leiterplattenlayouts, Grundlagen der Herstellung

Intended Learning Outcomes:

Teaching and Learning Methods:
Der inhaltliche Aufbau des Praktikums besteht aus zwei Abschnitten:

Im ersten Abschnitt werden die Teilnehmer in etwa acht Praktikumsterminen zunächst schrittweise an das Thema Raumfahrtelektronik herangeführt. In diesen Terminen werden jeweils interaktiv die theoretischen Grundlagen der Lerneinheit erarbeitet und direkt im Anschluss in praktischen Versuchen und Aufgabenstellungen angewendet.
Im zweiten Abschnitt widmen sich die Gruppen einer konkreten Problemstellung. Unter Anwendung der zuvor erlernten Grundlagen entwerfen, implementieren und testen die Teilnehmer ein einfaches elektronisches System in einem realen Raumfahrtprojekt. Hierbei müssen sowohl Systemdenken als auch spezifisches Fachwissen angewendet und mit den Projektpartnern kommuniziert werden.


**Media:**

**Reading List:**
Hering, Ekbert; Bressler Klaus; Gutekunst, Jürgen: Elektronik für Ingenieure und Naturwissenschaftler.

**Responsible for Module:**
Walter, Ulrich; Prof. Dr.

**Courses (Type of course, Weekly hours per semester), Instructor:**
Praktikum Raumfahrtelektronik (Praktikum, 4 SWS)
Dziura M [L], Dziura M, Rückerl S, Kaschubek D, Reinerth G, Biswas J
For further information in this module, please click campus.tum.de or here.
**Engineering Internship | Praktikum**

**Module Description**

**LRG0006: Engineering Internship | Engineering Internship**

Version of module description: Gültig ab winterterm 2023/24

<table>
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<th>Language:</th>
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<td>Bachelor</td>
<td>German/English</td>
<td>one semester</td>
<td>winter/summer semester</td>
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</table>

Credits:* 8

Total Hours: Self-study Hours: Contact Hours:

Number of credits may vary according to degree program. Please see Transcript of Records.

**Description of Examination Method:**
The industry internship is a course credit that must be completed in the form of a report. The report complies with the internship guidelines of the study program as adopted in the FPSO Appendix 3. In addition, the companies in which the students have completed the internship issue a corresponding certificate. It is important that the students worked for a total of each at least 4 weeks in two of the three areas (manufacturing, development or service) and that this is indicated in the certificate(s). If an area has already been fulfilled as part of the 8-week pre-study internship, this will be recognized.

**Repeat Examination:**
Next semester

(Recommended) **Prerequisites:**
Ideally, students will be in their 5th or 6th semester of the Bachelor's degree program Aerospace.

**Content:**
In the industry internship, the practical relevance of the theoretical knowledge acquired is established and deepened. It serves to apply the subject-specific knowledge in practice, but also to get to know the operational organization. The tasks are usually complex and require the skill to work in an international environment.

**Intended Learning Outcomes:**
After the industry internship (pre- and specialized internship) in general:
Students learn about their personal aptitude and interests in industrial practice and possible fields of activity. They learn to assess their own future opportunities and possible positions within a company. In their daily work they experience the communication channels and processes in
companies and learn to socialize within the company. They work in international teams and learn how to successfully carry out projects in a heterogeneous environment. Furthermore, they are able to evaluate technical and economic contexts in companies. The students learn to present their observations and experiences in written form in a creditable way.

After the technical internship:
Students will be able to evaluate the desired specialization within the aerospace field based on the overview gained in practice. They have gained extensive experience in the complex interaction of the sub-areas by gaining insight into two of the three areas (manufacturing, development, service). They are also able to document complex technical interrelationships in writing.

Teaching and Learning Methods:
Interns are usually supervised by training supervisors, taking into account the internship regulations of the program. They serve as a direct contact and mentor during the internship and teach the interns about technical topics in talks and discussions. By participating in day-to-day business and being placed in specific work areas, interns gain an understanding of organizational relationships, internal communications, and concrete process and machine knowledge. At the same time, they gain insights into the human side of operations and get to know the company as a social structure.

Media:
Internship, instructional interviews, demonstrations.

Reading List:
Internship guidelines for the Bachelor's program Aerospace.

Responsible for Module:
Department Aerospace and Geodesy, Internship - studiendekanat@lrg.tum.de

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.
Module Description

LRG0007: Project Seminar | Project Seminar

Version of module description: Gültig ab winterterm 2023/24

Module Level:
Bachelor

Language:
German/English

Duration:
one semester

Frequency:
winter/summer semester

Credits:*   
8

Total Hours:
240

Self-study Hours:
135

Contact Hours:
105

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The course work takes the form of a project. By working independently on a project, students
demonstrate their ability to develop solutions to realistic engineering tasks. For this purpose,
the following achievements must be made: Presentation of the work plan in the form of an oral
presentation, written report on the project, and final oral presentation.

At the beginning, the students present the work plan in an oral presentation. The objectives,
approach, risks and time/project management are formulated.

The students summarize important results and interpretations in a written report. Independent of
the chosen topics, this report contains an overview of the procedures and research results of the
respective project as well as the scientific classification of the topic in the overall technical context.

The groups present the results of the project seminar to the other project groups in the course of
an oral presentation. The goal is to show the deep understanding of the interaction between the
theoretical foundation and the practical application of the learned methods, (software) tools and/
or approaches. The students show their solution approaches, which they have developed and
implemented in the practical engineering project task from their chosen industry-specific, basic or
application or method-oriented specialization in the team.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Successfully completed basic studies (compulsory modules of semesters 1 to 4 of the Bachelor's
degree program Aerospace).
Content:
The project seminar consists of a project that is worked on jointly by several students. Topics can either be proposed by the students themselves or selected from a list of suggestions. These proposals must be approved in advance by a committee for processing within the framework of the project seminar.

The project seminar serves as an introduction to practical engineering methods, (software) tools and/or procedures and is intended to meaningfully complement practical experience in the field of aerospace and the respective domain-centered specialization. Thus, there is a further, practical, industry-specific, theory-, application- or method-oriented focus. Within the project seminar, the students are to demonstrate that they can independently handle the processing of the tasks set for them in groups.

Intended Learning Outcomes:
After successful completion, students possess a profound understanding of the interplay between the theoretical foundation and the practical application of the methods, (software) tools and/or approaches learned. They are thus able to develop solutions to practical engineering problems from their chosen industry-specific, basic or application/method-oriented major or specialization. By actively working as teams mentored by the lecturers, students learn project management, teamwork and presentation of projects.

Teaching and Learning Methods:
In lectures and hands-on tutorials, practical engineering methods, (software) tools and/or procedures from the chosen major or specialization are taught and students are introduced to devices, systems and/or software tools.
- In lectures, theoretical and methodological basics on the topics of project management, working in a project, teamwork and presentation of projects are taught.
- Students independently develop solutions to concrete realistic tasks in joint project work.
- In individual discussion units, students can clarify questions and discuss further topics with the supervisor.
The concrete teaching and learning methods depend on the specific requirements of the chosen project.

Media:
Lecture with media support, task descriptions, eLearning platforms, written reports and documents.

Reading List:
Literature is suggested by those responsible for the specific course.

Responsible for Module:
Prof. Markus Ryll

Courses (Type of course, Weekly hours per semester), Instructor:
For further information in this module, please click campus.tum.de or here.
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**Supplementary Courses**

- [LRG0079] Practical Training in Materials and Process Technologies for Carbon Composites | Composite-Bauweisen - Praktikum | 89-90

**Optional Engineering Elective**

- [LRG0079] Practical Training in Materials and Process Technologies for Carbon Composites | Composite-Bauweisen - Praktikum | 89-90

**Required Modules**

- [LRG0079] Practical Training in Materials and Process Technologies for Carbon Composites | Composite-Bauweisen - Praktikum | 89-90

**Elective**

- [LRG0079] Practical Training in Materials and Process Technologies for Carbon Composites | Composite-Bauweisen - Praktikum | 89-90
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