



Syllabus Book

Master Computational Mechanics

Description of the degree course

name of the degree course			shorthand expression of degree course
Master Computational Mechanics			M-CM
type	period of study	SWS	ECTS-Credits
Master	4	62	120
description			
<p>Homepage of the Program: www.uni-due.de/computationalmechanics</p> <p>The application of computer-based strategies for the solution of practice-oriented problems has dramatically increased in the past decades. The associated application areas are continually expanding and stretch from architecture and the various disciplines of machine construction (Finite Element/Volume Calculation) to areas of medicine (biomechanics) and biology (evolutionary simulations). The foundation of this development is a fundamental concept that allows for a reliable analysis of problems on the basis of continuum-mechanical model building, numerical processes and experimental techniques. This concept, which can be understood by the term Computational Mechanics, therefore provides connections between theoretical model building, numerical operations and experimental reality. An engineer whose area of specialization is classified in the above-mentioned field requires a solid understanding of the fundamentals in this area.</p> <p>To an increasing degree, complex knowledge in the area of Computational Mechanics is being demanded of developers and qualified operators of specialized and computer-based calculation processes. The demand for engineers of this type is constantly increasing around the world, which is also accounted for by the foundation of appropriate courses of study at reputable foreign universities. The planned course of study at the Essen campus of the University Duisburg-Essen is in line with this goal. The training endows engineers with the competence to responsibly apply and expand these complex computer-based calculation processes with a solid theoretical knowledge. In accordance with this model building must be properly interpreted, applied algorithms coherently combined, experiments correctly conducted and interpreted and the implementation programs accurately executed. The key words to understand here are the following:</p> <p>Model building: Linear and non-linear continuum mechanics, phenomenological material theory, structural mechanics, material sciences, homogenization processes.</p> <p>Algorithms: Numerical discretization and solution processes of mechanics, Finite Element Method, optimization processes, program development.</p> <p>Experiments: Material sciences, measurement technique, parameter identification of material models.</p> <p>Applications: Computer-based simulations in all areas of engineering science and practice.</p> <p>As a result, the program has an interdisciplinary character. Thus topic areas from applied</p>			

mechanics, engineering-oriented material sciences and various, widely diversified areas of applied engineering will be part of the curriculum. A well-grounded, theoretical basic knowledge forms the connection between these various areas. Finally, it is the purpose of the Computational Mechanics program to train engineers with the ability to recognize application possibilities and the limits of calculation models as well as to apply and expand existing calculation systems. In summary, the internationally oriented Computational Mechanics program will offer its students an in-depth training in the methodology of an integrated treatment of the mechanical problems of engineering. An intellectual intertwining and interaction of theoretical model building, numerical diffusion, experimental verification and simulation-specific application especially belongs to this.

The program in CM will be equally attractive for domestic as well as foreign students. First of all, the program can build upon either a domestic or a foreign Bachelor of Science or can function as an additional qualification to the German Diploma. In addition to being a professionally qualifying degree, the acquired title of Master of Science will also make possible further doctoral studies at all national and international universities. Due to the increasing internationality and attractiveness of CM for foreign students, most of the lectures (80% and more) will be offered in English.

Study Plan Overview

1. Semester (WS)	2. Semester (SS)	3. Semester (WS)	4. Sem. (SS)
Tensor Calculus FG 1.2 (PM; 7/4/210)	Finite Element Method Foundation FG 1.2 (PM; 7/4/210)	Nonlinear Finite Element Method FG 1.2 (PM 7/4/210)	Master-Thesis + Colloquium (30/-/900) Modul 9
Continuum Mechanics FG 1.3 (PM; 7/4/210)	Thermodynamics of Materials FG 1.2 (PM; 7/4/210)	Elective Courses (WPM; 5/4/150)	
Introduction to Numerical Methods FG 1.1 (PM; 7/4/210)	Elective Courses (WPM; 5/4/150)	Elective Courses (WPM; 5/4/150)	
Computer Languages for Engineers	Elective Courses (WPM; 5/4/150)	Elective Courses (WPM; 5/4/150)	
Testing of Metallic Materials FG 2.7 (PM; 5/4/150)	Elective Courses (WPM; 5/4/150)	Soft Skills I (WM; 4/3/120)	
		Soft Skills II (WM; 4/3/120)	
Module (CR/SWS/work load=CR*30h)			
5 (31/20/930)	5 (29/20/870)	5 (30/22/900)	- (30/-/900)
<u>Elective Courses</u>			
	2. Semester (SS)	3. Semester (WS)	
Subject Group 1: Mathematical and Natural Scientific Basics			
1.1 Numerical Mathematics	Advanced Numerical Methods	Parallel Computing	
1.2 Mechanics	-	Computational Inelasticity	
1.3 Computational Mechanics	FEM - Coupled Problems	FEM - Multiphase Materials	
Subject Group 2: Technical Basics / Applications			
2.1 Waste Management	-	Simulation of Landfill Bodies	
2.2 Soil Mechanics	Geotechnics Project with Lab	Modeling and Numerical Simulation of Geotechnical Problems	
2.3 Informatics	Advanced Computer Architecture	CSCW and Software Engineering	
2.4 Concrete Structures Engineering	Design of Concrete Structures	Pre-stressed Concrete	
		Finite Element Method Modeling Concrete Structures	
2.5 <u>Structural Steelwork</u>	Finite Element Method: Modeling in Steel Structures	Finite Element Method Design of Structural Connection	
2.6 Statics	CAD in Civil Engineering	Analysis of Structures	
2.7 Mechanical Working	Fatigue and Lifetime of Machine Elements	Schwingungsanalyse mit Matlab*	
2.8 Computational Fluid Dynamic	Computational Fluid Dynamics		
2.9 Material Science	Werkstoffauswahl für hohe Temperaturen und Leichtbau*	Technische Schadensanalyse*	
2.10 Mechantronics	Advanced Modeling and Simulation Techniques	--	

* Courses language: German

Study plan Detail

				V	Ü	P	S	Cr
Master Computational Mechanics				32	30	0	0	120

1.	Computer Languages for Engineers	Dr. rer. nat. Baeck	e	2	2	0	0	5
	Continuum Mechanics	Prof. Dr.-Ing. Ricken	e	2	2	0	0	7
	Introduction to Numerical Methods	Prof. Dr. Klawonn	e	2	2	0	0	7
	Tensor Calculus	Prof. Dr.-Ing. Bluhm	e	2	2	0	0	7
	Testing of Metallic Materials	Prof. Dr.-Ing. Mauk	e	2	2	0	0	5
Total:				10	10	0	0	31

2.	Finite Element Method Foundation	Prof. Dr.-Ing. habil. Schröder	e	2	2	0	0	7
	Thermodynamics of Materials	Prof. Dr.-Ing. Bluhm	e	2	2	0	0	7
	Elective Courses SS1		e	2	2	0	0	5
	Elective Courses SS2		e	2	2	0	0	5
	Elective Courses SS3		e	2	2	0	0	5
Total:				10	10	0	0	29

3.	Nonlinear Finite Element Method	Prof. Dr.-Ing. habil. Schröder	e	2	2	0	0	7
	Soft Skills 1		d e	2	1	0	0	4
	Soft Skills 2		d e	2	1	0	0	4
	Elective Courses WS1		d e	2	2	0	0	5
	Elective Courses WS2		d e	2	2	0	0	5
	Elective Courses WS3		d e	2	2	0	0	5
Total:				12	10	0	0	30

4.	Master-Thesis		d e	0	0	0	0	30
Total:				0	0	0	0	30

Modul- und lecture catalogue – Elective Courses SS 1-3

module name	faculty
Elective Courses SS 1-3	engineering science
used in degree course	
<ul style="list-style-type: none"> • Master Computational Mechanics 	

year	duration	type of module
1	1	Elective Course

exam regulation requirements
recommended requirements
Tensor Calculus, Continuum Mechanics, Numerical Mathematics I, Computer Languages for Engineers I

Nr.	courses	semester	SWS	workload in h	ECTS-Credits
1		2	4	150	5
2		2	4	150	5
3		2	4	150	5
total			12	450	15

Courses
<ul style="list-style-type: none"> • Advanced Computer Architecture • Advanced Numerical Methods • CAD in Civil Engineering • Computational Fluid Dynamics • Concepts of Environment Protection • Design of Concrete Structures • Fatigue and Lifetime of Machine Elements • Finite Element Method - Coupled Problems • Finite Element Method - Modelling in Steel Structures • Geotechnics Project with Lab • Werkstoffauswahl für hohe Temperaturen und Leichtbau
description
Students must choose between a select number of elective subjects which will permit them to further expand on the major subject of their study program. In this manner, the depth of the instruction shall be enhanced. This can be valuable for a clearly defined professional application as well as for a scientifically-oriented MA study for use in academic research.
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.

Modul- und lecture catalogue – Elective Courses WS 1-3

module name	faculty
Elective Courses WS 1-3	engineering science
used in degree course	
<ul style="list-style-type: none"> • Master Computational Mechanics 	

year	duration	type of module
1	1	Elective Course

exam regulation requirements
recommended requirements
Tensor Calculus, Continuum Mechanics, Numerical Mathematics I, Computer Languages for Engineers I, Finite Element Method Foundation, Thermodynamics of Materials

Nr.	courses	semester	SWS	workload in h	ECTS-Credits
1		3	4	150	5
2		3	4	150	5
3		3	4	150	5
total			12	450	15

Courses
<ul style="list-style-type: none"> • Advanced Modeling and Simulation Techniques • Analysis of Structures • Computational Inelasticity • CSCW and Software Engineering • Finite Element Method - Design of Structural Connection • Finite Element Method - Modelling Concrete Structures • Finite Element Method - Multiphase Materials • Modelling and Numerical Simulation of Geotechnical Problems • Parallel Computing • Pre-stressed Concrete • Schadenskunde • Schwingungsanalyse mit MATLAB • Simulation of Landfill Bodies
description
Students must choose between a select number of elective subjects which will permit them to further expand on the major subject of their study program. In this manner, the depth of the instruction shall be enhanced. This can be valuable for a clearly defined professional application as well as for a scientifically-oriented MA study for use in academic research.
kind of examination
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module name	shorthand expression of module
Computer Languages for Engineers	
lecturer	department
Dr. rer. nat. Ernst Baeck	Statics

semester	cycle	language	requirements
1	WS	englisch	none

SWS	presence hours	self-study hours	workload in h	ECTS-Credits
4	60	90	150	5

teaching form
Lecture /Tutorial
learning objectives
<p>The participants will gain the competence of implementing complex numeric-mathematical and continuum-mechanical problems by means of the established programming language. The students will learn to abstract problems within the scope of algorithms at first. They will achieve the competence of implementing algorithms by means of classical procedural programming under the use of classical software-realities (e.g. common FORTRAN-FE-platforms like FEAP). In addition they will learn to implement algorithms within a modern object oriented approach for standard software-realities. The participants will also learn to map the data to common container-class-concepts and to implement these by means of standardized libraries.</p>
description
<p><u>Procedural Languages</u></p> <ul style="list-style-type: none"> • fields and structures of data • working with files with sequential and direct access • implementing of indexed lists • memory-management presupposing static fields (Memory-Mapping) <p><u>Object-oriented Languages</u></p> <ul style="list-style-type: none"> • fundamental terms for object-oriented modelling • container-classes • recursive structures of data, chained lists and hierarchic structures • use of template-libraries <p><u>Examples of implementing iterative algorithms</u></p> <ul style="list-style-type: none"> • Gauss-Algorithm with coloumn pivo seach • Gauss-Algorithm as triangular decomposition • Cholesky-Method as triangular decomposition considering compact data storage • Solving a system of linear equations with several right hand sides • Gauss-Seidel Method • Jakobi Method for determining the intrinsic value of a symmetric matrix <p><u>Examples of implementing recursive algorithms</u></p> <ul style="list-style-type: none"> • Hoare's Quick-Sort • Backtracking algorithms (e.g. Eight Queens Puzzle, Knight's Tour)

kind of examination

In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.

literature

- N. Wirth, „Algorithmen und Datenstrukturen“,
- R. Sedgewick „Algorithms in C++“
- S. Chapman „FORTRAN 90/95 for Scientists and Engineers“

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module name	shorthand expression of module
Continuum Mechanics	Conti
lecturer	department
Prof. Dr.-Ing. Tim Ricken	Computational Mechanics

semester	cycle	language	requirements
1	WS	englisch	none

SWS	presence hours	self-study hours	workload in h	ECTS-Credits
4	60	150	210	7

teaching form
Lecture / Tutorial
learning objectives
<p>In the lecture students will acquire the skills necessary to describe the mechanical behavior of materials with the help of continuum mechanics. First, representations using familiar mechanical quantities from the bachelor study (i.e. stress and strain) will be formulated within the framework of continuum mechanics. Through this, students will acquire the skills for the abstraction of mechanical variables. Hereafter, the classical static and dynamic equilibrium relations will be derived from the balance equations. This will enable students to formulate concrete boundary-and-initial value problems out of the abstract formulations of continuum mechanics. Lastly, the derivations for the simple elastic material equations will be discussed so that the students will be in the position to independently expand and reformulate these equations within the framework of a thermodynamically consistent examination.</p>
description
<p><u>Kinematics</u></p> <ul style="list-style-type: none"> • Motion • Transport theorems • Deformations and strain measurements • Deformations and strain velocities • Lie Derivation • Polar Decomposition • Spectral Decomposition Forces and stresses • Cauchy's lemma and theorem • Cauchy, Kirchhoff and Piola-Kirchhoff stress tensors Balance equations and entropy inequality <p><u>Thermodynamic Modeling</u></p> <ul style="list-style-type: none"> • Balance equation of mass • Balance equation of momentum • Balance equation of moment of momentum • Balance equation of energy (first law of thermodynamics) • Entropy inequality (second law of thermodynamics) <p><u>Material Theory</u></p> <ul style="list-style-type: none"> • Concepts • Principles: Determinism, Equipresence, Local Action, Material Objectivity, Material Symmetry • Material Objectivity for Stresses • Constitutive Modeling

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- Helmholtz free Energy
- Material laws for Elastic Materials
- Linearization of Stresses

kind of examination

In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.

literature

Holzapfel, G.A.: Nonlinear solid mechanics. Wiley, 2000.
Hutter, K. & Jöhnk, K.: Continuum methods of physical modeling. Springer, 2004.
Müller, I.: Grundzüge der Thermodynamik. Springer, 1994.
Wilmanski, K.: Thermomechanics of continua. Springer, 1998.

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module name	shorthand expression of module
Introduction to Numerical Methods	
lecturer	department
Prof. Dr. Axel Klawonn	Numerical Mathematics

semester	cycle	language	requirements
1	WS	englisch	none

SWS	presence hours	self-study hours	workload in h	ECTS-Credits
4	60	150	210	7

teaching form
Lecture /Tutorial
learning objectives
A sound knowledge of numerical methods, next to the basics of the relevant engineering methods, form the basis for the study of computational mechanics. Successfully studying computational mechanics is unthinkable without understanding numerical methods and their foundations. Thus, an introduction to the basic numerical methods is given in this course, allowing the students to acquire a fundamental understanding of the methods relevant for computational mechanics. Algorithmic thinking and the implementation of algorithms in a programming language should be fostered.
description
In modern engineering, computer simulations of complicated models are becoming more and more important as the complexity of considered problems increases. Often simulation is the only way to gain insight into complex phenomena; otherwise the comprehension of these phenomena would be difficult or even impossible to otherwise achieve. Good examples include crash tests in the automotive industry and simulations in biomechanics. Numerical simulation is also often cost-effective alternative to physical experiments. In this course the basic principles for the numerical solution of mathematical problems will be addressed as they appear in mathematical modelling of engineering problems. The development of appropriate algorithms will be considered with both theoretical studies and computer implementation. The topics addressed during this course will be selected from the following: <ol style="list-style-type: none"> 1. Linear systems of equations 2. Nonlinear equations and systems of equations 3. Least square problems 4. Eigenvalue problems 5. Interpolation 6. Integration 7. Iterative solution of linear systems of equations 8. Stability and condition of algorithms 9. Computer arithmetic
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture. The successful solution of the homework assignments is considered a prerequisite for participation in the exam.
literature
a) Stewart, G.W., Afternotes on numerical analysis. Society for Industrial and Applied Mathematics (SIAM), Philadelphia, PA, 1996. x+200 pp.

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b) Schwarz, H.R., Numerical analysis. John Wiley & Sons, Ltd., Chichester, 1989. xiv+517 pp.

c) Quarteroni, A., Sacco, F., Saleri, F., Numerical mathematics. Second edition. Texts in Applied Mathematics 37, Springer-Verlag, Berlin, 2007. xviii+655 pp.

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module name	shorthand expression of module
Tensor Calculus	Tensor
lecturer	department
Prof. Dr.-Ing. Joachim Bluhm	Mechanics

semester	cycle	language	requirements
1	WS	englisch	none

SWS	presence hours	self-study hours	workload in h	ECTS-Credits
4	60	150	210	7

teaching form
Lecture (2 SWS) Tutorial (2 SWS)
learning objectives
In the lecture students will acquire the skills necessary to describe complex physical facts and laws with the help of the effective and compact tensor calculus. The students are able to better understanding of mathematical theories and modelling in the continuum mechanics and thermodynamics.
description
<ul style="list-style-type: none"> • Aspects of tensor calculus in vector algebra • The arbitrary basic system • Operations using the component representation • Operations using the tensor representation • Shift between coordinate systems • Gradient, Divergence and Rotation of tensor fields • Differentiation of tensor fields • Cauchy law
kind of examination
According to the examination regulation the type and duration of the examination will be defined from the lecturer before the semester starts.
literature
<p>Ogden, R.W.: Non-Linear Elastic Deformations Dover Publications, INC., 1984</p> <p>Holzapfel, G.A.: Nonlinear Solid Mechanics, Wiley, 2000</p> <p>Wiggers, P.: Nichtlineare Finite-Element-Methode, Springer, 2001</p> <p>de Boer, R., Schröder, J.: Tensor Calculus for Engineers - with Applications to Continuum and Computational Mechanics, 2007</p>

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module name	shorthand expression of module
Testing of Metallic Materials	TestMat
lecturer	department
Prof. Dr.-Ing. Paul Josef Mauk	Mechanical Working

semester	cycle	language	requirements
1	WS	englisch	none

SWS	presence hours	self-study hours	workload in h	ECTS-Credits
4	60	90	150	5

teaching form
Lecture/Exercises/laboratory
learning objectives
The student knows the destructive and non-destructive tests for metallic materials and their results for strength and toughness for metallic materials
description
The content of this module focuses on the procedures and methods used to test metallic materials. Based on the crystalline construction of metallic materials and the causes of metallic plasticity, fundamental attempts to determine the stability and tenacity in static and dynamic loads will be outlined. Alongside the standard material mechanical tests, the procedures of the substance analysis and the analysis methods will be described. The metallographic investigation methods via light-optical microscope bring us to the x-ray-graphical and electron microscope methods. Corrosion test procedures in chemical and especially electro-chemical corrosion as well as thermal corrosion accompany the study. The test of physical characteristics of metals should supplement the material-mechanical test procedures. In the case of the non-destructive test procedures, both acoustic as well as radiographic tests will be treated. The electric and magnetic testing procedures as well as the testing of surface smoothness comprise the content of this module.
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.
literature
Schmidt, Werner M; Dietrich, Hermann; Praxis der mechanischen Werkstoffprüfung Expert Verlag, Esslingen, 1999, Band 585 ISBN 3-8169-1612-0
Pöhlandt, K.; Werkstoffprüfung für die Umformtechnik Springer Verlag, Berlin, 1986 ISBN 3-540-16722-6
Blumenauer, Horst; Werkstoffprüfung Deutscher Verlag für Grundstoffindustrie, Stuttgart, 1994

ISBN 3-342-00547-5

Weiler, Wolfgang W.;
Härteprüfung an Metallen und Kunststoffen
Expert Verlag, Esslingen, 1998, Band 155
ISBN 3-8169-0552-8

Steeb, Siegfried;
Zerstörungsfreie Werkstück- und Werkstoffprüfung
Expert Verlag, Esslingen, 1993, Band 243
ISBN 3-8169-0964-7

Bergmann, Wolfgang:
Werkstofftechnik 2 – Werkstoffherstellung – Werkstoffverarbeitung –
Werkstoffanwendung
Hanser Verlag, München, 2002
ISBN 3-446-21639-1

Shackelford, James F.;
Werkstofftechnologie für Ingenieure
Pearson Studium Verlag, München, 2005
ISBN 3-8273-7159-7

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module name	shorthand expression of module
Finite Element Method Foundation	FEM-Found
lecturer	department
Prof. Dr.-Ing. habil. Jörg Schröder	Mechanics

semester	cycle	language	requirements
2	SS	englisch	none

SWS	presence hours	self-study hours	workload in h	ECTS-Credits
4	60	150	210	7

teaching form
The lecture is accompanied by numerous tutorial sessions during which associated computer simulations will be constructed and run.
learning objectives
Basic target of computational mechanics is to describe and predict the mechanical behavior of materials by using numerical simulation methods. For this purpose the Finite Element Method plays the major role, where the mechanical response of (mostly solid) materials is calculated by defining boundary conditions. In this module the foundations of this method are explained and deepened in exercises where the students have to implement numerical routines independently. The goal is to qualify the students to solve simple boundary value problems based on the Finite Element Method. In addition, the students are intended to be aware of the performance of the method, but also of the limitations of applicability.
description
The lecture addresses methods for numerical solutions of mechanical initial- and boundary value problems. We will primarily focus on the foundations of the linear Finite-Element Method. The lecture is organized as follows: - Motivation and overview - Mathematical foundations and definitions - Finite-Difference Method - Linear Finite-Element Method
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.
literature
[1] O.C. Zienkiewicz, R.L. Taylor [2005], The Finite Element Method - Its Basis and Fundamentals, Elsevier [2] R.D. Cook, D.S. Malkus, M.E. Plesha [1989], Concepts and Applications of Finite Element Analysis, Wiley [3] R. de Boer, J. Schröder [2008], Tensor Calculus for Engineers - with Applications to Continuum and Computational Mechanics

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module name	shorthand expression of module
Thermodynamics of Materials	Thermodyn
lecturer	department
Prof. Dr.-Ing. Joachim Bluhm	Mechanics

semester	cycle	language	requirements
2	SS	English	none

SWS	presence hours	self-study hours	workload in h	ECTS-Credits
4	60	150	210	7

teaching form
Lecture (2 SWS) Tutorial (2 SWS)
learning objectives
<p>The students will gain -the ability to express global and local statements regarding the laws of thermodynamics.</p> <p>- the ability to express definitive field equations, to complete systems of equations (fundamental relationships, evolution equations) and to define process variables in a problem-oriented manner.</p> <p>-the ability to express well-known fundamental approaches for fluids and solids.</p> <p>-the ability to formulate a description of the system of equations of non-stationary behaviours.</p>
description
<p>In order to gain restriction for constitutive relations and dissipation mechanism, the second law of thermodynamics (entropy inequality) has been usefully applied in continuum mechanics. The aim of the course is the derivation of restriction regarding the structure of constitutive equations and the formulation of dissipative effects for different material models. Contents of the Lecture:</p> <p><u>Fundamentals of Mechanics</u></p> <ul style="list-style-type: none"> • Balance of Energy • Entropy Inequality Principal of material objectivity Constitutive Sizes and Process Variables Constitutive Relationship and Dissipation Mechanism • incompressible fluids • ideal gases • elastic solids (non-linear equations, Hooke's law) • thermo-elastic solids • elastic-plastic solids • viscous materials <p>The lecture will be supplemented by a tutorial. The goal of the tutorial will be the development of a Maple-Code for the calculation of boundary and initial value problems of non-stationary processes in thermo-elastic solids.</p>
kind of examination
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literature
<p>- Haupt, P.: Continuum mechanics and theory of materials. Springer.</p>

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- Wilmański, K.: Thermomechanics of continua, Springer.
- Hutter, K. & Jöhnk, K.: Continuum Methods of Physical Modeling - Continuum Mechanics, Dimensional Analysis, Turbulence. Springer.

Syllabus Book for Master Computational Mechanics

module name	shorthand expression of module
Nonlinear Finite Element Method	FEM-NonLin
lecturer	department
Prof. Dr.-Ing. habil. Jörg Schröder	Mechanics

semester	cycle	language	requirements
3	WS	englisch	none

SWS	presence hours	self-study hours	workload in h	ECTS-Credits
4	60	150	210	7

teaching form

The lecture is accompanied by numerous tutorial sessions during which associated computer simulations will be constructed and run.

learning objectives

In modern engineering applications nonlinear systems of equations occur which have to be solved numerically for the simulation of mechanical problems. Thus, comprehensive knowledge of the numerical methods required for handling the particular nonlinear problems is necessary in order to be able to estimate the reliability of the numerical results. The mostly used method is the nonlinear Finite-Element Method, which is main topic of the course. This module imparts advanced skills including extended Finite Element techniques, whereas the module “Finite Element Method Foundation” explains the fundamentals. The student will gain knowledge necessary for solving advanced engineering problems numerically. Besides, the lecture provides a basis for the solution of research-oriented problems in the field of discretization methods and algorithms of applied mechanics.

description

The lecture addresses methods to numerically solve geometrically nonlinear initial- and boundary value problems in the field of mechanics. After a short introduction to the nonlinear continuum mechanics, the main topic of this course is the nonlinear Finite-Element Method.

The lecture is organized as follows:

- Motivation and overview
- Foundations of continuum mechanics
- Geometrically nonlinear problems (standard displacement method, Lagrange and Euler formulation)
- Mixed Finite-Element formulations
- Structure dynamics algorithms

kind of examination

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literature

- [1] O.C. Zienkiewicz, R.L. Taylor [2005], The Finite Element Method for Solids and Structural Mechanics, Elsevier
- [2] T. Belytschko, W.K. Liu, B. Moran [2000], Nonlinear Finite Elements for Continua and Structures, Wiley
- [3] R. de Boer, J. Schröder [2008], Tensor Calculus for Engineers - with Applications to Continuum and Computational Mechanics

module name	faculty
Elective Courses SS	engineering science
used in degree course	
<ul style="list-style-type: none"> • Master Computational Mechanics 	

year	duration	type of module
1	1	Elective Science

exam regulation requirements
recommended requirements
Tensor Calculus, Continuum Mechanics, Numerical Mathematics I, Computer Languages for Engineers I

Nr.	courses	semester	SWS	workload in h	ECTS-Credits
1		2	4	150	5
2		2	4	150	5
3		2	4	150	5
total			12	450	15

Courses
<ul style="list-style-type: none"> • Advanced Computer Architecture • Advanced Numerical Methods • CAD in Civil Engineering • Computational Fluid Dynamics • Concepts of Environment Protection • Design of Concrete Structures • Fatigue and Lifetime of Machine Elements • Finite Element Method - Coupled Problems • Finite Element Method - Modelling in Steel Structures • Geotechnics Project with Lab • Selection of materials for high temperatures and lightweight design
description
Students must choose between a select number of elective subjects which will permit them to further expand on the major subject of their study program. In this manner, the depth of the instruction shall be enhanced. This can be valuable for a clearly defined professional application as well as for a scientifically-oriented MA study for use in academic research.
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
Advanced Computer Architecture	ACA
lecturer	department
Prof. Dr.-Ing. Axel Hunger	Informatics

SWS	cycle	language	requirements
3	SS	englisch	none

teaching form
Lectures and Tutorials with usage of MS-Power Point
learning objectives
The students are able to describe modern concepts of computer architectures and to explain their advantages against conventional von-Neumann computer architectures. They are further able to evaluate computer architectures with regard to efficiency related to different applications.
description
This course discusses the modern computer architecture concepts that allow the construction of high performing computer systems and networks. In the first lecture component, concepts are introduced which enable modern computers to overcome the limitations of the traditional von-Neumann concept of designing computers, such as pipelining, superscalar and vector architectures. Based on these concepts, distributed computer architectures are explained including arrays of computers as well as different types of loosely and tightly coupled CPUs. In this context permutation networks are introduced as special aspects of highly specialized and performing computer arrays. A third topic is cache coherency in parallel systems. Finally modern supercomputers and their properties are presented, and a survey of current developments in the area of "Grid Computing" is given.
kind of examination
Written examination 90 min.
literature
1. D.E.Culler, J.P.Singh, A.Gupta Parallel Computer Architecture: A Hardware/Software Approach Morgan Kaufmann, 1999, ISBN 1-55860-343-3
2. J.L.Hennessy, D.A.Patterson Computer Architecture: A Quantitative Approach Morgan Kaufmann Publishers, Inc., 3rd edition, 2003

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
Advanced Numerical Methods	NumMeth
lecturer	department
Prof. Dr. Axel Klawonn	Numerical Mathematics

SWS	cycle	language	requirements
4	SS	englisch	none

teaching form
Lecture /Tutorial
learning objectives
In this course, advanced numerical methods and algorithms are considered building on the basic numerical methods from the course "Introduction to Numerical Methods"; the abilities and skills already obtained in the introductory course will be enhanced. Differential equations play an important role in modelling mechanical problems, e.g., elasticity, plasticity, vibrations, etc. Thus, differential equations and their efficient solution is in the focus of this course. Without a sound understanding of numerical methods for the solution of stationary and instationary differential equations, it is often not possible to correctly evaluate the results obtained from commercial software packages. The fundamental knowledge and algorithms are treated in this course. Algorithmic thinking and the implementation of algorithms in a programming language should be fostered.
description
Differential equations play an important role in modeling complex technical problems such as elasticity, plasticity, vibrations, fluid dynamics, etc. In this course different basic classes of ordinary (ODE) and partial differential (PDE) equations will be considered. The focus will be on the numerical solutions of these equations, i.e., on the development of algorithms, their convergence analysis, and implementation on a computer.
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture. The successful completion of the homework assignments is considered a prerequisite for participation in the exam.
literature
a) Rappaz, M., Bellet, M., Deville, M., Numerical modeling in materials science and engineering. Springer Series in Computational Mathematics, 32. Springer-Verlag, Berlin, 2003. xii+540 pp.
b) Schwarz, H.R., Numerical analysis. John Wiley & Sons, Ltd., Chichester, 1989. xiv+517 pp.
c) Quarteroni, A., Sacco, F., Saleri, F., Numerical mathematics. Second edition. Texts in Applied Mathematics 37, Springer-Verlag, Berlin, 2007. xviii+655 pp.

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
CAD in Civil Engineering	CAD
lecturer	department
Prof. Dr.-Ing. Jochen Menkenhagen	Statics

SWS	cycle	language	requirements
4	SS	englisch	none

teaching form
Seminar
learning objectives
<p>Students will learn to construct two-dimensional design sketches with basic elements of a CAD-programme. In addition, three-dimensional modelling of systems, based on these two-dimensional sketches, will be learnt. Based on CAD-modelling, the participants will learn to create a processed link of the recorded data for the analysis of structures from the data base of the CAD-programme. The students will learn the automatic generation of input data for computing programmes, based on the data recorded in the CAD-modelling. The covered topics will be enlarged upon by rendering practical examples. .</p>
description
<p><u>Basic functions of CAD</u></p> <ul style="list-style-type: none"> • Modelling with the elements of a two-dimensional construction • Modelling with the elements of a three-dimensional construction • Linking of three-dimensional objects with Boolean operators <p><u>Automation and script programming</u></p> <ul style="list-style-type: none"> • Basis of script programming. The details are given by the capabilities of the chosen software (e.g. VBA and COM-objects) • Modelling of project specific structures of data • Modelling of a surface in order to detect the data necessary for the automation. • Preparation of the project data and export for an optionally following calculation step. • Programme controlled realization of the calculated postprocessors.
kind of examination
<p>In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.</p>
literature
- AutoCAD 2006, VBA: A Programmers Reference

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
Computational Fluid Dynamics	CFD
lecturer	department
Prof. Dr.-Ing. habil. Klaus Görner	Computational Fluid Dynamic

SWS	cycle	language	requirements
4	SS	englisch	none

teaching form
Lecture /Tutorial
learning objectives
<p>The students should come into the position to understand the effects and phenomenons of reacting flows and to handle the knowledge transfer into mathematical models. On this basis applications to civil engineering (flows in buildings, flows around buildings) and similar fields can be understood and be handled in simple examples.</p> <p>Understanding the basics of:</p> <ul style="list-style-type: none"> - Fluid dynamics - Reaction - Heat transfer - Mathematical modelling of flows in general - Numerical solution of the describing equations
description
<p>Balancing Equations</p> <ul style="list-style-type: none"> - Euler-/Lagrange Description of the Flow Field Laminar Flow Turbulent Flow - Time-averaged equation - Turbulence models - Two-phase flow Description of the Heat Transfer - Conduction - Convective transport - Radiation - Radiative qualities Description of Chemical Reactions - Basics Numerical Solution of Equations/Systems of Equations Examples for CFD-applications - Simple flow situations - Two phase flows - Reactive Flows - Flow situations around buildings - Flow situation in buildings
kind of examination
According to the examination regulation the type and duration of the examination will be defined from the lecturer before the semester starts.
literature
<p>Görner, K.: Technische Verbrennungssysteme. Springer Verlag, Berlin Heidelberg, 1991</p> <p>Goerner, K.; Klasen, Th.: Modelling, simulation and validation of the solid biomass combustion in different plants. Progr. Comp. Fluid Dyn., Vol.6, Nos.4/5, 2006</p> <p>Al-Halbouni, A.; Giese, A.; Flamme, M.; Goerner, K.: Applied modelling for bio and lean gas fired micro gas turbines. Progr. Comp. Fluid Dyn., Vol.6, Nos.4/5, 2006</p>

lecture name	shorthand expression of lecture
Design of Concrete Structures	DCS
lecturer	department
Prof. Dr.-Ing. Martina Schnellenbach-Held	Concrete Structures Engineering

SWS	cycle	language	requirements
4	SS	englisch	none

teaching form
a) Lecture: Auditorium lecture, Lecture notes b) Tutorial Session: Auditorium Tutorial
learning objectives
The students in this module gain deeper knowledge in building and civil engineering. As part of this event they learn material-specific peculiarities as well as the design of engineering structures with appropriate assessment procedures. Also they will be able to calculate short- and long-term deflections of reinforced concrete structures, gain knowledge of using strut and tie models within designs, gain familiarity with the performance of the fatigue verification and be able to solve design and construction tasks for building structures and civil engineering works.
description
The objective of this module is to give students deeper knowledge in the field of building and civil engineering to convey. The students learn particularities of time-dependent material behaviour, modelling and the design of constructions of special concrete and the assessment of water impermeable concrete structures. This will be showed in examples of bridge constructions of reinforced concrete and prestressed concrete. This knowledge enables the students to design structure under special requirements.
The content of this lecture:
<ul style="list-style-type: none"> - Deformation properties of reinforced concrete structures - Strut and tie models - Fatigue - Self-equilibrating stresses, restraint, minimum reinforcement - Water impermeable concrete structures - Structural engineering projects– conceptual, preliminary and detailed design - Lightweight aggregate concrete, high-performance concrete, ultra-high-performance concrete
kind of examination
Four take-home projects, written examination
literature
<ul style="list-style-type: none"> - Schnellenbach-Held: Skript zur Vorlesung - Betonkalender 2002 – 2006, Ernst & Sohn - Avak/Goris „Stahlbetonbau aktuell, Praxishandbuch 2004+2005“, Bauwerk-Verlag

lecture name	shorthand expression of lecture
Fatigue and Lifetime of Machine Elements	FLME
lecturer	department
Prof. Dr.-Ing. Paul Josef Mauk	Mechanical Working

SWS	cycle	language	requirements
4		englisch	none

teaching form
Lecture/Exercise
learning objectives
The student knows how to check the safety and life time of a real machine component based on the static and dynamic loadings. The student can take into account the influence of design notches and cracks on safety and operational use.
description
Module: Structure and Fatigue-Strength, Fatigue and Life Time of Machine Elements Based on static and dynamic boundary tensions, the durability of metallic materials and the parameters influencing them (component size, mean stress, surface, etc.) will be examined. The effect of structural notches upon different materials results in the determination of shape stability and reliability. These results, coupled with the parameters of fracture mechanical metallic materials, establish both the structure and fatigue-strength of machine and system parts. Questions concerning life span and loading capacity will be tested using examples and the results will be examined. The treatment of creep strength/ resistance at raised temperatures supplements the content.
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.
literature
Rösler, J., Harders, H., Bäker, M. Mechanisches Verhalten der Werkstoffe Teubner Verlag, Wiesbaden, Juni 2006 ISBN-13 978-3-8351-0008-4
Schott, G. Werkstoffermüdung – Ermüdungsfestigkeit Deutscher Verlag für Grundstoffindustrie, Stuttgart, 1997 ISBN-3-342-00511-4
Radaj, D. Ermüdungsfestigkeit – Grundlagen für Leichtbau, Maschinen- und Stahlbau Springer-Verlag, Berlin, 1995 ISBN-3-540-58348-3
Haibach, Erwin; Betriebsfestigkeit – Verfahren und Daten zur Bauteilberechnung Springer-Verlag, Berlin, 2002 ISBN 3-540-43142-X

Syllabus Book for Master Computational Mechanics

Dowling, N., E.
Mechanical Behavior of Materials – Engineering Methods for
Deformation, Fracture, and Fatigue
Prentice Hall, Upper Saddle River, New Jersey, 2007
ISBN 0-13-186312-6

Hertzberg, R., W.
Deformation and Fracture Mechanics of Engineering Materials
John Wiley & Sons, Inc., New York, 1996
ISBN 0-471-01214-9

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
Finite Element Method - Coupled Problems	FEM - Coupled
lecturer	department
Prof. Dr.-Ing. Tim Ricken	Computational Mechanics

SWS	cycle	language	requirements
4	SS	englisch	none

teaching form
a) Lecture: Auditorium lecture, Lecture notes b) Tutorial Session: Auditorium Tutorial in PC Pool
learning objectives
<p>With the Finite Element Method (FEM) the formulation of more complex questions with coupled field equations can be dealt with alongside the formulation of pure mechanical questions. Examples of this are</p> <ul style="list-style-type: none"> • thermo-mechanical coupling • electro-mechanical coupling • chemical mechanical coupling or combinations of these. <p>Students will be taught how to numerically analyze and solve coupled mechanical using the Finite Element Method. With this, students will learn techniques with which to solve other coupled problems that are not explicitly dealt with in the course. Students will thereby be taught how to design solution strategies for general coupled problems.</p>
Description
<p>The treatment of these tasks, one the one hand, calls for the development of coupled material equations which do not contradict the fundamental thermo-dynamic principles, but on the other hand the expansion of the system of equations can lead to an additional process variable (i.e. the temperature, the electrical field or a chemical condition variable) which may negatively influence the properties of numerical solutions within the framework of the finite element approximation. In order to gain a stable solution to coupled problems with the help of the Finite Element Method the following conditions must be met:</p> <ul style="list-style-type: none"> • the possible fields of use • the thermo-dynamic consistent description • the appropriate Finite Element formulation and • the appropriate numerical approximation procedures <p>The lectures will be complemented with practice exercises on the computer. Here independent finite element multi-field problems will be programmed and commercial programs for the solution of multi-field problems will be put into practice.</p>
kind of examination
<p>In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.</p>
literature
<p>Holzapfel, G.A.: Nonlinear solid mechanics. Wiley, 2000. Hutter, K. & Jöhnk, K.: Continuum methods of physical modeling. Springer, 2004. Müller, I.: Grundzüge der Thermodynamik. Springer, 1994. Wilmanski, K.: Thermomechanics of continua. Springer, 1998.</p>

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
Geotechnics Project with Lab	GeoLab
lecturer	department
Prof. Dr.-Ing. Werner Richwien	Soil Mechanics

SWS	cycle	language	requirements
4	SS	English	none

teaching form
Lecture / Tutorial / laboratory practicum
learning objectives
The students learn how to bring in their specialized knowledge into a team. They learn to independently deal with the individual working steps of a geotechnical project and to select and carry out the necessary and appropriate field and lab tests. The students will learn how to effectively report the results of their work with both written documents and diagrams.
description
During this course students are assigned a certain construction project in order to learn how to specify the necessary field and lab tests to determine the soil parameters necessary for the constructional design. The students form groups for each project. As a preliminary step each student group specifies the field investigations for their project. These concepts are presented in short lectures and discussed by all participants. In the second project phase the lab tests needed for design are selected, presented and discussed. Next the students perform some of the selected lab tests under guidance of the laboratory staff. The course continues with lectures about the drawing of reports on the results of the field and laboratory investigations. Each group prepares a final report that concludes the course.
kind of examination
oral examination 30 min.
literature
Richwien, W.; Lesny, K.: Bodenmechanisches Praktikum, 11. Auflage, Verlag Glückauf, 2004 Buja, H.: Handbuch der Baugrunderkundung, Werner Verlag, 1999 Smolczyk, Ulrich (Hrsg.): Geotechnical Engineering Handbook, Volume 1, Ernst und Sohn, 2003 Lancellotta, R.: Geotechnical Engineering, Balkema, 1995

lecture name	shorthand expression of lecture
Werkstoffauswahl für hohe Temperaturen und Leichtbau	
lecturer	department
Prof. Dr.-Ing. habil. Alfons Fischer	Material Science

SWS	cycle	language	requirements
4	SS	German	none

teaching form
Lecture / Tutorial
learning objectives
The lecture serves the purpose of providing necessary knowledge for the engineering profession associated with materials used at raised temperatures and for lightweight construction. Priority will be given to studying the connection between the usage and manufacturing properties. Examples from the areas of machine and plant construction as well as moved constructions will be introduced. Study will be supplemented with tutorial sessions.
description
Based upon the basic principles of materials science and production engineering, the criteria and possible strategies for a targeted material selection are introduced. Beside the usage and manufacturing properties, other properties which influence selection, such as the price, worldwide availability, status of international standardization, etc. make up an integral part of the lecture. The practice of material selection is geared towards the approach which is described in Michael F. Ashby's book, "Materials Selection in Mechanical Design." To this end, with the help of corresponding software, students will be able to independently solve tasks.
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.
literature
Bürgel; Handbuch Hochtemperaturwerkstofftechnik, Vieweg Schatt; Konstruktionswerkstoffe, Deutscher Verlag für Grundstoffindustrie Budinski; Engineering Materials, Pearson Ashby; Werkstoffe 1 und 2, Elsevier Ashby; Materials Selection in Mechanical Design, Butterworth

module name	faculty
Elective Courses WS 1-3	engineering science
used in degree course	
<ul style="list-style-type: none"> • Master Computational Mechanics 	

year	duration	type of module
1	1	elective

exam regulation requirements
recommended requirements
Tensor Calculus, Continuum Mechanics, Numerical Mathematics I, Computer Languages for Engineers I, Finite Element Method Foundation, Thermodynamics of Materials

Nr.	courses	semester	SWS	workload in h	ECTS-Credits
1		3	4	150	5
2		3	4	150	5
3		3	4	150	5
total			12	450	15

Courses
<ul style="list-style-type: none"> • Advanced Modeling and Simulation Techniques • Analysis of Structures • Computational Inelasticity • CSCW und Programmentwurfstechnik • Finite Element Method - Design of Structural Connection • Finite Element Method - Modelling Concrete Structures • Finite Element Method - Multiphase Materials • Modelling and Numerical Simulation of Geotechnical Problems • Parallel Computing • Pre-stressed Concrete • Schadenskunde • Schwingungsanalyse mit MATLAB • Simulation of Landfill Bodies
description
Students must choose between select numbers of elective subjects which will permit them to further expand on the major subject of their study program. In this manner, the depth of the instruction shall be enhanced. This can be valuable for a clearly defined professional application as well as for a scientifically-oriented MA study for use in academic research.
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
Advanced Modeling and Simulation Techniques	ModSim
lecturer	department
Prof. Dr.-Ing. Dieter Schramm	Mechantronics

SWS	cycle	language	requirements
4		English	none

teaching form
lecture (2 SWS), exercises (2 SWS) Lecture: presentation of PowerPoint slides with supplemental calculations worked out on the overhead projector Exercises: step-by-step solution of examples of technical/dynamical systems using the overhead projector Computer exercises: practical application of simulation software like Matlab/Simulink and Dymola for modeling and simulation of technical/dynamical systems examples
learning objectives
The students will be able to appropriately choose and apply mathematical methods to efficiently set up versatile simulation models of complex mechanical and mechatronic systems which is one of the key abilities needed in the related study program “computational mechanics”. They will be able to apply these methods to a variety of complex problems in the focus of the study program; furthermore, they will be in a position to interpret and discuss simulation results and to judge the relevance of the solution to the problem at hand. During the lecture they gain “hands on” experience in applying the methods learned using standard engineering software like Matlab/Simulink and Dymola. In addition students know how to identify and optimize parameters of mechanical and mechatronic systems.
description
The lecture is dedicated to the modeling and simulation of mechanical and mechatronic systems within the lecture and the application within hands-on exercises. The specific course contents are as follows: - definitions and conceptions - domain specific and domain independent modeling methods in different technical domains (e.g. mechanical, hydraulic, electric, electronic) - modeling of mechatronic systems - modeling of systems with concentrated and distributed parameters - set up and advanced solution methods for ordinary differential equations and differential-algebraic equations - analysis of linear systems - modal analysis - stability of mechatronic systems - linear and non-linear parameter identification and optimization methods - introduction in the application of Matlab/Simulink and Dymola – applications
kind of examination
written or oral examinations as determined by the lecturer
literature
- F.E. Cellier: Continuous System Modeling, Springer Verlag, 1991 - M. Hermann: Numerik gewöhnlicher Differentialgleichungen. München, Wien: Oldenbourg, 2004 - H. Bossel : Systemdynamik. Braunschweig, Wiesbaden: Vieweg, 1987 - D. Möller: Modellbildung, Simulation und Identifikation Dynamischer Systeme, Springer-Lehrbuch, 1992 - P. Fritzson: Principles of Object-Oriented Modelling and Simulation with Modelica - Slides and handouts in both English and German

lecture name	shorthand expression of lecture
Analysis of Structures	AS
lecturer	department
Prof. Dr.-Ing. Jochen Menkenhagen	Statics

SWS	cycle	language	requirements
4	WS	English	none

teaching form
Seminar
learning objectives
The participants will learn to use spatial elements for the modelling of structures. Based on the procedure of linear calculations students will learn to use the analysis of stability based on the FEM and FSM. The students will learn the importance of this approach when considering geometrical and physical non-linearity. Students will also learn to interpret the results of the calculations as well as the iteration regimes. Towards the end of the course the dynamic analysis of systems will be covered with regard to the previously covered skills.
description
<u>Modelling</u> <ul style="list-style-type: none"> • Even frames • Modelling of surface- and volume-structures • Calculation and verifying of the calculated results of spatial systems • Geometrically non-linear calculations (2nd theory) • Physically non-linear calculations, material laws <u>Analysis of structures</u> <ul style="list-style-type: none"> • Analysis of stability of profiles under the use of the method of finite stripes • Forms of failure of profile geometry (local, global failure of stability) Dynamic analysis (frequency analysis, modal analysis)
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.
literature
<ul style="list-style-type: none"> - FEM für Praktiker – Band 1: Grundlagen - FEM für Praktiker – Band 2: Strukturdynamik - FEM für Praktiker – Band 3: Temperaturfelder

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
Computational Inelasticity	Com Inelas
lecturer	department
Prof. Dr.-Ing. habil. Jörg Schröder	Mechanics

SWS	cycle	language	requirements
4	WS	English	none

teaching form
The lecture is accompanied by numerous tutorial sessions during which associated computer simulations will be constructed and run.
learning objectives
Engineering applications require more and more the use of modern materials which are characterized by nonlinear mechanical properties. For the simulation of such materials the mathematical description of the material behavior is as much important as the numerical implementation. The main goal of this module is to impart fundamental knowledge with respect to nonlinear constitutive material equations as well as their numerical treatment. The module explains standard properties as isotropic elasto-plasticity at small strains and is completed by modern requirements to material modeling such as finite strains or anisotropy. The student gains skills with a view to numerical material description and gets to know possibilities and limitations of simulating modern materials.
description
This lecture addresses methods for the numerical solution of physically nonlinear initial- and boundary value problems in the field of mechanics. Numerous nonlinear material laws are presented, and the lecture is organized as follows: - Motivation and overview - Damage at small strains - Elasto-plasticity at small strains - Hyperelasticity (finite strains) - Anisotropy
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.
literature
[1] J.C. Simo, T.J.R. Hughes [2004], Computational Inelasticity, Springer [2] J. Lemaitre [1996], A Course on Damage Mechanics, Springer [3] I. Doghri [2000], Mechanics of Deformable Solids, Springer

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
CSCW and Software Engineering	CSCW
lecturer	department
Prof. Dr.-Ing. Axel Hunger Dr.-Ing. Stefan Werner	Informatics

SWS	cycle	language	requirements
4	WS	English	none

teaching form
Lectures, Seminars and Labs
learning objectives
The students will be able to recognize the meaning of the teamwork for the software development process and to understand the influence of relevant planning and estimation parameters. The potential of groupware support will be identified and the students should be able to meaningfully plan the employment of appropriate tools.
description
At the beginning of the lecture the basic concepts of distributed systems and software project management are discussed. Later the fundamentals of computer supported cooperative working are introduced. The second part of the lecture combines previously separately treated topics towards a computer support for distributed software engineering teams. In doing so, focus will be set on virtual teams in modern software engineering processes. Topics include organization of virtual teams and intercultural communication and groupware. Finally process models to support distributed software engineering teams will be presented. In the lab the students are acquainted with different synchronous and asynchronous Groupware-Systems and how to use these systems within the software engineering process, especially in distributed teams.
kind of examination
written examination 90 min.
literature
1 Borghoff, U.M.; Schlichter, J.H.: Computer Supported Cooperative Work, Springer Verlag 2000 2 Altmann, J.: Cooperative Software Development: Computer-Supported Coordination and Cooperation, PhD-Thesis, Trauner, Linz, 1999 3 Werner, S.: Synchrone Groupware für die Software Engineering Ausbildung, dissertation.de-Verlag, Berlin 2003 4 Henrich, A.: Management von Softwareprojekten, R. Oldenbourg Verlag, München, 2001

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
Finite Element Method - Modelling Concrete Structures	FEM-CS
lecturer	department
Prof. Dr.-Ing. Martina Schnellenbach-Held	Concrete Structures Engineering

SWS	cycle	language	requirements
4	WS	German/English	none

teaching form
a) Lecture: Auditorium lecture, Lecture notes b) Tutorial Session: Auditorium tutorial
learning objectives
Due to the increased IT services today, the design of constructions of civil engineering is mainly based on computer calculation methods. The calculation of structures with linear and non-linear finite element method (FEM) is becoming increasingly important. Building on skills already learned of the finite element method shows this module the specifics of the not elastic composite material reinforced concrete for the FEM calculation. Given these findings students are able to calculate constructions of reinforced concrete in a practical manner. With this knowledge it is possible for them to design constructions via nonlinear finite element analysis.
description
Through complex structures and the increased demand for a possible safety calculation among economic aspects the calculation of using FEM is becoming increasingly important. The content of this lecture: <ul style="list-style-type: none"> - Theoretic fundamentals - Types of elements - Linear finite element analysis - Discretisation - Modeling concrete structures - Nonlinear finite element analysis of concrete structures - Methods of iteration - Material laws <p>With these findings, it is possible to the students to model and to calculate the material, support and deformation behaviour of composite materials. Moreover, it is possible for them to model and calculate solid structures under a safety technical and economic point of view.</p>
kind of examination
Four take-home projects, written examination
literature
<ul style="list-style-type: none"> - Schnellenbach-Held, Keuser: Finite Elemente im Massivbau – Skript zur Vorlesung - Bathe, K.J.: Finite Element Procedures in Engineering Analysis, Prentice Hall Inc., Englewood Cliffs, New Jersey - Krätzig, W.B.; Basar, Y.: Tragwerke: Theorie und Anwendung der Methode der Finiten Elemente, Springer Verlag, Berlin – Heidelberg, 1997 - Stempniewski, Eibl: Finite Elemente im Stahlbeton, Beton-Kalender 1996, Verlag Ernst & Sohn, Berlin

lecture name	shorthand expression of lecture
Finite Element Method - Multiphase Materials	MultMat
lecturer	department
Prof. Dr.-Ing. Tim Ricken	Computational Mechanics

SWS	cycle	language	requirements
4	WS	English	none

teaching form
a) Lecture: Auditorium lecture, Lecture notes b) Tutorial Session: Auditorium tutorial / PC-Pool
learning objectives
<p>For many industrial applications a description of materials which are made up of many components is needed. Examples of this are liquid-saturated porous grounds, filters where gas is passed through or biomaterials. In the lecture the behavioral response of the materials within the framework of a continuum mechanical description will be discussed.</p> <p>Students will be able to</p> <ul style="list-style-type: none"> • discuss the continuum mechanics of multi-phase systems • formulate thermo-dynamically consistent material equations within multi-phase systems • formulate boundary conditions within multi-phase systems • prepare the coupled equation system for numerical treatment • verify the calculation concept with the help of numerical example calculations
description
<p>The Theory of Porous Media will be introduced as a conceptual access point for the discussion of discrete multi-phase materials. The conceptual procedure for the development of thermo-dynamically consistent material equations will be also be discussed. The solution of the resulting equation system occurs numerically under the use of the Finite Element Method (FEM). On account of the mostly strong, coupled and non-linear character of the equation system which is to be solved, special element models will be introduced.</p> <ul style="list-style-type: none"> • Motivation and Overview • Introduction to the Theory of Porous Media (TPM) • Development of thermo-dynamically consistent material equations • Treatment of Continuum Mechanics • Liquid saturated porous solids • Discussion of boundary conditions • Preparation of the coupled equation system for numerical treatment • Verification of the calculation concept with the help of numerical example calculations
kind of examination
<p>In accordance with examination regulations §17, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.</p>
literature
<p>de Boer, R.: Theory of porous media - highlights in the historical development and current state, Springer-Verlag, 2000</p> <p>Ricken, T.: Kapillarität in porösen Medien - Theoretische Untersuchung und numerische Simulation, Dissertation, Shaker Verlag, Aachen, 2002</p> <p>Ricken, T., Schwarz, A., Bluhm, J.: A Triphasic Model of Transversely Isotropic Biological Tissue with Application to Stress and Biological Induced Growth, Computational Materials Science 39, 124 – 136, 2007</p>

lecture name	shorthand expression of lecture
Modelling and Numerical Simulation of Geotechnical Problems	MNSGP
lecturer	department
Prof. Dr.-Ing. Werner Richwien Dr.-Ing. Kerstin Lesny	Soil Mechanics

SWS	cycle	language	requirements
4	WS	English	none

teaching form
The lecture is accompanied by numerous tutorial sessions during which associated computer simulations will be constructed and run.
learning objectives
The students will acquire the ability to deal with complex geotechnical problems, which they basically know from the Bachelor studies. First, the students learn how to structure such tasks, to identify the different problems to be solved and to divide the complex task in single design steps. Within the design numerical methods will be applied. First, the students will be familiarized with standard software which is widely used in engineering practice. They learn how to use the software but also to consider the limits of these programmes. After that, the students will become familiar with the application of the finite element method in Geotechnics. They get to know complex constitutive models to describe the material behaviour of different kinds of soil. They learn how to choose a suitable constitutive model for different problems, how to identify the required model parameters and to evaluate the model verification. At the end, the students will have acquired the ability to generate a FE-model for simple problems, to perform the calculation and to critically analyse the results.
description
Based on various geotechnical problems (e. g. design of a construction pit including dewatering system, stability and serviceability of shallow foundations on layered soil) strategies will be developed in the first part of this lecture for treating complex problems in Geotechnics (i. e. defining different design or construction stages and the corresponding loading). In the tutorial an introduction of commercial geotechnical software to be applied will be provided. After that, the students may work on the problems on their own under appropriate guidance. In the second part of the lecture different constitutive models of soil mechanics will be introduced. Among these are the models developed by Mohr-Coulomb and Drucker-Prager, the Hardening Soil Model, the Cam-Clay Model and a hypoplastic model. The basic formulation of these models, their limits of application, the required model parameters and their determination will be discussed. Using the commercial programme PLAXIS the application of the Finite Element Method to geotechnical problems will be shown. Modelling of structural components and soil, mesh generation and choosing appropriate constitutive models for structure and soil will be discussed. In the tutorial simple problems such as foundation or slope stability will be modelled and the results will be evaluated based on a comparison to conventional design methods. Further on, the effect of different constitutive models on the results of the analysis will be investigated. By modelling element tests such as direct shear or triaxial tests the need for verification will be evaluated as well.
kind of examination
oral examination 30min
literature
Chen, W.F.; Baladi, G.Y.: Soil Plasticity-Theory and Implementation, Elsevier, 1985 Desai, C.; Siriwardane, H.: Constitutive Laws for Engineering Materials with Special Emphasis on Geologic Matrials, Prentice Hall, 1984 Kolymbas D.: Constitutive Modelling of Granular Matrials, Springer, 2000

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Manuals PLAXIS, 2003

Wu, W., Bauer, E. (1994): A Simple Hypoplastic Constitutive Model for Sand, Int. J. for Numerical and Analytical Methods in Geomechanics, Vol. 18, p. 833-862

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lecture name	shorthand expression of lecture
Parallel Computing	ParComp
lecturer	department
Dr. rer. nat. Oliver Rheinbach	Mathematics

SWS	cycle	language	requirements
4	WS	German	none

teaching form
Auditorium Lecture / Tutorial
learning objectives
Today, the fastest computers of the world are massively parallel systems with distributed memory and hundred thousands of processors. Smaller parallel computers made from commodity components are widely in use in industry and science. Moreover, multicore technology has further increased the interest in parallel programming and computing. This course will cover theoretical and practical aspects of parallel scientific computing. This will include basic principles of the design of parallel algorithms as well as their implementation on parallel computers and the related software standards. In particular, the parallel solution of equation systems, e.g. arising from the discretization of mechanical problems, may be covered in the course.
description
The lecture will cover: Efficiency of parallel algorithms, Basic principles of the design of efficient parallel algorithms, parallel computing using shared memory machines and related software standards (e.g. OpenMP), parallel computing using distributed memory machines and related software standards (e.g. MPI), parallel linear algebra, e.g. parallel solution of linear equation systems In the exercise parallel algorithms will be designed and implemented by the students using corresponding software libraries and parallel numerical software.
kind of examination
In accordance with examination regulations §17, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.
literature
William Gropp, Ewing Lusk, Anthony Skjellum, Using MPI: Portable Parallel Programming with the Message-Passing Interface, MIT press, 2000 Anne Greenbaum, Iterative Methods for Solving Linear Systems, SIAM, 1997 Michael Quinn, Parallel Programming in C with MPI and OpenMP, McGraw-Hill, 2003 Ananth Grama, Anshul Gupta, George Karypis, Introduction to Parallel Computing: Design and Analysis of Algorithms, Addison-Wesley, 2nd ed. 2003

lecture name	shorthand expression of lecture
Pre-stressed Concrete	PC
lecturer	department
Prof. Dr.-Ing. Martina Schnellenbach-Held	Concrete Structures Engineering

SWS	cycle	language	requirements
4	WS	German/English	none

teaching form
a) Lecture: Auditorium lecture, Lecture notes b) Tutorial Session: Auditorium tutorial
learning objectives
A special part of civil engineering is the design of prestressed concrete structures. In this module the students learn the design of prestressed concrete components and their peculiarities as concerning material theory, modelling and calculation. It is possible for them to formulate and evaluate time-dependent deformations of concrete. In addition, they will dominate the basics of the design and execution of components of prestressed concrete.
description
Prestressed concrete components are increasingly used in civil engineering. For this reason this module dedicates the design of prestressed concrete components special attention. The students learn the technical background of prestressed concrete technology, material-specific peculiarities as well as the modeling and design of prestressed concrete components. The content of this lecture: <ul style="list-style-type: none"> - Prestressing technology - Centric prestressed concrete elements - Load case prestressing for statically determinate and indeterminate systems - Cross sectional properties and forms - Time dependent material behavior - Loss of prestressing - Design: ultimate and serviceability limit state - Conceptual, preliminary and detailed design of prestressed structures
kind of examination
Four take-home projects, written examination
literature
<ul style="list-style-type: none"> - Schnellenbach-Held: Grundlagen des Spannbetonbaus und Spannbeton – Bemessung und Konstruktion – Skripte zur Vorlesung

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lecture name	shorthand expression of lecture
Technische Schadensanalyse	
lecturer	department
Prof. Dr.-Ing. habil. Alfons Fischer	Material Science

SWS	cycle	language	requirements
3	WS	German	none

teaching form
Lecture / Tutorial
learning objectives
The basics of mechanical and chemical stresses will be presented in lecture and evaluated with respect to failure initiation and propagation. Examples from all areas of engineering are used to show the appearances of failures in the underlying mechanisms. This knowledge will be further developed through exercises using failed parts and in conjunction with proper reporting.
description
This lecture focusses on modern strategies of failure analysis. It starts with the basic failure mechanisms of mechanically, chemically, and thermally induced failures and its failure appearances. After the failure mechanisms are known possible counters to measure are presented and discussed. The exercise deals with real failed parts. The students will carry out complete failure analyses incl. appropriate reporting.
kind of examination
According to the examination regulation the type and duration of the examination will be defined from the lecturer before the semester starts.
literature
Broichhausen, Josef: Schadenskunde : Analyse und Vermeidung von Schäden in Konstruktion, Fertigung und Betrieb. Du: 33WFB1760, E: 41WBF83
Lange, Günter [Hrsg.]: Systematische Beurteilung technischer Schadensfälle. Du: 43ZHE1904, E: 41ZLP1230
Grosch, Johann: [Serie] Schadenskunde im Maschinenbau : charakteristische Schadensursachen - Analyse und Aussagen von Schadensfällen. E: 41ZLI1374
Kaesche, Helmut: Die Korrosion der Metalle : physikalisch-chemische Prinzipien und aktuelle Probleme. Du: D33ZMU1213, E: 31ZMP1006(2)
Kunze, Egon [Hrsg.] Korrosion und Korrosionsschutz Du: D33ZMP1226, E E40ZMP1266
VDI-Richtlinie 3822: Schadensanalyse, Teil 1- Teil 5 Digitale Bibliothek über VDI-Richtlinien

lecture name		shorthand expression of lecture	
Schwingungsanalyse mit MATLAB		MATLAB	
lecturer		department	
Dr.-Ing. Bernhardt Weyh		Mechanical Working	
SWS	cycle	language	requirements
4	WS	German	none

teaching form

Lectures / Exercises for the PC

learning objectives

The student will gain competence with - MATLAB including insight in function range of a modern program environment; - Conceiving, modeling, structuring and preparing of simple vibration problems; - Symbolic supported formulation of motion equations; - Execution of numerical system-analysis and -synthesis; - Evaluation, visualization and interpretation of example problems.

description

The MATLAB program package is a tool for the numerical calculation of technical systems ranging from simple to complex. It is useful for the quick analysis and synthesis of dynamical processes, especially in developing prototypes, and is currently utilized in increasing number in industry. In this course an introduction to MATLAB will be given with selected examples of problems including: the analysis of vibrations of passive and active linear and nonlinear systems. This introduction will be supported with assigned exercises on the computer. These problems include the connection of symbolic and numeric calculations. For interpretation of the results 2D- and 3D-visualisation techniques will be used. In connection with the introduction to the MATLAB-programming environment and its language elements the following problems are addressed:

- Vibration analysis of linear systems: natural and forced vibrations; modal analysis for vibration assessment (damping- and resonance-behavior); examples of structural dynamics with FE-discretisation on base of beam-elements.
- Analysis of nonlinear systems: calculation of steady and non steady processes (introduction to block orientated programming); linearization techniques.
- Introduction to computer algebra in MATLAB with MAPLE-kernel, symbolic formulation of rigid-body motion equations as well as combining symbolic and numeric procedures.

kind of examination

In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.

literature

Angermann, Beuschel, Rau, Wohlfahrt: MATLAB-Simulink-Stateflow, 2.Aufl., Oldenbourg Verlag München 2003

Dresig, H.: Schwingungen mechanischer Antriebssysteme. Springer-Verlag, Berlin 2001

Eich-Soellner, Führer: Numerical Methods in Multibody Dynamics. Teubner-Verlag, Stuttgart 1998

Hoffmann, Brunner: MATLAB & Tools für die Simulation dynamischer Systeme, Addison-Wesley Verlag GmbH 2002

Müller, Schiehlen: Linear Vibrations. Martinus Nijhoff Publishers, Dordrecht 1985

Pietruszka, W.D.: MATLAB in der Ingenieurpraxis. B:G:Teubner Verlag, Stuttgart 2005

Pratap, R: Getting Started with MATLAB 6. A Quick Introduction for Scientists and Engineers, Oxford University Press, New York-Oxford 2002

Schiehlen Eberhard: Technische Dynamik. 2. neubearb. und erg. Aufl., Teubner-Verlag, Stuttgart 1986

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lecture name	shorthand expression of lecture
Simulation of Landfill Bodies	Sim Landfill
lecturer	department
Prof. Dr.-Ing. Renatus Widmann	Waste Management

SWS	cycle	language	requirements
4	WS	English	none

teaching form
Lectures and exercises are completed with the use of computer simulations
learning objectives
The lectures will review methods used to manage the standards of waste disposal techniques. In addition the biological, chemical and physical activities in a landfill body will be described. With both the implementation of the Theory of Porous Media and the learned skills about the activities in a landfill, the numerical simulation model will be illustrated. The end goal is to demonstrate the student's ability to characterize a landfill body, also simulating its long-time scale emissions.
description
In the long-term a process-oriented and experimental verified numerical simulation used to appraise the disposal's emissions characteristics can significantly contribute to a risk-assessment of the disposal maintenance phase, closure care and post closure care. In municipal waste landfills the modeling of transport and conversion processes is also important for waste management (and interesting as well). Biological, chemical and physical activities are closely bounded, likely being described by only a few coupled differential equations. A model based on the Theory of Porous Media TPM and experimental appraisals is introduced to characterize the generated emissions of landfills in long-term scenarios.
kind of examination
In accordance with examination regulations, the type and duration of the examination will be defined by the lecturer prior to the start of the semester. As an example, an examination can be a written test with a length of 60 to 120 minutes or an oral examination with a length of 30 to 60 minutes. The language of the examination is the same as the language of the lecture.
literature
Ustohalova, V.: Process Oriented Modeling of the Long-term Behavior Impact of Landfills in Closure Care and Post Closure Care – Decompositions and Transport Processes, Dissertation, Shaker Verlag, Aachen, 2006
Widmann, R., Ustohalova, V., Ricken, T.: Modelling of decomposition processes in landfills with applications to the organic phase transitions, 19th International Conference on Solid Waste Technology and Management, Philadelphia, 2004
Deutsche Gesellschaft für Geotechnik e.V. (DGGT): Geotechnik der Deponien und Altlasten. GDA-Empfehlungen, 3. Auflage, Ernst & Sohn Verlag, 1997

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module name	shorthand expression of module
Soft Skills	
lecture name	shorthand expression of lecture
Soft Skills 1	Soft I
Soft Skills 2	Soft II
lecturer	department
NN Prof. Dr.-Ing. Tim Ricken	- Computational Mechanics

semester	cycle	language	requirements
3	WS	German/English	

SWS	presence hours	self-study hours	workload in h	ECTS-Credits
3 each	45	75	120	4

Syllabus Book for Master Computational Mechanics

lecture name	shorthand expression of lecture
Master-Thesis	

semester	cycle	language
4	WS	German/English

description	presence hours	self-study hours	workload in h	ECTS-Credits
Master-Thesis	0	810	810	27
Master-Thesis Colloquium		90	90	3

Examination Form
In addition to a written elaboration of the master's thesis, students are required to prove the originality of their work during a mandatory colloquium.

Imprint

University Duisburg Essen
Faculty of Engineering
Prof. Dr.-Ing. Tim Ricken
Universitätsstr. 15
45141 Essen
Germany

Phone: +49 / (0)201 / 1832681
Fax: +49 / (0)201 / 1832680
Email: tim.ricken@uni-due.de

The actual version of the Syllabus Book can be found:
<http://www.uni-due.de/computationalmechanics/>
Legally binding is only the exam regulation.

Legend

WS Winter semester
SS Sommer semester
SWS Hours per week per semester
Cr. Credits
V Lecture
Ü Exercise
P Laboratory
S Seminar
d German
e English