RUHR-UNIVERSITÄT BOCHUM

RUB

FAKULTÄT FÜR
BAU- UND UMWELT-
INGENIEURWISSENSCHAFTEN

FAKULTÄT FÜR
GEOGRAPHIE UND
GEOWISSENSCHAFTEN

Directory of Modules

M.Sc. Subsurface Engineering

- Module Descriptions PO 2024
- Curriculum

SuSe 2026 Valid: 02.04.2026

Modifications:

Module No.	Module Name	Modification
SE-CO-03	Numerical Modeling in Geotechnics and Tunneling	Change in teaching staff
SE-CO-04	Concrete Technology and Structural Durability	Change in teaching staff
SE-CO-10	Advanced Constitutive Models for Soils	Change in teaching staff
SE-CO-21	Optimization Aided Design - Reinforced Concrete	No longer available
SE-O-8	High-Performance Computing on Multicore Processors	No longer available
SE-O-9	High-Performance Computing on Clusters	No longer available
SE-O-20	German A1/A2	No longer available
SE-O-22	Deep Learning for Engineers	New
SE-O-23	German A1	New, Exam registration with the instructor in class
SE-O-24	German A2	New, Exam registration with the instructor in class

Curriculum Subsurface Engineering

Category	Specializ.	Module No.	Module name	Coordinator / Lecturers	CP	Sem.	
Compulsary: 33 CP	Both Specializations (GT + SCU)	SE-C-1	Mathematical Aspects of Differential Equations and Numerical Mathematics	Prof. M. Kronbichler (coordinator)	6	1	WiSe
		SE-C-2	Finite Element Methods in Linear Structural Mechanics	Prof. R. Sauer (coordinator)	6	1	WiSe
		SE-C-3	Fundamentals of Geoscience for Subsurface Engineers		6	1	WiSe
			a) Physical Geology for non-geologists	Prof. T. Backers (coordinator)	3		
			b) Acquisition, analysis, and interpretation of geophysical measurements	Prof. R. Harrington, Prof. J. Bedford	3		
		SE-C-4	Groundwater Hydraulics	Dr. T. Heinze (coordinator)	5	1	WiSe
		SE-C-5	Soil Behaviour and Simple Constitutive Models		6	1	WiSe
			a) Soil Mechanics	Dr. N. Irani	3		
			b) Soil Behaviour under Monotonic, Cyclic and Dynamic Loading	Prof. T. Wichtmann (coordinator)	1.5		
			c) Simple Constitutive Models for Soils	Dr. N. Irani	1.5		
		SE-C-6	Project Work	Professors, lecturers and assistants	4	3	WiSe
Compulsary Optional: 42 CP	Geotechnics and Tunneling (GT)	SE-CO-1	Foundation Engineering and Utility Pipe Construction: Design-Engin.-Techn.	Prof. M. Thewes (coordinator)	6	3	WiSe
			a) Design, engineering and technologies in Foundation Engineering	Dr. B. Schößer	3		
			b) Design, engineering and technologies in Utility Pipe Construction		3		
		SE-CO-2	Conventional and Mechanised Tunneling: Design-Engineering-Technologies	Prof. M. Thewes (coordinator)	6	2	SuSe
			a) Design, engineering and technologies in Tunneling	Dr. B. Schößer	3		
			b) Design, engineering and technologies in Pipeline Construction		3		
		SE-CO-3	Numerical Simulation in Geotechnics and Tunneling	Prof. T. Wichtmann (coord.), Dr. M. Salimi	6	2	SuSe
		SE-CO-4	Concrete Technology and Structural Durability	Prof. I. Curosu (coordinator)	6	3	WiSe
		SE-CO-5	Operation and Maintenance of Tunnels and Utility Pipes	Prof. M. Thewes (coordinator)	6	3	WiSe
			a) Facility management of underground transportation infrastructure	Prof. R. Leuker	3		
			b) Pipeline maintenance and network management	Prof. B. Bosseler	3		
		SE-CO-6	Design of Geotechnical Structures - Shallow and Deep Foundations	Prof. T. Wichtmann (coord.), Dr. N. Irani	6	2	SuSe
		SE-CO-7	Soil Dynamics and Geotechnical Earthquake Engineering	Prof. T. Wichtmann (coordinator)	6	3	WiSe
			a) Soil Dynamics	Dr. M. Goudarzy	3		
			b) Geotechnical Earthquake Engineering	Dr. F. Prada, Dr. N. Irani	3		
		SE-CO-14	Design of Geotechnical Structures - Excavation Pits, Retaining Structures and Soil Improvement	Prof. T. Wichtmann (coordinator)	6	3	WiSe
	Both Specializations (GT + SCU)	SE-CO-8	Numerical Methods and Stochastics	Prof. M. Kronbichler (coordinator)	6	2	SuSe
		SE-CO-10	Advanced Constitutive Models for Geomaterials	Prof. T. Wichtmann (coord.), Dr. M. Tafili	6	2	SuSe
		SE-CO-19	Mechanical Modeling of Materials	Prof. D. Balzani (coordinator)	6	1,3	Wise
		SE-CO-20	Inelastic Finite Element Methods for Structures	Prof. R. Sauer (coord.), Dr. V. Gudzulic	6	3	WiSe
		SE-CO-22	Geothermal Drilling Engineering and Subsurface Technologies	Prof. R. Bracke (coordinator)	5	3	WiSe
		SE-CO-23	Nonlinear Finite Element Methods for Structures	Prof. R. Sauer (coordinator)	6	2	SuSe
		SE-CO-24	Rock Mass Mechanics and Rock Engineering	Prof. T. Backers (coord.), Dr. M. Duda	6	2	SuSe
	Subsurface Characterization and Utilization (SCU)	SE-CO-12	Applied Geophysics	Prof. J. Renner (coordinator)	10	2	SuSe
			a) Reservoir Geophysics		5		
			b) Rock Physics		5		
		SE-CO-13	Geothermal Energy Systems	Prof. R. Bracke (coordinator)	5	2	SuSe
		SE-CO-15	Hydrogeological Methods	Dr. T. Heinze (coordinator)	6	2	SuSe
			a) Analysis of Measurement Results				
			b) Hydrogeological Field Exercises				
		SE-CO-16	Seismotectonics and Seismic Hazard	Prof. R. Harrington (coord.), Dr. D. Essing	6	3	WiSe
		SE-CO-17	Selected Topics in Reservoir Characterization		9		both
			a) Deep geothermal energy	Prof. J. Renner (coordinator)	5	2	SuSe
			b) Well logging	Prof. T. Reinsch	4	3	WiSe
		SE-CO-18	Reservoir Engineering	Prof. E.H. Saenger (coordinator)	5	3	WiSe
		SE-CO-25	Rock Mass Stress Fields	Prof. T. Backers (coordinator)	5	3	WiSe
			a) Stress Field and Rock Mass Behaviour				
			b) Stress Field Modelling and Simulation				
		SE-CO-26	Ground Exploration Methods		11	2	SoSe
			a) Optimization methods for geophysics	Prof. J. Bedford (coordinator)	6		
			b) Gravity and magnetics/Potential fields	Dr. K. Fischer	5		
Optional: 15 CP	Both Specializations (GT + SCU)	SE-O-1	Practical Training on Tunneling and Pipeline Construction Techniques	Prof. M. Thewes (coordinator)	2	2	SuSe
		SE-O-2	Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice	Prof. M. Thewes (coordinator)	2	3	WiSe
		SE-O-3	Technologies in Mechanised Tunneling	Prof. M. Thewes (coordinator) Dr. G. Wehrmeyer	2	2	SuSe
		SE-O-4	Practical Soil Mechanics	Prof. T. Wichtmann (coord.), Dr. W. Baille	3	3	WiSe
		SE-O-5	Environmental Geotechnics	Prof. T. Wichtmann (coordinator) Dr. W. Baille, Dr. D. König	3	2	SuSe
		SE-O-6	Variational Calculus and Tensor Analysis	Prof. J. Waimann (coord.), Dr. U. Hoppe	5	3	WiSe
		SE-O-7	Digital Rock Physics	Prof. E.H. Saenger (coordinator)	5	2	SuSe
		SE-O-10	Scientific Programming	Prof. A. Vogel (coordinator)	6	3	WiSe
		SE-O-16	Introduction to advanced numerical methods for particulate media	Prof. T. Wichtmann (coord.), Dr. M. Salimi	3	3	WiSe
		SE-O-17	Uncertainty Quantification in FE Analyses with Surrogate Modeling	Prof. R. Sauer (coordinator) Dr. B.T. Cao, Dr. G. Neu	6	3	WiSe
		SE-O-18	Problematic Soils	Prof. T. Wichtmann (coord.), Dr. W. Baille	3	3	WiSe
		SE-O-19	Computational Structural Optimization	Prof. R. Sauer (coord.), Prof. A. Saxena	6	3	WiSe
		SE-O-21	Selected Topics of Geotechnical and Geoenvironmental Engineering	Prof. T. Wichtmann (coord.), Dr. D. König	2	2,3	both
		SE-O-22	Deep Learning for Engineers	Prof. A. Vogel (coordinator)	6	2	SuSe
		SE-O-23	German A1	J. Salzinger	5	1,3	WiSe
		SE-O-24	German A2	J. Salzinger	5	2	SoSe
		SE-O-14	Training of Competences (part 1)		4	1,2,3,4	both
		SE-O-15	Training of Competences (part 2)		4	1,2,3,4	both
Master Thesis: 30 CP		SE-MT	Master Thesis	Professors, lecturers and assistants	30	4	SuSe

Courses from completed previous master programs cannot be acknowledged for the SSE program.

Modules

Index by areas of study

1) M.Sc. SSE Compulsory Courses, ECTS: 33

Weight of the mark for the final score

FAK = 1

DIV = 120

2) M.Sc. SSE Compulsory Optional Courses, ECTS: 42

Weight of the mark for the final score

FAK = 1

DIV = 120

3) M.SC. SSE Optional Courses, ECTS: 15

Weight of the mark for the final score

FAK = 1

DIV = 120

4) M.Sc. SSE Master's Thesis, ECTS: 30

Weight of the mark for the final score

FAK = 1

DIV = 120

Advanced Constitutive Models for Geomaterials

Advanced Constitutive Models for Geomaterials

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP44 /SE-CO-10/CE-W06	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Advanced Constitutive Models for Geomaterials	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Merita Tafili

Admission requirements

Learning outcome, core skills

After successfully completing the module, the students are able to

- model the material behavior of soil using suitable, advanced constitutive models,
- select suitable numerical methods and constitutive models for practical questions and assess limitations according to the selected approaches,
- calibrate the parameters of the advanced constitutive models and evaluate the model performance based on single integration point simulations

Contents

a)

The course deals with the introduction of advanced soil mechanical behavior and appropriate constitutive models allowing to capture advanced effects. Model formulations and parameter calibration for different soil model families are taught. In addition, an introduction to single integration point finite element simulations with Incremental Driver (ID) is provided and simulations of different laboratory tests are conducted with ID using different elasto-plastic and hypoplastic constitutive models.

Advanced soil mechanics:

- Critical state soil mechanics
- Crushable soil mechanics
- Unsaturated soil mechanics
- Soil memory effects and their modelling
- Clay structure and small-strain stiffness anisotropy
- Influence of temperature on soil behavior and its modelling

Sophisticated constitutive models for soils:

- Modified Cam-Clay model
- Sanisand
- Hypoplasticity with Intergranular Strain
- Clay Hypoplasticity
- Hypoplasticity for crushable soils
- Visco-hypoplasticity

- Barcelona Basic Model

Educational form / Language

a) Lecture (4 WLH) / English

Examination methods

• Written exam 'Advanced Constitutive Models for Geomaterials' (180 min., Part of modul grade 100,0 %)

• Optional homework to achieve bonus points for the written exam

Requirements for the award of credit points

- Passed final written exam

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Computational Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Applied Geophysics

Applied Geophysics

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-12	10 CP	300 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Reservoir Geophysics b) Rock Physics	a) 3 WLH (45 h) b) 3 WLH (45 h)	a) 120 h b) 90 h	a) each summer b) each summer

Module coordinator and lecturer(s)

Prof. Dr. Jörg Renner
a) Prof. Dr. Jörg Renner
b) Prof. Dr. Jörg Renner

Admission requirements

Recommended previous knowledge:
Sound mathematical skills (vector calculus, differential- and integral calculus)

Learning outcome, core skills

After successful completion of the module students

- appreciate the scale-dependent approach to the physical characterization of rocks (micro-to decimeter-scale) and reservoirs (deci- to kilometer-scale)
- understand the relation between physical properties of rocks and their chemical composition and microstructure
- learned the use and limits of empirical and theoretical concepts for the description of heterogeneous media
- know the practical aspects of a suite of methods in exploration geophysics
- are familiar with the mathematical description of physical processes on rock and reservoir scale
- understand the origin of the governing partial differential equations and master some approaches to their solution

Contents

a)

- Introduction to reservoirs (hydrocarbon, geothermal)
- Physical properties of reservoir fluids
- Hydraulic transport (Kozeny-Carman relation) and storage (linear poro-elasticity I: isostatic stress states)
- Theory and practice of pumping tests (diffusion equation, scaling)
- Geothermics (add advection to diffusion)
- Aspects of waves in real media (wave equation, linear poro-elasticity II: add deviatoric stresses)

b)

- Introduction to rocks and minerals
- Porosity and interface phenomena
- Hydraulic transport in rocks (Darcy's law, permeability models)
- Elasticity (stress, strain, Hooke's law, averaging schemes)
- Failure of rocks (fracture and friction)

- Laboratory practical: students independently conduct simple experiments to determine basic physical properties of rocks (density, porosity, permeability, elastic wave velocities, electrical conductivity) and fluids (density, viscosity)

Educational form / Language

a) Lecture (3 WLH) / English
b) Lecture (3 WLH) / English / German

Examination methods

• Written exam 'Applied Geophysics' (180 min., Part of modul grade 100,0 %, + report on lab experiments)

Requirements for the award of credit points

Passed module exam

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 10,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Literature: Jaeger, Cook, Zimmerman “Fundamentals of Rock Mechanics”; Gueguen, Palciauskas “Introduction to the physics of rocks“; Schön “Physical properties of rocks“; Mavko, Mukerji, Dvorkin “The rock physics handbook“; AGU reference shelf “Rock physics and phase relations“; Sully “Elements of petroleum geology”; Wang “Theory of linear poro-elasticity”; Fetter “Applied hydrogeology”; Zoback “Reservoir geomechanics”; Carcione “Wave-fields in real media”

Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice

Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-O-2	2 CP	60 h	3. Sem.	1 Semester[s]	20

Courses	Contact hours	Self-study	Frequency
a) Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice	a) 2 WLH (30 h)	a) 30 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes

a) Prof. Dr.-Ing. Markus Thewes

Admission requirements

Learning outcome, core skills

In this module, practical knowledge about planning, construction and management of current projects in tunneling and subsurface construction practice is offered through selected lectures of guest experts of by participation in on the worldwide largest conferences for tunneling, the STUVA conference. This module is offered every two years (in the uneven years) in cooperation with STUVA e.V.

Contents

a)

The module deals with the extended practical knowledge of tunnel design, construction, operation and safety. Typical topics include:

- Tunnel construction and tunnel operation
- International projects
- BIM, monitoring, digitalization
- Technical alteration to national and international standards
- Combined construction techniques
- Mechanized tunneling
- Developments in segmental lining (tubbing)
- Artificial freezing of ground
- Tunneling in swelling soil
- Safety in road tunnels
- Tunnel planning, tunnel refurbishment
- Start of operation and energy saving
- Traffic tunnel and geothermic applications in tunneling

Educational form / Language

a) Internship / English

Examination methods

• Internship 'Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice' (60 h., ungraded, Full time participation)

Requirements for the award of credit points

- Full time participation

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 0, ungraded

Further Information

Selected Topics of Geotechnical and Geoenvironmental Engineering
Ausgewählte Kapitel aus Grundbau und Umweltgeotechnik

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
BI-W30/SE-O-21	2 CP	60 h	2./3. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Selected Topics of Geotechnical and Geoenvironmental Engineering	a) 1 WLH (15 h)	a) 45 h	a) each sem.

Module coordinator and lecturer(s)
Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. D. König

Admission requirements
Recommended previous knowledge:
Completed modules in soil mechanics and foundation engineering

Learning outcome, core skills
The students

- gain an impression of the complexity of practical construction tasks and learn about solutions to specific problems,
- are able to to engage with innovative ideas and solution strategies,
- can transfer the solutions learned to other situations.

Contents
a)
In this course, current construction projects and methods are presented by experts e.g. from construction industry. The tasks, technical constraints, planning and design principles, construction works, difficulties encountered, and solutions are explained.

Educational form / Language
a) Lecture (1 WLH) / German

Examination methods
• Oral exam 'Selected Topics of Geotechnical and Geoenvironmental Engineering' (0 h., ungraded, Colloquium)

Requirements for the award of credit points
- Participation
- Passed module examination: oral exam

Module applicability
- M.Sc. Civil Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 0, ungraded

Further Information

Perhaps excursion/conference participation

Computational Structural Optimization

Computational Structural Optimization

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-WP35/BI-W74/SE-O-19	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Computational Structural Optimization	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr. Roger A. Sauer

a) Prof. Anupam Saxena

Admission requirements

Recommended previous knowledge:

Basics knowledge in Mathematics, Programming, FEM and Structural Analysis

Learning outcome, core skills

After successfully completing the module, the students

- have advanced knowledge regarding topology optimization and its integration in computational models
- are able to independently implement topology optimization code in FE-Analysis frameworks
- can perform computational topology optimization and apply it to any engineering problem
- can critically interpret the results of a topology optimization

Contents

a)

The course covers the basic knowledge of topology optimization and its implementation in computational frameworks. In particular, the following topics are taught in the course:

- Introduction in finite-element theory and the development of code to perform FE-Analysis
- Theory of topology optimization with code implementation
- Application of topology optimization in computational models with different complexity levels

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Project report 'Computational Structural Optimization' (30 h., Part of modul grade 100,0 %, Project work with coding assignments and a written report (90%), optional presentation, with Oral examination (10%))

Requirements for the award of credit points

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Concrete Technology and Structural Durability

Concrete Technology and Structural Durability

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-04	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Fundamentals of cement-based construction materials	a) 2 WLH (30 h)	a) 30 h	a) each winter
b) Durability of reinforced concrete structures	b) 2 WLH (30 h)	b) 30 h	b) each winter
c) Special concretes for tunnelling	c) 2 WLH (30 h)	c) 30 h	c) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. habil. Iurie Curosu
a) Prof. Dr.-Ing. habil. Iurie Curosu
b) Prof. Dr.-Ing. habil. Iurie Curosu
c) Prof. Dr.-Ing. habil. Iurie Curosu

Admission requirements

Learning outcome, core skills

After successfully completing the module, the students

- gain basic knowledge of the decisive construction materials in civil engineering, in general,
- can judge on the essential deterioration processes in reinforced concrete elements,
- are able to define suitable concrete compositions for specific applications.

Contents

a)
The course covers the basics of cement-based construction materials.
Material properties and testing principles:

- chemical and physical basics
- strength and deformations

Cement-based construction materials

- constituents (binder, aggregate, additives)
- concrete (basics and material design)
- production and processing of concrete
- cement hydration and concrete hardening

In exercises the students design different concrete compositions on the basis of practical examples. The theoretical exercises are complemented by laboratory sessions on cement, fresh-state concrete properties and mechanical testing of concrete.

b)
The course covers the physical and chemical environmental effects on concrete structures, focusing on transport processes within the microstructure and corrosion mechanisms.

- exposures and transport processes of harmful substances
- corrosion processes and preventive measures
- performance-based service life assessment

In case of damage, inspection methods and testing procedures are introduced, followed by suitable repair measures and material-related requirements.

c)
The course covers special concrete compositions in view of their application in the field of tunnelling.

- special cements and concrete additives
- hydration process, fresh and hardened concrete properties
- hydration heat and strength development

Thereby, the course addresses special types of concrete as sprayed concrete, fibre-reinforced concrete, concrete for tunnel lining and grouting materials for backfilling.

Educational form / Language

a) Tutorial (1 WLH) / Lecture (1 WLH) / English
b) Laboratory / Lecture (1 WLH) / English
c) Lecture (2 WLH) / English

Examination methods

• Written exam 'Concrete Technology and Structural Durability' (120 min., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Conventional and Mechanised Tunneling: Design – Engineering – Technologies

Conventional and Mechanised Tunneling: Design – Engineering – Technologies

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
BI-WP11/SE-CO-2	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Design, engineering and technologies in Tunneling and Pipeline Construction	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes

a) Prof. Dr.-Ing. Markus Thewes, Dr.-Ing. Britta Schößer

Admission requirements

Recommended previous knowledge:

Bachelor-level knowledge of construction operations and construction process engineering, Bachelor-level knowledge of foundation engineering and soil mechanics

Learning outcome, core skills

The module is intended to familiarize students comprehensively with the whole field of tunneling. The participants will acquire in-depth knowledge for engineering tasks in the areas of planning, construction and operation of tunnels. The students will learn to independently work on tasks from these areas and to develop a specific understanding of the methods. They will be enabled to solve the common problems of tunnel design and construction and to work independently and purposefully. Relations of this area with other areas of civil engineering as an interdisciplinary task are recognized and integrated into the solutions. The students will acquire knowledge that is necessary for the preparation and execution of construction projects of tunnel construction. The methods commonly used in practice shall be applied.

Contents

a)

The lecture deals with the extended basic knowledge of Tunnel Engineering.

a) Design, engineering and technologies in Tunneling

- Planning methods for tunnel constructions
- Methods and components of for temporary and final tunnel lining
- Conventional Tunneling
- Excavation techniques for soil and rock
- Conventional tunneling with mechanized excavation of the rock mass
- Sprayed concrete method
- Compressed air method
- Mechanized tunneling, different Tunnel Boring Machines adapted to the boundary conditions on rock and soil formations
- Single-shell and double-shell tunnel linings
- Special construction methods
- Monitoring and process management
- Special features of tunneling logistics and ventilation
- Safety aspects during construction and operation

- Settlement prediction for green-field and buildings

b) Design, engineering and technologies for Trenchless Construction Techniques (manned)

- Technical principals of manned techniques – steerable
- Microtunnelling,
- Pipe Jacking
- Construction and structural analysis of Jacking Pipes
- Jacking Forces, Jacking Force Prediction

Educational form / Language

a) Tutorial (1 WLH) / Lecture (3 WLH) / English

Examination methods

• Written exam 'Design, engineering and technologies in Tunneling and Pipeline Construction' (120 min., Part of modul grade 100,0 %, optionally English or German)
• Term paper 'Design, engineering and technologies in Tunneling and Pipeline Construction - Homework' (30 h., Part of modul grade 0,0 %, optionally English or German)

Requirements for the award of credit points

- Presentation of the results of the homework assignment
- Passed written examination of the module

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Deep Learning for Engineers

Deep Learning for Engineers

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
CE-WP33/DLE	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Deep Learning for Engineers	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr. Andreas Vogel

a) Prof. Dr. Andreas Vogel, Assistants

Admission requirements

Learning outcome, core skills

After successfully completing the module, the students

- have acquired fundamental skills and knowledge in deep learning, including training concepts and neural network architecture designs,
- are able to develop, train and employ deep learning models for scientific applications,
- can assess the benefits and limitations of neural networks for their projects.

Contents

a)

The lecture covers deep learning concepts and techniques, including:

- general ideas and mathematical background
- training and regularization methods
- neural network architectures
  (feed-forward, convolutional, physics-informed, autoencoder, ...)
- application to scientific and engineering problems
- employment on modern computer hardware

In hands-on sessions, practical exercises are used to discuss and illustrate the presented content.

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Deep Learning for Engineers' (120 min., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Computational Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement					
Module number SE-CO-14	**Credits** 6 CP	**Workload** 180 h	**Semester[s]** 3. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 120 h	**Frequency** a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann

a) Dr.-Ing. Merita Tafili, Dr.-Ing. Nazanin Irani, Prof. Dr.-Ing. Torsten Wichtmann

Admission requirements

Learning outcome, core skills

After successfully completing the module, the students are able to

- perform the proofs of ultimate limit state and serviceability limit state for different types of retaining structures as well as other components of construction pits in accordance with Eurocode 7, supported by in-situ testing and laboratory experiments,
- recommend the appropriate retaining structure according to soil conditions, expected loads and design requirements,
- recommend the appropriate method of soil improvement according to soil conditions, expected loads and design requirements

Contents

a)

The course:

- Introduces possible failure mechanisms of retaining systems, soil slopes as well as excavation pits and soil dikes
- Gives a general overview to different type of retaining structures (e.g. flexible and rigid) with active and passive facings
- Discusses different calculation methods to determine the safety factor of the slopes, excavation pits and retaining structures against failure
- Explains multitude of supporting techniques (e.g. back anchoring, nailing, etc.) with their corresponding design methods
- Gives an overview to geosynthetic soil reinforced geostructures
- Introduces different methods of soil improvement

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement' (180 min., Part of modul grade 100,0 %)

• Homework with GGU application to geotechnical problems, giving bonus points for the exam.

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Tutorials include computer exercises with program GGU

Design of Geotechnical Structures – Shallow and Deep Foundations

Design of Geotechnical Structures – Shallow and Deep Foundations

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-6	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Design of Geotechnical Structures – Shallow and Deep Foundations	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann

a) Dr.-Ing. Nazanin Irani, Prof. Dr.-Ing. Torsten Wichtmann

Admission requirements

Learning outcome, core skills

After successfully completing the module, the students are able to

- perform the proofs of ultimate limit state and serviceability limit state for different types of foundations in accordance with Eurocode 7, supported by in-situ testing and laboratory experiments,
- recommend the appropriate foundation type according to soil conditions, expected loads and design requirements

Contents

a)

The course deals with the design of the following foundation types:

- Shallow single and strip foundations
- Plate foundations
- Single pile foundations under vertical loading
- Single pile foundations under horizontal loading
- Pile groups under vertical or horizontal loading
- Drilled-shaft (caisson) foundations

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Design of Geotechnical Structures – Shallow and Deep Foundations' (180 min., Part of modul grade 100,0 %)

• Homework with GGU application to geotechnical problems, giving bonus points for the exam.

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Digital Rock Physics

Digital Rock Physics

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-O-7	5 CP	150 h	2. Sem.	1 Semester[s]	20

Courses	Contact hours	Self-study	Frequency
a) Digital Rock Physics	a) 3 WLH (45 h)	a) 105 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr. Erik Saenger

a) Prof. Dr. Erik Saenger

Admission requirements

Learning outcome, core skills

The students will learn the fundamentals of digital rock physics. This broad range of knowledge will be taught with a special emphasis on geothermal and hydrocarbon exploration.

After successful completion of this module, the students will:

- know the fundamentals of digital rock physics:
  - e.g. use of high-performance computer systems
  - e.g. understand the resolution limits of CT devices
- be able apply the fundamentals of digital rock physics:
  - to predict effective material properties
  - to improve digital images with respect to the real rock
- be able to apply the fundamentals of digital rock physics to scientific projects:
  - to upscale elastic properties to understand field scale observations
  - to interpret uncertainties in the digital rock physics workflow

Contents

a)

- The basics of the digital rock physics workflow will be introduced: CT-imaging, reconstruction, segmentation, calculation of physical properties.
- The basics of parallel computing on high-performance computer systems will be introduced.
- The basics of finite-different-schemes to solve the elastodynamic wave equation will be introduced.
- The parallel computer program "Heidimod" to model elastic waves in highly heterogeneous and anisotropic media will be introduced in detail and will be applied to problems in the field of digital rock physics

Educational form / Language

a) Tutorial (2 WLH) / Lecture (1 WLH) / English / German

Examination methods

• Term paper 'Digital Rock Physics' (30 h., Part of modul grade 100,0 %)

Requirements for the award of credit points

final report on computer exercises

Module applicability

- M.Sc. Subsurface Engineering

• M.Sc. Geosciences
Weight of the mark for the final score Percentage of total grade [%] = 5,00 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Environmental Geotechnics

Environmental Geotechnics

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
SE-O-5	3 CP	90 h	2. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Environmental Geotechnics	a) 2 WLH (30 h)	a) 60 h	a) each summer

Module coordinator and lecturer(s)
Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Wiebke Baille, Dr.-Ing. D. König

Admission requirements
Recommended previous knowledge:
completed module Soil and rock behaviour (including lecture: Soil behaviour and simple constitutive models for soils).

Learning outcome, core skills
After successfully completing the modules, the students are able to

- assess environmental pollutants with regard to their hazard potential and migration behaviour in soil and groundwater,
- develop strategies for the demobilization of pollutants and remediation of contaminated sites based on a comprehensive understanding of physical-chemical properties of soils,
- identify the design principles of technical barrier systems used for landfills and low contaminated soils.

Contents
a)
Interdisciplinary knowledge necessary for the safe disposal of environmentally hazardous substances and the remediation of contaminated soil is presented from the perspective of soil, groundwater and soil-air interactions. Furthermore, technical barriers for the encapsulation of landfills will be addressed.
The lecture contents cover the following topics:

- Relevant environmental pollutants and their respective industrial sectors
- Advective and diffusive transport of pollutants in porous media
- Methods for soil remediation and containment of pollutants
- Barrier systems for landfills and low contaminated soils
- Individual project work dealing with specific questions of environmental geotechnics
- Future challenges of environmental geotechnics

Educational form / Language
a) Project / Lecture (2 WLH) / English

Examination methods
• Term paper 'Environmental Geotechnics - Project work' (0 h., ungraded)
• Written exam 'Environmental Geotechnics' (90 min., Part of modul grade 100,0 %)

Requirements for the award of credit points
Passed final module examination: written examination
Presentation of the project

Module applicability
• M.Sc. Subsurface Engineering
Weight of the mark for the final score
Percentage of total grade [%] = 3,00 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Rock Mass Mechanics and Rock Engineering

Felsbau

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP23/SE-CO-24	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Rock Mass Mechanics b) Rock Engineering c) Rock Mechanical Lab Training	a) 2 WLH (30 h) b) 2 WLH (30 h) c) 1 WLH (15 h)	a) 45 h b) 45 h c) 15 h	a) each summer b) each summer c) each summer

Module coordinator and lecturer(s)

Prof. Dr. Tobias Backers
a) Dr. Mandy Duda
b) Dr. Mandy Duda
c) Dr. Mandy Duda

Admission requirements

Recommended previous knowledge:
Completed modules in mechanics, soil mechanics and foundation engineering

Learning outcome, core skills

As a field of geomechanics, rock mass mechanics deals with the description of the rheological properties and associated material models of rock and discontinuities; through integration, the deformation behaviour of rock mass (= rock + discontinuities) can be evaluated in response to changes in thermal, hydraulic or mechanical boundary conditions. Understanding the thermos-hydro-mechanical behaviour of rock mass forms the basis for its use as a structural or material resource.

Rock engineering deals with structural measures in rock mass. The structural engineering measures include excavation, stabilization, extraction, foundations, and the creation of cavities. Based on the fundamentals of rock mass mechanics, the principles of rock engineering are discussed.

Laboratory experiments to describe and classify rock and rock mass will be conducted

Participants are familiar with the fundamentals of rheology, the mechanical behaviour of rocks and discontinuities, rock mass classification and mechanical properties of rock mass. They know and understand the typical characteristic properties in terms of their significance and magnitude and how there are derived from laboratory experiments. Furthermore, they deepen their knowledge of geomechanical principles and interrelations. Participants are also familiar with the basics of constructing and securing rock structures considering the properties of rock and discontinuities as a mechanical system.

Contents

a)
Deformation und Versagen von Gestein; Einführung in die Versuchstechnik; Deformation und Versagen von Trennflächen; Gebirgsklassifikationen; Deformation und Versagen von Fels; Charakteristika von Tunneln, Stollen und Felskavernen; Prinzipien des Hohlraumbaus; Gründungen auf Fels und Böschungen aus Fels; Aufgabenstellungen und Messgrößen bei der geotechnisch/geomechanischen Überwachung; felsmechanische numerische Simulation

b)

see above

c)
see above

Educational form / Language
a) Lecture with tutorial / English
b) Lecture with tutorial / English
c) Laboratory / English

Examination methods
• Written exam 'Felsbau' (90 min., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc. Susbsurface Engineering
- M.Sc. Geosciences
- M.Sc. Civil Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information
German-language lecture materials will be provided.

Finite Element Methods in Linear Structural Mechanics

Finite Element Methods in Linear Structural Mechanics

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
CE-P05/BI-P08/SE-C-2/FEM-I	6 CP	180 h	1. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Finite Element Methods in Linear Structural Mechanics	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr. Roger A. Sauer

a) Prof. Dr. Roger A. Sauer

Admission requirements

Recommended previous knowledge:

Basics in Mathematics, Mechanics and Structural Analysis (Bachelor level)

Learning outcome, core skills

After successfully completing the module, the students

- have basic knowledge of the Finite Element Method (FEM),
- are able to transfer initial boundary value problems of structural mechanics into discretized calculation models based on FEM and thus to solve simple tasks of structural mechanics independently (e.g. calculation of truss structures, disc-like or volume structures),
- have advanced knowledge to understand the functionality of calculation programs based on FEM and to critically evaluate their results,
- are able to independently implement corresponding user-defined elements in FE programs and perform numerical analyses of beam and shell structures.

Contents

a)

The course covers the basic knowledge of linear FEM, which is based on the principle of virtual work.

In particular, the following topics are taught in the course:

- Isoparametric finite elements for trusses, two-dimensional elements, beams, three-dimensional volume elements for application in statics and dynamics,
- consistent explanation of the fundamentals (basic equations, principle of variation),
- Numerical integration, assembly of the elements to a discretized structure and the solution of the static and dynamic structure equation,
- Discussion of stiffening effects ("locking") and their avoidance.

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Finite Element Methods in Linear Structural Mechanics' (120 min., Part of modul grade 100,0 %)
• Optional tasks to be solved at home and announced during the course, to get the bonus points for the exam.

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Foundation Engineering and Utility Pipe Construction: Design – Engineering – Technologies

Foundation Engineering and Utility Pipe Construction: Design – Engineering – Technologies

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP10/SE-CO-1	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Design, engineering and technologies in Foundation Engineering and Utility Pipe Construction	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes

a) Prof. Dr.-Ing. Markus Thewes, Dr.-Ing. Britta Schößer

Admission requirements

Recommended previous knowledge:

Bachelor-level knowledge of construction operations and construction process engineering, Bachelor-level knowledge of foundation engineering and soil mechanics

Learning outcome, core skills

The module intends to provide students with a comprehensive understanding of the field of design, engineering and technology regarding Foundation Engineering and Utility Pipe construction. They will acquire in-depth knowledge for special areas of foundation engineering for the accomplishment of engineering tasks on areas planning, construction and operation. Foundation engineering is the field of civil engineering, which deals with the design and construction of subsurface structures which typically are built in open excavation pits. The students will learn to work on tasks from these areas and to develop an understanding of the methods. They will be enabled to independently solve the common problems of foundation engineering and utility pipe construction. Connections of this field with other areas of the building industry as interdisciplinary task are recognized and integrated into the solutions of project processing. The students acquire knowledge that is necessary for the preparation and processing of construction projects in construction management. The methods commonly used in practice shall be applied.

Contents

a)

The lecture deals with the extended basic knowledge of construction process engineering.

Design, engineering and technologies in Foundation Engineering

- Dewatering / Water management
- Construction pit system (Girder System, Diaphragm Wall, Bored Pile Wall, etc.)
- Caisson systems
- Grout injection techniques (low and high pressure methods, etc.)
- Injected piles
- Underpinning
- Cut and Cover method
- Conventional sealing methods (waterproofing)
- Construction of jointing

- Open trench methods in Pipeline Construction

Pipeline Construction (Trenchless Construction Techniques - unmanned)

- Technical principals of unmanned techniques – steerable
- Technical principals of unmanned techniques – non-steerable
- HDD Horizontal Directional Drilling, Direct Pipe

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Design, engineering and technologies in Foundation Engineering and Utility Pipe Construction' (120 min., Part of modul grade 100,0 %, optionally English or German)
• Term paper 'Process Technology and Construction Management - Homework' (30 h., Part of modul grade 0,0 %, optionally English or German)

Requirements for the award of credit points

- Presentation of the results of the homework assignment
- Passed written examination of the module

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Environmental Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
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Further Information

Fundamentals of Geoscience for Subsurface Engineers

Fundamentals of Geoscience for Subsurface Engineers

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-C-3	6 CP	180 h	1. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Physical Geology for non-geologists b) Acquisition, analysis, and interpretation of geophysical measurements	a) 2 WLH (30 h) b) 3.33 WLH (49.95 h)	a) 60 h b) 40 h	a) each winter b) each winter

Module coordinator and lecturer(s)

Prof. Dr. Tobias Backers

a) Prof. Dr. Tobias Backers

b) Dr. Marco Roth, Prof. Dr. Rebecca Harrington, Prof. Dr. Jonathan Bedford, Dr. Kaspar Fischer

Admission requirements

Learning outcome, core skills

After successful completion of the course the students will

- have a thorough understanding of the System Earth and its complexities, and understand the societal and engineering relevance of geological processes and materials
- be able to assess and solve practical and scientific engineering challenges against this background
- have gained experience in taking geophysical measurements for a variety of commonly used methods,
- understand the physics of the data acquisition and processing in addition to the related geological concepts.

Contents

a)

This course consists of two components (i) basics: self study of course material and (ii) application and discussion: two days field camp.

It covers topics in geology that are relevant to civil engineering:

- Formation of rocks, geological features (e.g., stratification, faults, joints, folds), plate tectonics, and geological formations
- Weathering, erosion and mass wasting and the influence of climate
- Basic concepts of hydrogeology and engineering geology.
- The human impact on Earth's environment

b)

This course consists of three consecutive parts.

1. Acquisition: Students work together in small groups to conduct geophysical field surveys on (or close to) RUB campus. Measurement techniques will include refraction seismics, geomagnetics, ground penetrating radar, and resistivity.
2. Analysis: Students work under classroom instruction and self-study to process the data from the acquisitions.
3. Interpretation: Students produce a report containing a background description of the methods and geological interpretation of the processed measurements.

Educational form / Language
a) / German / English
b) / English

Examination methods
• Test 'Physical Geology for non-geologists' (15 h., Part of modul grade 50,0 %, self-study (English and German material) and weekly online interrogation)
• Exercises 'Acquisition, analysis, and interpretation of geophysical measurements - Report' (0 h., Part of modul grade 50,0 %, 4 half-days of fieldwork for acquisition. 20 hours of classroom time for learning data processing approaches and associated geophysical and geological concepts.)

Requirements for the award of credit points
- Pass the online interrogations, compulsory attendance in the field camps
- and achieving passing score on the graded written report.

Module applicability
- M.Sc. Subsurface Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information
b) 2 full days (4 half-days) of fieldwork and 20 hours of classroom time

For the fieldwork, students should ensure that they are dressed appropriately for working outside during Autumn weather. All registered students will receive an email with more details.

Geothermal Drilling Engineering and Subsurface Technologies Geothermal Drilling Engineering and Subsurface Technologies					
Module number 139080	**Credits** 5 CP	**Workload** 150 h	**Semester[s]** 3. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Geothermal Drilling Engineering and Subsurface Technologies			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 90 h	**Frequency** a) each winter

Module coordinator and lecturer(s)
Prof. Dr. rer. nat. Rolf Bracke
a) Prof. Dr. rer. nat. Rolf Bracke

Admission requirements
Recommended previous knowledge:
English language skills: "Test of English as a Foreign Language" (TOEFL): the test result in the internet version (iBT) should be at least 80 points, or "International English Language Testing System" (IELTS): minimum overall score "6" ("academic").

Learning outcome, core skills
The course provides an introduction to the principles of resource geology, deep drilling technologies, reservoir production and subsurface technologies. Students will learn how to evaluate a resource and propose suitable utilization concepts, plan a drilling project including well design, and select tools and equipment for reservoir production and monitoring. The lecture is accompanied by an exercise with practical examples and two excursions

Students will be able to:

- explain resource geology methods and parameters,
- define conceptual reservoir models
- tell principles of resource management
- compute thermal power outputs,
- explain the main methods and parameters of drilling technology
- develop drilling and production concepts,
- calculate casing designs,
- describe potential drilling problems,
- define the composition of the cost structure of a drilling project
- describe reservoir test principles,
- calculate production parameters

Contents
a)

- Introduction to subsurface technologies and applications
- Geothermal resource characterization: temperature, pressure, and, fluid flow in the geological subsurface + 1 excursion
- Geological and mininig law act

- Deep drilling basics (drilling rig, strings, and, bits) + 1 excursion
- Drilling techniques and processes (conventional and advanced drilling technologies);
- Casing design and calculation;
- Drilling fluid/mud system;
- Cementation and well control;
- Health safety and environment;
- Economics and Reporting;
- Well integrity and Logging technologies
- Monitoring techniques
- Reservoir production technologies
- Deep geothermal heat exchangers

Educational form / Language

a) Tutorial (1 WLH) / Lecture (3 WLH) / English

Examination methods

• Written exam 'Geothermal Drilling Engineering and Subsurface Technologies' (90 min., Part of modul grade 100,0 %)

• Semester-accompanying exercises

Requirements for the award of credit points

- Passed final module examination: written exam
- Passed semester-accompanying exercises

Module applicability

MSc. Mechanical Engineering

MSc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 5,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Geothermal Energy Systems Geothermal Energy Systems					
Module number SE-CO-13	**Credits** 5 CP	**Workload** 150 h	**Semester[s]** 1. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Geothermal Energy Systems			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 90 h	**Frequency** a) each summer

Module coordinator and lecturer(s)

Prof. Dr. rer. nat. Rolf Bracke

a) Prof. Dr. rer. nat. Rolf Bracke

Admission requirements

Learning outcome, core skills

- After the course the students know how geothermal heat pumps can be used for heating and cooling. Students are able to dimension borehole heat exchangers (BHE) for small shallow geothermal systems (≤30 kW). They are also able to plan large systems which require a design by simulations. They can decide which design techniques and software is required for a specific site and project. The students know how a Thermal Response Test enhances the quality of the planning process and are able to interpret the measured data of the test.
- The students know the fundamentals of electricity generation from geothermal resources at low and at high enthalpy. They describe the function of the components of a power plant and understand the thermodynamics of fluid and steam cycles. They are able to design simple district heating networks and develop concepts for industrial applications for infrastructural and agricultural uses.

Contents

a)

- Global geothermal resources
- Elements of thermodynamics, fluid mechanics, and heat transfer applied to geothermal energy conversion systems
- Power plant technologies based on flash steam, direct steam, binary conversion systems, and hybrid systems
- Cooling technologies
- District heating networks and direct uses
- Pumping the reservoir
- Hybrid uses (water desalination)
- Mine water applications
- Corrosion and scaling processes
- Social and environmental impacts
- Case studies
- Economics, finance, and risk analysis of a geothermal project

Educational form / Language

a) Tutorial (1 WLH) / Lecture (3 WLH) / English

Examination methods

• Written exam 'Geothermal Energy Systems' (60 min., Part of modul grade 100,0 %, Optional homework (40 h), max. 10 pages, 4 weeks time for completion, submission deadline is announced at the beginning of the semester, bonus points in the examination in case of successful completion), exercise tasks)

Requirements for the award of credit points
pass the examination

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geoscience

Weight of the mark for the final score
Percentage of total grade [%] = 5,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

German A1
German A1

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-W13/SE-O-23	5 CP	150 h	1./3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) German A1	a) 4 WLH (60 h)	a) 30 h	a) each winter

Module coordinator and lecturer(s)
M.A. Julia Salzinger
a) M.A. Julia Salzinger

Admission requirements
Recommended previous knowledge:
This course is aimed at beginners without any previous knowledge (Common European Framework of Reference for Languages)

Learning outcome, core skills
Students

- can understand and use familiar everyday expressions.
- engage in simple spoken communication.
- read and understand short written texts.
- write short personal messages and texts.
- use basic grammar structures and vocabulary accurately.
- develop listening comprehension for everyday contexts.
- gain confidence in using German in real-life situations.

Contents
a)
This course introduces students to the basics of the German language and helps them build essential communication skills for everyday situations. Through engaging activities, students learn to understand and use familiar expressions, ask and answer simple questions, and describe themselves and their surroundings.

The course covers key topics such as personal information, family and hobbies, shopping, food and drink, daily routines, travel, and health. Emphasis is placed on listening and speaking, with integrated reading and writing tasks. Basic grammar, vocabulary, and pronunciation are taught in context to support meaningful communication.

Educational form / Language
a) Seminar / German / English

Examination methods
• Written exam 'German A1' (70 min., Part of modul grade 100,0 %, Written exam (percentage of the overall grade 75%) with Oral exam (20 minutes/pair, percentage of the overall grade 25%))
• Compulsory attendance 'German A1 - Course attendance' (0 <Ohne>, Part of modul grade 0,0 %, Preliminary work for the exam)
• Course attendance (75%)

Requirements for the award of credit points

- Course attendance (75%)
- Passing the final written and oral exam

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 5,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Exam registration with the instructor in class

German A2 German A2					
Module number CE-W14/SE-O-24	**Credits** 5 CP	**Workload** 150 h	**Semester[s]** 2./4. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) German A2			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 90 h	**Frequency** a) each summer

Module coordinator and lecturer(s)
M.A. Julia Salzinger
a) M.A. Julia Salzinger

Admission requirements
Recommended previous knowledge:
This course is aimed at beginners who have finished A1 (Common European Framework of Reference for Languages)

Learning outcome, core skills
Students can

- communicate in simple everyday situations (e.g., shopping, travel, work)
- describe personal background, daily routines, and surroundings
- talk about past events using the Perfekt tense
- understand simple spoken German when it is clear and slow
- read and understand short, practical texts (emails, signs, schedules)
- write short messages, emails, and basic descriptions
- use basic grammar structures (present tense, modal verbs, simple clauses)
- ask and answer questions in familiar contexts
- use common vocabulary for everyday topics (food, travel, health, etc.)
- handle simple social interactions politely (*du* vs. *Sie*, requests, greetings)

Contents
a)
This course introduces students to the basics of the German language and helps them build essential communication skills for everyday situations. Through engaging activities, students learn to understand and use familiar expressions, ask and answer simple questions, and describe themselves and their surroundings.

The course covers key topics such as personal information, family and hobbies, shopping, food and drink, daily routines, travel, and health. Emphasis is placed on listening and speaking, with integrated reading and writing tasks. Basic grammar, vocabulary, and pronunciation are taught in context to support meaningful communication.

Educational form / Language
a) Seminar / German / English

Examination methods
• Written exam 'German A2' (70 min., Part of modul grade 100,0 %, Written exam (percentage of the overall grade 75%) with Oral exam (20 minutes/pair, percentage of the overall grade 25%))

• Compulsory attendance 'German A2 - Course attendance' (0 <Ohne>, Part of modul grade 0,0 %, Preliminary work for the exam) • Course attendance (75%)
Requirements for the award of credit points • Course attendance (75%) • Passing the final written and oral exam
Module applicability • M.Sc. Computational Engineering • M.Sc. Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = 5,00 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information Exam registration with the instructor in class

Ground Exploration Methods

Ground Exploration Methods

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
SE-CO-26	11 CP	330 h	2. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Optimization methods for geophysics b) Gravity and magnetics / Potential fields	a) 4 WLH (60 h) b) 3 WLH (45 h)	a) 120 h b) 105 h	a) each summer b) each summer

Module coordinator and lecturer(s)

Prof. Dr. Jonathan Bedford
a) Prof. Dr. Jonathan Bedford
b) Dr. Kaspar Fischer

Admission requirements

Recommended previous knowledge:
a) For students enrolled in MSc programs who have completed math and physics modules in their Bsc education.

Completion of Introduction to programming in python or Introduction to programming in Matlab.

b) Participants are expected to have prior knowledge of basic geophysics, vector calculus and differential equations, as well as familiarity with fundamental gravity and magnetic concepts at BSc level. Basic experience with a scientific computing environment (e.g. Matlab or Python) is recommended. Passed courses: Continuum mechanics of the module Physics of the solid Earth, Introduction to programming in Python of the module Python programming for Geosciences.

Learning outcome, core skills

a) After completion of the module the student will be able to:

- understand how model parameters are optimized by the geoscientific research community and the various approaches for estimating model uncertainties,
- propose optimization strategies given the specific model parameters, datasets, physics, and constraints of the problem,

and

- implement simple linear and non-linear optimizations on a computer.

b) After completion of the module the student will be able to:

- Describe gravitational and magnetic fields and the geoid.
- Compute gravitational and magnetic fields from their potential.
- Formulate and solve basic forward and inverse problems in gravity and magnetics.
- Apply standard corrections to regional gravity and magnetic data and understand key terms used in potential-field applications.
- Interpret gravity and magnetic anomaly maps in terms of subsurface density and magnetization structure (e.g. basins, intrusions, ore bodies).
- Assess resolution limits, non-uniqueness, and the role of prior information in potential-field inversions.
- Construct simple quantitative models from measured data and implement basic processing and modelling workflows in a scientific computing environment.

Contents

a)

First we will explore classical optimization approaches, that have been developed heavily in geophysics over the past decades, and that can nowadays be classed as sub-types of supervised machine learning that are suitable for models with a few thousand parameters. In this course, we will first cover these classical inversion approaches before understanding the approaches that faciliate the optimization of millions (to billions) of parameters in deep learning.

The lecture series will through the following topics:
(1) Introduction to concepts of data vector, model vector, and model assumptions (d, m, and G of traditional geophysical inversion problems). (2) Linear problems and their solution through the matrix solution of normal equations (least squares regression). (3) Non-linear inverse problems and their iterative solutions. (4) How data errors translate into model uncertainties. (5) The concepts of regularization and parameter constraints. (6) Model resolution and data sensitivity (7) Terminology of traditional geophysical inversion in more universal, machine learning optimization language. Distinctions between three types of machine learning (supervised, unsupervised, reinforcement) and how these relate to the framwework of classical linear and non-linear optimization approaches. (8) Introduction to the optimization methods of deep learning and understand how modern optimization problems scale on modern computing hardware.

b)

- Newtonian potential and gravitational field.
- Magnetic potential, magnetization, and the geomagnetic field.
- The geoid and regional gravity fields.
- Spherical harmonic analysis of global gravity and magnetic fields.
- Forward and inverse methods in potential-field geophysics.
- Fourier-domain modelling, upward continuation, analytic signal, and Hilbert transformation.
- Gravity and magnetic anomalies of typical geological structures (e.g. sedimentary basins, faults, intrusions, ore bodies).
- Data acquisition and processing for gravity and magnetic surveys (reference fields, basic corrections, anomaly calculation).
- Numerical exercises on forward modelling, simple inversion, and data processing in a scientific computing environment.

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English
b) Tutorial (1 WLH) / Lecture (2 WLH) / English

Examination methods

• Exercises 'Optimization methods for geophysics' (<Ohne>, Part of modul grade 55,0 %, Weekly, 20-minute long quizzes during weeks 2-10: The best 5 results from a total of 9 quizzes will be counted towards 60% of the final grade. 10% of the grade will be assessed from participation. 30% will come from a final independent coding exercise that takes place under exam conditions during the semester exam period.Therefore, there is a mixed mode of assessment including written quizzes, an examined programming exercise, and general effort of participation.)
• Written exam 'Gravity and magnetics / Potential fields' (<Ohne>, Part of modul grade 45,0 %, The module is assessed by a written examination and additional continuous assessment during the teaching period. The written examination contributes 60% to the final module grade. The continuous assessment component (e.g. assignments, quizzes, or programming exercises) contributes 40% to the final module grade. The final

module grade is determined from the combined percentage score of the continuous assessment and the written examination.)

Requirements for the award of credit points

- a) Credit points can be awarded if the student accumulates >=50% across the various modes of assessment.
- b) The final grade of the combined percentage score of the continuous assessment and the written examination must reach 50% or more.

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 11,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

a) Each week, we will introduce new concepts in the 2 hour lecture slot (with 10 minute break halfway through). On later day in the week, there will be a 2 hour practical in which students carry out an optimization exercise. Starting in week 2, there will be a quiz (20 minutes in duration) at the beginning of each lecture. Starting in week 10, there will be a series of exam preparation programming exercises in which students accumulate their own working optimization scripts that will be useful in the exam and beyond.

b) The module consists of weekly lectures and accompanying exercises. Each week, new theoretical concepts are introduced in a 90-minute lecture. These concepts are then applied and deepened in a 45-minute exercise session, which may include analytical problem solving, numerical assignments, and computer-based data processing or modelling tasks. In weeks with a stronger numerical focus, the balance between lecture and exercise time may be adjusted accordingly.

Groundwater Hydraulics

Groundwater Hydraulics

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-C-4	5 CP	150 h	1. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Groundwater Hydraulics	a) 4 WLH (60 h)	a) 90 h	a) each winter

Module coordinator and lecturer(s)

PD Dr. Thomas Heinze

a) PD Dr. Thomas Heinze

Admission requirements

Learning outcome, core skills

After completion of this module, the students will

- be able to describe and evaluate groundwater flow and conservative mass transport in the subsurface.
- know methods of experimental investigation and determination of hydraulic parameters under different boundary conditions, and can derive and evaluate these mathematically.
- be familiar with the evaluation and interpretation of groundwater hydraulic parameters and use them to deal with classical hydrogeological problems.

Contents

a)

- Methods for the collection and evaluation of hydraulic parameters (Darcy-tests, pump tests, Slug&Bail tests)
- Conveyance of knowledge about groundwater flow and the construction of groundwater level plans
- Execution and evaluation of pumping tests by means of graphical and analytical solutions
- Practical tasks for lowering the groundwater level through well systems in excavation pits or calculation of well yield

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Groundwater Hydraulics' (60 min., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Passing the written examination

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 5,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

- Relevant literature and specific study material will be supplied at the beginning of the lectures.

Hydrogeological Methods
Hydrogeological Methods

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-15	6 CP	180 h	2. Sem.	1 Semester[s]	8

Courses	Contact hours	Self-study	Frequency
a) Analysis of measurement results b) Hydrogeological Field Exercises	a) 2 WLH (30 h) b) 3 WLH (45 h)	a) 50 h b) 55 h	a) each summer b) each summer

Module coordinator and lecturer(s)
PD Dr. Thomas Heinze
a) PD Dr. Thomas Heinze
b) PD Dr. Thomas Heinze

Admission requirements
Recommended previous knowledge:
Passing of the examination for "Groundwater Hydraulics"

Learning outcome, core skills
At the end of the module, participants will

- be able to perform various hydrogeological field experiments and analyze the results,
- understand the concept of applying organic substances as Tracers for groundwater flow,
- plan and execute tracer tests, use field and laboratory equipment for tracer detection, process and analyze the tracer test results,
- write a scientific report,
- communicate with water- and environmental authorities and
- transfer theoretical knowledge to practical applications.

Contents
a)
Computer-based analysis of measurement results from the field exercises using GIS, EXCEL, MATLAB, and specialized software for the respective tasks: Analysis of pumping tests using curve matching to obtain aquifer properties & characterize aquifer; Curve matching of tracer passage curves to obtain transport properties; (Inverse) modeling of infiltration experiments to obtain infiltration capacity of the soil; GIS based catchment analysis and calculations of groundwater recharge.

b)
The most important hydrogeological Field methods will be used to evaluate and plan the water supply well: pumping tests, infiltration tests, run of measurements extraction of groundwater and petrochemical sampling determination of petrochemical and physical groundwater parameters, use of hydrochemical analyses in the field, shallow drilling, hydrogeological and engineering geology goal characterization of the soil profile in boreholes, measuring of the groundwater level and plotting of groundwater contour maps. All the data of the performed experiments are documented and interpreted in a written report.

Educational form / Language
a) Seminar / English
b) Block seminar / English

Examination methods

• Term paper 'Hydrogeological Methods' (10 h., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Pass Written report (part of final mark 100 %) and active participation on the field exercises

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

relevant literature and specific study material will be supplied at the beginning of the lectures

b) Block course (4 days)

Inelastic Finite Element Methods for Structures Inelastic Finite Element Methods for Structures					
Module number BI-WP59/CE-WP06/SE-CO-20	**Credits** 6 CP	**Workload** 180 h	**Semester[s]** 3. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Inelastic Finite Element Methods for Structures			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 120 h	**Frequency** a) each winter

Module coordinator and lecturer(s)
Prof. Dr. Roger A. Sauer
a) Dr.-Ing. Vladislav Gudzulic, Prof. Dr. Roger A. Sauer

Admission requirements
Recommended previous knowledge:
Basic knowledge of tensor analysis, continuum mechanics and linear Finite Element Methods.

Previous participation in the course Nonlinear Finite Element Method for Structures is recommended and participation Object-Oriented Modeling and Implementation of Structural Analysis Software is advantageous.

Learning outcome, core skills
After successfully completing the module the students will

- understand the fundamentals of dissipative processes in the context of modeling inelasticity in quasi-brittle materials, using concrete as the main example.
- learn the computational approaches for modeling elastoplastic, damage and friction behavior.
- be familiar with the concept of strain localization and localized failure, including their mathematical and numerical implications, as well as strategies to address them.
- gain practical experience with implementation and algorithmic treatment of inelasticity in the context of incremental-iterative nonlinear structural analysis.
- develop skills to select appropriate numerical methods and material models, including multi-scale approaches, for practical problems and critically assess their limitations.
- be able to perform incremental analyses of progressive structural failure, critically evaluate the results, and assess the key design parameters such as load and deformation at the onset of inelasticity and structural redundancy (plastic reserve/residual strength).

Contents
a)
The course is concerned with inelastic material models including their algorithmic formulation and implementation in the framework of nonlinear finite element method. Strain localization and localized failure will be explored in detail, focusing on their mathematical and numerical implications, as well as the strategies to address them. Further, the course covers the fundamental theory and implementation aspects of frictional contact. Special attention will be given to efficient algorithms for physically nonlinear structural analyses, including elastoplastic and damage models for quasi-brittle materials, as well as friction algorithms. While concrete serves as a primary example, these modeling approaches are equally applicable to other materials such as rocks, fiber composites, sea ice, bone, stiff soils, and wood. The course includes

coding exercises and a final assignment, where students implement a selected inelastic model into a finite element program and apply it to nonlinear structural analysis.

Educational form / Language
a) Lecture with tutorial / English

Examination methods
• Term paper 'Inelastic Finite Element Methods for Structures' (90 h., Part of modul grade 100,0 %, Project work (implementation of an inelastic model into FE code) with final student presentation / bonus points for homework assignments)

Requirements for the award of credit points
- Passed final module examination

Module applicability
- M.Sc. Civil Engineering
- M.Sc. Computational Engieering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Introduction to advanced numerical methods for particulate media

Introduction to advanced numerical methods for particulate media

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-O-16	3 CP	90 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Introduction to advanced numerical methods for particulate media	a) 2 WLH (30 h)	a) 60 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Mohammad Salimi

Admission requirements

Recommended previous knowledge:
completed module in Numerical Simulation in Geotechnics

Learning outcome, core skills

After successfully completing the module, students will be able to:

- Understand DEM fundamentals and applications
- Implement particle and boundary modeling techniques
- Apply force models and contact detection schemes
- Utilize time integration methods
- Comprehend DEM's strengths and limitations
- Develop basic DEM code for triaxial test simulations
- Apply DEM to real-world geotechnical engineering problems

Contents

a)
This course introduces the Discrete Element Method (DEM), a powerful computational technique for analyzing particulate materials in subsurface engineering. The lecture contents cover the following topics:

1. Foundations of Computational Methods
2. Theoretical Fundamentals
3. Computational Aspects
4. Soft Sphere Approach in Detail
5. Damping Mechanisms
6. Stress Analysis in DEM
7. Strain and Measurable Quantities
8. Forces and Torques
9. Advanced Contact Models
10. Non-Spherical Particle Shapes
11. Boundary Conditions
12. Model Validation and Calibration
13. Servo Mechanisms and Scaling
14. Advanced Forces and Torques
15. DEM in Practice

The course emphasizes physical understanding over programming details, using easy-to-follow slides and practical examples. This course provides a foundation for those interested in pursuing advanced topics in computational methods for particulate media.

Educational form / Language

a) Lecture (2 WLH) / English

Examination methods

• Term paper 'Introduction to advanced numerical methods for particulate media' (60 h., Part of modul grade 100,0 %, deadline will be announced at the beginning of the semester)

Requirements for the award of credit points

- Successful completion and presentation of the final project

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Civil Engineering
- M.Sc. Computational Engineering

The skills and knowledge gained in this course are transferable to various fields dealing with particulate media and computational modeling.

Weight of the mark for the final score

Percentage of total grade [%] = 3,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Master Thesis
Master Thesis

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-MT	30 CP	900 h	Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Master Thesis		a) 900 h	a) keine Angabe

Module coordinator and lecturer(s)
All professors of the study program
a) Professors, Lecturers and Assistants

Admission requirements
In order to be admitted to the master's thesis, modules amounting to 70 credit points must be successfully completed.

Learning outcome, core skills
With the completion of the master thesis

- the students acquire the ability to plan, organize, develop, operate and present complex problems in Subsurface Engineering.
- qualifies students to work independently in the field of Subsurface Engineering under the supervision of an advisor.
- the associated presentation serves to promote the students' ability to deal with subject-specific problems and to present them in an appropriate and comprehensible manner.

Further, it serves to prove whether the students have acquired the profound specialised knowledge, which is required to take the step from their studies to professional life, whether they have developed the ability to deal with problems from their in-depth subject by applying scientific methods, and to apply their scientific knowledge.

Contents
a)
The master thesis can either be a theoretical or a practical work. The topic is determined by the respective supervisor. The results should both be visualized and illustrated in writing in a detailed manner. This particularly includes a summary, an outline and a list of the references used within a specific thesis.

Educational form / Language
a) Final thesis / English / German

Examination methods
• Final thesis 'Master Thesis' (900 h., Part of modul grade 100,0 %, Review of the Master Thesis Report and Oral Presentation (30 min))

Requirements for the award of credit points
- Successful evaluation (grade greater than 50%) of Master Thesis and Oral Presentation

Module applicability
- M.Sc. Subsurface Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 30,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information Independent work in seminar rooms and computer labs; testing plants, where applicable. The topic of a Master Thesis is formulated by a lecturer of the course. The student conducts research independently and presents the results in the form of a final written report and an oral presentation (upon agreement with the respective lecturer).

Mathematical Aspects of Differential Equations and Numerical Mathematics

Mathematical Aspects of Differential Equations and Numerical Mathematics

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
CE-P01/SE-C-1/MADENM	6 CP	180 h	1. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Mathematical Aspects of Differential Equations and Numerical Mathematics	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr. Martin Kronbichler
a) Prof. Dr. Martin Kronbichler

Admission requirements

Recommended previous knowledge:
No prior knowledge or preliminary modules. Basic calculus and experience with matrices.

Learning outcome, core skills

The course will focus on the mathematical formulation of differential equations with applications to elastic theory and fluid mechanics. It gives an introduction to geometric linear algebra with emphasis on function spaces, coupled with the elementary aspects of partial differential equations. The students should learn to understand the mathematics side of the Finite Element Method (FEM) for elliptic PDE
in low dimensions, appropriate Sobolev geometries, the FEM for Dirichlet and Neumann problems. For that reason, the basic principles in methods of error estimation are described to realize the understanding of fast and efficient solvers for the resulting matrix equations. As overall learning goal, the students should attain familiarity with modern methods and concepts for the numerical solution
of complicated mathematical problems.
After successfully completing the module, the students

- should understand the mathematics side of the Finite Element Method for elliptic PDE in low
- dimensions, appropriate Sobolev geometries, the FEM for Dirichlet and Neumann problems,should attain familiarity with modern methods and concepts for the numerical solution of complicated mathematical problems.

Contents

a)
Linear algebra: Basic concepts and techniques for finite- and infinite-dimensional function spaces stressing the role of linear differential operators. Numerical algorithms for solving linear systems. The mathematics of the finite element method in the context of elliptic partial differential equations (model problems) in dimension two.

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Mathematical Aspects of Differential Equations and Numerical Mathematics' (120 min., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Remark: Due to the mixed background of the students, the exercise sessions often amount to additional lectures.

Mechanical Modeling of Materials

Mechanical Modeling of Materials

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-P02/SE-CO-19/MMoM	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Mechanical Modelling of Materials	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Daniel Balzani
a) Prof. Dr.-Ing. Daniel Balzani

Admission requirements

Recommended previous knowledge:
Basic knowledge in Mathematics and Mechanics (Statics, Dynamics and Strength of Materials)

Learning outcome, core skills

The objective of this course is to present advanced issues of mechanics and the continuum-based modelling of materials starting with basic rheological models. The concepts introduced will be applied to numerous classes of materials. Basic constitutive formulations will be discussed numerically.

After successfully completing the module, the students

- should have a deep understanding of the theoretical basis of classical material models,
- should know how to derive constitutive equations from rheological models,
- should be able to implement a material model with a suitable algorithmic treatment in finite element software.

Contents

a)
Several advanced issues of the mechanical behaviour of materials are addressed in this course. More precisely, the following topics will be covered:

- Basic concepts of continuum mechanics (introduction)
- Introduction to the rheology of materials
- Theoretical concepts of constitutive modelling
- Derivation of 1- and 3-dimensional models in the geometrically linearized setting for
  - Linear- and nonlinear elasticity
  - Damage
  - Visco-elasticity
  - Elasto-plasticity
- Aspects of parameter identification/adjustment
- Algorithmic implementation in the context of the finite element method and analysis of simple boundary and initial value problems

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods
• Written exam 'Mechanical Modeling of Materials' (90 min., Part of modul grade 100,0 %)
Requirements for the award of credit points • Passed final module examination
Module applicability • M.Sc. Computational Engineering • M.Sc. Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = 6,00 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Nonlinear Finite Element Methods for Structures

Nonlinear Finite Element Methods for Structures

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP05/CE-WP04/SE-CO-23	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Nonlinear Finite Element Methods for Structures	a) 4 WLH (60 h)	a) 120 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr. Roger A. Sauer

a) Assistants, Prof. Dr. Roger A. Sauer

Admission requirements

Recommended previous knowledge:

Finite Element Methods in Linear Structural Mechanics (CE-P05/SE-C-2/FEM-I), Basic knowledge in Structural Mechanics

Learning outcome, core skills

After successfully completing the module, the students

- understand the origins and implications of nonlinearities in structural mechanics
- are able to formulate and solve nonlinear engineering problems with the finite element method accounting for geometrical and material nonlinearities
- can perform structural analyses, where the linear (1st order) theory is not valid (e.g. cables, membrane structures, load bearing and stability analyses beyond limit loads), and they can assess the results.

Contents

a)

The main topics of the course are:

- formulation and finite element discretization of the basic equations for nonlinear materials and geometrically nonlinear analysis in structural mechanics
- development of algorithms for the solution of the underlying nonlinear material and structural equations
- application to analyze the structural behavior considering material nonlinearity and large deformations
- nonlinear stability analysis of structures

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Nonlinear Finite Element Methods for Structures' (120 min., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Civil Engineering

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Numerical Methods and Stochastics Numerical Methods and Stochastics					
Module number CE-WP08/SE-CO-8/NMS	**Credits** 6 CP	**Workload** 180 h	**Semester[s]** 2. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Numerical Methods and Stochastics			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 120 h	**Frequency** a) each summer

Module coordinator and lecturer(s)
Prof. Dr. Martin Kronbichler
a) Assistants, Prof. Dr. Martin Kronbichler

Admission requirements
Recommended previous knowledge:
Basic knowledge of: partial differential equations, numerical methods and stochastics

Learning outcome, core skills
Students should become familiar with modern numerical and stochastic methods

After successfully completing the module, the students

- should be able to formulate and analyze data from a probabilistic perspective,
- should understand the theoretical aspects of FEM and FVM methods,
- should be familiar with modern iterative solvers for large systems of linear equations and their necessity for numerical PDE solving,
- should be familiar with standard methods for solving optimization problems.

Contents
a)
Numerical Methods:

- Boundary value problems for ordinary differential equations (shooting, difference and finite element methods)
- Finite element methods (brief retrospection as a basis for further material)
- Efficient solvers (preconditioned conjugate gradient and multigrid algorithms)
- Finite volume methods (systems in divergence form, discretization, relation to finite element methods)
- Nonlinear optimization (gradient-type methods, derivative-free methods, simulated annealing)

Stochastics:

- Fundamental concepts of probability and statistics, such as random variables, univariate distributions & densities, descriptive statistics, parameter estimation, & law of large no
- Regression, such as univariate and multivariate linear regression, least-squares estimation, data transformations, qualitative predictors, and regularization
- Exploratory data analysis, such as qq-plots and summary statistics

Educational form / Language
a) Tutorial (1 WLH) / Lecture (3 WLH) / English

Examination methods • Written exam 'Numerical Methods and Stochastics' (180 min., Part of modul grade 100,0 %)
Requirements for the award of credit points • Passed final module examination
Module applicability • M.Sc. Computational Engineering • M.Sc. Civil Engineering • M.Sc. Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = 6,00 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Numerical Simulation in Geotechnics and Tunneling
Numerical Simulation in Geotechnics and Tunneling

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP24/CE-WP09/SE-CO-3	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Numerical Simulation in Geotechnics and Tunneling	a) 4 WLH (60 h)	a) 60 h	a) each summer

Module coordinator and lecturer(s)
Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Mohammad Salimi

Admission requirements

Learning outcome, core skills
After successfully completing the module, the students are able to

- implement numerical models of complex boundary value problems in geotechnical engineering and tunneling, creating the adequate geometrical models,
- evaluate numerical models and their results in a critical way,
- acquire adequate knowledge in fundamentals of the finite element method to be able to adopt numerical simulation in design and control of geotechnical or tunneling problems with focus on the interactions between the soil and structures.

Contents
a)
The course deals with the numerical modeling of various geotechnical structures and tunnels:

- Overall insight to the numerical simulation of geotechnical problems by using the finite element method and concise review of simple constitutive models
- Introduction to Hardening Soil (HS) and Hardening Soil Small Strain (HSS) model and calibration of constitutive parameters of the HS and HSS model
- Simulation of lab tests and optimization of constitutive parameters
- Details for proper simulation in geotechnics by addressing constructional details, optimum discretization, boundary and initial conditions
- Fundamentals of contact elements and their applications in geotechnical modeling
- Considering water pressures in numerical simulations: soil-water interactions in drained, undrained, consolidation, and fully coupled hydromechanical analyses
- Creation of models, execution of calculations and analysis of results for various geotechnical boundary value problems: shallow foundations, retaining walls, excavation, embankments, consolidation, slope failure, tunneling
- Methods to validate and verify the reliability of numerical models by exploring the numerical outputs in space and time and the evaluation of numerical results
- Introduction to FE simulations with Plaxis 2D and numgeo
- Introduction to Finite Element Limit Analysis (FELA) and the FE software OptumG2
- Comparison of Plaxis2D, numgeo and OptumG2 for different boundary value problems
- Brief overview of other numerical methods (e.g. DEM, MPM, boundary element method)

Educational form / Language

a) Lecture (4 WLH) / English

Examination methods

• Written exam 'Numerical Simulation in Geotechnics and Tunneling' (180 min., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Computational Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Operation and Maintenance of Tunnels and Utility Pipes

Operation and Maintenance of Tunnels and Utility Pipes

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP26/SE-CO-5	6 CP	180 h	3. Sem.	1 Semester[s]	20

Courses	Contact hours	Self-study	Frequency
a) Facility management of under-ground transportation infrastructure b) Pipeline maintenance and network management	a) 2 WLH (30 h) b) 2 WLH (30 h)	a) 60 h b) 60 h	a) each winter b) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes
a) Dr.-Ing. Roland Leuker, Prof. Dr.-Ing. Markus Thewes
b) Prof. Dr.-Ing. Markus Thewes, Dr.-Ing. habil. Bert Bosseler

Admission requirements

Recommended previous knowledge:
Knowledge in "construction operation and construction process engineering" as well as constructional knowledge

Learning outcome, core skills

This module teaches a wide range of aspects of operation and maintenance of tunnels and underground utility pipelines. Aspects of structural protection and the necessary methods and techniques of building maintenance are presented, the equipment and techniques of operating concepts (normal and emergency operation) of underground infrastructure are shown and management concepts and evaluation mechanisms for economic and financial efficiency studies are discussed. The students should thus be put in a position to select appropriate measures for the maintenance of tunnels and utility pipes, or to carry out profitability analyses of such structures - for example based on principles for the operation and maintenance of tunnels and lines. For a professional activity as operators of pipeline networks or tunnel constructions such basic knowledge is indispensable. Basic skills for operation and maintenance of underground infrastructure are presented. These are – in reference to a declining new construction activity and increasing maintenance requirements of the enormously large existing infrastructure stock – of high importance for the future occupational profile of civil and environmental engineers.

Contents

a)

The courses of this part-module deal with the extended basic knowledge of operation and maintenance of tunnels. This includes:

- Regulations and boundary conditions in reference to transport modes
- Operating equipment in tunnels
- Operation of tunnels (concepts, features and structure of control center operation, surveillance and inspection)
- Safety and security
- Rehabilitation and maintenance (points of maintenance, upgrade under operation, rehabilitation techniques, rehabilitation under operation)

- Building management / Tunnel Facility Management (collecting and processing of operation data, operating concept e.g. PPP, Lifecycle-Management)

b)
The courses of this part-module deal with the extended basic knowledge of operation and Maintenance of lines. This includes:

- Introduction: underground sewer and pipeline engineering
- Open cut method – practical use
- Structural safety of pipes in open-cut construction
- New sewers and pipelines using trenchless methods including pipe jacking
- Rehabilitation – objectives and tasks
- Rehabilitation – Replacement
- Rehabilitation – Repair
- Rehabilitation - Renovation
- Service-life of sewers and pipelines including tightness, root resistance, heavy rainfall events

Educational form / Language
a) Lecture (2 WLH) / English
b) Lecture (2 WLH) / English

Examination methods
• Written exam 'Operation and Maintenance of Tunnels and Utility pipes' (120 min., Part of modul grade 100,0 %, optinally Englisch or German)

Requirements for the award of credit points
- Passed module examination: Written exam

Module applicability
- M.Sc. Civil Engineering
- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score
Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information
b) Digital teaching within the meaning of the HDVO

<table>
<tr><td colspan="6">Practical Soil Mechanics
Practical Soil Mechanics</td></tr>
<tr><td>Module number
SE-O-4</td><td>Credits
3 CP</td><td>Workload
90 h</td><td>Semester[s]
3. Sem.</td><td>Duration
1 Semester[s]</td><td>Group size
no limitation</td></tr>
<tr><td colspan="3">Courses
a) Practical Soil Mechanics</td><td>Contact hours
a) 2 WLH (30 h)</td><td>Self-study
a) 60 h</td><td>Frequency
a) each winter</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Wiebke Baille</td></tr>
<tr><td colspan="6">Admission requirements
Recommended previous knowledge:
Completed module in Soil and Rock behaviour (Soil behaviour and simple constitutive models for soils)</td></tr>
<tr><td colspan="6">Learning outcome, core skills
After successfully completing the modules, the students can
• develop strategies for the experimental investigation of practical geotechnical problems,
• analyze the results of the experimental investigation.</td></tr>
<tr><td colspan="6">Contents
a)
Different measuring methods used in geotechnical laboratory and field tests are presented. The structure of a measuring chain is explained. Selected laboratory and field tests will be performed and analyzed by the students (including discussion / interpretation of the test results):
• Soil classification tests (water content, grain size distribution, Atterberg limits (plasticity properties), maximum and minimum density, particle density),
• Determination of shear strength parameters (direct shear test, triaxial test),
• Determination of compressibility of soils (oedometer test)</td></tr>
<tr><td colspan="6">Educational form / Language
a) Seminar / English / German</td></tr>
<tr><td colspan="6">Examination methods
• Exercises 'Practical Soil Mechanics - Exercises' (15 h., Part of modul grade 100,0 %, with oral Examination)</td></tr>
<tr><td colspan="6">Requirements for the award of credit points
• Exercises (protocols and analysis of performed tests) with oral examination
• Attendance during classes.</td></tr>
<tr><td colspan="6">Module applicability
• M.Sc. Subsurface Engineering</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Percentage of total grade [%] = 3,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.</td></tr>
<tr><td colspan="6">Further Information</td></tr>
</table>

Practical Training on Tunneling and Pipeline Construction Techniques

Practical Training on Tunneling and Pipeline Construction Techniques

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
BI-W03/SE-O-1	2 CP	60 h	2. Sem.	1 Week Semester[s]	20

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Practical Training on Tunneling and Pipeline Construction Methods	a) 3 WLH (45 h)	a) 15 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes

a) Prof. Dr.-Ing. Markus Thewes

Admission requirements

Learning outcome, core skills

The module is designed to give students a basic understanding of the processes and techniques used in tunnel and pipeline construction that are common processing and building material testing methods. The students should learn to independently apply standards from these areas in a practice-oriented way and to develop a corresponding basic understanding. They should be acquired to critically examine the usual construction site conditions and the conditions of the techniques of tunnel and pipeline construction and foundation engineering.

Contents

a)

The Practical Training results in basic knowledge to selected and to monitor techniques of Tunneling, Pipeline Construction and Foundation Engineering:

- Sprayed Concrete (Shotcrete) in conventional tunneling
- Early strength testing of sprayed concrete
- Foam conditioning of soil in mechanized tunneling
- Sealing techniques: welding and testing of plastic geomembranes
- Chemical sealing and rehabilitation processes of leaks and concrete damage
- In-situ inspection of utility pipes
- Application of bentonite suspensions: standardised test methods

Educational form / Language

a) Internship / Block seminar / English

Examination methods

• Internship 'Practical Training on Tunneling and Pipeline Construction Methods' (60 h., ungraded, Regular participation)

Requirements for the award of credit points

- Full time participation

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 0, ungraded
Further Information Usually takes place in the first week of the lecture-free period in the summer semester.

Problematic Soils Problematic Soils					
Module number SE-O-18	**Credits** 3 CP	**Workload** 90 h	**Semester[s]** 3. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Problematic Soils			**Contact hours** a) 2 WLH (30 h)	**Self-study** a) 60 h	**Frequency** a) each winter

Module coordinator and lecturer(s)
Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Wiebke Baille

Admission requirements

Learning outcome, core skills
After successfully completing the modules, the students are able to

- assess unsaturated soil behaviour, special soil mechanical properties, phenomena, and the behavior of problematic soils,
- can design an appropriate experimental program (laboratory / field tests) for an investigation of problematic soils,
- assess difficult ground conditions and develop solutions for these situations.

Contents
a)
The course deals firstly with the basics of unsaturated soil behaviour, and further with different phenomena, that can cause difficulties in civil works for some types of soils:

- Unsaturated soil behaviour
- Swelling and shrinkage behaviour
- Physico-chemical effects in clays
- Structure and fabric, compacted soils
- Collapsible soils
- Soft plastic and organic soils
- Experimental methods for investigations on these soils and phenomena

Educational form / Language
a) Lecture with tutorial / English

Examination methods
• Written exam 'Problematic Soils' (180 min., Part of modul grade 100,0 %)

Requirements for the award of credit points
- Passed final written examination

Module applicability
- M.Sc. Subsurface Engieering

Weight of the mark for the final score
Percentage of total grade [%] = 3,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Project Work Project Work					
Module number SE-C-6	**Credits** 4 CP	**Workload** 120 h	**Semester[s]** 3. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Project Work			**Contact hours**	**Self-study** a) 120 h	**Frequency** a) each winter

Module coordinator and lecturer(s)
All professors of the study program
a) Professors, Lecturers and Assistants

Admission requirements

Learning outcome, core skills
After completion of the project work, the students

- will have gained experience in working on a problem individually or in small groups.
- are able to organize and Coordinate the assignment of tasks independently under the supervision of an advisor.
- should have gathered new information and insights into the activities of practicing engineers while acquiring skills in innovative research fields.
- will be able to present technical projects, and to develop problem solution strategies and will hence also obtain worthwhile communication skills.

Contents
a)
The project topic is usually determined by the respective lecturer or one of his/her assistants. In addition to this, students may also conduct project work on topics defined by companies from industry or other equivalent institutions. However, the project work must be completed under the supervision of one of the lecturers from the study program Subsurface engineering. The student -or a small group of students - conducts a project independently and presents the results in the form of a written report and optionally, an oral presentation (upon agreement with the respective lecturer). The projects are usually devised so as to integrate interdisciplinary aspects such as

- Noticing problems and describing them
- Formulating envisaged goals
- Team-oriented problem solutions
- Organizing and optimizing one's time and work plan
- Interdisciplinary problem solutions
- Literature research and evaluation as well as the consultation of experts
- Documentation, illustration and presentation of results

Educational form / Language
a) / English / German

Examination methods
• Term paper 'Project Work' (120 h., Part of modul grade 100,0 %, Oral Presentation (20 min))

Requirements for the award of credit points

The project paper and presentation will be graded. For this purpose, the individual achievements of the students within the project groups are separately evaluated. The evaluation includes: Written report / 75% (100% without a final presentation) and Final presentation / 25% (optional)
Module applicability • M.Sc. Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = 4,00 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Reservoir Engineering Reservoir Engineering					
Module number SE-CO-18	**Credits** 5 CP	**Workload** 150 h	**Semester[s]** 3. Sem.	**Duration** 1 Semester[s]	**Group size** 20
Courses a) Reservoir Engineering			**Contact hours** a) 3 WLH (45 h)	**Self-study** a) 105 h	**Frequency** a) each winter

Module coordinator and lecturer(s)

Prof. Dr. Erik Saenger

a) Prof. Dr. Erik Saenger

Admission requirements

Learning outcome, core skills

The students will learn the fundamentals of reservoir engineering. This broad range of knowledge will be taught with a special emphasis to geothermal and hydrocarbon exploration. After successful completion of the course, the students will be able:

- to understand microseismic monitoring
- to understand geophysical data from boreholes
- apply the fundamentals of reservoir engineering to estimate the risks of reservoir stimulations and to estimate reservoir permeability
- to transfer the fundamentals of reservoir engineering to scientific projects, e.g. to transfer
- the knowledge of several case histories to new sites and to plan a reservoir monitoring system

Contents

a)

- Fundamentals of reservoir engineering with the focus on geothermal applications
- Interpretation of downhole measurements
- Interpretation of spinner results
- Measuring reservoir permeability
- Conceptual models of geothermal fields
- Reservoir modelling
- Reservoir monitoring
- Reservoir stimulation
- Case Histories

Educational form / Language

a) Tutorial (1 WLH) / Lecture (2 WLH) / English

Examination methods

• Oral exam 'Reservoir Engineering' (60 min., Part of modul grade 100,0 %, Presentation with lecture (45 min) + Discussion (15 min))

Requirements for the award of credit points

- Pass module exam

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 5,00 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information

Rock Mass Stress Field Rock Mass Stress Field					
Module number SE-CO-25	**Credits** 5 CP	**Workload** 150 h	**Semester[s]** 3. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Stress Field and Rock Mass Behaviour b) Stress Field Modelling and Simulation			**Contact hours** a) 2 WLH (30 h) b) 1 WLH (15 h)	**Self-study** a) 55 h b) 50 h	**Frequency** a) each winter b) each winter

Module coordinator and lecturer(s)
Prof. Dr. Tobias Backers
a) Prof. Dr. Tobias Backers
b) Prof. Dr. Tobias Backers

Admission requirements

Learning outcome, core skills
Stresses in the Earth's crust are the driving 'force' of many processes and a definitive quantity of assessing the stability of geologic structures such as interfaces or faults. In addition, knowledge of the stresses at work is of extraordinary importance in the design of structures in the near-surface and deep subsurface.
The English language course develops the mechanical principles for the representation of the stress field in the Earth's crust and discusses the sources of stress. Methods for estimating and measuring stresses are introduced.

This includes modeling of the primary field (green and brown field) and the derivation of secondary stresses by civil engineering structural engineering measures.

The simulation of the alteration of the in-situ stresses is in many rock and mining projects and mining projects to estimate the secondary stresses and the load on the geological structures and geological structures as well as civil engineering works. In addition to the lecture “Stress Field and Rock Mass behaviour”, exemplary models are created autodidactically using standard software of rock are created autodidactically and the resulting stresses and their distribution are simulated.

The rule is to work in teams; depending on the industry, these teams are composed internationally, depending on the industry. The English-language course takes this into account.

The students are familiar with rock and rock mass behavior and the sources of stress in the Earth's crust. They know how to estimate and measure rock mass stress. In addition, the enrolled students are familiar with the determination of stress alterations and redistributions by anthropogenic sources.

The students are familiar with the numerical simulation of stress alterations due to geological or constructional features using a commercial software package.

Contents
a)

- Definition of stress,
- Rock deformation,
- Rock failure,
- Rock mass definition,
- Sources of stress in the earth crust,
- Methods of stress measurement and stress modelling,

- Determination of stress alterations and stress redistribution

b)
see above

Educational form / Language

a) Lecture with tutorial / English
b) Lecture with tutorial / English

Examination methods

• Oral exam 'Rock Mass Stress Fields' (0 min., Part of modul grade 100,0 %, successful submission (i.e. 50%) of 90% of the weekly homework)

Requirements for the award of credit points

- Passing the oral examination, successful submission (i.e. 50%) of 90% of the weekly homework

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geoscience

Weight of the mark for the final score

Percentage of total grade [%] = 5,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Scientific Programming

Scientific Programming

Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-P04/SE-O-10/SP	6 CP	180 h	3 Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Scientific Programming	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr. Andreas Vogel

a) Prof. Dr. Andreas Vogel, Assistants

Admission requirements

Learning outcome, core skills

After successfully completing the module, the students

- have acquired the fundamental skills for the development of software solutions, including programming concepts and constructs, data structures and algorithms,
- are able to analyze problems with respect to their structure and requirements and are capable of designing and implementing suitable software code,
- can implement typical problems in scientific computing using the Python programming language and are able to quickly adapt the learned concepts to other programming languages.

Contents

a)

The lecture covers programming concepts such as

- procedural programming, including data types, statements and functions,
- object-oriented programming, including encapsulation, polymorphism and inheritance,
- generic programming.

Furthermore, fundamental data structures as well as efficient algorithms are presented, relevant software libraries are surveyed, and the organization of software projects is discussed.

In hands-on sessions, programming exercises are used to discuss and illustrate the presente

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Scientific Programming' (120 min., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Computational Engineering
- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.
Further Information

Seismotectonics and Seismic Hazard

Seismotectonics and Seismic Hazard

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
SE-CO-16	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Seismotectonics and Seismic Hazard	a) 4 WLH (60 h)	a) 120 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr. Rebecca Harrington
a) Prof. Dr. Rebecca Harrington

Admission requirements

Learning outcome, core skills

A multidisciplinary approach is strongly needed in order to better understand the seismic potential of any region in the world. Geological data give us a long-term (thousands of years) view of earthquake phenomena, but they are limited to the first meters of the crust. Seismological and geophysical data can generally better describe deformation processes occurring at depth, but usually with a smaller temporal (tens of years) and spatial resolution. This course will provide an introduction to the earthquake problem from both geological and geophysical points of view, with emphasis on the methodologies commonly used to produce the data necessary to understand and quantify the seismic hazard in any active region.
After successful completion of the module, students will be able to

- Understand the relationship between lithosphere rheology and earthquake distribution;
- Understand the relationship between frictional properties and faulting;
- Understand the basics of earthquake detection and location;
- Understand the relationship among subsequent earthquakes (earthquake and fault interactions);
- Understand the primary (faulting) and secondary (liquefaction, landslides, etc.) effects produced by seismic events;
- Understand the basics of Tectonic Geodesy;
- Understand the basics of Tectonic Geomorphology;
- Understand the basics of Paleoseismology;
- Understand the basics of probabilistic and deterministic seismic hazard calculations.

Contents

a)
Topics included in the course are: Rheology of the lithosphere, frictional properties of faults, the seismic cycle, earthquake location, geological effects of earthquakes, tectonic geodesy, tectonic geomorphology, paleoseismology, earthquake and fault interactions, probabilistic and deterministic seismic hazard.
In addition to theoretical information presented via lecture material, the practical exercises teach fundamental data analysis via MATLAB, and other software distributed during the course.

Educational form / Language

a) Tutorial (2 WLH) / Lecture (2 WLH) / English / German

Examination methods

• Written exam 'Seismotectonics and Seismic Hazard' (2 h., Part of modul grade 100,0 %, includes evaluated written reports of the exercises)

Requirements for the award of credit points

- Exercises must be completed (evaluated written reports) with a passing grade of 60% in order to access the final exam.
- Pass the final exam.

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Students must have successfully completed a BSc in the earth sciences. The course consists of exercises as well as lecture, and exercises must be completed with a passing grade (60%) to access to the final exam on which the module grade will be based. The course will take place in English, therefore effective oral and written communication skills in English are required.
Literature:

- Structural Geology, Haakon Fossen, Cambridge University Press, 2013.
- The Geology of Earthquakes, R. S. Yeats, K. Sieh and C. R. Allen, Oxford University Press, 1997.
- The Mechanics of Earthquakes and Faulting, C. H. Scholz, Cambridge University Press, 2012.
- Paleoseismology, J. P. McCalpin, Academic Press, 2nd Ed.

Selected Topics in Reservoir Characterization

Selected Topics in Reservoir Characterization

Module number SE-CO-17	**Credits** 9 CP	**Workload** 270 h	**Semester[s]** 2./3. Sem.	**Duration** 2 Semester[s]	**Group size** 15

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Deep geothermal energy b) Well logging	a) 3 WLH (45 h) b) 2 WLH (30 h)	a) 115 h b) 80 h	a) each summer b) each winter

Module coordinator and lecturer(s)

Prof. Dr. Jörg Renner

a) Prof. Dr. Jörg Renner

b) Prof. Dr. Thomas Reinsch

Admission requirements

Recommended previous knowledge:

Basic knowledge in mathematics and physics, basic command of sheet-calculation software

Learning outcome, core skills

After successful completion of the module students

- appreciate the differences of hydrothermal and petrothermal energy provision learned to make basic calculations regarding the feasibility of geothermal energy provision (in general and site specific)
- understand the approach to geophysical surveys in boreholes
- are familiar with the basic data processing methods and correlation approaches applied to outcomes of different logging methods

Contents

a)

- classification of geothermal systems
- dimensioning geothermal plants
- flow through porous and fractured rocks
- monitoring fluid injection and stimulation measures
- heat transfer mechanisms

b)

- Borehole completion
- Logging tools and their application
- Measurement principles applied in wellbores

Educational form / Language

a) Tutorial (1 WLH) / Lecture (2 WLH) / English

b) Block seminar / English

Examination methods

• Written exam 'Deep Geothermal Energy' (120 min., Part of modul grade 55,0 %, part of modul grade 37 % + handed-in assignments, part of modul grade 18%)

• Written exam 'Borehole logging' (120 min., Part of modul grade 45,0 %, depending on number of participants announced at start of class: writtenexam (2 h., part of modul grade 45 %,) or term paper (part of modul grade 45%))

Requirements for the award of credit points

- Passed exams

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 9,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Soil Behaviour and Simple Constitutive Models

Soil Behaviour and Simple Constitutive Models

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-C-5	6 CP	180 h	1. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Soil Mechanics b) Soil Behaviour under Monotonic, Cyclic and Dynamic Loading c) Simple Constitutive Models for Soils	a) 2 WLH (30 h) b) 1 WLH (15 h) c) 1 WLH (15 h)	a) 60 h b) 30 h c) 30 h	a) each winter b) each winter c) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Torsten Wichtmann

a) Dr.-Ing. Nazanin Irani

b) Prof. Dr.-Ing. Torsten Wichtmann

c) Dr.-Ing. Nazanin Irani

Admission requirements

Learning outcome, core skills

After successfully completing the module, the students

- know how to describe and classify soils,
- are able to select suitable methods for ground investigation,
- can derive relevant soil properties from laboratory tests,
- are able to calculate vertical and horizontal stresses in the ground and on structures,
- know how to calculate time-dependent settlement,
- can assess the soil behaviour under monotonic, cyclic and dynamic loading in drained and undrained conditions,
- are able to apply simple constitutive laws to model the fundamental soil behaviour in numerical simulations and understand the limitations of these models,
- are able to determine the parameters of simple constitutive models from laboratory test results

Contents

a)

The course deals with the basic knowledge of Soil Mechanics:

- Description and classification of soils
- Soil properties and state parameters
- Site investigations
- Effect of groundwater in soils, seepage flow
- Vertical stresses in the ground
- Settlement and consolidation calculations
- Shear strength
- Earth pressure

b)

The course teaches advanced knowledge regarding the behaviour of various types of soils under more complex loading conditions. It addresses suitable testing methods, relevant soil properties, and their further use in analytical or numerical methods for the design of geotechnical structures. The following loading types are considered:

- Drained and undrained monotonic loading, critical states
- Undrained cyclic loading, liquefaction resistance
- Drained high-cyclic loading, cumulative deformations
- Dynamic loading

c)
The course introduces fundamentals of standard elastoplasticity applied to geotechnical materials in accordance to failure criteria. Additionally, it discusses the fundamentals, advantages and limitations of widely used simple constitutive models for soils such as:

- Linear Elastic (LE) model
- Mohr-Coulomb (MC) model
- Hardening Soil (HS) model

Finally, the calibration of simple constitutive models from laboratory tests will be discussed and these models will be applied to different geotechnical problems.

Educational form / Language
a) Lecture (2 WLH) / English
b) Lecture (1 WLH) / English
c) Lecture (1 WLH) / English

Examination methods
• Written exam 'Soil Behaviour and Simple Constitutive Models' (180 min., Part of modul grade 100,0 %)

Requirements for the award of credit points

- Passing the written examination

Module applicability

- M.Sc. Subsurface Engineering

Weight of the mark for the final score
Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Soil Dynamics and Geotechnical Earthquake Engineering
Soil Dynamics and Geotechnical Earthquake Engineering

Module number	Credits	Workload	Semester[s]	Duration	Group size
SE-CO-7	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Soil Dynamics	a) 2 WLH (30 h)	a) 60 h	a) each winter
b) Geotechnical Earthquake Engineering	b) 2 WLH (30 h)	b) 60 h	b) each winter

Module coordinator and lecturer(s)
Prof. Dr.-Ing. Torsten Wichtmann
a) Dr.-Ing. Meisam Goudarzy
b) Dr.-Ing. Felipe Prada, Dr.-Ing. Nazanin Irani

Admission requirements

Learning outcome, core skills
After successfully completing the modules, the students are able to

- understand soil dynamic problems and describe them mathematically,
- design and evaluate laboratory or field testing programs to determine dynamic soil properties,
- estimate dynamic soil properties by means of empirical approaches,
- design foundations subjected to dynamic loading (e.g. machine foundations),
- determine the loading resulting from earthquakes considering the ground conditions,
- estimate the risk of soil liquefaction and choose suitable countermeasures,
- design geotechnical structures (e.g. foundations, slopes) against earthquake loads.

Contents
a)
The lecture deals with the fundamentals of Soil Dynamics:

- Fundamentals of vibration theory
- Homogeneous systems
- Wave propagation in elastic isotropic half space
- Laboratory tests on dynamic characteristics of soils
- Methods to estimate dynamic characteristics of soils
- Dynamic field measurement methods
- Design of dynamically loaded foundations
- Soil-structure interaction under dynamic loading
- High cyclic loading of soils (practical problem: offshore wind turbines)
- Laboratory exercise (Resonant column experiment, wave velocity measurements).

b)
The lecture covers the effects of a seismic event on geotechnical structures and the design of such structures against earthquakes:

- Principles of Engineering Seismicity: earthquake description, source characterization, intensity, magnitude and duration parameters, maximum magnitude, concept of response spectra, ground motion prediction (attenuation equations)
- Deterministic and probabilistic estimation of seismic hazard. Microzoning studies.

- Causes of soil liquefaction under seismic loading; methods to estimate the liquefaction risk; countermeasures
- Design of slopes against seismic loading
- Design of retaining structures against seismic loading
- Ground response analysis

Educational form / Language

a) Lecture with tutorial / English
b) Lecture with tutorial / English

Examination methods

• Written exam 'Soil Dynamics and Geotechnical Earthquake Engineering' (180 min., Part of modul grade 100,0 %)
• Homework with bonus points for the exam for both parts of the module.

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc. Subsurface Engineering
- M.Sc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Technologies in Mechanised Tunneling

Technologies in Mechanised Tunneling

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
BI-W51/SE-O-3	2 CP	60 h	2. Sem.	1 Semester[s]	20

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Technologies in Mechanised Tunneling	a) 2 WLH (30 h)	a) 30 h	a) each summer

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Markus Thewes
a) Dr.-Ing. Gerhard Wehrmeyer

Admission requirements

Recommended previous knowledge:
Bachelor-level knowledge of construction operations and construction process engineering, Bachelor-level knowledge of foundation engineering and soil mechanics

Learning outcome, core skills

The performance-related design and the process engineering layout of a Tunnel Boring Machine (TBM) is an important interface on tunnel construction sites between the disciplines of civil engineering, geotechnics and mechanical engineering.
The associated know-how enables the engineer to make a correct selection and dimensioning of individual components of the TBM and thus potentially determines the safety as well as the structural and economic success of a mechanised tunnel advance. It is therefore an indispensable tool for future Tunnel Engineers and Tunnel Project Managers in the field of mechanized tunneling. The students are introduced to the different machine types and details, which vary depending on the specific geotechnical boundary conditions.
They will learn how to dimension them, to which details a special attention must be paid, which special solutions exist and in which direction research and development is in this area currently moving.

Contents

a)
The lecture deals with the extended basic knowledge of construction process engineering.

- Definition of different types of Tunnel Boring Machines and application ranges
- Detailed consideration of assembly units
- Shield (geometrical correlations, hydraulic forces of thrust jacks, load assumptions and evidence)
- Cutting wheel / cutterhead (excavation process, soil excavation, application ranges, wear and change of cutting tools)
- Cutterhead Drive (torque, sealing systems, lubrication and monitoring)
- Handling of segmental linings and of alternative tunnel lining systems
- Conveyor systems (hydraulic transport, screw conveyor, belt conveyor, monitoring of excavation volume)
- Backup installations and TBM Logistics
- Customized solutions (accessible Cutting Wheel, Variable Density Machines)
- Emerging Technologies (Robotics, large Diameter, Diagnosis and Maintenance)

Educational form / Language

a) Lecture (2 WLH) / English

Examination methods

• Written exam 'Technologies in Mechanised Tunneling' (60 min., Part of modul grade 100,0 %, optionally English or German)

Requirements for the award of credit points

- Passed Module examination

Module applicability

- MSc Civil Engineering
- MSc Subsurface Engineering
- MSc Geosciences
- MSc Mechanical Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 2,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information

Training of Competences (Part 1) Training of Competences (Part 1)					
Module number CE-W01/SE-O-14/ToC I	**Credits** 4 CP	**Workload** 120 h	**Semester[s]** 1./3. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Training of Competences and German Language course			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 60 h	**Frequency** a) each winter

Module coordinator and lecturer(s)
N.N.
a) University Language Center (ZFA) of Ruhr-University Bochum

Admission requirements

Learning outcome, core skills
After successfully completing the module, the students

- are able to employ at a minimum level all four skills (speaking, listening, reading and writing) in familiar universal contexts or shared knowledge situations such as greeting, small talk, shopping, making appointments, eating out, orientation, biography, healthcare etc.

Contents
a)
The learning goals of this German language course fulfill the special requirements of foreign students majoring in a subject that uses English as a teaching language. On a basic level, the main focus of the course lies on action-oriented speaking, listening, reading and writing comprehension so that the students learn to cope with everyday situations of their life in Germany. The classes consist of small groups, ensuring that students have ample opportunities to speak as well as having their individual needs attended to. All of our instructors are university graduates experienced in teaching DaF (Deutsch als Fremdsprache - German as a foreign language) and have been selected for their experience in working with students and their ability to make language learning an active and rewarding process. An optional intensive block course after the winter semester helps to activate and to intensify the newly acquired language skills.

Educational form / Language
a) Lecture with tutorial / English / German

Examination methods
• Written exam 'Training of Competences and German Language course' (120 min., Part of modul grade 100,0 %, and Homework (20 h) / German)

Requirements for the award of credit points
- Passed final module examination

Module applicability
- M.Sc. Computational Engineering
- M.Sc. Subsurface engineering
- Special offer for foreign students of the course

Weight of the mark for the final score

Percentage of total grade [%] = 4,00 * 100 * FAK / DIV FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.
Further Information University Language Center (ZFA) of Ruhr-University Bochum

Training of Competences (Part 2) Training of Competences (Part 2)					
Module number CE-W02/SE-O-15/ToC II	**Credits** 4 CP	**Workload** 120 h	**Semester[s]** 2./4. Sem.	**Duration** 1 Semester[s]	**Group size** no limitation
Courses a) Training of Competences (Part 2)			**Contact hours** a) 4 WLH (60 h)	**Self-study** a) 60 h	**Frequency** a) each summer

Module coordinator and lecturer(s)
N.N.
a) University Language Center (ZFA) of Ruhr-University Bochum

Admission requirements
Participation on CE-W01/SE-O14/ToC I is obligatory

Learning outcome, core skills
After successfully completing the module, the students

- are able to employ at an intermediate level all four skills (speaking, listening, reading and writing) in familiar universal contexts or shared knowledge situations such as greeting, small talk, shopping, making appointments, eating out, orientation, biography, healthcare etc.

Contents
a)
The learning goals of this German language course fulfill the special requirements of foreign students majoring in a subject that uses English as a teaching language. The main focus of the course lies on intermediate level action-oriented speaking, listening, reading and writing comprehension so that the students learn to cope with everyday situations of their life in Germany. This course continues the learning goals of the module Training of Competences 1.

Educational form / Language
a) Lecture (4 WLH) / English / German

Examination methods
• Written exam 'Training of Competences (Part 2)' (120 min., Part of modul grade 100,0 %)

Requirements for the award of credit points
- Passed final module examination

Module applicability
- M.Sc. Computational Engineering
- M.Sc. Subsurface engineering
- Special offer for foreign students of the course

Weight of the mark for the final score
Percentage of total grade [%] = 4,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information
University Language Center (ZFA) of Ruhr-University Bochum

Uncertainty Quantification in FE Analyses with Surrogate Modeling

Uncertainty Quantification in FE Analyses with Surrogate Modeling

Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP58/CE-WP29/SE-O-17	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	Contact hours	Self-study	Frequency
a) Uncertainty Quantification b) Surrogate Modeling	a) 2 WLH (30 h) b) 2 WLH (30 h)	a) 60 h b) 60 h	a) each winter b) each winter

Module coordinator and lecturer(s)

Prof. Dr. Roger A. Sauer
a) Dr.-Ing. Gerrit E. Neu
b) Dr.-Ing. Ba Trung Cao

Admission requirements

Recommended previous knowledge:
Fundamental knowledge in structural analysis, Finite Element Method, probability theory, and basic programming (MATLAB, Python)

Learning outcome, core skills

The course equips students with theoretical foundations and practical skills to model, propagate, and mitigate uncertainties in structural analysis. Students will be able to define an uncertainty quantification problem, evaluate the effect of aleatory, epistemic as well as polymorphic uncertainty onto computational models and to interpret the results. It delves into surrogate modeling methods that approximate high-fidelity simulations, enabling efficient uncertainty assessment in complex systems. Applications to structural reliability, optimization, and risk-informed decision-making are emphasized, with hands-on experience using state-of-the-art computational tools.

After successfully completing the modules, the students are able to

- Understand the role and significance of uncertainty in structural engineering and computational models.
- Apply probabilistic and non-probabilistic methods for modeling uncertain parameters.
- Develop and implement surrogate models for efficient uncertainty propagation and sensitivity analysis.
- Use state-of-the-art tools and frameworks to solve real-world problems involving uncertain data.

Contents

a)
The course deals with the uncertain data involving in structural analysis:

- Fundamentals of uncertainty quantification: types and sources of uncertainty (aleatory vs. epistemic)
- Sources of uncertainty in structural engineering: material properties, geometry, boundary conditions, and external loads
- Computing with uncertainty models: stochastic model, interval analysis, fuzzy logic, and polymorphic model
- Evaluation of model responses due to uncertain inputs: Quantification by statistical measures, sensitivity analysis and structural reliability

b)

The course deals with the development of numerical surrogate models to accelerate the computation with uncertain data:

- Surrogate models based on black-box machine learning techniques (Artificial Neural Network)
- Surrogate models based on reduced order methods (Proper Orthogonal Decomposition)
- Surrogate models based on hybrid combination (Physics-informed machine learning)
- Comparison of surrogate modelling techniques: accuracy vs. computational efficiency

Educational form / Language

a) Lecture (2 WLH) / English
b) Lecture (2 WLH) / English

Examination methods

• Term paper 'Uncertainty Quantification in FE Analyses with Surrogate Modeling' (90 h., Part of modul grade 100,0 %, Final project assignment + presentation of the results is used to determine the final grade Deadline will be announced at the beginning of the semester.)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Subsurface Engieering
- M.Sc. Computational Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6,00 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information

Variational Calculus and Tensor Analysis

Variational Calculus and Tensor Analysis

Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
CE-WP01/SE-O-6/VCTA	5 CP	150 h	3. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Variational Calculus and Tensor Analysis	a) 3 WLH (45 h)	a) 105 h	a) each winter

Module coordinator and lecturer(s)

Prof. Dr.-Ing. Johanna Waimann

a) Dr.-Ing. Ulrich Hoppe

Admission requirements

Recommended previous knowledge:

Mathematics

Learning outcome, core skills

After successfully completing the module, the students will be able

- to read, write and interpret tensor expression in index and abstract notation,
- to know and apply tools for formulating and manipulating the equations of continuum mechanics,
- to understand and solve variational problems in mechanics.

Contents

a)

- Tensor Analysis: Vector and tensor notation, vector and tensor algebra, dual bases, coordinates in Euclidean space, differential calculus, scalar invariants and spectral analysis, isotropic functions
- Variational Calculus: First variation, boundary conditions, PDEs: weak and strong form, constrained minimization problems, Lagrange multipliers, applications to continuum mechanics

Educational form / Language

a) Tutorial (1 WLH) / Lecture (2 WLH) / English

Examination methods

• Written exam 'Variational Calculus and Tensor Analysis' (90 min., Part of modul grade 100,0 %, or Oral Examination (30 Min). Examination Methods will be defined at the beginning of the Semester due to the number of participants)

Requirements for the award of credit points

- Passed final written examination

Module applicability

- M.Sc Computational Engineering
- M.Sc Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 5,00 * 100 * FAK / DIV

FAK: The weighting factors can be taken from the table of contents.

DIV: The values can be taken from the table of contents.

Further Information