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M.Sc. Subsurface Engineering

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Index by areas of study

1) MSc SSE Compulsory Courses, ECTS: 33

Weight of the mark for the final score

FAK = 1

DIV = 120

Mathematical Aspects of Differential Equations and Numerical Mathematics (CE-P01/SE-C-1/MADENM, 6 ECTS, each winter semester).....	44
Finite Element Methods in Linear Structural Mechanics (CE-P05/SE-C-2/FEM-I, 6 ECTS, each winter semester).....	22
Geology of the Earth's Crust (SE-C-3, 6 ECTS, each winter semester).....	26
Groundwater Hydraulics (SE-C-4, 5 ECTS, each winter semester).....	32
Soil and Rock Behaviour (SE-C-5, 6 ECTS, each winter semester).....	70
Project Work (SE-C-6, 4 ECTS, each winter semester).....	60

2) MSc SSE Compulsory Optional Courses, ECTS: 42

Weight of the mark for the final score

FAK = 1

DIV = 120

Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement (SE-CO-14, 6 ECTS, each winter semester).....	15
Foundation Engineering and Utility Pipe Construction: Design – Engineering – Technologies (BI-WP10/SE-CO-1, 6 ECTS, each winter semester).....	24
Conventional and Mechanised Tunneling: Design – Engineering – Technologies (BI-WP11/SE-CO-2, 6 ECTS, each summer semester).....	13
Numerical Simulation in Geotechnics and Tunneling (BI-WP24/SE-CO-3, 6 ECTS, each summer semester).....	50
Operation and Maintenance of Tunnels and Utility Pipes (BI-WP26/SE-CO-5, 6 ECTS, each winter semester).....	52
Design of Geotechnical Structures – Shallow and Deep Foundations (SE-CO-6, 6 ECTS, each summer semester).....	17
Problematic Soils and Soil Dynamics (SE-CO-7, 6 ECTS, each winter semester).....	58
Numerical Methods and Stochastics (CE-WP08/SE-CO-8/NMS, 6 ECTS, each summer semester).....	48
Mechanical Modeling of Materials (CE-P02/SE-CO-19/MMoM, 6 ECTS, each winter semester).....	46
Constitutive Models for Geomaterials (BI-WP44/SE-CO-10, 6 ECTS, each summer semester).....	11
Ground Exploration Methods (SE-CO-11, 10 ECTS, each winter semester).....	30

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Applied Geophysics (SE-CO-12, 10 ECTS, each summer semester).....	7
Geothermal Energy Systems (SE-CO-13, 5 ECTS, each summer semester).....	28
Hydrogeological Methods (SE-CO-15, 8 ECTS, each summer semester).....	38
Seismotectonics and Seismic Hazard (SE-CO-16, 6 ECTS, each winter semester).....	66
Selected Topics in Reservoir Characterization (SE-CO-17, 9 ECTS, siehe Lehrveranstaltung(en)).....	68
Reservoir Engineering (SE-CO-18, 5 ECTS, each winter semester).....	62

3) MSc SSE Optional Courses, ECTS: 15

Weight of the mark for the final score

FAK = 1

DIV = 120

Practical Training on Tunneling and Pipeline Construction Techniques (BI-W03/SE-O-1, 2 ECTS, each summer semester).....	56
Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice (SE-O-2, 2 ECTS, each winter semester).....	9
Technologies in Mechanised Tunneling (BI-W51/SE-O-3, 2 ECTS, each summer semester).....	72
Practical Soil Mechanics (SE-O-4, 3 ECTS, each winter semester).....	54
Environmental Geotechnics (SE-O-5, 3 ECTS, each summer semester).....	20
Variational Calculus and Tensor Analysis (CE-WP01/SE-O-6/VCTA, 5 ECTS, each winter semester).....	77
Digital Rock Physics (SE-O-7, 5 ECTS, each summer semester).....	18
High-Performance Computing on Multicore Processors (BI-WP56/CE-WP25/SE-O-8, 6 ECTS, each summer semester).....	36
High-Performance Computing on Clusters (BI-WP55/SE-O-9, 6 ECTS, each winter semester).....	34
Scientific Programming (CE-P04/SE-O-10/SP, 6 ECTS, each winter semester).....	64
Training of Competences (Part 1 (CE-W01/SE-O-14/ToC I, 4 ECTS, each winter semester).....	74
Training of Competences (Part 2) (CE-W02/SE-O-15/ToC II, 4 ECTS, each summer semester).....	76
Introduction to advanced numerical methods for particulate media (SE-O-16, 3 ECTS, each winter semester).....	40

4) MSc SSE Master's Thesis, ECTS: 30

Weight of the mark for the final score

FAK = 1

DIV = 120

Master Thesis (SE-MT, 30 ECTS,).....	42
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Applied Geophysics					
Applied Geophysics					
Module number SE-CO-12	Credits 10 CP	Workload 300 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Reservoir Geophysics b) Rock Physics			Contact hours a) 3 WLH (45 h) b) 3 WLH (45 h)	Self-study a) 120 h b) 90 h	Frequency 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 <ul style="list-style-type: none"> • 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) <ul style="list-style-type: none"> • 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) <ul style="list-style-type: none"> • 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 / German
- b) Lecture (3 WLH) / English / German

Examination methods

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

Requirements for the award of credit points

Passed module exam

Module applicability

MSc Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $10 * 100 * \text{FAK} / \text{DIV}$

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 SE-0-2	Credits 2 CP	Workload 60 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size 20
Courses a) Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency 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: <ul style="list-style-type: none"> • 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) / English / German					
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

- MSc Subsurface Engineering
- MSc Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 0, ungraded

Further Information

Constitutive Models for Geomaterials					
Constitutive Models for Geomaterials					
Module number BI-WP44/SE-CO-10	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) FEM for Nonlinear Analyses of Inelastic Materials and Structures b) Advanced Constitutive Models for Soils			Contact hours a) 2 WLH (30 h) b) 2 WLH (30 h)	Self-study a) 60 h b) 60 h	Frequency a) each summer b) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Prof. PhD Roger A. Sauer b) Dr.-Ing. Christoph Schmüdderich, Dr.-Ing. Merita Tafili					
Admission requirements					
Learning outcome, core skills After successfully completing the modules, the students are able to <ul style="list-style-type: none"> • formulate and to implement inelastic material models for ductile and brittle materials within the context of the finite element method and to perform nonlinear ultimate load structural analyses • model the material behavior of soil using suitable, complex constitutive models, • select suitable numerical methods and constitutive models for practical questions and assess limitations according to the selected approaches. 					
Contents a) The course is concerned with inelastic material models including their algorithmic formulation and implementation in the framework of nonlinear finite element analyses. Special attention will be paid to efficient algorithms for physically nonlinear structural analyses considering elastoplastic models for metals, soils and concrete as well as damaged based models for brittle materials. As a final assignment, the formulation and implementation of inelastic material models into an existing finite element program and its application to nonlinear structural analyses will be performed in autonomous teamwork by the participants. b) The course extends the existing knowledge on soil behaviour and constitutive modeling by introducing the concept of Critical State Soil Mechanics as well as sophisticated constitutive models. Among others, the following constitutive models are covered: Modified Cam-Clay (MCC), Hypoplasticity with intergranular strain (Hypo-IGS), Viscoplasticity, and Sanisand, where the latter belongs to the group of bounding surface plasticity models. Calibration of parameters for different constitutive models is taught. In addition, introduction to one integration point finite element simulations with Incremental Driver (ID) is provided and simulations of different laboratory tests are conducted with ID using elastic, elasto-plastic and hypoplastic constitutive models.					
Educational form / Language a) Tutorial (1 WLH) / Lecture (1 WLH) / English b) Lecture (2 WLH) / English					

Examination methods

- Written exam 'Constitutive Models for Geomaterials' (120 min., Part of modul grade 100 %)
- Optional homework to achieve bonus points for the written examination

Requirements for the award of credit points

- Final written examination

Module applicability

- MSc Civil Engineering
- MSc Computational Engineering
- MSc Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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]	25
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 Schößler					
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					
<ul style="list-style-type: none"> • 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 %, optionally English or German)
- Term paper 'Design, engineering and technologies in Tunneling and Pipeline Construction - Homework' (30 h., Part of modul grade 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

- MSc. Civil Engineering
- MSc. Subsurface Engineering
- Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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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, Prof. Dr.-Ing. Torsten Wichtmann					
Admission requirements					
Learning outcome, core skills After successfully completing the modules, the students are able to <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • 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 / German					
Examination methods • Written exam 'Design of Geotechnical Structures – Excavation Pits, Retaining Structures and Soil Improvement' (180 min., Part of modul grade 100 %)					
Requirements for the award of credit points					

Passed final written examination

Module applicability

MSc Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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 – Shallow and Deep Foundations					
Design of Geotechnical Structures – Shallow and Deep Foundations					
Module number SE-CO-6	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Design of Geotechnical Structures – Shallow and Deep Foundations			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Dr.-Ing. Merita Tafili, Prof. Dr.-Ing. Torsten Wichtmann					
Admission requirements					
Learning outcome, core skills After successfully completing the modules, the students are able to <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • 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 / German					
Examination methods • Written exam 'Design of Geotechnical Structures – Shallow and Deep Foundations' (180 min., Part of modul grade 100 %)					
Requirements for the award of credit points Passed final written examination					
Module applicability MSc Subsurface Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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 SE-O-7	Credits 5 CP	Workload 150 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size 20
Courses a) Digital Rock Physics			Contact hours a) 3 WLH (45 h)	Self-study a) 105 h	Frequency 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: <ul style="list-style-type: none"> • know the fundamentals of digital rock physics: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - to upscale elastic properties to understand field scale observations - to interpret uncertainties in the digital rock physics workflow 					
Contents a) <ul style="list-style-type: none"> • 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 %)					
Requirements for the award of credit points final report on computer exercises					
Module applicability MSc Subsurface Engineering					

MSc Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = $5 * 100 * \text{FAK} / \text{DIV}$

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 SE-O-5	Credits 3 CP	Workload 90 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Environmental Geotechnics			Contact hours a) 2 WLH (30 h)	Self-study a) 60 h	Frequency a) each summer
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Dr.-Ing. Wiebke Baille, Prof. Dr.-Ing. Torsten Wichtmann, Dr.-Ing. D. König					
Admission requirements Recommended previous knowledge: completed module in Computational Methods-1 (including lecture: Soil behaviour and simple constitutive models for soils).					
Learning outcome, core skills After successfully completing the modules, the students are able to <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • 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 <ul style="list-style-type: none"> • Term paper 'Environmental Geotechnics - Project work' (0 h., ungraded) • Written exam 'Environmental Geotechnics' (90 min., Part of modul grade 100 %) 					
Requirements for the award of credit points Passed final module examination: written examination Presentation of the project					

Module applicability

MSc Subsurface Engineering

Weight of the mark for the final scorePercentage of total grade [%] = $3 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

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/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. PhD Roger A. Sauer a) Prof. PhD 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					
<ul style="list-style-type: none"> • 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:					
<ul style="list-style-type: none"> • 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 %)					

• 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

- MSc. Computational Engineering
- MSc. Subsurface Engineering
- MSc. Civil Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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]	25
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 Schößler					
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					
<ul style="list-style-type: none"> • 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 %, optionally English or German)
- Term paper 'Process Technology and Construction Management - Homework' (30 h., Part of modul grade 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

- MSc Civil Engineering
- MSc Environmental Engineering
- Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Geology of the Earth's Crust					
Geology of the Earth's Crust					
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) Special methods in structural geology b) Structural geology field camp			b) 2 WLH (30 h)	a) 50 h b) 60 h	a) each winter b) each winter
Module coordinator and lecturer(s)					
Prof. Dr. Wolfgang Friederich a) Prof. Dr. Christophe Pascal b) Prof. Dr. Jörg Renner					
Admission requirements					
Learning outcome, core skills					
After successful completion of the course the students are					
<ul style="list-style-type: none"> • familiar with the main characteristics of the different types of sedimentary basins, • know the mechanisms driving basin subsidence, • able to elaborate a coherent geological model from field data. 					
Contents					
a) This lecture addresses various aspects of tectonic fractures. Firstly, the different types of fractures are introduced in detail with emphasis to their identification and correct interpretation in nature. In the following, fundamentals of fracture mechanics are presented in relation to specific characteristics of natural fractures. The discussion is then expanded to include the impact of fractures on fluid and heat transfer, in particular, and their relevance for operation of geo-energy systems.					
b) The exercise involves the structural/geological mapping in fine detail of selected areas using traditional techniques and tools (i.e. compass, hammer, lens...). As such the field camp aims to strengthen field work experience and sharpen geologist skills. In the course of the writing of the report, the student will learn how to analyse field data and how to extract from them a coherent geological synthesis					
Educational form / Language					
a) Block seminar / English / German b) Internship / kein Typ gewählt / English / German					
Examination methods					
• Written exam 'Geology of the Earth's Crust' (120 min., Part of modul grade 100 %) • Term paper 'Geology of the Earth's Crust - Essay' (20 h., Part of modul grade 0 %)					
Requirements for the award of credit points					
Pass the examinations and compulsory attendance in the field camp					
Module applicability					
MSc Subsurface Engineering					
Weight of the mark for the final score					

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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: Davis and Reynolds, 1996. Structural Geology of Rocks and Regions, John Wiley & Sons. Twiss and Moores, 1992 (2007). Structural Geology, Freeman

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 <ul style="list-style-type: none"> • 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) <ul style="list-style-type: none"> • 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 / German					
Examination methods					

• Written exam 'Geothermal Energy Systems' (60 min., Part of modul grade 100 %, 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

MSc Subsurface Engineering

MSc Geoscience

Weight of the mark for the final score

Percentage of total grade [%] = $5 * 100 * \text{FAK} / \text{DIV}$

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

Ground Exploration Methods					
Ground Exploration Methods					
Module number SE-CO-11	Credits 10 CP	Workload 300 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Geophysical Inverse Problems b) Seismic and electromagnetic field methods			Contact hours a) 3 WLH (45 h) b) 3 WLH (45 h)	Self-study a) 105 h b) 105 h	Frequency a) each winter b) each winter
Module coordinator and lecturer(s) Prof. Dr. Wolfgang Friederich a) Prof. Dr. Wolfgang Friederich b) Prof. Dr. Wolfgang Friederich					
Admission requirements					
Learning outcome, core skills <ul style="list-style-type: none"> • Students understand the theoretical foundations of seismic and electromagnetic field methods and know up-to-date measuring and data-acquisition procedures. They know and understand state-of-the-art methods of data analysis and interpretation. • Students understand the general philosophy of how to properly set up and solve geophysical inverse problems to create subsurface models from geophysical field surveys. They know different approaches to mathematically formulate an inverse problem and various techniques to obtain solutions in practice. They are able to solve small-scale problems themselves by writing a computer program. 					
Contents a) Mathematical precursor on linear vector and Hilbert spaces, the continuous linear inverse problem with exact and uncertain data, discrete linear inverse problems with uncertain data, singular value decomposition, resolution analysis, conjugate gradient minimization, linearized iterative inverse problems b) Data acquisition in reflection seismics, seismic data processing, ray and wave-equation migration, basic electromagnetic theory, electromagnetic fields in matter, geoelectric sounding and induced polarization, electromagnetic diffusion and waves in matter and ground penetrating radar					
Educational form / Language a) Lecture (3 WLH) / English / German b) Lecture (3 WLH) / English / German					
Examination methods • Written exam 'Ground Exploration Methods' (120 min., Part of modul grade 100 %)					
Requirements for the award of credit points passed module examination, bonus points for voluntary presentation of solutions to exercises					
Module applicability MSc Subsurface Engineering MSc Geosciences					
Weight of the mark for the final score					

Percentage of total grade [%] = $10 * 100 * \text{FAK} / \text{DIV}$

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: Parker, R.: Geophysical Inverse Problems; Menke, W.: Geophysical Data Analysis, Discrete Inverse Theory; Feynman: Lectures on Electrodynamics; Telford, Geldart, Sheriff: Applied Geophysics, Everett, M., Near surface applied geophysics, 403 pp. Cambridge University Press, 2013

Groundwater Hydraulics					
Groundwater Hydraulics					
Module number SE-C-4	Credits 5 CP	Workload 150 h	Semester[s] 1. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Groundwater Hydraulics			Contact hours a) 4 WLH (60 h)	Self-study a) 90 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr. Stefan Wohnlich a) Dr. Thomas Heinze					
Admission requirements					
Learning outcome, core skills After completion of this module, the students will <ul style="list-style-type: none"> • 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) <ul style="list-style-type: none"> • 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 / German					
Examination methods • Written exam 'Groundwater Hydraulics' (60 min., Part of modul grade 100 %)					
Requirements for the award of credit points Passing the written examination					
Module applicability MSc Subsurface Engineering MSc Geosciences					
Weight of the mark for the final score Percentage of total grade [%] = $5 * 100 * \text{FAK} / \text{DIV}$ 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.

High-Performance Computing on Clusters					
High-Performance Computing on Clusters					
Module number BI-WP55/SE-O-9	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) High-Performance Computing on Clusters			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr. Andreas Vogel a) Prof. Dr. Andreas Vogel					
Admission requirements					
Learning outcome, core skills After successfully completing the module the students <ul style="list-style-type: none"> • are enabled to design and create programs for parallel computing clusters • can critically evaluate distributed-memory systems and programming patterns • can assess the mathematical properties of iterative solvers and their scalability 					
Contents a) The lecture deals with the parallelization on cluster computers. Distributed-memory programming concepts (MPI) are introduced and best-practice implementation is presented based on applications from scientific computing including the finite element method and machine learning. Special attention is paid to scalable solvers for systems of equations on distributed-memory systems, focusing on iterative schemes such as simple splitting methods (Richardson, Jacobi, Gauß-Seidel, SOR), Krylov-methods (Gradient descent, CG, BiCGStab) and, in particular, the multigrid method. The mathematical foundations for iterative solvers are reviewed, suitable object-oriented interface structures are developed and an implementation of these solvers for modern parallel computer architectures is developed. Numerical experiments and self-developed software implementations are used to discuss and illustrate the theoretical results.					
Educational form / Language a) Tutorial (2 WLH) / Lecture (2 WLH) / English					
Examination methods • Written exam 'High-Performance Computing on Clusters' (120 min., Part of modul grade 100 %)					
Requirements for the award of credit points Passed written examination					
Module applicability <ul style="list-style-type: none"> • MSc Computational Engineering • MSc Civil Engineering • MSc Applied Computer Science • MSc Subsurface Engineering 					

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Computerlab Exercises

High-Performance Computing on Multicore Processors					
High-Performance Computing on Multicore Processors					
Module number	Credits	Workload	Semester[s]	Duration	Group size
BI-WP56/CE-WP25/SE-O-8	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation
Courses			Contact hours	Self-study	Frequency
a) High-Performance Computing on Multicore Processors			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					
Admission requirements					
Learning outcome, core skills					
After successfully completing the module, the students					
<ul style="list-style-type: none"> • are enabled to design and create programs for multicore processors, • can critically evaluate multi-threaded programs and shared-memory access patterns, • can assess the benefits and challenges of multicore programming techniques. 					
Contents					
a) The lecture addresses parallelization on multicore processors. Thread-based programming concepts and techniques, including pthreads, C++11 threads, OpenMP and SYCL, are introduced and best practices are highlighted using applications from scientific computing. An overview of the relevant hardware aspects including multicore architectures and memory hierarchies is provided. An in-depth introduction to multi-threaded programming on multicore systems with special emphasis on shared-memory parallelization is given and parallelization patterns, thread management and memory access strategies are discussed. In hands-on sessions, programming 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 'High-Performance Computing on Multi- and Manycore Processors' (120 min., Part of modul grade 100 %)					
Requirements for the award of credit points					
Passed written examination					
Module applicability					
<ul style="list-style-type: none"> • MSc Computational Engineering • MSc Civil Engineering • MSc Applied Computer Science • MSc Subsurface Engineering 					

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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Further Information

Hydrogeological Methods					
Hydrogeological Methods					
Module number SE-CO-15	Credits 8 CP	Workload 240 h	Semester[s] 2. Sem.	Duration 1 week Semester[s]	Group size 40
Courses a) Tracers in Hydrogeology b) Hydrogeological Field Camp			Contact hours a) 3 WLH (45 h) b) 3 WLH (45 h)	Self-study a) 75 h b) 75 h	Frequency a) each summer b) each summer
Module coordinator and lecturer(s) Prof. Dr. Stefan Wohnlich a) Dr. Thomas Heinze b) Prof. Dr. Stefan Wohnlich					
Admission requirements					
Learning outcome, core skills At the end of the module, participants will <ul style="list-style-type: none"> • 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) Basics concepts, terms and methods in tracer hydrology: different kind of tracers, their chemical and hydrodynamical properties, planning and performance of the tracer tests under real world conditions: tracer injection, sampling, analytical detection. Moreover, the hydrogeological interpretation of the results, calculation of hydrodynamic parameters as well as the use of computer programs will be trained and documented by writing a report. 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) Block seminar / English / German b) Tutorial (2 WLH) / Lecture (1 WLH) / German					
Examination methods • Term paper 'Hydrogeological Methods' (10 h., Part of modul grade 100 %)					
Requirements for the award of credit points					

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

Module applicability

MSc Subsurface Engineering

MSc Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = $8 * 100 * \text{FAK} / \text{DIV}$

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

Introduction to advanced numerical methods for particulate media					
Introduction to advanced numerical methods for particulate media					
Module number SE-O-16	Credits 3 CP	Workload 90 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Introduction to advanced numerical methods for particulate media			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) Prof. Dr.-Ing. Torsten Wichtmann, Dr.-Ing. Mohammad Salimi					
Admission requirements Recommended previous knowledge: completed module in Numerical Simulations in Geotechnics					
Learning outcome, core skills After successfully completing the module, students will be able to: <ul style="list-style-type: none"> • 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: <ol style="list-style-type: none"> 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 %, 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

- MSc. Subsurface Engineering
- MSc. Civil Engineering
- MSc. 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 [%] = $3 * 100 * \text{FAK} / \text{DIV}$

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

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Further Information

Master Thesis					
Master Thesis					
Module number SE-MT	Credits 30 CP	Workload 900 h	Semester[s] Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Master Thesis			Contact hours	Self-study a) 900 h	Frequency a) keine Angabe
Module coordinator and lecturer(s) Alle Professorinnen und Professoren des Studiengangs 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 <ul style="list-style-type: none"> • 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. <p>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.</p>					
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) / English / German					
Examination methods • Final thesis 'Master Thesis' (900 h., Part of modul grade 100 %, Review of the Master Thesis Report and Oral Presentation (30 min))					
Requirements for the award of credit points Successful evaluation (grade not greater than 4) of Master Thesis and Oral Presentation					
Module applicability MSc Subsurface Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $30 * 100 * \text{FAK} / \text{DIV}$					

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

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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. Gerhard Röhrle a) Prof. Dr. Gerhard Röhrle					
Admission requirements					
Recommended previous knowledge: No prior knowledge or preliminary modules. Basic calculus and experience with matrices.					
Learning outcome, core skills					
<p>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.</p> <p>After successfully completing the module, the students</p> <ul style="list-style-type: none"> • 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 %)					
Requirements for the award of credit points					

Passed final module examination

Module applicability

MSc Computational Engineering

MSc Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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-PO2/SE-CO-19/MMoM	6 CP	180 h	1. / 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					
<p>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.</p> <p>After successfully completing the module, the students</p> <ul style="list-style-type: none"> • 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					
<p>a)</p> <p>Several advanced issues of the mechanical behaviour of materials are addressed in this course. More precisely, the following topics will be covered:</p> <ul style="list-style-type: none"> • 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 <ul style="list-style-type: none"> - 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 %)
Requirements for the award of credit points
Module applicability MSc. Computational Engineering
Weight of the mark for the final score Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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) Jun.-Prof. Dr. Markus Weimar a) Jun.-Prof. Dr. Markus Weimar, Prof. Dr. Johannes Lederer, Assistants					
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 <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • 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 'Written Examination' (180 min., Part of modul grade 100 %)
Requirements for the award of credit points Passed final module examination
Module applicability <ul style="list-style-type: none">• MSc Computational Engineering• MSc Bauingenieurwesen• MSc Subsurface Engineering
Weight of the mark for the final score Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$ 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/SE-CO-3	6 CP	180 h	2. Sem.	1 Semester[s]	no limitation
Courses			Contact hours	Self-study	Frequency
a) Numerical Simulation in Tunneling			a) 2 WLH (30 h)	a) 60 h	a) each summer
b) Numerical Simulation in Geotechnics			b) 2 WLH (30 h)	b) 60 h	b) each summer
Module coordinator and lecturer(s)					
Prof. Dr. techn. Günther Meschke					
a) Prof. Dr. techn. Günther Meschke					
b) Dr.-Ing. Christoph Schmüdderich					
Admission requirements					
Recommended previous knowledge:					
Completed module in Computational Methods					
Learning outcome, core skills					
After successfully completing the modules, the students are able to					
<ul style="list-style-type: none"> • implement numerical models of complex boundary value problems of tunnels and geotechnics, 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 problems with focus on the interactions between the soil and structures. 					
Contents					
a)					
The course deals with the numerical modeling of tunnel structures and tunnel driving:					
<ul style="list-style-type: none"> • basic aspects of numerical modeling of tunnel construction problems, • practical application of FE software environments to model a conventional tunnel advance in 3D • automatic and parameter-controlled generation of complex models 					
b)					
The course deals with the numerical modeling of geotechnical structures and construction methods:					
<ul style="list-style-type: none"> • Overall insight to the numerical simulation of geotechnical problems by using the finite element method • Details for proper simulation in geomechanics by addressing constructional details, optimum discretization, boundary and initial conditions • Quick review of simple constitutive models, including calibration and discussion of important criteria to choose relevant constitutive models for distinct applications • 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 • The soil-water interactions in drained, undrained and consolidation analyses, fully coupled hydromechanical finite element solutions. 					

<ul style="list-style-type: none"> • Creation of models, execution of calculations and analysis of results for various geotechnical structures: shallow foundations, retaining walls, excavation, embankments, consolidation, slope failure • Fundamentals of contact elements and their applications in geotechnical modeling • Introduction to FE simulations with Plaxis 2D and other FE programs (Abaqus, Numgeo, etc.) • Brief overview of other numerical methods (e.g. DEM, MPM, boundary element method).
<p>Educational form / Language</p> <p>a) Lecture (2 WLH) / English b) Lecture (2 WLH) / English</p>
<p>Examination methods</p> <ul style="list-style-type: none"> • Written exam 'Numerical Simulation in Geotechnics and Tunneling' (180 min., Part of modul grade 100 %, Language of the written examination in English or German by choice of the student)
<p>Requirements for the award of credit points</p> <ul style="list-style-type: none"> • Passed final module examination: approved final written examination
<p>Module applicability</p> <ul style="list-style-type: none"> • MSc Civil Engineering • MSc Subsurface Engineering • MSc Computational Engineering
<p>Weight of the mark for the final score</p> <p>Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$</p> <p>FAK: The weighting factors can be taken from the table of contents. DIV: The values can be taken from the table of contents.</p>
<p>Further Information</p>

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:					
<ul style="list-style-type: none"> • 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 %, optionally Englisch or German)

Requirements for the award of credit points

- Passed module examination: Written exam

Module applicability

- MSc Civil Engineering
- MSc Subsurface Engineering
- Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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

Practical Soil Mechanics					
Practical Soil Mechanics					
Module number SE-O-4	Credits 3 CP	Workload 90 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Practical Soil Mechanics			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, Prof. Dr.-Ing. Torsten Wichtmann					
Admission requirements Recommended previous knowledge: Completed module in Computational Methods-1 (Soil behaviour and simple constitutive models for soils)					
Learning outcome, core skills After successfully completing the modules, the students can <ul style="list-style-type: none"> • develop strategies for the experimental investigation of practical geotechnical problems, • analyze the results of the experimental investigation. 					
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): <ul style="list-style-type: none"> • 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) 					
Educational form / Language a) Seminar / English / German					
Examination methods <ul style="list-style-type: none"> • Exercises 'Practical Soil Mechanics - Exercises' (<Ohne>, Part of modul grade 0 %) • Written exam 'Practical Soil Mechanics' (90 min., Part of modul grade 100 %) 					
Requirements for the award of credit points Passed final module examination: written examination Exercises (protocols and analysis of performed tests) Attendance during classes.					
Module applicability MSc Subsurface Engineering					
Weight of the mark for the final score Percentage of total grade [%] = 3 * 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

Practical Training on Tunneling and Pipeline Construction Techniques					
Practical Training on Tunneling and Pipeline Construction Techniques					
Module number BI-W03/SE-O-1	Credits 2 CP	Workload 60 h	Semester[s] 2. Sem.	Duration 1 Week Semester[s]	Group size 20
Courses a) Practical Training on Tunneling and Pipeline Construction Methods			Contact hours a) 3 WLH (45 h)	Self-study a) 15 h	Frequency 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: <ul style="list-style-type: none"> • 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 <ul style="list-style-type: none"> • Full time participation 					
Module applicability <ul style="list-style-type: none"> • MSc. Civil Engineering • MSc. 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 and Soil Dynamics					
Problematic Soils and Soil Dynamics					
Module number SE-CO-7	Credits 6 CP	Workload 180 h	Semester[s] 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Problematic soils b) Soil dynamics c) Geotechnical earthquake engineering			Contact hours a) 2 WLH (30 h) b) 1 WLH (15 h) c) 1 WLH (15 h)	Self-study a) 60 h b) 45 h c) 15 h	Frequency a) each winter b) each winter c) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Torsten Wichtmann a) Dr.-Ing. Wiebke Baille b) Dr.-Ing. Meisam Goudarzy c) N.N.					
Admission requirements					
Learning outcome, core skills After successfully completing the modules, the students are able to <ul style="list-style-type: none"> • assess special soil mechanical properties, phenomena, and the behavior of problematic soils • and can design an appropriate experimental program (laboratory / field tests) for an investigation of problematic soils, • understand soil dynamic problems and describe them mathematically, • determine the loading resulting from earthquakes and design geotechnical structures for these loads, • assess difficult ground and loading conditions and develop solutions for these situations. 					
Contents a) The course deals with different phenomena, that can cause difficulties in civil works for some types of soils: <ul style="list-style-type: none"> • Soft plastic and organic soils • Swelling and shrinkage behaviour • Collapsible soils • Physico-chemical effects • Structure and fabric, compacted soils • Unsaturated soils • Experimental methods for investigations on these soils and phenomena b) The lecture deals with the fundamentals of Soil Dynamics: <ul style="list-style-type: none"> • Fundamentals of vibration theory • 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, Bender elements).

c)

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

- 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
- c) Lecture with tutorial / English

Examination methods

- Written exam 'Problematic Soils and Soil Dynamics' (180 min., Part of modul grade 100 %)

Requirements for the award of credit points

- Passed final written examination

Module applicability

- MSc Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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) Alle Professorinnen und Professoren des Studiengangs a) Professors, Lecturers and Assistants					
Admission requirements					
Learning outcome, core skills After completion of the project work, the students <ul style="list-style-type: none"> • 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 <ul style="list-style-type: none"> • 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 %, 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

no information

Weight of the mark for the final score

Percentage of total grade [%] = $4 * 100 * \text{FAK} / \text{DIV}$

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: <ul style="list-style-type: none"> • 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) <ul style="list-style-type: none"> • 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 / German					
Examination methods • Oral exam 'Reservoir Engineering' (60 min., Part of modul grade 100 %, Presentation with lecture (45 min) + Discussion (15 min))					
Requirements for the award of credit points pass module exam					
Module applicability MSc Subsurface Engineering					

Weight of the mark for the final score

Percentage of total grade [%] = $5 * 100 * \text{FAK} / \text{DIV}$

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 CE-PO4/SE-O-10/SP	Credits 6 CP	Workload 180 h	Semester[s] 3 Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Scientific Programming			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency 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 <ul style="list-style-type: none"> • 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 capable to design and implement suitable software applications, • can code typical programs for 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 <ul style="list-style-type: none"> • procedural programming techniques, including statements, control flow and constructs, • object-oriented programming and modeling, including encapsulation, polymorphism, inheritance as well as UML diagrams, • 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 presented content, employing the Python programming language for selected scientific applications.					
Educational form / Language a) Tutorial (2 WLH) / Lecture (2 WLH) / English					
Examination methods • Written exam 'Scientific Programming' (120 min., Part of modul grade 100 %)					
Requirements for the award of credit points <ul style="list-style-type: none"> • Passed final module examination 					
Module applicability <ul style="list-style-type: none"> • MSc. Computational Engineering • MSc. Subsurface Engineering 					
Weight of the mark for the final score					

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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 SE-CO-16	Credits 6 CP	Workload 180 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Seismotectonics and Seismic Hazard			Contact hours a) 4 WLH (60 h)	Self-study a) 120 h	Frequency 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 <ul style="list-style-type: none"> • 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 %, 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

MSC Subsurface Engineering

MSc Geosciences

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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			a) 3 WLH (45 h)	a) 85 h	a) each summer
b) Well logging rudiments			b) 2 WLH (30 h)	b) 55 h	b) each winter
c) Well logging II, analysis, interpretation			c) 2 WLH (30 h)	c) 55 h	c) each summer
Module coordinator and lecturer(s)					
Prof. Dr. Jörg Renner					
a) Prof. Dr. Jörg Renner					
b) Prof. Dr. Jörg Renner					
c) Prof. Dr. Jörg Renner					
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					
<ul style="list-style-type: none"> • 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 • can operate the "industry standard", wellcad 					
Contents					
a)					
<ul style="list-style-type: none"> • classification of geothermal systems • dimensioning geothermal plants • flow through porous and fractured rocks • monitoring fluid injection and stimulation measures • heat transfer mechanisms 					
b)					
<ul style="list-style-type: none"> • Borehole completion • Logging tools • Basics of measurements 					
c)					
<ul style="list-style-type: none"> • Introduction to wellcad • Case studies 					
Educational form / Language					
a) Tutorial (1 WLH) / Lecture (2 WLH) / English / German					

- b) Tutorial (1 WLH) / Lecture (1 WLH) / English / German
c) Tutorial (1 WLH) / Lecture (1 WLH) / English / German

Examination methods

- Written exam 'Selected Topics in Reservoir Characterization' (3 h., Part of modul grade 100 %, + pass handed in assignments)
- Term paper 'Selected Topics in Reservoir Characterization - Homework I' (0 h., ungraded)
- Term paper 'Selected Topics in Reservoir Characterization - Homework II' (0 h., ungraded)

Requirements for the award of credit points

Passed exams

Module applicability

no information

Weight of the mark for the final score

Percentage of total grade [%] = $9 * 100 * \text{FAK} / \text{DIV}$

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 and Rock Behaviour					
Soil and Rock Behaviour					
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 Behaviour and Simple Constitutive Models for Soils b) Stress Field and Rock Mass Behavior			a) 2 WLH (30 h) b) 4 WLH (60 h)	a) 60 h b) 30 h	a) each winter b) each winter
Module coordinator and lecturer(s)					
Prof. Dr.-Ing. Torsten Wichtmann a) Prof. Dr.-Ing. Torsten Wichtmann b) Prof. Dr. Tobias Backers					
Admission requirements					
Learning outcome, core skills					
After successfully completing the module, the students					
<ul style="list-style-type: none"> • can assess the constitutive behaviour of the soil under different hydromechanical loading conditions, • are able to develop strategies 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, • are familiar with rock and rock mass behaviour and the sources of stress in the earth's crust. They know how to estimate and measure rock mass stress. 					
Contents					
a) The course introduces the conventional and advanced laboratory testing methods and addresses expected soil behaviour under monotonic and cyclic loading conditions from numerical modeling perspectives. Fundamentals of standard elastoplasticity applied to geotechnical materials in accordance to failure criteria will be introduced. Additionally, it discusses the fundamentals, advantages and limitations of widely used simple constitutive models for soils such as:					
<ul style="list-style-type: none"> • 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.					
b) 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.					
Educational form / Language					
a) Lecture (2 WLH) / English / German b) Block seminar / English / German					

Examination methods

- Seminar 'Stress Field and Rock Mass Behavior' (60 h.)
- Written exam 'Soil and rock behaviour' (180 min., Part of modul grade 100 %)

Requirements for the award of credit points

Passing the written examination

Module applicability

MSc Subsurface Engineering

Weight of the mark for the final score

Percentage of total grade [%] = $6 * 100 * \text{FAK} / \text{DIV}$

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 BI-W51/SE-O-3	Credits 2 CP	Workload 60 h	Semester[s] 2. Sem.	Duration 1 Semester[s]	Group size 20
Courses a) Technologies in Mechanised Tunneling			Contact hours a) 2 WLH (30 h)	Self-study a) 30 h	Frequency 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. <ul style="list-style-type: none"> • 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					

<p>Examination methods</p> <ul style="list-style-type: none"> • Written exam 'Technologies in Mechanised Tunneling' (60 min., Part of modul grade 100 %, optionally English or German)
<p>Requirements for the award of credit points</p> <ul style="list-style-type: none"> • Passed Module examination
<p>Module applicability</p> <ul style="list-style-type: none"> • MSc Civil Engineering • MSc Subsurface Engineering • MSc Geosciences • MSc Mechanical Engineering
<p>Weight of the mark for the final score</p> <p>Percentage of total grade [%] = $2 * 100 * \text{FAK} / \text{DIV}$</p> <p>FAK: The weighting factors can be taken from the table of contents.</p> <p>DIV: The values can be taken from the table of contents.</p>
<p>Further Information</p>

Training of Competences (Part 1)					
Training of Competences (Part 1)					
Module number	Credits	Workload	Semester[s]	Duration	Group size
CE-W01/SE-O-14/ToC I	4 CP	120 h	1 Sem.	1 Semester[s]	no limitation
Courses			Contact hours	Self-study	Frequency
a) Training of Competences and German Language course			a) 4 WLH (60 h)	a) 60 h	a) each winter
Module coordinator and lecturer(s)					
N.N. a)					
Admission requirements					
Learning outcome, core skills					
After successfully completing the module, the students					
<ul style="list-style-type: none"> 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 'Written examination' (120 min., Part of modul grade 100 %, and Homework (20 h) / German)					
Requirements for the award of credit points					
Passed final module examination					
Module applicability					
<ul style="list-style-type: none"> MSc. Computational Engineering Special offer for foreign students of the course 					
Weight of the mark for the final score					
Percentage of total grade [%] = $4 * 100 * \text{FAK} / \text{DIV}$ 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 Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Training of Competences II			Contact hours a) 4 WLH (60 h)	Self-study a) 60 h	Frequency a) each summer
Module coordinator and lecturer(s) N.N. a)					
Admission requirements Participation on CE-W01 is obligatory					
Learning outcome, core skills After successfully completing the module, the students <ul style="list-style-type: none"> 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 'Written examination' (120 min., Part of modul grade 100 %)					
Requirements for the award of credit points Passed final module examination					
Module applicability <ul style="list-style-type: none"> MSc. Computational Engineering Special offer for foreign students of the course Weight of					
Weight of the mark for the final score Percentage of total grade [%] = $4 * 100 * \text{FAK} / \text{DIV}$ 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					

Variational Calculus and Tensor Analysis					
Variational Calculus and Tensor Analysis					
Module number CE-WP01/SE-O-6/VCTA	Credits 5 CP	Workload 150 h	Semester[s] 1. / 3. Sem.	Duration 1 Semester[s]	Group size no limitation
Courses a) Variational Calculus and Tensor Analysis			Contact hours a) 3 WLH (45 h)	Self-study a) 105 h	Frequency a) each winter
Module coordinator and lecturer(s) Prof. Dr.-Ing. Johanna Waimann a) Prof. Dr.-Ing. Daniel Balzani, Prof. Dr. rer. nat. Khanh Chau Le					
Admission requirements Recommended previous knowledge: Mathematics					
Learning outcome, core skills After successfully completing the module, the students will be able <ul style="list-style-type: none"> • 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) <ul style="list-style-type: none"> • 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 / German					
Examination methods • Written exam 'Variational Calculus and Tensor Analysis' (90 min., Part of modul grade 100 %, 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 MSc Computational Engineering MSc Subsurface Engineering					
Weight of the mark for the final score Percentage of total grade [%] = $5 * 100 * \text{FAK} / \text{DIV}$ 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

Curriculum Subsurface Engineering

Kind of Module	Specialization	Code	Module Name	Coordinators and Lecturers	CP	WLH	Sem.	WiSe / SoSe	Examination Methods
Compulsary: 33 CP		SE-C-1	Mathematical Aspects of Differential Equations and Numerical Mathematics	Prof. Dr. Gerhard Röhrle	6	4	1	WiSe	exam (180 min)
		SE-C-2	Finite Element Methods in Linear Structural Mechanics	Prof. Sauer	6	4	1	WiSe	exam (180 min)
		SE-C-3	Geology of the Earth's Crust a) Special methods in structural geology (block course) b) Structural geology field camp	Prof. C. Pascal Prof. W. Friederich, Prof. J. Renner	6 3 3	4	1	WiSe	exam (120 min) essay (20 h)
		SE-C-4	Groundwater Hydraulics	Dr. T. Heinze	5	4	1	WiSe	exam (60 min)
		SE-C-5	Soil and rock behaviour a) Soil Behaviour and Simple Constitutive Models for Soils b) Stress field and rock mass behavior (block course)	Prof. T. Wichtmann (coordinator) Prof. T. Backers	6 3 3	6 2	1	WiSe	exam (180 min)
		SE-C-6	Project Work	Professors, lecturers and assistants	4	-	3	WiSe	Home Assignment + presentation

Compulsary Optional: GT + SCU: 42	Geotechnics and Tunneling GT: 30 CP (If You choose this Specialization)							
	SE-CO-1	Foundation Engineering and Utility Pipe Construction: Design-Engin.-Techn. a) Design, engineering and technologies in Foundation Engineering b) Design, engineering and technologies in Utility Pipe Construction	Prof. M. Thewes (coordinator) Dr. B. Schoesser	6 3 3	4	3	WiSe	exam (120 min) Home Assignment (30 h)
	SE-CO-2	Conventional and Mechanised Tunneling: Design-Engineering-Technologies a) Design, engineering and technologies in Tunneling b) Design, engineering and technologies in Pipeline Construction	Prof. M. Thewes (coordinator) Dr. B. Schoesser	6 3 3	4	2	SuSe	exam (120 min) Home Assignment (30 h)
	SE-CO-3	Numerical Simulation in Geotechnics and Tunneling a) Numerical Simulation in Tunneling b) Numerical Simulation in Geotechnics	Prof. G. Meschke (coordinator) Dr. C. Schmüderich	6 3 3	4	2	SuSe	exam (180 min)
	SE-CO-5	Operation and Maintenance of Tunnels and Utility Pipes a) Facility management of underground transportation infrastructure b) Pipeline maintenance and network management	Prof. M. Thewes (coordinator) Prof. R. Leuker Prof. B. Bosseler	6 3 3	4	3	WiSe	exam (120 min) 60 min 60 min
	SE-CO-6	Design of Geotechnical Structures 1 Shallow and Deep Foundations	Prof. T. Wichtmann (coordinator) Dr. M. Tafili, Dr. N. Irani, Dr. M. Salimi	6	4	2	SuSe	exam (180 min)
	SE-CO-14	Design of Geotechnical Structures 2 Excavation Pits, Retaining Structures and Soil Improvement	Prof. T. Wichtmann (coordinator) Dr. M. Tafili, Dr. N. Irani, Dr. M. Salimi	6	4	3	WiSe	exam (180 min)
	SE-CO-7	Problematic Soils and Soil Dynamics a) Problematic soils b) Soil Dynamics c) Geotechnical Earthquake Engineering	Prof. T. Wichtmann (coordinator) Dr. W. Baille Dr. M. Goudarzy Dr. F. Prada (Lehrbeauftragter)	6 3 2 1	4 2 1 1	3	WiSe	exam (180 min)
	SE-CO-8	Numerical Methods and Stochastics	Jun.-Prof. Dr. Markus Weimar, Prof. J. Lederer	6	4	2	SuSe	exam (180 min)
	SE-CO-10	Constitutive models for geomaterials a) FEM for Nonlinear Analyses of Inelastic Materials and Structures b) Advanced Constitutive Models for Soils	Prof. T. Wichtmann (coordinator) Prof. R. Sauer Dr. M. Tafili, Dr. C. Schmüderich	6 3 3	4	2	SuSe	exam (120 min) optional Home-work
	SE-CO-11	Ground Exploration Methods a) Geophysical Inverse Problems b) Seismic and electromagnetic field methods	Prof. W. Friederich (coordinator)	10 5 5	6	3	WiSe	exam (120 min)
	SE-CO-19	Mechanical Modeling of Materials	Prof. D. Balzani (coordinator)	6	4	3	WiSe	exam (90 min)
	SE-CO-12	Applied Geophysics a) Reservoir Geophysics b) Rock Physics	Prof. J. Renner (coordinator)	10 5 5	6	2	SuSe	exam (180 min) report on Lab experiments
	SE-CO-13	Geothermal Energy Systems	Prof. R. Bracke (coordinator)	5	4	2	SuSe	exam (60 min) Optional Homework (40 h)
	SE-CO-15	Hydrogeological Methods a) Tracers in Hydrogeology b) Hydrogeological Field Camp	Dr. T. Heinze	8	6	2	SuSe	report (10 h) + active Participation
	SE-CO-16	Seismotectonics and Seismic Hazard	Prof. R. Harrington (coordinator), Dr. A. Verdecchia	6	4	3	WiSe	exam (120 min) + reports
	SE-CO-17	Selected Topics in Reservoir Characterization a) Deep geothermal energy b) Well logging rudiments c) Well logging II, analysis, interpretation	Prof. J. Renner (coordinator)	9 5 2 2	7 3 2 2	both SuSe WiSe SuSe	exam (180 min) + handed in Assignments	
	SE-CO-18	Reservoir Engineering	Prof. E. H. Saenger (coordinator)	5	3	3	WiSe	Oral Talk (60 min)

Optional: 15 CP	Subsurface Characterization and Utilization SCU: 30 CP (If You choose this Specialization)							
	SE-O-1	Practical Training on Tunneling and Pipeline Construction Techniques	Prof. M. Thewes (coordinator)	2	3	2	SuSe	full time participation
	SE-O-2	Aspects of Design and Construction of Tunnels and other Subsurface Infrastructure in Practice	Prof. M. Thewes (coordinator)	2	2	3	WiSe	full time participation
	SE-O-3	Technologies in Mechanised Tunneling	Prof. M. Thewes (coordinator), Dr. G. Wehrmeyer	2	2	2	SuSe	exam (60 min)
	SE-O-4	Practical Soil Mechanics	Prof. T. Wichtmann (coordinator), Dr. W. Baille	3	2	3	WiSe	exam (90 min) + Exercise Protocols + Attendance
	SE-O-5	Environmental Geotechnics	Prof. T. Wichtmann (coordinator), Dr. W. Baille, Dr. D. König	3	2	2	SuSe	exam (90 min) + Presentation
	SE-O-6	Variational Calculus and Tensor Analysis	Prof. Dr.-Ing. Johanna Waimann, Prof. Dr.-Ing. Daniel Balzani, Prof. Dr. rer. nat. Khanh Chau Le	5	3	3	WiSe	exam (90 min)
	SE-O-7	Digital Rock Physics	Prof. E. Saenger (coordinator)	5	3	2	SuSe	Home Assignment (30 h)
	SE-O-8	High Performance Computing on Multicore Processors	Prof. A. Vogel (coordinator)	6	4	2	SuSe	exam (120 min)
	SE-O-9	High Performance Computing on Clusters	Prof. A. Vogel (coordinator)	6	4	3	WiSe	exam (120 min)
	SE-O-10	Scientific Programming	Prof. A. Vogel (coordinator)	6	4	3	WiSe	exam + report about Exercises
	SE-O-14	Training of Competences (Part 1)	University Language Center (ZFA) of Ruhr-University Bochum	4	4	1	WiSe	exam (120 min) + Homework (20 h)
	SE-O-15	Training of Competences (Part 2)	University Language Center (ZFA) of Ruhr-University Bochum	4	4	2	SoSe	exam (120 min)
	SE-O-16	Introduction to advanced numerical methods for particulate media	Prof. T. Wichtmann (coordinator), Dr.-Ing. M. Salimi	3	2	3	WiSe	Homework (60h)

Master Thesis: 30 CP	SE-MT	Master Thesis	Professors, lecturers and assistants	30	-	4	SuSe	Master Thesis and Oral Presentation
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All Modules: 120 CP	SE-C	Subtotal Compulsary Courses		33		1	WiSe	
	SE-CO	Subtotal Compulsary Optional Courses (Minimum 30 CP in chosen Specialization)		42		2,3	both	
	SE-O	Subtotal Optional Courses		15		2,3	both	
	SE-MT	Subtotal Master Thesis		30		4	SuSe	
	Sum			120				