Program overview

30-Nov-2016 8:42

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

Code	Omschrijving	ECTS	p1	p2	p3	p4	p5
AES Master 2016	**Applied Earth Sciences Master 2016**						
AES-PE&G Track Petroleum Engineering & Geosciences (PE&G)							
AES-PE&G Specialisation Petroleum Engineering (PE&G-PE)							
AES-PE&G Specialisation Petroleum Engineering 1st Year							
AES0102	Image Analysis	1					
AES1011	Matlab / Programming	2					
AES1300	Properties of Hydrocarbons & Oilfield Fluids	3					
AES1304	Introduction to Petroleum Engineering and NAM Visit	3					
AES1310-10	Rock Fluid Physics	3					
AES1320	Modelling of Fluid Flow in Porous Media	3					
AES1330	Drilling & Production Engineering	4					
AES1340	Reservoir Engineering	2					
AES1350	Reservoir Simulation	2					
AES1360	Production Optimisation	3					
AES1500	Fundamentals of Borehole Logging	4					
AES1510	Geologic Interpretation of Seismic Data	3					
AES1520	Log Evaluation	2					
AES1802	Geological Fieldwork	3					
AES1820-09	Reservoir Characterisation & Development	4					
AES1890	Sedimentary Systems	3					
AES1920	Geostatistics	2					
AES1930	Quantification of Rock Reservoir Images	1					
AES3820	Petroleum Geology	3					
WI4012ta	Mathematics, Special Subjects	4					
AES-PE&G PE Electives (5 EC)							
AES-PE&G Specialisation Petroleum Engineering 2nd Year							
AES2009	Field Development Project	9					
AESM2006	Final Thesis Petroleum Engineering	45					
AES-PE&G PE Electives (5 EC)							
AES1050	GSE Student competition course	5					
AES1370-12	Non-Thermal Enhanced and Improved Oil Recovery	3					
AES1460	Heavy Oil	2					
AES1470	Geothermics	2					
AES1490	Advanced Reservoir Simulation	2					
AES1760	Introduction to Log Evaluation	1					
AESM1805	Regional Geology Field Trip	1					
AESM2604	Geothermal Field Trip	2					
AES-PE&G Specialisation Reservoir Geology (PE&G-RG)							
AES-PE&G Specialisation Reservoir Geology 1st year							
AES0102	Image Analysis	1					
AES1011	Matlab / Programming	2					
AES1300	Properties of Hydrocarbons & Oilfield Fluids	3					
AES1310-10	Rock Fluid Physics	3					
AES1320	Modelling of Fluid Flow in Porous Media	3					
AES1340	Reservoir Engineering	2					
AES1510	Geologic Interpretation of Seismic Data	3					
AES1520	Log Evaluation	2					
AES1800	Exploration Geology (including Remote Sensing)	3					
AES1802	Geological Fieldwork	3					
AES1820-09	Reservoir Characterisation & Development	4					
AES1830	Reservoir Sedimentology	3					
AES1840	Advanced Structural Geology	3					
AES1850	Geological Modelling	4					
AES1860-05	Analysis of Sedimentary Data	3					
AES1890	Sedimentary Systems	3					
AES1902	Reservoir Geological Fieldwork (Huesca)	6					
AES1920	Geostatistics	2					
AES1930	Quantification of Rock Reservoir Images	1					
AES3820	Petroleum Geology	3					
AES-PE&G RG Electives (3 EC)							
AES-PE&G Specialisation Reservoir Geology 2nd Year							
		9					

AES2009	Field Development Project	
AESM2007	Final Thesis Reservoir Geology	45

AES-PE&G RG Elective Courses (6 ec)

AES1050	GSE Student competition course	5
AESM2604	Geothermal Field Trip	2

AES-AG Track Applied Geophysics (AG)

AES-AG Track Applied Geophysics 1st Year

AES-AG TU Delft semester 1; a minimum of 25 EC should be passed

AES-AG Two out of the following three blocks of TUD courses must be passed

AES-AG Geology and interpretation

AES1510	Geologic Interpretation of Seismic Data	3
AES1890	Sedimentary Systems	3
AES3820	Petroleum Geology	3

AES-AG Electromagnetic Methods

AES1540-11	Electromagnetic Exploration Methods	6

AES-AG Seismic wave propagation and imaging

AES1560	Advanced Reflection Seismology and Seismic Imaging	6

AES-AG Additional TUD courses

AES1011	Matlab / Programming	2
AES1501	Methods of Exploration Geophysics	3
AES1550-06	Geophysics Special Subjects	6
AES1590-12	Seismic resolution	5
CIE4606	Geodesy and Remote Sensing	5

AES-AG ETH Zürich semester 2; a minimum of 25 EC should be passed

AES-AG Two out of the following three blocks of ETH courses must be passed

AES-AG Track Applied Geophysics 2nd Year

AES-AG RWTH Aachen semester 3; a minimum of 25 EC should be passed

AES-AG Three out of four following blocks of RWTH courses must be passed

AES-AG Semester 4 Thesis

AESM2506	Final Thesis Applied Geophysics	30

AES-RE Track Resource Engineering (RE)

AES-RE Track Resource Engineering 1st Year

AESM1020	Mine Feasibility Case Study	5
AESM1021	Mine Operational Management	5
AESM1021 Toets 1	*Assignment*	*3*
AESM1021 Toets 2	*Exam*	*2*
AESM1022	Principles of Mine Design	5
AESM1023	Computer-aided Mine Design and Optimization	5
AESM1024	Legal, Health and Safety	5
AESM1024 Toets 1	*Individual Assignment*	*1,5*
AESM1024 Toets 2	*Group Assignment*	*2*
AESM1024 Toets 3	*Final Assignment*	*1,5*
AESM1025	Data Analysis and Resource Modeling	5
AESM1026	Economic Geology & Mineral Exploration: Introduction for Geo-Resource Engineers	5
AESM4151-2	Additional Assignment for Geo-Resource Engineers (for MS4151)	2

AES-RE Track Resource Engineering 2nd Year

AESM2020	Research Driven Project	15
AESM2023	Thesis Proposal	5
AESM2025	Final Thesis Geo-Resource Engineering	40

AES-RE Specialisation Mining Engineering (RE-EMC)

AES-RE Specialisation Mining Engineering (EMC) 2nd Year

AESM1023	Computer-aided Mine Design and Optimization	5
AESM1024	Legal, Health and Safety	5
AESM1025	Data Analysis and Resource Modeling	5
AESM2010	Final Thesis Resource Engineering	30
AESM2022	Project Execution and Mine Startup Planning	10
AESM2300-1	Investments Scenarios	1
CME2300	Financial Engineering	4

AES-GE Track Geo-Engineering (GE)

AES-GE Required Courses (34 ECTS)

AES1630	Engineering Geology	4
AESM1700	Consolidation of Soils	3
CIE4361	Behaviour of Soils and Rocks	6
CIE4365-16	Modelling Coupled Processes for Engineering Applications	5
CIE4366	Numerical Modelling in Geo-Engineering	6
CIE4395	Risk and Variability in GeoEngineering	4
CIE5320	Site Characterisation, Testing and Physical Model	6

AES-GE Focus Elective Courses (28 EC without Ethics convergence course and 24 EC with)

AES1050	GSE Student competition course	5
AES1501	Methods of Exploration Geophysics	3

AES1640-11	Environmental Geotechnics	4
AES1720-11	Rock Mechanics Applications	5
AES1730	Introduction to Geotechnical Engineering	3
AESM2901-16	Geoscience and Engineering Fieldwork	10
CIE4353	Continuum Mechanics	6
CIE4362	Soil Structure Interaction	3
CIE4363	Deep excavation	4
CIE4367-16	Embankments and Geosynthetics	3
CIE4390	Geo Risk Management	3
CIE4780	Trending Topics in Geo-Engineering	4
CIE5305	Bored and Immersed Tunneling	4
CIE5340	Soil Dynamics	3
CIE5741	Trenchless Technologies	4
OE44030	Offshore Geotechnical Engineering	4

AES-GE Choose for 20 EC Extra Courses or 2 of the possibilities listed below up to 20 EC in total

AES0404-10	Traineeship	10
AES4011-10	Additional Thesis	10
CIE4061-09	Multidisciplinary Project	10

AES-GE 10 EC Extra Courses

AES-GE Thesis (40 ECTS)

AESM2606	Final Thesis Geo-Engineering	40

AES-GE Convergence courses (to be taken if course content(s) not part of student BSc programme) choose 1 out of 2

CIE4510	Climate Change: Science & Ethics	4
WM0312CIE	Philosophy, Technology Assessment and Ethics for CIE	4

AES-GRS Track Geoscience and Remote Sensing (GRS)

AES-GRS Variant-linked subjects (compulsory) 18 EC

CIE4601	Physics of the Earth and Atmosphere	5
CIE4606	Geodesy and Remote Sensing	5
CIE4611	Geo-measurement processing	5
CIE4615	Geoscience and Remote Sensing fieldwork	3

AES-GRS Compulsory for all students 10 EC out of 15 EC (if WM0325 TA is not passed in BSc, then CIE4613 (5 EC) is compulsory)

CIE4603-16	Geo-signal Analysis	6
CIE4604	Simulation and visualization	5

AES-GRS Choose at least 12 EC of the possibilities listed below

CIE4522-15	GPS for Civil Engineering and Geosciences	4
CIE4602	Ice, snow and climate change: observation and modeling	4
CIE4605	Atmospheric science	4
CIE4607	Oceans, sea-level and bathymetry	4
CIE4608	Atmospheric observation	4
CIE4609	Geodesy and natural hazards	4
CIE4610	Mass transport in the Earth's system	4
CIE4614	Land surveying and civil infrastructure	4

AES-GRS Elective courses (20 EC to a total of 60 EC in the 1st year)

AES1050	GSE Student competition course	5

AES-GRS Free electives (CIE/AES-courses)

AES-GRS Choose 20 EC of the possibilities listed below

AES4011-10	Additional Thesis	10
CIE4040-09	Internship	10
CIE4061-09	Multidisciplinary Project	10
CIE4612	Research Seminar Geoscience and Remote Sensing II	1
CIE5601	Journal club on climate change and geoscience	3
CIE5602	Research Seminar Geoscience and Remote Sensing I	1
CIE5603	Advanced project on GRS	3

AES-GRS Free electives for 10 EC (CIE/AES-courses)

AES-GRS Free electives for 10 EC

AES-GRS Thesis

AESM2640	Final Thesis Geoscience and Remote Sensing	40

AES Convergence Programs

AES Convergence Program CCP-1 Geology for PE / AG

AES Convergence Program CCP-3 Geology & Engineering for PE / RG

AES Convergence Program CCP-5 Geology, Geomechanics and Ethics for GE

AES1730	Introduction to Geotechnical Engineering	3
AESB1130	Geology 1: basics	5
CIE4420	Geohydrology 1	4

AES Convergence Program Choose one out of two

CIE4510	Climate Change: Science & Ethics	4
WM0312CIE	Philosophy, Technology Assessment and Ethics for CIE	4

AES Elective Courses

AES1050	GSE Student competition course	5
AES1370-12	Non-Thermal Enhanced and Improved Oil Recovery	3

AES1460	Heavy Oil	2
AES1470	Geothermics	2
AES1490	Advanced Reservoir Simulation	2
CIE4510	Climate Change: Science & Ethics	4

AES Annotations (Information see the Implementation Regulations 2016-2017)

AES Annotation Technology in Sustainable Development

AES Annotation Entrepreneurship

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Master 2016	
Introduction 1	For more information, please check the regulations: http://studenten.tudelft.nl/en/students/faculty-specific/ceg/regulations-ter-rules-and-guidelines/

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AES-PE&G Track Petroleum Engineering & Geosciences (PE&G)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-PE&G Specialisation Petroleum Engineering (PE&G-PE)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-PE&G Specialisation Petroleum Engineering 1st Year

AES0102	Image Analysis	1
Responsible Instructor	Dr. K.H.A.A. Wolf	
Contact Hours / Week x/x/x/x	x/0/0/0 3 to 4 afternoons per group	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Required for	AES1930	
Expected prior knowledge	. Knowledge about petrography and porous textures would be convenient. . Familiar with Excel and/or a comparable program for data handling and x,y-plots.	
Course Contents	Explanation of image analysis principles and techniques; practical exercises using applications from applied earth sciences, by means of a specialised computer program.	
Course Contents Continuation	Follow-ups are (AES1930) grain framework reconstructions and optional "final thesis" work in the lab oratory. Furthermore it is useful for users of the CT-Scanners.	
Study Goals	The MSc-student - becomes aware of the possibilities of Image Analysis as a general technical and scientific tool, - understands and is able to apply the typical image analysis way of thinking. - is able to insert this technique in the list of possible solutions to quantify texture problems during his graduate research work and in a future job; among others, working with CT-scan data.	
Education Method	Three half days computer aided practical exercises. Two students share one software licence.	
Course Relations	The course is a compulsory introduction for the advanced image analysis courses in the MSc-Petroleum Geology and MSc-Reservoir Engineering	
Literature and Study Materials	Introduction to Quantitative Image Analysis. Available on Blackboard.	
Prerequisites	Basic knowledge of petrography, petrology and/or mineralogy would be welcome. You are familiar with Excel and/or a comparable spreadsheet program for data handling and x,y-plots.	
Assessment	Attendance 100% and three final exercises with exercise elements from the complete course.	
Tags	Design Energy Fluid Mechanics Image processing Logics Matlab Practicals Software	
Expected prior Knowledge	Excel or a comparable spreadsheet program. In addition, some knowledge about sedimentary rocks, textures and porous media, would be welcome.	
Academic Skills	Basics for texture quantification. The image analysis results of a rock image are used for the development of grain and pore frameworks, fracture density distributions, permeability reconstructions and deviations in texture regularities.	
Literature & Study Materials	See Blackboard	
Judgement	Three assignments at the last day. Three image problems must be solved. If succeeded, the student has passed.	
Permitted Materials during Exam	No exam, a test.	
Collegerama	No	

AES1011	Matlab / Programming	2
Responsible Instructor	Dr.ir. D.S. Draganov	
Contact Hours / Week x/x/x/x	8-10 half day sessions	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Required for	1st-year MSc students Petroleum Engineering, Geosciences and Applied Geophysics.	
Expected prior knowledge	Prior knowledge of basic computer programming concepts (variable types, if-then-else structures, for loops, while loops, subroutines and functions etc.) No prior knowledge of MALTAB is required, but some prior exposure to another programming language (e.g. Fortran, C, C++, Basic) is expected.	
Course Contents	The aim of this course is to provide 1st-year MSc students Petroleum Engineering and Geosciences a working knowledge of the programming language MATLAB. The course is also meant to serve as a refresher of basis computer programming skills.	
Study Goals	* Refresh elementary concepts from computer programming. * Obtain skills to write simple programs in MATLAB.	
Education Method	Eight times four hours of scheduled self-study with supervision. Computer exercises.	
Assessment	Assignments.	
Tags	Matlab	
Expected prior Knowledge	BSc-level of algorithmic thinking	
Academic Skills	self-study	
Literature & Study Materials	all learning material is available on Blackboard	
Judgement	by last assignment	
Permitted Materials during Exam	N.A.	
Collegerama	No	

AES1300	Properties of Hydrocarbons & Oilfield Fluids	3
Responsible Instructor	Dr. D.V. Voskov	
Contact Hours / Week x/x/x/x	4/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Rock Fluid Physics (AES1310); Reservoir Engineering (AES1340) Production Optimisation (AES1360); Log Evaluation (AES1520)	
Expected prior knowledge	Knowledge of basic petroleum engineering or hydrology, macroscopic thermodynamics, calculus and Matlab.	
Course Contents	Physical-chemical properties of hydrocarbons and other subsurface fluids; classification of hydrocarbon systems encountered in oilfield operations; volumetric and phase behavior; z-factors; P-T diagrams; PVT- behavior; basic prototype reservoir and production engineering calculations.	
Study Goals	In this course the focus is on relating applications/correlations to fundamental understanding of processes/behavior. Therefore, the students first get acquainted with the most important physical-chemical properties of hydrocarbons and other oilfield fluids; then properties and correlations typically used in the oil and gas industry are introduced before the relations between these properties and correlations are explained.	
Education Method	In total 16 lectures of 2 hours. Lectures are divided into classical lecturers and practical lectures during which (computer) exercises will be done. A number of assignments including solutions is offered which can be done during the practicals or as homework.	
Computer Use	Matlab	
Literature and Study Materials	Lecture notes by Currie; modified and further elaborated by Guo; slides on Blackboard (BB); assignment with solutions on BB.	
Books	The Properties of Petroleum Fluids, by William D. McCain	
Reader	Slides are posted on BB, Study of the textbook is highly recommended.	
Assessment	80 % Closed-book exam 20% Assignments	
Permitted Materials during Tests	Closed-book exam.	
Enrolment / Application	Self-enrollment BB course	
Contact	Denis Voskov d.v.voskov@tudelft.nl	
Expected prior Knowledge	See expected prior knowledge above.	
Academic Skills	See expected prior knowledge above.	
Literature & Study Materials	See literature and study materials above.	
Judgement	80% written closed-book exam 20% Assignments	
Permitted Materials during Exam	Will be announced in class before exam.	

AES1304	Introduction to Petroleum Engineering and NAM Visit	3

Responsible Instructor	Prof.dr. P.L.J. Zitha
Contact Hours / Week x/x/x/x	(2 weeks).0.0.(3 days)
Education Period	1 4
Start Education	1
Exam Period	none
Course Language	English
Expected prior knowledge	BSc in Applied Earth Sciences or Other Specializations (Convergence Profile)
Summary	This course will provide students an overview of the Petroleum Industry and more specifically on the Petroleum Engineering discipline. It will cover oil and gas exploration and production business drivers, current industry status, engineering and economic aspects, technology, etc. It will also will survey the Petroleum Engineering issues that must be addressed for the development of an oil or gas field. An introduction of the main Petroleum Engineering disciplines that will be treated in-depth in MSc programme will be also be given.
Course Contents	An introduction to the upstream oil industry, with one week spent in Delft working on theory and group exercises and the second week spent at Shell Rijswijk and Assen at the NAM office. The first week introduces the basic concepts of the oil production process and the second week gives insight into the operation of a producing company, the philisophy of the company and the challenges faced by management.
Study Goals	- To obtain an overview of the key elements of the petroleum lifecycle - To obtain awareness of the industrial practice of an oil- and gas company. - To be confronted with the entrance level requirements for the MSc Petroleum Engineering -To get an overview of the remainder of the MSc Petroleum Engineering Master Courses
Education Method	Project Lectures and exercises (first week). Lectures and field visits (second week).
Computer Use	Yes
Course Relations	Comes before all other subjects in MSc
Literature and Study Materials	Handouts Optional: 1) Jahn, F., Cook, M. and Graham, M.: "Hydrocarbon Exploration and Production" Elsevier, 1998.
Prerequisites	Completed BSc
Assessment	Signed-off exercise and assessed reports and presentations
Remarks	The obligatory reports of the internship at the NAM will be assessed. For more information about the organization contact the instructor.
Expected prior Knowledge	BSc Applied Earth Sciences
Academic Skills	Presentation, Reporting
Literature & Study Materials	Lecture notes
Judgement	Presentations and reports
Permitted Materials during Exam	None
Collegerama	No

AES1310-10	Rock Fluid Physics	3
Responsible Instructor	Dr. H. Hajibeygi	
Contact Hours / Week x/x/x/x	Lectures: 6/0/0/0 Practical: 2/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Modeling Flow in Porous Media (AES1320); Applied Reservoir Engineering(AES1340); Reservoir Simulation (AES1350); Log Evaluation (AES1520)	
Expected prior knowledge	BSc in Engineering or Sciences. Basic knowledge on Matlab programing, Basic knowledge of Partial Differential Equations.	
Summary	Fundamentals of flow and transport of single- and multi-phase flow in porous media.	
Course Contents	Single phase flow - Introduction to rock fluid interactions - Darcy's law (Darcy's experiment, Relation with Navier-Stokes, heterogeneous media, anisotropic media) - Forchheimer equation - Slip factor - One-dimensional Upscaling (Averaging, Homogenization, Dykstra-Parson coefficient, Reservoir Simulation) - 1D Laminar incompressible fully developed flow in circular cylinder - 1D transient radial flow conditions - Well testing - Diffusion/Dispersion Effects Some basics on two-phase flow - Interfacial tension - Capillary pressure and wettability - Relative Permability - Multiphase flow and transport equations - Capillary end effect Lab-practical: - Darcy in heterogeneous soil	
Study Goals	1. Explain experimental and mathematical methods to measure porosity of a rock. 2. Obtain permeability of a rock sample, based on bundle of tubes (BOT) model. 3. Develop an experimental setup to measure and quantify permeability of a given sand-pack and verify their result with that obtained from Carman-Kozeny equation. 4. Solve mathematical formulations describing single-phase flow in 1D porous media, analytically. 5. Apply solutions to transient radial flow equation to predict reservoir properties. This is called well-testing study. 6. Apply Darcys law for laminar flows to relate velocity and pressure in porous media. 7. Apply non-Darcys correlations to relate velocity and pressure gradient, if the flow regime is not laminar. 8. Determine Peclet Number and mixing zone for a given solution plot of tracer concentration in a 1D porous media. 9. Apply J-function to relate capillary functions in different porous media. 10. Determine which relative permeability curve represents the flow of a phase in a two-phase flow in a given rock sample, based on its wettability and pore structure. 11. Obtain capillary pressure curve of a given sample, based on bundle of tubes (BOT) model.	
Education Method	The course consists of -at least- 26 h lectures. 5 computer classes of around 3 hours are planned to assist students with their HW assignments. One session of ~3 hrs should be booked for a practical lab course.	
Reader	Handouts, slides, and more references will be all posted on BB. Text book of Advanced Petrophysics by Prof. Ekwere Peters is recommended, but not required.	
Assessment	- Written exam (70%); - HW Assignments and Projects (20%), - Lab course (report & experimental part) (10%) At least 50% of (HW+Lab) must be obtained in order to sit for the exam. All HW assignments and Lab report delivery is per-requisit for passing the course.	
Permitted Materials during Tests	Closed book written exam	
Contact	H. Hajibeygi tel: 015 27 88482 Room: CT 3.25 Email: H.Hajibeygi@tudelft.nl	
Expected prior Knowledge	- Basic undergraduate courses on mathematics, linear algebra. - Basic knowledge of Matlab programming. - Good level of English. The course will be offered in English language only.	
Academic Skills	- Know how to write HW/project report (will be explained in the first session) - Be able to work with equations and solve 1D PDEs (will be practiced in the class, but knowing it will help a lot).	
Literature & Study Materials	Textbook of "Advanced Petrophysics" by Prof. Ekwere Peters is recommended, but not required.	
Judgement	Written exam (70%) + HW Assignments (20%) + Lab report (10%). At least 50% of (HW+Lab) must be obtained in order to sit for the exam. All HW assignments and the Lab report must be delivered in order to pass the course.	
Permitted Materials during Exam	None.	
Collegerama	No	

AES1320	Modelling of Fluid Flow in Porous Media	3
Responsible Instructor	Dr. D.V. Voskov	
Contact Hours / Week x/x/x/x	Lectures: 0/2/0/0; practical: 0/1/0/0 and 4 compu exc.	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Expected prior knowledge	Basic mathematics and statistics: WI1266ta, WI1228ta, WI1229ta,WI1230ta, WI1231ta, WI1275t, WI2034ta TA2090, chemieTA1200, Numerical analysis WI3097, Phys. Transport phenomena TN4780tu, wi2273ta, ta3000, image analysis introduction	
Summary	Fundamentals and modelling of multi-phase flow in porous media	
Course Contents	Two-phase flow: Buckley Levertt flow, Method of Characteristics, Gas Injection processes, Vertical Equilibrium, Segregated flow, Interface models, Dietz and Dake's approximations. Applications To discern important physical mechanisms that have a large impact on oil recovery. Interpretation of laboratory experiments e.g. for obtaining constitutive relations.	
Study Goals	The main purpose of this course is to understand the physics and modelling of two-phase flow and transport through porous media and particularly in the petroleum industry. The student learns to formulate the relevant transport problems and solve simple 1-D and 2-D problems with a Matlab as an experimental tool. Lab practical will provide insight in the physics of two-phase flow. The course forms the basis for the applied courses in the second year.	
Education Method	The course consists of lectures, computer exercises and 2 lab practicals.	
Literature and Study Materials	Lecture notes, papers posted on blackboard web site. Reference literature: Dake, L.P., Fundamentals of Reservoir Engineering, Elsevier (1978).	
Assessment	Grade consists of: Written exam (60%) (individual) and lab report (40%) (group). To pass the course all parts should be completed and the grade for the examn should at least be 5.	
Expected prior Knowledge	Basic mathematics and statistics: WI1266ta, WI1228ta, WI1229ta,WI1230ta, WI1231ta, WI1275t, WI2034ta TA2090, chemieTA1200, Numerical analysis WI3097, Phys. Transport phenomena TN4780tu, wi2273ta, ta3000, image analysis introduction	
Academic Skills	see expected prior knowledge.	
Literature & Study Materials	Lecture notes, papers posted on blackboard web site. Reference literature: Dake, L.P., Fundamentals of Reservoir Engineering, Elsevier (1978).	
Judgement	see assessment.	
Permitted Materials during Exam	students may bring a basic calculator (not programmable calculator or communication device) and a ruler	
Collegerama	No	

AES1330	Drilling & Production Engineering	4
Responsible Instructor	Prof.dr. P.L.J. Zitha	
Contact Hours / Week x/x/x/x	0/8/8/0	
Education Period	2 3	
Start Education	2	
Exam Period	3 4	
Course Language	English	
Expected prior knowledge	AES1304, AES1300, Matlab	
Summary	Drilling technology, drill string design, deviated drilling, fishing techniques, well control, coiled tubing, cementation, completions, artificial lift, perforating, sand control, well inflow performance, stimulation, production chemistry, surface facilities, pipelines	
Course Contents	This course covers the design, construction and operation of the wells and surface facilities through which oil and gas is produced. The emphasis is on practical and operational aspects, especially including during drilling and production operations, but it is grounded upon fundamental principles of Petroleum Engineering. Artificial lift, well productivity, formation damage and well stimulation (acidizing and fracturing) are part of the core of the programme of this course. Guest lecturers from the industry give some of the lectures. Laboratory experiments on drilling fluids form part of the course, together with the writing of a report on these experiments. A one day visit is made to a drilling rig and other facilities. Computer simulators are used to explain and design drilling operations, well completions and surface facilities, including a one-day exercise with a realistic well-control simulator.	
Study Goals	1. Understanding of methods of construction of wells and surface facilities, and safety issues. 2. Theoretical prediction of the most important factors in the design of wells and surface facilities. 3. Be able to do calculations needed for the design and and execution of artificial lift, well productivity, formation damage and well stimulation (acidizing and fracturing) operations. 3. Gain understanding of the fundamental aspects and practice of the main conventional and unconventional oil and gas production operations.	
Education Method	Lectures, exercises, computer simulations, laboratory experiments and site visits.	
Literature and Study Materials	Lecture notes	
Assessment	'Open-book' examinations, exercises, written reports and presentations.	
Permitted Materials during Tests	Lecture notes, lecturer handouts (old exams and exercises are forbidden)	
Expected prior Knowledge	Introduction to Petroleum Engineering, Rock-Fluid Physics, Single- and two-phase flow in porous media	
Academic Skills	Modeling aspects of well inflow performance and impact of formation damage and well stimulation.	
Literature & Study Materials	We provide lecture notes with bibliography and references.	
Judgement	Written exam, take home assignements	
Permitted Materials during Exam	Only lecture notes provided by us.	
Collegerama	No	

AES1340	Reservoir Engineering	2
Responsible Instructor	Dr. H. Hajibeygi	
Responsible Instructor	Dr. P.J. van den Hoek	
Contact Hours / Week x/x/x/x	Lectures: 0.0.2.0 + Practical: 0.0.6.0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Expected prior knowledge	AES1300, AES1310, AES1320	
Summary	Reserves, Well testing, displacement by water, enhanced oil recovery. The course is often offered by an invited external lecturer.	
Course Contents	Material balance calculations for oil and gas reservoirs, fundamentals of well testing and its analysis, displacement characteristics and sweep for waterfloods, stream line concept, fundamentals of EOR for gas, chemical and thermal methods.	
Study Goals	To understand the reservoir engineering methodology that is required to predict recovery from petroleum reservoirs.	
Education Method	Lectures, compulsory practice sessions and computer exercises.	
Literature and Study Materials	Lecture notes, papers and information provided on Blackboard.	
Assessment	exercises and written final examination. Practice session and computer exercises are compulsory. A student cannot pass the course without attending the practice sessions or getting an excuse from the instructor.	
Expected prior Knowledge	See expected prior knowledge above.	
Academic Skills	See expected prior knowledge and study goals above.	
Literature & Study Materials	See literature and study materials above.	
Judgement	Examination: Based on exercises and a written examination Credits: 2 ECTS	
Permitted Materials during Exam	Will be announced in class before exam.	
Collegerama	No	

AES1350	Reservoir Simulation	2
Responsible Instructor	Dr. H. Hajibeygi	
Contact Hours / Week x/x/x/x	Practical: 0.0.0.7	
Education Period	4	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	Partial differential equations (PDE), Basic knowledge about numerical methods, Prerequisite courses are: AES1300, AES1310, AES1320.	
Summary	In this course students develop their own 2D 2phase reservoir simulator, under different fluid physics (incompressible, slightly-compressible, and fully compressible).	
Course Contents	Classical numerical methods for the sequential and fully implicit solutions of PDEs describing flow and transport of components in heterogeneous and homogeneous oil reservoirs. Different formulations ranging from incompressible waterflood to 2phase compressible models are covered in this class. Numerical solutions of facilities, specially wells, are also discussed and practiced in the class.	
Study Goals	- Develop a single-phase flow (pressure and velocity) simulator for a 1D and 2D heterogeneous reservoir. - Develop a first-order upwind-based explicit and implicit saturation transport solver for a two-phase system with constant velocity. - Develop 1D and 2D IMPES simulator for 2phase systems. - Explain the fully implicit formulation for multiphase flow simulations and describe its advantages and disadvantages with respect to the IMPES strategy.	
Education Method	Lectures & computer exercises. Also, students should bring their laptops with themselves (if available) at the lectures. Computer exercises are in computer rooms (no laptop is necessary, but still recommended).	
Computer Use	Students should be familiar with MatLab software.	
Literature and Study Materials	Lecture notes, papers and information provided on Blackboard. Reference literature: Petroleum Reservoir Simulation, K.Aziz & A.Settari, ISBN 0-85334-787-5 (Recommended)	
Prerequisites	Parial differential equations, AES1300, AES1310, AES1320	
Assessment	Individually written scientific 3 reports based on the developed simulation assignments, along with oral defense for selective students. Last lecture session will be used for final exam (if taken).	
Expected prior Knowledge	- AES1300, AES1310, AES1320. - basic programming with Matlab. - basic knowledge of PDE's.	
Academic Skills	- AES1300, AES1310, AES1320. - basic programming with Matlab. - basic knowledge of PDE's.	
Literature & Study Materials	- All materials will be posted on BB. - Reference literature: Petroleum Reservoir Simulation, K.Aziz & A.Settari, ISBN 0-85334-787-5 (Recommended)	
Judgement	Examination: Based on exercises and possible oral defense (if required) as announced by the lecturer at start of the course. Final exam can also take place at the last lecture session. Credits: 2 ECTS	
Permitted Materials during Exam	- Developed simulators of individual students. - Computer. - No course materials will be allowed.	
Collegerama	No	

AES1360	Production Optimisation	3
Responsible Instructor	Prof.dr.ir. J.D. Jansen	
Contact Hours / Week x/x/x/x	Lectures: 0.0.0.3 + Practical: 0.0.0.7	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Required for	AES2009 Field development project	
Expected prior knowledge	AES1300 Properties of hydrocarbons and oilfield fluids AES1330 Drilling and production engineering Basic knowledge of physical transport phenomena Basic knowledge of ordinary differential equations Basic skills in Matlab programming	
Summary	This course aims at providing skills in the development and use of mathematical and computer models for flow through the various parts of an oil and gas production system. The underlying idea is that a basic understanding of the numerical implementation of theoretical concepts should be an important element in the education of all engineering students, even though only a few of them will become tool developers and most of them will just be users of software tools whose inner workings are hidden behind slick user interfaces.	
Course Contents	Nodal analysis of oil and gas wells. Topics include: A recap of production systems and properties of reservoir fluids, single-phase and multi-phase flow through pipes, restrictions and the near-well reservoir, oil well productivity. Six afternoons of computer practical form an obligatory part of the course.	
Study Goals	At the end of this course, the student should be able to demonstrate 1. skills in applying nodal analysis techniques to analyse and optimise wellbore flow in oil and gas production systems 2. skills in developing Matlab models of single-phase and multi-phase flow through the elements of an oil or gas production system 3. skills in performing simple oil and gas production engineering calculations using hand calculations 4. understanding of the concepts used in computer models for nodal analysis of oil and gas production systems 5. understanding of hydrocarbon phase behaviour and black- and volatile-oil models for use in production engineering calculations 6. understanding of single-phase and multi-phase models for flow through pipes, restrictions and the near-well reservoir	
Education Method	Lectures and computer practicals	
Literature and Study Materials	Jansen, J.D., 2017: Nodal analysis of oil and gas wells system modeling and numerical implementation. SPE Textbook Series. SPE, Richardson. This book is currently in production. If it is not yet available when the 2017 classes start, an author version will be handed out in class.	
Assessment	Written exam and signed-off MATLAB exercises	
Expected prior Knowledge	AES1300 Properties of hydrocarbons and oilfield fluids AES1330 Drilling and production engineering Basic knowledge of physical transport phenomena Basic knowledge of ordinary differential equations Basic skills in Matlab programming	
Academic Skills	Problem solving; programming	
Literature & Study Materials	Jansen, J.D., 2017: Nodal analysis of oil and gas wells system modeling and numerical implementation. SPE Textbook Series. SPE, Richardson. This book is currently in production. If it is not yet available when the 2017 classes start, an author version will be handed out in class. In addition an up-to-date collection of worked-out exam questions is available via Blackboard.	
Judgement	Written exam; obligatory Matlab exercises	
Permitted Materials during Exam	Jansen, J.D., 2017: Nodal analysis of oil and gas wells system modeling and numerical implementation. SPE Textbook Series. SPE, Richardson. This book is currently in production. If it is not yet available when the 2017 classes start, an author version will be handed out in class. No other materials are allowed during the exam.	
Collegerama	Yes	

AES1500	Fundamentals of Borehole Logging	4
Responsible Instructor	Dr. A. Barnhoorn	
Contact Hours / Week x/x/x/x	Lectures: 0.0.4.0 + Practical: 0.0.7.0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Summary	Principles, acoustic logging, VSP, seismic surveys, Electro-magnetic measurements, NMR, MRI	
Course Contents	Measurements in boreholes to determine petrophysical parameters comprise several disciplines. We can distinguish between such techniques as Density logging (porosity assessment) Sonic logging (porosity) Gamma ray (shale volume) Neutron, pulsed neutron (porosity) Resistivity (saturation, Archies law) Spontaneous potential (shale volume) Magnetic resonance imaging (MRI) Underlying physical principles are within the fields of acoustic and electromagnetic wave theory and solid state physics (radioactivity and relaxation phenomena). More specifically, wave equations for acoustic, elastic and poro-elastic media will be treated. Boundary conditions and reflection and transmision coefficients. Biot-Gassmann theory. Tortuosity and formation factor. Tube waves and Stoneley waves and their relation to formation permeability. The relation between acoustic and EM wave theory and the principles of MRI will be treated.	
Study Goals	This course is designed to teach the student the fundamentals of acoustic borehole logging in the way that the physical principles are understood and can be applied to borehole logging practice and related disciplines (VSP, seismic surveys, EM).	
Education Method	Lectures provided by a (temporary) staff member of the Petrophysics group.	
Literature and Study Materials	Lecture notes	
Assessment	written exam	
Expected prior Knowledge	earlier MSc AES courses	
Academic Skills	Integration, Interpretation, Critical Thinking	
Literature & Study Materials	Handouts & scientific papers	
Judgement	Exam (100%)	
Permitted Materials during Exam	non-graphical calculator, pens, pencils	
Collegerama	No	

AES1510	Geologic Interpretation of Seismic Data	3
Responsible Instructor	Drs. G. Diephuis	
Contact Hours / Week x/x/x/x	Lectures: 0.2.0.0 + Practical: 0.7.0.0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Expected prior knowledge	TA3520	
Summary	Seismic interpretation, resolution, generation of synthetic seismograms, well geophysics,seismic forward and inverse modelling, principles of the 3-D seismic method, structural interpretation, velocity modelling and time-to-depth conversion, seismic-stratigraphy in basin analysis, lithologic/quantitative interpretation, seismic attributes, time lapse (4D) seismic. Case histories	
Course Contents	The course intends to introduce seismic evaluation techniques as applied in industry. Since the PETREL package is used in the practice sessions, an introduction into its use will be given, together with a concise hand-out. Knowledge of the seismic fundamentals is needed, including principal aspects of acquisition and processing techniques. After a brief introduction/recapitulation of acquisition and processing, evaluation techniques will be presented along the lines of a generic workflow, starting with the generation of synthetic seismograms and its use of calibrating the seismic data to wells. This is followed by an introduction into interpretation techniques and by a methodical treatment of different tectonic styles and their appearance on seismic. In addition time will be spent on seismo-stratigraphic techniques and examples. Best-practice techniques will be discussed and rehearsed in the practical exercises for event identification and horizon and fault interpretation. Attention will be paid to time to depth conversion and well geophysics. Participants will be made aware of the principles of quantitative interpretation the effects of hydrocarbon fill. Finally some novel techniques will be dealt with summarily.	
Study Goals	- To provide an understanding of the nature of seismic information in the context of an integrated and multidisciplinary working environment as in the oil- and gas exploration- and production industry. - Being able to use seismic information for geological and/or exploration/production goals. - Become familiar with PETREL software	
Education Method	Block of lectures and practicals: Lectures and practical exercises are given interchangeably. PETREL software will be introduced	
Literature and Study Materials	Lecture notes, handouts, including selected chapters from textbooks.	
Assessment	written exam	
Expected prior Knowledge	Basic knowledge seismic method	
Academic Skills	BSc (Applied) Geosciences or Mathematics or Physics or Chemistry	
Literature & Study Materials	Will be provided in the course	
Judgement	The exam will be taken twice a year. The students understanding of all practical aspects of seismic interpretation is tested as well as the overview of the different types of interpretation tools, and their role in the whole sequence of data processing, reservoir exploration, exploitation and management. Attendance at the lectures and practicals is compulsory. Students are not allowed to participate in the exam if more than a single practical session is missed. Some practicals may count for the final mark. A limited number of bonus points can be earned	
Permitted Materials during Exam	Calculator	
Collegerama	Yes	

AES1520	Log Evaluation	2
Responsible Instructor	Dr. A. Barnhoorn	
Contact Hours / Week x/x/x/x	Lectures: 0/0/2/0 and practical: 0/0/2/0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Expected prior knowledge	AES1300, AES1310, AES1500	
Summary	Log evaluation, theory, practical applications, computer practice.	
Course Contents	The student will learn how to interpret various types of borehole logs. The course consists of a series of literature topics and related exercises to understand the methods and procedures which are needed to calculate the contents of, among others, rock pores and the rock matrix.	
Study Goals	Identify main factors that affect hydrocarbon exploration from borehole logging data. Analyse various types of borehole logs and gather recipes (relationships between parameters, cross-plots etc.) in the scientific literature for quantification of the borehole signatures. Integrate information of different borehole logs to compute rock and pore characteristics for all the important rock types within the borehole logs (especially seal, reservoir and source lithologies) Integrate sonics and advanced log evaluation techniques into log evaluation procedures Evaluate full potential of the logs for hydrocarbon exploration Assess uncertainties of your own conclusions and criticise your own outcomes Summarize, present and defend your case to your fellow students (they act as management committee of a major oil company)	
Education Method	Lectures and (computer) practicals	
Literature and Study Materials	Course notes and literature delivered by the lecturer during the course Reference literature Lecture notes and Blackboard Pages of TA3500 Schlumberger handbooks	
Assessment	Written exam at the end of course and 2 practical reports made in groups	
Remarks	none	
Expected prior Knowledge	Earlier MSc AES courses	
Academic Skills	Interpretation and Integration of Multiple datasets, critical thinking	
Literature & Study Materials	Lecture notes, papers, e-book chapters	
Judgement	20% Practical 1, 20% Practical 2, 60% Exam	
Permitted Materials during Exam	non-graphical calculator, pemcils, ruler and pen	
Collegerama	No	

AES1802	Geological Fieldwork	3
Responsible Instructor	Drs. J.C. Blom	
Contact Hours / Week x/x/x/x	Fieldwork (1 week)	
Education Period	4	
Start Education	4	
Exam Period	none	
Course Language	English	
Expected prior knowledge	TA2910, TA2911, TA2920, TA2921, TA3942, TA3610, AES1810, AES1820	
Course Contents	The outcrop training course will be held in Germany. The course will lead the participants through outcrop equivalents of all relevant reservoirs in the subsurface of The Netherlands and their specific development aspects. These comprise: fluvial reservoirs of the Carboniferous (including coals as source rock for gas), Rotliegend (proximal conglomerates, Aeolian and distal playa lake deposits), shallow marine carbonate reefs of the Zechstein, anhydrite caprock, Jurassic oil source rock, Lower Cretaceous shallow marine clastic Bentheim Sandstone (including oil source rock and cap rock) and Upper Cretaceous Chalk.	
Study Goals	To gain an understanding of geologic aspects and problems in the production of hydrocarbons, based on excersizes on real outcrops.	
Education Method	5 day Excursion The outcrops to be studied are in quarries, and for each outcrop a comprehensive programme of assignments is set up. This includes a description of the sedimentological setting, characterization of permeability baffles and conduits and the design of optimal well trajectories. The participants will write a short field course report about all these assignments (learning points only).	
Literature and Study Materials	Excursion guidebook will be handed out.	
Assessment	Written report, produced in groups, containing the learning points for the respective students.	
Enrolment / Application	Enrollment for this course will be done by sending an e-mail stating you want to participate to the excursion organiser, Jan Kees Blom (j.c.blom@tudelft.nl). Enrollment will be complete if and when a confirmation reply e-mail has been received by the student.	
Expected prior Knowledge	AES3820 Petroleum Geology AES1890 Sedimentary Systems AES1820-09 Reservoir Characterisation & Development	
Academic Skills	During the excursion we will visit a number of old quarries and natural outcrops, showing analogs for reservoir rocks in the Dutch subsurface. The students are asked to apply the knowledge of these reservoirs and geology in general to these outcrops in order to comprehend how these reservoirs may actually look in the subsurface. They are asked to analyse the outcrop in terms of suitable rock types and their distribution, synthese porosity and permeability data within these rocks and evaluate how they would produce from these rocks if they had been reservoirs in the subsurface.	
Literature & Study Materials	Excursion guide book will be handed out at the start of the excursion	
Judgement	Judgement will be based on the quality of the report.	
Permitted Materials during Exam	no exam	
Collegerama	No	

AES1820-09	Reservoir Characterisation & Development	4
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	lectures 0.0.0.2 + practical 0.0.0.7	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Course Contents	Reservoir characterization for field development prepares the student for the field development course. It discusses how geological models are used to make field development decisions: Where to drill development/infill wells; how to determine well productivity; how to assess block connectivity in a field; where to complete a well; how to determine cumulative probability estimates from the combination of geological uncertainties; how to prepare data for input into reservoir simulation; and how to develop a field in an economic viable way. In the beginning of the course there will be an overview of production geological concepts such that the participants are familiar with this methodology that now is almost entirely computer-based.	
Study Goals	Petroleum engineers and reservoir geologists need to know how to develop a field in an economically and technological appropriate way, including proper data acquisition, interpretation and uncertainty assessment of relevant field parameters.	
Education Method	A written examination will account for 50% of the final grade; performance during the practicals for the rest.	
Literature and Study Materials	All lecture presentations are made available on Blackboard. Reference literature: Book: Petroleum Geoscience by J. Gluyas and R. Swarbrick, Blackwell Publishing, 359 p. (this book is also used in a few other courses)	
Assessment	Examination: Written examination of 3 hours duration. Performance during practicals is taken into account for the final grade (50%). Presence during practicals will also be taken into account. Presence during lectures is required as otherwise topics need to be explained again during the practicals.	
Expected prior Knowledge	The course Petroleum Geology (AES 3820) is a requirement for this course.	
Academic Skills	Basic knowledge of geology, drilling and economics	
Literature & Study Materials	PPT online material	
Judgement	Yes	
Permitted Materials during Exam	A calculator (for calculating ONLY)	
Collegerama	No	

AES1890	Sedimentary Systems	3
Responsible Instructor	Dr. J.E.A. Storms	
Contact Hours / Week x/x/x/x	0.3.0.0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Course Contents	Introduction to principles and applications of Sequence Stratigraphy. Discussion of fluvial, deltaic, shallow-marine, and deep-marine siliciclastic systems, as well as a range of carbonate environments in a sequence-stratigraphic context. Discussion of the causes and effects of allogenic and autogenic perturbations on sedimentary systems. Application of sequence stratigraphy to problems of geological reservoir modelling and characterisation.	
Study Goals	1) To acquire a basic understanding of the vocabulary and application of sequence stratigraphy; 2) To acquire a basic understanding of the controls on depositional heterogeneity in a sequence-stratigraphic context.	
Education Method	lectures and self-study exercises	
Assessment	written exam	

AES1920	Geostatistics	2
Responsible Instructor	Dr.ir. F.C. Vossepoel	
Contact Hours / Week x/x/x/x	2.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Expected prior knowledge	Basic univariate and multivariate statistics	
Course Contents	This introductory course is intended as an overview of the principles of (geo)statistical interpolation and simulation. The course starts with a brief recapitulation of univariate and bivariate statistics, after which attention will be devoted to multivariate methods of classification and assignment. The section on data analysis serves as an introduction to the main topic of the course: modelling of spatial variability. Geostatistical concepts and methods (random variables, random functions, declustering, covariance, variograms, simple kriging, ordinary kriging, block kriging, indicator kriging, cokriging, object-based methods) will be discussed in the light of application to reservoir modelling. Throughout the course, the emphasis will be on understanding of the possibilities and limitations of the various techniques; mathematical derivations will be kept to a minimum. Special attention will be given to quantification of uncertainty and the application of stochastic simulation techniques. Stochastic simulation of equiprobable realisations of spatial variables will be discussed, as well as stochastic methods for testing of hypotheses.	
Study Goals	1) To acquire a general understanding of the range of statistical methods available for modelling of subsurface properties; 2) To select methods which are appropriate to the problem at hand, based on an awareness of their underlying assumptions and inherent limitations.	
Education Method	Lectures	
Assessment	Written exam	

AES1930	Quantification of Rock Reservoir Images	1
Responsible Instructor	Dr. K.H.A.A. Wolf	
Responsible for assignments	J.G. van Meel	
Contact Hours / Week x/x/x/x	4 afternoons	
Education Period	2	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Required for	MSc-students, first year.	
Expected prior knowledge	Introduction to Image Analysis (AES0102), introduction to Petrophysics (AESB3341 or AES1760), basic knowledge of Excel and statistics (i.e. frequency distributions).	
Parts	1	
Summary	The students learn how to obtain, interpret and calculate grain- and pore-frameworks from images of reservoir rock. This to identify 2D grain and pore size distributions and to reconstruct in a statistical way 3D, porosity-, permeability- and capillary distributions.	
Course Contents	Image analysis on reservoir rock; theory and practice. Porous networks and grain frameworks are characterized and quantified in order to acquire parameters for permeability calculation, pore-network development and flow modelling.	
Study Goals	The student learns to work with images of pores and related grain-frameworks. Image quantification is used to create a database that for 3D reconstruction. In addition, various analysis pitfalls are discussed. The results porosity, permeability and capillary results can be used for (Monte Carlo)flow modelling, prediction of capillary behaviour, and as a first step to 3D CT-scan image analysis.	
Education Method	Computer: Qwin image analysis systems and Excel.	
Computer Use	Yes	
Course Relations	Rock-fluid interaction, reservoir modelling, various andvanced courses in Petrophysics.	
Literature and Study Materials	On Blackboard	
Practical Guide	On Blackboard	
Books	No	
Reader	On Blackboard	
Prerequisites	AES0102, AESB3341 or AES1760	
Assessment	100 % attendance and a report	
Exam Hours	No	
Permitted Materials during Tests	-	
Enrolment / Application	Enrol on Blackboard	
Special Information	None	
Remarks	None	
Tags	Analysis Circuits Databases Design Fluid Mechanics Geo Engineering Geology Image processing Practicals Stochastics	
Contact	k.h.a.a.wolf@tudelft.nl	
Expected prior Knowledge	Introduction to Image Analysis (AES0102) and Introduction to Petrophysics (AESB3341 or AES1760).	
Academic Skills	The student learns to work with images of pores and related grain-frameworks. Image quantification is used to create a database that for 3D reconstruction. In addition, various analysis pitfalls are discussed. The results porosity, permeability and capillary results can be used for (Monte Carlo)flow modelling, prediction of capillary behaviour, and as a first step to 3D CT-scan image analysis.	
Literature & Study Materials	Blackboard	
Judgement	Report	
Permitted Materials during Exam	-	
Collegerama	No	

AES3820	Petroleum Geology	3
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	2/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Expected prior knowledge	General Geology, Fluid Flow in Rocks	
Summary	Organic Rocks, Maturation, Migration, Reservoir Rocks, Seals, Traps, Exploration, Production.	
Course Contents	This course gives an overview of the conditions that are necessary for oil and gas to accumulate in reservoirs. This is first illustrated in concepts and then in a few relevant case studies. The life of a reservoir is discussed from initial basin studies to exploration, appraisal development and finally abandonment. The task of the petroleum geologist during these various phases is illustrated, as well as his interaction with other disciplines such as reservoir engineering, geophysics, and petrophysics. Material on hand includes among others cores, logs and seismic lines.	
Study Goals	The objective of this course is to give the student a thorough introduction into petroleum geology.	
Education Method	The course consists of lectures. Some exercises and hands-on practicals may be included.	
Literature and Study Materials	Gluyas J. & Swarbrick R. (2004) Petroleum Geosciences. Blasckwell Publishing.	
Assessment	Written exam	
Expected prior Knowledge	Basic geology	
Academic Skills	General academic skills	
Literature & Study Materials	Online material and collegerama	
Judgement	Yes	
Permitted Materials during Exam	Calculators for calculations ONLY	
Collegerama	Yes	

WI4012ta	Mathematics, Special Subjects	4
Responsible Instructor	Dr.ir. M.B. van Gijzen	
Contact Hours / Week x/x/x/x	x/x/x/x	
Education Period	2	
Start Education	2	
Exam Period	Exam by appointment	
Course Language	English	
Course Contents	A number of partial differential equations will be discussed that are of interest in technical applications. The Laplace equation will be treated as an example of an equilibrium in incompressible ground water flow. Examples of time dependent problems that will be discussed are the wave equation, the convection-diffusion equation and the transport equation. As discretization techniques the Finite Difference, Finite Volume and Finite Element Method will be treated.	
Study Goals	To understand and to be able to apply the discussed numerical methods and to estimate the error in the calculations. To be able to assess the quality of a numerical simulation.	
Education Method	Lectures and computer assignment	
Literature and Study Materials	Numerical Methods in Scientific Computing by J. van Kan, A. Segal and F. Vermolen (VSSD, 2005). http://www.vssd.nl/hlf/a002.htm	
Assessment	Take home assignments and computer assignment in combination with an oral exam	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-PE&G PE Electives (5 EC)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-PE&G Specialisation Petroleum Engineering 2nd Year

AES2009	Field Development Project	9
Responsible Instructor	Prof. W.R. Rossen	
Instructor	Prof.dr.ir. J.D. Jansen	
Instructor	P.R.A. Betts	
Instructor	Drs. J.C. Blom	
Instructor	Drs. G. Diephuis	
Instructor	Drs. A.A. Sieders	
Instructor	Ir. W.J.A.M. Swinkels	
Contact Hours / Week x/x/x/x	6 weeks design project	
Education Period	1	
Start Education	1	
Exam Period	none	
Course Language	English	
Summary	Field development process from appraisal to full field development	
Course Contents	On the basis of real field data, the whole field development process will be passed through from appraisal to full field development. Specific knowledge acquired in earlier courses(geophysics, petrophysics, geology, reservoir technology, drilling and production technology) will be used to set up and execute a field development program using seismic, petrophysical and reservoir data. A field development plan will be developed and presented to a management panel.	
Study Goals	The application of acquired knowledge on a realistic field study. - Gaining an overview of the interaction between the specialist disciplines in petroleum engineering. - Learning to deal with inaccuracy and uncertainty. - Working in a multidisciplinary team	
Education Method	Project, working in teams	
Literature and Study Materials	Handouts and lecture notes of previous courses and Reference literature	
Prerequisites	1. Students may not take AES2009 until they have completed the Bachelor of Science programme. 2 Students who have been admitted to the MSc program on the basis of a Dutch higher vocational institute Bachelor degree, and were assigned a subsidiary programme of courses for the MSc degree, must have completed this programme before they are allowed to take AES2009. 3. Students may not take AES2009 until they have completed a total of 19 ECTS from the following courses of the core programme: Properties of Hydrocarbons (AES1300), Rock Fluid Physics (AES1310), Modelling of Fluid Flow in Porous Media (AES1320), Geologic Interpretation of Seismic Data (AES1510), Log Evaluation (AES1520), Sedimentary systems (AES1890), Production Geology (AES1810)*, Reservoir Engineering (AES1340), Geostatistics (AES1920)** and Reservoir Characterisation and Development (AES1820* or AES1820-09**). Additionally, students with the specification 'Petroleum Engineering' are recommended to have completed the courses Drilling and Production (AES1330) and Production Optimisation (AES1360). Please note, though, these two additional courses do not count toward the required total of 20 ECTS. * for students who started fall 2009 or earlier; ** for students who started fall 2010 or later	
Assessment	Assessment will be in groups. A Field Development Report will be written by each group, and presented to a Panel. This project takes 6 consecutive weeks.	
Remarks	Students must attend all class sessions except in exceptional circumstances with prior approval of instructor.	
Expected prior Knowledge	See prerequisites.	
Academic Skills	See prerequisites.	
Literature & Study Materials	Materials posted on Blackboard site.	
Judgement	Grades are based on the oral presentation at the conclusion of the course (1/3) and the written report (2/3).	
Permitted Materials during Exam	Grades are based on the oral presentation on the last day of the course and the written report. There is no final exam.	
Collegerama	No	

AESM2006	Final Thesis Petroleum Engineering	45
Responsible Instructor	Prof. W.R. Rossen	
Contact Hours / Week x/x/x/x		
Education Period	None (Self Study)	
Start Education	1 2 3 4 5	
Exam Period	Different, to be announced Exam by appointment	
Course Language	English	
Course Contents	Research on topic selected with a approval of staff supervisor. Written report and oral presentation.	
Study Goals	In-depth research into an aspect of field of study relevant to MSc. Demonstrate analytical ability, independence, judgment, and ability to communicate in speaking and in writing.	
Education Method	Independent research, supervised by staff member with, possibly, daily supervision by a PhD student.	
Assessment	A committee reads the thesis, attends a public persentation of the results, amd questions the student. The committee awards a grade according to criteria decided by the Exam Committee.	
Expected prior Knowledge	Curriculum of the MSc.	
Academic Skills	Knowledge of the field of study, independence and judgment in research.	
Literature & Study Materials	Varies.	
Judgement	A committee reads the thesis, attends a public persentation of the results, amd questions the student. A grade is awardede according to criteria decided by the Exam Committee.	
Permitted Materials during Exam	Not applicable.	
Collegerama	No	

AES-PE&G PE Electives (5 EC)

AES1050	GSE Student competition course	5
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	na	
Education Period	1 2 3 4	
Start Education	1 2 3 4 5	
Exam Period	none	
Course Language	English	
Course Contents	The GSE Student Competition Course is a platform offered to encourage and stimulate participation of teams of students to high level scientific competitions which can be within TUDelft, national or international. The GSE Student Competition Course provides a workflow which participants are required to follow in order to be eligible for the 5EC associated with the course. The workflow is as follows 1) the team intending to participate to the competition writes a motivation letter which includes, among others, i) a description of the competition ii) the expected added value for the educational growth of the students iii) a motivation statement from all members of the team and iv) the name of a technical advisor in charge of the daily supervision of the participating team. If costs are involved in the participation, the letter should also include information on how these will be covered. The letter is evaluated by the Course responsible and two other GSE staff members (Prof. Dr. B. Rossen and Dr. G. Drijkoningen) and participation is approved/rejected. The way the participation will be graded is also discussed and agreed upon at this stage At the end of the competition, the participating team will submit a short report describing the activities and experiences made during the competition itself. The technical advisor proposes a grade which is then discussed with the three staff members responsible of the Course.	
Study Goals	The goal of the GSE Student Competition Course is to improve technical knowledge and strengthen the group working skills of the participating team. Upon succesful completion of the competition, the participating students will have learned a variety of technical tools (depending on the type of competition) and will be able to work in a small team under time and competition pressure to present their results in a competitive arena in front of an external jury	
Education Method	Learning through competition	
Assessment	The pass/no pass boundary and the grading will depend on the type of competition and will be discussed prior to the start of the competition itself	
Expected prior Knowledge	Expected prior knowledge depends very much on the competition. Because only scientifically challenging competitions will be considered, only MSc students will be allowed with a strong background. Intrinsic in the idea of a competitive team, the participants will have different backgrounds (geophysics, engineering, geology etc)	
Academic Skills	Key to success and, therefore to earning the 5EC is the ability to form a real team during the competition. The necessary first step of this process is the ability of putting together a winning team composed of experts also able to work together. The value of strong cooperation will only increase during the competition	
Literature & Study Materials	will depend on the specific compeititons	
Judgement	The technical advisor (if present) will propose a grade to the staff members responsible of the course; these will have the final decision.	
Permitted Materials during Exam	no exam in the classical sense of the term is foreseen the assessment will be based on the report presented by the participating team and on insights provided by the technical advisor	
Collegerama	No	

AES1370-12	Non-Thermal Enhanced and Improved Oil Recovery	3
Responsible Instructor	R. Farajzadeh	
Contact Hours / Week x/x/x/x	5 days	
Education Period	4	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	AES1310-10, 1320 and 1340 (Rock Fluid Physics, Modelling of fluid flow in porous media and Reservoir Engineering).	
Course Contents	This course provides a survey of analytical models for EOR processes; a brief discussion of numerical simulation of EOR; waterflooding and enhanced waterflooding; miscible and immiscible gas EOR; and chemical EOR. The course covers methods of recovery for target reservoirs distinct from those in AES1460, Heavy Oil.	
Study Goals	Students will learn simple analytical tools for modeling a variety of EOR processes, and learn about the specific processes of enhanced waterflooding, miscible and immiscible gas EOR; and chemical EOR.	
Education Method	Excersises will be handed out and collected on each of the five days.	
Assessment	Course grade will be the average of the daily score from the exercises.	

AES1460	Heavy Oil	2
Responsible Instructor	Prof.ir. C.P.J.W. van Kruijsdijk	
Contact Hours / Week x/x/x/x		
Education Period	3	
Start Education	3	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	With the conventional oil and gas reserves declining, the industry is looking at unconventional resources to fill the upcoming production gap. Unconventional resources comprise of tight gas, shale gas and gas hydrates as well as shale oil and (extra) heavy oil. This course will focus on the (extra) heavy oil resources such as the extensive deposits in Canada and Venezuela.	
Study Goals	To understand the nature of heavy oil and the methods of heavy-oil recovery; to research one particular method in detail.	
Education Method	The course will consist of 4 sets of lectures plus an independent research paper to be researched and written by the student.	
Assessment	Instead of a written exam, each participant will be required to write a critical assessment of a heavy oil recovery method of choice.	

AES1470	Geothermics	2
Responsible Instructor	Prof.dr. D.F. Bruhn	
Contact Hours / Week x/x/x/x	0/0/0/4	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Required for	MSc	
Expected prior knowledge	Technical or Geoscience and Engineering background	
Course Contents	Scope: Due to the growing interest for sustainable energy production, CTG offers an introductory course on geothermal energy. The course covers the following subjects: - Sources and renewability, - Geology of geothermal reservoirs, - Geothermal energy production technologies, - Physics of heat and mass transfer in the porous rock, - Geochemical aspects, - Exergy aspects, - Geothermal reservoir management, - Current state of development. During the course, the participants are familiarized with: The environmental and technological issues of geothermal energy exploitation and the effect of physical and chemical factors on the geothermal reservoir porosity and permeability. A groupwork is the final part of the course: Participants choose a topic and write a report which will be discussed after circa six or seven lectures of 2 to 4 hours.	
Study Goals	Getting acquainted with the (geo-)technical aspects of the development of a geothermal infra-structure.	
Education Method	THIS COURSE IS MERGED WITH THE PRACTICALS AND LECTURES FOR: 1. THE RESEARCH SCHOOL GEOTHERMAL LECTURES AND PRACTICALS, AND, 2. THE SUSTAINABLE ENERGY AND TECHNOLOGY GEOTHERMAL COURSE (Lectures combined with practicals).	
Literature and Study Materials	Blackboard.	
Practical Guide	Blackboard.	
Assessment	Group assignment and report.	
Exam Hours	None: one afternoon presentations and report discussion.	
Enrolment / Application	Blackboard or the secretary of the Department of Geoscience and Engineering	

AES1490	Advanced Reservoir Simulation	2
Responsible Instructor	Prof.dr.ir. J.D. Jansen	
Contact Hours / Week x/x/x/x	0/2/0/0 + 7 pr	
Education Period	2	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	To successfully complete this course you are supposed to start with a basic knowledge of differential equations, linear algebra and numerical analysis. For Applied Earth Sciences students it is preferred that you have successfully completed the courses AES1340/1350 (Applied reservoir engineering and simulation, Parts 1 & 2). For students without a background in reservoir engineering it is possible to attend but you will be required to do some additional reading to familiarize yourself with the subject matter.	
Parts	Elements of systems and control theory as applied to reservoir simulation (e.g. recovery optimization, computer-assisted history matching, model reduction). Multi-scale reservoir simulation. Compositional reservoir simulation.	
Course Contents	This elective course covers advanced topics in reservoir simulation and optimization. The former addresses the main challenges in the state-of-the-art simulators for multi-phase flow in realistic oil reservoirs. Topics of interests include multi-scale and iterative multi-scale methods, but depending on the need of students it will include upscaling, Adaptive-Implicit-Methods, Automatic Differentiation, and CPR-based solvers for fully implicit systems. The application of systems and control theory to the flow of fluids in oil or gas reservoirs will be covered in the second part of the course. Moreover, compositional simulation and geo-mechanics may form part of the material. The course format is dynamically adjusted during the course period depending on the needs, wishes and capacities of the students enrolled. The course material exists of a textbook, journal and conference papers, and printed lecture notes.	
Study Goals	Explain challenges related to flow and transport equations for realistic oil reservoirs. Develop a 1D multiscale flow simulator, and analyze its performance. Develop a 1D compositional non-isothermal simulator and perform the numerical convergence study for condensing and vaporizing gas drive. Provide an introduction to the use of system analysis techniques for reservoir management. Provide the background knowledge required to perform MSc thesis work in the area of closed-loop reservoir management, also known as smart fields.	
Education Method	Lectures, discussions, reading exercises, Matlab exercises	
Literature and Study Materials	J.D.Jansen: "A systems description of flow through porous media", Springer, 2013 Electronically available for TU Delft affiliates via the TU Delft Library J.D.Jansen: "Gradient-based optimization of flow through porous media". Lecture notes via Blackboard H. Hajibeygi: Iterative Multiscale Finite Volume Method for Multiphase flow in Porous Media with Complex Physics, ETH Zurich, 2011 (Available for free to the public: http://dx.doi.org/10.3929/ethz-a-006696714). D.V.Voskov Thermal-compositional simulation, lecture notes via BlackBoard	
Assessment	Oral exam or delivery of a project (upon prior agreement with individual students)	
Special Information	This course is jointly taught by Dr. H. Hajibeygi (Multiscale simulation), Dr. D.Voskov (Compositional simulation) and Prof. J.D. Jansen (Reservoir Systems and Control)	
Remarks	This elective course is primarily intended for 2nd-year MSc students who are performing MSc thesis work in the area of reservoir simulation and 'smart fields'. However, anyone interested in advanced reservoir simulation topics, especially if he/she is a PhD student working on reservoir simulation or optimization (smart fields), is welcome to join. Over the past years, the course was attended by several students and researchers from Applied Earth Sciences (CiTG), Mathematics (EWI) and Systems & Control (3me).	
Expected prior Knowledge	To successfully complete this course you are supposed to start with a basic knowledge of differential equations, linear algebra and numerical analysis. For Applied Earth Sciences students it is preferred that you have successfully completed the courses AES1340/1350 (Applied reservoir engineering and simulation, Parts 1 & 2). For students without a background in reservoir engineering it is possible to attend but you will be required to do some additional reading to familiarize yourself with the subject matter.	
Academic Skills	Problem solving; analysis	
Literature & Study Materials	J.D.Jansen: "A systems description of flow through porous media", Springer, 2013 Electronically available for TU Delft affiliates via the TU Delft Library J.D.Jansen: "Gradient-based optimization of flow through porous media". Lecture notes via Blackboard H. Hajibeygi: Iterative Multiscale Finite Volume Method for Multiphase flow in Porous Media with Complex Physics, ETH Zurich, 2011 (Available for free to the public: http://dx.doi.org/10.3929/ethz-a-006696714). D.V.Voskov Thermal-compositional simulation, lecture notes via BlackBoard	
Judgement	Oral exam	
Permitted Materials during Exam	To be discussed with relevant lecturer prior to exam.	
Collegerama	No	

AES1760	Introduction to Log Evaluation	1
Responsible Instructor	Dr. K.H.A.A. Wolf	
Contact Hours / Week x/x/x/x	5 afternoons	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	All MSc-students who didn't receive courses in open hole log evaluation.	
Expected prior knowledge	Maths, physics, chemistry basics.	
Course Contents	Crash course log-evaluation for non-geoscientists	
Course Contents Continuation	MSc-petrophysics courses and the Field development program.	
Study Goals	Learning the basics of log-evaluation.	
Education Method	Lectures combined with practicals.	
Computer Use	Wifi available. Courses on Blackboard. All assignments and lecture notes are on Blackboard.	
Literature and Study Materials	Blackboard	
Practical Guide	Blackboard	
Prerequisites	BSc-diploma	
Assessment	Written test/exam.	
Tags	Analysis Calculus Drawing Energy Geo Engineering Geology Practicals Technology	
Contact	Karl-Heinz Wolf ____________________________ Dr. K-H.A.A. Wolf Associate Professor in Petrophysics Head of the Geoscience & Engineering Laboratory TU Delft / Department of Geoscience & Engineering Stevinweg 1, 2628 CN, Delft POB 5028, 2600 GA Delft The Netherlands. Office: +31 (0) 152 786 029 Mobile: +31 (0) 648 875 958 E-mail: k.h.a.a.wolf@tudelft.nl	
Expected prior Knowledge	BSc knowledge on physics, maths, chemistry. If possible the student is familiar with the basic knowledge of geology, petrography and mineralogy.	
Academic Skills	The knowledge here obtained helps the student to measure and quantify data on rocks, fluids and porous media for the use in theoretical and practical questions regarding reservoir-geology/engineering, rock/soil mechanics, geophysics and production engineering.	
Literature & Study Materials	See Blacboard	
Judgement	Open book exam, written.	
Permitted Materials during Exam	(colour) pencil, marker, simple calculator, ruler, geometric triangle. All info available on Blackboard for this course.	
Collegerama	No	

AESM1805	Regional Geology Field Trip	1
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	x/4 hours preparation, 1 week excursion and 3 days reporting/x/x	
Education Period	3	
Start Education	3	
Exam Period	3	
Course Language	English	
Expected prior knowledge	General Geology Fieldwork Vesc	
Summary	Traversing a variety of geological settings, the excursion through the High Atlas of Morocco and adjacent domains forms a unique opportunity for students to get acquainted with a variety of geological tools and notions fundamental for their career in Industry and Academia	
Course Contents	The course consists of an excursion across the High Atlas of Morocco and adjacent regions. The excursion involves a combination of analytical tools (from seismic analysis to rock description) and addresses a variety of geological settings (from extension to contraction, from carbonate systems to fluviatiles and deep water sediments). More in detail, the excursion will analyse the building of the High Atlas, the evolution of the terrigenous system prior to and during rifting, the history of extension and the associated carbonate system and various types of deformation structures (folding, faulting and diapirism). During the excursion a constant link will be developed between fundamental knowledge and applied issues, especially those related to hydrocarbons.	
Study Goals	Having followed successfully the excursion, the student will be able to identify the main features of mountain building and extensional tectonics leading to passive continental margin formation. He/she will be able to define sedimentary systems both in the fluviatile and the carbonate domain. Eventually, the student will be able to provide geological content to geophysical images from the subsurface.	
Education Method	The excursion is preceded by a theoretical class in which the important geological and educational features of the excursion are presented. The excursion itself is developed along two parallel lines, one dedicated to the quantitative understanding of the regional geology, the other one focussing on specific observations such as sedimentology and structural geology. During the second one, students are asked to perform some specific exercises and analyses in the field.	
Literature and Study Materials	Hand outs and literature distributed during the preparation of the excursion	
Assessment	The students are judged on the basis of their motivation and engagement during the excursion (20%), the fieldbook which they will hand in a few days after the excursion (30%), and the answers to the exercises proposed in the field and organized in a series of deliverables (50%).	
Expected prior Knowledge	General Geology - Fieldwork Vesc	
Academic Skills	Ability to read multiscale outcrops and extract geologic information - ability to find answers to geological problems relevant for hydrocarbon exploration and production	
Literature & Study Materials	hand outs and papers provided	
Judgement	attitude in the field, ability to collect notes and to extract geologically relevant information from the discussions during the excursion	
Permitted Materials during Exam	no exam will take place	
Collegerama	No	

AESM2604	Geothermal Field Trip	2
Responsible Instructor	Prof.dr. D.F. Bruhn	
Contact Hours / Week x/x/x/x	full 7 days week (66 hours), period is different each year depending on the destination	
Education Period	4 Different, to be announced	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	BSc in Earth Sciences or Process Engineering Target group are PhD candidates and MSc students with a particular interest in geothermal energy.	
Course Contents	Participants are going to see various steps and sites of geothermal power production in Iceland, learn about historical as well as about modern energy production technologies from geothermal heat. We will visit a modern geothermal power station at Hellisheiði, located near Hengill volcano in southwest Iceland. The plant has a capacity of 303 MW of electricity and 400 MW of hot water. Students will learn about the development of geothermal power production: from investigating the geological system to power conversion. Depending on industry developments, we will visit a deep geothermal drill site, most likely in the south-western part of Iceland. The geology of the region will be explored, including Þingvellir National Park in the rift valley between the North American and Eurasian Plates. Participants will geothermal surface manifestations such as the famous Strokkur geyser and investigate exhumed geothermal systems in Geitafell, South Iceland.	
Study Goals	-At the end of this course, the student knows the development of geothermal power production. -The student can explain the general challenges and modern approaches to geothermal power. -The student can describe and recognize classic geothermal surface manifestations. -The student is able to describe and characterize hydrothermal mineralisations in rocks. -The student is able to characterize the basic features of the subsurface geothermal system.	
Education Method	One week in the field in Iceland. 1 preparatory seminar Seminar with students presentations on a topic preparing the field trip.	
Course Relations	AES1305SET Geothermal Energy and Applications	
Assessment	Seminar presentation + report Each student has to give a seminar presentation of 10 minutes Each student has to write a report on the field trip. Report must include daily field notes, and explanation of observations. Evaluation is based on completeness and demonstrated understanding of course content.	
Remarks	Good shoes, rock hammer, compass.	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-PE&G Specialisation Reservoir Geology (PE&G-RG)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-PE&G Specialisation Reservoir Geology 1st year

AES0102	Image Analysis	1
Responsible Instructor	Dr. K.H.A.A. Wolf	
Contact Hours / Week x/x/x/x	x/0/0/0 3 to 4 afternoons per group	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Required for	AES1930	
Expected prior knowledge	. Knowledge about petrography and porous textures would be convenient. . Familiar with Excel and/or a comparable program for data handling and x,y-plots.	
Course Contents	Explanation of image analysis principles and techniques; practical exercises using applications from applied earth sciences, by means of a specialised computer program.	
Course Contents Continuation	Follow-ups are (AES1930) grain framework reconstructions and optional "final thesis" work in the lab oratory. Furthermore it is useful for users of the CT-Scanners.	
Study Goals	The MSc-student - becomes aware of the possibilities of Image Analysis as a general technical and scientific tool, - understands and is able to apply the typical image analysis way of thinking. - is able to insert this technique in the list of possible solutions to quantify texture problems during his graduate research work and in a future job; among others, working with CT-scan data.	
Education Method	Three half days computer aided practical exercises. Two students share one software licence.	
Course Relations	The course is a compulsory introduction for the advanced image analysis courses in the MSc-Petroleum Geology and MSc-Reservoir Engineering	
Literature and Study Materials	Introduction to Quantitative Image Analysis. Available on Blackboard.	
Prerequisites	Basic knowledge of petrography, petrology and/or mineralogy would be welcome. You are familiar with Excel and/or a comparable spreadsheet program for data handling and x,y-plots.	
Assessment	Attendance 100% and three final exercises with exercise elements from the complete course.	
Tags	Design Energy Fluid Mechanics Image processing Logics Matlab Practicals Software	
Expected prior Knowledge	Excel or a comparable spreadsheet program. In addition, some knowledge about sedimentary rocks, textures and porous media, would be welcome.	
Academic Skills	Basics for texture quantification. The image analysis results of a rock image are used for the development of grain and pore frameworks, fracture density distributions, permeability reconstructions and deviations in texture regularities.	
Literature & Study Materials	See Blackboard	
Judgement	Three assignments at the last day. Three image problems must be solved. If succeeded, the student has passed.	
Permitted Materials during Exam	No exam, a test.	
Collegerama	No	

AES1011	Matlab / Programming	2
Responsible Instructor	Dr.ir. D.S. Draganov	
Contact Hours / Week x/x/x/x	8-10 half day sessions	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Required for	1st-year MSc students Petroleum Engineering, Geosciences and Applied Geophysics.	
Expected prior knowledge	Prior knowledge of basic computer programming concepts (variable types, if-then-else structures, for loops, while loops, subroutines and functions etc.) No prior knowledge of MALTAB is required, but some prior exposure to another programming language (e.g. Fortran, C, C++, Basic) is expected.	
Course Contents	The aim of this course is to provide 1st-year MSc students Petroleum Engineering and Geosciences a working knowledge of the programming language MATLAB. The course is also meant to serve as a refresher of basis computer programming skills.	
Study Goals	* Refresh elementary concepts from computer programming. * Obtain skills to write simple programs in MATLAB.	
Education Method	Eight times four hours of scheduled self-study with supervision. Computer exercises.	
Assessment	Assignments.	
Tags	Matlab	
Expected prior Knowledge	BSc-level of algorithmic thinking	
Academic Skills	self-study	
Literature & Study Materials	all learning material is available on Blackboard	
Judgement	by last assignment	
Permitted Materials during Exam	N.A.	
Collegerama	No	

AES1300	Properties of Hydrocarbons & Oilfield Fluids	3
Responsible Instructor	Dr. D.V. Voskov	
Contact Hours / Week x/x/x/x	4/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Rock Fluid Physics (AES1310); Reservoir Engineering (AES1340) Production Optimisation (AES1360); Log Evaluation (AES1520)	
Expected prior knowledge	Knowledge of basic petroleum engineering or hydrology, macroscopic thermodynamics, calculus and Matlab.	
Course Contents	Physical-chemical properties of hydrocarbons and other subsurface fluids; classification of hydrocarbon systems encountered in oilfield operations; volumetric and phase behavior; z-factors; P-T diagrams; PVT- behavior; basic prototype reservoir and production engineering calculations.	
Study Goals	In this course the focus is on relating applications/correlations to fundamental understanding of processes/behavior. Therefore, the students first get acquainted with the most important physical-chemical properties of hydrocarbons and other oilfield fluids; then properties and correlations typically used in the oil and gas industry are introduced before the relations between these properties and correlations are explained.	
Education Method	In total 16 lectures of 2 hours. Lectures are divided into classical lecturers and practical lectures during which (computer) exercises will be done. A number of assignments including solutions is offered which can be done during the practicals or as homework.	
Computer Use	Matlab	
Literature and Study Materials	Lecture notes by Currie; modified and further elaborated by Guo; slides on Blackboard (BB); assignment with solutions on BB.	
Books	The Properties of Petroleum Fluids, by William D. McCain	
Reader	Slides are posted on BB, Study of the textbook is highly recommended.	
Assessment	80 % Closed-book exam 20% Assignments	
Permitted Materials during Tests	Closed-book exam.	
Enrolment / Application	Self-enrollment BB course	
Contact	Denis Voskov d.v.voskov@tudelft.nl	
Expected prior Knowledge	See expected prior knowledge above.	
Academic Skills	See expected prior knowledge above.	
Literature & Study Materials	See literature and study materials above.	
Judgement	80% written closed-book exam 20% Assignments	
Permitted Materials during Exam	Will be announced in class before exam.	

AES1310-10	Rock Fluid Physics	3
Responsible Instructor	Dr. H. Hajibeygi	
Contact Hours / Week x/x/x/x	Lectures: 6/0/0/0 Practical: 2/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Modeling Flow in Porous Media (AES1320); Applied Reservoir Engineering(AES1340); Reservoir Simulation (AES1350); Log Evaluation (AES1520)	
Expected prior knowledge	BSc in Engineering or Sciences. Basic knowledge on Matlab programing, Basic knowledge of Partial Differential Equations.	
Summary	Fundamentals of flow and transport of single- and multi-phase flow in porous media.	
Course Contents	Single phase flow - Introduction to rock fluid interactions - Darcy's law (Darcy's experiment, Relation with Navier-Stokes, heterogeneous media, anisotropic media) - Forchheimer equation - Slip factor - One-dimensional Upscaling (Averaging, Homogenization, Dykstra-Parson coefficient, Reservoir Simulation) - 1D Laminar incompressible fully developed flow in circular cylinder - 1D transient radial flow conditions - Well testing - Diffusion/Dispersion Effects Some basics on two-phase flow - Interfacial tension - Capillary pressure and wettability - Relative Permability - Multiphase flow and transport equations - Capillary end effect Lab-practical: - Darcy in heterogeneous soil	
Study Goals	1. Explain experimental and mathematical methods to measure porosity of a rock. 2. Obtain permeability of a rock sample, based on bundle of tubes (BOT) model. 3. Develop an experimental setup to measure and quantify permeability of a given sand-pack and verify their result with that obtained from Carman-Kozeny equation. 4. Solve mathematical formulations describing single-phase flow in 1D porous media, analytically. 5. Apply solutions to transient radial flow equation to predict reservoir properties. This is called well-testing study. 6. Apply Darcys law for laminar flows to relate velocity and pressure in porous media. 7. Apply non-Darcys correlations to relate velocity and pressure gradient, if the flow regime is not laminar. 8. Determine Peclet Number and mixing zone for a given solution plot of tracer concentration in a 1D porous media. 9. Apply J-function to relate capillary functions in different porous media. 10. Determine which relative permeability curve represents the flow of a phase in a two-phase flow in a given rock sample, based on its wettability and pore structure. 11. Obtain capillary pressure curve of a given sample, based on bundle of tubes (BOT) model.	
Education Method	The course consists of -at least- 26 h lectures. 5 computer classes of around 3 hours are planned to assist students with their HW assignments. One session of ~3 hrs should be booked for a practical lab course.	
Reader	Handouts, slides, and more references will be all posted on BB. Text book of Advanced Petrophysics by Prof. Ekwere Peters is recommended, but not required.	
Assessment	- Written exam (70%); - HW Assignments and Projects (20%), - Lab course (report & experimental part) (10%) At least 50% of (HW+Lab) must be obtained in order to sit for the exam. All HW assignments and Lab report delivery is per-requisit for passing the course.	
Permitted Materials during Tests	Closed book written exam	
Contact	H. Hajibeygi tel: 015 27 88482 Room: CT 3.25 Email: H.Hajibeygi@tudelft.nl	
Expected prior Knowledge	- Basic undergraduate courses on mathematics, linear algebra. - Basic knowledge of Matlab programming. - Good level of English. The course will be offered in English language only.	
Academic Skills	- Know how to write HW/project report (will be explained in the first session) - Be able to work with equations and solve 1D PDEs (will be practiced in the class, but knowing it will help a lot).	
Literature & Study Materials	Textbook of "Advanced Petrophysics" by Prof. Ekwere Peters is recommended, but not required.	
Judgement	Written exam (70%) + HW Assignments (20%) + Lab report (10%). At least 50% of (HW+Lab) must be obtained in order to sit for the exam. All HW assignments and the Lab report must be delivered in order to pass the course.	
Permitted Materials during Exam	None.	
Collegerama	No	

AES1320	Modelling of Fluid Flow in Porous Media	3
Responsible Instructor	Dr. D.V. Voskov	
Contact Hours / Week x/x/x/x	Lectures: 0/2/0/0; practical: 0/1/0/0 and 4 compu exc.	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Expected prior knowledge	Basic mathematics and statistics: WI1266ta, WI1228ta, WI1229ta,WI1230ta, WI1231ta, WI1275t, WI2034ta TA2090, chemieTA1200, Numerical analysis WI3097, Phys. Transport phenomena TN4780tu, wi2273ta, ta3000, image analysis introduction	
Summary	Fundamentals and modelling of multi-phase flow in porous media	
Course Contents	Two-phase flow: Buckley Levertt flow, Method of Characteristics, Gas Injection processes, Vertical Equilibrium, Segregated flow, Interface models, Dietz and Dake's approximations. Applications To discern important physical mechanisms that have a large impact on oil recovery. Interpretation of laboratory experiments e.g. for obtaining constitutive relations.	
Study Goals	The main purpose of this course is to understand the physics and modelling of two-phase flow and transport through porous media and particularly in the petroleum industry. The student learns to formulate the relevant transport problems and solve simple 1-D and 2-D problems with a Matlab as an experimental tool. Lab practical will provide insight in the physics of two-phase flow. The course forms the basis for the applied courses in the second year.	
Education Method	The course consists of lectures, computer exercises and 2 lab practicals.	
Literature and Study Materials	Lecture notes, papers posted on blackboard web site. Reference literature: Dake, L.P., Fundamentals of Reservoir Engineering, Elsevier (1978).	
Assessment	Grade consists of: Written exam (60%) (individual) and lab report (40%) (group). To pass the course all parts should be completed and the grade for the examn should at least be 5.	
Expected prior Knowledge	Basic mathematics and statistics: WI1266ta, WI1228ta, WI1229ta,WI1230ta, WI1231ta, WI1275t, WI2034ta TA2090, chemieTA1200, Numerical analysis WI3097, Phys. Transport phenomena TN4780tu, wi2273ta, ta3000, image analysis introduction	
Academic Skills	see expected prior knowledge.	
Literature & Study Materials	Lecture notes, papers posted on blackboard web site. Reference literature: Dake, L.P., Fundamentals of Reservoir Engineering, Elsevier (1978).	
Judgement	see assessment.	
Permitted Materials during Exam	students may bring a basic calculator (not programmable calculator or communication device) and a ruler	
Collegerama	No	

AES1340	Reservoir Engineering	2
Responsible Instructor	Dr. H. Hajibeygi	
Responsible Instructor	Dr. P.J. van den Hoek	
Contact Hours / Week x/x/x/x	Lectures: 0.0.2.0 + Practical: 0.0.6.0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Expected prior knowledge	AES1300, AES1310, AES1320	
Summary	Reserves, Well testing, displacement by water, enhanced oil recovery. The course is often offered by an invited external lecturer.	
Course Contents	Material balance calculations for oil and gas reservoirs, fundamentals of well testing and its analysis, displacement characteristics and sweep for waterfloods, stream line concept, fundamentals of EOR for gas, chemical and thermal methods.	
Study Goals	To understand the reservoir engineering methodology that is required to predict recovery from petroleum reservoirs.	
Education Method	Lectures, compulsory practice sessions and computer exercises.	
Literature and Study Materials	Lecture notes, papers and information provided on Blackboard.	
Assessment	exercises and written final examination. Practice session and computer exercises are compulsory. A student cannot pass the course without attending the practice sessions or getting an excuse from the instructor.	
Expected prior Knowledge	See expected prior knowledge above.	
Academic Skills	See expected prior knowledge and study goals above.	
Literature & Study Materials	See literature and study materials above.	
Judgement	Examination: Based on exercises and a written examination Credits: 2 ECTS	
Permitted Materials during Exam	Will be announced in class before exam.	
Collegerama	No	

AES1510	Geologic Interpretation of Seismic Data	3
Responsible Instructor	Drs. G. Diephuis	
Contact Hours / Week x/x/x/x	Lectures: 0.2.0.0 + Practical: 0.7.0.0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Expected prior knowledge	TA3520	
Summary	Seismic interpretation, resolution, generation of synthetic seismograms, well geophysics,seismic forward and inverse modelling, principles of the 3-D seismic method, structural interpretation, velocity modelling and time-to-depth conversion, seismic-stratigraphy in basin analysis, lithologic/quantitative interpretation, seismic attributes, time lapse (4D) seismic. Case histories	
Course Contents	The course intends to introduce seismic evaluation techniques as applied in industry. Since the PETREL package is used in the practice sessions, an introduction into its use will be given, together with a concise hand-out. Knowledge of the seismic fundamentals is needed, including principal aspects of acquisition and processing techniques. After a brief introduction/recapitulation of acquisition and processing, evaluation techniques will be presented along the lines of a generic workflow, starting with the generation of synthetic seismograms and its use of calibrating the seismic data to wells. This is followed by an introduction into interpretation techniques and by a methodical treatment of different tectonic styles and their appearance on seismic. In addition time will be spent on seismo-stratigraphic techniques and examples. Best-practice techniques will be discussed and rehearsed in the practical exercises for event identification and horizon and fault interpretation. Attention will be paid to time to depth conversion and well geophysics. Participants will be made aware of the principles of quantitative interpretation the effects of hydrocarbon fill. Finally some novel techniques will be dealt with summarily.	
Study Goals	- To provide an understanding of the nature of seismic information in the context of an integrated and multidisciplinary working environment as in the oil- and gas exploration- and production industry. - Being able to use seismic information for geological and/or exploration/production goals. - Become familiar with PETREL software	
Education Method	Block of lectures and practicals: Lectures and practical exercises are given interchangeably. PETREL software will be introduced	
Literature and Study Materials	Lecture notes, handouts, including selected chapters from textbooks.	
Assessment	written exam	
Expected prior Knowledge	Basic knowledge seismic method	
Academic Skills	BSc (Applied) Geosciences or Mathematics or Physics or Chemistry	
Literature & Study Materials	Will be provided in the course	
Judgement	The exam will be taken twice a year. The students understanding of all practical aspects of seismic interpretation is tested as well as the overview of the different types of interpretation tools, and their role in the whole sequence of data processing, reservoir exploration, exploitation and management. Attendance at the lectures and practicals is compulsory. Students are not allowed to participate in the exam if more than a single practical session is missed. Some practicals may count for the final mark. A limited number of bonus points can be earned	
Permitted Materials during Exam	Calculator	
Collegerama	Yes	

AES1520	Log Evaluation	2

Responsible Instructor	Dr. A. Barnhoorn
Contact Hours / Week x/x/x/x	Lectures: 0/0/2/0 and practical: 0/0/2/0
Education Period	3
Start Education	3
Exam Period	3 4
Course Language	English
Expected prior knowledge	AES1300, AES1310, AES1500
Summary	Log evaluation, theory, practical applications, computer practice.
Course Contents	The student will learn how to interpret various types of borehole logs. The course consists of a series of literature topics and related exercises to understand the methods and procedures which are needed to calculate the contents of, among others, rock pores and the rock matrix.
Study Goals	Identify main factors that affect hydrocarbon exploration from borehole logging data. Analyse various types of borehole logs and gather recipes (relationships between parameters, cross-plots etc.) in the scientific literature for quantification of the borehole signatures. Integrate information of different borehole logs to compute rock and pore characteristics for all the important rock types within the borehole logs (especially seal, reservoir and source lithologies) Integrate sonics and advanced log evaluation techniques into log evaluation procedures Evaluate full potential of the logs for hydrocarbon exploration Assess uncertainties of your own conclusions and criticise your own outcomes Summarize, present and defend your case to your fellow students (they act as management committee of a major oil company)
Education Method	Lectures and (computer) practicals
Literature and Study Materials	Course notes and literature delivered by the lecturer during the course Reference literature Lecture notes and Blackboard Pages of TA3500 Schlumberger handbooks
Assessment	Written exam at the end of course and 2 practical reports made in groups
Remarks	none
Expected prior Knowledge	Earlier MSc AES courses
Academic Skills	Interpretation and Integration of Multiple datasets, critical thinking
Literature & Study Materials	Lecture notes, papers, e-book chapters
Judgement	20% Practical 1, 20% Practical 2, 60% Exam
Permitted Materials during Exam	non-graphical calculator, pemcils, ruler and pen
Collegerama	No

AES1800	Exploration Geology (including Remote Sensing)	3

Responsible Instructor	Dr. J.E.A. Storms
Contact Hours / Week x/x/x/x	0/5 mornings + 1 x 2 hrs/0/0
Education Period	2
Start Education	2
Exam Period	2 Different, to be announced
Course Language	English
Expected prior knowledge	BSc in Applied Earth Sciences or similar BSc + AES1000
Summary	Sedimentary basins, hydrocarbon occurrence, traps, reservoir quality
Course Contents	The origin and evolution of sedimentary basins, and their exploration potential will be discussed in terms of a petroleum system, made up of a source rock, reservoir rock, seal rock, and overburden rock, and comprising the processes of trap formation, as well as the generation, migration and accumulation of hydrocarbons.The main exploration tools are presented, and the common approach to evaluate the required ingredients for the presence of oil and/or gas accumulations (trap, reservoir, seal and HC charge) will be discussed. The link between the typical development of different basin types (rift basins, deltas, deep water foldbelts, carbonate provinces) with petroleum systems will be demonstrated with examples of oil and gas fields in several important petroleum provinces around the globe.
Study Goals	To gain an understanding of the geological factors that govern the accumulation of hydrocarbons in sedimentary basins, and to identify exploration targets.
Education Method	Lectures and assignments
Literature and Study Materials	Handouts Reference literature J. Gluyas & R. Swarbrick, 2004. Petroleum Geoscience. E.A. Beaumont & N.H. Foster (Eds), 1999, Exploring for oil and gas traps. P.A. Allen & J.R. Allen: Basin Analysis ~ Principles and Applications
Assessment	Written examination, the retake will be an individual assignment
Remarks	Guest lectures on Remote Sensing Tools and Applications for Exploration and Exploration Economics will be part of the program.

AES1802	Geological Fieldwork	3
Responsible Instructor	Drs. J.C. Blom	
Contact Hours / Week x/x/x/x	Fieldwork (1 week)	
Education Period	4	
Start Education	4	
Exam Period	none	
Course Language	English	
Expected prior knowledge	TA2910, TA2911, TA2920, TA2921, TA3942, TA3610, AES1810, AES1820	
Course Contents	The outcrop training course will be held in Germany. The course will lead the participants through outcrop equivalents of all relevant reservoirs in the subsurface of The Netherlands and their specific development aspects. These comprise: fluvial reservoirs of the Carboniferous (including coals as source rock for gas), Rotliegend (proximal conglomerates, Aeolian and distal playa lake deposits), shallow marine carbonate reefs of the Zechstein, anhydrite caprock, Jurassic oil source rock, Lower Cretaceous shallow marine clastic Bentheim Sandstone (including oil source rock and cap rock) and Upper Cretaceous Chalk.	
Study Goals	To gain an understanding of geologic aspects and problems in the production of hydrocarbons, based on excersizes on real outcrops.	
Education Method	5 day Excursion The outcrops to be studied are in quarries, and for each outcrop a comprehensive programme of assignments is set up. This includes a description of the sedimentological setting, characterization of permeability baffles and conduits and the design of optimal well trajectories. The participants will write a short field course report about all these assignments (learning points only).	
Literature and Study Materials	Excursion guidebook will be handed out.	
Assessment	Written report, produced in groups, containing the learning points for the respective students.	
Enrolment / Application	Enrollment for this course will be done by sending an e-mail stating you want to participate to the excursion organiser, Jan Kees Blom (j.c.blom@tudelft.nl). Enrollment will be complete if and when a confirmation reply e-mail has been received by the student.	
Expected prior Knowledge	AES3820 Petroleum Geology AES1890 Sedimentary Systems AES1820-09 Reservoir Characterisation & Development	
Academic Skills	During the excursion we will visit a number of old quarries and natural outcrops, showing analogs for reservoir rocks in the Dutch subsurface. The students are asked to apply the knowledge of these reservoirs and geology in general to these outcrops in order to comprehend how these reservoirs may actually look in the subsurface. They are asked to analyse the outcrop in terms of suitable rock types and their distribution, synthese porosity and permeability data within these rocks and evaluate how they would produce from these rocks if they had been reservoirs in the subsurface.	
Literature & Study Materials	Excursion guide book will be handed out at the start of the excursion	
Judgement	Judgement will be based on the quality of the report.	
Permitted Materials during Exam	no exam	
Collegerama	No	

AES1820-09	Reservoir Characterisation & Development	4
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	lectures 0.0.0.2 + practical 0.0.0.7	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Course Contents	Reservoir characterization for field development prepares the student for the field development course. It discusses how geological models are used to make field development decisions: Where to drill development/infill wells; how to determine well productivity; how to assess block connectivity in a field; where to complete a well; how to determine cumulative probability estimates from the combination of geological uncertainties; how to prepare data for input into reservoir simulation; and how to develop a field in an economic viable way. In the beginning of the course there will be an overview of production geological concepts such that the participants are familiar with this methodology that now is almost entirely computer-based.	
Study Goals	Petroleum engineers and reservoir geologists need to know how to develop a field in an economically and technological appropriate way, including proper data acquisition, interpretation and uncertainty assessment of relevant field parameters.	
Education Method	A written examination will account for 50% of the final grade; performance during the practicals for the rest.	
Literature and Study Materials	All lecture presentations are made available on Blackboard. Reference literature: Book: Petroleum Geoscience by J. Gluyas and R. Swarbrick, Blackwell Publishing, 359 p. (this book is also used in a few other courses)	
Assessment	Examination: Written examination of 3 hours duration. Performance during practicals is taken into account for the final grade (50%). Presence during practicals will also be taken into account. Presence during lectures is required as otherwise topics need to be explained again during the practicals.	
Expected prior Knowledge	The course Petroleum Geology (AES 3820) is a requirement for this course.	
Academic Skills	Basic knowledge of geology, drilling and economics	
Literature & Study Materials	PPT online material	
Judgement	Yes	
Permitted Materials during Exam	A calculator (for calculating ONLY)	
Collegerama	No	

AES1830	Reservoir Sedimentology	3
Responsible Instructor	Dr. M.E. Donselaar	
Contact Hours / Week x/x/x/x	0.3.0.0	
Education Period	2	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	Knowledge of Sedimentology at the TU Delft BSc level (see course description AESB2230).	
Summary	The course deals with the sedimentary achitecture, i.e., the size, shape, internal permeability distribution and spatial arrangement of fluvial and tidal sedimentary systems. Focus will be on (1) the processes that produce the sedimentary architecture, and (2) the impact on reservoir quality.	
Course Contents	The course is given as a tutorial. The Instructor will introduce the course subjects in PowerPoint presentations. The students study selected papers on the different aspects of the subjects. In regular sessions the contents of the studied material will be discussed. The students give an oral presentation and write an essay on one of the topics (modules; see below) of the literature study. The following topics have been addressed in recent years: - Topic 1: Labyrinth-type fluvial reservoirs; - Topic 2: heterolithic estuarine systems;	
Study Goals	The aim of the course is to gain a thorough understanding of the complexity of fluvial, tidal and deepmarine reservoirs, and of the geological factors that determine this complexity. The course serves as a solid basis for the Huesca Reservoir Geology Fieldwork AES1902.	
Education Method	The course is given as a tutorial.	
Literature and Study Materials	Literature will be posted on Blackboard course site	
Assessment	The mark is composed of (1) the literature report, (2) the Powerpoint presentation during the last session, (3) the handed-in assignments, and (4) the level of participation in the discussions during the course.	
Expected prior Knowledge	Knowledge of the basics of Sedimentology is strongly recommended. This knowledge is found in the BSc course AESB2230 Sedimentology and Reservoir Geology. Powerpoints of this course are on Blackboard.	
Academic Skills	Analysis of scientific publications, insight in three-dimensionality of rocks	
Literature & Study Materials	Annotated literature with assignments will be posted on Blackboard.	
Judgement	See: Assessment	
Permitted Materials during Exam	The course has no exam. The course is concluded with a literature-based case study and an oral presentation	
Collegerama	No	

AES1840	Advanced Structural Geology	3
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	0/0/2/0	
Education Period	3	
Start Education	3	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	General Geology I, II and III	
Summary	The course addresses the mechanic processes causing multiscale deformation in rocks and analyzes their consequences for the physical properties of reservoirs	
Course Contents	The main focus of this course is on the multi-scale analysis of deformation patterns (fractures, faults and folds) in geologic bodies characterized by sedimentological and structural heterogeneities. In the first part of the course, we will discuss the stress and strain fields developing in complex geologic bodies, i.e. bodies with different lithology and non-trivial structures. The second part is devoted to the definition of the types of structures which form in the areas experiencing deformation, i.e. the way deformation is accommodated. We will first focus on distributed fracturing to pass subsequently to zone of localized deformation (faults) and eventually to folds In the third part of the course we will focus on subsurface reservoirs addressing the geomechanic behavior (also of wells) and discussing the impact of fractures on physical properties of reservoir-scale geological bodies. These different steps are discussed theoretically and further approached with practical exercises All these issues are of major importance in the endeavor of providing better predictions on subsurface geology in a number of issues ranging from hydrocarbons and water to mineralization.	
Study Goals	Provide the students with a process-oriented knowledge of deformation patterns associated with fracturing, faulting and folding and how they influence the physical properties of reservoirs. Students will be able to predict stress fields in heterogeneous bodies, the resulting distribution and type of fracturing under different stress conditions. Students will also acquire notions of borehole and reservoir geomechanics	
Education Method	The course includes lectures and practicals.	
Literature and Study Materials	Slides used in the class as well as relevant papers will be available on Blackboard. The suggested book is Structural Geology, by H. Fossen, Cambridge University Press	
Assessment	Report of practical work and written exam	
Expected prior Knowledge	General Geology I, II and II - vesc feild work	
Academic Skills	Ability to read and work on English literature, to perform relatively simple mathematical and physical operations and interpret geological record from outcrops and subsurface	
Literature & Study Materials	Slides used in the class as well as relevant papers will be available on Blackboard. The suggested book is Structural Geology, by H. Fossen, Cambridge University Press	
Judgement	Practicals and written exam	
Permitted Materials during Exam	Coloured pencils, ruler and scales	
Collegerama	No	

AES1850	Geological Modelling	4
Responsible Instructor	Dr. J.E.A. Storms	
Contact Hours / Week x/x/x/x	Lectures: 0.0.2.0 + Practical: 0.0.7.0	
Education Period	3	
Start Education	3	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	Courses 1st year MSc RG, PE or AG	
Summary	2-D/3-D models, geostatistics, stratigraphy, sedimentology, lithology, deterministic models, process-based models	
Course Contents	Geoscientists find resources by assessing the characteristics and constraints of the earth subsurface. The subsurface has been formed over millions of years, and by the interaction of a host of sedimentary processes and time-varying boundary conditions like climate, sea level and tectonics. This course aims at exploring Geological Modeling techniques as: 1. Learning tools to study complex interactions of sedimentary depositional systems, tectonics and time varying boundary conditions. 2. Quantitative tools to create geological models of the subsurface, including realizations of subsurface properties like grain-size distribution, porosity and permeability. 3. A means to quantify uncertainties in the subsurface models by running sensitivity tests.	
Study Goals	(1) The student is able to discuss the difference between process models and stochastic models. (2) The student is able to apply software or provided code and evaluate the produced model output of these models. (3) The student is able to justify which model approach (process model, stochastic model) can be best used for solving problems in the characterization of the grain-size or facies distribution in a reservoir. (4) The student is able to identify various sources of error and their effects in applying geological model techniques.	
Education Method	lectures, computer practicals and assignments.	
Literature and Study Materials	handouts	
Assessment	Assignment	

AES1860-05	Analysis of Sedimentary Data	3
Responsible Instructor	Drs. M.M. van Tooren	
Contact Hours / Week x/x/x/x	14 hrs lectures, 1 day company visit, 6 half days practical	
Education Period	1	
Start Education	1	
Exam Period	1	
Course Language	English	
Expected prior knowledge	Sedimentary geology at introductory level (BSc) is mandatory; knowledge of optical sedimentology and mineralogy is useful	
Course Contents	Introduction to the acquisition and interpretation of common sedimentary data on different scales of observation (regional, outcrop, layers/cores, microtexture). The lectures focus on information obtained from siliciclastic rocks and carbonate rocks. Visit to PanTerra Geoconsultants B.V: the same topics come up; focus on activities by PanTerra; study and interpretation of information obtained from cores. Practicals. Two assignments. Theoretical knowledge has to be applied by studying selected sets of thin section of siliciclastic rocks and carbonate rocks; both sets are derived from existing hydrocarbon fields. The assignments focus on the information obtained from microscopic observations in relation to reservoir characteristics of these fields. Additional literature has to be studied.	
Study Goals	Students are expected to be able to interpret sedimentary data on different scales of observation. The emphasis is laid on the interpretation of core data and micro-texture. Students are expected to be able to analyse siliciclastic and carbonate rocks microscopically and to be able to interpret the obtained information in relation to knowledge they selected from lectures and literature. Students must be able to write a concise report about the studied material.	
Education Method	Lectures, practicals and a visit to PanTerra Geoconsultants B.V.	
Literature and Study Materials	To be announced on Blackboard	
Assessment	The written assignments have to be combined into one final report. This report is assessed. There is no written exam	
Expected prior Knowledge	Sedimentary geology at introductory level (BSc) is mandatory; knowledge of optical sedimentology and mineralogy is useful	
Academic Skills	Observation, literature studies, report writing	
Literature & Study Materials	Available on BB; additional textbooks can be used during the practicals	
Judgement	The written assignments have to be combined into one final report. This report is assessed. There is no written exam	
Permitted Materials during Exam	There is no exam	
Collegerama	No	

AES1890	Sedimentary Systems	3
Responsible Instructor	Dr. J.E.A. Storms	
Contact Hours / Week x/x/x/x	0.3.0.0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Course Contents	Introduction to principles and applications of Sequence Stratigraphy. Discussion of fluvial, deltaic, shallow-marine, and deep-marine siliciclastic systems, as well as a range of carbonate environments in a sequence-stratigraphic context. Discussion of the causes and effects of allogenic and autogenic perturbations on sedimentary systems. Application of sequence stratigraphy to problems of geological reservoir modelling and characterisation.	
Study Goals	1) To acquire a basic understanding of the vocabulary and application of sequence stratigraphy; 2) To acquire a basic understanding of the controls on depositional heterogeneity in a sequence-stratigraphic context.	
Education Method	lectures and self-study exercises	
Assessment	written exam	

AES1902	Reservoir Geological Fieldwork (Huesca)	6
Responsible Instructor	Dr. M.E. Donselaar	
Contact Hours / Week x/x/x/x	0.0.0.8	
Education Period	4	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	Condition for participating in the fieldwork: students must have passed the following courses: TA2910 Sedimentologie TA2911 Practicum Sedimentologie TA2920 Structurele geologie TA2921 Geologische constructies TA3942 Geologisch veldwerk Vesc AES1510 Geological interpretation of seismic data AES1870 Sequence stratigraphy AES1810 Production geology (exam in April).	
Summary	Reservoir architecture, influence of permeability baffles to flow, construction of a static 3-D deterministic geological model in a reservoir-equivalent outcrop setting, variability of facies associations, shape and extent of permeability baffles.	
Course Contents	The course consists of three parts: 1) Introductory field trip (three days). The aims of the introductory field trip are to (a) explain the geological framework of the fieldwork,(b)introduce the fluvial facies characteristics and their relation to reservoir setting. 2) Sedimentological fieldwork (1.5 weeks). The objective of this part is to obtain a good understanding of the sedimentology, spatial distribution and reservoir potential of the fluvial deposits in the study area. This will be achieved by the detailed outcrop description of the lithofacies characteristics of the various types of fluvial sediment, and by the correlation of fluvial sediment bodies. 3) Integration with subsurface data and model building (1.5 weeks, partial overlap with fieldwork). The aim of this part is to build a static 3D reservoir architecture model based on the integration of outcrop and subsurface data. For this, a selection of subsurface data is available, including wireline logs from two wells, a core from one well, and a set of borehole image logs (FMS/FMI).	
Study Goals	Gaining insight in the complexity and challenges of fluvial reservoir architecture, correlation methods, integration of sedimentological, petrophysical and geophysical data. Learning to work in a team.	
Education Method	Fieldwork	
Literature and Study Materials	Relevant literature will be posted on Blackboard, and is also available as literature map in the fieldwork base camp.	
Assessment	The fieldwork assessment is composed on two parts: 1. Contribution to the written fieldwork report, and 2. Execution of the fieldwork (performance in the field, participation in the discussions, cooperation, etc.).	
Expected prior Knowledge	Course Reservoir Sedimentology AES1830	
Academic Skills	Insight in three-dimensional problems	
Literature & Study Materials	Literature is posted on Blackboard	
Judgement	See: Assessment	
Permitted Materials during Exam	There is no exam to this course.	
Collegerama	No	

AES1920	Geostatistics	2
Responsible Instructor	Dr.ir. F.C. Vossepoel	
Contact Hours / Week x/x/x/x	2.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Expected prior knowledge	Basic univariate and multivariate statistics	
Course Contents	This introductory course is intended as an overview of the principles of (geo)statistical interpolation and simulation. The course starts with a brief recapitulation of univariate and bivariate statistics, after which attention will be devoted to multivariate methods of classification and assignment. The section on data analysis serves as an introduction to the main topic of the course: modelling of spatial variability. Geostatistical concepts and methods (random variables, random functions, declustering, covariance, variograms, simple kriging, ordinary kriging, block kriging, indicator kriging, cokriging, object-based methods) will be discussed in the light of application to reservoir modelling. Throughout the course, the emphasis will be on understanding of the possibilities and limitations of the various techniques; mathematical derivations will be kept to a minimum. Special attention will be given to quantification of uncertainty and the application of stochastic simulation techniques. Stochastic simulation of equiprobable realisations of spatial variables will be discussed, as well as stochastic methods for testing of hypotheses.	
Study Goals	1) To acquire a general understanding of the range of statistical methods available for modelling of subsurface properties; 2) To select methods which are appropriate to the problem at hand, based on an awareness of their underlying assumptions and inherent limitations.	
Education Method	Lectures	
Assessment	Written exam	

AES1930	Quantification of Rock Reservoir Images	1
Responsible Instructor	Dr. K.H.A.A. Wolf	
Responsible for assignments	J.G. van Meel	
Contact Hours / Week x/x/x/x	4 afternoons	
Education Period	2	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Required for	MSc-students, first year.	
Expected prior knowledge	Introduction to Image Analysis (AES0102), introduction to Petrophysics (AESB3341 or AES1760), basic knowledge of Excel and statistics (i.e. frequency distributions).	
Parts	1	
Summary	The students learn how to obtain, interpret and calculate grain- and pore-frameworks from images of reservoir rock. This to identify 2D grain and pore size distributions and to reconstruct in a statistical way 3D, porosity-, permeability- and capillary distributions.	
Course Contents	Image analysis on reservoir rock; theory and practice. Porous networks and grain frameworks are characterized and quantified in order to acquire parameters for permeability calculation, pore-network development and flow modelling.	
Study Goals	The student learns to work with images of pores and related grain-frameworks. Image quantification is used to create a database that for 3D reconstruction. In addition, various analysis pitfalls are discussed. The results porosity, permeability and capillary results can be used for (Monte Carlo)flow modelling, prediction of capillary behaviour, and as a first step to 3D CT-scan image analysis.	
Education Method	Computer: Qwin image analysis systems and Excel.	
Computer Use	Yes	
Course Relations	Rock-fluid interaction, reservoir modelling, various andvanced courses in Petrophysics.	
Literature and Study Materials	On Blackboard	
Practical Guide	On Blackboard	
Books	No	
Reader	On Blackboard	
Prerequisites	AES0102, AESB3341 or AES1760	
Assessment	100 % attendance and a report	
Exam Hours	No	
Permitted Materials during Tests	-	
Enrolment / Application	Enrol on Blackboard	
Special Information	None	
Remarks	None	
Tags	Analysis Circuits Databases Design Fluid Mechanics Geo Engineering Geology Image processing Practicals Stochastics	
Contact	k.h.a.a.wolf@tudelft.nl	
Expected prior Knowledge	Introduction to Image Analysis (AES0102) and Introduction to Petrophysics (AESB3341 or AES1760).	
Academic Skills	The student learns to work with images of pores and related grain-frameworks. Image quantification is used to create a database that for 3D reconstruction. In addition, various analysis pitfalls are discussed. The results porosity, permeability and capillary results can be used for (Monte Carlo)flow modelling, prediction of capillary behaviour, and as a first step to 3D CT-scan image analysis.	
Literature & Study Materials	Blackboard	
Judgement	Report	
Permitted Materials during Exam	-	
Collegerama	No	

AES3820	Petroleum Geology	3
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	2/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Expected prior knowledge	General Geology, Fluid Flow in Rocks	
Summary	Organic Rocks, Maturation, Migration, Reservoir Rocks, Seals, Traps, Exploration, Production.	
Course Contents	This course gives an overview of the conditions that are necessary for oil and gas to accumulate in reservoirs. This is first illustrated in concepts and then in a few relevant case studies. The life of a reservoir is discussed from initial basin studies to exploration, appraisal development and finally abandonment. The task of the petroleum geologist during these various phases is illustrated, as well as his interaction with other disciplines such as reservoir engineering, geophysics, and petrophysics. Material on hand includes among others cores, logs and seismic lines.	
Study Goals	The objective of this course is to give the student a thorough introduction into petroleum geology.	
Education Method	The course consists of lectures. Some exercises and hands-on practicals may be included.	
Literature and Study Materials	Gluyas J. & Swarbrick R. (2004) Petroleum Geosciences. Blasckwell Publishing.	
Assessment	Written exam	
Expected prior Knowledge	Basic geology	
Academic Skills	General academic skills	
Literature & Study Materials	Online material and collegerama	
Judgement	Yes	
Permitted Materials during Exam	Calculators for calculations ONLY	
Collegerama	Yes	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-PE&G RG Electives (3 EC)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-PE&G Specialisation Reservoir Geology 2nd Year

AES2009	Field Development Project	9
Responsible Instructor	Prof. W.R. Rossen	
Instructor	Prof.dr.ir. J.D. Jansen	
Instructor	P.R.A. Betts	
Instructor	Drs. J.C. Blom	
Instructor	Drs. G. Diephuis	
Instructor	Drs. A.A. Sieders	
Instructor	Ir. W.J.A.M. Swinkels	
Contact Hours / Week x/x/x/x	6 weeks design project	
Education Period	1	
Start Education	1	
Exam Period	none	
Course Language	English	
Summary	Field development process from appraisal to full field development	
Course Contents	On the basis of real field data, the whole field development process will be passed through from appraisal to full field development. Specific knowledge acquired in earlier courses(geophysics, petrophysics, geology, reservoir technology, drilling and production technology) will be used to set up and execute a field development program using seismic, petrophysical and reservoir data. A field development plan will be developed and presented to a management panel.	
Study Goals	The application of acquired knowledge on a realistic field study. - Gaining an overview of the interaction between the specialist disciplines in petroleum engineering. - Learning to deal with inaccuracy and uncertainty. - Working in a multidisciplinary team	
Education Method	Project, working in teams	
Literature and Study Materials	Handouts and lecture notes of previous courses and Reference literature	
Prerequisites	1. Students may not take AES2009 until they have completed the Bachelor of Science programme. 2 Students who have been admitted to the MSc program on the basis of a Dutch higher vocational institute Bachelor degree, and were assigned a subsidiary programme of courses for the MSc degree, must have completed this programme before they are allowed to take AES2009. 3. Students may not take AES2009 until they have completed a total of 19 ECTS from the following courses of the core programme: Properties of Hydrocarbons (AES1300), Rock Fluid Physics (AES1310), Modelling of Fluid Flow in Porous Media (AES1320), Geologic Interpretation of Seismic Data (AES1510), Log Evaluation (AES1520), Sedimentary systems (AES1890), Production Geology (AES1810)*, Reservoir Engineering (AES1340), Geostatistics (AES1920)** and Reservoir Characterisation and Development (AES1820* or AES1820-09**). Additionally, students with the specification 'Petroleum Engineering' are recommended to have completed the courses Drilling and Production (AES1330) and Production Optimisation (AES1360). Please note, though, these two additional courses do not count toward the required total of 20 ECTS. * for students who started fall 2009 or earlier; ** for students who started fall 2010 or later	
Assessment	Assessment will be in groups. A Field Development Report will be written by each group, and presented to a Panel. This project takes 6 consecutive weeks.	
Remarks	Students must attend all class sessions except in exceptional circumstances with prior approval of instructor.	
Expected prior Knowledge	See prerequisites.	
Academic Skills	See prerequisites.	
Literature & Study Materials	Materials posted on Blackboard site.	
Judgement	Grades are based on the oral presentation at the conclusion of the course (1/3) and the written report (2/3).	
Permitted Materials during Exam	Grades are based on the oral presentation on the last day of the course and the written report. There is no final exam.	
Collegerama	No	

AESM2007	Final Thesis Reservoir Geology	45
Responsible Instructor	Dr. J.E.A. Storms	
Contact Hours / Week x/x/x/x		
Education Period	None (Self Study)	
Start Education	1 2 3 4 5	
Exam Period	Different, to be announced Exam by appointment	
Course Language	English	
Course Contents	Each AES Master program will be concluded with an individual graduation thesis: a research project of ca 9 months reported in a graduation thesis. The subject of the graduation project is to be decided jointly by the student and the graduation coordinator or a staff member. Usually, the topic is part of a Ph.D. research, in which case the Ph.D. student concerned will supervise the graduation project. The graduation research project can also take place at an external company or research institute. In any case, the graduation coordinator remains responsible for the quality requirements of the project and the supervision. The graduation subject will be within the area of the specialization. The research results will be presented in public to the graduation committee (colloquium) by means of a 45 minute lecture, after which questions can be posed. Following the colloquium, the student will be examined on his thesis by the graduation committee during a closed session.	
Study Goals	The graduate student learns to apply the skills and knowledge gained in the preceding study in a research project he has to carry out independently. Furthermore, the graduate student displays the knowledge and skills obtained during his preceding study by convincingly presenting the results of his research.	
Education Method	Project	
Assessment	The grade for this course is based on an objective assessment of five criteria: quality of the work, quality of the results, performance during thesis, quality of the written presentation, and quality of the oral presentation and defense. See also 'Graduation Rulings' of the 'Teaching and examination regulations Master's degree Applied Earth Sciences'	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-PE&G RG Elective Courses (6 ec)

AES1050	GSE Student competition course	5
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	na	
Education Period	1 2 3 4	
Start Education	1 2 3 4 5	
Exam Period	none	
Course Language	English	
Course Contents	The GSE Student Competition Course is a platform offered to encourage and stimulate participation of teams of students to high level scientific competitions which can be within TUDelft, national or international. The GSE Student Competition Course provides a workflow which participants are required to follow in order to be eligible for the 5EC associated with the course. The workflow is as follows 1) the team intending to participate to the competition writes a motivation letter which includes, among others, i) a description of the competition ii) the expected added value for the educational growth of the students iii) a motivation statement from all members of the team and iv) the name of a technical advisor in charge of the daily supervision of the participating team. If costs are involved in the participation, the letter should also include information on how these will be covered. The letter is evaluated by the Course responsible and two other GSE staff members (Prof. Dr. B. Rossen and Dr. G. Drijkoningen) and participation is approved/rejected. The way the participation will be graded is also discussed and agreed upon at this stage At the end of the competition, the participating team will submit a short report describing the activities and experiences made during the competition itself. The technical advisor proposes a grade which is then discussed with the three staff members responsible of the Course.	
Study Goals	The goal of the GSE Student Competition Course is to improve technical knowledge and strengthen the group working skills of the participating team. Upon succesful completion of the competition, the participating students will have learned a variety of technical tools (depending on the type of competition) and will be able to work in a small team under time and competition pressure to present their results in a competitive arena in front of an external jury	
Education Method	Learning through competition	
Assessment	The pass/no pass boundary and the grading will depend on the type of competition and will be discussed prior to the start of the competition itself	
Expected prior Knowledge	Expected prior knowledge depends very much on the competition. Because only scientifically challenging competitions will be considered, only MSc students will be allowed with a strong background. Intrinsic in the idea of a competitive team, the participants will have different backgrounds (geophysics, engineering, geology etc)	
Academic Skills	Key to success and, therefore to earning the 5EC is the ability to form a real team during the competition. The necessary first step of this process is the ability of putting together a winning team composed of experts also able to work together. The value of strong cooperation will only increase during the competition	
Literature & Study Materials	will depend on the specific compeititons	
Judgement	The technical advisor (if present) will propose a grade to the staff members responsible of the course; these will have the final decision.	
Permitted Materials during Exam	no exam in the classical sense of the term is foreseen the assessment will be based on the report presented by the participating team and on insights provided by the technical advisor	
Collegerama	No	

AESM2604	Geothermal Field Trip	2
Responsible Instructor	Prof.dr. D.F. Bruhn	
Contact Hours / Week x/x/x/x	full 7 days week (66 hours), period is different each year depending on the destination	
Education Period	4 Different, to be announced	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	BSc in Earth Sciences or Process Engineering Target group are PhD candidates and MSc students with a particular interest in geothermal energy.	
Course Contents	Participants are going to see various steps and sites of geothermal power production in Iceland, learn about historical as well as about modern energy production technologies from geothermal heat. We will visit a modern geothermal power station at Hellisheiði, located near Hengill volcano in southwest Iceland. The plant has a capacity of 303 MW of electricity and 400 MW of hot water. Students will learn about the development of geothermal power production: from investigating the geological system to power conversion. Depending on industry developments, we will visit a deep geothermal drill site, most likely in the south-western part of Iceland. The geology of the region will be explored, including Þingvellir National Park in the rift valley between the North American and Eurasian Plates. Participants will geothermal surface manifestations such as the famous Strokkur geyser and investigate exhumed geothermal systems in Geitafell, South Iceland.	
Study Goals	-At the end of this course, the student knows the development of geothermal power production. -The student can explain the general challenges and modern approaches to geothermal power. -The student can describe and recognize classic geothermal surface manifestations. -The student is able to describe and characterize hydrothermal mineralisations in rocks. -The student is able to characterize the basic features of the subsurface geothermal system.	
Education Method	One week in the field in Iceland. 1 preparatory seminar Seminar with students presentations on a topic preparing the field trip.	
Course Relations	AES1305SET Geothermal Energy and Applications	
Assessment	Seminar presentation + report Each student has to give a seminar presentation of 10 minutes Each student has to write a report on the field trip. Report must include daily field notes, and explanation of observations. Evaluation is based on completeness and demonstrated understanding of course content.	
Remarks	Good shoes, rock hammer, compass.	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Track Applied Geophysics (AG)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Track Applied Geophysics 1st Year

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG TU Delft semester 1; a minimum of 25 EC should be passed

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Two out of the following three blocks of TUD courses must be passed

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Geology and interpretation

AES1510	Geologic Interpretation of Seismic Data	3
Responsible Instructor	Drs. G. Diephuis	
Contact Hours / Week x/x/x/x	Lectures: 0.2.0.0 + Practical: 0.7.0.0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Expected prior knowledge	TA3520	
Summary	Seismic interpretation, resolution, generation of synthetic seismograms, well geophysics,seismic forward and inverse modelling, principles of the 3-D seismic method, structural interpretation, velocity modelling and time-to-depth conversion, seismic-stratigraphy in basin analysis, lithologic/quantitative interpretation, seismic attributes, time lapse (4D) seismic. Case histories	
Course Contents	The course intends to introduce seismic evaluation techniques as applied in industry. Since the PETREL package is used in the practice sessions, an introduction into its use will be given, together with a concise hand-out. Knowledge of the seismic fundamentals is needed, including principal aspects of acquisition and processing techniques. After a brief introduction/recapitulation of acquisition and processing, evaluation techniques will be presented along the lines of a generic workflow, starting with the generation of synthetic seismograms and its use of calibrating the seismic data to wells. This is followed by an introduction into interpretation techniques and by a methodical treatment of different tectonic styles and their appearance on seismic. In addition time will be spent on seismo-stratigraphic techniques and examples. Best-practice techniques will be discussed and rehearsed in the practical exercises for event identification and horizon and fault interpretation. Attention will be paid to time to depth conversion and well geophysics. Participants will be made aware of the principles of quantitative interpretation the effects of hydrocarbon fill. Finally some novel techniques will be dealt with summarily.	
Study Goals	- To provide an understanding of the nature of seismic information in the context of an integrated and multidisciplinary working environment as in the oil- and gas exploration- and production industry. - Being able to use seismic information for geological and/or exploration/production goals. - Become familiar with PETREL software	
Education Method	Block of lectures and practicals: Lectures and practical exercises are given interchangeably. PETREL software will be introduced	
Literature and Study Materials	Lecture notes, handouts, including selected chapters from textbooks.	
Assessment	written exam	
Expected prior Knowledge	Basic knowledge seismic method	
Academic Skills	BSc (Applied) Geosciences or Mathematics or Physics or Chemistry	
Literature & Study Materials	Will be provided in the course	
Judgement	The exam will be taken twice a year. The students understanding of all practical aspects of seismic interpretation is tested as well as the overview of the different types of interpretation tools, and their role in the whole sequence of data processing, reservoir exploration, exploitation and management. Attendance at the lectures and practicals is compulsory. Students are not allowed to participate in the exam if more than a single practical session is missed. Some practicals may count for the final mark. A limited number of bonus points can be earned	
Permitted Materials during Exam	Calculator	
Collegerama	Yes	

AES1890	Sedimentary Systems	3
Responsible Instructor	Dr. J.E.A. Storms	
Contact Hours / Week x/x/x/x	0.3.0.0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Course Contents	Introduction to principles and applications of Sequence Stratigraphy. Discussion of fluvial, deltaic, shallow-marine, and deep-marine siliciclastic systems, as well as a range of carbonate environments in a sequence-stratigraphic context. Discussion of the causes and effects of allogenic and autogenic perturbations on sedimentary systems. Application of sequence stratigraphy to problems of geological reservoir modelling and characterisation.	
Study Goals	1) To acquire a basic understanding of the vocabulary and application of sequence stratigraphy; 2) To acquire a basic understanding of the controls on depositional heterogeneity in a sequence-stratigraphic context.	
Education Method	lectures and self-study exercises	
Assessment	written exam	

AES3820	Petroleum Geology	3
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	2/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Expected prior knowledge	General Geology, Fluid Flow in Rocks	
Summary	Organic Rocks, Maturation, Migration, Reservoir Rocks, Seals, Traps, Exploration, Production.	
Course Contents	This course gives an overview of the conditions that are necessary for oil and gas to accumulate in reservoirs. This is first illustrated in concepts and then in a few relevant case studies. The life of a reservoir is discussed from initial basin studies to exploration, appraisal development and finally abandonment. The task of the petroleum geologist during these various phases is illustrated, as well as his interaction with other disciplines such as reservoir engineering, geophysics, and petrophysics. Material on hand includes among others cores, logs and seismic lines.	
Study Goals	The objective of this course is to give the student a thorough introduction into petroleum geology.	
Education Method	The course consists of lectures. Some exercises and hands-on practicals may be included.	
Literature and Study Materials	Gluyas J. & Swarbrick R. (2004) Petroleum Geosciences. Blasckwell Publishing.	
Assessment	Written exam	
Expected prior Knowledge	Basic geology	
Academic Skills	General academic skills	
Literature & Study Materials	Online material and collegerama	
Judgement	Yes	
Permitted Materials during Exam	Calculators for calculations ONLY	
Collegerama	Yes	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Electromagnetic Methods

AES1540-11	Electromagnetic Exploration Methods	6
Responsible Instructor	Prof.dr.ir. E.C. Slob	
Contact Hours / Week x/x/x/x	4/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1	
Course Language	English	
Course Contents	The theory of electromagnetic fields and waves is described for electromagnetic geophysical methods for subsurface exploration and monitoring of subsurface processes. A distinction is made between diffusive electromagnetic fields and wave fields. For wave fields the model behind practical applications consists of fields generated by electric or magnetic dipoles and scattered by a subsurface object in a two half-spaces configuration. This model is derived and discussed in detail as the model to understand ground-penetrating radar (GPR) data. For diffusive electromagnetic fields marine and land applications are considered. The model behind the marine methods consist of a horizontal electric dipole somewhere in the sea and electric and magnetic receivers either on the sea floor or floating in a streamer behind the source. In the land applications the source is either an electric dipole in contact with the earth surface or a magnetic dipole in the air. The course only treats the marine method for the determination whether a reservoir contains brine or oil and the land method with magnetic dipoles in the air for hydrogeophysical applications. Practical aspects of acquisition and processing for GPR, induction tools, and CSEM are discussed.	
Study Goals	The student will acquire a thorough understanding of electromagnetic field theory, which can be demonstrated through the ability to derive and interpret solutions of partial differential equations in a configuration containing one or more horizontal interfaces for electromagnetic diffusive and wave fields. Students are able to describe and explain the principles of equivalence and reciprocity, and to decompose the electromagnetic field in TE- and TM-modes. The students are able to derive, explain, and use volume imaging technology as a linear filter step applied to measured GPR data. The student will be able to link the theory to the exploration methods used in practice and be able to describe and apply basic data processing and interpretation techniques on computed or acquired data.	
Education Method	14 lectures of 2 hours	
Course Relations	prepares for modeling and inversion courses, data processing course, and the field work course, in second semester.	
Reader	lecture notes	
Prerequisites	PDE, vector algebra, LTI systems and signal theory, electricity & magnetism.	
Assessment	three hour written exam, re-exam is oral upon appointment	
Expected prior Knowledge	BSc-level in linear algebra, calculus, differential equations, LTI systems and signal theory, electricity and magnetism	
Academic Skills	self-study, deriving new equations, systematic analysis and gaining understanding of the underlying physics of mathematical expressions.	
Literature & Study Materials	course notes, lectures, and other materials are available on Blackboard, including old exams and a literature list is given in the lecture notes	
Judgement	through final written exam	
Permitted Materials during Exam	pen, pencils	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Seismic wave propagation and imaging

AES1560	Advanced Reflection Seismology and Seismic Imaging	6
Responsible Instructor	Prof.dr.ir. C.P.A. Wapenaar	
Contact Hours / Week x/x/x/x	block of 28 hrs in weeks 5-8/x/x/x	
Education Period	1	
Start Education	1	
Exam Period	1	
Course Language	English	
Required for	Geophysics Special Subjects (AES1550)	
Course Contents	The course starts with the fundamentals of seismic wave theory, which covers the propagation of waves through homogeneous and inhomogeneous media, decomposition of waves into downgoing and upgoing wave fields, and reflection of waves at interfaces between layers with different geological properties. Next, it discusses more advanced concepts like Rayleighs reciprocity theorem, Greens functions and wave field representations, from which forward and inverse wave field extrapolation algorithms are derived. Finally, these concepts are used together to derive a systematic forward model of seismic reflection data and it is shown how seismic imaging and multiple elimination can be derived by applying the inverse of this model to the seismic data.	
Study Goals	At the end of the course, students should be able to Derive the linearized acoustic wave equation from conservation laws and constitutive equations, Derive 3D spherical- and plane-wave solutions and explain the space-time behaviour of these waves, Explain the difference between homogeneous and inhomogeneous plane waves, Explain the space-time Fourier transform as a decomposition of waves into plane waves, Derive the matrix form of the two-way wave equation in wavenumber-frequency domain, Derive decomposition operators to decompose the two-way wavefield into down- and upgoing waves, Decompose the two-way wave equation into a coupled system of one-way wave equations, Derive forward extrapolation operators for down- and upgoing waves in wavenumber-frequency domain, Derive inverse extrapolation operators for down- and upgoing waves in wavenumber-frequency domain, Derive reflection and transmission operators in wavenumber-frequency domain, Derive and explain Rayleighs reciprocity theorem in space-frequency domain, Use Rayleighs reciprocity theorem to derive convolution- and correlation-type wavefield representations, Use convolution-type wavefield representations to derive forward extrapolation in space-frequency domain, Use correlation-type wavefield representations to derive inverse extrapolation in space-frequency domain, Combine extrapolation, reflection and decomposition operators into forward model of seismic data, Derive decomposition, multiple elimination and imaging schemes from forward model of seismic data.	
Education Method	14 two-hour lectures. The other hours are used for self-study and preparation for the exam.	
Literature and Study Materials	Elastic wave field extrapolation by C.P.A. Wapenaar and A.J. Berkhout (1989, Elsevier). Available at the lecturer.	
Assessment	Written exam	
Expected prior Knowledge	Introduction to reflection seismology (AES3520)	
Academic Skills	Good mathematical and physical insight	
Literature & Study Materials	Elastic wave field extrapolation by C.P.A. Wapenaar and A.J. Berkhout (1989, Elsevier). Available at the lecturer.	
Judgement	Written exam	
Permitted Materials during Exam	None	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Additional TUD courses

AES1011	Matlab / Programming	2
Responsible Instructor	Dr.ir. D.S. Draganov	
Contact Hours / Week x/x/x/x	8-10 half day sessions	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Required for	1st-year MSc students Petroleum Engineering, Geosciences and Applied Geophysics.	
Expected prior knowledge	Prior knowledge of basic computer programming concepts (variable types, if-then-else structures, for loops, while loops, subroutines and functions etc.) No prior knowledge of MALTAB is required, but some prior exposure to another programming language (e.g. Fortran, C, C++, Basic) is expected.	
Course Contents	The aim of this course is to provide 1st-year MSc students Petroleum Engineering and Geosciences a working knowledge of the programming language MATLAB. The course is also meant to serve as a refresher of basis computer programming skills.	
Study Goals	* Refresh elementary concepts from computer programming. * Obtain skills to write simple programs in MATLAB.	
Education Method	Eight times four hours of scheduled self-study with supervision. Computer exercises.	
Assessment	Assignments.	
Tags	Matlab	
Expected prior Knowledge	BSc-level of algorithmic thinking	
Academic Skills	self-study	
Literature & Study Materials	all learning material is available on Blackboard	
Judgement	by last assignment	
Permitted Materials during Exam	N.A.	
Collegerama	No	

AES1501	Methods of Exploration Geophysics	3
Responsible Instructor	Prof.dr.ir. E.C. Slob	
Course Coordinator	Dr.ir. G.G. Drijkoningen	
Course Coordinator	Dr. R. Ghose	
Contact Hours / Week x/x/x/x	during first 4 weeks: 2 till 4 hours/week	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	This course treats potential, diffusion, and wave methods that are used in exploration geophysics. Signal theory for signals in linear time-invariant systems is reviewed. Potential, diffusion, and wave fields in a homogeneous space and generated by a localized source in 3D are derived and described in wavenumber-frequency, space-frequency, and space-time domains. Examples of these techniques are given for geo-electric, diffusive electromagnetic, and seismic wave methods used in exploration geophysics. The underlying reasons behind the relations between geophysical properties and physical properties are treated, as well ways how to obtain some of the key physical properties from the geophysical data.	
Study Goals	Knowledge of the basic measurement principles and underlying theory of exploration methods used in applied geophysics. To be able to derive solutions of partial differential equations with constant coefficients. To be able to give a physical interpretation of these solutions. To be able to explain the difference in field behavior of potential, diffusive, and wave fields. To be able to describe the relation between physical and geophysical material properties.	
Education Method	14 hours of lectures and 66 hours of self-study.	
Course Relations	prepares for AES1560, AES1590-11	
Reader	lecture notes	
Assessment	written exam in week 4	
Exam Hours	two hours for final exam at the end of week 4	
Permitted Materials during Tests	none	
Contact	Evert Slob 88732	
Expected prior Knowledge	BSc-level knowledge of geophysical methods	
Academic Skills	self-studying	
Literature & Study Materials	textbook, lectures, and suggestions for further reading are available on Blackboard	
Judgement	based on exam result	
Permitted Materials during Exam	pen, pencils.	
Collegerama	No	

AES1550-06	Geophysics Special Subjects	6
Responsible Instructor	Prof.dr.ir. C.P.A. Wapenaar	
Contact Hours / Week x/x/x/x	0/4/0/0	
Education Period	2	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	The course aims at bringing the students understanding of wave theory to a higher level and teaches them to analyze and evaluate geophysical methodologies in terms of the underlying theory. The course treats in a systematic way the unification of different types of wave equations, decomposition, reciprocity and representation theorems. Moreover, it is explained how these concepts underlie a number of current advanced geophysical methods, such as seismic interferometry, time-lapse seismic, internal multiple elimination etc. (these subjects may change from year to year, hence the name Geophysics Special Subjects). The students are required to select a paper from the current geophysical literature, analyze and evaluate it, and discuss it via an oral presentation with the lecturer and their fellow students.	
Study Goals	At the end of the course, students should be able to Derive a unified equation for acoustic, electromagnetic and other wave and diffusion phenomena, Use operator theory to derive symmetry properties of the unified two-way wave equation, Use these symmetry properties to derive unified two-way wavefield reciprocity theorems, Use these unified reciprocity theorems to derive unified two-way wavefield representations, Use pseudo-differential theory to derive a symmetric unified one-way wave equation, Use symmetric one-way wave equation to derive unified one-way wavefield reciprocity theorems, Use these unified reciprocity theorems to derive unified one-way wavefield representations, Use the acquired knowledge to analyze and evaluate a recent advanced geophysical method.	
Education Method	14 two-hour lectures. The other hours are used for self-study, preparation for the exam and a presentation.	
Assessment	Examination: written examination, plus presentation of a paper on a current topic in geophysics	
Expected prior Knowledge	Advanced Reflection Seismology and Seismic Imaging (AES1560)	
Academic Skills	Very good mathematical and physical insight	
Literature & Study Materials	Lecture notes, provided by the lecturer.	
Judgement	Written examination, plus presentation of a paper on a current topic in geophysics	
Permitted Materials during Exam	None	
Collegerama	No	

AES1590-12	Seismic resolution	5
Responsible Instructor	Dr. R. Ghose	
Contact Hours / Week x/x/x/x	0/2/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 Different, to be announced	
Course Language	English	
Course Contents	Fundamental concepts and criteria related to seismic resolution. In-depth discourse on thin bed resolution, tuning effect and interference. Spectral properties of earth and resolution. Fresnel volume, migration and resolution. Improving seismic resolution: various approaches in data acquisition, processing and interpretation, including challenges in extending the seismic bandwidth, seismic source and receiver considerations, vibroseis, P versus S, receiver array, tuning of gun signature, inverse Q filtering, importance of low frequencies, deconvolution, time-frequency analysis, ray versus finite-frequency, forward and inverse approaches. The total college hours for this course will be 4 hours/week, which will include tests and the presentations.	
Study Goals	After this course, the students are able to take decision on different aspects of seismic resolution and how to optimize them. They are able to apply the fundamental concepts related to seismic resolution and work with various key parameters that are involved, and the prevalent and emerging ideas toward improving seismic resolution in practice. They are able to indicate the strengths and weaknesses of different concepts and approaches related to seismic resolution through discussions on key journal publications. The students are also able to describe the contribution of seismic source and receiver, acquisition parameters, and various data processing steps for achieving a desired resolution.	
Education Method	Lectures, study of journal articles, discussions.	
Reader		
Assessment	Tests, presentation, assignments.	
Contact	Dr. Ranajit Ghose	
Expected prior Knowledge	An exposure to the fundamentals of seismic exploration methods and the basic wave propagation theories will be advantageous.	
Academic Skills	Mathematical and quantitative skills; Comprehension and presentation of important research articles	
Literature & Study Materials	Lecture material/illustrations and literature references will be provided on the blackboard site.	
Judgement	Tests, presentations, assignments.	
Permitted Materials during Exam	Closed-book test, without consulting internet and mobile telephone. Hand calculators (without stored material/text in the meomry) are allowed	
Collegerama	No	

CIE4606	Geodesy and Remote Sensing	5
Responsible Instructor	Dr.ir. D.C. Slobbe	
Contact Hours / Week x/x/x/x	6.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	After defining the discipline of Geodesy and its role in Earth sciences, we explore the reference systems and reference frames used in Geodesy (both for time and positions). In particular, we will study the way they are defined and how their realizations are obtained in practice. Second, we will classify the two main positioning methods by the type of measurements used to compute a position solution, and work out in detail positioning using Global Navigation Satellite Systems (GNSS). Next, we treat the determination of the Earth's gravity field and figure. Starting with the fundamentals of potential theory, we will derive Geodetic Boundary Value Problems and outline the strategy to solve them using gravity measurements performed at the Earth's surface. In a separate lecture, we will discuss the meaning of the word "height" in view of what we learned about the figure of the Earth. The second part of this course treats the physical principles of remote sensing based on electromagnetic radiation. First, we will explore the different forms of interaction of electromagnetic radiation with the Earths surface and the Earths atmosphere. After that, we will compare the remote sensing measurement techniques (i.e., electro-optical systems, ranging systems, and radar) in terms of underlying physical principles and limitations. Finally, given that we want to study a particular phenomenon or process on Earth, we will learn how to select an appropriate survey platform and, if applicable, orbit design by taking into account requirements regarding target accuracy, spatial coverage, and spatial/temporal resolution.	
Study Goals	After this course students are able to: 1. Explain the role of Geodesy in Earth Sciences; 2. Analyze the reference systems used in Geodesy in terms of: (i) definition and (ii) the ways their realizations are obtained; 3. Apply coordinate transformations among the reference systems used in Geodesy; 4. Explain how positions can be obtained from GNSS code and carrier phase measurements; 5. Summarize the procedure how to derive the figure of the Earth from gravity observations; 6. Describe the different forms of interaction of electromagnetic radiation with the Earths surface; 7. Describe the different forms of interaction of electromagnetic radiation with the Earths atmosphere; 8. Compare the remote sensing measurement techniques in terms of underlying physical principles and limitations; 9. Select an appropriate survey platform and, if applicable, orbit design to acquire data from a particular phenomenon or process on Earth by taking into account requirements regarding target accuracy, spatial coverage, and spatial/temporal resolution.	
Education Method	Lectures, in-class assignments, in-class demonstrations, and take-home assignments	
Assessment	The student's final grade will consist of a final written exam and one or more take-home assignments.	
Expected prior Knowledge	The expected prior knowledge is the same knowledge required for enrolling in the MSc-track Geoscience and Remote Sensing, which can be found at http://www.tudelft.nl/en/study/master-of-science/master-programmes/applied-earth-sciences/msc-programme/tracks/geoscience-and-remote-sensing/programme/prior-knowledge/	
Academic Skills	Thinking (critical, analytical); Interpretation; Problem solving	
Literature & Study Materials	1) Lecture slides; 2) Some chapters of selected textbooks (provided via BlackBoard or available online); 3) Rees, W. G. (2013). Physical principles of remote sensing. Cambridge University Press.	
Judgement	The result of the final exam will make up 70% of the final grade, and the assignments will be worth the remaining 30% of the final grade.	
Permitted Materials during Exam	Formula sheet (will be provided) and pocket calculator.	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG ETH Zürich semester 2; a minimum of 25 EC should be passed

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Two out of the following three blocks of ETH courses must be passed

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Track Applied Geophysics 2nd Year

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG RWTH Aachen semester 3; a minimum of 25 EC should be passed

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Three out of four following blocks of RWTH courses must be passed

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-AG Semester 4 Thesis

AESM2506	Final Thesis Applied Geophysics	30
Responsible Instructor	Prof.dr.ir. E.C. Slob	
Contact Hours / Week x/x/x/x		
Education Period	None (Self Study)	
Start Education	3	
Exam Period	Different, to be announced Exam by appointment	
Course Language	English	
Course Contents	The final project is a graudation thesis: A research project of about 7 months, the results of which are reported in a thesis. The results are presented in public to the graduation committee. The subject of the graduation project is to be decided jointly with the graduation coordinator and the student. In October of the second MSc year, a group of staff members of ETH, RWTH, and TUD will come together to inform the group of students on the possible graduation subjects. These subjects are usually related to one of the PhD research projects, in which case the PhD student will be the daily supervisor of the graudation project. The research can also take place in an external company or institute. In any case, there will always be an academic member of staff responsible for the quality requirements and supervision. The colloquium consists of a public presentation of the graduation thesis (see AES2005) by means of a 20 minute lecture, after which questions can be posed. Next to the presentation, the candidate will be examined on his thesis by the graduation committee in a closed session.	
Study Goals	The gaduate student learns to apply the skills and knowledge gained in the preceeding study in a research project he/she is to carry out independently. The graduate student displays the knowledge and skills obtained during his specialization by convincingly presenting the results of his research.	
Education Method	individual research project under daily supervision by a scientific staff member	
Assessment	assessment of final report, public presentation and oral examination	
Contact	Evert Slob tel: +31 15 2788732 Hansruedi Maurer, tel: +41 44 633 6838 Christoph Clauser, tel: +49 241 809 4825	
Expected prior Knowledge	85 EC from the program should be finished before you can start	
Academic Skills	self-study, project management, time management, literature search, literature research, report writing, oral presentation, defending yourself in oral exam	
Literature & Study Materials	given by supervisor depending on project, acquired through literature search	
Judgement	by assessment of work during project, written report and oral examination	
Permitted Materials during Exam	thesis report	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-RE Track Resource Engineering (RE)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-RE Track Resource Engineering 1st Year

AESM1020	Mine Feasibility Case Study	5
Responsible Instructor	Ir. M. Keersemaker	
Contact Hours / Week x/x/x/x	0/0/0/varied	
Education Period	4	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	Case study to include all aspects necessary for definition of a professional mine feasibility study. The case may differ every year.	
Study Goals	Apply knowledge of mining, project management, economics, resources, risk management to an industrial relevant dataset; create a feasibility study report; present the report in a professional matter	
Education Method	lectures and case studies	
Assessment	Group and Individual Assignments	
Tags	Databases Economics Geology Group work Projects	
Expected prior Knowledge	BSc Applied Earth Science or equivalent	
Academic Skills	Skills: Thinking, Interpretation, writing report, oral presentation, cooperation Ethics and integrity: Moral awareness/sensitivity, social and environmental impact Citizenship: awareness of responsibilities	
Literature & Study Materials	CostMine Handbooks, SME Handbook	
Judgement	written report (70%) and oral presentation and discussion (30%)	
Permitted Materials during Exam	NA	
Collegerama	No	

AESM1021	Mine Operational Management	5
Responsible Instructor	Ir. M. Keersemaker	
Course Coordinator	Dr.ir. J. Benndorf	
Contact Hours / Week x/x/x/x	0/0/8/0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Required for	Master of Science in Resource Engineering	
Course Contents	The course includes the following topics: Leadership and soft skills Business excellence Grade control and streaming Maintenance Manpower and organisation structures Mine costing Sensors for material characterization	
Study Goals	Students are able to describe streaming and processes for material characterization and separation Students are able to design a mine organization with maintenance requirements Students are able to analyze their own leadership style Students are able to apply basic business improvement techniques and describe business excellence processes	
Education Method	Lectures,individual and group assignments	
Assessment	graded assignments (60%) and exam (40%)	
Contact	M.Keersemaker@tudelft.nl	
Expected prior Knowledge	BSc Applied earth Science or equivalent	
Academic Skills	Skills: Thinking, oral presentation, interpretation Ethics: Moral awareness, Professionalism Integrity: reflection on own behaviour and behaviour of others	
Literature & Study Materials	handouts	
Judgement	graded assignments (60%) and exam (40%)	
Permitted Materials during Exam	calculator	
Collegerama	No	

AESM1021 Toets 1	Assignment	3
Responsible Instructor	Ir. M. Keersemaker	
Contact Hours / Week x/x/x/x	0/0/8/0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	refer to AESM1021	
Study Goals	refer to AESM1021	
Education Method	refer to AESM1021	
Assessment	Combination of individual and small group assignments on streaming/optimisation, sensing and mine organisation/costs	
Contact	M. Keersemaker	
Expected prior Knowledge	refer to AESM1021	
Academic Skills	refer to AESM1021	
Literature & Study Materials	refer to AESM1021	
Judgement	Combined grades for 3 course elements with equal weight accounts for 60% of final grade	
Permitted Materials during Exam	refer to AESM1021	
Collegerama	No	

AESM1021 Toets 2	Exam	2
Responsible Instructor	Ir. M. Keersemaker	
Contact Hours / Week x/x/x/x	0/0/8/0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	refer to AESM1021	
Study Goals	refer to AEMS1021	
Education Method	refer to AESM1021	
Assessment	Exam to test knowledge shared during course	
Expected prior Knowledge	refer to AESM1021	
Academic Skills	refer to AESM1021	
Literature & Study Materials	refer to AESM1021	
Judgement	Exam accounts for 40% of fin al grade	
Permitted Materials during Exam	calculator	
Collegerama	No	

AESM1022	Principles of Mine Design	5
Responsible Instructor	Dr.ir. J. Benndorf	
Contact Hours / Week x/x/x/x	0/6/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Course Contents	Part A Underground Mining Methods for underground exploitation of metalliferous and other ores as well as coal and other minerals; Review of methods: Underground mining methods: room-and-pillar, stope-and-pillar sublevel stoping, shrinkage stoping, cut-and-fill mining, longwall mining, sublevel caving and block caving. Mine Planning stages and phases in finding and exploiting a mineral deposit. Mine Planning principles. Environmental impact of underground operations. Shaft sinking and equipping; road heading technology; drilling and blasting, explosives. Mechanical breakage and excavation; support of underground workings. Mine ventilation; hazardous gases, mine climate; human working environment. Part B Surface Mining Mineral reserves. surface mining project development factors; surface mining methods. long range development and production planning, production rate and level determination; Open pit mining: pit geometry and overall layout design; final pit optimization techniques, floating cone, 2D, 2.5D and 3D L-G approaches; stripping strategies, pushback strategies, mid to short range production planning, sequencing and scheduling; cutoff grade definition and grade control; equipment selection and fleet optimization; slope management and support; pit dewatering; drilling and blasting design, explosives; dump design and waste management; environmental considerations, health and safety; pit closure and rehabilitation methods and scheduling. Open cast mining: area stripping techniques; dragline mining; bucket wheel mining; stripping shovel mining; panel and bench design; stripping and spoiling strategies, special case handling (multiple-seam deposit, deep seems, etc); reclamation methods and planning.	
Study Goals	Students are able to analyze external market environment for a given mining project Students are able to evaluate critical factors impacting major design decisions in surface and underground mining and derive performance indicators. These factors include the mineral resource, safety, social and environmental impact, permitting, process efficiency and economics. Students are able to apply mine planning principles to surface and underground mining for strategic mine planning Students are able to design a surface and underground operation including long-term planning, mine development and short-term operational planning including auxiliary decisions and evaluate its performance indicators	
Education Method	The education form is a blend of on-campus lectures and self-responsible studies and project work. It includes Lectures, assignments, practical work in projects of 2 to 4 students and self-studying.	
Assessment	The assessment consists of a set of assignments (50%) and a written exam (50%).	
Expected prior Knowledge	BSc in Applied Earth Sciences from TU Delft or a BSc of comparable level and content	
Literature & Study Materials	The slides will be provided digitally, references for additional reading and self-study are provided at the beginning of the different secstions.	

AESM1023	Computer-aided Mine Design and Optimization	5
Responsible Instructor	Dr.ir. J. Benndorf	
Co-responsible for assignments	Dr. M.W.N. Buxton	
Contact Hours / Week x/x/x/x	0/6/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Course Contents	Principles of optimization including Linear Programming, Dynamic Programming, Integer Programming, Stochastic integer Programming, Simulation based optimization. Optimization in Mining decisions: cut-off grade optimization, ultimate pit limit definition using Lerch-Grossmann algorithm, Push back design and Optimization, Long-term mine planning optimization, short-term production scheduling optimization, materials handling simulation and optimization, blending strategies. Stochastic simulation models and applications for the mining industry: Simulation based resource/reserve classification, Cost effective drilling programs, Reserve risk quantification, selectivity and Dilution, Uncertainty in pit design and production scheduling with simulated ore bodies, Profitability and risk based grade control, Assessing risk in recoverable reserves and meeting project production schedules ahead of mining, Risk based optimal design for sublevel open	
Study Goals	Students recognize the potential of optimization in the planning and operation phase of a mine and the risk and opportunity associated with it. Students are able to apply basic concepts of mathematical optimization and to identify applications along the chain of mining. Student can apply methods basic methods of optimizations to simple cases in cut-off grade estimation, final pit limit and push back design, long-term mine planning and short-term production scheduling. Students can apply strategies to mitigate against the critical character of geological uncertainty in mining project risk Students are able to select methods for evaluating geological uncertainty and integrate it into robust decision making in mining.	
Education Method	Lectures, assignments, practical work in projects of 2 to 4 students, self-studying	
Assessment	The assessment consists of a set of assignments (50%) and an examination (50%).	
Expected prior Knowledge	BSC Applied Earth Sciences at TU Delft or a BSc with comparable level and content	
Collegerama	No	

AESM1024	Legal, Health and Safety	5
Responsible Instructor	Ir. M. Keersemaker	
Contact Hours / Week x/x/x/x	5/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	The course includes the following topics: Safety systems Safety culture Statistics in legal, health and safety History of health and safety Safety structure: Organisation Safety processes: Standards, policies and procedures, Risk assessment and management, Policy support and reinforcement, Toolbox topics Job safety analyses Safe working procedures Health topics: Fatigue management, Noise Incident investigation Contracts Legal framework Environmental aspects associated with LHS	
Study Goals	Students are able to: explain and describe the importance of Health and safety management in the mining industry find and apply legal requirements and applicable international standards in a mining project case apply knowledge of safety procedures and standards in the field prepare a job hazard analysis and risk assessment and develop mitigation and safety procedures set up an incident investigation	
Education Method	Lectures, Case studies, guest speakers, field exercises, oral presentations; self study	
Assessment	assignments both individual and groups	
Tags	Fieldwork	
Contact	M.Keersemaker@tudelft.nl	
Expected prior Knowledge	Bsc in Applied Earth Science or equivalent	
Academic Skills	Skills: Interpretation, writing reports, oral presentations, cooperation, problem solving Ethics: moral awareness, judgemental skills, professionalism Integrity: refelection of own behaviour and behaviour of others Citizenship: swareness and responsibility	
Literature & Study Materials	Hand outs; slides	
Judgement	Individual and group assignments (small group project, fieldwork, oral presentations); weighted grades	
Permitted Materials during Exam	NA	
Collegerama	Yes	

AESM1024 Toets 1	*Individual Assignment*	*1.5*
Responsible Instructor	Ir. M. Keersemaker	
Contact Hours / Week x/x/x/x	5/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	refer to AESM1024	
Study Goals	refer to AESM1024	
Education Method	refer to AESM1024	
Assessment	4 individual assignments will be given about Toolbox topic, Statistics, JSA and Safety Observations	
Contact	M. Keersemaker	
Expected prior Knowledge	refer to AESM1024	
Academic Skills	refer to AESM1024	
Literature & Study Materials	refer to AESM1024	
Judgement	4 Assignments have equal weight and form 40% of the final grade	
Permitted Materials during Exam	refer to AESM1024	
Collegerama	No	

AESM1024 Toets 2	Group Assignment	2
Responsible Instructor	Ir. M. Keersemaker	
Contact Hours / Week x/x/x/x	5/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	refer to AESM1024	
Study Goals	refer to AESM1024	
Education Method	refer to AESM1024	
Assessment	2 combined group assignments on incident investigation and risk	
Contact	M. Keersemaker	
Expected prior Knowledge	refer to AESM1024	
Academic Skills	refer to AESM1024	
Literature & Study Materials	refer to AESM1024	
Judgement	Combined group assignments account for 30% of the final grade	
Permitted Materials during Exam	refer to AESM1024	
Collegerama	No	

AESM1024 Toets 3	Final Assignment	1.5
Responsible Instructor	Ir. M. Keersemaker	
Contact Hours / Week x/x/x/x	5/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	refer to AESM1024	
Study Goals	refer to AESM1024	
Education Method	refer to AESM1024	
Assessment	One pager capturing learnings from course	
Contact	M. Keersemaker	
Expected prior Knowledge	refer to AESM1024	
Academic Skills	refer to AESM1024	
Literature & Study Materials	refer to AESM1024	
Judgement	This final assignment accounts for 30% of final grade	
Permitted Materials during Exam	refer to AESM1024	
Collegerama	No	

AESM1025	Data Analysis and Resource Modeling	5
Responsible Instructor	Dr.ir. J. Benndorf	
Contact Hours / Week x/x/x/x	6/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	Importance of Resource Modeling and Estimation in the Value Chain of Mining, uni-variate and multi-variate Explorative Data Analysis, Analysis of Spatial Continuity, the Spatial Random Function Model, Model Assumptions of Stationarity and Ergodicity, Inference of a Spatial Random Function using unbiased Estimators, Dealing with Preferential Sampling, Variography and Variogram Modeling, Simple Methods for Spatial Estimation including the Polygon Method, Triangulation, Inverse Distance Power and Polynomial Regression, Geostatistical Methods for Spatial Estimation including Simple Kriging, Ordinary Kriging and Universal Kriging, Integrating Secondary Information into Spatial Modeling using Techniques of Co-Kriging, other methods including Indicator Kriging and Block Kriging, Introduction in Modeling spatial Uncertainty using Conditional Simulation, the Method of Sequential Gaussian Simulation, Geostatistical Considerations in Estimating Reserves in Terms of Volume-Variance Relationship for defining Smallest Minable Units and Grade Tonnage Curves, Applications in Mining Cases, Introduction to CRIRSCO-based International Reporting standards (example JORC Code).	
Study Goals	Students recognize the importance for Mineral Resource modeling and estimation and understand its contribution to the mining value chain. Students can explain basic terminology related to Mineral Resources and Reserves. Student can apply methods of explorative data analysis and variography and identify suitable methods for spatial modeling of ore body attributes related to the problem on hand. Students are able to discuss the critical character of the SMU-size to recoverable reserves. Students are able to judge model assumptions and its practical implications for application. Students are able to perform a simple computer aided resource estimation exercise from drill hole data to reporting on resources using typical commercially available software.	
Education Method	Lectures, assignments, practical work in projects of 2 to 4 students, self-studying	
Assessment	The assessment consists of a set of assignments (50%) and a written exam (50%)	
Expected prior Knowledge	BSc in Applied Earth Sciences at TU Delft or a BSc with comparable level and content	
Literature & Study Materials	To be handed out during class, list of literature available on blackboard	
Permitted Materials during Exam	2 x A4 sheets, hand written, with main content	

AESM1026	Economic Geology & Mineral Exploration: Introduction for Geo-Resource Engineers	5
Responsible Instructor	Dr. J.H.L. Voncken	
Course Coordinator	Dr. M.W.N. Buxton	
Contact Hours / Week x/x/x/x	3/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Master Resource Engineering	
Expected prior knowledge	Physics, Chemistry, Geology and Petrography basics	
Course Contents	Definitions, important concepts, important properties and aspects: ore mineral versus industrial mineral, grade, grade, cut-off grade, resources, reserves, by-products, mineralogical form, grain size and shape, undesirable substances (unfavourable in processing), size and shape of the ore body, ore character (e.g. loose or consolidated, stratiform, vein, etc.), location of the ore body, cost of capital, environmental factors, taxation, political factors. Ore formation processes and their relation to plate tectonics. Genetic grouping of ores (magmatic, hydrothermal, allochthonous, autochthonous). Reference will be made to the following specific commodities: Aluminium, Coal, Cobalt, Copper, Diamonds, Gold, Iron, Lead, Nickel, Platinum Group Elements, Rare Earths, Zinc. Analysis of ores: chemical analysis and microscopic analysis (mineral textures).	
Study Goals	The student will at the end of the course: 1. be able to define what ore minerals are and what ores are, 2. be able to explain the most important economic, technical and environmental aspects of mining, 3. be able to explain and analyse the genetic grouping of ores and the general formation processes of ore deposits, 4. be able to describe, explain and evaluate the geology of the most important commodities in mining, 5. and be able to explain how ores are analysed, and evaluate the methods used. 6. be able to analyse and interpret images of ores/ore minerals 7. be able to apply some economic and some environmental aspects of the mining of an ore deposit.	
Education Method	Combination of lectures, knowledge clips, self-study and group work	
Assessment	Written exam (40%), Assignment (in groups), assignment to be chosen per group out of 24 possible given assignments, with compiling professional written report, comprising literature study, and comparative review (30%). assignment belonging to knowledge clips (30%), with compiling professional written report, comprising literature study, and comparative review.	
Permitted Materials during Tests	Calculator	
Special Information	Dr. J.H.L. Voncken Delft University of Technology Faculty of Civil Engineering & Geosciences Department of Geosciences and Engineering, CEG Resource Engineering Room 3.19 Stevinweg 1 2628 CN Delft The Netherlands Tel: 31 -15 -278 3618 Email: j.h.l.voncken@tudelft.nl	

Expected prior Knowledge	Physics, Chemistry, Geology and Petrography basics
Academic Skills	Communication, cooperation, working in groups, reading proficiency, oral communication, written communication, critical thinking, analytical thinking.
Literature & Study Materials	Lecture slides, papers (titles given during lectures), Internet sites
Judgement	Written exam: 40% Assignment chosen from list of subjects: 30% Assignment referring to knowldge clips: 30%
Permitted Materials during Exam	Calculator
Collegerama	No

AESM4151-2	**Additional Assignment for Geo-Resource Engineers (for MS4151)**	**2**
Responsible Instructor	Dr. J.H.L. Voncken	
Course Coordinator	Dr. M.W.N. Buxton	
Contact Hours / Week x/x/x/x	0/x/0/0	
Education Period	2	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	Please consult the course description for MS4151. AESM4151-2 concerns an extra assignment for Resource Engineering.	
Study Goals	Please consult the course description for MS4151.	
Education Method	Please consult the course description for MS4151.	
Assessment	Written report	
Contact	Dr. J.H.L. Voncken Faculty CITG Geosciences and Engineering Resource Engineering Room 3.19 Stevinweg 1 2628 CN Delft 015 - 27 83618 J.H.L.Voncken@tudelft.nl	
Expected prior Knowledge	Please consult the course description for MS4151.	
Literature & Study Materials	Please consult the course description for MS4151.	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-RE Track Resource Engineering 2nd Year

AESM2020	Research Driven Project	15
Responsible Instructor	Dr. M.W.N. Buxton	
Contact Hours / Week x/x/x/x	na/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	The research driven project can take place within the context of ongoing research at the department, or in collaboration with partner institutions such as consultancies, government and non government organisations in the Netherlands or abroad. If a student wishes to do a research driven project at a mining engineering company or institute of his own choice, this has to be approved by the course coordinator, at the latest two months before starting with the course (that will be in the month of July). The conditions for acceptance of such projects are e.g. situated in a research-oriented environment; providing a qualified researcher as supervisor; brief project proposal describing the research question, research methods, motivation, background information; The project aims to research a problem within the mining/geo/environmental scope. The project aims to answer this research question using research methods, literature review, data analyses, deriving discussion and conclusions based on the data and literature research, written down in a report or an article. Data and findings are to be presented in an oral presentation for the group of students. The student is responsible for time management, cooperation within the research group, proper referring and scientific integrity. The supervisor is responsible for supervising the student and keeping track of the deliverables and time schedule.	
Study Goals	The main objectives are to translate a mining/geo/environmental engineering problem into a relevant research question. to design a suitable research plan to investigate the research question according to methodological and scientific standards and within the given time-space. to perform research under supervision and develop your research skills to apply techniques if relevant to handle, analyse, interpret and evaluate data in a correct manner to synthesize and conclude upon the results to define effective communication strategies with the supervisor . to write a coherent research paper	
Education Method	Self-study Research driven project work during 10 weeks. The student can choose out of subjects supplied by the department of resource engineering at TUDelft or choose a research subject within a mining engineering company/institute. A research subject at a mining engineering company/institute is to be agreed upon with the course coordinator 2 months before starting this course (so before July).	
Assessment	A professional, written report (85%). To be finished within the time scope of 10 weeks. Presentation to be assessed by a committee of appointed specialists (15%).	
Expected prior Knowledge	Have successfully completed the core courses of the programme in the 1st master year;	
Academic Skills	Completion of Bachelors & Masters Courses	
Literature & Study Materials	Self Study	
Judgement	Self Study	
Permitted Materials during Exam	N/A	
Collegerama	No	

AESM2023	Thesis Proposal	5
Responsible Instructor	Dr. M.W.N. Buxton	
Contact Hours / Week x/x/x/x	0/3/0/0	
Education Period	2	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	Preparation of Thesis Proposal	
Study Goals	The objective is for students to define their Masters thesis topic by means of a pre-thesis literature review and assessment. The goals are to: Define the hypothesis Define the research questions Define the proposed methodology Propose a project plan with defined mileston	
Education Method	Self Study & Literature Review	
Assessment	The outcome is a written document which is submitted to the principle supervisor for approval. Based on the supervisors review of the document the student is allowed to proceed towards his/her final thesis geo-resource engineering. Alternatively, in the event of an unsatisfactory assessment the student will be requested to restart the procedure using a new topic.	
Expected prior Knowledge	Prior Masters & Bachelors Courses	
Academic Skills	Completion of previous courses	
Literature & Study Materials	Self Study	
Judgement	Self Study	
Permitted Materials during Exam	n/a	
Collegerama	No	

AESM2025	Final Thesis Geo-Resource Engineering	40
Responsible Instructor	Dr. M.W.N. Buxton	
Contact Hours / Week x/x/x/x	0/x/x/x	
Education Period	2 3 4	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	Each AES Master program will be concluded with an individual graduation thesis: a research project reported in a graduation thesis. The subject of the graduation project is to be decided jointly by the student and the graduation coordinator or a staff member. The graduation research project can also take place at an external company or research institute. In any case, the graduation coordinator remains responsible for the quality requirements of the project and the supervision. The graduation subject will be within the area of the specialization. The research results will be presented in public to the graduation committee (colloquium) by means of a 25 minute lecture, after which questions can be posed. Following the colloquium, the student will be examined on his thesis by the graduation committee during a closed session. Before starting their final thesis, students must have passed the course AESM2023 Thesis proposal.	
Study Goals	The graduate student learns to apply the skills and knowledge gained in the preceding study in a research project he has to carry out independently. Furthermore, the graduate student displays the knowledge and skills obtained during his preceding study by convincingly presenting the results of his research.	
Education Method	Project	
Assessment	The grade for this course is based on an objective assessment of five criteria: quality of the work, quality of the results, performance during thesis, quality of the written presentation, and quality of the oral presentation and defense. See also 'Graduation Rulings' of the 'Teaching and examination regulations Master's degree Applied Earth Sciences'	
Expected prior Knowledge	Having passed the course AESM2023 Thesis proposal	
Academic Skills	Skills developed during course	
Literature & Study Materials	Self Study	
Judgement	-	
Permitted Materials during Exam	N/A	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-RE Specialisation Mining Engineering (RE-EMC)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-RE Specialisation Mining Engineering (EMC) 2nd Year

AESM1023	Computer-aided Mine Design and Optimization	5
Responsible Instructor	Dr.ir. J. Benndorf	
Co-responsible for assignments	Dr. M.W.N. Buxton	
Contact Hours / Week x/x/x/x	0/6/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Course Contents	Principles of optimization including Linear Programming, Dynamic Programming, Integer Programming, Stochastic integer Programming, Simulation based optimization. Optimization in Mining decisions: cut-off grade optimization, ultimate pit limit definition using Lerch-Grossmann algorithm, Push back design and Optimization, Long-term mine planning optimization, short-term production scheduling optimization, materials handling simulation and optimization, blending strategies. Stochastic simulation models and applications for the mining industry: Simulation based resource/reserve classification, Cost effective drilling programs, Reserve risk quantification, selectivity and Dilution, Uncertainty in pit design and production scheduling with simulated ore bodies, Profitability and risk based grade control, Assessing risk in recoverable reserves and meeting project production schedules ahead of mining, Risk based optimal design for sublevel open	
Study Goals	Students recognize the potential of optimization in the planning and operation phase of a mine and the risk and opportunity associated with it. Students are able to apply basic concepts of mathematical optimization and to identify applications along the chain of mining. Student can apply methods basic methods of optimizations to simple cases in cut-off grade estimation, final pit limit and push back design, long-term mine planning and short-term production scheduling. Students can apply strategies to mitigate against the critical character of geological uncertainty in mining project risk Students are able to select methods for evaluating geological uncertainty and integrate it into robust decision making in mining.	
Education Method	Lectures, assignments, practical work in projects of 2 to 4 students, self-studying	
Assessment	The assessment consists of a set of assignments (50%) and an examination (50%).	
Expected prior Knowledge	BSC Applied Earth Sciences at TU Delft or a BSc with comparable level and content	
Collegerama	No	

AESM1024	Legal, Health and Safety	5
Responsible Instructor	Ir. M. Keersemaker	
Contact Hours / Week x/x/x/x	5/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	The course includes the following topics: Safety systems Safety culture Statistics in legal, health and safety History of health and safety Safety structure: Organisation Safety processes: Standards, policies and procedures, Risk assessment and management, Policy support and reinforcement, Toolbox topics Job safety analyses Safe working procedures Health topics: Fatigue management, Noise Incident investigation Contracts Legal framework Environmental aspects associated with LHS	
Study Goals	Students are able to: explain and describe the importance of Health and safety management in the mining industry find and apply legal requirements and applicable international standards in a mining project case apply knowledge of safety procedures and standards in the field prepare a job hazard analysis and risk assessment and develop mitigation and safety procedures set up an incident investigation	
Education Method	Lectures, Case studies, guest speakers, field exercises, oral presentations; self study	
Assessment	assignments both individual and groups	
Tags	Fieldwork	
Contact	M.Keersemaker@tudelft.nl	
Expected prior Knowledge	Bsc in Applied Earth Science or equivalent	
Academic Skills	Skills: Interpretation, writing reports, oral presentations, cooperation, problem solving Ethics: moral awareness, judgemental skills, professionalism Integrity: refelection of own behaviour and behaviour of others Citizenship: swareness and responsibility	
Literature & Study Materials	Hand outs; slides	
Judgement	Individual and group assignments (small group project, fieldwork, oral presentations); weighted grades	
Permitted Materials during Exam	NA	
Collegerama	Yes	

AESM1025	Data Analysis and Resource Modeling	5
Responsible Instructor	Dr.ir. J. Benndorf	
Contact Hours / Week x/x/x/x	6/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	Importance of Resource Modeling and Estimation in the Value Chain of Mining, uni-variate and multi-variate Explorative Data Analysis, Analysis of Spatial Continuity, the Spatial Random Function Model, Model Assumptions of Stationarity and Ergodicity, Inference of a Spatial Random Function using unbiased Estimators, Dealing with Preferential Sampling, Variography and Variogram Modeling, Simple Methods for Spatial Estimation including the Polygon Method, Triangulation, Inverse Distance Power and Polynomial Regression, Geostatistical Methods for Spatial Estimation including Simple Kriging, Ordinary Kriging and Universal Kriging, Integrating Secondary Information into Spatial Modeling using Techniques of Co-Kriging, other methods including Indicator Kriging and Block Kriging, Introduction in Modeling spatial Uncertainty using Conditional Simulation, the Method of Sequential Gaussian Simulation, Geostatistical Considerations in Estimating Reserves in Terms of Volume-Variance Relationship for defining Smallest Minable Units and Grade Tonnage Curves, Applications in Mining Cases, Introduction to CRIRSCO-based International Reporting standards (example JORC Code).	
Study Goals	Students recognize the importance for Mineral Resource modeling and estimation and understand its contribution to the mining value chain. Students can explain basic terminology related to Mineral Resources and Reserves. Student can apply methods of explorative data analysis and variography and identify suitable methods for spatial modeling of ore body attributes related to the problem on hand. Students are able to discuss the critical character of the SMU-size to recoverable reserves. Students are able to judge model assumptions and its practical implications for application. Students are able to perform a simple computer aided resource estimation exercise from drill hole data to reporting on resources using typical commercially available software.	
Education Method	Lectures, assignments, practical work in projects of 2 to 4 students, self-studying	
Assessment	The assessment consists of a set of assignments (50%) and a written exam (50%)	
Expected prior Knowledge	BSc in Applied Earth Sciences at TU Delft or a BSc with comparable level and content	
Literature & Study Materials	To be handed out during class, list of literature available on blackboard	
Permitted Materials during Exam	2 x A4 sheets, hand written, with main content	

AESM2010	Final Thesis Resource Engineering	30
Responsible Instructor	Dr. M.W.N. Buxton	
Contact Hours / Week x/x/x/x		
Education Period	Different, to be announced	
Start Education	1 2 3 4 5	
Exam Period	1 2 3 4 Different, to be announced Exam by appointment	
Course Language	English	
Course Contents	Each AES Master program will be concluded with an individual graduation thesis: a research project reported in a graduation thesis. The subject of the graduation project is to be decided jointly by the student and the graduation coordinator or a staff member. The graduation research project can also take place at an external company or research institute. In any case, the graduation coordinator remains responsible for the quality requirements of the project and the supervision. The graduation subject will be within the area of the specialization. The research results will be presented in public to the graduation committee (colloquium) by means of a 25 minute lecture, after which questions can be posed. Following the colloquium, the student will be examined on his thesis by the graduation committee during a closed session. Before starting their final thesis, students must have passed the course AESM2023 Thesis proposal.	
Study Goals	The graduate student learns to apply the skills and knowledge gained in the preceding study in a research project he has to carry out independently. Furthermore, the graduate student displays the knowledge and skills obtained during his preceding study by convincingly presenting the results of his research.	
Education Method	Project	
Assessment	The grade for this course is based on an objective assessment of five criteria: quality of the work, quality of the results, performance during thesis, quality of the written presentation, and quality of the oral presentation and defense. See also 'Graduation Rulings' of the 'Teaching and examination regulations Master's degree Applied Earth Sciences'	
Expected prior Knowledge	Having passed the course AESM2023 Thesis proposal	
Academic Skills	Previous course material	
Literature & Study Materials	Self Study	
Judgement	-	
Permitted Materials during Exam	n/a	
Collegerama	No	

AESM2022	Project Execution and Mine Startup Planning	10
Responsible Instructor	Ir. M. Keersemaker	
Contact Hours / Week x/x/x/x	8/0/0/0	
Education Period	2	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Required for	EMC Program	
Course Contents	Case study to define a Project Execution Plan in a contractor construction and mine start-up scenario. It involves Project scheduling work breakdown structure execution approach cost estimation and budgeting equipment supply strategy commissioning and operations maintenance strategy manpower planning and organization set up, reporting system HSE management procedures risk management plan	
Study Goals	Integrate all previous course content and apply to real mine case	
Education Method	Introductory lectures; self study and group work	
Computer Use	laptop required	
Assessment	A written execution plan and report (70%) and oral presentation and discussion (30%).	
Tags	Projects	
Contact	M. Keersemaker	
Expected prior Knowledge	Core courses in Master program for Geo-Resource Engineering	
Academic Skills	Skills: Thinking, Interpretation, writing report, oral presentation, cooperation Ethics and integrity: Moral awareness/sensitivity, social and environmental impact Citizenship: awareness of responsibilities	
Literature & Study Materials	Handouts	
Judgement	Report is 70%; presentation and oral defense is 30%	
Permitted Materials during Exam	Not Applicable	
Collegerama	No	

AESM2300-1	Investments Scenarios	1
Responsible Instructor	Dr. M.W.N. Buxton	
Contact Hours / Week x/x/x/x	x/0/0/0	
Education Period	1	
Start Education	1	
Course Language	English	

CME2300	Financial Engineering	4
Responsible Instructor	Ir. drs. J.G. Verlaan	
Contact Hours / Week x/x/x/x	4.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Compulsory course for master CME - Construction Management & Engineering (3TU)	
Summary	Reader Financial Engineering (pdf on BlackBoard) Short overview of the theory of the firm Sources of finance, cost of finance, capital markets Cash flow models, decision rules like payback period, C/B ratio, NPV Financial accounting Financing (international) projects, project finance Political and social factors Portfolio management Financial risk management	
Course Contents	This course deals with the finance issues related to the implementation of civil engineering projects. It introduces economic engineering concepts and finance-related topics such as project financing and financial accounting. This course requires the student to study in detail: # Finance and the firm, covering topics such as sources of finance, cost of finance, financial structures, working capital management and financial accounting # Capital Budgeting Decisions and Risk, covering topics such as Capital Budgeting, Political and Social factors, Portfolio Management and Risk Considerations # Project finance, covering topics such as international capital markets, stakeholder/actors viewpoints and cash flow modelling of projects including characteristics of typical projects like oil wells, open mining, infrastructure and office buildings	
Study Goals	The intended learning outcomes of this course are: # To give students a knowledge of financing and financial implications of civil engineering projects from both a firm and a project perspective, including perspectives from financial involved actors # To give students an understanding of the project life-cycle and its impact on and relationship with project finance # The ability of students to deal with uncertain political and social factors and financial risks	
Education Method	This course will include lectures, case studies and an individual assignment.	
Books	Principles of Corporate Finance, Brealy, Myers and Allen, Eleventh Global Edition	
Assessment	The final assessment is a written examination (40 multiple choice questions). The use of an calculator is allowed. No cell phones or tablets are allowed.	
Contact	CME Secretary's Office, CiTG room 3.40, mrs. Sandra Schuchmann - Hagman, s.c.m.schuchmann@tudelft.nl tel: +31 (0)15 27 84774	
Expected prior Knowledge	No prior knowledge is required.	
Academic Skills	To prepare for the future interdisciplinary world of work (engineering and finance, projects), to broaden academic skills with respect to optimization and to obtain interdisciplinary competences.	
Judgement	The result of the multiple choice exam should be 6.0 or higher.	
Permitted Materials during Exam	* The use of a calculator is allowed, but no mobile phones or tablets / iPads. * No books or dictionaries are allowed	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GE Track Geo-Engineering (GE)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GE Required Courses (34 ECTS)

AES1630	Engineering Geology	4
Responsible Instructor	Dr.ir. D.J.M. Ngan-Tillard	
Contact Hours / Week x/x/x/x	8.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Geoscience and Engineering Fieldwork in Spain	
Expected prior knowledge	General Geology or Geology for engineers is recommended but not compulsory.	
Summary	Geology for engineers and Engineering Geology. Engineering properties of major types of soils and rocks, their variations according to geological and climatic setting and their impact on construction projects.	
Course Contents	This course is primarily intended to provide an overview of the engineering geological characteristics of the major types of soils and rocks, and their impact on engineering design and construction. The ways the source materials, the agents responsible for their formation and the climatic conditions in which they were formed govern their mineralogy and fabric, and thus their behaviour, are highlighted. This course addresses the following issues: - how the engineering properties of soils and rocks vary according to the geological conditions governing their deposition and their subsequent stress history - how the behaviour of some geological materials deviate from those of "textbook" soils and rocks - how geological properties impact on engineering behaviour	
Study Goals	Students can predict the engineering geological characteristics of the major types of soils and rocks, and their impact on engineering design and construction. They are able to carry out feasibility studies for projects based on real geological maps and information.	
Education Method	Lectures, worksheet practicals The course consists of 2 blocks: 1 Soils: Engineering geology of soils and sediments 2 Rocks: Engineering geology of rocks: igneous, metamorphic and sedimentary. Tuition is based broadly on four hours of lectures and four hours of practicals per week. Engineering geologists working with the industry are invited to share their expertise on given geological environments.	
Literature and Study Materials	AES1630 documents available on Blackboard TEXTBOOKS 1) Fookes, P.G., 1997. The First Glossop Lecture. 'Geology for Engineers: the Geological Model, Prediction and Performance'. Quarterly Journal of Engineering Geology and Hydrogeology, 30, 293-431. 2) Waltham, T., 2009, Foundations of Engineering Geology, 3rd edition(Paperback) 3) Bell, F.G., 1981. Engineering Properties of Soils and Rocks. Butterworths (1rst edition), 149 pp. RECOMMENDED REFERENCE READINGS 1) Bell, F.G., 2000. Engineering Properties of Soils and Rocks. Blackwell Science (4th edition), 482 pp. 2) Fookes, P.G., Lee, E.M. & Milligan, G., 2005. Geomorphology for Engineers. Whittles Publishing, 851 pp. PERIODICALS The following are the principal periodicals in the field of Engineering Geology and should be regularly consulted: 1) Engineering Geology, Elsevier. 2) Quarterly Journal of Engineering Geology & Hydrogeology, Geological Society of London 3) The Bulletin of Engineering Geology and the Environment, International Association for Engineering Geology and the Environment.	
Assessment	Three written assignments, one oral assignment and one written exam. Submission of the first, second and third worksheets is due as at the end of the second, fifth and seventh week respectively to Dominique Ngan-Tillard by e-mail.	
Enrolment / Application	Please enroll the AES1630 BB site before the first lecture.	
Expected prior Knowledge	General Geology or Geology for engineers is recommended but not compulsory.	
Academic Skills	All aspects of an Academic attitude (skills, ethics, integrity and citizenship)are developed in the course. Aspects such as ethics, integrity, and citizenship are part of the feasibility studies of the last two worksheets.	
Literature & Study Materials	AES1630 documents available on Blackboard TEXTBOOKS 1) Fookes, P.G., 1997. The First Glossop Lecture. 'Geology for Engineers: the Geological Model, Prediction and Performance'. Quarterly Journal of Engineering Geology and Hydrogeology, 30, 293-431. 2) Waltham, T., 2009, Foundations of Engineering Geology, 3rd edition(Paperback) 3) Bell, F.G., 1981. Engineering Properties of Soils and Rocks. Butterworths (1rst edition), 149 pp. RECOMMENDED REFERENCE READINGS 1) Bell, F.G., 2000. Engineering Properties of Soils and Rocks. Blackwell Science (4th edition), 482 pp. 2) Fookes, P.G., Lee, E.M. & Milligan, G., 2005. Geomorphology for Engineers. Whittles Publishing, 851 pp. PERIODICALS The following are the principal periodicals in the field of Engineering Geology and should be regularly consulted: 1) Engineering Geology, Elsevier. 2) Quarterly Journal of Engineering Geology & Hydrogeology, Geological Society of London 3) The Bulletin of Engineering Geology and the Environment, International Association for Engineering Geology and the Environment.	
Judgement	The assessment of the written assignments will be based on questions posed within the Worksheets. The submission will be assessed on the basis of its technical content and relevance to engineering geology. The oral assignment will consist of the presentation of a poster on sandstone, answers to questions from the audience and formulation of questions about posters presented by other groups. The exam will consist of a case study and knowledge/thinking questions.	
Permitted Materials during Exam	None	
Collegerama	No	

AESM1700	Consolidation of Soils	3
Responsible Instructor	Prof.dr. C. Jommi	
Contact Hours / Week x/x/x/x	0/0/4/0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	

CIE4361	Behaviour of Soils and Rocks	6
Responsible Instructor	Dr.ir. R.B.J. Brinkgreve	
Contact Hours / Week x/x/x/x	0.8.0.0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Required for	MSc Geo-engineering	
Expected prior knowledge	BSc courses "Grondmechanica" (soil mechanics) and "Toegepaste mechanica" (Applied mechanics)	
Course Contents	The course deals with the mechanical behaviour (stress-strain response) of soils and rocks, as well as with constitutive models describing the various features of soil and rock behaviour. In addition to the theoretical details of the models, attention is paid to model parameter determination and the application of models via the finite element method. The following topics are included: 1. Introduction to continuum mechanics, stress, strain; 2. Soil behaviour in compression and shear; 3. Undrained soil behaviour, undrained strength; 4. Normally-consolidated and over-consolidated soils; 5. Elasticity, Hooke's law; 6. Modelling pore pressures and undrained behaviour; 7. Simulation of standard lab tests; 8. Non-linear elasticity; 9. Failure criteria (Mohr-Coulomb, Tresca, Hoek-Brown, other); 10. Plasticity theory; 11. The linear-elastic perfectly plastic model; 12. Material hardening & softening; 13. Critical State soil mechanics, Cam-Clay theory; 14. Soft Soil model, Hardening Soil model; 15. Anisotropy, structure and de-structuration; 16. Small-strain stiffness, cyclic loading, liquefaction 17. Hypoplastic model; 18. Time-dependent behaviour, creep; 19. Rock behaviour; 20. Hoek-Brown model, Jointed Rock model; 21. Application of models; 22. Possibilities & limitations.	
Study Goals	After the course, students are able to: 1. Identify various features of soil and rock behaviour; 2. Explain the possibilities and limitations of models; 3. Select appropriate models for practical applications; 4. Determine model parameters based on site investigation data or otherwise; 5. Explain the behaviour of the models under specific conditions.	
Education Method	Lectures, workshops, assignments, computer exercises, exam	
Computer Use	During some lectures the PLAXIS finite element program for geotechnical applications is used to simulate model tests and to analyse practical applications.	
Course Relations	The CIE4361 course has links to other Geo-engineering courses: 1. CIE4380 Numerical modelling in geo-engineering; 2. CIE5320 Site characterization, testing and physical modelling; 3. CIE4353 Continuum mechanics	
Literature and Study Materials	Recommended lectures notes / textbooks / backgrounds: 1. Sitters C.W.M. (1996) Material Models for Soil and Rock; 2. Sitters C.W.M. (1997) Continuum mechanics; 3. Molenkamp F. (2003) Continuum mechanics; 4. Brinkgreve R.B.J. (1994) Geomaterial Models and Numerical Analysis of Softening; 5. Brinkgreve R.B.J. et al. (2012) PLAXIS Finite Element Code for Soil and Rock Analysis. (see links on Blackboard)	
Books	1. Yamamuro J.A., Kaliakin V.N. (2005) Soil Constitutive Models: Evaluation, Selection and Calibration. ASCE Geotechnical Special Publication No. 128.	
Reader	1. Sitters C.W.M. (1996) Material Models for Soil and Rock (although hardly used)	
Assessment	Four Assignments need to be completed before students can participate in the Exam. The Exam is a digital exam using Maple TA on the exam server.	
Permitted Materials during Tests	Writing equipment and (scientific) calculator	
Enrolment / Application	Via Blackboard	
Contact	Responsible for course: Dr. Ronald B.J. Brinkgreve Second lecturer: Prof. Michael A. Hicks Assistant: Dr. Phil Vardon (Geo-engineering section)	
Expected prior Knowledge	BSc courses "Grondmechanica" (soil mechanics) and "Toegepaste mechanica" (Applied mechanics)	
Academic Skills	Dealing with formulas; making calculations	
Literature & Study Materials	Available on Blackboard	

Judgement	The final mark is based on the results of the Exam.
Permitted Materials during Exam	Standard scientific calculator
Collegerama	Yes

CIE4365-16	**Modelling Coupled Processes for Engineering Applications**	**5**
Responsible Instructor	Prof.dr.ir. T.J. Heimovaara	
Instructor	Dr. B.M. van Breukelen	
Contact Hours / Week x/x/x/x	0/0/0/5	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Course Contents	Many processes in the geo- and environmental engineering show a complex interaction with each other. This course focusses on obtaining experience with modelling coupled processes for engineering applications in the sub-surface, during water treatment and in the atmosphere. An example related to the subsurface is consolidation during loading of saturated and unsaturated deformable porous media, like soils. Deformations in such media lead to changes in the pore volume and corresponding changes in pore fluid pressures which initiate seepage and affect the general behaviour. Understanding such coupled processes is of great importance to settlements and stability, in particular when permeability is small, compressibility is large and strength is limited. Other examples of coupled processes are the thermo-chemo-hydro-mechanical coupled processes found in situations where flow of water, heat and solutes play an important role such as waste management (in landfills, in underground nuclear repositories and in engineered systems). A very recent field where coupled processes play a significant role is biology as a driving force for the dynamics in temperature, chemistry, hydrology and mechanics in the so-called Biological Geo and Civil Engineering. For water treatment we can think of, flow of water through a sand filter with simultaneous oxidation of reduced iron and filtration of the formed iron flocs resulting in clogging of the filter combined with the growth of biomass and decomposition of waste water. Modelling of coupled processes plays an important role in nearly all fields of geo- and environmental engineering.In this course the students develop skills for analyzing and modelling coupled processes. They can derive the controlling partial differential equations and implement these equations in Matlab or Python to solve realistic problems. The processes discussed during the course should be familiar as they have already been addressed in different courses before. In this course the students are expected to solve realistic problems where these processes are coupled to each other.	
Study Goals	The student can recognize the occurrence of coupled processes in the environment, develop and implement mechanistic conceptual models how the processes interact. The students can define relevant initial and boundary conditions and implement realistic complex problems in modern simulation and engineering tools like Matlab or Python. The students can debug the code and generate useful output required for analyzing coupled processes. The students can report their findings in a concise report.	
Education Method	During the course period, the students are supposed to follow six (short) lectures in which different approaches to coupled processes are introduced. During these six lectures a series of assignments will be introduced. The students are expected to carry out the assignments in which coupled problems of increasing complexity will need to be analysed and implemented. During the lecture hours, teachers and teachning assistents are available for support. The assignments will be tailored to the MSc track the students are following: Geo-Engineering or Environmental Engineering. The students are expected to read background material in the form of research articles from the literature and chapters from several hand books available in digital form in the TU Delft library. The assignments need to be carried out during the lecture period. Assignments needed to submitted individually, however students are encouraged to work in groups of four.	
Computer Use	Tutorial lectures will be held in the computer room. All assignments are computer based and require programming in Matlab or Python. Tutorials will be provided and students are expected to be able to work with these tools. Students are expected to download the latest versions of Matlab and Python on their laptop for this course.	
Assessment	The achieved level of knowledge, understanding and problem solving skills of the impact of coupled processes in the sub-surface for engineering will be assessed with the assignments and during the final individual exam. The exam consists of a series of questions which are related to the assignments carried out earlier by the students. The final grade for CIE4365 is based upon the result of the exam and the assignments, 50%/50%.	
Expected prior Knowledge	BSc Civil Engineering or Applied Science (or equivalent). Core program of either the Geo-Engineering track or Environmental Engineering track.	
Academic Skills	Critical thinking, analytical thinking and problem solving are the main academic skills which will be trained. In addition, students will need to collaborate intensively with their colleagues so organizational and interpersonal skills will be developed as well.	
Literature & Study Materials	Background material, papers and chapters from relevant literature will be provided via Blackboard. All slides etc are also available.	
Judgement	All assignments will be graded and averaged in a single grade. The students take an individual exam. The average grade of the assignments and the exam is the final grade.	
Permitted Materials during Exam	Anything except a computer. However, exam might be on a computer depending on how far we are able to develop this exam.	
Collegerama	No	

CIE4366	Numerical Modelling in Geo-Engineering	6
Responsible Instructor	Dr. P.J. Vardon	
Contact Hours / Week x/x/x/x	0.0.8.0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	Introduction to finite element analysis: basic formulation and example applications. Theoretical aspects: basic principles; 1D finite elements, including application to beam bending theory and beams on an elastic foundation; 2D finite elements; derivation of finite element equations for linear elasticity; material non-linearity; derivation of finite element equations for steady state seepage; transient, coupled and dynamic systems; 3D finite elements, including comparison between 2D and 3D analysis; finite element mesh numbering; storage schemes; equation solvers; local coordinate systems; programming the finite element method; structure charts. Related topics: mesh generation; adaptive mesh refinement; stochastic analysis; finite differences; inverse analysis; computer programming. Applications: case histories; coursework examples, including the use of existing finite element codes for applications in geotechnical and geo-environmental engineering.	
Study Goals	After the course the student will be familiar with the basic principles of modelling in Geo-Engineering. In particular the course aims to enable students to: Formulate the basic equations of the finite element method Explain how finite element programs work Design, perform and evaluate an appropriate finite element investigation with sometimes vague requirements. Use basic scientific programming techniques, including limited modification of finite element programs Describe non-standard finite element techniques unavailable in commercial codes Judge modelling results critically.	
Education Method	Lectures, computer laboratory tutorials and assignments	
Literature and Study Materials	Course book: Programming the finite element method, 4th edition, I.M. Smith and D.V. Griffiths, John Wiley & Sons Limited, 2004. Accompanying notes.	
Assessment	Coursework and written exam.	
Tags	Algoritmics Analysis Calculus Geo Engineering Mathematics Modelling Numeric Methods	
Expected prior Knowledge	Basic geo-engineering problems (e.g. CTB2310 Soil Mechanics). Basic calculus (e.g. CTB1001 Analyse).	
Academic Skills	Report writing. Engineering investigation.	
Literature & Study Materials	Programming the finite element method, 4th Edition, I.M. Smith and D.V. Griffiths, John Wiley & Sons Limited, 2004	
Judgement	One mark, based on 3 coursework assignments (60%) and written exam (40%). One additional coursework will be formative only, where the student will only pass or fail.	
Permitted Materials during Exam	Standard calculator.	
Collegerama	No	

CIE4395	Risk and Variability in GeoEngineering	4
Responsible Instructor	Prof.dr. M.A. Hicks	
Contact Hours / Week x/x/x/x	0/0/0/4	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Summary	Conventional geotechnical analysis follows a deterministic approach. This involves sub-dividing the problem domain into distinct material zones (or layers), and then assigning constant values to the material properties within in each zone. This leads to a single analysis and, in the case of stability assessments for example, to a single factor of safety. This course takes account of the fact that, even in so-called uniform soil deposits or layers, there exists spatial variability of material properties (often referred to as heterogeneity). This spatial variability influences material behaviour, groundwater behaviour and the performance of geotechnical structures. It also means that we are never really sure what we have in the ground and so this leads to uncertainty in design. The course considers the measurement, characterisation and numerical modelling of spatial variability, as well as methods for quantifying the effects of spatial variability and uncertainty on geotechnical performance. This involves stochastic analysis and leads to probabilistic definitions of response: in particular, reliability, which is the probability of failure not occurring. By linking probability of failure with consequence of failure, risk assessments may also be made.	
Course Contents	Introduction to risk and variability. Statistical characterisation of in situ data: cone penetration testing; frequency diagrams; probability density functions; point statistics; properties of the normal distribution; sources of error in evaluating site data; depth-dependency; stages in data interpretation; importance of spatial statistics; scale of fluctuation and its measurement; practical applications. Modelling of spatial variability: local averaging theory; random fields; local average subdivision; univariate, multi-variate and reduced variate random fields; application to liquefaction potential. Outline of the stochastic process: pre-analysis stage; analysis stage; mapping of random fields; Monte Carlo analysis; numerical modelling; post-analysis stage; reliability and probability of failure; performance probability density functions and performance cumulative distribution functions. Influence of spatial variability on geo-structural performance: importance of scale of fluctuation; problem-dependency; comparing deterministic and stochastic approaches; range of solutions; sensitivity of solutions to input parameters; comparing 2D and 3D analyses; assessment of risk. Implications for geotechnical design: Eurocode 7; characteristic values; partial factors.	
Study Goals	After the course the student will be familiar with methodology for the measurement, characterisation and numerical modelling of spatial variability, as well as methods for quantifying the effects of spatial variability and uncertainty on geotechnical performance. The student will also be aware of the importance in considering spatial variability in geotechnical design and risk assessments.	
Education Method	Lectures and assignments.	
Literature and Study Materials	Accompanying notes and technical papers.	
Assessment	Written 3 hour exam (75% of total mark) and coursework (25% of total mark).	
Expected prior Knowledge	Background in soil mechanics.	
Academic Skills	Soil mechanics and analytical skills.	
Literature & Study Materials	Selection of papers, ppt presentations and notes given during lectures.	
Judgement	One mark, based on written exam and coursework.	
Permitted Materials during Exam	Standard calculator.	
Collegerama	No	

CIE5320	Site Characterisation, Testing and Physical Model	6
Responsible Instructor	Dr. A. Askarinejad	
Contact Hours / Week x/x/x/x	12/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Geoscience and Engineering Fieldwork in Spain	
Course Contents	This course deals with the set up and execution of site investigations for civil engineering projects, both onshore and offshore, with an emphasis on geotechnical and geological factors that can be of influence on the realisation of the projects. Attention is paid to standard and advanced techniques to collect geotechnical data (walk along survey, laboratory and in-situ testing, monitoring data) and to the problems that some specific soil and rock types can impose. In the accompanying laboratory practical, a number of important soil and rock tests are carried out. During field excursions, students are exposed to real ground and site investigation. The course further deals with physical modelling and experimental techniques in soil mechanics in general. It includes a short introduction to measurement and control theory, the types of actuators and sensors commonly used and the scaling laws that apply for full and reduced scale geotechnical modelling. Some of the physical model tests in use nowadays are highlighted with examples. A series of simulation exercises called 'Engineering geology games' are proposed to students, during which site investigations are designed for a variety of construction projects and geological environments. During one of these games, the design and excecution of a site investigation for a civil engineering project in the Netherlands is simulated. Data is provided, analysed and used to produce a conceptual model of the ground, forecast ground properties relevant to the project and design additional site investigation keeping in mind cost efficiency. The Engineering Geology games are preceeded by an introduction to general geology and geological map reading.	
Study Goals	The goal of this course is to give an overview of the available laboratory tests and in-situ site investigation techniques, as well as a basic understanding of measurement and control theory. Students will be able to explain the fundamentals of physical modelling, and can derive the governing questions and scaling laws required to interpret the results of a physical modelling. Students will develop the ability to design a site investigation for different geological situations. Students can explain why and how the standard and advanced geotechnical laboratory tests are conducted. Students are able to write technical site investigation reports.	
Education Method	A combination of lectures, readings and practicals (field and lab work and simulation exercises) is proposed. A schedule concerning subjects, dates, places and lecturers is handed out at the beginning of the course.	
Literature and Study Materials	Texbooks: - Geotechnical engineering and soil testing, by Amir Wadi. Al-Khafaji, Orlando B. Andersland (available at TUD library as e-book) - Geotechnical engineering handbook, Braja M. Das, (available at TUD library as e-book) - Site Investigation, by Clayton, CR, Matthews, MC, Simons, NE, Wiley-Blackwell, 1995 - Geotechnical Centrifuge Technology, by Taylor, RN - Engineering Geology: principles and practice, by David Price, Springer, 2007 Recommended readings: - Geotechnical Modelling, by David Muir Wood Scientific papers which will be uploaded on the Blackboard.	
Prerequisites	Fundamental concepts of soil mechanics and standard geotechnical laboratory tests. Basic understanding of rock mechanics.	
Assessment	Assessment based on performance at laboratory work (30%), site investigation games (20%), physical modelling exercise (20%) and oral exam (30%)	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GE Focus Elective Courses (28 EC without Ethics convergence course and 24 EC with)

AES1050	GSE Student competition course	5
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	na	
Education Period	1 2 3 4	
Start Education	1 2 3 4 5	
Exam Period	none	
Course Language	English	
Course Contents	The GSE Student Competition Course is a platform offered to encourage and stimulate participation of teams of students to high level scientific competitions which can be within TUDelft, national or international. The GSE Student Competition Course provides a workflow which participants are required to follow in order to be eligible for the 5EC associated with the course. The workflow is as follows 1) the team intending to participate to the competition writes a motivation letter which includes, among others, i) a description of the competition ii) the expected added value for the educational growth of the students iii) a motivation statement from all members of the team and iv) the name of a technical advisor in charge of the daily supervision of the participating team. If costs are involved in the participation, the letter should also include information on how these will be covered. The letter is evaluated by the Course responsible and two other GSE staff members (Prof. Dr. B. Rossen and Dr. G. Drijkoningen) and participation is approved/rejected. The way the participation will be graded is also discussed and agreed upon at this stage At the end of the competition, the participating team will submit a short report describing the activities and experiences made during the competition itself. The technical advisor proposes a grade which is then discussed with the three staff members responsible of the Course.	
Study Goals	The goal of the GSE Student Competition Course is to improve technical knowledge and strengthen the group working skills of the participating team. Upon succesful completion of the competition, the participating students will have learned a variety of technical tools (depending on the type of competition) and will be able to work in a small team under time and competition pressure to present their results in a competitive arena in front of an external jury	
Education Method	Learning through competition	
Assessment	The pass/no pass boundary and the grading will depend on the type of competition and will be discussed prior to the start of the competition itself	
Expected prior Knowledge	Expected prior knowledge depends very much on the competition. Because only scientifically challenging competitions will be considered, only MSc students will be allowed with a strong background. Intrinsic in the idea of a competitive team, the participants will have different backgrounds (geophysics, engineering, geology etc)	
Academic Skills	Key to success and, therefore to earning the 5EC is the ability to form a real team during the competition. The necessary first step of this process is the ability of putting together a winning team composed of experts also able to work together. The value of strong cooperation will only increase during the competition	
Literature & Study Materials	will depend on the specific compeititons	
Judgement	The technical advisor (if present) will propose a grade to the staff members responsible of the course; these will have the final decision.	
Permitted Materials during Exam	no exam in the classical sense of the term is foreseen the assessment will be based on the report presented by the participating team and on insights provided by the technical advisor	
Collegerama	No	

AES1501	Methods of Exploration Geophysics	3
Responsible Instructor	Prof.dr.ir. E.C. Slob	
Course Coordinator	Dr.ir. G.G. Drijkoningen	
Course Coordinator	Dr. R. Ghose	
Contact Hours / Week x/x/x/x	during first 4 weeks: 2 till 4 hours/week	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	This course treats potential, diffusion, and wave methods that are used in exploration geophysics. Signal theory for signals in linear time-invariant systems is reviewed. Potential, diffusion, and wave fields in a homogeneous space and generated by a localized source in 3D are derived and described in wavenumber-frequency, space-frequency, and space-time domains. Examples of these techniques are given for geo-electric, diffusive electromagnetic, and seismic wave methods used in exploration geophysics. The underlying reasons behind the relations between geophysical properties and physical properties are treated, as well ways how to obtain some of the key physical properties from the geophysical data.	
Study Goals	Knowledge of the basic measurement principles and underlying theory of exploration methods used in applied geophysics. To be able to derive solutions of partial differential equations with constant coefficients. To be able to give a physical interpretation of these solutions. To be able to explain the difference in field behavior of potential, diffusive, and wave fields. To be able to describe the relation between physical and geophysical material properties.	
Education Method	14 hours of lectures and 66 hours of self-study.	
Course Relations	prepares for AES1560, AES1590-11	
Reader	lecture notes	
Assessment	written exam in week 4	
Exam Hours	two hours for final exam at the end of week 4	
Permitted Materials during Tests	none	
Contact	Evert Slob 88732	
Expected prior Knowledge	BSc-level knowledge of geophysical methods	
Academic Skills	self-studying	
Literature & Study Materials	textbook, lectures, and suggestions for further reading are available on Blackboard	
Judgement	based on exam result	
Permitted Materials during Exam	pen, pencils.	
Collegerama	No	

AES1640-11	Environmental Geotechnics	4
Responsible Instructor	Prof.dr.ir. T.J. Heimovaara	
Contact Hours / Week x/x/x/x	4/0/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Expected prior knowledge	Basic knowledge of groundwater flow (Darcy's Law), solute transport, high school chemistry and partial differential equations.	
Summary	This course covers the processes and technology involved with the sustainable management of the sub-surface. The course is based on the source-path-object concept in risk management. Using this concept, the fundamentals of the essential processes are introduced related to several application cases. During the lectures the students are introduced to current state of the art technologies for site investigation, (mathematical) concepts for risk management, engineered barriers, remediation and monitoring.	
Course Contents	The course is built around the source-path-object concept in Environmental Risk Management. The rationale behind the course is that the subsurface provides modern day society with a wide range of services, which the environmental community tends to call "ecosystem services". These services include, issues such as element cycling (carbon, nitrogen, phosphates), water cycling and filtration, basic foundation for building infra-structure, repository for biodiversity, etc. Civil- and geo-engineers are more and more making use of these "ecosystem services" in their solutions to engineering problems and therefore they require a thorough understanding of the backgrounds of these services. In the lectures application examples will be given from amongst others: soil-remediation, shallow depth geothermal energy, waste-management, building with recycled materials and biobased geo-engineering. The lectures will draw from the following topics: - General introduction to sustainable subsurface management and ecosystem services; - Environmental risk assessment in general, special focus to sub-surface issues; - Principles of groundwater flow; - Principles of solute transport; - General physical chemistry (acid base chemistry, reactions and mass action equations); - General Redox chemistry; - Equilibrium processes in the subsurface; - Non-equilibrium processes in the subsurface; - Subsurface (micro)biological metabolism; - Isotope fractionation; - In-situ remediation technology (pump & treat, vapour extraction, bio-degradation, chemical oxidation, heat enhanced technology); - Bio-based geo-engineering	
Study Goals	After passing this course the students will: - be able to quantitatively analyse the role of groundwater flow, solute transport and bio-geochemical processes in the sustainable management of the subsurface; - be able to develop conceptual models in order to develop solutions to engineering issues related to the sustainable management of the sub-surface; - be able to quantitatively handle measured data in order to make predictions about the functioning of the sub-surface system; - understand the concepts behind different technologies which can be used to engineer the processes in the sub-surface	
Education Method	During a time period of 7 weeks, two lectures of two hours are given per week. Presence at the lectures and regular study of the contents form the basis for a successful exam. Students are expected to study and practise themselves. Working together is advisable.	
Literature and Study Materials	Lecture notes, articles (cases) and assignments are provided via Black Board. Example exams including answers are also available.	
Assessment	The achieved level of Environmental Geotechnical knowledge and problem solving skills will be assessed during the final exam. The exam consists of a series of questions which are similar to the assignments prepared for and discussed during the tutorial lectures. At least one of the questions will consist of a real life problem in which the complete scope of the lectures will be covered. The exam is open-book, this means that all material including worked examples may be brought to the exam. The exam is an individual assessment so no networked devices or network ready devices are allowed at the exam. The final grade for AES1640 is based the result of the exam. Test assignments will be given during the course of the lectures. These, however, do not count for the final grade.	
Expected prior Knowledge	Basic knowledge of groundwater flow (Darcy's Law), solute transport, high school chemistry and partial differential equations.	
Academic Skills	Reading, Analysing, Problem solving	
Literature & Study Materials	Will be given on Blackboard. Different chapters from books which are electronically available via the TU Delft Library	
Judgement	Final exam	
Permitted Materials during Exam	Open book, all materials except electronic devices which are connected to the internet.	
Collegerama	No	

AES1720-11	Rock Mechanics Applications	5
Responsible Instructor	Dr.ir. D.J.M. Ngan-Tillard	
Gast Instructor	Ir. J.S. van der Schrier	
Contact Hours / Week x/x/x/x	0/0/8 + 1 day excursion in week 2.5/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Required for	The content of AES1720-11 is recommended for the Geoscience and Engineering fieldwork in Spain	
Summary	Intact rock material, construction materials, discontinuities in rock masses, determination of rock mass parameters, modeling of discontinuous rock masses, testing and monitoring, excavation and support principles, application of these principles to various projects.	
Course Contents	- Properties and testing of intact rock and construction materials. Characterisation and properties of discontinuities in rock. Characterisation and properties of discontinuous rock masses. Large and small scale testing and monitoring of discontinuities and discontinuous rock masses. - Mechanical behaviour of rock masses, included dynamic and time-dependent behaviour. Principles of flow through discontinuities and discontinuous rock masses. Weathering and susceptibilty to weathering of discontinuous rock masses. - Principle of excavation methods. Excavatability, wear and performance of cutting tools. Influence of blasting and other vibrations. Influence of stress and stress changes. - Principle of support methods. - Rock mass classification systems. Possibilities for analytical and numerical modelling of discontinuous rock masses. - Application of principles of rock mass excavation and support to slopes, tunnel, dam, foundation, rock dredging and sea water breaker design. - Monitoring, analysis, prediction and mitigation of subsidence due to solid removal. - Case histories. - Visit to the Underground laboratory for Numclear Waste Disposal in Mol, Belgium, exposure to various tunnelling methods and tunnel support and Multi-physics coupled processes in Boom Clay.	
Study Goals	Students are able to: - explain how to characterize, test, and monitor rock. material, rock discontinuities and rock masses for a wide range of geo-engineering and environmental applications - select models that capture the essentials of the rock behaviour observed in the lab or in situ and highlight limitations of these models. - appraise ground conditions and evaluate ground parameters, even from sparse and incomplete data sets, and formulate ground risks associated to projects. - evaluate analytically the stability of various structures founded in or on rocks. - design basic stabilization measures and recommend more advanced methods for critical situations. - apply to new projects lessons learned from case histories. - work on rock mechanics and rock engineering problems independently and in group, compile results in written reports, and defend them orally.	
Education Method	Lectures, guess lectures, exercises, laboratory tests, case studies, 1 day fieldwork	
Literature and Study Materials	Book 'Introduction to rock mechanics', Goodman, 2nd edition, hand-outs. Reference literature: Practical Rock Engineering, Hoek, edition 2000 (http://www.rocscience.com/hoek/PracticalRockEngineering.asp) Engineering Rock Mechanics, John Harrison and John Hudson - An introduction to Principles, 2000 - Illustrative worked Examples, 2000	
Prerequisites	Basic Rock Mechanics or Soil Mechanics	
Assessment	Written exam (70%), case study report (20%), and quarry design (10%)	
Enrolment / Application	Please enroll the BB site for AES1720-11 before the start of the course.	
Elective	Yes	
Tags	Geo Engineering Projects Underground	
Expected prior Knowledge	Basic Rock Mechanics or Soil Mechanics	
Academic Skills	All aspects of an academic attitude are integrated into the course. Aspects such as Ethics, integrity and citizenship are part of the case study provided by the industry.	
Literature & Study Materials	Book 'Introduction to rock mechanics', Goodman, 2nd edition, hand-outs. Reference literature: Practical Rock Engineering, Hoek, edition 2000 (http://www.rocscience.com/hoek/PracticalRockEngineering.asp) Engineering Rock Mechanics, John Harrison and John Hudson - An introduction to Principles, 2000 - Illustrative worked Examples, 2000	
Judgement	Written exam (70%), case study report (20%), and quarry design (10%)	
Permitted Materials during Exam	Simple non programmable calculator, drawing instruments	
Collegerama	No	

AES1730	Introduction to Geotechnical Engineering	3
Responsible Instructor	Prof.dr. C. Jommi	
Contact Hours / Week x/x/x/x	4.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Offshore soil mechanics (OE4624), BSc students from AES and HBO students	
Summary	Physico-chemical properties of soils. Ground water flow. Stresses and strains in soils. Effective stress principle. Soil stiffness and strength. Basic laboratory tests. Drained and undrained response. Settlements, bearing capacity, earth pressure and sheet-piles. Stability of cuts and slopes.	
Course Contents	The course gives an introduction to fundamental aspects of soil mechanics, e.g. soil composition, stress, strain, strength and stiffness and ground water flow. Implications of these properties for applications, such as settlement predictions, bearing capacity of shallow and deep foundations, retaining structures (e.g. sheet pile, quay wall), stability of cuts and slopes.	
Study Goals	The course is addressed to Applied Earth Science, Road and Railway and Offshore Engineering students who have little or no prior knowledge of soil mechanics and geotechnical engineering, and to students coming from HBO. At the end of the course the student should be faimiliar with basic soil mechanics and foundation engineering, to allow further education at MSc level and application of basic concepts in design.	
Education Method	Lectures, tutorials, self-study	
Literature and Study Materials	Materials - Soil mechanics by A. Verruijt, 2001 - Craig's Soil Mechanics by R.F. Craig (and J. Knappet), 2012 - Lecture notes	
Prerequisites	Basic mechanics, knowledge of the concept of stress and strain and elasticity.	
Assessment	Written examination including: - multiple choice questions - applied questions	

AESM2901-16	Geoscience and Engineering Fieldwork	10
Responsible Instructor	Dr.ir. L.A. van Paassen	
Contact Hours / Week x/x/x/x	block of 4 hours during weeks 1.1 & 1.2 and 1.5 to 1. 8. Full time on site during weeks 1.3 and 1.4	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	CIE5320 Site investigation, testing & physical modelling; AES1630 Engineering Geology Recommended: AESM1720 Rock mechanics Applications	
Course Contents	Integrated field course for MSc students Geo-Engineering who are in their second year and like to get hands on experience characterizing a wide range of soil and rock types, assessing their geotechnical material and mass properties using standard field tests and methods, presenting this data using GIS methods in a geotechnical baseline report, which is then used for to assess the stability of manmade/natural slopes and a tender preparation for a civil engineering project	
Study Goals	Students learn to: - apply basic site investigation methods (desk study, walkover survey using standard geological field kit) and use these observations to: - identify soil and rock types, using soil and rock mass classification systems - identify geohazards (rock fall, slope failure, subsidence, karst, etc..) based on field observations, - obtain geotechnical parameters for the preliminary design of civil engineering constructions (tunnel, dam, roadcuts and embankments) or geohazard risk assessment. - To acknowledge the complexity and challenges of geo-engineering projects. - Perform a geo-risk analysis (identify and quantify the relevant mechanisms, quantify the probability of occurrence and potential damage). - Prepare a geotechnical baseline report for constructions or mitigation of hazards. - To work in a team	
Education Method	5 days fieldwork preparation 2.5 weeks fieldwork (including 4 days excursion/instruction, 8 days independent work) 5 days reporting	
Assessment	The fieldwork assessment is composed on two parts: 1. Contribution to the written fieldwork reports and 2. Execution of the fieldwork (performance in the field, participation in the discussions, cooperation, etc.).	
Enrolment / Application	Students should confirm their participation 3 months in advance	
Expected prior Knowledge	CIE5320 Site investigation, testing & physical modelling; AES1630 Engineering Geology Recommended: AESM1720 Rock mechanics Applications	
Academic Skills	Equipment and Logistics, Teamwork, Literature search, Report writing	
Literature & Study Materials	see Blackboard	
Judgement	Fieldwork reports are judged using the thesis graduation procedure	
Permitted Materials during Exam	not applicable	
Collegerama	No	

CIE4353	Continuum Mechanics	6
Course Coordinator	Ir. C. Kasbergen	
Instructor	Dr. A. Scarpas	
Instructor	Prof.dr. M.A. Hicks	
Contact Hours / Week x/x/x/x	4/4/0/0	
Education Period	1 2	
Start Education	1	
Exam Period	2 3	
Course Language	English	
Course Contents	The course starts with the basics of tensor algebra. Various orders of tensors and their associated tensorial operators (like dyadic product, (double) dot product, cross product) are explained in 3 different tensor notation styles: direct, base and index notation. With this knowledge, tensor expressions are judged on their correctness, and simple proofs for tensor equalities are discussed. The next topic concerns motion and deformation. Deformation will be the basis for the derivation of small and large/ finite strain tensors in the reference and the current configuration. This is followed by the polar decomposition of the deformation gradient tensor and the spectral decomposition into the principal stretches and their corresponding directions. Furthermore the stress tensor is introduced, including traction and stress components, principal stresses and their directions, and isotropic and deviatoric stress tensors. Material time derivatives of vector and tensor fields are described and their physical significance is clarified. The core part of the course is related to mechanical balance laws and several basic continuum theories like hyperelasticity, plasticity and viscoelasticity, all setup in a thermodynamic large deformation framework. Several material models based on combinations of the before mentioned theories are discussed, for example the Generalized Maxwell model. Finally the basic laws of physics for multi-phase materials are formulated. The same physical laws are deployed for each phase of the multi-phase continuum, inclusive of interaction terms. Then constitutive laws for each of the phases and their interactions are discussed. Also, as a special topic , a constitutive framework for materials with strong discontinuities is presented.	
Study Goals	1. To master three notation conventions (direct, base and index notation) commonly used in tensor algebra to perform calculus on tensor-based mathematical expressions. 2. To reproduce several notions in continuum mechanics, like deformation, strain and stress, all in a large deformation framework; using these notions in the application of mechanical balance laws and deformation decompositions. 3. To explain the important continuum theories like hyperelasticity, plasticity and viscoelasticity setup in a thermodynamics large deformation framework, and to apply these theories to develop and interpret elasto-visco-plastic models (e.g. the generalized Maxwell model) ; to reproduce the mechanics and physics of strong discontinuities and multi-phase continuum materials in large deformation and flow.	
Education Method	Lectures and homework exercises	
Course Relations	CIE4353 uses CTB1001, CTB1002, CTB1110, CTB1310, CTB2210, CTB2400, WI1030WBMT, WI1031WBMT, WI2031WBMT, WB1630, WB1631, WB2630	
Literature and Study Materials	Additional reading material: - Eglit, M.E., Hodges, D.H., "Continuum Mechanics via problems and exercises", Part 1: Theory and Problems, World Scientific Publishing Co. Pte. Ltd, 1996, ISBN: 981-02-2962-3. Part 2: Answer and Solutions, World Scientific Publishing Co. Pte. Ltd, 1996, ISBN: 981-02-2963-1. - Haupt, P., "Continuum Mechanics and theory of materials", Springer-Verlag, 2000, ISBN: 3-540-66114-x.	
Assessment	Written exam (open book) and assignments	
Expected prior Knowledge	Basic knowledge of mechanics and linear algebra	
Academic Skills	Thinking, interpreting and application skills in mathematics and mechanics, problem solving	
Literature & Study Materials	Lecture slides, literature provided during lectures and the books mentioned above as additional reading material	
Judgement	Final mark consists for 50% of the mark of the examination and 50% of the mark of the homework assignments	
Permitted Materials during Exam	Lecture slides, worked out assignments and notes written in class	
Collegerama	No	

CIE4362	Soil Structure Interaction	3
Responsible Instructor	Ing. H.J. Everts	
Instructor	Ing. H.J. Everts	
Responsible for assignments	Dr. K.G. Gavin	
Contact Hours / Week x/x/x/x	0/0/0/4	
Education Period	4	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	CTB1410, CTB2320, CTB2310	
Course Contents	Main topics concern the interaction between the structure and the supporting foundation and or soil. Examples of typical items are: - The design of appropriate foundations regarding the characteristics (strength and stiffness) of soil and structure according to Eurocode 7; - The effects of interaction between soil and structure; - The design of laterally loaded piles, due to soil deformations or external loads; - The use of EEM to predict the behavior of pile groups - The installation of piles - The adaption of foundations	
Study Goals	To gain the knowledge and the proficiency to identify all relevant aspects concerning the design, behaviour and installation of foundations.	
Education Method	Lectures and exercise	
Literature and Study Materials	Lecture notes (under construction); will be put on black board	
Assessment	Defending a written report and answering questions concerning the interaction between structures and soil during a 30 minutes oral exam between (in general) 2 students and instructors	
Elective	Yes	
Contact	ing. H.J. Everts (0.500; h.j.everts@tudelft.nl; 0622138379)	
Expected prior Knowledge	BSc-Civil engineering or equivalent, CTB1410, CTB2320	
Permitted Materials during Exam	none	
Collegerama	No	

CIE4363	Deep excavation	4
Responsible Instructor	Ing. H.J. Everts	
Instructor	Ing. H.J. Everts	
Responsible for assignments	Dr. K.G. Gavin	
Contact Hours / Week x/x/x/x	4.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	BSc- Civil engineering or equivalent, CTB1410, CTB2320, CTB2310	
Course Contents	Main topics concern the design of building pits and the prediction of the effects on the surrounding structures. Main topics to be studied: - the design of building pits and retaining structures; - effects on surroundings - the design of under water concrete floors, including anchorage; - the design of tension piles The main topics of designing retaining structures are: - specification and interpretation of soil investigation; - determination of design parameters (soil and structure); - design models(spring models and finite element models); - installation methods; - effects of installation of sheetpiles on adjacent structures(settlements,vibrations, noise); - costs.	
Study Goals	The course intends to get the knowledge and the proficiency to identify all relevant aspects concerning the design and realization of building pits.	
Education Method	Lectures, instruction and exercise	
Literature and Study Materials	Syllabus: - CIE4363 "Foundation Engineering and Underground Construction; - CUR166 Damwandconstructies, availability to be discussed with the lecturer; - Lecture notes, available at blackboard	
Assessment	Defending a written report and answering questions concerning the design of building pits during a 30 minutes discussion between 2 students and instructors.	
Remarks	The course can easilly be combined with CIE5305 (bored and immersed tunnels), but can also be followed seperately.	
Elective	Yes	
Contact	ing. H.J. Everts (0.500; h.j.everts@tudelft.nl; 0622138379) prof. dr. K. Gavin;	
Collegerama	No	

CIE4367-16	Embankments and Geosynthetics	3
Responsible Instructor	Prof.dr. C. Jommi	
Contact Hours / Week x/x/x/x	0.0.0.4	
Education Period	4	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	The course deals with embankments for earthworks, with special focus on dikes and road and railway construction. Embankments are often built on soft soil. Therefore, deformation, for example settlement and stability, are important items in embankment design. Furthermore, due to soft soil behaviour, the construction of an embankment will have consequences for its surroundings. A special category of embankments is formed by water retaining structures, such as dikes and levees. These types of embankments were constructed in the past, some even in the Middle Ages. To prove that they still meet the design requirements, stability assessment of these old dikes and levees is required. Main items of the course are: Consolidation behaviour and analysis of settlements Strength of soil and stability analysis Field and Laboratory testing: choice of the parameters Construction techniques Attention will be given to geosynthetics, which can be used to reduce the footprint of soil structures. In order to understand the interaction between soil and geosynthetics, the different kinds of geosynthetics are described and their material properties are dealt with. This gives insight in: Strength / stiffness Permeability Durability Interaction between geosynthetics and various soil types, leading to soil reinforcement.	
Study Goals	At the end of the course the student should be familiar with: - relevant aspects of the engineering behaviour of embankments - subsoil and construction soil characterisation - design rules - assessment techniques	
Education Method	Lectures & practice. Compulsory home assignements	
Assessment	Written assignements : 60% Oral examination: 40%	
Literature & Study Materials	Lecture notes, literature CUR 162 Building on soft soils, available at Civieltechnisch Centrum Uitvoering Research en Regelgeving: P.O.Box 420, 2800 AK Gouda (NL)	

CIE4390	Geo Risk Management	3
Responsible Instructor	Ing. H.J. Everts	
Instructor	Ing. H.J. Everts	
Responsible for assignments	Dr. K.G. Gavin	
Contact Hours / Week x/x/x/x	0.4.0.0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Course Contents	Introduction: Ground-related risk and the construction industry, challenges and opportunities, construction projects, processes and contracts. Geo-bloopers, state-of-the-art construction and a vision towards the future. From uncertainty via risk to geo risk management: The concepts of uncertainty, risk, and ground conditions, introduction of the GeoQ concept with 6 steps and 6 project phases, the link with the RISMAN approach, the position of GeoQ towards soil mechanics, geotechnical engineering, quality management, hazard management and knowledge management. The human factor in ground risk management: Individuals and risk - the concepts of individuals, risk perceptions and how individuals contribute to geo risk management. Teams and risk - the concept of the team, teams and risk communication and how teams contribute to geo risk management. Clients, society and ground-related risk. The GeoQ ground risk management process: The 6 steps of the GeoQ process gathering information, identifying risk, classifying risk, remediating risk, evaluating risk, mobilising risk. The 6 project phases of the GeoQ process feasibility, pre-design, design, contracting, construction and maintenance. Ground risk management tools in 6 project phases: Site classification, scenario analysis, team-based risk indentification and classification, risk-driven ground investigations, risk allocation and dealing with differing site conditions, the approach of the Geotechnical Baseline Report, Dispute Review Boards, conventional and innovative contracts, the observational method, the life cycle approach for cost-effective maintenance, an ICT-supported and risk-driven approach for dike safety assessment. Ground risk management and ground properties: Ground layering and properties, geostatistics, dealing with different types of uncertainties and combining different types of information, sampling theories, groundwater related problems. Ground risk management and underground construction: Tunneling techniques, ground conditions and risk profiles, specialist foundation techniques, interaction with existing structures. Ground risk management and building projects: Projects and construction methods with various risk profiles, parking garages, construction pits, interaction with existing structures, external risks e.g. vibration and noise, use of experience data and GeoBrain. Ground risk management and dikes: Mechanics of ground, stability and risk, dealing with proven strength, advisors-factor (Bergambacht), relations with failure probability, (un)identified anomalies. Ground risk management and infrastructure projects: Mechanics of ground, settlements and risk, observational method, risks related to vacuumconsolidation and other ground improvement techniques, case Betuwe Route Waardse Alliance. Geoenvironmental ground risk management: Impact on building and infrastructure projects during 6 main project phases, processes of (polluted) groundwater flow, dissipation of contamination, geo-biological processes and technical solutions like flexible emission control. Ground risk management and some special issues: Apparent reliability of standards, decision problem offshore projects, sand reclamation projects.	
Study Goals	After the course the student is aware of the inherent risk of ground within civil engineering and construction, including the impact and difficulties of the human factor. Furthermore, the student is able to apply principles of ground-related risk management during the entire process for a variety of civil engineering constructions.	
Education Method	Lectures	
Assessment	Written exam (open questions)	
Expected prior Knowledge	BSc- Civil engineering or equivalent	
Permitted Materials during Exam	free choice	
Collegerama	No	

CIE4780	Trending Topics in Geo-Engineering	4
Responsible Instructor	Dr.ir. W. Broere	
Contact Hours / Week x/x/x/x	0/0/4/0	
Education Period	3	
Start Education	3	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	Course CTB3385/CIE3300, Use of Underground Space	
Summary	The course is a follow up of the course CTB3385 Use of Underground Space. It deals in depth with a number of topics related to the realisation and use of underground constructions. New developments in construction technologies, integral design of underground solutions and operational safety will be addressed as well as a number of case studies.	
Course Contents	* Bored Tunnels: new developments * Immersed tunnels: new developments * Deep building pits * Diaphragm walls * Engineering aspects of bored tunnels: excavation and separation * Integral design * Operational Safety * Tunnel safety for road tunnels * Recent research in shield soil interaction * Renovation of immersed tunnels * Case studies of major tunnelling projects * Visit major project related to subsurface construction	
Study Goals	Students obtain knowledge of the recent developments in the use of underground space and construction technology used for subsurface construction. Based on this knowledge they are able to study and assess complex circumstances, resulting in rational and integral solutions. Study load: Lectures 2 x 14 hours Related to lectures 14 hours Self study 36 hours Writing a paper 24 hours Exam preparation 8 hours Oral exam 1 hour Total 111 hours	
Education Method	Lectures, cases and writing a short paper.	
Literature and Study Materials	Lecture notes, handouts, available at Blackboard.	
Assessment	The student will write a short paper (6-8 pages) on one of the topics addressed during the course or on a topic that is agreed upon. After the paper is graded the assessment finishes with an oral exam.	
Contact	The student-assistants of Underground Space Technology can be contacted at E: StudassOGB-CiTG@tudelft.nl T: 85256	
Expected prior Knowledge	Course CTB3385/CIE3300, Use of Underground Space	
Academic Skills		
Literature & Study Materials	Lecture notes, handouts, available at Blackboard.	
Judgement	The student will write a short paper (6-8 pages) on one of the topics addressed during the course or on a topic that is agreed upon. After the paper is graded the assessment finishes with an oral exam.	
Permitted Materials during Exam	Students' paper	
Collegerama	No	

CIE5305	Bored and Immersed Tunneling	4
Responsible Instructor	Dr.ir. K.J. Bakker	
Instructor	Ir. K.J. Reinders	
Contact Hours / Week x/x/x/x	4/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	Soil Mechanics 2 CIE 2310 Concrete Structures 2 CIE 3150 Hydraulic structures CIE3330	
Summary	Design and construction of tunnels for traffic. Functional requirements, determination of boundary conditions, spatial and structional design and construction aspects of bored and immerse tunnel.	
Course Contents	The course is closely related to Foundations and construction, CIE4363;, lectures are given as combination lectures. There is a combined exercise. On demand however, a separate exercise and exam for CIE5305 is possible. The course extensively treats tunneling methods. A distinction is made between the New Austrian Tunnel Method (NATM), bored tunnels and immersed tunnels. General issues related to tunnel structures. Functional and operational requirements, the longitudinal profile, the cross section and the starting/finishing shaft and/or access and exit road. NATM tunnels and the immersed tunnels. Different types of bored tunnel construction; NATM-method, slurry shield and earth pressure balance shield. Stability during construction; frontal support, settlements during construction. Loads on a tunnel and force distribution in the lining. Start and reception shaft and construction procedures. Requirements concerning the longitudinal and transverse profiles. For immersed tunnels, construction in the dock, transport and immersion. Stability during floating and after the tunnel has been sunk. Special aspects such as ventilation, fire, permeability and explosions. A case study on a tunnel project is done in a group of four students.	
Study Goals	After the course, the student will be able to: 1. Make a plan for a tunnel; choice of location and track; 2. Make a decision on the type of tunnel; bored or immersed; 3. Make a choice for the construction method and execution; 4. To determine the mechanical boundary conditions for structural design; 5. To evaluate structural forces both during construction and as well as for Service conditions; 6. To evaluate construction effects; settlements, stability and influences on other structures; 7. To design the excavations and related structures for start and reception shafts; 8. To evaluate the transport and placing of immersed tunnels; 9. To make a design for both constructions.	
Education Method	Lectures with illustrations (video, numerical examples). An excursion to tunnelling projects, exercise in groups of four students to evaluate a tunnel project and in addition to that to make a design for a tunnel; location, track, construction and structural design.	
Literature and Study Materials	Lecture notes: "Bored and Immersed tunnels" and handouts. The exercise o-n the case study is handed out during o-ne of the lecture hours.	
Assessment	Prerequisite 1. To deliver a written report on the case study; 2. To attend the Tunnelling excursion. Test type: design exercise and oral exam	
Expected prior Knowledge	Students are expected to have knowledge on Structural Engineering at the least on BSc level or equivalent	
Academic Skills	Structural, Hydraulic and geotecnical engineering. To combine knowledge of different engineering fields into the design of a spcific Civil Structure; Analysis and Synthesis	
Literature & Study Materials	Lecture notes: "Bored and Immersed tunnels" and handouts. The exercise o-n the case study is handed out during o-ne of the lecture hours.	
Judgement	One mark, based on design exercise and oral exam	
Permitted Materials during Exam	-	
Collegerama	No	

CIE5340	Soil Dynamics	3
Responsible Instructor	Prof.dr. M.A. Hicks	
Contact Hours / Week x/x/x/x	0/0/0/4	
Education Period	4	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	Soil dynamics is an important discipline within the field of soil mechanics and foundation engineering. Especially in countries with a higher risk of earthquakes, for example Japan and the United States of America, soil dynamics is a vital part of earthquake engineering. Earthquake engineering is the science to design earthquake resistant buildings and infrastructure. In Delta countries like the Netherlands there are not very strong earthquakes, but here soil dynamics is important for other reasons. Because of the expanding cities and because of the growing number of traffic jams, more underground structures like bored tunnels, underground railway stations and parking garages are build close to the foundations of already existing buildings. Vibrations due to demolishing of old structures, installation of foundation piles and sheet piles, passing trains or other vibrating sources may create structural damage or personal discomfort. Soil dynamical knowledge is needed to explain, predict and solve these problems.	
Study Goals	The students are given the background knowledge both to formulate and solve practical problems occurring in soil dynamics and to interpret the calculated results. 28 h lectures/contact hours 2 h practical exercise 10 h report on practical exercise 42 h self-study 7 h preparation exam 1 h oral exam --------+ 90 h (6 h * 30 h/ECTS)	
Education Method	Lessons + practical exercise	
Literature and Study Materials	Syllabus: Soil dynamics in urban areas (at start available at blackboard) prints of sheets and notes	
Assessment	Assignments during the course. Oral examination based on the lectures, lecture notes, the practical exercise and the accompanying report made by the student.	
Enrolment / Application	Please enroll by sending an e-mail to the teacher (p.holscher-3@tudelft.nl) with your name and student number before going to the first lecture. In this way a free lecture note can be made in time for the student.	
Remarks	The practical experiment: one outside field measurements. Measuring wave speed from impulsive excitation, train vibrations in the soil and in a simple structure. The exercise is carried out as a group, but the report will be written as an individual. The report will be written partially before the test and partially after the test. Both the lecture notes and this report will be discussed during the oral examination. Teachers dr. ir. P. Hölscher e-mail Paul.Hoelscher-3@tudelft.nl tel. 015-278 90 30 (Thursday/Friday) or tel. 088-335 73 43 (Monday/Tuesday) dr. ir. K. van Dalen e-mail K.N.vanDalen@tudelft.nl	
Expected prior Knowledge	B.Sc. courses CTB1210 (Dynamics and Modelling; required), CTB2300 (Dynamics of Systems; strongly advised) and CTB2310/AESB2330 (Soil Mechanics, which contains the Theory of Elasticity; required). As an alternative for CTB2300 & CTB1210, one can take the M.Sc. course CIE4145 (Dynamics and an Introduction into Continuum Mechanics), or courses AESB1320 and AESB1420.	
Academic Skills	Analytics and structural mechanics.	
Literature & Study Materials	Lecture notes and lecture slides.	
Judgement	The final grade will be based on the written assignments, report of the field test and an oral exam.	
Permitted Materials during Exam	The written assignments and report of the field test.	
Collegerama	Yes	

CIE5741	Trenchless Technologies	4
Responsible Instructor	Dr.ir. W. Broere	
Contact Hours / Week x/x/x/x	0/4/0/0	
Education Period	2	
Start Education	2	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	The course covers the use of trenchless technologies, which is a versatile installation method for small infrastructure (gas, water, sewers, etc). It is meant as an addition to other specialistic courses and the topics studied here can also be applied in other courses. Next to the installation process and the design of the linings, the organisation of a TT project will be discussed. The course deals with basic aspects of: - Cables and ducts - Geology and geotechnics in relation to boring techniques and bore fluids - The technique of Horizonal Directional Drilling (HDD) - The technique of Micro-tunnelling - Boring equipment - Measuring equipment - Steering equipment - Technical calculations for HDD and Micro-tunnelling - Technical calulations for stresses in pipelines - Renovation of existing pipelines - Research on trenchless technology and innovative applications - Influence of contract types on project execution - Role of the contractor and engineering office - Risks and risk management - Case discussions	
Study Goals	Students will be able to identify and describe the methods available for trenchless installation and rehabilitation of cables and ducts. They will be able to make a preliminary design for new pipe line installations.	
Education Method	lectures paper and oral exam	
Literature and Study Materials	obligatory lecturenote(s)/textbook(s): Reader "Reader Trenchless Technology CIE5741" by W. Broere, S. van der Woude Available via Microweb or as pdf on BB	
Assessment	As part of the course, the students (in groups of max. 2 students) have to make a preliminary design and risk assessment for a river crossing of a large diameter pipeline, using HDD or micro-tunnelling. This design is based on the lecture notes as well as the relevant national codes and standards. The resulting design is discussed and commented during an oral examination.	
Remarks	Multidisciplinary course for Civil Engineering, Mechanical Engineering and Applied Earth Sciences. The course covers the use of trenchless technologies (drilling, tunnelling, and renovation techniques). These techniques are widely used for the installation and renovation of tunnel-, pipe- and cable systems for small infrastructure (oil, gas, water, sewerage). The course offers basic theoretical and practical knowledge of the techniques and used materials. Legal, administrative aspects and innovation will form an integral part of the course.	
Contact	The student-assistants of Underground Space Technology can be contacted at E: StudassOGB-CiTG@tudelft.nl T: 85256	
Expected prior Knowledge	Basic understanding of soil mechanics and structural mechanics is advisable but not mandatory.	
Academic Skills		
Literature & Study Materials	obligatory lecturenote(s)/textbook(s): Reader "Reader Trenchless Technology CIE5741" by W. Broere, S. van der Woude Available via Microweb or as pdf on BB	
Judgement	The oral examination discusses the students' paper as well as topics from the course. The final mark is based on the report and oral discussion.	
Permitted Materials during Exam	Students' paper	
Collegerama	No	

OE44030	Offshore Geotechnical Engineering	4
Responsible Instructor	F. Pisano	
Contact Hours / Week x/x/x/x	0/0/4/0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	The course addresses relevant topics in Soil Mechanics and Geotechnical Engineering related to o ffshore energy production (oil&gas developments and renewable sources). The core subject is the analysis and design of the most common foundation types for off shore structures. After some preliminary recaps on soil behaviour, the response of marine soils to environmental cyclic loading is illustrated and discussed. Then, essential concepts about subsea site investigation are discussed. The course core topics are widely addressed, concerning the analysis/design of both shallow and deep offshore foundations.	
Study Goals	The main learning objectives are: 1. to recognise and describe the main features of offshore soil behaviour under environmental loading; 2. to describe the principles for planning o ffshore site surveys for soil characterization purposes; 3. to analyse/design of the main shallow foundation types(including spudcans and suction units) according to standard analytical approaches 4. to analyse/design of offshore piles according to standard analytical approaches	
Education Method	- in class theoretical and practical sessions - possible assignments on the most relevant topics	
Assessment	Written Exam	
Remarks	Old course code: OE4624-15	
Department	3mE Department Maritime & Transport Technology	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GE Choose for 20 EC Extra Courses or 2 of the possibilities listed below up to 20 EC in total

AES0404-10	Traineeship	10
Responsible Instructor	Dr. M.W.N. Buxton	
Responsible Instructor	Dr. D.V. Voskov	
Responsible Instructor	Prof.dr. P.L.J. Zitha	
Contact Hours / Week x/x/x/x		
Education Period	1 2 3 4	
Start Education	1 2 3 4	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	The internship should consist of a small project in a research or operational environment, where the student can apply some of the skills and knowledge acquired during his/her first three years of study and get acquainted with the petroleum industry. The student shall have a dedicated assignment with a clearly defined deliverable. The contents of the internship shall be agreed between the student, the company and the university supervisor before the start of the internship period and shall be documented in an "Internship Contract".	
Study Goals	Get hands-on experience with the operations of a producing company. Experience how technology is applied to advance business. Gain awareness about philosophy and challenges faced by decision makers in the industry. Obtain insight for the orientation of the thesis and future employment.	
Education Method	Supervised desk-study assignments which are part of project and immersion into a team project to witness and participate in its day-to-day activities.	
Assessment	The student shall document the project work in a small report, which forms the basis for assessment of the internship. If the company requires that the report remains confidential, a copy has to be made available to the University supervisor on a temporary basis, under a confidentiality agreement if required. Students are allowed to spend up to 12 weeks for their internships. Internships will be awarded 1.2 EC/week, with a maximum of 6 EC.	

AES4011-10	Additional Thesis	10
Responsible Instructor	Prof.dr.ir. T.J. Heimovaara	
Contact Hours / Week x/x/x/x		
Education Period	None (Self Study)	
Start Education	1 2 3 4 5	
Exam Period	Different, to be announced Exam by appointment	
Course Language	English	
Course Contents	See text for Master Thesis Project	
Study Goals	See text for Master Thesis Project	
Education Method	See text for Master Thesis Project	
Assessment	See text for Master Thesis Project	
Expected prior Knowledge	see text for Master Thesis Project	
Academic Skills	see text for Master Thesis Project	
Literature & Study Materials	see text for Master Thesis Project	
Judgement	see text for Master Thesis Project	
Permitted Materials during Exam	see text for Master Thesis Project	
Collegerama	No	

CIE4061-09	Multidisciplinary Project	10

Responsible Instructor	Y. de las Heras
Contact Hours / Week x/x/x/x	n.a.
Education Period	Different, to be announced
Start Education	1
Exam Period	none
Course Language	Dutch English
Course Contents	Solve an actual and recent civil engineering problem in a multidisciplinary team. Integrate several studies and designs into a coherent entity, based on knowledge, understanding and skills acquired in the preceding years. Attention will be on quality control and the evaluation of the design process. Knowledge and skills obtained during the BSc projects will be used in this project. The course is divided into three phases: phase 1: inception plan; phase 2: preliminary design and studies; phase 3: process evaluation with respect to interdisciplinary aspects; final report. Description Phase 1: preliminary investigation (Problem exploration and treatment). By means of supplied and found information (project file, informers, literature) an inventory and analysis of the problem must be made. This results in a (substantive) problem formulation and an objective. Coupled to that, a treatment will be formulated. Which methods will be used, which contribution can different disciplines provide to the project, which steps have been passed through successively, which information is still necessary, where can that information be found? Finally the organization of the group must be fixed. Phase 2: design. At this stage is alternatively worked for the complete problem and for sub-problems. The work exists for a part of research, for a another part of developing design alternatives or solution alternatives, and from developing the sub-problems. Ongoing, the consistency with the whole design must be monitored. Phase 3: Round-off. In the round-off, the last hand is laid to the results of the project. First of all the handed in report is discussed with the speculator team, whereupon the definite version is made. The participants evaluate the project, both substantive and concerning the project process. Finally, the presentation is prepared and a summary for the presentation is established. Note 1: If students from Building Engineering want to do the masterproject they will be doing the High Rise project. Teams are formed together with the students form the Faculty of Architecture with a task to design a big scale high-rise building. The teams consist of about five students. Each student is assigned to represent a specific dicsipline (architect, stuctural engineer, project manager, building services engineer, etc.) with a specifc task and responsibility in the team, covering architectural and functional design, structural design, building physics, finishes, building services, real estate development and construction and management. The civil engineering students are mostly assigned the function of the stuctural engineer. The time reserved for this workshop project is approx. 8 weeks. The teams are coached and guided in the lines of the mentioned disciplines, by a number of lecturers from the faculty of Architecture and Civil Engineering and engineers and architects from daily parctice. For more information see: www.aal.Bk.tudelft.nl Note 2:. For students who aim for an Integral Design Managemnt (IDM) annotation within their respective MSc track and specialisation, this course/project is mandatory. Moreover, IDM-students must apply integral design and management knowledge and skills obtained at the IDM courses CIE 3380 and CIE 4480. This includes knowledge and skills on integral design and maintenance, project- and asset management, and information systems. Depending on the students MSc track and specialisation three domains of application are considered: water, infra and building.
Study Goals	1. Design learning on a sub-sector of civil engineering in multidisciplinary link. 2. Integrated appliance of knowledge and skills from previous years. 3. Application of design knowledge and skills from the first, second and third year. 4. Learning to work by means of an interdisciplinary approach. 5. Learning to report, present and defending the end product. 6. Learning to apply elementary quality guarantee principles (e.g. MCE, SWOT) during the design process. 7. Evaluate learning of the interdisciplinary work process For IDM-students: 8. Application of integral design and management knowledge from IDM courses CIE3380 and CIE4480.
Education Method	Teamwork in a group of 4 - 6 students
Literature and Study Materials	A syllabus is available via Blackboard CIE4061-09; the e-book "report writing" is recommended. This e-book is part of the course on report writing (WM0201), and can be downloaded from the blackboardsite of that course. Also the manual of the master project is available on blackboard and can be obtained at the international office of CEG.
Prerequisites	Starting the project is only allowed when you have completed your BSc: "Students may not embark on the multidisciplinary project until, in case of a subsidiary programme outlined in Article3, subsection 2, this programme has been rounded of and, if applicable, the bachelor of science programme of civil engineering at Delft University has been rounded of." (Article 17 of Teaching and Examination Regularion, implementation regulations 2006-2007) Article 3 sub 2 reads: "Students who have been admitted to the course on the basis of a bachelor's degree gained from a Dutch higher vocational institute must complete a susidiary programme as stipulated in article 11 sub1" For IDM-students: completed courses CIE3380 (or BSc equivalent) and CIE4480.
Assessment	The group has to write a report and to give an oral presentation. The mark is based on: Written and oral report 1. Readability of report 2. Size (not too large, not too small) 3. Readaility of drawings 4. Quality oral presentation Group process 1. Is there a division of tasks 2. Is the project well prepared 3. Has there been delivered in time Quality final design 1. Assessment and choice of alternatives 2. Good schematisation of the real problem 3. Contentional quality of design and computations

	Integration and multidisciplinary aspects 1. Coherence of the different parts 2. View on the full scope of the project
Enrolment / Application	The students have to form a group by themselves. Ideas for subjects can be found via the coordinator; ideas of the group itself are welcomed. As soon as a group is formed, they should register with the coordinator. Groupwork can be done outside the Netherlands; the group should realise that this require a lengthy preparation period.
Special Information	Important notice: There is no single "responsible instructor" for this subject. Consult Blackboard for details.
Expected prior Knowledge	See prerequisites
Academic Skills	See prerequisites
Literature & Study Materials	A syllabus is available via Blackboard CIE4061-09; the e-book "report writing" is recommended. This e-book is part of the course on report writing (WM0201), and can be downloaded from the blackboardsite of that course. Also the manual of the master project is available on blackboard and can be obtained at the international office of CEG.
Judgement	See assessment
Permitted Materials during Exam	n.a.
Collegerama	No

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GE 10 EC Extra Courses

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GE Thesis (40 ECTS)

AESM2606	Final Thesis Geo-Engineering	40
Responsible Instructor	Dr.ir. D.J.M. Ngan-Tillard	
Contact Hours / Week x/x/x/x		
Education Period	None (Self Study)	
Start Education	1 2 3 4 5	
Exam Period	Different, to be announced Exam by appointment	
Course Language	English	
Course Contents	MSc graduation thesis on one of the research topics proposed by staff members.Graduation thesis projects proposed by the industry can be selected provided adequate supervisors in the faculty can be found.	
Study Goals	Students are able to: - relate their thesis work to state-of-the-art literature - integrate knowledge gained during studies - apply experimental/computer/design skills acquired during studies - develop a sound scientific argumentation - contribute personally to the project - reflect in a scientific way about their own results - take initiatives in their research project - work independently - write a structured and consistent scientific report in English - present orally and defend their work	
Education Method	Individual literature study, in situ or laboratory experiments, analytical or numerical work. Progress meetings with direct supervisors and graduation committee.	
Assessment	Students are evaluated following the guidelines of the faculty, based on their scientific approach, the quality of their results, their behavioural competencies,and the quality of their report, oral presentation and defence	
Expected prior Knowledge	Students need to acquire sufficient knowledge to start and defend their graduation thesis. - They may embark on the Final Thesis only when they have no more than 15 credits of uncompleted subjects of the Master's degree course from all their other subjects of the course. - They are only allowed to present their Final Thesis if they have successfully completed all other obligations.	
Academic Skills	The following aspects related to academic attitude have been identified by the VSNU and are developed during the MSc graduation process: "- Skills: Thinking (critical, analytical), Interpretation Writing reports, reviews, articles, Oral presentation, Cooperation, Problem solving - Ethics: Moral awareness/sensitivity, Judgemental skills Debating and discussion, Professionalism - Integrity: Reasoning/arguing, Logic, Philosophy of science Reflection on own behaviour and behaviour of others. No plagiarism, no fraud. - Citizenship: Awareness of and reflection on and responsibility towards the social (international) context and consequences of technology and scientific actions."	
Literature & Study Materials	All relevant literature allowing to relate MSc graduation work to current state of the art.	
Judgement	The MSc graduation work is judged using the guide for determining Master thesis grading of the faculty of Civil Engineering and Geoscience.	
Permitted Materials during Exam	MSc graduation thesis, notes, oral presentation, materials and equipments used during the graduation work.	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GE Convergence courses (to be taken if course content(s) not part of student BSc programme) choose 1 out of 2

CIE4510	Climate Change: Science & Ethics	4
Responsible Instructor	Prof.dr.ing. R. Klees	
Instructor	Prof.dr.ing. R. Klees	
Instructor	Prof.dr.ir. H.W.J. Russchenberg	
Instructor	Dr.ir. B. Taebi	
Instructor	Dr. M. Vizcaino	
Contact Hours / Week x/x/x/x	0/6/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	

Course Contents

Climate change is one of the most profound and complex issues affecting our society and economy today. Many scientists argue that there are too many variable factors to effectively see the big picture, while other scientists who believe human activity is to blame for global warming are ready to outline specific actions to prevent more damage. Skeptics believe that climate change is part of the natural global progression and that human activity will neither worsen nor improve our situation.

Those who are in favor of a global effort to reverse climate change believe that current climate models are underestimating the magnitude of future warming and argue that the uncertainty surrounding this threat is no excuse for inaction. Skeptics in turn argue that scientists who want to attract attention to themselves, who want to attract great funding to themselves, have found a way to scare the public by making things bigger and more dangerous than they really are. Despite continuing uncertainties about the detailed linkages, extreme weather events are increasingly being attributed to human interference, and greater emphasis is emerging on the need to prevent and to adapt to climatic changes.

The course provides an introduction to the basic physics of the climate system, how climate has changed in the past and how climate will change in the future. The focus in on the energy balance of the climate system and how this balance is affected by greenhouse gases and aerosols; the physical processes in the atmosphere and oceans that shape the climate; the response of the oceans, ice sheets and glaciers to global warming; the evidence for past and present climate change; climate models and model uncertainties; climate predictions.

A second focal point of the course is the broader societal and ethical aspects of climate change. In particular, we will focus on past emissions and responsibilities, implications of global warming on human safety and security, the distribution of burdens and benefits, emission rights, international justice and intergenerational justice.

Syllabus:

Introduction to climate physics
Instrumental records of the Earths climate
Radiative heat transfer
Atmospheric circulation
Clouds, aersols, and climate
The carbon cycle
Forcings and feedbacks in the climate system
Climate change and sea level rise
Climate modeling and predictions

Study Goals

After completing the course, the student

has a basic understanding of climate physics
understands how the climate responds to human activities
knows how future climate is predicted and the role of model uncertainties
is familiar with and understands the scientific discussions related to climate change
can distinguish facts and myths of the climate change debate
is aware of the social and ethical aspects related to climate change.

Education Method

Video lectures (edx course 12.340x Global Warming Science)
In-class question-and-answer and feedback sessions related to the video lectures
In-class lectures to address specific topics not covered by the video lectures
Climate lab

Assessment

Written exam, which accounts for 60% of your grade of the course
Group essay and presentation on a topic related to the societal and ethical aspects related to climate change, which accounts for 40% of your grade of the course

A grade of 60% or higher for the entire course AND a "pass" for the climate lab constitutes a passing grade. Without a "pass" for the climate lab, no mark will be given.

Expected prior Knowledge

BSc diploma

Academic Skills

Critical thinking
Written and verbal communication
Ability to speak and listen
Reading
Teamwork
Conceptual thinking
Interpretation
Moral awareness & sensitivity
Judgemental skills
Debating and discussion

Literature & Study Materials

1. video lectures
2. in-class lectures
3. Kump, Kasting & Cane, The Earth System
4. Farmer & Cook, Climate Change: A modern synthesis
5. IPCC Fifth Assessment Report (AR5), http://www.ipcc.ch/report/ar5/
6. Online material for further reading, e.g.,
US EPA homepage, http://www.epa.gov/climatechange/index.html
Understanding climate change, http://www2.ucar.edu/news/backgrounders/understanding-climate-change-global-warming
NASA global climate change, https://climate.nasa.gov

	Online reports of the US National Academic Press (NAP)
Judgement	60% written exam on climate science 40% group essay on climate ethics, oral presentation, and defense Climate lab (pass/fail); a "pass" is pre-requisite to get a mark for the course
Permitted Materials during Exam	Pocket calculator
Collegerama	No

WM0312CIE	**Philosophy, Technology Assessment and Ethics for CIE**	**4**
Module Manager	Dr.mr.ir. N. Doorn	
Instructor	Dr.mr.ir. N. Doorn	
Instructor	Dr.ir. U. Pesch	
Contact Hours / Week x/x/x/x	0/0/0/2	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Course Contents	Philosophy Module What is science, and what is technology? Brief overview of their history; positions on the influence of science and technology on society; The fact/value distinction; logic and argumentation theory; Methodology: foundations of scientific and technological knowledge; role of scientific explanations. Technology Assessment Module Why does technology fail? Technology Assessment as bridging the gap between society and the engineering community; Introduction to TA-methods and traditional forecasting: extrapolations, experts interview and the 'common sense'-method, scenario's, scenario workshops; Drivers of technological change, the relation between technological change and society Constructive Technology Assessment, participatory technology development; Practice of TA; politics, steering technological innovation of Sustainable Development. Ethics Module Introduction to moral dilemmas in engineering practice; Analysis of moral dilemmas in engineering practice and their backgrounds; professional codes of conduct and conflicting loyalties; legal rights and duties of engineers; Ethics, i.e. the foundation of judgments about good and bad / responsible and irresponsible acts; Introduction to some topics especially relevant for engineering: risks, responsibility and sustainability.	
Study Goals	Philosophy: - is able to recognize the different positions in the debate on the interaction between science, technology and society and to take a well-argued position in this debate; - has insight in the nature of scientific and technological knowledge and can explain the difference between science and technology; - can distinguish between factual and value-laden statements; - can apply elementary knowledge of logic and argumentation theory to simple arguments Technology Assessment: - Ability to recognize patterns of interaction between technological and societal change - Ability to assess the value and limitations of TA-methods and -results - Ability to apply some TA-methods to concrete situations Ethics: - is able to recognize and analyze the ethical aspects and problems of their future professional practice; - is able to explain the different backgrounds to these problems (ethics, law, organizations); - is able to discuss and - if possible - solve ethical dilemmas in their future professional practice on the basis of the ethical material provided.	
Education Method	Virtual learning environment, introductory lecture and small number of question hours. Compulsory: assignment (more information will be provided during the introductory lecture)	
Literature and Study Materials	- Ibo van de Poel and Lambèr Royakkers (2011). Ethics, Technology, and Engineering: An Introduction. Wiley Blackwell, West Sussex (ISBN 978-1-4443-3094-6 (hardcover) / 978-1-4443-3095-3 (paperback). - Reader WM0312CIE: Philosophy, Technology Assessment and Ethics for Civil Engineering (version 2016) - Reader Responsible Innovation(available on blackboard) - Virtual learning environment (blackboard).	
Assessment	In the June exam period, there is a digital (on-campus) exam about the entire course material. There is one resit in the August exam period; there are no other resits during the year. An example of an exam will be available on Blackboard. Students are not allowed to bring any study materials with them during the test (i.e., it is a "closed book exam"). The final course grade is based on: the grade for the exam (80 %). the grade for the TA assignment (20%).	
Category	MSc niveau	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Track Geoscience and Remote Sensing (GRS)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Variant-linked subjects (compulsory) 18 EC

CIE4601	Physics of the Earth and Atmosphere	5

Responsible Instructor	Dr. S.R. de Roode
Instructor	Prof.dr. L.L.A. Vermeersen
Contact Hours / Week x/x/x/x	6.0.0.0
Education Period	1
Start Education	1
Exam Period	1 2
Course Language	English
Expected prior knowledge	Basic mathematical skills. Experience with Matlab is desirable.
Course Contents	This course will present a common introduction to the major Earth system components, including the atmosphere, ocean and solid earth. Basic physical principles will be discussed and numerous examples from observations will be shown to provide the students with an elementary background in some key phenomena that occur on Earth. An example of some questions that will be addressed in the lectures are: * why do we need the greenhouse effect for a livable planet? * why does warm air rise and why can't we fly in gliders during nighttime? * how does the pressure in the atmosphere or ocean vary with height? * why does the wind approximately flow along lines of equal air pressure? * why is the weather typically dry and sunny in an high pressure system? * how can we use satellite altimetry to estimate the flow velocity in the ocean? * how does one model transport of heat and mass in an earth-system model? * what drives plate motion? * which locations on Earth are most vulnerable to earthquakes and volcanoes? * how much is the Earth's shape changing on a daily basis? * what happens below the Earth surface? An introduction to the Earth System ES1. Components (spheres: atmosphere, hydrosphere, lithosphere, biosphere, cryosphere) and interactions (internal/external) ES2. Energy balance of the Earth System An introduction to the atmosphere A1. Atmospheric composition and vertical structure A2. Radiative transfer and the earth-atmosphere energy balance, greenhouse effect A3. Key physical laws: Conservation equations: mass, heat, moisture and momentum Thermodynamics: gas law, Clausius-Clapeyron A4. Vertical stability of the atmosphere (troposphere) A5. Water in the atmosphere Large-scale dynamics of the atmosphere and oceans AO1. Equations of motion with coriolis force (Hadley cells...) AO2. Ocean vertical structure (and bottom pressure) AO3. Geostrophic currents, thermal wind relationship , inertial oscillations AO4. Currents with friction; Ekman layer; Ekman transport An introduction to the Solid Earth SE1. Earth structure, lithosphere structure, heat flow SE2. Plate tectonics, mantle convection, hot spots SE3. Gravity and isostasy SE4. Tidal potential and solid earth tides SE5. Surface loading and elastic deformation SE6. Viscoelastic deformation
Study Goals	To get acquainted with the most important physical processes in the Earth system. AO1. Being able to apply the energy balance to a planet with a single-slab atmosphere. AO2. Being able to apply the hydrostatic balance equation, the gas law and the Clausius-Clapeyron equation. AO3. Being able to calculate the vertical stability of the atmosphere. AO4. Being able to express the conservation equations for momentum, heat and mass in a dimensionless form and to be able to assess the dominant terms that, for example, lead to the geostrophic balance equations. Understand the meaning of the Reynolds and Rossby numbers. AO5. Being able to derive and apply the relation of Ekman pumping. AO6. Being able to derive and apply the relation between the wind field and the large-scale ocean gyres. AE: to be added
Education Method	15x2 lecture hours. Six sets of exercises will be provided which will take about ~ 10 hours per set. Experience with Matlab (or IDL, Python etc.) is desirable. Otherwise it is expected that the student will take an effort to learn its basic features. The students will have the opportunity to work on the exercises under the supervision of the instructors (6x2 hours). The exercises will be graded and will determine 50% of the final grade.
Computer Use	Matlab
Books	"Atmosphere, Ocean and Climate Dynamics' by Marshall and Plumb, This Dynamic Earth by Kious and Tilling (open source), handouts, lecture notes.
Assessment	At the end of the course there will be a written exam on the subjects discussed in the course. The final grade for the course is determined for 50% by the assignment, and for 50% by the written exam. If your grade for the written exercises is less than 5.5, you will not be allowed to participate in the written exam. Moreover, to pass the course the score of the written exam also needs to be higher than 5.5.

CIE4606	Geodesy and Remote Sensing	5
Responsible Instructor	Dr.ir. D.C. Slobbe	
Contact Hours / Week x/x/x/x	6.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	After defining the discipline of Geodesy and its role in Earth sciences, we explore the reference systems and reference frames used in Geodesy (both for time and positions). In particular, we will study the way they are defined and how their realizations are obtained in practice. Second, we will classify the two main positioning methods by the type of measurements used to compute a position solution, and work out in detail positioning using Global Navigation Satellite Systems (GNSS). Next, we treat the determination of the Earth's gravity field and figure. Starting with the fundamentals of potential theory, we will derive Geodetic Boundary Value Problems and outline the strategy to solve them using gravity measurements performed at the Earth's surface. In a separate lecture, we will discuss the meaning of the word "height" in view of what we learned about the figure of the Earth. The second part of this course treats the physical principles of remote sensing based on electromagnetic radiation. First, we will explore the different forms of interaction of electromagnetic radiation with the Earths surface and the Earths atmosphere. After that, we will compare the remote sensing measurement techniques (i.e., electro-optical systems, ranging systems, and radar) in terms of underlying physical principles and limitations. Finally, given that we want to study a particular phenomenon or process on Earth, we will learn how to select an appropriate survey platform and, if applicable, orbit design by taking into account requirements regarding target accuracy, spatial coverage, and spatial/temporal resolution.	
Study Goals	After this course students are able to: 1. Explain the role of Geodesy in Earth Sciences; 2. Analyze the reference systems used in Geodesy in terms of: (i) definition and (ii) the ways their realizations are obtained; 3. Apply coordinate transformations among the reference systems used in Geodesy; 4. Explain how positions can be obtained from GNSS code and carrier phase measurements; 5. Summarize the procedure how to derive the figure of the Earth from gravity observations; 6. Describe the different forms of interaction of electromagnetic radiation with the Earths surface; 7. Describe the different forms of interaction of electromagnetic radiation with the Earths atmosphere; 8. Compare the remote sensing measurement techniques in terms of underlying physical principles and limitations; 9. Select an appropriate survey platform and, if applicable, orbit design to acquire data from a particular phenomenon or process on Earth by taking into account requirements regarding target accuracy, spatial coverage, and spatial/temporal resolution.	
Education Method	Lectures, in-class assignments, in-class demonstrations, and take-home assignments	
Assessment	The student's final grade will consist of a final written exam and one or more take-home assignments.	
Expected prior Knowledge	The expected prior knowledge is the same knowledge required for enrolling in the MSc-track Geoscience and Remote Sensing, which can be found at http://www.tudelft.nl/en/study/master-of-science/master-programmes/applied-earth-sciences/msc-programme/tracks/geoscience-and-remote-sensing/programme/prior-knowledge/	
Academic Skills	Thinking (critical, analytical); Interpretation; Problem solving	
Literature & Study Materials	1) Lecture slides; 2) Some chapters of selected textbooks (provided via BlackBoard or available online); 3) Rees, W. G. (2013). Physical principles of remote sensing. Cambridge University Press.	
Judgement	The result of the final exam will make up 70% of the final grade, and the assignments will be worth the remaining 30% of the final grade.	
Permitted Materials during Exam	Formula sheet (will be provided) and pocket calculator.	
Collegerama	No	

CIE4611	Geo-measurement processing	5
Responsible Instructor	Dr.ir. A.A. Verhagen	
Assistent	S. Samiei Esfahany	
Contact Hours / Week x/x/x/x	6.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	CIE4615 Geoscience and Remote Sensing Fieldwork	
Course Contents	The aim of this course is to convey the necessary knowledge and to develop practical skills for working with random variables, combining measurements for parameter estimation purposes, and testing the validity of measurements and models. Measurements are key to the approach in Geoscience and Remote Sensing exercised in Delft, and support Civil Engineering activities through land surveying. The focus of this course is on the mathematical statistical aspects in the process of going from measurements to results, interpretation, decisions and conclusions. Emphasis is given to develop working knowledge; most of the course effort will be on applications (with actual measurement data). 1. Refresher probability and statistics: random variable, Probability Density Function (PDF), multi-variate distributions, mean, variance, variance matrix, correlation, methods to assess the statistical distribution of empirical data (histogram, Q-Q-plot). 2. Transformation of random variables/vectors, error propagation laws, error budget. 3. Parameter estimation, estimation error, (weighted) least-squares, regression, surface fitting, curve and harmonic function or polynomial fitting, assessment of the fit, geometry of least-squares. 4. Best Linear Unbiased Estimation (BLUE), non-linear least-squares and linearization. 5. Maximum likelihood estimation, estimation of variance factor, confidence intervals and regions, optimality with Gauss Markov model. 6. Detection and validation, probabilities of incorrect decision (level of significance, missed detection, power), statistical hypothesis testing, quality control. 7. Ill-conditioned problems, instability, consequences, constraints, minimum norm solution, regularization.	
Study Goals	After taking this course students should be able to - apply the error propagation laws; - describe and apply the following estimation principles: weighted least-squares, best linear unbiased estimation, maximum likelihood estimation; - set-up an observation model and estimate a set of unknown parameters from a given set of geo-measurements (e.g., remote sensing, GNSS, gravimetry, surveying); - make a quality assessment and interpret the estimation results; - test for errors in measurement data and the observation model; - devise a regularization approach for ill-conditioned problems.	
Education Method	lectures and supervised instructions / exercises	
Computer Use	Matlab will be used for the assignment work; an introduction to Matlab will be given. Demos and examples will be given as well.	
Assessment	Series of assignments, plus written examination at the end. There will be three graded assignments, on which the students can work in pairs.	
Tags	Calculus Lineair Algebra Mathematics Matlab Optimalisation Stochastics	
Expected prior Knowledge	General calculus and linear algebra. Basic (BSc) course on Probability and Statistics.	
Academic Skills	Mathematics, critical thinking, analysis, visualisaton	
Literature & Study Materials	Reader Probability and Observation Theory	
Judgement	Final grade for this course will be weighted average of the exam (50%) and assignment grades (50%). Pass and fail criteria are described on Blackboard.	
Permitted Materials during Exam	Formula sheet (will be provided) and pocket calculator.	
Collegerama	No	

CIE4615	Geoscience and Remote Sensing fieldwork	3
Responsible Instructor	Dr.ir. A.A. Verhagen	
Contact Hours / Week x/x/x/x	an	
Education Period	4	
Start Education	4	
Exam Period	none	
Course Language	English	
Expected prior knowledge	CIE4606, CIE4611	
Course Contents	The course will be taught in the field in Northern Iceland. Both natural geophysical processes as well as human-induced deformation are causing vertical and horizontal movements of the Earths surface in this region. Moreover, there are mass displacements due to groundwater circulation and volcanic processes. The aim of this course is to synthesize the knowledge and skills obtained in the first year of the Geoscience and Remote Sensing master track. It includes: 1. Hands-on practice in planning and making observations with different techniques (e.g. GNSS, leveling, total station, gravimeter, meteo stations). 2. Data processing, analysis and interpretation. 3. Background classes on the physical processes being measured. The assignment is given to the students in the form of a project on which they have to work in a team of 6-10 members.	
Study Goals	The aim of the course is to teach the practical side of making measurements in the field in order to constrain physical processes of the Earth and atmosphere that act at various spatial and temporal scales. After completion of this course the student will be able to: plan a field campaign that is appropriate for the physical process to be measured, collect data in the field using different measurement techniques, explain and quantify the error sources associated with the field measurements, process and analyse the data collected in the field to give meaningful constraints on the physical process, effectively communicate with peers, assessors and clients, contribute to a project as a team player and to the overall project management.	
Education Method	- Instruction in the field - Supervised data collection, processing and analysis - Presentations	
Assessment	The project teams have to report orally on their progress and planning every day, with alternating team representatives. A plenary mid-term and final review meeting will be held during the fieldwork, where the teams have to present their results. Both review meetings will be accompanied with a peer and self evaluation (anonymous feedback will be given).	
Enrolment / Application	An information meeting will be organised in December and May prior to the fieldwork. The course is compulsory for all Geoscience and Remote Sensing students. Students from outside this Master track can only join in exceptional cases (depending on prior knowledge and group size); this should be discussed with the responsible lecturer.	
Remarks	The fieldwork will be in the last two weeks of the fourth quarter (exam weeks). Students will have to pay some of the costs for the fieldwork (travelling and stay) themselves. More information will be available on the blackboard site of this course.	
Tags	Analysis Fieldwork Group Dynamics/Project Organisation Group work Integrated Intensive Involved Modelling Practicals Project Project planning / management	
Expected prior Knowledge	Knowledge related to geo-measurement processing, reference systems, signal analysis and interpretation, Matlab, visualisation tools.	
Academic Skills	Literature study, critical thinking, research skills, discussion with peers and client, presentation, project management, fieldwork	
Literature & Study Materials	All materials will be provided on site.	
Judgement	The assessment is based on the daily interaction and the review meetings. Grading components: 30% group grade for overall performance of the team; 35% individual grade for technical skills, 35% individual grade for team/project skills (commitment, planning, initiative, communication).	
Permitted Materials during Exam	Not applicable	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Compulsory for all students 10 EC out of 15 EC (if WM0325 TA is not passed in BSc, then CIE4613 (5 EC) is compulsory)

CIE4603-16	Geo-signal Analysis	6

Responsible Instructor	Dr. R.C. Lindenbergh
Contact Hours / Week x/x/x/x	0.4.0.0 lectures, 0.4.0.0 computer
Education Period	2
Start Education	2
Exam Period	2 3
Course Language	English
Expected prior knowledge	Linear algebra, calculus, basic statistics, basic programming
Course Contents	The course consists of two blocks of equal size: Fourier methods and Geospatial analysis. Each block is divided over four weeks. Week by week course contents 1. Deterministic Interpolation: deterministic vs. stochastic interpolation; exactness; inverse distance interpolation, nearest neighbours, Voronoi diagram, Delaunay triangulation, Triangulated Irregular Networks (TIN), searching for neighbors, computational complexity 2. Stochastic Interpolation: Spherical, Gaussian, exponential and nugget models; positive definiteness; Experimental variograms; minimizing the variance, redundancy matrix & proximity vector; Ordinary Kriging, Simple Kriging, BLUE + BLUP vs. Kriging, Kriging variance, screening & smoothing effect, filtering with Kriging; 3. Principal Component Analysis (PCA): mathematics and properties of PCA; singular value decomposition; link between PCA and singular value decomposition; visualization of the PCA; PCA assumptions and limitations; applications of PCA (finding patterns, data compression, filtering, prediction). 4. Pattern Recognition/classification: multidimensional statistics, cluster analysis, expectation maximization, representation of real world objects by features, PCA for classification, segmentation, simple classification techniques, (Un)supervised classification 5. Fourier Series & Fourier Transform 6. Discrete Fourier Transform (DFT): Fourier series, discrete sequences, periodic sampling, the DFT, understanding the DFT equation, DFT leakage, convolution, zero padding, windowing, relation with Fourier series and the Fourier transform; FFT; 2D DFT & FFT. 7. Filtering and Smoothing: spatial domain & frequency domain filters; smoothing filters, whitening filters; optimal filters; digital filters; FIR filter design; low-pass and high-pass filters; Fourier smoothing; digital re-sampling. 8. Analysis of random signals: random signals; discrete-time random processes; stationarity and ergodicity, covariance sequence, power spectral density, periodogram-based spectral estimation.
Study Goals	This course provides basic understanding of and practical experiences with some of the most important data analysis techniques used in geosciences and remote sensing: principal component analysis, Fourier analysis, interpolation, filtering and smoothing, and classification. Our goal is to provide a good conceptual grasp of these widely used tools. The data, considering processes that vary both in space and time, may stem from ground-based, airborne or space-borne sensors. After this course the student should be able to assess the spatial and/or temporal information content of data. Notably the student will learn to assess which data components are relevant for a certain application, to detect patterns in noisy data, and to visualize data of different dimensions. He/she should also be able to justify a choice for a certain method, to apply the methods to the processing of real data using a programming environment like MATLAB, and to assess the quality of the results.
Education Method	Education method/course set-up (on a weekly basis) 4 hours lecturing 2 hours supervised instruction (exercise class) 2 hours supervised work on and presentation of assignments 3 hours self study 3 hours doing exercises and solving problems 4 hours working on graded assignments part of the exercises/assignments are with a system like Matlab
Assessment	Written exam and assignments. Course grade is the average of the mark for the exam (50 %) and the mark for the assignments (50 %). The mark for each component should be at least 5
Contact	Roderik Lindenbergh, r.c.lindenbergh@tudelft.nl CITG building, room 2.25
Expected prior Knowledge	Linear algebra, calculus, basic statistics, basic programming
Academic Skills	Presenting (Assigment results will be presented in classroom) Academic writing (assignments) Collaboration (Assignmenents will be done in groups of two)
Literature & Study Materials	Lecture notes and slides; Background reading: Understanding Digital Signal Processing (3rd Edition), R. Lyons Multivariate Geostatistics, H. Wackernagel Mathematical Principles of Remote Sensing, A.S. Milman Digital processing of random signals, B. Porat
Judgement	See assessment
Permitted Materials during Exam	A simple pocket calculator without memory is allowed.
Collegerama	No

CIE4604	Simulation and visualization	5
Responsible Instructor	Dr.ir. H. van der Marel	
Instructor	Dr. T. Vlemmix	
Contact Hours / Week x/x/x/x	0.8.0.0	
Education Period	2	
Start Education	2	
Exam Period	none	
Course Language	English	
Expected prior knowledge	Matlab basics	
Course Contents	This course deals with simulation and visualization of remote sensing applications for geoscience. For many science and engineering applications, this is needed in order to process and interpret observations from an instrument or sensor, or to develop a robust simulation environment to better understand the nature of the problem being investigated. To do this requires a diverse range of skills that involve not only programming, but also knowledge such as how to break down the problem into logical elements, how to manage the data sets involved, or how to visualize your results for presentations and interpretation. Through a series of hands-on interactive sessions, students in this course will have the opportunity to develop these and other skills by working through a range of scientific and engineering tasks and problems that they are likely to encounter in their future academic/industrial careers. These include topics such as: Reading, analyzing and visualizing (large) datasets with observations Using a simulation environment and evaluating simulated results(analyzing the problem, generating observations, assessing results) Implementing tasks such as least squares, integration, and others effectively Working with gridded data sets (file formats, resampling, spatial filtering) Visualizing geographical data sets Automating tasks through basic shell scripting Data editing and outlier detection techniques	
Study Goals	At the end of the course, students will be able: to apply and implement sound programming practices to solve common science/engineering problems to evaluate, analyse and use simulations to validate retrieval algorithms to assess, justify and reflect on the correctness of numerical solutions to analyze, evaluate, visualize and summarize (potentially large) data sets (in a variety of formats) to integrate and visualize complex results in a clear and illustrative manner The topics and assignments provided will be fairly generic in nature, so the course should appeal to students outside the GSR Msc program as well.	
Education Method	A majority of the contact hours will be spent in a studio classroom setting, and students will work on a series of custom assignments under the guidance of a tutor. The remaining contact hours will be self-study.	
Literature and Study Materials	Lecture notes, online resources.	
Assessment	The final mark will be based on a series of graded individual assignments. There will be no final exam.	
Tags	Algoritmics Analysis Databases Diverse Geo Engineering Matlab Numeric Methods Physics Practicals Programming Programming concepts Research Methods Small groups Software Stochastics Technology	
Expected prior Knowledge	Matlab basics. Furthermore it is assumed students have followed the mandatory courses in Q1 of Geoscience and Remote Sensing or have comparable knowledge.	
Academic Skills	Data analysis, programming and visualization.	
Literature & Study Materials	Lecture notes. On-line materials.	
Judgement	Students are expected to complete all six graded assignments. However, should a student fail to complete a graded assignment he/she will receive zero points for this assignment. After grading of the final assignment the final grade will be computed as the average of the 6 individual grades (not completed assignments will receive a grade of zero).	
Permitted Materials during Exam	not applicable.	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Choose at least 12 EC of the possibilities listed below

CIE4522-15	GPS for Civil Engineering and Geosciences	4
Responsible Instructor	Dr.ir. H. van der Marel	
Instructor	Dr.ir. C.C.J.M. Tiberius	
Instructor	Dr.ir. A.A. Verhagen	
Contact Hours / Week x/x/x/x	0/0/0/4	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Course Contents	Global Navigation Satellite Systems (GNSS), such as GPS, have revolutionized positioning and navigation, and resulted in novel applications. This course addresses the principles of GNSS, and covers the main applications in Civil Engineering and Geosciences: 1. Fundamental principles of Global Navigation Satellite Systems (GNSS) This part covers the basic principles and components of GNSS; the American GPS, Russian Glonass, European Galileo, and Chinese BeiDou system. You will learn how a basic GNSS receiver a handheld, mobile phone or car navigation receiver - computes the position and get a basic understanding of the error sources, accuracy and limitations of GNSS. Topics are: space segment, user and control segment, overview of systems, signal structure, clocks, receiver architecture and signal processing, pseudorange measurement, broadcast and precise ephemeris, signal propagation error sources, multipath, standalone or single point positioning, estimation of position, velocity and time, smartphone and car-navigation applications, augmentations systems (SBAS). 2. High-precision positioning and navigation This part focusses on methods to improve the accuracy of standard GPS positioning down to the millimeter level. You will discover the techniques that make millimetre GNSS possible: interferometric measurement principle, differential/relative positioning with two (or more) receivers, carrier phase measurement, mathematical models with Single- and Double-Differences, carrier-phase ambiguity resolution, parameter estimation for dynamic processes (e.g. a moving receiver), Kalman-filter. 3. GPS infrastructure, high-precision implementation aspects, and applications In this part you will learn how to apply the high-precision techniques in an operational setting for civil engineering, land-surveying, mapping, hydrography, transport and traffic applications. Different operational scenarios will be covered: fully autonomous, setting up your own base stations, or make use of service providers, network RTK services, and how to make use of permanent GPS networks and the International GNSS Service (IGS) for Precise Point Positioning. Real-time operation and tele-communication aspects are also covered, as well as post-processing applications and available free services for Precise Point Positioning. 4. Professional GPS applications The teachers will select together with the students one or more topics; 3-4 students will work on the same topic, but not together. Each student will do his/her own study, prepare for a discussion session on the topic, and a topic presentation to the plenary. Possible topics are: - machine-guidance (e.g. in road and infrastructure works) - GPS-tracker, e.g. of a buoy in an estuary for hydrological studies, or application in sports - positioning a drone for imaging the Earths surface - offshore positioning - high-integrity applications (Receiver Autonomous Integrity Monitoring - RAIM) with applications in aviation, railway and road vehicles - monitoring and measurement of plate tectonics, seismic deformations, land subsidence and cryospheric deformation - international reference frame and Earth Rotation determination using global networks (IGS) - water vapour estimation with GNSS for weather forecasting and climate research - Total Electron Content and electron density observations of the ionosphere and space weather applications - radio occultation techniques using GNSS receivers on board Low Earth Orbiting satellites for atmospheric profiling - GNSS-reflectometry, for ocean altimetry, ocean state and soil moisture measurements, using GNSS receivers from space or airplanes, and Tsunami monitoring from space - GNSS-INS integration and applications for airborne gravimetry and/or automated vehicles - time transfer and timing applications	
Study Goals	After successfully completing this course, a student is able to: explain the basic ranging, timing and positioning principles of GPS. apply standalone positioning and obtain a position solution given a set of pseudorange measurements. evaluate the effects of error sources on GPS ranging and positioning and propose effective methods to mitigate or eliminate the resulting errors. compute and evaluate performance figures make an educated choice for a mode of operation (or a GPS positioning mode) given an application in civil engineering or geosciences.	
Education Method	Two hours of lecturing per week, and two hours of instruction/help/kick-off on that weeks assignment.	
Assessment	Students will be graded primarily through a series of assignments (toets01). The assignments can be done individually, or in groups of two students. Next, there is a short (1 hour) written exam at the end (toets02), and an oral presentation on a subject of their own choice (small casestudy) just a presentation, no report (toets03). The weighting is 50%-25%-25%.	
Elective	Yes	
Tags	Algoritmics Building & Spatial Development Diverse Embedded systems Fieldwork Geo Engineering Information & Communication Physics Rail & Road Engineering / Planning Signals and Systems Small groups Technology Transport & Logistics Water Engineering Water management	
Expected prior Knowledge	This course provides an introduction to GPS. Prior knowledge on related subjects such as parameter estimation theory, as covered in CIE4611 Geo-measurement processing, and basic measurement principles and reference systems, as covered in	

	CIE4606 Geodesy and Remote Sensing is recommended. Relevant material can be provided on request.
Academic Skills	literature study, critical thinking, research abilities, problem solving, discussion with peers, presenting an application idea, application to practical problems
Literature & Study Materials	In addition to the lecture-slides, a set of hand-outs on essential topics of this course, supplemented with selected papers for further reading and background.
Judgement	The weighting is 50% assignments (toets01), 25% for a short (1 hour) written exam at the end (toets02), and 25% for the oral presentation on a subject of their own choice (toets03).
Permitted Materials during Exam	No materials are allowed during the exam.
Collegerama	No

CIE4602	Ice, snow and climate change: observation and modeling	4
Responsible Instructor	Dr. M. Vizcaino	
Contact Hours / Week x/x/x/x	0.0.6.0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	1.The Cryosphere and Climate Change a.Overview of Cryosphere components: glaciers, ice sheets, sea-ice, seasonal snow cover, frozen ground b.Global and Polar climate change c.Sea-ice change: processes, observations and models 2.Snow and ice surface processes (accumulation, melt, refreezing, sublimation) a.From snow to ice; classification of snow and ice covered surfaces b.Polar meteorology: processes and observations c.The Surface Energy and Mass budget: radiation fluxes, melt, albedo d.Optical and near-infrared remote sensing techniques applied to snow and ice surfaces e.Modeling glacier and ice sheet surface processes 3.Glacier flow a.The flow and temperature of ice masses b.Observation of ice flow (InSAR, feature tracking) c.Models of ice flow d.Basal hydrology, glacial surges 4.Ice sheet and Climate coupling a.Processes and observations of mass loss of the Greenland and Antarctic ice sheets b.The glacial cycles of the last three million years c.Monitoring ice sheet calving fronts, elevation change, and thickness d.Predicting future Greenland and Antarctic ice sheet evolution	
Study Goals	This is a course on the physics of the parts of the Earth System that contain frozen water (the seasonal snow cover, sea-ice, glaciers, and the Greenland and Antarctic ice sheets), on their interaction with the physical climate system, and on the techniques to observe these parts of the Earth remotely. Special emphasis will be given to glaciers and the Greenland and Antarctic ice sheets, that are currently losing mass at an accelerated pace and becoming a major contributor to sea level rise. After this course, students are able to: identify the mechanisms of current mass loss from glaciers, shrinkage of the Arctic sea cover, and reduction of the seasonal snow cover connect ice and snow changes with global climate change identify the impacts of snow and ice change on human societies and the environment apply optical, infrared and other remote sensing techniques to monitor ice and snow change combine observational and modeling tools to monitor and predict ice and snow change identify current challenges in the observation and modeling of ice and snow surfaces	
Education Method	Materials: lectures, videos, numerical exercises and problems, guided assignments, practical classes. The student will use several remote-sensing techniques to monitor glacier, snow-cover, ice sheet and/or sea-ice change. He/she will use models to simulate and/or analyze glacier flow, surface melt, global and local climate change, and/or coupled ice -sheet/climate evolution.	
Assessment	The Assessment will be done from Assignments (50% of the final mark) and a written exam (50% of the final mark). Assignments may be done in small groups. The Exam will be a mixture of short theoretical questions, multiple choice and numerical exercises.	
Elective	Yes	
Tags	Physics Research Methods Technology	
Expected prior Knowledge	Physics at the Bachelor Level. Recommended: CIE4613 Climate Change and ethics and CIE4601 Physics of the Earth and atmosphere.	
Academic Skills	Programming, data manipulation, data visualization (e.g. QGIS, ArcGIS, MATLAB)	
Literature & Study Materials	Required: - Slides from lectures in class as posted in Blackboard - Numerical exercises and problems posted in Blackboard Recommended: - The Physics of Glaciers, Paterson & Cuffey - "Remote sensing of the Cryosphere" by Marco Tedesco - Polar remote sensing, Masson & Lubin http://link.springer.com/book/10.1007%2F3-540-30785-0 http://link.springer.com/book/10.1007%2F3-540-30565-3 - Fifth Assessment Report of the International Panel of Climate Change, chapters on Observations of the Cryosphere and on Sea Level.	
Judgement	Final mark: 50% from Assignments 50% from written exam The passing mark is 6.0 Both parts need to be passed with a minimum of 5.0	

Permitted Materials during Exam	Pocket calculator
Collegerama	No

CIE4605	**Atmospheric science**	**4**
Responsible Instructor	Dr. S.R. de Roode	
Instructor	S. Basu	
Contact Hours / Week x/x/x/x	0.0.6.0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	This course deals with atmospheric processes on all relevant scales: the global scale (weather systems), intermediate scale (deep convection, turbulence), to the smallest scales of cloud droplets and aerosols. After reviewing fundamental concepts of radiative transfer and atmospheric thermodynamics, concepts from dynamic meteorology (cyclones, frontal systems) will be addressed. Moving to smaller scales, the theory of turbulent atmospheric boundary layers will be treated, distinguishing between convective, neutral and stable boundary layers (i.e. day-time and night-time situations). This paves the way towards addressing cloud formation processes, i.e. cloud dynamics and cloud-microphysics, and rain formation. Apart from treating the underlying principles and concepts, also attention will be devoted to observation, modelling and forecasting of the phenomena.	
Study Goals	After completion of this course the student will be able to master the principles of: large scale weather phenomena (cyclones, fronts, storms) cloud formation, cloud microphysics, rain formation deep convection, extreme weather day-time and night-time atmospheric boundary layers observation, modelling and forecasting of weather phenomena on different scales	
Education Method	2 hours of lecturing 4 hours of supervised computer-based and regular exercises. This 'learning by doing' approach forms an important element of the course.	
Assessment	The grade will be based on a combination of homework exercises and a (written) exam.	
Expected prior Knowledge	Anyone with a BS degree in technical studies (e.g. Civil Engineering, Applied Earth Sciences, Mechanical Engineering, Aerospace Engineering or Applied Physics) and an interest in meteorology and climate should be able to follow this course.	
Academic Skills	Experience with software like Matlab is very helpful to do the practical exercises.	
Literature & Study Materials	A great text book that covers most of the topics addressed in teh course is "Atmospheric Science, An Introductory Survey", by John Wallace and Peter Hobbs.	
Judgement	50% of the final grade will be based on mandatory homework exercises and 50% by the written exam.	
Permitted Materials during Exam	Calculator.	
Collegerama	No	

CIE4607	Oceans, sea-level and bathymetry	4
Responsible Instructor	Dr. R.E.M. Riva	
Contact Hours / Week x/x/x/x	0.0.4.0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	The ocean surface is continuously changing due to processes acting at different spatial and temporal scales. Sea level is affected by sub-daily tides, by multi-yearly changes in ocean circulation (e.g., El Nino), but also by climate change, by long-term geophysical processes and by changes in ocean bathymetry. For instance, global mean sea level is currently rising at a rate of about 3 mm/yr and is expected to accelerate during the coming decades, potentially rising by more than one meter by the end of the century. Monitoring and understanding sea level changes requires a combination of different techniques, in order to capture processes that take place in the open ocean as well as those that affect coastal areas. The course is about he observation techniques used to measure sea level variations including their potential and limitations, the analysis of the data provided by the measurement sensors, and their application to the study of the geophysical processes causing sea level variations. The course is structured as follows: Satellite radar altimetry Basic concept, satellite missions, overview applications, general data processing From altimeter range to sea surface heights From sea surface heights to the dynamic topography Marine gravity and sea floor topography (bathymetry) Applications of satellite altimetry in oceanography and climate research - Ocean currents from dynamic topography - Mesoscale eddies - El Nino monitoring and forecasting - Monitoring deep ocean convection from space - Hurricane evolution Tides and tide gauges Ocean tides - Tide gauges, principles, systems and record - Extracting information about sea level change from tide gauge data Sea level change Glacial Isostatic Adjustment Global mean sea level, available measurements and the sea level budget Spatial variability of sea level change - Sea level reconstructions and future projections Bathymetry - Basic principles of echo-sounding	
Study Goals	After successful completion of this course, the student: - can explain the basic principles of satellite altimetry and the altimeter data processing - has an overview of the major oceanographic and geodetic applications of satellite altimetry - is able to extract sea level records from tide gauge and satellite observations - can describe the different contributors to sea level change at global and regional scales - can explain how to determine ocean bathymetry	
Education Method	On a weekly basis: 2 x 2 hours of lecturing 7 hours of self-study and working on graded assignments	
Assessment	The student knowledge is assessed by means of: - graded assignments (50% of the final grade); - written examination at the end of the course (50% of the final grade).	
Expected prior Knowledge	Basic use of Matlab (data manipulation and visualisation).	

CIE4608	Atmospheric observation	4
Responsible Instructor	C.M.H. Unal	
Instructor	C.M.H. Unal	
Instructor	Dr. T. Vlemmix	
Contact Hours / Week x/x/x/x	0.0.0.6	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Course Contents	1.Introduction: Relation between atmospheric and observation scales of the atmosphere (compared to ocean) and introduction to multi-scale observations. sensors introduction (platform types, remote-sensing / in-situ, passive / active sensor systems, wavelength, range). review of the concepts of absorption, extinction and scattering. 2.Observation of the dry atmospheric composition (gases and aerosols): a)Satellite and ground-based observation Intro: scientific questions and challenges concerning the ozone layer, air quality and the climate system, short description of chemical composition of the atmosphere. Core: physical principles of the solar backscatter observation techniques (UV and visible). Ground-based observation techniques of the atmosphere, aerosol Sun photometer and Brewer/Dobson instrument for ozone detection. Satellite retrieval, most notably the DOAS (Differential Optical Absorption Spectroscopy) technique used for detection of trace gases. Description of various satellite instruments for monitoring the chemical composition of the atmosphere (GOME, SCIAMACHY, GOME-2, OMI and TROPOMI). Touched upon: chemistry and dynamics of the atmosphere related to the ozone layer and air quality, the radiation balance of the atmosphere and the enhanced greenhouse effect (IPCC); validation with ground-based instrumentation and radiosondes; using satellite observations and inverse modeling to quantify emissions. b)Direct height-resolved measurements of trace-gasses and aerosol using lidar (laser-radar) systems. Intro: Overview of lidar technology and capabilities, both ground and space-based. Core: Derivation of the equations for elastic backscatter lidars and polarization lidars (useful for cloud and aerosol remote sensing) and Differential Absorption Lidars (useful for trace-gas profile measurements). Two illustrative application areas are presented: volcanic ash aerosol detection and ozone profile retrievals. 3. Observation of the wet atmospheric composition (condensed water): a) with the radar (precipitation and cloud) Scanning and profiling weather/atmospheric radars, wave, antenna and radar polarization, polarimetric basis to characterize precipitation, Doppler radar spectral estimation, Doppler signal processing, spectral polarimetry, raindrop size distribution retrieval techniques, radar rainfall estimation, attenuation estimation. b) with the lidar (cloud) An overview of Cloud remote sensing using lidars is presented. Both ground and space-based perspectives are covered and the complementarity of combined lidar and radar measurements is discussed. 4.Observation of the atmospheric dynamics during clear air and precipitation: Techniques to retrieve wind and turbulence with Doppler radar, Doppler lidar, Radio Acoustic Sounding System (RASS) and sonic anemometer are introduced.	
Study Goals	This course aims at providing up-to-date knowledge on atmospheric observations required in the fields of weather, climate and air quality. The course is comprised of three parts, each approaching the atmosphere from a different viewpoint and introducing specific measurement techniques: the dry atmospheric composition (gases and aerosols), the wet atmospheric composition (cloud and precipitation) and the dynamic processes of the atmosphere. The learning objectives are: - The student can describe the sensors, their measurements and the state-of-the art techniques used to measure the different components of the atmosphere. - The student can explain these techniques, the equations taken into consideration and the related signal processing. - The student can interpret atmospheric measurements from different sensors. - The student can select the appropriate sensor, measurement and technique in order to estimate a specific physical property of the atmospheric medium.	
Education Method	Every week: lecturing (3x2 hours) Every two weeks: one guided assignment (4 hours)	
Assessment	written exam --> 63% homework --> 7% 4 graded assignments --> 30% (10%, 5%, 5%, 10%)	
Contact	Christine Unal - c.m.h.unal@tudelft.nl	
Literature & Study Materials	Study materials consist of lecture slides, selected chapters from textbooks and articles.	
Permitted Materials during Exam	A list of equations is provided.	

CIE4609	Geodesy and natural hazards	4
Responsible Instructor	Prof.dr.ir. R.F. Hanssen	
Contact Hours / Week x/x/x/x	0.0.0.6	
Education Period	4	
Start Education	4	
Exam Period	none	
Course Language	English	
Course Contents	In this course we will study various natural hazards, such as earthquakes, volcanic eruptions, tsunami's, landslides and flooding, in combination with geodetic techniques to monitor (or forecast) them. Particular emphasis will be given to the measurement of surface deformation using satellite radar interferometry (InSAR). Topics to be covered on geodynamic signals include: 1. Earthquake physics and the seismic cycle, earthquake deformation modelling, probabilistic earthquake forecasting, real-time earthquake prediction, earthquake mitigation, earthquake case study: 2011 Japan. 2. Volcanic settings, physics of magma flow and eruption, volcanic hazards, volcano monitoring (deformation, seismicity, gas emissions), volcano deformation modelling, volcanic eruption prediction and mitigation, volcanic case study: 2010 Eyjafjallajökull. 3. Landslide physics: slope stability and role of water, landslide triggering, landslide monitoring (deformation, water pressure, temperature), landslide prediction, landslide prevention and mitigation. 4. Land subsidence, flooding mitigation, dike monitoring, case study: Netherlands. Topics to be covered on geodetic observations are: 1. Basic principles of radar techniques 2. Signal processing techniques to produce high resolution SAR radar imagery 3. Interfrerometric processing approaches 4. Time series analysis	
Study Goals	After completion of this course the student will be able to: explain the physics involved in each of the natural hazards covered, describe the observation techniques appropriate for each of the hazards, compute surface deformation associated with the hazards, apply GNSS and radar interferometry to measure surface deformation, explain how the hazards can be predicted/forecast and/or mitigated.	
Education Method	A combination of lectures, supervised lab instruction, self-study and assignments. Some of the assignments use Matlab	
Assessment	Graded assignments and a term paper.	

CIE4610	Mass transport in the Earth's system	4

Responsible Instructor: Dr. P.G. Ditmar

Contact Hours / Week x/x/x/x: 0.0.0.6

Education Period: 4

Start Education: 4

Exam Period: none

Course Language: English

Expected prior knowledge: Calculus, basics of Matlab programming

Course Contents

The course is devoted to large-scale mass transport in various compartments of the Earths system (continental hydrology, ice sheets, solid Earth) and to the techniques exploited to observe it, with a primary focus on satellite gravimetry. The course consists of three major parts:

1. Basics: general information about gravity and gravimetry; introduction of basic terms and concepts
2. Theory: mathematical representations of the Earths gravity and its link to mass transport; quantification of mass transport processes in practice
3. Applications: usage of mass transport observations in geoscicences.

The list of topics covered by the course includes:

Physical principles of gravimetry
Contemporary satellite gravimetry missions: their capabilities and limitations
Spectral representation of harmonic functions. Spherical harmonics
Representation of mass transport in spectral and spatial domain
Link between mass transport and geocentre motion
Post-processing of satellite mass transport observations
Application of mass transport observations in hydrology (e.g., to predict floods and quantify the consumption of ground water resources)
Application of mass transport observations in ice sheet studies (e.g., to quantify the response of ice sheets to global warming and the associated sea level rise)
Application of mass transport observations in solid Earth studies (e.g., to gain more knowledge about glacial isostatic adjustment and megathrust earthquakes)

The course is set up to meet the growing public concern about the future of our planet, its climate, its environment and about a shortage of natural resources, including water. Any strategy of protection against these threats requires a profound understanding of the Earths system, which is subject to a multitude of dynamic processes. On-going large-scale mass transport is one of them. The knowledge of it is of crucial importance for better understanding climatologically driven processes related to continental water stocks, including glaciers and ice sheets, as well as (in combination with information about the Earths structure) for the exploration of geodynamic processes such as plate tectonics and glacial isostatic adjustment.

Study Goals

By the end of the course the student:

understands and can properly use the basic terms and concepts related to the Earths gravity field, which is the primary indicator of mass transport in the Earths system
is able to collect gravity field data with a relative gravimeter, as well as to make a basic processing of those data
can transform a 2-D and 3-D harmonic function (e.g., gravitational potential) of polar/spherical coordinates into the spectral domain and back
is able to convert a time-varying gravity field model into a global mass transport model
can quantify selected mass transport processes related to hydrology, ice sheets, and solid Earth, as well as to assess the accuracy and reliability of the obtained estimates
can discuss the importance of selected mass transport processes for society, industry, or/and science
is able to critically analyze scientific publications related to mass transport in the Earths system

Education Method

The primary education method of the course is learning-by-doing. Most of topics are taught in the form of a 3-step procedure: (i) classical lecture; (ii) completion of assignments in the class; (iii) individual completion of a homework assignment. Lectures in the last part of the course are given not only by the responsible lecturer, but also by invited experts. At the end of the course, a student workshop is organised, where each student gives a short presentation related to a topic of choice on the basis of state-of-the-art scientific publications. Finally, each student completes a design assignment by doing a mini-research related to a chosen mass transport process. The obtained results are summarized in the form of a final report that resembles a scientific publication.

Literature and Study Materials: Lecture slides, lecture notes, scientific articles and reports

Assessment

Homework assignments
Oral presentation
Design assignment and the corresponding report to be prepared in the form of a scientific paper
Active involvement into discussions in class

No written examination at the end

Expected prior Knowledge: Calculus, basics of Matlab programming

Academic Skills

The course is devoted to large-scale mass transport in various compartments of the Earths system (continental hydrology, ice sheets, solid Earth) and to the techniques exploited to observe it, with a primary focus on satellite gravimetry. The course consists of three major parts:

1. Basics: general information about gravity and gravimetry; introduction of basic terms and concepts
2. Theory: mathematical representations of the Earths gravity and its link to mass transport; quantification of mass transport processes in practice
3. Applications: usage of mass transport observations in geoscicences.

The list of topics covered by the course includes:

Physical principles of gravimetry
Contemporary satellite gravimetry missions: their capabilities and limitations
Spectral representation of harmonic functions. Spherical harmonics
Representation of mass transport in spectral and spatial domain
Link between mass transport and geocentre motion
Post-processing of satellite mass transport observations
Application of mass transport observations in hydrology (e.g., to predict floods and quantify the consumption of ground water resources)
Application of mass transport observations in ice sheet studies (e.g., to quantify the response of ice sheets to global warming and the associated sea level rise)

	Application of mass transport observations in solid Earth studies (e.g., to gain more knowledge about glacial isostatic adjustment and megathrust earthquakes) The course is set up to meet the growing public concern about the future of our planet, its climate, its environment and about a shortage of natural resources, including water. Any strategy of protection against these threats requires a profound understanding of the Earths system, which is subject to a multitude of dynamic processes. On-going large-scale mass transport is one of them. The knowledge of it is of crucial importance for better understanding climatologically driven processes related to continental water stocks, including glaciers and ice sheets, as well as (in combination with information about the Earths structure) for the exploration of geodynamic processes such as plate tectonics and glacial isostatic adjustment.
Literature & Study Materials	Lecture slides, lecture notes, scientific articles and reports
Judgement	Homework assignments Oral presentation Design assignment and the corresponding report to be prepared in the form of a scientific paper Active involvement into discussions in class No written examination at the end
Permitted Materials during Exam	N/A
Collegerama	No

CIE4614	Land surveying and civil infrastructure	4
Responsible Instructor	Dr.ir. B.G.H. Gorte	
Instructor	Dr.ir. A.A. Verhagen	
Contact Hours / Week x/x/x/x	0.0.6.0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	Surveying is of key importance for any construction or infrastructural project in the planning and preparation phase and the construction phase itself, but also afterwards during the actual operation. Applications to be considered are tunnelling (e.g. the Noord-Zuidlijn in Amsterdam, and the Spoorzone in Delft), planning and construction of roads and railways, monitoring and maintaining dikes, construction and monitoring of buildings, bridges and dams. In this course you will learn how to solve a number of specific surveying problems: which techniques are available and can be used for specific applications in relation with the required accuracy? The larger part of the course concerns the acquisition and processing of point clouds: massive numbers of measurements in 3D space. Point clouds are acquired from multi-view recordings made by "ordinary" (b/w or color) cameras, or by range cameras, like the Kinect, and laser ranging instruments. After completing a survey, 3d measurement and object reconstruction can be performed on the basis of the acquired point cloud. Recognition of objects and extraction of other relevant information from point clouds are covered in the course, as well as representation of the results by means of Digital Terrain Models.	
Course Contents Continuation	A more detailed list of applications, for which highly accurate surveying measurements are required, includes: Design of the buildings or infrastructure: produce accurate topographical plans, maps, and digital terrain models. Earthwork calculations and cut-and-fill (earth-moving) operations Control of the building process: is everything built according to the design? Tunnel boring: drilling in the right direction. Monitoring during the construction process to check for deformations Impact of wind and earthquakes on high rise buildings and bridges. This is also important for design and material testing. Deformations that may occur after completion of the construction. 3D-modeling of buildings and constructions. * Comparison of as-built situation to existing CAD drawing The following topics are addressed during the course: Equipment: Total stations, imaging cameras, low cost range cameras (Kinect, Swissranger), laser scanners (phase vs pulsed). Aerial, terrestrial and mobile systems. Math fundamentals, camera models, projective geometry, collinearity equations, coordinate transforms, ineterior and exterior orientation Estimation, model inversion, non-linear least squares, orientation, bundle adjustment Image analysis, correspondences, matching (least squares and correlation), epipolar planes, dense matching Algorithms: forward and inverse modeling, ICP, SIFT, segmentation, Hough transform Products: plans, maps, elevation models, ortho images, point clouds, 3d object models	
Study Goals	After completing the course Land Surveying and Civil Infrastructure students will be able to: - explain the principle of surveying techniques such as tachymetry, photogrammetry, and laser scanning - distinguish between appropriate techniques for measuring and mapping in support of applications in infrastructural and construction works, deformation monitoring - make inferences on the accuracy and precision obtained with different measurement set-ups - explain in detail the relationships between coordinate systems of cameras, intensity and range images, point clouds, and the object space; describe various coordinate transformations that occur in various processing phases - perform orientation of single camera and multiple camera configurations and explain the methodologies involved - understand how digital terrain models (DTM) can be constructed by dense matching in aerial images - describe steps involved in the production of end products, such as orthoimages and 3D models, from point clouds	
Education Method	Lectures (20 hours) and Guest lectures (4 hours) Practicals and guided assignments (18 hours) Homework assignments and self-study (70 hours) Students will take surveying measurements using different techniques (tachymetry, photogrametry, laser scanning). Practicals are accompanied with graded assignments. Focus will be on key aspects of algorithms and data processing.	
Assessment	Graded assignments of practicals (during class): 20%, Homework assignment (by small teams): 50%. Oral Exam, discussion of assignments (individual): 30%	
Expected prior Knowledge	CTB3310 (Surveying and Mapping) or equivalent.	
Academic Skills	Creativity, design, collaboration	
Literature & Study Materials	Powerpoint presensations, Reader probability and statiscics	
Judgement	Comparing and selecting alternative measurement and surveying approaches	
Permitted Materials during Exam	n/a (oral exam)	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Elective courses (20 EC to a total of 60 EC in the 1st year)

AES1050	GSE Student competition course	5
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	na	
Education Period	1 2 3 4	
Start Education	1 2 3 4 5	
Exam Period	none	
Course Language	English	
Course Contents	The GSE Student Competition Course is a platform offered to encourage and stimulate participation of teams of students to high level scientific competitions which can be within TUDelft, national or international. The GSE Student Competition Course provides a workflow which participants are required to follow in order to be eligible for the 5EC associated with the course. The workflow is as follows 1) the team intending to participate to the competition writes a motivation letter which includes, among others, i) a description of the competition ii) the expected added value for the educational growth of the students iii) a motivation statement from all members of the team and iv) the name of a technical advisor in charge of the daily supervision of the participating team. If costs are involved in the participation, the letter should also include information on how these will be covered. The letter is evaluated by the Course responsible and two other GSE staff members (Prof. Dr. B. Rossen and Dr. G. Drijkoningen) and participation is approved/rejected. The way the participation will be graded is also discussed and agreed upon at this stage At the end of the competition, the participating team will submit a short report describing the activities and experiences made during the competition itself. The technical advisor proposes a grade which is then discussed with the three staff members responsible of the Course.	
Study Goals	The goal of the GSE Student Competition Course is to improve technical knowledge and strengthen the group working skills of the participating team. Upon succesful completion of the competition, the participating students will have learned a variety of technical tools (depending on the type of competition) and will be able to work in a small team under time and competition pressure to present their results in a competitive arena in front of an external jury	
Education Method	Learning through competition	
Assessment	The pass/no pass boundary and the grading will depend on the type of competition and will be discussed prior to the start of the competition itself	
Expected prior Knowledge	Expected prior knowledge depends very much on the competition. Because only scientifically challenging competitions will be considered, only MSc students will be allowed with a strong background. Intrinsic in the idea of a competitive team, the participants will have different backgrounds (geophysics, engineering, geology etc)	
Academic Skills	Key to success and, therefore to earning the 5EC is the ability to form a real team during the competition. The necessary first step of this process is the ability of putting together a winning team composed of experts also able to work together. The value of strong cooperation will only increase during the competition	
Literature & Study Materials	will depend on the specific compeititons	
Judgement	The technical advisor (if present) will propose a grade to the staff members responsible of the course; these will have the final decision.	
Permitted Materials during Exam	no exam in the classical sense of the term is foreseen the assessment will be based on the report presented by the participating team and on insights provided by the technical advisor	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Free electives (CIE/AES-courses)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Choose 20 EC of the possibilities listed below

AES4011-10	Additional Thesis	10
Responsible Instructor	Prof.dr.ir. T.J. Heimovaara	
Contact Hours / Week x/x/x/x		
Education Period	None (Self Study)	
Start Education	1 2 3 4 5	
Exam Period	Different, to be announced Exam by appointment	
Course Language	English	
Course Contents	See text for Master Thesis Project	
Study Goals	See text for Master Thesis Project	
Education Method	See text for Master Thesis Project	
Assessment	See text for Master Thesis Project	
Expected prior Knowledge	see text for Master Thesis Project	
Academic Skills	see text for Master Thesis Project	
Literature & Study Materials	see text for Master Thesis Project	
Judgement	see text for Master Thesis Project	
Permitted Materials during Exam	see text for Master Thesis Project	
Collegerama	No	

CIE4040-09	Internship	10
Responsible Instructor	Dr.ir. J.H. Baggen	
Instructor	M.L.Y. Kraeger-Holland	
Contact Hours / Week x/x/x/x	n.a.	
Exam Period	none	
Course Language	Dutch English	
Course Contents	The internship consists of a personal project of at least 7 fulltime weeks in an environment of day-to-day practice of civil engineering companies or institutes (contractors, consultancies, government, non-governmental organisations, etc.) in the Netherlands or abroad. An internship provides the opportunity to get a glance of the technical, social, economic and organizational aspects of civil engineering and/or related fields as a profession. The student is completing a project in which he/she can apply the academic skills and knowledge acquired in earlier education. The student should aim for a project with clear deliverables of a sufficient academic level.	
Study Goals	Learning objectives are: 1. demonstrate engineering skills: technical skills, interpreting results, creativity, usability for company 2. familiarize with academic approach: experimental work/computer skills/design skills, extending knowledge/methods, argumention, ambtion 3. show ability to write a technical report: which is structured/consistent, language proficient, with correct use of literature/references, use of figures/tables/equations 4. demonstrate behavioural competences and skills: taking initiative, responsibility, showing communication skills, independency 5. being able to reflect on personal functioning in an evaluation report: reflect on personal objectives, indicate personal strengths/weaknesses, indicate future personal improvement, drawing conclusions for future professional carreer	
Education Method	Practical work experience for a period of at least 7 weeks full time (or part time equivalent) / 280 hours, including desk research and reporting.	
Prerequisites	A completed and signed internship agreement BEFORE the start of the internship is required to have to internship officially accepted. Retro-acceptance is NOT possible.	
Assessment	Based upon: - A technical report on the students' personal project, including a separate 1 page summary, - An evaluation report, a reflection of students learning process based on his/her learning objectives.	
Enrolment / Application	For registration two forms can be downloaded from Blackboard: - the Registration form - the Internship Agreement form. Both forms have to be completed and the Internship Agreement has to be signed by company supervisor, university supervisor and internship coordinator. After completed both forms (Registration form in MS Excel format and Internship Agreement scanned with signatures) must be e-mailed together to the automated registration system InternshipAgreement-CIE4040@tudelft.nl	
Remarks	An internship can be performed any time during the academic year	
Contact	Internship Office: Building 23, room 2.73 Opening hours desk: Monday-Friday 12:30 - 13:30. ms M.L.Y. Kraeger - Holland (assistant internship coordinator), phone +31 (0) 15 27 81174 ms A. Scheltema BSc (internship office assistant), phone +31 (0) 15 27 81964 e-mail: Internship-CEG@tudelft.nl	
Literature & Study Materials	On Blackboard are available: - Internship Manual - downloadable blank Registration form - downloadable blank Internship Agreement form - all the available internship offers - downloadable template for summary.	
Judgement	Assessments by company supervisor (as daily supervisor), university supervisor (an expert university staff member) and internship coordinator.	

CIE4061-09	Multidisciplinary Project	10

Responsible Instructor
Y. de las Heras

Contact Hours / Week x/x/x/x
n.a.

Education Period
Different, to be announced

Start Education
1

Exam Period
none

Course Language
Dutch
English

Course Contents
Solve an actual and recent civil engineering problem in a multidisciplinary team. Integrate several studies and designs into a coherent entity, based on knowledge, understanding and skills acquired in the preceding years. Attention will be on quality control and the evaluation of the design process. Knowledge and skills obtained during the BSc projects will be used in this project. The course is divided into three phases: phase 1: inception plan; phase 2: preliminary design and studies; phase 3: process evaluation with respect to interdisciplinary aspects; final report.

Description

Phase 1: preliminary investigation (Problem exploration and treatment). By means of supplied and found information (project file, informers, literature) an inventory and analysis of the problem must be made. This results in a (substantive) problem formulation and an objective. Coupled to that, a treatment will be formulated. Which methods will be used, which contribution can different disciplines provide to the project, which steps have been passed through successively, which information is still necessary, where can that information be found? Finally the organization of the group must be fixed.

Phase 2: design. At this stage is alternatively worked for the complete problem and for sub-problems. The work exists for a part of research, for a another part of developing design alternatives or solution alternatives, and from developing the sub-problems. Ongoing, the consistency with the whole design must be monitored.

Phase 3: Round-off. In the round-off, the last hand is laid to the results of the project. First of all the handed in report is discussed with the speculator team, whereupon the definite version is made. The participants evaluate the project, both substantive and concerning the project process. Finally, the presentation is prepared and a summary for the presentation is established.

Note 1:
If students from Building Engineering want to do the masterproject they will be doing the High Rise project.
Teams are formed together with the students form the Faculty of Architecture with a task to design a big scale high-rise building. The teams consist of about five students. Each student is assigned to represent a specific dicsipline (architect, stuctural engineer, project manager, building services engineer, etc.) with a specifc task and responsibility in the team, covering architectural and functional design, structural design, building physics, finishes, building services, real estate development and construction and management. The civil engineering students are mostly assigned the function of the stuctural engineer. The time reserved for this workshop project is approx. 8 weeks. The teams are coached and guided in the lines of the mentioned disciplines, by a number of lecturers from the faculty of Architecture and Civil Engineering and engineers and architects from daily parctice.

For more information see: www.aal.Bk.tudelft.nl

Note 2:.
For students who aim for an Integral Design Managemnt (IDM) annotation within their respective MSc track and specialisation, this course/project is mandatory. Moreover, IDM-students must apply integral design and management knowledge and skills obtained at the IDM courses CIE 3380 and CIE 4480. This includes knowledge and skills on integral design and maintenance, project- and asset management, and information systems. Depending on the students MSc track and specialisation three domains of application are considered: water, infra and building.

Study Goals
1. Design learning on a sub-sector of civil engineering in multidisciplinary link.
2. Integrated appliance of knowledge and skills from previous years.
3. Application of design knowledge and skills from the first, second and third year.
4. Learning to work by means of an interdisciplinary approach.
5. Learning to report, present and defending the end product.
6. Learning to apply elementary quality guarantee principles (e.g. MCE, SWOT) during the design process.
7. Evaluate learning of the interdisciplinary work process

For IDM-students:
8. Application of integral design and management knowledge from IDM courses CIE3380 and CIE4480.

Education Method
Teamwork in a group of 4 - 6 students

Literature and Study Materials
A syllabus is available via Blackboard CIE4061-09; the e-book "report writing" is recommended. This e-book is part of the course on report writing (WM0201), and can be downloaded from the blackboardsite of that course.
Also the manual of the master project is available on blackboard and can be obtained at the international office of CEG.

Prerequisites
Starting the project is only allowed when you have completed your BSc:

"Students may not embark on the multidisciplinary project until, in case of a subsidiary programme outlined in Article3, subsection 2, this programme has been rounded of and, if applicable, the bachelor of science programme of civil engineering at Delft University has been rounded of."
(Article 17 of Teaching and Examination Regularion, implementation regulations 2006-2007)

Article 3 sub 2 reads:
"Students who have been admitted to the course on the basis of a bachelor's degree gained from a Dutch higher vocational institute must complete a susidiary programme as stipulated in article 11 sub1"

For IDM-students: completed courses CIE3380 (or BSc equivalent) and CIE4480.

Assessment
The group has to write a report and to give an oral presentation. The mark is based on:
Written and oral report
1. Readability of report
2. Size (not too large, not too small)
3. Readaility of drawings
4. Quality oral presentation
Group process
1. Is there a division of tasks
2. Is the project well prepared
3. Has there been delivered in time
Quality final design
1. Assessment and choice of alternatives
2. Good schematisation of the real problem
3. Contentional quality of design and computations

	Integration and multidisciplinary aspects 1. Coherence of the different parts 2. View on the full scope of the project
Enrolment / Application	The students have to form a group by themselves. Ideas for subjects can be found via the coordinator; ideas of the group itself are welcomed. As soon as a group is formed, they should register with the coordinator. Groupwork can be done outside the Netherlands; the group should realise that this require a lengthy preparation period.
Special Information	Important notice: There is no single "responsible instructor" for this subject. Consult Blackboard for details.
Expected prior Knowledge	See prerequisites
Academic Skills	See prerequisites
Literature & Study Materials	A syllabus is available via Blackboard CIE4061-09; the e-book "report writing" is recommended. This e-book is part of the course on report writing (WM0201), and can be downloaded from the blackboardsite of that course. Also the manual of the master project is available on blackboard and can be obtained at the international office of CEG.
Judgement	See assessment
Permitted Materials during Exam	n.a.
Collegerama	No

CIE4612	**Research Seminar Geoscience and Remote Sensing II**	**1**
Responsible Instructor	Dr.ir. D.C. Slobbe	
Contact Hours / Week x/x/x/x	0.0.2.2	
Education Period	3 4	
Start Education	3	
Exam Period	none	
Course Language	English	
Course Contents	Topics at the cutting edge of geoscience and remote sensing.	
Study Goals	The aim of the course is inform students about the breadth of and the state of the art in the field of geoscience and remote sensing (GRS). After taking the course, the student will be able to: 1) discuss examples of the current limits of scientific knowledge in the field of GRS; 2) describe examples of real-world applications of subjects covered in GRS; 3) analyse scientific presentations in a systematic manner.	
Education Method	Seminars given by leading researchers in geoscience and remote sensing.	
Assessment	Report	
Expected prior Knowledge	No prior knowledge is expected.	
Academic Skills	Thinking (critical, analytical); Debating and discussion.	
Literature & Study Materials	N/A	
Judgement	Each critique will be judged to either be at a satisfactory level or not. Credit will be awarded for the entire course if the number of satisfactory critiques is equal to (or greater than) the number of seminars less two. In other words, two talks can be missed without penalty.	
Permitted Materials during Exam	N/A	
Collegerama	No	

CIE5601	Journal club on climate change and geoscience	3
Responsible Instructor	Prof.dr.ir. H.W.J. Russchenberg	
Contact Hours / Week x/x/x/x	nvt	
Education Period	1	
Start Education	1	
Exam Period	none	
Course Language	English	
Expected prior knowledge	This course is open to students of all MSc programmes with an interest in Earth Science, Hydrology, and Climate Change. The course Climate Change and Ethics (CIE4510 or CIE4613) is recommended.	
Course Contents	This course is organized as a Journal Club. We will select a few topics where 'Earth Science meets Society Demands'. Think of climate change, fossile and renewable energy, water safety, water and food, geo-engineering, urban climate, Earth quakes due to oil and gas exploration.	
Study Goals	-To deepen and advance knowledge and skills in specialized topics of Earth Sciences. -To deepen insights in the role of the (geo-)engineer and geoscientist in society. -To prepare the students for potential MSc assignnments.	
Education Method	Weekly sessions in which we discuss a scientific paper. For each session a student prepares a presentation and discussion about a selected paper. All other students are expected to have read the paper in advance.	
Literature and Study Materials	Journal papers	
Assessment	oral	
Expected prior Knowledge	This course is open to students of all MSc programmes with an interest in Earth Science, Hydrology, and Climate Change. The course Climate Change and Ethics (CIE4510 or CIE4613) is recommended.	
Academic Skills	-Critical reading and analysis of journal papers -Presentation skills -Discussion skills	
Literature & Study Materials	Journal papers	
Judgement	oral	
Permitted Materials during Exam	none	
Collegerama	No	

CIE5602	Research Seminar Geoscience and Remote Sensing I	1
Responsible Instructor	Dr.ir. D.C. Slobbe	
Contact Hours / Week x/x/x/x	2.2.0.0	
Education Period	1 2	
Start Education	1	
Exam Period	none	
Course Language	English	
Course Contents	Topics at the cutting edge of geoscience and remote sensing.	
Study Goals	The aim of the course is inform students about the breadth of and the state of the art in the field of geoscience and remote sensing (GRS). After taking the course, the student will be able to: 1) discuss examples of the current limits of scientific knowledge in the field of GRS; 2) describe examples of real-world applications of subjects covered in GRS; 3) analyse scientific presentations in a systematic manner.	
Education Method	Seminars given by leading researchers in geoscience and remote sensing.	
Assessment	Report	
Expected prior Knowledge	No prior knowledge is expected.	
Academic Skills	Thinking (critical, analytical); Debating and discussion.	
Literature & Study Materials	N/A	
Judgement	Each critique will be judged to either be at a satisfactory level or not. Credit will be awarded for the entire course if the number of satisfactory critiques is equal to (or greater than) the number of seminars less two. In other words, two talks can be missed without penalty.	
Permitted Materials during Exam	N/A	
Collegerama	No	

CIE5603	Advanced project on GRS	3
Responsible Instructor	Dr.ir. H. van der Marel	
Contact Hours / Week x/x/x/x		
Education Period	4	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	Develop your own app: remote sensing data on your mobile display. In cooperation with a company and PhD students, you will develop an app to visualize remote sensing and model data on your phone.	
Study Goals	- understanding geo-physical observations; - understanding data processing; - understanding data visualization	
Education Method	Lectures, group work , practicals	
Assessment	report, demonstration	
Special Information	Important! The project might be in quarter 2 instead of 4. Please check before you enroll.	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Free electives for 10 EC (CIE/AES-courses)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Free electives for 10 EC

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES-GRS Thesis

AESM2640	Final Thesis Geoscience and Remote Sensing	40
Responsible Instructor	Dr.ir. A.A. Verhagen	
Contact Hours / Week x/x/x/x		
Education Period	None (Self Study)	
Start Education	1 2 3 4 5	
Exam Period	Different, to be announced Exam by appointment	
Course Language	English	
Course Contents	This course represents the research component of the Msc degree. The student will apply the knowledge gained in the coursework component to a focused research topic under the guidance of one or more staff members. The topic can cover any aspect of Geoscience and Remote Sensing, with the results presented in a thesis report and final presentation.	
Study Goals	The Msc thesis project is intended to give the student an opportunity to conduct independent research on a topic of his/her choice, with the goal of developing individual thinking and experience exploring a topic in-depth, as well as effectively communicating the results.	
Education Method	Independent research work, regular progress meetings with supervisors, project presentations to fellow students and staff.	
Assessment	Written MSc graduation report and an oral presentation and defense.	
Special Information	When starting your graduation report, contact the graduation coordinator (Sandra Verhagen).	
Expected prior Knowledge	Master programme should be finished with max. 15 EC course work to be finished.	
Academic Skills	See Study Goals.	
Literature & Study Materials	Discuss with supervisor.	
Judgement	Final thesis, presentation and oral defense will be assessed by the graduation committee. Criteria: scientific approach (25%), quality of result/product (25%), behavioural competences (20%), quality of written presentation (15%), quality of oral presentation and defense (15%).	
Permitted Materials during Exam	Not applicable.	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Convergence Programs

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Convergence Program CCP-1 Geology for PE / AG

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Convergence Program CCP-3 Geology & Engineering for PE / RG

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Convergence Program CCP-5 Geology, Geomechanics and Ethics for GE

AES1730	Introduction to Geotechnical Engineering	3
Responsible Instructor	Prof.dr. C. Jommi	
Contact Hours / Week x/x/x/x	4.0.0.0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Required for	Offshore soil mechanics (OE4624), BSc students from AES and HBO students	
Summary	Physico-chemical properties of soils. Ground water flow. Stresses and strains in soils. Effective stress principle. Soil stiffness and strength. Basic laboratory tests. Drained and undrained response. Settlements, bearing capacity, earth pressure and sheet-piles. Stability of cuts and slopes.	
Course Contents	The course gives an introduction to fundamental aspects of soil mechanics, e.g. soil composition, stress, strain, strength and stiffness and ground water flow. Implications of these properties for applications, such as settlement predictions, bearing capacity of shallow and deep foundations, retaining structures (e.g. sheet pile, quay wall), stability of cuts and slopes.	
Study Goals	The course is addressed to Applied Earth Science, Road and Railway and Offshore Engineering students who have little or no prior knowledge of soil mechanics and geotechnical engineering, and to students coming from HBO. At the end of the course the student should be faimiliar with basic soil mechanics and foundation engineering, to allow further education at MSc level and application of basic concepts in design.	
Education Method	Lectures, tutorials, self-study	
Literature and Study Materials	Materials - Soil mechanics by A. Verruijt, 2001 - Craig's Soil Mechanics by R.F. Craig (and J. Knappet), 2012 - Lecture notes	
Prerequisites	Basic mechanics, knowledge of the concept of stress and strain and elasticity.	
Assessment	Written examination including: - multiple choice questions - applied questions	

AESB1130	Geology 1: basics	5
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	7/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Parts	The Geology 1 course is composed of three parts dedicated to 1) general knowledge of the system Earth, 2) tools for the 3D geometric representation of geological objects and 3) methods and techniques for the recognition of fundamental minerals and rocks.	
Course Contents	General knowledge of the system Earth, tools for the 3D geometric representation of geological objects and methods and techniques for the recognition of fundamental minerals and rocks. Part 1: the rock cycle, the structure and functioning of the Earth and its outer layer, the lithosphere; horizontal deformations and vertical movements; the climate system; notions of hydrogeology; sedimentary systems from the source to the sink (marine systems). Part 2: focuses on tools to represent the architecture of geologic bodies on maps and how these can be used to infer the geological evolution of a specific region Part 3: This part has both a theoretical and a practical part. Basics of crystallography and mineralogy: Bravais lattices, symmetry elements, crystal classes and crystal systems; crystallographic axes, crystal habit, twins, systematics of mineralogy, crystal structures, physical properties of minerals, macroscopic identification of minerals.	
Study Goals	The goal of the Geology I course is to provide students basic knowledge and skills to understand relevant geological processes and enable them to make geological predictions required by their future careers. Knowledge: Students will be able to: - Describe the first order structure and functioning of the Earth. This includes basic knowledge of i) elements, minerals and rocks, ii) of the internal structure of the Earth with particular attention to the lithosphere and the crust, and iii) of plate tectonics. - Describe the main characteristics of sedimentary, igneous and metamorphic rocks and will have an understanding of how these rocks were formed. - Describe kinematics and basic physics of vertical movements (subsidence creating sedimentary basins and uplift creating relief) and horizontal deformations at lithospheric to thin section scale. They will be able to quantify simple relations between relief and crustal structure. They will be able to extract deformation scenarios from simple geological documents such as geological and seismic sections. - Describe exogene processes and their impact on the sedimentary record. Processes include climate, terrestrial water flow and oceanography. - Describe the main sedimentary environments and their evolution through time. Students will also be able to infer such evolutionary schemes from simple geological records such as stratigraphic columns and use them for simple paleogeographic reconstructions. Skills. Students will be able to: Describe the internal structure of crystals and minerals - Summarize the characteristics of crystal classes and crystal systems - Describe the physical properties of minerals - Analyse the external symmetry of crystals and define the crystal class and crystal system - analyse physical properties of minerals and to identify a selected group of minerals - Interpret geologic maps, geologic sections and other basic documents such as seismic section to infer the 3D architecture of the area/volume of investigation - Use the techniques mentioned above to constrain larger scale processes and make predictions for spatially and temporally unknown parts of the Earth system (mainly Earth upper crust).	
Education Method	The course Geology 1 is a combination of lectures and laboratory work with practicals with maps, physical samples etc. In total there will be 28hrs of lectures, 35hrs of practicals, 4,5hrs of tests and 3hrs for the repetition.	
Literature and Study Materials	The book adopted for the Geology 1 course is Understanding Earth (Grotzinger and Jordan) Handouts of lectures will be available on Blackboard	
Assessment	Tests will be carried out at the end of each component. Test of part 1 will consist of a written exam; tests of parts 2 and 3 will have a written exam and practical exercises. A repetition for each part is offered at the end of the second period.	
Permitted Materials during Tests	To be specified in the lectures before tests.	
Remarks	The Geology 1 course is valid for 5 ECTS which corresponds to 140hrs, that is, 67,5 contact hours and 72,5hrs of self-study. Hereby the self-study hours roughly correspond to the contact hours with a few hours preparation for tests, this differs per student. The contact hours are evenly split among the three components: Part 1: General Geology (G. Bertotti) Part 2: Geological sections and maps (J.C. Blom) Part 3: Basic mineralogy (M.M. van Tooren)	
Contact	Prof. Dr. G. Bertotti G.bertotti@tudelft.nl tel: +31 (0)15 27 86033	
Expected prior Knowledge	none - introductory course	
Academic Skills	understanding and reading English texts; use basic mathematics tools and physical concepts	
Literature & Study Materials	The book adopted for the Geology 1 course is Understanding Earth (Grotzinger and Jordan) Handouts of lectures will be available on Blackboard	
Judgement	A grade will be given for each of the three building blocks. The final grade results from the average of the three tests (equivalent in weight). The grade of part 1 corresponds to that of the written exam. Mark for part 2 will include results from the exam and the assignments. Grade of part 3 results from the theoretical and practical parts, each counting for 50%.	
Permitted Materials during Exam	Coloured pencils, rulers and scales	
Collegerama	No	

CIE4420	Geohydrology 1	4
Responsible Instructor	Dr.ir. M. Bakker	
Contact Hours / Week x/x/x/x	0/0/8/0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	The course consists of seven topics: (1) Principles of groundwater flow, (2) Steady groundwater flow in one and two dimensions, including flow to wells and the method of images, (3) Steady flow in semi-confined systems such as below polders and lakes, (4) Transient groundwater flow including the effect of changes in surface water levels, transient wells, and pumping tests, (5) Finite difference solutions of groundwater flow, (6) Seawater intrusion and variable density flow in coastal aquifers, and (7) Time series analysis.	
Study Goals	Upon successful completion, students will be able to (1) identify the processes that play a major role in groundwater systems, (2) conceptualize a groundwater system, (3) solve geohydrological problems, and (4) estimate the effect of interventions in the groundwater system.	
Education Method	Lectures, in-class problem solving, homework problems, computer assignments.	
Course Relations	Geohydrology I is required for Geohydrology II.	
Books	Recommended textbook: C.R. Fitts. 2012. Groundwater Science. Second Edition. Academic Press.	
Reader	Course notes will be made available through Blackboard.	
Assessment	Written exam. Homework problems.	
Permitted Materials during Tests		
Expected prior Knowledge	Hydrology I, Fluid Mechanics, Differential Equations, Computer Programming in Python	
Academic Skills		
Literature & Study Materials		
Judgement		
Permitted Materials during Exam	Students may bring one sheet of A4 paper with handwritten formulas on both sides to the exam and a regular scientific calculator.	
Collegerama	No	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Convergence Program Choose one out of two

CIE4510	Climate Change: Science & Ethics	4
Responsible Instructor	Prof.dr.ing. R. Klees	
Instructor	Prof.dr.ing. R. Klees	
Instructor	Prof.dr.ir. H.W.J. Russchenberg	
Instructor	Dr.ir. B. Taebi	
Instructor	Dr. M. Vizcaino	
Contact Hours / Week x/x/x/x	0/6/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	

Course Contents

Climate change is one of the most profound and complex issues affecting our society and economy today. Many scientists argue that there are too many variable factors to effectively see the big picture, while other scientists who believe human activity is to blame for global warming are ready to outline specific actions to prevent more damage. Skeptics believe that climate change is part of the natural global progression and that human activity will neither worsen nor improve our situation.

Those who are in favor of a global effort to reverse climate change believe that current climate models are underestimating the magnitude of future warming and argue that the uncertainty surrounding this threat is no excuse for inaction. Skeptics in turn argue that scientists who want to attract attention to themselves, who want to attract great funding to themselves, have found a way to scare the public by making things bigger and more dangerous than they really are. Despite continuing uncertainties about the detailed linkages, extreme weather events are increasingly being attributed to human interference, and greater emphasis is emerging on the need to prevent and to adapt to climatic changes.

The course provides an introduction to the basic physics of the climate system, how climate has changed in the past and how climate will change in the future. The focus in on the energy balance of the climate system and how this balance is affected by greenhouse gases and aerosols; the physical processes in the atmosphere and oceans that shape the climate; the response of the oceans, ice sheets and glaciers to global warming; the evidence for past and present climate change; climate models and model uncertainties; climate predictions.

A second focal point of the course is the broader societal and ethical aspects of climate change. In particular, we will focus on past emissions and responsibilities, implications of global warming on human safety and security, the distribution of burdens and benefits, emission rights, international justice and intergenerational justice.

Syllabus:

Introduction to climate physics
Instrumental records of the Earths climate
Radiative heat transfer
Atmospheric circulation
Clouds, aersols, and climate
The carbon cycle
Forcings and feedbacks in the climate system
Climate change and sea level rise
Climate modeling and predictions

Study Goals

After completing the course, the student

has a basic understanding of climate physics
understands how the climate responds to human activities
knows how future climate is predicted and the role of model uncertainties
is familiar with and understands the scientific discussions related to climate change
can distinguish facts and myths of the climate change debate
is aware of the social and ethical aspects related to climate change.

Education Method

Video lectures (edx course 12.340x Global Warming Science)
In-class question-and-answer and feedback sessions related to the video lectures
In-class lectures to address specific topics not covered by the video lectures
Climate lab

Assessment

Written exam, which accounts for 60% of your grade of the course
Group essay and presentation on a topic related to the societal and ethical aspects related to climate change, which accounts for 40% of your grade of the course

A grade of 60% or higher for the entire course AND a "pass" for the climate lab constitutes a passing grade. Without a "pass" for the climate lab, no mark will be given.

Expected prior Knowledge

BSc diploma

Academic Skills

Critical thinking
Written and verbal communication
Ability to speak and listen
Reading
Teamwork
Conceptual thinking
Interpretation
Moral awareness & sensitivity
Judgemental skills
Debating and discussion

Literature & Study Materials

1. video lectures
2. in-class lectures
3. Kump, Kasting & Cane, The Earth System
4. Farmer & Cook, Climate Change: A modern synthesis
5. IPCC Fifth Assessment Report (AR5), http://www.ipcc.ch/report/ar5/
6. Online material for further reading, e.g.,
US EPA homepage, http://www.epa.gov/climatechange/index.html
Understanding climate change, http://www2.ucar.edu/news/backgrounders/understanding-climate-change-global-warming
NASA global climate change, https://climate.nasa.gov

	Online reports of the US National Academic Press (NAP)
Judgement	60% written exam on climate science 40% group essay on climate ethics, oral presentation, and defense Climate lab (pass/fail); a "pass" is pre-requisite to get a mark for the course
Permitted Materials during Exam	Pocket calculator
Collegerama	No

WM0312CIE	**Philosophy, Technology Assessment and Ethics for CIE**	**4**
Module Manager	Dr.mr.ir. N. Doorn	
Instructor	Dr.mr.ir. N. Doorn	
Instructor	Dr.ir. U. Pesch	
Contact Hours / Week x/x/x/x	0/0/0/2	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Course Contents	Philosophy Module What is science, and what is technology? Brief overview of their history; positions on the influence of science and technology on society; The fact/value distinction; logic and argumentation theory; Methodology: foundations of scientific and technological knowledge; role of scientific explanations. Technology Assessment Module Why does technology fail? Technology Assessment as bridging the gap between society and the engineering community; Introduction to TA-methods and traditional forecasting: extrapolations, experts interview and the 'common sense'-method, scenario's, scenario workshops; Drivers of technological change, the relation between technological change and society Constructive Technology Assessment, participatory technology development; Practice of TA; politics, steering technological innovation of Sustainable Development. Ethics Module Introduction to moral dilemmas in engineering practice; Analysis of moral dilemmas in engineering practice and their backgrounds; professional codes of conduct and conflicting loyalties; legal rights and duties of engineers; Ethics, i.e. the foundation of judgments about good and bad / responsible and irresponsible acts; Introduction to some topics especially relevant for engineering: risks, responsibility and sustainability.	
Study Goals	Philosophy: - is able to recognize the different positions in the debate on the interaction between science, technology and society and to take a well-argued position in this debate; - has insight in the nature of scientific and technological knowledge and can explain the difference between science and technology; - can distinguish between factual and value-laden statements; - can apply elementary knowledge of logic and argumentation theory to simple arguments Technology Assessment: - Ability to recognize patterns of interaction between technological and societal change - Ability to assess the value and limitations of TA-methods and -results - Ability to apply some TA-methods to concrete situations Ethics: - is able to recognize and analyze the ethical aspects and problems of their future professional practice; - is able to explain the different backgrounds to these problems (ethics, law, organizations); - is able to discuss and - if possible - solve ethical dilemmas in their future professional practice on the basis of the ethical material provided.	
Education Method	Virtual learning environment, introductory lecture and small number of question hours. Compulsory: assignment (more information will be provided during the introductory lecture)	
Literature and Study Materials	- Ibo van de Poel and Lambèr Royakkers (2011). Ethics, Technology, and Engineering: An Introduction. Wiley Blackwell, West Sussex (ISBN 978-1-4443-3094-6 (hardcover) / 978-1-4443-3095-3 (paperback). - Reader WM0312CIE: Philosophy, Technology Assessment and Ethics for Civil Engineering (version 2016) - Reader Responsible Innovation(available on blackboard) - Virtual learning environment (blackboard).	
Assessment	In the June exam period, there is a digital (on-campus) exam about the entire course material. There is one resit in the August exam period; there are no other resits during the year. An example of an exam will be available on Blackboard. Students are not allowed to bring any study materials with them during the test (i.e., it is a "closed book exam"). The final course grade is based on: the grade for the exam (80 %). the grade for the TA assignment (20%).	
Category	MSc niveau	

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Elective Courses

AES1050	GSE Student competition course	5
Responsible Instructor	Dr. G. Bertotti	
Contact Hours / Week x/x/x/x	na	
Education Period	1 2 3 4	
Start Education	1 2 3 4 5	
Exam Period	none	
Course Language	English	
Course Contents	The GSE Student Competition Course is a platform offered to encourage and stimulate participation of teams of students to high level scientific competitions which can be within TUDelft, national or international. The GSE Student Competition Course provides a workflow which participants are required to follow in order to be eligible for the 5EC associated with the course. The workflow is as follows 1) the team intending to participate to the competition writes a motivation letter which includes, among others, i) a description of the competition ii) the expected added value for the educational growth of the students iii) a motivation statement from all members of the team and iv) the name of a technical advisor in charge of the daily supervision of the participating team. If costs are involved in the participation, the letter should also include information on how these will be covered. The letter is evaluated by the Course responsible and two other GSE staff members (Prof. Dr. B. Rossen and Dr. G. Drijkoningen) and participation is approved/rejected. The way the participation will be graded is also discussed and agreed upon at this stage At the end of the competition, the participating team will submit a short report describing the activities and experiences made during the competition itself. The technical advisor proposes a grade which is then discussed with the three staff members responsible of the Course.	
Study Goals	The goal of the GSE Student Competition Course is to improve technical knowledge and strengthen the group working skills of the participating team. Upon succesful completion of the competition, the participating students will have learned a variety of technical tools (depending on the type of competition) and will be able to work in a small team under time and competition pressure to present their results in a competitive arena in front of an external jury	
Education Method	Learning through competition	
Assessment	The pass/no pass boundary and the grading will depend on the type of competition and will be discussed prior to the start of the competition itself	
Expected prior Knowledge	Expected prior knowledge depends very much on the competition. Because only scientifically challenging competitions will be considered, only MSc students will be allowed with a strong background. Intrinsic in the idea of a competitive team, the participants will have different backgrounds (geophysics, engineering, geology etc)	
Academic Skills	Key to success and, therefore to earning the 5EC is the ability to form a real team during the competition. The necessary first step of this process is the ability of putting together a winning team composed of experts also able to work together. The value of strong cooperation will only increase during the competition	
Literature & Study Materials	will depend on the specific compeititons	
Judgement	The technical advisor (if present) will propose a grade to the staff members responsible of the course; these will have the final decision.	
Permitted Materials during Exam	no exam in the classical sense of the term is foreseen the assessment will be based on the report presented by the participating team and on insights provided by the technical advisor	
Collegerama	No	

AES1370-12	Non-Thermal Enhanced and Improved Oil Recovery	3
Responsible Instructor	R. Farajzadeh	
Contact Hours / Week x/x/x/x	5 days	
Education Period	4	
Start Education	4	
Exam Period	Different, to be announced	
Course Language	English	
Expected prior knowledge	AES1310-10, 1320 and 1340 (Rock Fluid Physics, Modelling of fluid flow in porous media and Reservoir Engineering).	
Course Contents	This course provides a survey of analytical models for EOR processes; a brief discussion of numerical simulation of EOR; waterflooding and enhanced waterflooding; miscible and immiscible gas EOR; and chemical EOR. The course covers methods of recovery for target reservoirs distinct from those in AES1460, Heavy Oil.	
Study Goals	Students will learn simple analytical tools for modeling a variety of EOR processes, and learn about the specific processes of enhanced waterflooding, miscible and immiscible gas EOR; and chemical EOR.	
Education Method	Excersises will be handed out and collected on each of the five days.	
Assessment	Course grade will be the average of the daily score from the exercises.	

AES1460	Heavy Oil	2
Responsible Instructor	Prof.ir. C.P.J.W. van Kruijsdijk	
Contact Hours / Week x/x/x/x		
Education Period	3	
Start Education	3	
Exam Period	Different, to be announced	
Course Language	English	
Course Contents	With the conventional oil and gas reserves declining, the industry is looking at unconventional resources to fill the upcoming production gap. Unconventional resources comprise of tight gas, shale gas and gas hydrates as well as shale oil and (extra) heavy oil. This course will focus on the (extra) heavy oil resources such as the extensive deposits in Canada and Venezuela.	
Study Goals	To understand the nature of heavy oil and the methods of heavy-oil recovery; to research one particular method in detail.	
Education Method	The course will consist of 4 sets of lectures plus an independent research paper to be researched and written by the student.	
Assessment	Instead of a written exam, each participant will be required to write a critical assessment of a heavy oil recovery method of choice.	

AES1470	Geothermics	2
Responsible Instructor	Prof.dr. D.F. Bruhn	
Contact Hours / Week x/x/x/x	0/0/0/4	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Required for	MSc	
Expected prior knowledge	Technical or Geoscience and Engineering background	
Course Contents	Scope: Due to the growing interest for sustainable energy production, CTG offers an introductory course on geothermal energy. The course covers the following subjects: - Sources and renewability, - Geology of geothermal reservoirs, - Geothermal energy production technologies, - Physics of heat and mass transfer in the porous rock, - Geochemical aspects, - Exergy aspects, - Geothermal reservoir management, - Current state of development. During the course, the participants are familiarized with: The environmental and technological issues of geothermal energy exploitation and the effect of physical and chemical factors on the geothermal reservoir porosity and permeability. A groupwork is the final part of the course: Participants choose a topic and write a report which will be discussed after circa six or seven lectures of 2 to 4 hours.	
Study Goals	Getting acquainted with the (geo-)technical aspects of the development of a geothermal infra-structure.	
Education Method	THIS COURSE IS MERGED WITH THE PRACTICALS AND LECTURES FOR: 1. THE RESEARCH SCHOOL GEOTHERMAL LECTURES AND PRACTICALS, AND, 2. THE SUSTAINABLE ENERGY AND TECHNOLOGY GEOTHERMAL COURSE (Lectures combined with practicals).	
Literature and Study Materials	Blackboard.	
Practical Guide	Blackboard.	
Assessment	Group assignment and report.	
Exam Hours	None: one afternoon presentations and report discussion.	
Enrolment / Application	Blackboard or the secretary of the Department of Geoscience and Engineering	

AES1490	**Advanced Reservoir Simulation**	2

Responsible Instructor	Prof.dr.ir. J.D. Jansen
Contact Hours / Week x/x/x/x	0/2/0/0 + 7 pr
Education Period	2
Start Education	2
Exam Period	Different, to be announced
Course Language	English
Expected prior knowledge	To successfully complete this course you are supposed to start with a basic knowledge of differential equations, linear algebra and numerical analysis. For Applied Earth Sciences students it is preferred that you have successfully completed the courses AES1340/1350 (Applied reservoir engineering and simulation, Parts 1 & 2). For students without a background in reservoir engineering it is possible to attend but you will be required to do some additional reading to familiarize yourself with the subject matter.
Parts	Elements of systems and control theory as applied to reservoir simulation (e.g. recovery optimization, computer-assisted history matching, model reduction). Multi-scale reservoir simulation. Compositional reservoir simulation.
Course Contents	This elective course covers advanced topics in reservoir simulation and optimization. The former addresses the main challenges in the state-of-the-art simulators for multi-phase flow in realistic oil reservoirs. Topics of interests include multi-scale and iterative multi-scale methods, but depending on the need of students it will include upscaling, Adaptive-Implicit-Methods, Automatic Differentiation, and CPR-based solvers for fully implicit systems. The application of systems and control theory to the flow of fluids in oil or gas reservoirs will be covered in the second part of the course. Moreover, compositional simulation and geo-mechanics may form part of the material. The course format is dynamically adjusted during the course period depending on the needs, wishes and capacities of the students enrolled. The course material exists of a textbook, journal and conference papers, and printed lecture notes.
Study Goals	Explain challenges related to flow and transport equations for realistic oil reservoirs. Develop a 1D multiscale flow simulator, and analyze its performance. Develop a 1D compositional non-isothermal simulator and perform the numerical convergence study for condensing and vaporizing gas drive. Provide an introduction to the use of system analysis techniques for reservoir management. Provide the background knowledge required to perform MSc thesis work in the area of closed-loop reservoir management, also known as smart fields.
Education Method	Lectures, discussions, reading exercises, Matlab exercises
Literature and Study Materials	J.D.Jansen: "A systems description of flow through porous media", Springer, 2013 Electronically available for TU Delft affiliates via the TU Delft Library J.D.Jansen: "Gradient-based optimization of flow through porous media". Lecture notes via Blackboard H. Hajibeygi: Iterative Multiscale Finite Volume Method for Multiphase flow in Porous Media with Complex Physics, ETH Zurich, 2011 (Available for free to the public: http://dx.doi.org/10.3929/ethz-a-006696714). D.V.Voskov Thermal-compositional simulation, lecture notes via BlackBoard
Assessment	Oral exam or delivery of a project (upon prior agreement with individual students)
Special Information	This course is jointly taught by Dr. H. Hajibeygi (Multiscale simulation), Dr. D.Voskov (Compositional simulation) and Prof. J.D. Jansen (Reservoir Systems and Control)
Remarks	This elective course is primarily intended for 2nd-year MSc students who are performing MSc thesis work in the area of reservoir simulation and 'smart fields'. However, anyone interested in advanced reservoir simulation topics, especially if he/she is a PhD student working on reservoir simulation or optimization (smart fields), is welcome to join. Over the past years, the course was attended by several students and researchers from Applied Earth Sciences (CiTG), Mathematics (EWI) and Systems & Control (3me).
Expected prior Knowledge	To successfully complete this course you are supposed to start with a basic knowledge of differential equations, linear algebra and numerical analysis. For Applied Earth Sciences students it is preferred that you have successfully completed the courses AES1340/1350 (Applied reservoir engineering and simulation, Parts 1 & 2). For students without a background in reservoir engineering it is possible to attend but you will be required to do some additional reading to familiarize yourself with the subject matter.
Academic Skills	Problem solving; analysis
Literature & Study Materials	J.D.Jansen: "A systems description of flow through porous media", Springer, 2013 Electronically available for TU Delft affiliates via the TU Delft Library J.D.Jansen: "Gradient-based optimization of flow through porous media". Lecture notes via Blackboard H. Hajibeygi: Iterative Multiscale Finite Volume Method for Multiphase flow in Porous Media with Complex Physics, ETH Zurich, 2011 (Available for free to the public: http://dx.doi.org/10.3929/ethz-a-006696714). D.V.Voskov Thermal-compositional simulation, lecture notes via BlackBoard
Judgement	Oral exam
Permitted Materials during Exam	To be discussed with relevant lecturer prior to exam.
Collegerama	No

CIE4510	Climate Change: Science & Ethics	4
Responsible Instructor	Prof.dr.ing. R. Klees	
Instructor	Prof.dr.ing. R. Klees	
Instructor	Prof.dr.ir. H.W.J. Russchenberg	
Instructor	Dr.ir. B. Taebi	
Instructor	Dr. M. Vizcaino	
Contact Hours / Week x/x/x/x	0/6/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	

Course Contents

Climate change is one of the most profound and complex issues affecting our society and economy today. Many scientists argue that there are too many variable factors to effectively see the big picture, while other scientists who believe human activity is to blame for global warming are ready to outline specific actions to prevent more damage. Skeptics believe that climate change is part of the natural global progression and that human activity will neither worsen nor improve our situation.

Those who are in favor of a global effort to reverse climate change believe that current climate models are underestimating the magnitude of future warming and argue that the uncertainty surrounding this threat is no excuse for inaction. Skeptics in turn argue that scientists who want to attract attention to themselves, who want to attract great funding to themselves, have found a way to scare the public by making things bigger and more dangerous than they really are. Despite continuing uncertainties about the detailed linkages, extreme weather events are increasingly being attributed to human interference, and greater emphasis is emerging on the need to prevent and to adapt to climatic changes.

The course provides an introduction to the basic physics of the climate system, how climate has changed in the past and how climate will change in the future. The focus in on the energy balance of the climate system and how this balance is affected by greenhouse gases and aerosols; the physical processes in the atmosphere and oceans that shape the climate; the response of the oceans, ice sheets and glaciers to global warming; the evidence for past and present climate change; climate models and model uncertainties; climate predictions.

A second focal point of the course is the broader societal and ethical aspects of climate change. In particular, we will focus on past emissions and responsibilities, implications of global warming on human safety and security, the distribution of burdens and benefits, emission rights, international justice and intergenerational justice.

Syllabus:

Introduction to climate physics
Instrumental records of the Earths climate
Radiative heat transfer
Atmospheric circulation
Clouds, aersols, and climate
The carbon cycle
Forcings and feedbacks in the climate system
Climate change and sea level rise
Climate modeling and predictions

Study Goals

After completing the course, the student

has a basic understanding of climate physics
understands how the climate responds to human activities
knows how future climate is predicted and the role of model uncertainties
is familiar with and understands the scientific discussions related to climate change
can distinguish facts and myths of the climate change debate
is aware of the social and ethical aspects related to climate change.

Education Method

Video lectures (edx course 12.340x Global Warming Science)
In-class question-and-answer and feedback sessions related to the video lectures
In-class lectures to address specific topics not covered by the video lectures
Climate lab

Assessment

Written exam, which accounts for 60% of your grade of the course
Group essay and presentation on a topic related to the societal and ethical aspects related to climate change, which accounts for 40% of your grade of the course

A grade of 60% or higher for the entire course AND a "pass" for the climate lab constitutes a passing grade. Without a "pass" for the climate lab, no mark will be given.

Expected prior Knowledge

BSc diploma

Academic Skills

Critical thinking
Written and verbal communication
Ability to speak and listen
Reading
Teamwork
Conceptual thinking
Interpretation
Moral awareness & sensitivity
Judgemental skills
Debating and discussion

Literature & Study Materials

1. video lectures
2. in-class lectures
3. Kump, Kasting & Cane, The Earth System
4. Farmer & Cook, Climate Change: A modern synthesis
5. IPCC Fifth Assessment Report (AR5), http://www.ipcc.ch/report/ar5/
6. Online material for further reading, e.g.,
US EPA homepage, http://www.epa.gov/climatechange/index.html
Understanding climate change, http://www2.ucar.edu/news/backgrounders/understanding-climate-change-global-warming
NASA global climate change, https://climate.nasa.gov

	Online reports of the US National Academic Press (NAP)
Judgement	60% written exam on climate science 40% group essay on climate ethics, oral presentation, and defense Climate lab (pass/fail); a "pass" is pre-requisite to get a mark for the course
Permitted Materials during Exam	Pocket calculator
Collegerama	No

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Annotations (Information see the Implementation Regulations 2016-2017)

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Annotation Technology in Sustainable Development

Year	**2016/2017**
Organization	**Civil Engineering and Geosciences**
Education	**Master Applied Earth Sciences**

AES Annotation Entrepreneurship

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