Syllabus

MSc Chemical Engineering (M-CHE)

CPE Track

2015 / 2016

	Chemical & Process Engineering			
	Block 1A	Block 1B	Block 2A	Block 2B
Core modules	**Chemical Reaction Engineering** (5 EC, Brilman)		**Multiphase Reaction Technology** (5 EC, Kersten)	
	Process Intensification Principles (5 EC, Rivas)	**Advanced Molecular Separations** (5 EC, de Vos)	**Process plant design (and TD & flowsheeting)** (15 EC, van der Ham)	
Electives (scheduled)	**Multi-component mass transport** (5 EC, Benes)		**Process Equipment Design** (5 EC, van der Meer)	**Catalysis in the Process Industry** (5 EC, Seshan)
	Membranes for Gas Separation (5 EC, Nijmeijer/Bouwmeester ea)			
	Membrane Process Plant Design (5 EC, van der Ham)	**Intro to Computat. Fluid Dynamics** (5 EC, Lammertink)		
	Colloids and Interfaces (5 EC, Lammertink)	**Catalysis for Sustainable Techns.** (5 EC, Seshan)		
	Transport Phenomena (5 EC, van der Meer)	**Cost Management and Engineering** (5 EC, Pol/Joosten)		
Electives (n.s.)	**Theory of Phase Equilibria** (5 EC, van der Hoef)			
	Chemical Product Development (5 EC, Nijmeijer)			
	Contract Research (5 EC, Betlem)			
	Capita selecta (5 EC)			

	Chemical & Process Engineering (M2)			
	Block 1A	Block 1B	Block 2A	Block 2B
Core modules	**Internship** (20 EC, Folkers)			
	Final project MSc (45 EC)			

Block structure

The MSc Chemical Engineering program is a 2-year program (120 EC). As all other BSc and MSc programs at the University of Twente the year starts in September and ends at the beginning of July. Each year is divided into 4 blocks, which are referred to as 1A, 1B, 2A and 2B.

Block		Weeks	Dates
Block 1A	Instruction weeks	36 - 43	Aug 31 - Oct 23
	Exam weeks	44, 45	Oct 26 - Nov 6
Block 1B	Instruction weeks	46 - 51, 1, 2	Nov 9 - Dec 18, Jan 4 - Jan 15
	Exam weeks	3, 4	Jan 18 - Jan 29
Block 2A	Instruction weeks	5 - 8, 10 - 13	Febr 1 - Febr 26, March 7- April 1
	Exam weeks	14, 15	April 4 - April 15
Block 2B	Instruction weeks	16 - 24	April 18 - June 17
	Exam weeks	25, 26	June 20 - July 1

Core modules

193715020		Chemical Reaction Engineering
5 ec	1A+1B	
Lecturer(s)		dr.ir. D.W.F. Brilman
Objective		The main goal of the course 'Chemical Reaction Engineering' is to present a general introduction in the physical and chemical aspects of chemical reaction engineering. Following an introduction on ideal (model-) reactors, more complex systems will be discussed. Non-ideal behavior (residence time distribution), multiple reactions (product selectivity), heat effects and the effects of mass transfer in multiphase homogeneous and heterogeneous reaction systems will be discussed in detail. Setting up and solving mass and energy balances plays a major role in the design and operation of chemical reactors, and will play a major role in the course. At the end of the course one will be able to describe single en multiphase chemical reactors in terms of model reactors and determine the reactant conversion and selectivity, accounting for the effects of residence time distribution, mass transfer, reaction kinetics, equilibria and heat effects.
Prior knowledge		Desired: Introduction to Physical Transport Phenomena, Physical Transport Phenomena, Kinetics and Catalysis
Course material		Reader (required) “Chemical Reaction Engineering” Levenspiel (recommended) “Chemical Reactor Design”, Westerterp, Van Swaaij and Beenackers (recommended)

2015XXXXX		Process Intensification Principles
5 ec	1A	
Lecturer(s)		D. Fernandez Rivas
Content description		This is a very interactive course in which the students will have an active role together with the Instructor and invited scientists. The emerging field of Process Intensification provides a set of tools and routes that can aid the industry in our current world to meet the demands imposed by global competition, government oversight and social accountability, with vast applications in, among others, mechanical and chemical engineering. 1. Professionals with new ways of thinking as well as problem-solving skills are required by companies and universities, in order to tackle the wide range of societal challenges in general, and current limitations in chemical engineering in particular. It is crucial for a young professional of the future to have knowledge on actual chemical processes involving liquid, gas, and multiphasic flows, for both small- and large-scale techniques. These professionals will be able to re-design existing plants or processes, or prepare “greenfield” solutions keeping the safety and ecological constrains in mind. All these elements are needed to convince management teams of

	the relevance to invest in these new solutions.

201300049		**Advanced Molecular Separations**
5 ec	**1B**	
Lecturer(s)		Dr.ir. W.M. de Vos, dr.ir. B. Schuur
Objective		At the end of the course the students should: 1. Be able to list relevant industrial (advanced) separations, including those applied in the energy, bulk chemical, fine chemical, and pharmaceutical industries. Understand their working principles, molecular basis of separation and role within larger processes. 2. Be able to make a motivated decision for a separation technology based on the molecular properties of the molecules to be separated. 3. Be able to analyze a separation technology related case, asses the technical feasibility of different separation technologies, and develop a separation process. 4. For fluid separations and membrane based separations, be able to calculate mass transfer and thermodynamic properties within a separation process. Be able to design a functional extractant, adsorbant or membrane for a given molecular separation.
Content description		In Advanced Molecular Separations, separation technology is discussed starting from molecular properties up to full scale processes. The focus is on choosing a separation technology for given molecular properties, and the subsequent molecular design of more advanced separation technologies. For two separation technologies, fluid separations and membrane technology, the molecular design and separation process are treated in much greater detail, including a discussion on useful models to describe thermodynamics and mass transfer. The course will include two tests, one on fluid separations and one on barrier separations, but will also include two assignments on selecting the right separation technology for a given separation case
Course material		Reader and Henley, Seader and Roper: “Separation Process Principles, Interntl Student Version, Third edition”. ISBN: 9780470646113 (required)

193720020		**Multiphase Reaction Technology**
5 ec	**2A**	
Lecturer(s)		Prof.dr. S.R.A. Kersten
Objective		Aim of this course is to acquire insight and experience in the selection and use of reactors/contact equipment in the process technology.
Content description		In lecture and exercise sessions different types of equipment will be discussed, such as fluid beds, packed bed reactors, risers, bubble columns, dish columns, slurry reactors, stir tankreactors and trickle bed reactors. This course is finalized with a final assignment.

Prior knowledge	Required: Introduction Physical Transport Phenomena (191370091) Physical Transport Phenomena (191370201) Chemical Reaction Engineering (193715020)
Course material	Reader

201300045		**Process Plant Design**
15 ec	**2A**	
Lecturer(s)		Dr.ir. A.G.J. van der Ham
Objective		The objective of this process design course is to transfer a systematic method for process design. The method taught for the analysis and the design of chemical processes uses methods for “conceptual” design and “process systems design” which have been developed in the last twenty years. The lectures use fundamentals of this approach and translate them into applications
Content description		The basic disciplines taught in the undergraduate curriculum will be recapped, integrated and expanded. Many aspects of doing an industrial project design will be practiced. Such as: - Systematic process design starting from "process overall" to conceptual design, Index Flowsheet and Process Flow Diagram (PFD) level; - Phasing and project organization, how to handle alternatives selection and evaluation of processes and technologies; - Systematic literature search; - Functional analysis of existing processes and how to create concepts for improved designs; - Introduction in process simulation tools, for instance software like UniSim; - Simulation of the investigated process in a flowsheeter (for instance UniSim); - Application of HTRI for heat exchanger design; - Basics of heat exchanger selection and heat integration (pinch technology); - Equipment selection and design (down to basic dimensions needed for costing); - Detailed design of the reactor (in collaboration with MRT); - Basics and application of process control; - Basics and application of P&ID's; - Fundamentals and application of process safety; - Basics of process economics for economic evaluation; - Generation and evaluation of process alternatives on technical and economic feasibility; - Perspectives for future developments will be discussed; - If possible, the ACHEMA fair will be visited (2015). About 10 of the 15 EC is spent on the process design assignment, which is carried out in teams of four students in parallel to lectures and workshops. Each team will design a different process starting with a limited amount of information and submit their results in a final report, presentation (at the

	owner!) and an abstract for a conference (general NPS). The subjects are for each team and also each year different. Subjects are from industry and different research groups within the department. In general they are related to recent developments. The final mark is based on the quality of the tests, the progress meetings, final report, presentations and finally the participation in the lectures and workshops.
Prior knowledge	Only master students are allowed to participate. They should have finished CRE and Advanced Molecular Separation (or being in the process of finalizing these courses). It is also strongly advised to do the master course MRT in parallel.
Course material	“Chemical Engineering Design”, 2nd edition by G. Towler and R. Sinnot - ISBN: 978-0-08-096659-5 (recommended) “Product and Process Design Principles: Synthesis, analysis and Evaluation”, 3rd edition by W.D. Seider, J.D. Seader, D.R. Lewin and S. Widagdo. ISBN: 978-0-0470-41441-5 (recommended)

193799009		**Internship**
20 ec	**-**	
Contact person		Ing. A. Folkers
Aims		- to perform an assignment applying the principles and methods of Chemical Engineering in a practical situation, - to gain insights into the functioning of a professional organization, - to obtain specific competencies necessary for working in a professional institute or company, - to gain insights about the field of Chemical Engineering
Content description		The internship is an integral part of the Master of Science of Chemical Engineering programme. (Master's students with a preceding HBO-bachelor diploma have an adapted programme without an internship period. If these students wish, the may ask for an internship period as well as an additional course). The internship has to be scheduled in the first or the second year of the master, has to cover at least 13 weeks (20EC) and should be conducted preferably at a company but can also be conducted at a research institute or an university. Students may start the assignment after completing their bachelor Degree. The TNW master programmes offer several opportunities for adding an international dimension to the knowledge and the practical experience of a student. Therefore the internship may be carried out in the Netherlands or abroad. We believe a stay abroad is a valuable component of the study; therefore stimulating measures like the Twente Mobility Fund (TMF-fund)

	and the Erasmus-scholarship are available. The internship is coordinated by the internship coordinator. Orientation for internship has to start half a year prior to national internship and a year prior to international internship. This time is required for actual arrangements of the internship, such as getting an accommodation, visa and all formalities. Application for the internship has to be submitted to the Student Mobility System http://webapps.utwente.nl/srs/en/srsservlet All relevant information, internship posts and all required forms for the internship can be found on the Blackboard organization 'Internships TNW'. International students should also contact Rik Akse during the arrangement of the internship. (h.a.akse@utwente.nl)
More information	Blackboard Organizations: Internship TNW http://www.tnw.utwente.nl/che/education/internship

201300054 / 55		**Master Thesis**
25 / 20 ec	**-**	
Contact person		dr.ir. B.H.L. Betlem
Description		The individual master assignment is the completion of the master's programme. The main objective of the assignment is that the student learns and proves that (s)he is able to define, perform, complete and reflect a research project at a large degree of independence. The assignment is performed in one of the Chemical Engineering research chairs of the faculty of Science and Technology of the UT under the supervision of a mentor and the responsibility of a Master's Assignment Committee. Conditionally, the assignment can be done (partially) at another external UT-group or an external institute or organization.
Content description		The student has to perform a substantial research or design project that meets scientific criteria. The level of profundity and complexity is defined by the chairman of the MSc.-assignment committee. The student completes the assignment with a written report (the MSc.-thesis) and an oral public presentation.
Assessment		The MSc. project assignment will be assessed with two marks. The first mark covers the quality of the research performance, whereas the second mark covers the other three mentioned objectives, concerning the reporting and general aspects of the research
Codes		201300054 (25 ec): Master Thesis Scientific and Research Aspects (SRA)

	201300055 (20 ec): Master Thesis Reporting and General Aspects (RGA)

Elective modules

xxxxxxxxx 5 ec | -	Capita Selecta (CPE track)
Description	All research groups offer 5 EC Capita Selecta (C.S.) modules, that you can take as an elective in your MSc program. For detailed information on these, please contact the group leader for more information on the format and content. Underneath is the list of available C.S. courses (with contact persons)
Available courses	**C.S. Catalytic Processes and Materials** (193765000) Prof.dr.ir. L. Lefferts, prof.dr. K. Seshan **C.S. Inorganic Membranes** (193737000) Dr.ir. N.E. Benes, prof.dr. H.J.M. Bouwmeester, prof.dr.ir. A. Nijmeijer, prof.dr. A.J.A. Winnubst **C.S. Membrane Technology** (193735000) Dr.ir. A.J.B. Kemperman, prof.dr.ir. D.C. Nijmeijer, dr.ir. W.M. de Vos **C.S. Mesoscale Chemical Systems** (193780000) Prof.dr. J.G.E. Gardeniers **C.S. Photocatalytic Systems** (201000308) Prof.dr.ir. R.G.H. Lammertink, prof.dr. G. Mul **C.S. Soft Matter, Fluidics and Interfaces** (201000218) Prof.dr.ir. R.G.H. Lammertink **C.S. Sustainable Process Technology** (201200240) Dr.ir. D.W.F. Brilman, dr.ir. A.G.J. van der Ham, prof.dr. S.R.A. Kersten, dr.ir. G. van Rossum, dr.ir. B. Schuur

193765020 5 ec | 1B	Catalysis for Sustainable Technologies
Lecturer(s)	Prof.dr. K. Seshan
Objective	Understanding the key aspects environmentally friendly catalytic process using specific examples relevant to daily life.
Content description	Introduction. Legislation, specific environmental problems and solutions. Course description: The central theme of the course is the use of catalysis to solve current environmental problems. Legislation regarding environmental

	pollution is getting more stringent every day. Catalysis, by minimizing pollution, provides two ways to improve quality of our environment. These are:1: development of alternative cleaner / greener processes 2: cleaning up emissions from currant processes. In this course, the role of catalysis in both these situations will be discussed especially with the use of examples that cause environmental pollution. For the purpose of evaluation students are required to make a literature study on the topic assigned to them, make a report and present a colloquium.
Prior knowledge	Required: Kinetics and Catalysis
Course material	Lecture notes, presentation sheets

193765030		**Catalysis in the Process Industry**
5 ec	**2B**	
Lecturer(s)		Prof.dr. K. Seshan, prof.dr.ir. L. Lefferts
Objective		To understand factors involved in applying catalysis under industrial conditions.
Content description		Almost all the commercial petroleum/petrochemical processes for the generation of fuels and chemicals involve the use of a catalyst. Aspects of catalysis that are critical for application in such industrial processes will be discussed in this course. Typical examples of catalytic processes such as cracking, reforming, hydro-treating, alkylation and chemical processes as epoxidation, ammonia synthesis, oxy-chlorination will be taken up. Students are required to carry out a literature study on a topic provided and present the results in a colloquium and a report. Lectures will also include presentation by experts from industry with specific attention to the role of catalysis in the chemicals and fuels production.
Prior knowledge		Required: Kinetics and Catalysis
Course material		Lecture notes, presentation sheets, reading material

193735030		**Chemical product development**
5 ec	**-**	
Lecturer(s)		Prof.dr.ir. D.C. Nijmeijer, prof.dr.ir. R.G.H. Lammertink
Content description		The course covers the process from product idea to product or prototype. As such, the students proceed through the techniques used in designing and developing. Chemical engineers are often working in the development of new products where chemistry is often only one of the disciplines. Development is therefore mostly done in interdisciplinary teams. Understanding of costs, marketing and selling are therefore also important. The course is supported by lectures following the book of Hans Wesselingh et al. "Design and Develop". The main activities are carried out in small teams based on a product needs analysis.
Note		This course integrates a lot of the material you have been offered during the

	MSc and therefore is best followed in the end phase of your MSc.
Course material	Design and Develop, by J.A. Wesselingh, S. Zinck Kiil and M.E. Vigild
Assessment	Assignment, report

193735060		**Colloids and Interfaces**
5 ec	**1A**	
Lecturer(s)		Prof.dr.ir. R.G.H. Lammertink
Objective		Learning objectives of this course include: - Gain insight in important interfacial aspects including interfacial energy and surface potential. - Be able to explain and describe different interfacial phenomena (wetting, adsorption, colloidal stability). - Critically evaluate scientific literature on interfacial phenomena.
Content description		Description of interfaces and surfaces. All kinds of interfaces between different phases (gas, liquid, solid) are treated. Thermodynamic descriptions of these interfaces and adsorption onto them are deduced. Several techniques for characterizing interfaces are discussed. During contact hours, the contents of the book will be presented and discussed. For each topic, a case assignment will be offered. Learning objectives of this course include: Gain insight in important interfacial aspects. Be able to explain and describe different interfacial phenomena (wetting, adsorption, colloidal stability). Critically evaluate scientific literature on interfacial phenomena.
Course material		Interfacial Science An Introduction, G.T. Barnes and I.R. Gentle (required)

193799700		**Contract research (for study trip)**
5.0 ec	**-**	
Contact person		Dr.ir. B.H.L. Betlem
Objective		The objective is to conduct a some research commissioned by an internal or external client. The project must be performed to the satisfaction of both the client and the supervisor. Both of them will evaluate the project and report.
Content description		This Contract Research Assignment is conducted by groups of 2 students and is for the financial support of the international study tour. Projects are coming from internal and external customers. The assignment is coached by a staff member selected on the basis of the subject of the assignment. He/she coaches and helps the students but also grades the final result which is almost always a report for the customer.

201400244		**Cost Management and Engineering**
5 ec	**1B**	
Lecturer(s)		B.G.F. Pol, dr. R.A.M.G. Joosten

Objective	After successfully completing the course, students will - understand the basic theoretical concepts in Cost Management Engineering like cash flows, cost estimation and project input / output valuation techniques, Discounted Cash Flow analysis methods, cost of capital / choice of discount rate; - understand the basic problems and modeling techniques regarding uncertainty in long-horizon investment decisions or projects, and to understand and to cope fruitfully with informational challenges connected to this uncertainty; - be able to apply and integrate these concepts and techniques to perform basic economic evaluations of private sector and public sector projects; - have insight in several important differences in private and public sector projects and resulting differences in approach for the economic evaluation of private and the public sector projects; -have insight in important differences in the quality of financial data and be able to weigh their importance critically; - be aware of multi-attribute analysis as an alternative approach evaluation of projects and be able to use this method for (simplified) project evaluation; - be able to comment critically on the theoretical and practical validity of recommendations by third parties regarding investment decisions and surrounding issues as discussed; - be able to investigate simple applications of approaches taught independently and report in writing and in oral presentations their findings.
Content description	The course objective is to provide engineering students with the theoretical understanding and practical approaches as well as the tools and techniques for the economic and financial evaluation of stand-alone but also competing design solutions for processes, products, construction projects, services and the practical application of the approaches in more complex settings. Engineers must be able to model the economic impacts of their recommendations during the life cycle. The course will focus on monetary quantification, using different system boundaries and perspectives. Students are challenged to go out and gather information on real-life applications of cost management and engineering techniques.
Prior knowledge	It is obligatory to have completed one of the following courses: ST + international MSc - 373500 Membrane Technology, BME - 373504 Biomedical Membrane Applications 373500 C.S. Membrane Technology
Course material	“Engineering Economy”, WG Sullivan, EM Wicks, JT Luxhoj, Pearson Prentice Hall, ISBN 978-0133439274. (required)

193720040		**Introduction to Computational Fluid Dynamics**
5 ec	**1B**	
Lecturer(s)		Prof.dr.ir. R.G.H. Lammertink
Content		The course introduction to Computational Fluid Dynamics (CFD) focuses on

description	how fluid dynamics problems can be solved numerically. The course contains the full range from fundamental numerical methods to commercial CFD software. Initially, Matlab based routines will be used for discretized problems related to fluid flow. Subsequently, more integrated problems, containing momentum, mass and energy transport will be studied. Through practice sessions the student learns to implement flow problems in CFD software. The knowledge and skills of the student are tested through assignments / cases that will be performed in small groups. Towards the end of the course, a final assignment will be based on an experimental paper for which the numerical simulations need to be performed. The groups will present this in a poster session.
Prior knowledge	Required: Introduction to Physical Transport Phenomena (191370091); Physical Transport Phenomena (191370201)
Course material	Reader iCFD, R.G.H. Lammertink

201200118		**Membrane Process Plant Design**
5 ec	**1A**	
Lecturer(s)		Dr.ir. A.G.J. van der Ham
Objective		Training in systematic design and evaluation in technical and economic terms of a chemical process on industrial scale in which membranes take part..
Content description		Design and evaluation of an industrial scale (membrane) process plant based on a limited amount of information. The method taught for the analysis and design of chemical processes uses methods for 'conceptual design' and 'process systems design' which have been developed in the last twenty years. The lectures use fundamentals of this approach and translate them into applications in this case with special focus on membrane processes. Course content: - systematic process design - process simulation - process equipment design - process economics - technical and economical evaluation
Note		This course is for students Erasmus Mundus 3E Membrane Engineering
Course material		Lecture notes "Product and Process design Principles, synthesis, analysis and Evaluation". W.D. Seider, J.D. Seader, D.R. Lewin and S. Widagdo (recommended). "Chemical Engineering Design, Principles, Practice and Economics of Plant and Process Design", G. Tower & R.K. Sinnott., 2nd edition ISBN: 978-0-08-096659-5 (recommended).
Assessment		Group assignment

201200117	**Membranes for Gas Separation**

5 ec	1A	
Lecturer(s)		Prof.dr. H.J.M. Bouwmeester, prof.dr.ir. D.C. Nijmeijer
Objective		Understanding of basic principles of gas separation and gas transport in membranes.
Content description		1. Introduction, basic principles and theory 2. Polymer membranes 3. Metallic membranes 4. Carbon, zeolite and micro-porous (sol-gel derived) ceramic membranes 5. Mixed conducting oxide membranes 6. Competitive technologies for gas separation and treatment (cryogenic distillation, pressure swing adsorption, absorption methods etc.)
Instructional modes		Lectures and practicals
Course material		Lecture notes, slides, literature (will be provided through BB) "Materials Science of Membranes", Y. Yampolskii, I. Pinnau, B.D. Freeman, John Wiley & Sons, Ltd. 2006 (recommended, as background information) "Membrane Technology and Applications", R.W. Baker, John Wiley and Sons Ltd., 2004. (recommended, as background information)

201300050		**Multi-component Mass Transport**
5 ec	**1A**	
Lecturer(s)		Dr.ir. N.E. Benes
Objective		- Describe a number of limitations of the law of Fick, and mention physical processes for which these have implications; - Explain the concept of driving forces for mass transport by diffusion, and list 4 examples of driving forces; - Explain the concept of friction between molecules, and connect this to mobility and diffusion coefficient; - Explain the main concept of MS, and explain how the choice of type of flux and the Bootstrap relation relate to this; - Apply the MS theory (extend a Matlab code); - Think of relevant case study, based on literature; - Perform mass transport simulations and critically access the results; - Communicate work and findings to others
Content description		This course aims at understanding of mass transport in multi-component mixtures, based on a simplified version of the theory of Maxwell and Stefan. Main aim is for students to be able to understand the basic principles of diffusion in mixtures containing various different species, driven by a combination of different driving forces, and to apply this understanding in specific relevant chemical technology applications. Within the course a lot of attention is paid to contemplation and discussion, in order to consolidate the new knowledge and insights. Within this context,

	students are requested to give a lecture on one of the chapters in the book and to answer relevant case study, in which the multi-component characteristics of transport are evident. The case study involves the use, and stepwise extension, of an existing Matlab code, allowing the students to gradually and relatively independently simulate and study an eventually complex problem. The course relies on prior knowledge from: Equilibria II, Physical Chemistry, iFTV, FTV, Separation Technologies. The following topics are addressed: - Limitations of the law of Fick; - Driving forces for diffusion (potential gradients); - Friction between molecules; - Maxwell-Stefan (MS) concept; - Bootstrap; - Application of MS in relevant process (membranes, heterogeneous catalysis, transport at interfaces); - Extending Matlab code for relatively complex simulations.
Course material	“Mass Transfer in Multicomponent Mixtures”, J.A. Wesselingh and R. Krishna ISBN 978-90-71301-58-2 (required)

201300155		**Process Equipment Design**
5 ec	**2A**	
Lecturer(s)		Prof.dr.ir. T.H. van der Meer, dr.ir. T.C. Bor, dr.ir. A.G.J. van der Ham, dr.ir. N.P. Kruyt
Objective		The objective of this course is the transfer of insight, knowledge and experience for the technological design of (chemical) process equipment. An industrial process consists mainly of a reactor, separation equipment (for instance distillation), heat exchangers and pumps/compressors. In this course you will learn to design a compressor or pump, a heat exchanger and a distillation column including mechanical aspects for a given industrial process. The course starts with lectures to discuss the design in general and the design of the different types of unit operation in detail. Also the mechanical aspects are discussed.
Content description		Topics of the different lectures: - design methodology in general, - equipment for momentum transport (pumps, fans, compressors), - equipment for heat transfer, with and without phase transition, - equipment for mass transfer: focus on distillation. - mechanical design aspects of process equipment. The course is finalized with a group design assignment of three types of unit operations for momentum, heat and mass transfer from an industrial scale process. The group consists in general of 3 students. Finally, the mark is based on the report and an oral exam about the (group)design assignment.
Prior knowledge		Needed:

	Introduction Fluid Mechanics (191154131) Fluid Mechanics and Heat Transfer (191154141) or Introduction Physical Transport Phenomena (191370091) Physical Transport Phenomena Lab Course (191370201)
Course material	"Chemical Engineering Design", R.K. Sinnott & Gavin Towler, 5th edition, ISBN 978-0-7506-8551-1 (recommended)
Assessment	Group assignment, oral examination.

193720050		**Theory of Phase Equilibria**
5 ec	**-**	
Lecturer(s)		Dr.ir. M.A. van der Hoef
Content description		The first part of this course consists of a recapitulation of elementary thermodynamics from a more formal viewpoint by using state functions, rather than from processes, as is common in most undergraduate courses. This formalism will then be applied to a description of phase-equilibria between two or more phases of single component systems. This is followed by a description of phase equilibria in two- and three-component systems, where the solutions are considered to be ideal. Finally, non-idealicity is introduced via excess functions and activity models. The most important application is found in the calculation of the P-x,y diagram of a binary system, starting from well-known excess state functions such as the Peng-Robinson and the RKS equation of state. This calculation will require some code development. This course is highly suitable for self study, where assistance from the lecturer can be obtained on an individual basis, preferably by appointment. In any case it is requested to get into touch with the lecturer before commencing. In the case of self-study, the course can be done the whole year round. If there is sufficient interest, a limited set of lectures will be given, in principle in block 2B.

191141700		**Transport Phenomena**
5 ec	**1A**	
Lecturer(s)		Prof.dr.ir. T.H. van der Meer
Objective		After this course, the student is able to … - Translate a real life heat, mass or momentum transport problem into its mathematical formulation - Solve the mathematical equation resulting from this translation - Analyse the solutions found and their implications for the problem started with - Communication with specialists involved in computational fluid dynamics, discuss the formulation of a problem and its numerical solution with this

	specialist.
Content description	This course uses the book Transport Phenomena written by Bird, Stewart and Lightfoot. The main author of this classical book is Byron Bird. He wrote the first edition of this book many years ago after his stay at Delft University, where he had been teaching transport phenomena. There are several ways to teach this material. Here the way of increasing mathematical complexity is chosen. It starts with stationary diffusion processes, then a source term is added, after which instationary diffusion is treated. Mathematically this means that is started with the ordinary differential equation, the Laplace equation. With instationary diffusion one deals with a partial differential equation in time and space. Next complexity is added by including convective transport. Since the transport of heat, mass and momentum show many similarities, throughout the course problems from all three transport mechanisms are solved. During the tutorials the students work in groups of 3 to 4 on real life problems. The groups have to formulate these problems into an analytical model. They have to make appropriate assumptions, define the solution domain, formulate the describing differential equation(s) with appropriate boundary conditions, and derive the solution. For some of the problems a numerical solution of the full problem without any assumption is available. With this numerical solution the students then analyse the influence of the assumptions made by them in finding the analytical solution. In this way they get understanding of the underlying transport mechanisms. Each 4 groups will be assisted by a tutor, who helps them during the whole process.
Prior knowledge	Needed: Introduction Physical Transport Phenomena II (B-ST)
Course material	“Transport Phenomena”, R. Byron, Warren E. Stewart, Edwin N. Lightfoot, 2nd Edition ISBN: 0-471-41077-2 (required)