Module Descriptions

Master of Science Chemical Engineering

Absorption: Energy Science and Technology

Examination Regulations in the Version of: 2015
Index

Additive Key Qualifications

Additive Key Qualifications

Compulsory Modules

Fundamentals of Chemical Engineering II
Simulation and Modelling of Multi-Phase-Reactors
Simulation and Modeling

Practical Training

Industrial Practical
Advanced Laboratory Chemical Engineering
Research Intership

Special Subject

Special Subject Chemical and Electrochemical Processes

Special Subject Energy Science Technology

Energy Science and Technology I - General Aspects
Energy Science and Technology II - Applications
Energy Science and Technology III - Electrochemical EST

Compulsory Elective Modules

Plant Economics
Electrochemistry
Hydrogen as Energy Carrier
Lithium Ion Batteries
Seminar Chemical Engineering
Surface - Interfaces - Heterogeneous Catalysis - Electrocatalysis

Master Thesis

Master Thesis
## Additive Key Qualifications

Modules referring to Additive Key Qualifications

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<td>Syllabus</td>
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<td>Literature</td>
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<td>Workload</td>
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# Fundamentals of Chemical Engineering II

## Modules referring to Compulsory Modules

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<td>Dean of Studies, Chemistry, Faculty of Natural Sciences</td>
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<td>Prof. Dr.-Ing. R. Güttel; Faculty of Natural Sciences</td>
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<tr>
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<td>MSc Chemical Engineering, semester 1 to 3</td>
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<tr>
<td>Recommended prerequisites</td>
<td>basics of chemical engineering, chemical reaction engineering, thermal and mechanical process engineering</td>
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</table>
| Learning objectives | Chemical Reaction Engineering II  
The students should be able to  
- apply the concept of residence time distribution to real reactors  
- understand the interplay between reaction and mass transfer in multiphase reactors  
- design a multiphase reactor under realistic conditions  
Thermal Process Engineering II  
The students should be able to  
- apply the principles of thermal separation to design unit operations for realistic cases  
Mechanical Process Engineering II  
The students should be able to  
- understand transport of particles in fluids  
- design of equipment for particle transport |

Master of Science Chemical Engineering  
Date printed: 29. November 2018  
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- understand measurement techniques for particle characteristics
- design unit operations of manipulation of particulate systems

Syllabus

Chemical Reaction Engineering II
- residence time distribution
- real single-phase reactors
- noncatalytic fluid-fluid and fluid-solid reactions
- catalytic reaction
- design of single- and multiphase reactors

Thermal Process Engineering II
- distillation
- extraction
- drying
- absorption
- membrane separation

Mechanical Process Engineering II
- measurement techniques
- gas-solid separation
- gas-liquid separation
- agglomeration
- manipulation of particle size

Literature

Chemical Reaction Engineering II

Thermal Process Engineering II

Mechanical Process Engineering II
Rhodes, Introduction to Particle Technology, 2008, Wiley.
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<thead>
<tr>
<th><strong>Teaching and learning methods</strong></th>
<th>Lectures and tutorials</th>
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<td><strong>Workload</strong></td>
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<td><strong>Basis for</strong></td>
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Simulation and Modelling of Multi-Phase-Reactors

Modules referring to Compulsory Modules

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<td>Duration</td>
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<td>Cycle</td>
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<tr>
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<td>Dean of Studies, Chemistry, Faculty of Natural Sciences</td>
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<td>Instructor(s)</td>
<td>Prof. Dr.-Ing. R. Güttel, Faculty of Natural Sciences</td>
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<td>MSc Chemical Engineering, semester 1 to 3</td>
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<td>Learning objectives</td>
<td>Students should be able to</td>
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<tr>
<td></td>
<td>- discuss chemical engineering issues with focus on state of the art multiphase reactors</td>
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<tr>
<td>Syllabus</td>
<td>- perform a modelling and simulation study of multiphase reactors under real conditions</td>
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<tr>
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<td>- collect and analyze results of simulations</td>
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<td>- write a report including theoretical background, model development, results and discussion</td>
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<td>- introduction to modeling tool</td>
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<td>- types of multiphase reactors</td>
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<tr>
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<td>- model development</td>
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<td>- sensitivity analysis</td>
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<td></td>
<td>- reactor design for a realistic case</td>
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<td><strong>Literature</strong></td>
<td>Ullmanns encyclopedia</td>
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<tr>
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<td><strong>Teaching and learning methods</strong></td>
<td>Introduction to Aspen Custom Modeler or Comsol multiphysics supervision of self-instruction</td>
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Simulation and Modeling
Modules referring to Compulsory Modules

Code: 8803373964
ECTS credits: 5
Attendance time: keine Angaben
Language of instruction: English
Duration: 1 Semester
Cycle: each Winter Semester
Coordinator: Prof. Dr. A. Latz, Faculty of Natural Sciences, Helmholtz Institute Ulm
Instructor(s): Prof. Dr. A. Latz, Faculty of Natural Sciences, Helmholtz Institute Ulm

Allocation of study programmes: Third Semester MSc Advanced Materials, Nanomaterials

Recommended prerequisites: 

Learning objectives: Student will be able to

- understand the basic theoretical concepts of electrochemistry, non-equilibrium thermodynamics and chemical kinetics
- distinguish between the modeling approaches for different length and time scales
- perform discretization of transport equations using Finite difference, Finite Volume and Finite Element Techniques
- solve numerically ordinary and partial differential equations using standard software tools
- describe mathematically the operation of batteries and fuel cells

Syllabus: 

- Transport theory
- Thermodynamics and chemical kinetics of electrochemical systems
- Introduction to simulation techniques
- Discretization of transport equations and kinetic equations
- Fundamentals of systems theory
- Modelling of Batteries
- Modelling of fuel cells
- Software exercises
Literature


Teaching and learning methods

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<th></th>
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Workload

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<td>50 h revision</td>
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<td>Solving problems</td>
<td>32 h presence</td>
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<td>36 h preparation</td>
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<td>and revision</td>
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Assessment

The credit points will be awarded once the written exam has been passed. No prerequisites are necessary for exam registration.

Grading procedure

The grade of the module will be the grade of the exam.

Basis for

Master thesis
**Industrial Practical**
Modules referring to Practical Training

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**Coordinator**
<p>Dean of Studies - Chemistry</p>

**Instructor(s)**
<p>Lecturers - Institute for Chemical Engineering</p>

**Allocation of study programmes**
<p>Master Chemical Engineering, compulsory courses, semester 1-3</p>

**Recommended prerequisites**
<p>Bachelor`s competences Chemical Engineering</p>

**Learning objectives**
The internship serves to gain specialist knowledge and experience
from professional practice. In addition, the practical training provides insights into everyday professional life and prepares students for their career entry.

**Syllabus**

The industrial practice includes engineering related activities in the field of process engineering and chemical engineering.

**Literature**

If applicable, provided by the company responsible for the project.

**Teaching and learning methods**

External internship, min. 4 weeks full-time, internship report.

**Workload**

Min. 4 weeks full-time

**Assessment**

Not specified

**Grading procedure**

Not specified

**Basis for**

M.Sc. Chemical Engineering
## Advanced Laboratory Chemical Engineering

**Modules referring to Practical Training**

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<td>- intensify their knowledge of applied chemical engineering</td>
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<td>- perform theoretical and physical experiments</td>
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<td>- collect and analyze data of experiments</td>
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<td>- write a report including theoretical background, model development and experimental, results and discussion</td>
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Research Internship
Modules referring to Practical Training

**Code** 8803733738

**ECTS credits** 12

**Attendance time** keine Angaben

**Language of instruction** English

**Duration** 1 Semester

**Cycle** each Semester

**Coordinator** Dean of Studies - Chemistry

**Instructor(s)** Lecturers - Institute for Chemical Engineering

**Allocation of study programmes** Master Chemical Engineering, compulsory courses, semester 3

**Recommended prerequisites** Formal prerequisites (according to Study order and examination regulations):
none

Prerequisites regarding to the contents: Bachelor's competences in the field related to the subject

**Learning objectives** Students are able to
# perform a scientific literature research
# depict the state of scientific knowledge with respect to a specific topic
# deduce scientific questions from the state of the art
# propose a scientific methodology with respect to the topic
# perform a theoretical or practical scientific project
# apply the theoretical knowledge gained in the lectures in practice
# perform simulations for unit operations
# plan and perform experiments
# discuss the experimental results with respect to the simulation results and the theory

**Syllabus** research project in the subject of chemical engineering related to current research in the respective institute

**Literature** specific to topic, mainly upon own literature survey
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**Energy Science and Technology I - General Aspects**

Modules referring to Special Subject Energy Science Technology

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**Instructor(s)**

Prof. Dr. J. Kallo, Faculty of Engineering, Computer Science and Psychology

**Allocation of study programmes**

Master Energy Science and Technology, compulsory courses, semester 1 and 2
Master Chemical Engineering, compulsory courses, semester 1 and 2

**Recommended prerequisites**

Chemical Engineering: Bachelor’s competences in engineering
Course Energy Science and Technology II is based on course Energy Science and Technology I

**Learning objectives**

Energy Science and Technology I
Students should be able to

- comprehend the background and basic facts, components, and interactions in the field of energy technology.
- understand and explain the basic physical principles underlying mechanical - electrical energy conversion
- describe the structure and functional mechanisms of the basic types of electric machines (DC separately excited, parallel and series wound; asynchronous;
synchronous), and sketch their equivalent circuits as well as torque-speed characteristics
• solve simple problems related to the interrelations between voltage, current, power and torque in the different types of electric machines
• describe the structure of the electric grid with its various voltage levels and name its basic components
• describe the functional mechanisms of the different thermal power plants (gas turbines, steam process) and explain the basic components
• solve simple problems in the field of technical thermodynamics
• describe the functional mechanisms of hydro and wind power plants as well as explain the main components (such as e.g. types of water turbines) and their application
• solve simple problems in the field of hydro and wind power applications

Energy Science and Technology II

Students should be able to

• understand and explain the construction and functional mechanisms of hydro-, wind-, solar thermal- and photovoltaic power plants of different kinds and describe and explain their components.
• perform base calculations for the design, for the dimensioning of component parameters and for the operation of such power plants.
• explain the balance terms "cumulated energy input, energy gain ratio, energy pay-back time" and use them for approximative calculations.
• distinguish the different kinds of potentials in the use of regenerative sources with different technologies and give approximative quantities for them.
• reproduce approximative quantities of real use and perform elementary calculations in these fields.
• describe and explain the reasons for limitations in the use of regenerative sources.
• understand the technical possibilities for long-distance energy imports from regenerative sources and can point out the necessary effort and cost.
• describe possible storage technologies together with their problems.
• understand and describe structure and functional mechanisms in cogeneration as well as absorption cooling technologies together with their advantages/disadvantages.

Syllabus

Energy Science and Technology I

The course gives an overview on conventional (electric) power technology:

• Development and status of energy consumption and resources; its limitations and consequences
• Physical basics of mechanical – electrical energy conversion
• Types of electric machines: DC separately excited, parallel and series wound; asynchronous; synchronous, special forms like AC machines, linear drives, electronically commutated machines; their construction, function, characteristics and applications
• Structure and function of the electric power grid and its components
• Electric power generation by means of thermal power plants and their thermodynamic fundamentals: Entropy, Carnot -, (Joule) Brayton - and (Clausius) Rankine - cycle
• Nuclear power plants, nuclear fusion technology
• Electric power generation from renewable sources: Hydro and wind power, photovoltaics, further technologies in the field of renewables

Energy Science and Technology II

Master of Science Chemical Engineering

Date printed: 29. November 2018
The course gives an overview on technologies using renewable sources and the concepts of distributed power technologies. At the center of the course is a comparison of various technologies to produce electricity or thermal energy for room heating and warm water production in terms of

- primary energy input
- energy pay-back time and energy gain ratios
- consumption of materials, resources and area
- ecological impact
- economy and cost

To do so the physical fundamentals, the peculiarities and the degree of usage as well as the potential for use of the following technologies are discussed in detail:

- hydro power
- wind power
- photovoltaics
- low-temperature solar thermal power
- high-temperature thermal solar power for electricity generation and thermal processing

Further topics:

- Possibilities and implications of renewable energy imports over long distances like e.g. from North Africa to Europe
- Necessities for storage technologies and the problems associated
- Cogeneration concepts and absorption cooling

### Literature

**Energy Science and Technology I**

- Lecture manuscript, materials on E-learning platform ILIAS.
- Any physics textbook on magnetics.

**Energy Science and Technology II**

- Lecture manuscript, materials on E-learning platform (ILIAS).
- Distributed Generation in Liberalised Electricity Markets; OECD/IEA 2002.

### Teaching and learning methods

<table>
<thead>
<tr>
<th>Energy Science and Technology I</th>
<th>5 credit points</th>
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<tbody>
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<td>Lecture 3 h/week</td>
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<tr>
<td>Tutorial 1 h/week</td>
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<table>
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<th>Energy Science and Technology II</th>
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<tbody>
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<tr>
<td>Tutorial 1 h/week</td>
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### Workload

Energy Science and Technology I:
- Total 150 h
- Lecture: 48 h presence
  - 48 h preparation and revision
- Tutorial: 16 h presence
  - 22 h solving problems, revision
- Exam: 16 h preparation

Energy Science and Technology II:
- Total 150 h
- Lecture: 42 h presence
  - 42 h preparation and revision
- Tutorial: 14 h presence
  - 36 h solving problems, revision
- Exam: 16 h preparation

### Assessment

Module description will be available shortly.

### Grading procedure

Module description will be available shortly.

### Basis for

Module *Energy Science and Technology II-Applications*
# Energy Science and Technology II - Applications

Modules referring to Special Subject Energy Science Technology

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<tr>
<td>Duration</td>
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<td>Cycle</td>
<td>starts every Summer Semester</td>
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<tr>
<td>Coordinator</td>
<td>Dean of Studies - Electrical Engineering</td>
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| Instructor(s) | Prof. Dr. R.J. Behm, Prof. Dr. A. Latz, Prof. M. Fichtner, Prof Dr. W. Tillmetz, Dr. R. Zeis, Faculty of Natural Sciences  
Prof. Dr. U. Herr, Prof. Dr. J. Kallo, Prof. Dr. F. Scholz, Faculty of Engineering and Computer Science |
| Allocation of study programmes | Master Energy Science and Technology, compulsory courses, semester 2 and 3  
Master Chemical Engineering, compulsory courses, semester 2 and 3 |
| Recommended prerequisites | Module Engineering  
Module Energy Science and Technology I – General Aspects |
| Learning objectives | Students should be able to  
• integrate scientific principles of energy conversion and catalysis, knowledge about properties of the materials employed and engineering aspects of energy usage, conversion and storage and apply this to practical application  
• conduct advanced experiments and write corresponding reports  
• prepare and give a presentation on a topic in the field of energy science and technology based on literature and internet research |
| Syllabus | Energy Technology Lab I  
• Solar cells  
• DC / DC Converter  
• CHP system (combined heat and power)  
• H2 – storage  
• Lambda Probe  
• Impedance Spectroscopy |
• Heterogeneous Catalysis - CO oxidation
• Electrocatalysis – Methanol electrooxidation
• Electrocatalysis – Fuel Cell

Seminar Energy Science and Technology
• Current topics in the field of Energy Science and Technology
• Supervised preparation of student presentation
• Presentation and discussion in the seminar

<table>
<thead>
<tr>
<th>Literature</th>
<th>Check references for module <em>Energy Science and Technology I – General Aspects</em></th>
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</table>

| Teaching and learning methods | Energy Technology Lab I  
Second semester, 9 credit points  
Preparation of experiments (self-study + colloquium), experiments, presentations, writing reports  
Seminar EST  
Third semester, 2 credit points  
Preparation of presentations, presentations, discussion in the seminar; attendance minimum 80% |
|---|---|

| Workload | Energy Technology Lab: Total 270 h 126 h presence in lab and accompanying seminar 144 h preparation, writing reports, presentation  
Seminar Energy Science and Technology: Total 60 h 32 h presence 28 h preparation, search of literature, preparation of presentation and handout |
|---|---|

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Module description will be available shortly.</th>
</tr>
</thead>
</table>

<table>
<thead>
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<th>Grading procedure</th>
<th>Module description will be available shortly.</th>
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<table>
<thead>
<tr>
<th>Basis for</th>
<th>Master Thesis</th>
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</table>
# Energy Science and Technology III - Electrochemical EST

Modules referring to Special Subject Energy Science Technology

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<tr>
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<td>Duration</td>
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<tr>
<td>Cycle</td>
<td>each Winter Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. W. Tillmetz, Faculty of Natural Sciences, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Dr. Jörissen, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg</td>
</tr>
</tbody>
</table>
| Allocation of study programmes | Master Energy Science and Technology, compulsory courses, semester 3  
Master Chemical Engineering, compulsory courses, semester 3 |
| Recommended prerequisites | Energy Science and Technology:  
Modules *Chemistry I* and *Chemistry II* Module Engineering  
Chemical Engineering:  
*Formal prerequisites (according to Study order and examination regulations): none*  
Prerequisites regarding to the contents: Bachelor's competences in the field related to the subject |
| Learning objectives | The students should be able to  
• describe fuel cells and batteries with respect to components and their function  
• analyze the operating features of fuel cells and batteries  
• discuss research and development in the field of fuel cells and batteries |
| Syllabus | Energy Science and Technology III  
1) Fuel cells |
• Types, components, operational characteristics, degradation
• Catalysts, electrodes, bipolar plates, electrolytes,
• Test of performance
• Applications: Automobiles, buses, stationary CHP and back-up power, leisure market

1) Batteries:
• Rechargeable batteries and electrochemical double layer capacitors: types, characteristics, charge, discharge, degradation
• Electrolytes and electrodes, design principles
• Battery systems, battery management, thermal management, maintenance, safety

Energy Technology Lab II
• I/U characteristics of electrolyzer and fuel cell single cells
• Characteristics of a fuel cell system; hydrogen powered operational features of a fuel cell system combined with a battery (hybrid)
• Characteristics of a fuel cell test bench: Flow and pressure control, temperature and humidity control, sensors and data recording
• Operation of commercial fuel cell products: DMFC for remote power and on board power supply; Hydrogen Fuel Cell System for Back Up and Emergency Power Supply
• Characteristics of lead acid and alkaline batteries, electrochemical double layer capacitors, (charge/discharge behavior)

Literature

Teaching and learning methods
Energy Science and Technology III
5 credit points
Lecture 3 h/week
Solving problems 1 h/week

Energy Technology Laboratory II
4 credit points
4 h/week

Workload
Energy Science and Technology III:
Total 150 h
Lecture: 48 h presence
50 h preparation and revision
Solving problems: 16 h presence
20 h solving problems, revision
Exam: 16 h preparation

Energy Technology Laboratory II:
Total 120 h
64 h experiments in lab (presence)
16 h preparation of experiments
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<tbody>
<tr>
<td><strong>Grading procedure</strong></td>
<td>Module description will be available shortly.</td>
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<tr>
<td><strong>Basis for</strong></td>
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## Plant Economics

Modules referring to Compulsory Elective Modules

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<td>Language of instruction</td>
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<td>Duration</td>
<td>1 Semester</td>
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<tr>
<td>Cycle</td>
<td>each Summer Semester</td>
</tr>
<tr>
<td>Coordinator</td>
<td>Prof. Dr. Michael Hiete</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Prof. Dr. Michael Hiete</td>
</tr>
</tbody>
</table>

### Allocation of study programmes
- Master Chemistry and Management, elective (Chemistry and Management), 1.-3. semester
- Master Chemical Engineering, elective, 1.-3. semester

### Recommended prerequisites
- **Formal prerequisites (according to Study order and examination regulations):** none
- **Prerequisites regarding to the contents:** Bachelor's competences in the field related to the subject

### Learning objectives
Students gain an overview over tasks and methods of plant economics over the lifetime of plants and are able to apply them. Particularly, students know methods for investment appraisal and estimation of costs, for process and plant design. They are familiar with methods for quality management, maintenance and end-of-life management of plants and are able to apply these.

### Syllabus
- Introduction to plant economics
- Analysis and modelling of industrial production systems
- Project management in engineering
- Network and facility location planning
- Process selection and design, network design
- Investment appraisal
- Cost estimation
- Plant and process optimization
- Maintenance
- Quality management
• End-of-life management of plants in the field related to the subject

**Literature**


Further literature will be announced in the course.

**Teaching and learning methods**

- Lecture (2 hours per week)

**Workload**

- Presence time: 30 h
- Self study: 60 h
- Total: 90 h

**Assessment**

The credit points will be awarded once the written exam has been passed. No prerequisites are necessary for exam registration.

**Grading procedure**

The grade of the module will be the grade of the exam.

**Basis for**

- no data
Electrochemistry
Modules referring to Compulsory Elective Modules

Code 880374329

ECTS credits 4

Attendance time 3

Language of instruction English

Duration 1 Semester

Cycle each Winter Semester

Coordinator Prof. Dr. Timo Jacob

Instructor(s) Prof. Dr. Timo Jacob

Allocation of study programmes
Master Chemistry, Study Program Chemistry, Elective (Physical Chemistry or Energy Technology) oder Specialization (Physical Chemistry or Energy Technology), 1.-3. semester
Master Chemistry, Study Program Materials, Elective, 1.-3. semester
Master Chemistry and Management, Elective/Module Group 1 (Physical Chemistry) or Specialization/Module Group 2 (Physical Chemistry or Energy Technology), 1.-3. semester
Master Chemical Engineering, Elective, 1.-3. semester
Master Energy Science and Technology, Elective, 1.-3. semester

Recommended prerequisites
Formal prerequisites (according to Study order and examination regulations): none

Prerequisites regarding to the contents: Bachelor's competences in the field related to the subject

Learning objectives
Students, who have succesfully completed this module,
- dispose of knowledge in area of the electrochemistry and its related areas of application
- can apply electrochemical relations to problem formulations
- have an overview as well as detailed knowledge about systems and processes in the area of the electrochemical energy change / storage

Syllabus
In this module, the following contents are given:
(1) Repetition and deepening of electrochemical basics:
- Electrolytic conductivity
- Electrode reactions and electrode potentials
- Cell tension and potential courses in the cell
- Electrode potentials with current flow and overvoltage of electrodes
- Introduction to the electrochemistry of the solid states
(2) Applications from electrochemical processes in
- Batteries
- Fuel cells
- Electrochemical production procedures
- Electrolysis
- Photo (electro) chemical systems
- Sensors
- Corrosion
- Electroplating

**Literature**
- Hamann, Vielstich: *Elektrochemie*
- Bard, Faulkner: *Electrochemical Methods*
- Oldman, Myland, bond: *Electrochemical Science and Technology*

**Teaching and learning methods**
Lecture (2 hours) and Seminar (1 hour)

**Workload**
Presence: 45 h
Self study: 75 h
Total: 120 h

**Assessment**
The credit points will be awarded once the written or oral exam has been passed (depending on the number of participants). The type of examination will be announced in time - at least 4 weeks prior to the date of the exam. No prerequisites are necessary for exam registration.

**Grading procedure**
The grade of the module will be the grade of the exam.

**Basis for**
No data.
# Hydrogen as Energy Carrier

 Modules referring to Compulsory Elective Modules

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<tr>
<td>Coordinator</td>
<td>PD Dr. Christian Mohrdieck</td>
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<td>PD Dr. Christian Mohrdieck</td>
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<tr>
<td>Master Chemistry, Study Programm Chemistry, elective or specialization (Energy Technology), 1.-3. semester</td>
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<tr>
<td>Master Chemistry and Management, specialization / Module Group 2 (Energy Technology), 1.-3. semester</td>
</tr>
<tr>
<td>Master Energy Science and Technology, elective, 1.-3. semester</td>
</tr>
<tr>
<td>Master Advanced Materials, elective, 1.-3. semester</td>
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<tr>
<td>Master Teaching Chemistry, elective module, 1.-3. semester</td>
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<table>
<thead>
<tr>
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<tr>
<td><strong>Formal prerequisites (according to Study order and examination regulations):</strong> none</td>
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<table>
<thead>
<tr>
<th>Learning objectives</th>
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<tbody>
<tr>
<td>Students who have successfully completed this module</td>
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<tr>
<td>- are familiar with the scientific, technical and economic aspects of hydrogen as a promising and environmentally friendly energy source</td>
</tr>
<tr>
<td>- have an idea of technical applications</td>
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<table>
<thead>
<tr>
<th>Syllabus</th>
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<tbody>
<tr>
<td>This module provides the following content:</td>
</tr>
<tr>
<td>- Overview hydrogen in research and applications</td>
</tr>
<tr>
<td>- Production methods, logistics and infrastructure for hydrogen</td>
</tr>
<tr>
<td>- Hydrogen storage methods (non-compressed gaseous)</td>
</tr>
</tbody>
</table>
- Storage methods (compressed hydrogen gas)
- Hydrogen (re)fueling technology
- Process, stationary and alternative applications
- Application of hydrogen in transportation, fuel cell vehicles
- Hydrogen - Fuel Cell - Efficiency - Entropy
- Visit of hydrogen and fuel cell laboratory, witnessing a leakage test
- Visit of a hydrogen refueling station and fuel cell vehicle test drive
- Different pathways of hydrogen production and use. Comparison with other energy sources based on the complete energy chain efficiency and emissions
- Tool for the visualization of energy chain efficiency results
- Safety, regulations, codes and standards
- Future perspectives of hydrogen as an energy carrier

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Zuttel, Andreas; Borgschulte, Andreas; Schlapbach, Louis (eds.): Hydrogen as a future energy carrier (Wiley-VCH, Weinheim, 1. Auflage 2008)</td>
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<tr>
<td>- International seminar proceedings, 3rd (Springer Netherlands, 2003)</td>
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<table>
<thead>
<tr>
<th>Teaching and learning methods</th>
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<tbody>
<tr>
<td>Lecture (2 hours per week)</td>
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<table>
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<th>Workload</th>
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<tbody>
<tr>
<td>Presence: 30 h</td>
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<td>Private study: 60 h</td>
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<tr>
<td>The credit points will be awarded once the written or oral exam has been passed (depending on the number of participants). The type of examination will be announced in time - at least 4 weeks prior to the date of the exam. No prerequisites are necessary for exam registration.</td>
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<table>
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<tr>
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<td>The grade of the module will be the grade of the exam.</td>
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<table>
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<td>Research in field of Energy and Energy conversion</td>
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Lithium Ion Batteries
Modules referring to Compulsory Elective Modules

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<td>Duration</td>
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<tr>
<td>Cycle</td>
<td>each Winter Semester</td>
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<tr>
<td>Coordinator</td>
<td>Head of the ZSW or Head of the HIU</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Dr. Margret Wohlfahrt-Mehrens</td>
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Allocation of study programmes
- Master Chemistry, Study Programm Chemistry, elective or specialization (Energy Technology), 1.-3. semester
- Master Chemistry and Management, specialization / Module Group 2 (Energy Technology), 1.-3. semester
- Master Energy Science and Technology, elective, 1.-3. semester
- Master Advanced Materials, elective, 1.-3. semester
- Master Teaching Chemistry, elective module, 1.-3. semester

Recommended prerequisites
Formal prerequisites (according to Study order and examination regulations): none
Prerequisites regarding to the contents: Bachelor's competences in the field related to the subject

Learning objectives
Students who have successfully completed this module,
- are familiar with the basics of lithium-ion batteries
- know the correlations between binary and ternary phase diagrams and electrochemistry
- have distinctive knowledge of structure and property relationships in compounds

Syllabus
This module provides the following content:
- Electrochemical energy storage systems
- Introduction to Lithium batteries
- Basic principles I
- Cathode materials I
- Cathode materials II
- Nanomaterials
- Measurement techniques
- Anode materials I
- Anode materials II
- Electrolytes
- Electrode/Electrolyte interface (SEI)
- Battery management I
- Battery management II
- Alternative Systems, Lab visit ZSW

### Literature
- M. Whittingham, Intercalation compounds, in fast ion transport, Dordrecht (1993)

### Teaching and learning methods
Lecture (2 hours per week)

### Workload
Presence: 30 h
Private study: 60 h
Total: 90 h

### Assessment
The credit points will be awarded once the written or oral exam has been passed (depending on the number of participants). The type of examination will be announced in time - at least 4 weeks prior to the date of the exam. No prerequisites are necessary for exam registration.

### Grading procedure
The grade of the module will be the grade of the exam.

### Basis for
research in the field of Batteries
Seminar Chemical Engineering
Modules referring to Compulsory Elective Modules

Code 880374294
ECTS credits 2
Attendance time 1
Language of instruction English
Duration 2 Semester
Cycle each Semester
Coordinator Dean of Studies - Chemistry
Instructor(s) Lecturers - Institute of Chemical Engineering

Allocation of study programmes Master Chemical Engineering, elective courses, semester 2 or 3

Recommended prerequisites Formal prerequisites (according to Study order and examination regulations): none
Prerequisites regarding to the contents: Bachelor's competences in the field related to the subject

Learning objectives Students should be able to
- perform a scientific literature research
- extract relevant information from the literature with respect to topic assignment
- summarize and present the information in format of a scientific presentation

Syllabus - literature research
- structuring of information
- preparation and presentation of summary
- attendance of presentation from other students

Literature scientific literature for specific topic

Teaching and learning methods - self-instruction
- student presentations
| **Workload**          | Presence: 10 h (attendance required); depends on number of students  
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<td><strong>Basis for</strong></td>
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# Surface - Interfaces - Heterogeneous Catalysis - Electrocatalysis

Modules referring to Compulsory Elective Modules

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<tr>
<td>Coordinator</td>
<td>Prof. Dr. R. J. Behm, Faculty of Natural Sciences</td>
</tr>
<tr>
<td>Instructor(s)</td>
<td>Prof. Dr. R. J. Behm, Faculty of Natural Sciences</td>
</tr>
<tr>
<td>Allocation of study programmes</td>
<td>MasterChemical Engineering, compulsory courses, semester 2</td>
</tr>
</tbody>
</table>

### Recommended prerequisites

Module *Chemistry I*

### Learning objectives

Students should be able to

- describe basic aspects of solid surfaces and their properties (structure, electronic properties) as well as their interaction with adsorbates;
- describe basic principles of heterogeneous catalysis and catalytic reactions, and apply them to model reactions (CO oxidation and ammonia synthesis);
- explain fundamental principles of electrochemistry, including solid electrolyte interface, potentials, electrode kinetics, transport effects, basic electrochemical measurements;
- describe basic principles, energetics and kinetics of electrocatalytic reactions, focusing on fuel cell relevant reactions, and predict simple trends for suitable catalysts

### Syllabus

- Surfaces: Phenomenologic thermodynamics of surfaces, surface structure and electronic properties of solid surfaces, interaction of molecules with surfaces (thermodynamics, kinetics and energetics);
- Catalytic Surface Reaction (Heterogeneous Catalysis): Fundamental aspects, methodical approach, basic reaction types, activity, selectivity, electronic and structural effects, Sabatier principle, Bronstedt-Evans-Polanyi principle, model reactions (CO oxidation, ammonia synthesis);
• Electrochemistry: Galvanic cells, potentials in electrochemistry, standard electrode potential, electrochemical double layer, electrode kinetics, transport effects, experimental methods;
• Electrocatalysis: General aspects, influence of the electric potential on energetics and kinetics of electrocatalytic reactions, kinetic / transport limitations in electrocatalytic reactions, internal resistance effects, examples of electrocatalytic reactions, temperature effects.

**Literature**


**Teaching and learning methods**

- 5 credit points
- Lecture 3h/week
- Seminar 1h/week

**Workload**

- Total 150 h
- 56 h lecture and seminar (presence)
- 78 h preparation and revision of lecture and seminar and solving of problems
- 16 h preparation for exam

**Assessment**

- The credit points will be awarded once the oral exam has been passed. No prerequisites are necessary for exam registration.

**Grading procedure**

- The grade of the module will be the grade of the exam.

**Basis for**

- Module *Energy Science and Technology III-Electrochemical EST*
- Research in field of *Energy and storage materials*
## Master Thesis

**Modules referring to Master Thesis**

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<td>Duration</td>
<td>24 Wochen Semester</td>
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**Coordinator**

*Habilitated permanent members of Ulm University, in case of external master theses complemented by scientists qualified on a comparable level and individually assigned by the Examination Committee.*

**Instructor(s)**

*Head of the Examination Board (Prof. Dr. Ing. R. Güttel)*

**Allocation of study programmes**

*Master Chemical Engineering, compulsory module, semester 4*

**Recommended prerequisites**

*§ 19 of Study and Examination Regulations<br>Academic admission requirements for the bachelor's and the master's thesis in Chemical Engineering<br>*
Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship”. Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part “Research Internship". Admission to the master’s thesis is subject to having earned a minimum of 75 CP from the modules groups listed in § 18a (1) and having passed the module part "Research Internship".

Students are able to survey the project related literature to design or optimize an experimental set-up to project specific preparational and analytical tools to acquire data acquisition & analysis including error considerations to apply their acquired knowledge on writing scientific reports in order to deliver a scientifically consistent and formally complete thesis to prepare and deliver a scientific presentation based on the accomplishments gained during the thesis work.

Research topic

To design or optimize an experimental set-up to acquire data acquisition & analysis including error considerations to apply their acquired knowledge on writing scientific reports in order to deliver a scientifically consistent and formally complete thesis to prepare and deliver a scientific presentation based on the accomplishments gained during the thesis work.

Dates and contact

Contact information:

Email: info@university.edu
Phone: +1 (123) 456-7890
Address: University Avenue, City, State, Country

Learning objectives

- Survey project-related literature
- Design or optimize an experimental setup
- Use specific preparational and analytical tools
- Acquire data acquisition and analysis including error considerations
- Apply acquired knowledge on writing scientific reports
- Prepare and deliver a scientific presentation based on accomplishments gained during the thesis work.

Syllabus

Research topic

Literature

Learn more about the Master of Science Chemical Engineering at www.chemistry.edu
### Teaching and learning methods

- Independent work (experimental work, lab work etc.)

### Workload

<table>
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<th>Workload</th>
<th>Total: 900 h</th>
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### Assessment

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### Grading procedure

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</table>

### Basis for

| Basis for                  | M. Sc Chemical Engineering; PhD in this field |