# Module Handbook

## Study Programme

## Hydrogen Technologies

Technical University of Applied Sciences Würzburg-Schweinfurt

Faculty Mechanical Engineering

Ignaz-Schön-Str. 11

D-97421 Schweinfurt

Basis: Study and Examination Regulations for the Bachelor's Degree Programme in Hydrogen Technology Transnational

in the version of 01.10.2023

## Contents

# 1 Study Objective and Programme Profile

The purpose of the programme is to provide students with the ability to independently utilise scientific knowledge and methods in the field of hydrogen technology through practice-oriented teaching methods. In terms of content, the focus is on safe system technology and system operation, as well as on the processes for extraction, transport, distribution, and storage, including the associated physical foundations. This allows graduates to balance the hydrogen process chain and, on this basis, to develop approaches and technical concepts for improving the efficiency of hydrogen-based technologies. Their later professional employment is not limited to pure hydrogen technology; they can also work successfully in other areas of process engineering. The general principle is: “Anyone who can safely design and operate hydrogen plants can also do so with other media.”

In consideration of the spectrum and diversity of hydrogen technology, which requires a comprehensive basic education, the curriculum is designed to provide the necessary technical, methodological, social, and personal competencies. This equips students to quickly familiarise themselves with one of the numerous fields of application and pursue a career as an engineer.

The study of hydrogen technology in the relevant modules should also enable students to recognize the effects of technology on the environment and society and to take responsible action accordingly. Additionally, students acquire social, intercultural, and foreign language skills alongside their specialist knowledge through integrated internships and projects. This approach ensures the development of their practical problem-solving skills in an international environment, preparing them to take on executive roles.

The bachelor's degree programme in Hydrogen Technology is offered by THWS at GJU in Amman, Jordan. During the first four semesters, courses are held at the GJU. After that, students continue their studies at THWS in Schweinfurt until graduation. The students learn German simultaneously with the subject-related course content. The course content of the first and second semesters is taught entirely in English, while the course content of the third and fourth semesters is taught partly in German. In Schweinfurt, the students then attend German-language courses.

The programme also offers the "Hydrogen Technology dual" study variant, which combines theory and practice more intensively, enhancing the competence profile of dual students. By regularly alternating between study and practical phases, students apply what they have learned directly in the respective partner company, fostering a high level of professional orientation and self-organization. This intensive course of study allows students to test, substantiate, reflect upon, and deepen problem-solving methods and specialist knowledge acquired during company practice. Moreover, practical experience is integrated into the courses, allowing for analysis and processing.

# 2 Curriculum

## Study plan of the Bachelor's degree programme in Hydrogen Technology

### Structure and Modular Organisation oft the Study Programme (in relation to Credit Points of the European Credit Transfer System)

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="30">ECTS Credit Points</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th></tr>
<tr><td rowspan="7">Semester</td><td>1</td><td colspan="5">Engineering Mathematics 1 (1)</td><td colspan="5">Thermodynamics 1 (2)</td><td colspan="5">Chemistry, Electrochemistry (3)</td><td colspan="5">Materials Technology 1 (4)</td><td colspan="5">Engineering Mechanics (5)</td><td colspan="5">Computer Science, Digitalisation, Automation (6)</td></tr>
<tr><td>2</td><td colspan="5">Engineering Mathematics 2 (7)</td><td colspan="5">Thermodynamics 2 (8)</td><td colspan="5">Physics (9)</td><td colspan="5">Materials Technology 2 (10)</td><td colspan="5">Plants and Vessels 1 (11)</td><td colspan="5">Electrical Engineering (12)</td></tr>
<tr><td>3</td><td colspan="5">Renewable Energy and Energy Industry (13)</td><td colspan="5">Fluid Mechanics (14)</td><td colspan="5">Control and Feedback Control Systems in Hydrogen Plants (15)</td><td colspan="5">Measuring in Hydrogen Plants (16)</td><td colspan="5">Process Design and Simulation (17)</td><td colspan="5">Hydrogen Safety (18)</td></tr>
<tr><td>4</td><td colspan="5">Hydrogen Production (19)</td><td colspan="5">Fuel Cell (20)</td><td colspan="5">Hydrogen Storage, Transport and Distribution (21)</td><td colspan="5">Plants and Vessels 2 (22)</td><td colspan="5">Systematical Design of Plants (23)</td><td colspan="5">Specialised Elective 1 (24)</td></tr>
<tr><td>5</td><td colspan="5">Innovation and Development Processes and Founding (25)</td><td colspan="5">Computational Fluid Dynamics (26)</td><td colspan="5">Chemical Conversion with Hydrogen (27)</td><td colspan="5">Plant Operation (28)</td><td colspan="5">General Elective (29)</td><td colspan="5">Specialised Elective 2 Transfer Seminar (30) (30a)</td></tr>
<tr><td>6</td><td colspan="6">Seminar in Engineering (31)</td><td colspan="24">Practical Module (32)</td></tr>
<tr><td>7</td><td colspan="10">Application Project (33)</td><td colspan="3">Technical Lab Training (34)</td><td colspan="5">Cost Accounting and Ethics for Engineers (35)</td><td colspan="12">Bachelor Thesis (36)</td></tr>
</table>

### Structure and Modular Organisation (in relation to Semester Hours per Week SWS)

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="26">Semester Hours per Week (SWS)</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th></tr>
<tr><td rowspan="7">Semester</td><td>1</td><td colspan="6">Engineering Mathematics 1 (1)</td><td colspan="4">Thermodynamics 1 (2)</td><td colspan="4">Chemistry, Electrochemistry (3)</td><td colspan="4">Materials Technology 1 (4)</td><td colspan="4">Engineering Mechanics (5)</td><td colspan="4">Computer Science, Digitalisation, Automation (6)</td></tr>
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</table>

## 3. First Study Period – Basic Modules, 1st and 2nd Semester

| **Module: 1** | | | |
|---|---|---|---|
| **Engineering Mathematics 1** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Winter Semester | Total Workload: 150 h<br>90 contact hours (6 semester periods per week)<br>30 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** Prof. Dr. Storath | | | |
| **Lecturer:** | | | |
| N.N. | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Engineering Mathematics 1 (6 Semester Hours per Week) | | Seminar-type teaching, exercise | English |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory module, 1st Semester)<br>Bachelor Programme Mechanical Engineering (Compulsory module, 1st Semester) | | | |
| Provides the basis for module(s): | Engineering Mathematics 2 (7), Physics (9), Engineering Mechanics (5), Thermodynamics 1 and 2 (2, 8), Elektrical Engineering (12) | | |
| Builds on module(s): | none | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| School knowledge of mathematics, in particular: Sets, real numbers, limits, real functions and their basic properties, trigonometric functions, polynomial functions, fractional rational functions, exponential function, logarithm function, factorisation of polynomials, analytical geometry. | | | |
| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** | |
| Written exam | 90 to 120 min | English | |
| The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester. | | | |
| **Learning outcomes after successful termination of the module** | | | |
| The students<br>• explain the calculation methods in the complex number space.<br>• explain the fundamental theorem of algebra.<br>• apply the basics of vector calculus.<br>• solve systems of linear equations.<br>• name the basic methods of matrix calculation.<br>• explain the basics of differential calculus.<br>• apply the rules of integral calculus. | | | |
| **Module Content** | | | |

- Complex Numbers
  - Basics
  - Presentation forms
  - Complex calculus
- Vector Calculus
  - Concept of the vector
  - Graphical representation
  - Basis
  - Basic arithmetic operations
  - Cross product
  - Scalar product
- Calculation of Matrices
  - Linear systems of equations
  - Concept of matrix
  - Multiplication
  - Determinant
  - Inverse
  - Matrices and systems of linear equations
- Differential Calculus
  - The concept of the derivative
  - Derivatives of elementary functions
  - Derivation rules (sum, product, quotient, chain rule, powers with variables in the base and in the exponent)
  - Linearisation and tangent
  - Taylor polynomials
  - Newton's method for determining zeros
  - Rule of Bernoulli-de l'Hospital
  - Determination of extreme values
- Integral Calculus
  - The concept of the definite integral
  - Indefinite integrals and the main theorem
  - Root functions of elementary functions
  - Basic rules
  - Methods of integration
  - Partial fraction decomposition
- Indefinite Integrals

**Literature and other Learning Offers**

- P. Stingl, *Mathematik für Fachhochschulen.* Technik und Informatik. Hanser, 2009
- A. Fetzer und H. Fränkel, *Mathematik 1.* Berlin: Springer, 2007
- A. Fetzer und H. Fränkel, *Mathematik. Lehrbuch für Fachhochschulen, Band 2.* Berlin: Springer, 2012
- K. Meyberg und P. Vachenauer, *Höhere Mathematik 1.* Berlin:Springer, 2003
- L. Papula, *Mathematik für Ingenieure und Naturwissenschaftler, Band 1.* Wiesbaden: Springer Vieweg, 2014
- L. Papula, *Mathematik für Ingenieure und Naturwissenschaftler, Band 2.* Wiesbaden: Springer Vieweg, 2015
- L. Papula, *Mathematik für Ingenieure und Naturwissenschaftler, Klausur- und Übungsaufgaben.* Wiesbaden: Vieweg+Teubner, 2010
- T. Westermann, *Mathematik für Ingenieure*. Berlin: Springer, 2015
- S. Goebbels, S. Ritter, *Mathematik verstehen und anwenden.* Springer Verlag, 2013

**Special Feature**

# Module: 2

## Thermodynamics 1

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** N.N.

**Lecturer:**

N.N.

| Associated Course | Study Modes | Language |
|---|---|---|
| Thermodynamics 1 (4 Semster Hours per Week) | Seminar-type teaching, exercise | English |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 1st Semester)

| | |
|---|---|
| Provides the basis for module(s): | Thermodynamics 2(8), Renewable Energy and Energy Industry (13), Fluid Mechanics (14), Process Design and Simulation (17), Hydrogen Safety (18), Hydrogen Production (19), Fuel Cell (20), Hydrogen Storage, Transport and Distribution (21), Systematical Design of Plants (22), Chemical Conversion with Hydrogen (27), Plant Operation (28) |
| Builds on module(s): | Engineering Mathematics 1 (1) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

School knowledge advanced mathematics and physics

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam or portfolio | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

| **Learning outcomes after successful termination of the module** |
|---|
| The students<br>• use correct technical terminology in group discussions as well as questions and evaluate each other on the correct use of technical terminology. (e.g. first law of thermodynamics).<br>• specify the basic structure of left- and right-running circular processes and define suitable evaluation ratios to describe these processes.<br>• calculate thermal and caloric state variables, process variables, other variables (e.g. speeds, outputs) and evaluation indicators for circular processes and apply the individual methodical steps for the calculation and analysis of circular processes.<br>• analyse circular processes using the "ideal gas" work tool for essential influencing variables.<br>• describe real technical systems and machines that can be modeled with these cycles and evaluate the calculation performance (e.g. simplifications, assumptions) and the model performance (deviations between cycle and real machine).<br>• assess processes and real technical systems in terms of their suitability and quality and propose improvements.<br>• analyse problems from engineering practice, develop sub-questions from them, make reasonable, physically plausible hypotheses (e.g. in the case of incomplete data) and solve the sub-questions.<br>• use correct terminology in group discussions as well as questions and evaluate each other on the correct use of terminology. |
| **Module Content** |
| • Conservation laws of thermodynamics, thermal and caloric state variables of substances and process variables<br>• Nature and interrelations of energy (as a general term) and the forms of energy heat and work<br>• Methodology for dealing with thermodynamic problems<br>• Material model "ideal gas" and the behaviour of ideal gases<br>• Special (idealised) changes of state of ideal gases<br>• Left- and right- running cyclic processes with the working medium "ideal gas" (e.g. Carnot, Joule, Ericsson, Stirling, Otto, Diesel, Seiliger process)<br>• Introduction to the structure and mode of operation of power and working machines<br>• Introduction to the behaviour of machines under real conditions |

| **Literature and other Learning Offers** |
|---|
| • D. Labuhn und O. Romberg, Keine Panik vor Thermodynamik, 6. Auflage. Wiesbaden: Springer Vieweg, 2012.<br>• H. D. Baehr und S. Kabelac, Thermodynamik: Grundlagen und technische Anwendungen, 16., aktualisierte Auflage. Berlin, Heidelberg: Springer Vieweg, 2016.<br>• G. Cerbe und G. Wilhelms, Technische Thermodynamik: Theoretische Grundlagen und praktische Anwendungen, 18., überarbeitete Auflage. München: Hanser, 2017.<br>• H. Herwig, C. Kautz und A. Moschallski, Technische Thermodynamik: Grundlagen und Anleitung zum Lösen von Aufgaben, 2., überarbeitete Auflage. Wiesbaden: Springer Vieweg, 2016.<br>• W. Heidemann, Technische Thermodynamik: Grundkurs für das Bachelorstudium. Weinheim: Wiley VCH, 2016.<br>• Online-Tests and JiTE-Tasks eLearning-System THWS<br>• Interactive Simulations „Ideal Gas“, PhET-Website, z.B. https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties_en.html |
| **Special Feature** |
| |

| **Module: 3** | | | |
|---|---|---|---|
| **Chemistry, Electrochemistry** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** N.N. | | | |
| **Lecturer:** | | | |
| N.N. | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Chemistry, Electrochemistry (4 Semester Hours per Week) | | Seminar-type teaching, exercise, Lab course | English |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 1st Semester) | | | |
| Provides the basis for module(s):<br>Builds on module(s): | All technical modules | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| School knowledge mathematics, chemistry and physics | | | |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

| **Learning outcomes after successful termination of the module** |
|---|
| The students<br>• assess atoms in terms of their ability to form metallic, ionic, or covalent bonds.<br>• assign the proper oxidation states to the elements involved in a redox reaction and evaluate the reaction according to the electrochemical voltage series.<br>• explain the difference between an exothermic and an endothermic reaction, and the impact of the catalyst on the reaction process.<br>• calculate the standard enthalpy of reaction, as well as free enthalpy for individual molecules with the help of works of tables.<br>• calculate the resulting potential of a redox reaction as a function of the concentrations/partial pressures of the reactants ⇔ apply the Nernst equation.<br>• establish redox reaction equations for various fuel cell reactions.<br>• identify common metals and matrix materials for alkaline and acid fuel cells, as well as typical electrode and electrolyte poisons, such as CO2, CO, Cl ions.<br>• explain the basic electrochemical principle of an alkaline, a PEM fuel cell and an electrolyzer. |
| **Module Content** |
| • Atomic structure and the periodic table<br>• Bond types (covalent, ionic, metal bond)<br>• Basics of oxidation chemistry<br>• Acid-base concept<br>• Redox reactions<br>• Introduction to chemical thermodynamics and electrochemistry<br>• Electrochemistry of fuel cell types<br>• Chemistry of hydrogen |
| **Literature and other Learning Offers** |
| • G. Kickelbick, Chemie für Ingenieure, 1. Auflage, München: Addison-Wesley Verlag, 2008<br>• P. Kurzweiler, Angewandte Elektrochemie, 1. Auflage, Wiesbaden: Springer-Vieweg, 2020<br>• P. Kurzweiler, Brennstoffzellentechnik, 3. Auflage, Wiesbaden: Springer-Vieweg, 2016<br>• J. Töpler, J. Lehmann, Wasserstoff und Brennstoffzelle, 1. Auflage, Wiesbaden: Springer-Vieweg, 2014 |
| **Special Feature** |
| |

| **Module: 4** | | | |
|---|---|---|---|
| **Materials Technology 1** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** Prof. Dr. Spielfeld | | | |
| **Lecturer:** | | | |
| Prof. Dr. Spielfeld | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Materials Technology 1 (4 Semester Hours per Week) | | Seminar-type teaching | English |

| **Applicability and Study Semester:** | |
|---|---|
| Bachelor Programme Hydrogen Technologies (Compulsory Module,1st Semester) | |
| Provides the basis for module(s): | Materials Technoly 2 (10) |
| Builds on module(s): | Chemistry, Electrochemistry (3), Engineering Mechanics (5) |
| **Compulsory Conditions of Participation** | |
| none | |
| **Recommended Conditions of Participation** | |
| Chemistry, Electrochemistry (3), Engineering Mechanics (5) | |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- name different grid types of metals and represent them.
- evaluate different hardening mechanisms in metallurgy.
- identify different methods of mechanical materials testing.
- use phase diagrams: Lever rule, alloy science.
- describe the methodology of constructing phase diagrams.
- draw the iron - carbon diagram
- name fundamental structures in the Fe-C system.
- describe the processes to produce iron and steel

| **Module Content** |
|---|
| • The structure of atoms<br>• The groups of materials<br>• Crystallographic structure of metals<br>• Lattice defects: 0th, 1st, 2nd and 3rd dimension<br>• Lattice defects and hardening mechanisms<br>• Phase diagrams: Making phase diagrams<br>• Thermal analysis<br>• Basic types of phase diagrams<br>• The lever rule<br>• Basics of diffusion and heat treatment of metals<br>• Production of iron and steel<br>• The iron-carbon diagram<br>• Near-equilibrium microstructures in the Fe-C system<br>• Designation of steels<br>• Steels for use in the hydrogen context: Hydrogen pressure resistant steels<br>• Joining of metallic materials: Welding of steels and the influence of welding on the microstructure and properties (heat affected zone) |
| **Literature and other Learning Offers** |
| • Ruge, J./Wohlfahrt, H. (2013): Technologie der Werkstoffe - Herstellung, Verarbeitung, Einsatz, 9. Auflage, Springer-Vieweg.<br>• Bargel, H./Schulze, G. (Hrsg.) (2012): Werkstoffkunde, 11. Auflage, Springer-Vieweg.<br>• Berns, H./ Theisen, W.: Eisenwerkstoffe Stahl und Gusseisen, 4. Auflage, Springer.<br>• Mattes, K-J./Schneider, W.: Schweißtechnik: Schweißen von metallischen Konstruktionswerkstoffen, 6. Auflage, Hanser. |
| **Special Feature** |
| |

## Module: 5

| **Engineering Mechanics** | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** Prof. Dr. Christel | | | |
| **Lecturer:** | | | |
| Prof. Dr. Christel | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Engineering Mechanics (4 Semester Hours per Week) | | Seminar-type teaching, Exercises | English |

| **Applicability and Study Semester:** | |
|---|---|
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 1st Semester) | |
| Provides the basis for module(s): | Plants and Vessels 1 (11), Plants and Vessels 2 (22), Fluid Mdechanics (14) |
| Builds on module(s): | |

| **Compulsory Conditions of Participation** |
|---|
| none |
| **Recommended Conditions of Participation** |
| Solving of equations/inequalities, trigonometry, systems of linear equations. integral calculus |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

| Learning outcomes after successful termination of the module |
| --- |
| The students<br>• list the essential components of a mechanical substitute model (beams, rods, bearings, joints, load types, etc.), recognize the symbols in these substitute models and correctly assign, for instance, the bearing reactions or transferable internal forces.<br>• name the terms static and kinematic determinacy, describe their meaning and analyse simple mechanical systems in this respect.<br>• apply the principle of sectioning and construct suitable free-body diagrams for a given problem.<br>• write down the equilibrium conditions for a free-body diagram and solve the system of equations according to the variables sought (bearing/joint reactions, internal forces, bar/contact forces).<br>• list the essential terms and interrelationships in the field of strength theory and define them, in particular the terms stress and strain.<br>• define them, especially the terms stress and distortion.<br>• calculate the stresses and deformations for the basic load cases such as tension/compression, bending, torsion and the pressure load of boilers.<br>• analyse and optimize given designs in terms of strength verification, the problem of constraint forces in statically indeterminate systems, and the various stability cases.<br>• use the correct technical terminology in group discussions as well as in questions and assess each other regarding the correct use of technical terminology. |
| **Module Content** |
| • Addition of forces and equilibrium in central, general and spatial systems of forces<br>• Systems of rigid bodies, characteristics of selected joints and bearings, static determinacy<br>• Calculation of bearing reactions and internal forces. Calculation of centre of gravity<br>• Sectional principle, Newton's laws<br>• Calculation of stresses and deformations under tension/compression, bending and torsion<br>• Thin-walled containers under rotationally symmetrical loading Stress and distortion state, material laws, strength hypotheses<br>• Outlook on statically indeterminate systems and stability cases |
| **Literature and other Learning Offers** |
| • D. Gross, W. Hauger, J. Schröder und W. Wall, Technische Mechanik 1 (Statik), 14., aktualisierte Auflage. Berlin, Heidelberg: Springer Vieweg, 2019.<br>• D. Gross, W. Ehlers, P. Wriggers, J. Schröder und R. Müller, Formeln und Aufgaben zur Technische Mechanik 1 (Statik), 11., überarbeitete Auflage. Berlin, Heidelberg: Springer Vieweg, 2013.<br>• D. Gross, W. Hauger, J. Schröder und W. Wall, Technische Mechanik 2 (Elastostatik), 13. Auflage. Berlin Heidelberg: Springer, 2017.<br>• D. Gross, W. Ehlers, P. Wriggers, J. Schröder und R. Müller, Formeln und Aufgaben zur Technische Mechanik 2 (Elastostatik), 10., überarbeitete Auflage. Berlin, Heidelberg: Springer Vieweg, 2011.<br>• U. Gabbert und I. Raecke, Technische Mechanik für Wirtschaftsingenieure, 7., aktualisierte Auflage. München: Carl Hanser, 2013.<br>• M. Mayr, Technische Mechanik, 8. Auflage. München, Wien: Carl Hanser Verlag, 2015.<br>• O. Romberg und N. Hinrichs, Keine Panik vor Mechanik, 9. Auflage. Wiesbaden: Springer Vieweg, 2020.<br>• R. Christel: Lecture notes, video tutorials and tests, Schweinfurt: eLearning-System, 2021.<br>• Interactive simulations on the topics "equilibrium" and "vector addition" on the PhET website, e.g.. https://phet.colorado.edu/en/simulation/forces-and-motion-basics . |
| **Special Feature** |
| |

| **Module: 6** | | | |
|---|---|---|---|
| **Computer Science, Digitalisation, Automation** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** N.N. | | | |
| **Lecturer:** | | | |
| N.N | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Programming (1.75 Semester Hours per Week) | | Seminar-type teaching, Exercises | English |
| Digitalisation in Hydrogen Technology (1.75 Semester Hours per Week) | | Seminar-type teaching, Exercises | English |
| Project Work (0.5 Semester Hours per Week) | | Procect | English |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 1st Semester) | | | |
| Provides the basis for module(s): | Application Project (33) | | |
| Builds on module(s): | | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| School knowledge mathematics, physics, programming | | | |
| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** | |
| Project work consisting of project-accompanying attestation, final presentation and project documentationf | Examination during the semester | English | |
| The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester. | | | |

| **Learning outcomes after successful termination of the module** |
|---|
| The students<br>• state basic terms and contents of information technology architectures, software tools and their fields of application.<br>• decide based on the given task which solution approaches are best qualified for digitization.<br>• analyse the significance and optimization potential of digitization measures in hydrogen technology based on the use of connected sensors.<br>• tate the importance of communication, independent knowledge acquisition and social interaction.<br>• create their own programme codes to solve various problems and use the debugger for troubleshooting.<br>• name the different possibilities of graphical representation, choose the appropriate one for the task and use it for the presentation of results.<br>• evaluate the results about their plausibility, present them clearly and explain them vocally.<br>• plan the individual tasks and define a division of labour. |
| **Module Content** |
| • Refer to the description of the individual courses |
| **Literature and other Learning Offers** |
| • E. A. Hartmann, Digitalisierung souverän gestalten, Innovative Impulse im Maschinenbau, Springer Vieweg, 2021. Z.b. https://link.springer.com/book/10.1007/978-3-662-62377-0<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| Dual students work on a task in the project phase in cooperation with the practice partner |

| **Course** |
|---|
| **Programming** |
| **Lecturer:** |
| N.N |
| **Content** |
| • Basics of programming<br>• Graphical representation of functions<br>• Data import and export<br>• Basics of debugging |
| **Special Feature** |
| |

| **Courses** |
|---|
| **Digitalisation in Hydrogen Technology/Project Work** |
| **Lecturer:** |
| N.N. |
| **Content** |
| • Independent solution of a task from the technical environment of hydrogen technology within the framework of a project.<br>• Basics of digitalisation in hydrogen technology<br>• Basics of project work in software development |
| **Special Feature** |
| Dual students work on a task in the project phase in cooperation with the practice partner |

| **Module: 7** | | | |
|---|---|---|---|
| Engineering Mathematics 2 | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** N.N. | | | |
| **Lecturer:** | | | |
| N.N. | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Engineering Mathematics 2 (4 Semester Hours per Week) | | Seminar-type teaching, Exercises | English |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 2nd Semester) | | | |
| Provides the basis for module(s):<br>Builds on module(s): | Thermodynamics 2 (8), Electrical Engineering (12)<br>Engineering mathematics 1 (1) | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| Engineering Mathematics 1 (1) | | | |
| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** | |
| Written exam | 90 to 120 min | English | |
| The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester. | | | |

| **Learning outcomes after successful termination of the module** |
|---|
| The students<br>• characterise the local behaviour of functions of several variables with the help of differential calculus.<br>• solve application problems with two- and three-dimensional integrals with the use of Cartesian, spherical or cylindrical coordinates in mechanics (centre of gravity, surface moments, moments of inertia etc.).<br>• evaluate existence and uniqueness of solutions to given initial value problems using the theorems of Peano and Picard-Lindelöf.<br>• classify differential equations and select the solution method based on this.<br>• solve linear DSE with constant coefficients in the homogeneous and inhomogeneous case (characteristic polynomial, variation of constants, approach method) in physical-technical problems (mechanics, electrical engineering).<br>• state the concept of a DSE system and name its geometric interpretation as well as the connection between DSE systems of 1st order and DSE of higher order.<br>• calculate intrinsic values and intrinsic vectors of quadratic matrices.<br>• state the general concept of a parameterised curve as well as the related concepts of velocity vector, acceleration vector and arc length.<br>• state the forms of representation of plane curves and calculate tangent, normal, curvature and arc length. |
| **Module Content** |
| • Multidimensional differential calculus<br>o Partial derivative<br>o Gradient, Jacobian matrix<br>o Directional derivative<br>o Schwarz's theorem<br>o Multidimensional Taylor polynomials<br>o Total differential<br>o Tangential plane<br>o Implicit differentiation<br>o Hessian matrix<br>• Multidimensional integral calculus<br>o Integration over multidimensional domains<br>o Coordinate systems and associated transformations<br>o Fubini's theorem<br>• Ordinary differential equations<br>o Concept and meaning<br>o Direction fields<br>o Existence and uniqueness<br>o Separable DSE<br>o Linear DSE<br>o Linear DSE with constant coefficients<br>o DSE systems<br>o Eigenvalues and eigenvectors<br>o Linear DSE systems with constant coefficients<br>• Curves<br>o Basic terms (tangent, arc length, curvature)<br>o Plane curves |

| Literature and other Learning Offers |
| --- |
| • P. Stingl, *Mathematik für Fachhochschulen.* Technik und Informatik. Hanser, 2009<br>• A. Fetzer und H. Fränkel, *Mathematik 1.* Berlin: Springer, 2007<br>• A. Fetzer und H. Fränkel, *Mathematik. Lehrbuch für Fachhochschulen, Band 2.* Berlin: Springer, 2012<br>• K. Meyberg und P. Vachenauer, *Höhere Mathematik 1.* Berlin:Springer, 2003<br>• L. Papula, *Mathematik für Ingenieure und Naturwissenschaftler, Band 1.* Wiesbaden: Springer Vieweg, 2014 |
| **Special Feature** |
| |

## Module: 8

### Thermodynamics 2

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** N.N.

**Lecturer:**

N.N.

| Associated Course | Study Modes | Language |
|---|---|---|
| Thermodynamics 2 (4 Semester Hours per Week) | Seminar-type Teaching, Exercises | English |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 2nd Semester)

| | |
|---|---|
| Provides the basis for module(s): | Process Design and Simulation (17), Hydrogen Safety (18), Hydrogen Production (19), Fuel Cell (20), Hydrogen Storage, Transport and Distribution (21), Plants and Vessels 2 (22), Computational Fluid Dynamics (26), Chemical Conversion with Hydrogen (27), Plant Operation (28), Application Project (33) |
| Builds on module(s): | Engineering Mathematics 1 (1), Thermodynamics 1 (2) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

School knowledge advanced mathematics and physics

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam or portfolio | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

| **Learning outcomes after successful termination of the module** |
| --- |
| The students<br>• explain the basic relationships of thermodynamics and heat transfer using sketches and diagrams and apply the basic equations and relationships to exercises and technical problems.<br>• model and calculate thermodynamic cyclic processes using the working tool "real substance with phase change".<br>• Model thermodynamic and thermal engineering problems, solve them analytically and critically question the solutions.<br>• suggest improvements to processes and machines based on an evaluation.<br>• evaluate the influence of boundary conditions, process variables and interactions.<br>• solve complex thermodynamic and thermotechnical problems from engineering practice by separating them into sub-questions and solving them.<br>• evaluate plants and technical systems.<br>• develop new systems, plants, components and parts thermodynamically and thermotechnically correctly. |
| **Module Content** |
| • Repetition and elaboration of selected basics of thermodynamics<br>- Conservation laws of thermodynamics, state variables of substances and fundamental variables,<br>- Behaviour of ideal and real substances<br>- Relationships between heat, work and energy<br>• Introduction to changes of state of real substances under real conditions<br>• Introduction to the thermodynamics of mixtures using the example of humid air<br>• Left- and right- running circular processes with the working medium "real substance with phase change" (Clausius-Rankine- and cold steam process)<br>• Introduction to the structure and mode of action of power and working machines and to the behaviour of machines under real conditions<br>• Basics of heat transfer<br>- Stationary and transient heat conduction<br>- Heat transfer and convection<br>- Heat transfer by radiation<br>- Heat transfer<br>• Applications of the fundamentals of heat transfer using problems from everyday engineering practice, idealisation of real heat engineering problems<br>• Introduction to hydrogen technology<br>- Introduction to the production of hydrogen using the example of PEM electrolysers<br>- Introduction to the energetic use of hydrogen using the example of PEM fuel cells |

| Literature and other Learning Offers |
| --- |
| • H. D. Baehr und S. Kabelac, *Thermodynamik: Grundalgen und technische Anwendungen,* 16., aktualisierte Auflage. Berlin, Heidelberg: Springer Vieweg, 2016.<br>• G. Cerbe und G. Wilhelms, *Technische Thermodynamik: Theoretische Grundlagen und praktische Anwendungen,* 18., überarbeitete Auflage. München: Hanser, 2017.<br>• H. D. Baehr und K. Stephan, *Wärme- und Stoffübertragung,* 8. Auflage. Berlin: Springer-Verlag, 2013.<br>• H. Herwig, C. Kautz und a. Moschallski, *Technische Thermodynamik: Grundlagen und Anleitung zum Lösen von Aufgaben,* 2., überarbeitete Auflage. Wiesbaden: Springer Vieweg, 2016.<br>• W. Wagner, *Wärmeübertragung,* 4. Auflage. Würzburg: Vogel Fachbuch Verlag, 2011.<br>• P. Kurzweil, *Brennstoffzellentechnik,* 3. Auflage. Berlin: Springer-Verlag, 2016.<br>• G. Reich, *Regenerative Energietechnik,* 2. Auflage. Berlin: Springer-Verlag, 2018.<br>• Course materials in the THWS e-Learning system |
| **Special Feature** |
| |

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## Module: 9

### Physics

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** N.N.

**Lecturer:**
N.N.

| Associated Course | Study Modes | Language |
|---|---|---|
| Physics (4 Semester Hours per Week) | Seminar-type Teaching, Exercises, Lab course | English |

**Applicability and Study Semester:**
Bachelor's degree programme in hydrogen technology (compulsory module, 2nd semester)
Bachelor's degree programme in mechatronics (compulsory module, 1st semester)
Bachelor of Mechanical Engineering (compulsory module, 3rd semester)

| | |
|---|---|
| Provides the basis for module(s): | Thermodynamics 2 (8), Practical Module (32), Bachelor Thesis (36) |
| Builds on module(s): | Engineering Mathematics 1 (1) |

**Compulsory Conditions of Participation**
none

**Recommended Conditions of Participation**
School knowledge physics

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**
The students
- list the basic physical concepts of the topics "Waves", "Quantum Physics" and "Statistical Thermodynamics".
- state the essential basic equations of the above-mentioned topics.
- perform calculations based on these equations.
- apply the quantitative relationships expressed by the equations to technical systems.
- explain the significance of the basic terms and equations by means of example applications.

| Module Content |
| --- |
| • General properties of waves in linear media (superposition principle, Huygens principle)<br>• Wave functions of harmonic waves in one and multi-dimensional systems<br>• Interference effects in the superposition of waves (incl. refraction of waves)<br>• Natural oscillations in one-dimensional systems<br>• Physical description of sound waves and quantification of loudness oriented to physiological perception<br>• Fundamentals of the propagation of electromagnetic waves and their interaction with matter<br>• Description of electromagnetic waves in the particle image (photons)<br>• Fundamentals of the structure of atoms and quantised emission and absorption of energy<br>• Significance of energy quantization for thermal radiation (black body)<br>• Basics of statistical thermodynamics (atomistic derivation of the equation of state of the ideal gas, diffusion process, entropy as a statistical quantity) |
| **Literature and other Learning Offers** |
| • E. Hering, R. Martin und M. Stohrer, Physik für Ingenieure, 12. Auflage. Berlin: Springer Vieweg, 2016.<br>• P. A. Tipler, Physik für Wissenschaftler und Ingenieure, 7. Auflage, Berlin: Springer Spektrum, 2015.<br>• J. Rybach, Physik für Bachlors, 4. Auflage, München: Fachbuchverlag Leipzig, 2019.<br>• H. Kuchling, Taschenbuch der Physik, 21. Auflage, München, Fachbuchverlag Leipzig, 2014. |
| **Special Feature** |
| |

| **Module: 10** | | | |
|---|---|---|---|
| **Materials Technology 2** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** Prof. Dr. Spielfeld | | | |
| **Lecturer:** | | | |
| Prof. Dr. Spielfeld | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Materials Technology 2 (4 Semester Hours per Week) | | Seminar-type Teaching, Exercises | English |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module,2nd Semester) | | | |
| Provides the basis for module(s): | Hydrogen Safety (18) | | |
| Builds on module(s): | Materials Technology 1 (4) | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| Materials Technolgy 1 (4), Physics (9), Engineering Mechanics (5) | | | |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Written exam | 90 min to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- select the heat treatment for the use of steels and assess its influence on the manufacture of plants and vessels.
- select the mechanical-technological material testing methods for applications.
- list the most important non-ferrous metals and non-metallic materials.
- plan corrosion protection measures.
- describe the most important mechanisms of hydrogen embrittlement.
- evaluate the influence of fatigue stresses on components.
- list the basics of damage analysis.
- describe measures to prevent damage during production and operation of plants.

| Module Content |
|---|
| • Ferrous materials<br>• Heat treatment of steels (basics)<br>• Processes of heat treatment.<br>• Mechanical-technological material testing<br>• Casting: steel and cast iron<br>• Corrosion and corrosion protection<br>• Special mechanisms of hydrogen embrittlement<br>• Fiber composites and special manufacturing processes<br>• Dynamic component loading: materials and fatigue<br>• Materials databases<br>• Plastics and the environment, and the materials cycle<br>• Interactions between choices of materials and manufacturing processes<br>• Calculation of component costs |
| **Literature and other Learning Offers** |
| • Ruge, J./Wohlfahrt, H. (2013): Technologie der Werkstoffe - Herstellung, Verarbeitung, Einsatz, 9. Auflage, Springer-Vieweg.<br>• Bargel, H./Schulze, G. (Hrsg.) (2012): Werkstoffkunde, 11. Auflage, Springer-Vieweg.<br>• Berns, H./ Theisen, W.: Eisenwerkstoffe Stahl und Gusseisen, 4. Auflage, Springer. |
| **Special Feature** |
| |

# Module: 11

## Plants and Vessels 1

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Prof. Dr. Mengelkamp

**Lecturer:**

Dipl. -Ing. Benitz, Prof. Dr. Mengelkamp

| Associated Course | Study Modes | Language |
|---|---|---|
| Plants and Vessels 1 (4 Semester Hours per Week) | Seminar-type Teaching, Exercises, Lab course | English |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 2$^{nd}$ Semester)

| | |
|---|---|
| Provides the basis for module(s): | Plants and Vessels 2 (22) |
| Builds on module(s): | Engineering Mechanics (5) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

Solving of equations/inequalities, trigonometry, systems of linear equations. integral calculus

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- list and define the essential terms and relationships in the field of strength theory, in particular the terms stress and distortion.
- calculate the stresses and deformations for plane stress conditions.
- analyse and optimize given constructions regarding the strength verification.
- dimension and design components and verify strength.
- list manufacturing processes of vessels and evaluate them with reference to strength.
- use the essential contents of the Pressure Equipment Directive and current DIN standards.
- analyse and evaluate new scientific findings.
- communicate with other specialists in vessel construction.
- are aware of their responsibility to design and calculate pressure vessels safely.
- describe the effects of calculation, planning and commissioning errors on occupational safety and thus on society.

| Module Content |
| --- |
| • Calculation of stresses and deformations in flat stress states<br>• stress and distortion states, strength hypotheses, material laws<br>• Thin-walled rings and vessels under rotationally symmetrical loading<br>• Introduction to the pressure equipment directive and construction regulations<br>• construction elements in pressure vessel designs<br>• Requirements for pressure vessels (design, materials, fabrication, operation, maintenance, testing and safety)<br>• Permissible stresses and stress categories<br>• Design of pressure-retaining walls (spherical and cylindrical shells, flat and dished heads)<br>• Manufacturing processes in plant and vessel construction<br>• Consideration of connection loads<br>• Execution of stability verifications |
| **Literature and other Learning Offers** |
| • Gross, Hauger, Schröder, Wall, Technische Mechanik 2, Elastostatik, 13. Auflage, Springer Verlag, 2017<br>• Mayr, M., Technische Mechanik, 8. Auflage, Hanser Verlag, 2015<br>• Holzmann, Meyer, Schumpich, Technische Mechanik Festigkeitslehre, 13. Auflage, Springer Verlag, 2018<br>• Gabbert und Raecke, Technische Mechanik, 7. Auflage, Hanser Verlag, 2013<br>• Titze, H., Wilke, H-P., Groß, K., Elemente des Apparatebaues, Grundlagen Bauelemente Apparate, 3. Auflage Springer Verlag, 1992<br>• Schwaigerer, S., Mühlenbeck, G., Festigkeitsberechnung im Dampfkessel- Behälter- und Rohrleitungsbau, 5. Auflage Springer Verlag 1997<br>• Wagner, W., Festigkeitsberechnungen im Apparate- und Rohrleitungsbau, 8. Auflage Vogel Fachbuch Verlag 2012, Kamprath-Reihe<br>• DIN EN 13445-3 and AD2000 leaflets<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

# Module: 12

## Electrical Engineering

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** N.N.

**Lecturer:**

N.N.

| Associated Course | Study Modes | Language |
|---|---|---|
| Electrical Engineering (4 Semester Hours per Week) | Seminar-type Teaching, Exercises | English |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 2nd Semester)
Bachelor of Mechanical Engineering (compulsory module, 1st semester)

| | |
|---|---|
| Provides the basis for module(s): | None |
| Builds on module(s): | None |

**Compulsory Conditions of Participation**

None

**Recommended Conditions of Participation**

School knowledge mathematics and physics

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- use correct technical terminology in group discussions as well as in questions and exercises.
- analyse given electrical circuits to determine voltages and currents in the components.
- calculate the characteristic curves of DC and AC motors and apply the individual methodical steps for calculating and analyzing electrical equivalent circuits for this purpose.
- describe transient processes of coils and capacitors.
- evaluate the availability of individual motor types for different drives.
- evaluate processes and real technical systems about their suitability and quality and suggest improvements.
- analyse tasks from engineering practice, develop sub-questions from them, make reasonable, physically plausible assumptions (e.g. in the case of incomplete data) and solve the sub-questions.

| Module Content |
|---|
| • Direct current technology<br>Ohm's law, Kirchhoff's rules, star-delta conversion, superposition theorem, real sources<br>• Electric fields<br>Electric potential, Gaussian theorem of electrical engineering, capacitors<br>• Magnetic fields<br>Lorentz force, law of induction<br>• Alternating current technology<br>Characteristic values, pointer representation, power in the alternating current network<br>• Machines<br>Three-phase current, transformer, direct current motors, asynchronous motor |
| **Literature and other Learning Offers** |
| • G. Haagman, Grundlagen der Elektrotechnik. Das bewährte Lehrbuch für Studierende der Elektrotechnik und anderer technischer Studiengänge ab 1. Semester, 15., durchgesehene und korrigierte Auflage. Wiebelsheim: Aula-Verlag, 2011<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

# 4. Second Study Period – advanced modules, 3rd to 5th semester

| **Module: 13** | | | |
|---|---|---|---|
| **Renewable Energy and Energy Industry** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** N.N. | | | |
| **Lecturer:** | | | |
| N.N. | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Renewable Energy (2 Semester Hours per Week) | | Seminar-type Teaching, Exercises | English |
| Fundamentals of Energy Technology and Economy (2 Semester Hours per Week) | | Seminar-type Teaching, Exercises | English |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 3rd Semester) | | | |
| Provides the basis for module(s): | Hydrogen Production (19), Hydrogen Storage, Transport and Distribution (21), Plant Operation (28), Application Project (33), Bachelor Thesis (36) | | |
| Builds on module(s): | Thermodynamics 1 (2), Thermodynamics 2 (8), Physics (9), Electrical Engineering (12) | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| Fundamentals of thermodynamic and physics | | | |
| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** | |
| Written exam | 90 to 120 min | English | |
| The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester. | | | |

| Learning outcomes after successful termination of the module |
|---|
| The students<br>• use sketches and diagrams to explain the structure, basic function and operation of renewable energy systems.<br>• describe the structure and operation of supply networks and systems (electricity, natural gas, hydrogen).<br>• apply the appropriate equations and relationships to model and calculate energy systems.<br>• critically question the solutions to energy engineering problems.<br>• solve practical problems in connection with the operation and design of renewable energy systems.<br>• evaluate plants and technical systems and develop new systems, plants, components and parts.<br>• explain the system services in power supply systems.<br>• describe the analogies between electricity and gas supply systems.<br>• explain the difficulties of hydrogen injection into natural gas supply systems. |
| **Module Content** |
| Refer to the description of the individual courses |
| **Literature and other Learning Offers** |
| • H. D. Baehr und S. Kabelac, Thermodynamik: Grundlagen und technische Anwendungen, 16., aktualisierte Auflage. Berlin, Heidelberg: Springer Vieweg, 2016.<br>• G. Reich, Regenerative Energietechnik, 2. Auflage. Berlin: Springer-Verlag, 2018.<br>• V. Wesselak et. al., Regenerative Energietechnik, 3. Auflage. Berlin: Springer-Verlag, 2016.<br>• R. Zahoransky (Hrsg.), Energietechnik, 8. Auflage. Berlin: Springer-Verlag, 2019.<br>• J. Unger et. al., Alternative Energietechnik, 6. Auflage. Berlin: Springer-Verlag, 2020.<br>• K. Strauß, Kraftwerkstechnik, 7. Auflage. Berlin: Springer-Verlag, 2017.<br>• L. Müller, Handbuch der Elektrizitätswirtschaft, 2. Auflage. Berlin: Springer-Verlag, 2001.<br>• K. Pfleiderer, Strömungsmaschinen, 6. Auflage. Berlin: Springer-Verlag, 2004.<br>• W. Wagner, Wärmeübertragung, 4. Auflage. Würzburg: Vogel Fachbuch Verlag, 2011.<br>• P. Kurzweil, Brennstoffzellentechnik, 3. Auflage. Berlin: Springer-Verlag, 2016.<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

| **Course** |
|---|
| **Renewable Energy** |
| **Lecturer:** |
| N.N. |
| **Content** |
| • Potentials for the use of renewable energy sources (photovoltaics, solar thermal energy, wind power, hydropower, geothermal energy)<br>• Basics and design principles of systems for the use of regenerative energy sources (photovoltaics, solar thermal energy, wind power, hydropower, geothermal energy)<br>• Basic knowledge of the function and operation of energy plants for the use of regenerative energy sources (photovoltaics, solar thermal energy, wind power, hydropower, geothermal energy)<br>• Basic principles of construction and design of the required components |
| **Special Feature** |
| |

| **Courses** |
|---|
| **Fundamentals of Energy Technology and Economy** |
| **Lecturer:** |
| N.N. |
| **Content** |
| • Design of energy supply systems (electricity, natural gas, hydrogen)<br>• Operation of energy supply systems (electricity, natural gas, hydrogen)<br>• Economic evaluation and price models in energy supply systems |
| **Special Feature** |
| |

<table>
<tr><td colspan="4">Module: 14</td></tr>
<tr><td colspan="4">Fluid Mechanics</td></tr>
<tr><td>Duration</td><td>Semester</td><td>Workload</td><td>ECTS-Credit Points</td></tr>
<tr><td>1 Semester</td><td>Winter Semester</td><td>Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation</td><td>5</td></tr>
<tr><td colspan="4">Module Responsibility: N.N.</td></tr>
<tr><td colspan="4">Lecturer:</td></tr>
<tr><td colspan="4">N.N.</td></tr>
<tr><td colspan="2">Associated Course</td><td>Study Modes</td><td>Language</td></tr>
<tr><td colspan="2">Fluid Mechanics (4 Semester Hours per Week)</td><td>Seminar-type Teaching, Exercises</td><td>English</td></tr>
<tr><td colspan="4">Applicability and Study Semester:</td></tr>
<tr><td colspan="4">Bachelor Programme Hydrogen Technologies (Compulsory Module, 2nd Semester)<br>Bachelor Programme Mechanical Engineering (Compulsory Module, 3rd Semester)<br>Bachelor Programme Technical Mathematics (Specialised Elective Technology/Computer Science 5th Semester)<br>Bachelor Programme Technical Mathematics (Compulsory Module in Study Version Simulation in Mechanical Engineering, 4th Semester)</td></tr>
<tr><td colspan="2">Provides the basis for module(s):</td><td colspan="2">Computational Fluid Dynamics (26), Process Design and Simulation (17), Hydrogen Storage, Transport and Distribution (21), Plants and Vessels 2 (22), Systematical Design of Plants (23)</td></tr>
<tr><td colspan="2">Builds on module(s):</td><td colspan="2">Engineering Mechanics (5), Thermodynamics 1 (2), Engineering Mathematics 1 (1), Engineering Mathematics 2 (7)</td></tr>
<tr><td colspan="4">Compulsory Conditions of Participation</td></tr>
<tr><td colspan="4">none</td></tr>
<tr><td colspan="4">Recommended Conditions of Participation</td></tr>
<tr><td colspan="4">Fundamentals of Engineering Mechanics (5), Thermodynamics 1 (2), Engineering Mathematics 1 (1), Engineering Mathematics 2 (7)</td></tr>
<tr><td>Mode of examination / Requirements for the award of credit points</td><td colspan="2">Duration of the examination</td><td>Language of the examination</td></tr>
<tr><td>Written exam</td><td colspan="2">90 to 120 min</td><td>English</td></tr>
<tr><td colspan="4">The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.</td></tr>
</table>

| **Learning outcomes after successful termination of the module** |
|---|
| The students<br>• create control volumes, define current filaments and apply conservation of mass and momentum as well as Bernoulli's equation to them. In doing so, they assess the consequences of necessary simplifications when using these laws.<br>• state the physical causes for peculiarities in compressible flow and calculate compressible flow processes (gas dynamics) in isentropic flow and for vertical compression shocks.<br>• state the differences between frictionless idealized flow and frictional flow.<br>• state the background of the similarity theory, select suitable ratios for the realization of fluid mechanical similarity or for scale transfer and calculate target quantities such as drag forces with it.<br>• state the physical causes of laminar-turbulent transition and describe properties of turbulent flow.<br>• state the cause of flow separation and assess flow processes about the danger of flow separation.<br>• calculate pressure losses in piping systems with different internals and develop solution strategies for non-linear relationships.<br>• state the procedure for discretizing and solving the fluid mechanical conservation equations using the finite volume method, specify common grid types and select suitable boundary conditions. |
| **Module Content** |
| • Hydrostatics: pressure, forces on flat surfaces, hydrostatic uplift<br>• Conservation of mass, Bernoulli equation and momentum theorem<br>• Gas dynamics: isentropic flow, Laval nozzle, compression shock<br>• Frictional flow, Couette flow, Poiseuille flow<br>• Navier-Stokes equations, similarity theory<br>• Laminar-turbulent flow, critical Reynolds number<br>• flow around objects, flow separation<br>• Pressure loss calculation in piping systems with internals<br>• Computational Fluid Dynamics (CFD): finite volume methods, grid topologies, boundary conditions |
| **Literature and other Learning Offers** |
| • H. Sigloch, Technische Fluidmechanik, 10. Auflage. Berlin, Heidelberg: Springer, 2017.<br>• W. Bohl, W. Elmendorf, Technische Strömungslehre, 15. Auflage, Würzburg: Vogel, 2014.<br>• S. Bschorer, Technische Strömungslehre, 11. Auflage, Wiesbaden: Springer, 2018.<br>• H.C. Kuhlmann, Strömungsmechanik, 2. Auflage, Hallbergmoos: Pearson, 2014.<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

## Module: 15

### Control and Feedback Control Systems in Hydrogen Plants

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Prof. Dr. Kharitonov

**Lecturer:**

Prof. Dr. Kharitonov

| Associated Course | Study Modes | Language |
|---|---|---|
| Control and Feedback Control Systems in Hydrogen Plants (3 Semester Hours per Week) | Seminar-type Teaching, Exercises | German |
| Control and Feedback Control Systems in Hydrogen Plants (1 Semester Hour per Week) | Lab course | German |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 3rd Semester)

| | |
|---|---|
| Provides the basis for module(s): | Application Project (33), Technical Lab Training (34), Bachelor Thesis (36) |
| Builds on module(s): | Engineering Mathematics 1 (1), Engineering Mathematics 2 (7), Physics (9), Electrical Engineering (12) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

School knowledge advanced mathematics, physics

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- list the essential connections of a controlled system for relevant hydrogen technology applications (storage, transport and distribution).
- describe the structure and operation of a programmable logic controller, including plant safety aspects for hydrogen.
- classify the behavior of elementary control loop elements and count their system characteristic parameters.
- evaluate the control loop behavior about stability, dynamics and control deviation.
- create a simulation model for simple control loop systems and evaluate the simulation results.
- select a suitable controller for simple control loops using controller design methods and deterine the controller parameters.
- apply the acquired knowledge to practical examples, also in an exercise, e.g. in the computer room, using simulation programmes such as MATLAB/Simulink.

**Module Content**

| |
|---|
| Refer to the description of the individual courses |
| **Literature and other Learning Offers** |
| • Dorf, R.: Moderne Regelungstechnik, Pearson Studium, München, 10. überarbeitete Auflage, 2006<br>• Föllinger, O.: Regelungstechnik – Einführung in die Methoden und ihre Anwendung, VDE-Verlag, Berlin, 11. völlig neu bearbeitete Auflage, 2013<br>• Eichlseder, H., Klell, M.: Wasserstoff in der Fahrzeugtechnik, Springer Vieweg, Wiesbaden, 3. überarbeitete Auflage, 2012<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| Dual students work on a task in the laboratory internship in consultation with the practice partner |

| **Course** |
|---|
| **Control and Feedback Control Systems in Hydrogen Plants (Seminar-type Teaching)** |
| **Lecturer:** |
| Prof. Dr. Kharitonov |
| **Content** |
| • Difference between control and regulation<br>• Components of a control system and their safety aspects for hydrogen technology<br>• Control loop elements and their modelling in the time and frequency domain<br>• Control loop behaviour (stability, dynamics, steady-state accuracy)<br>• Control loop design procedures<br>• Simulation of control loops using MATLAB/Simulink |
| **Special Feature** |
| |

| **Course** |
|---|
| **Control and Feedback Control Systems in Hydrogen Plants (Lab course)** |
| **Lecturer:** |
| Prof. Dr Kharitonov |
| **Content** |
| • Simulation of control loops using MATLAB/Simulink<br>• Design, set-up, start-up and operation of a control system in the laboratory<br>• Estimation of the control performance<br>• Writing of a technical report<br>• Verbal presentation of the results |
| **Special Feature** |
| Dual students work on a task in the laboratory internship in consultation with the practice partner |

# Module: 16

## Measuring in Hydrogen Plants

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Prof. Dr. Wilke

**Lecturer:**

Prof. Dr. Wilke, Prof. Dr. Missbach

| Associated Course | Study Modes | Language |
|---|---|---|
| Measuring in Hydrogen Plants (3 Semester Hours per Week) | Seminar-type Teaching, Exercises | German |
| Measuring in Hydrogen Plants (1 Semester Hour per Week) | Lab course | German |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 3rd Semester)

| | |
|---|---|
| Provides the basis for module(s): | Plants and Vessels 2 (22), Systematic Design of Plants (23), Application Project (33), Technical Lab Training (34), Bachelor Thesis (36) |
| Builds on module(s): | Engineering Mathematics 1 (1), Engineering Mathematics 2 (7), Electrical Engineering (12) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

School knowledge advanced mathematics, physics

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

| Learning outcomes after successful termination of the module |
|---|
| The students<br>• specify the fundamentals of process engineering measurement technology.<br>• plan, design and build measuring systems to record measured variables in hydrogen plants.<br>• analyse process engineering plants as well as proposed measurement systems in order to evaluate and optimize them for the specific application purpose in the plant.<br>• assess the uncertainty of the measurement results obtained.<br>• form teams to work on and solve a practical task.<br>• assess their own role in the team and reflect on their own behavior.<br>• prepare a technical report in which the solution to the practical task is described in a way that is comprehensible to third parties.<br>• interpret the solution developed and present their conclusions in a short verbal presentation. |
| **Module Content** |
| Refer to the description of the individual courses |
| **Literature and other Learning Offers** |
| • J. Hoffmann, Taschenbuch der Messtechnik, 7. Auflage. München: Hanser, 2015.<br>• M. Bantel, Grundlagen der Messtechnik. München: Hanser, 2000.<br>• G. Strohrmann, Messtechnik im Chemiebetrieb,10. Auflage, München: Deutscher Industrieverlag, 2004<br>• DIN 1319-1:1995-01 Grundlagen der Messtechnik, Teil 1: Grundbegriffe<br>• DIN 1319-2:2005-10 Grundlagen der Messtechnik, Teil 2: Begriffe für Messmittel<br>• DIN 1319-3:1996-05 Grundlagen der Messtechnik, Teil 3: Auswertung von Messungen einer einzelnen Meßgröße, Meßunsicherheit<br>• DIN 1319-4:1999-02 Grundlagen der Messtechnik, Teil 4: Auswertung von Messungen; Meßunsicherheit<br>• DIN V ENV 13005 Leitfaden zur Angabe der Unsicherheit beim Messen; Deutsche Fassung ENV 13005:1999<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| Dual students work on a task in the laboratory internship in consultation with the practice partner |

| Course |
|---|
| **Measuring in Hydrogen Plants (Seminar-type Teaching)** |
| **Lecturer:** |
| Prof. Dr. Wilke |
| **Content** |
| • Basic metrological terms, error calculation, measurement inaccuracies, transducers<br>• Measurement system technology, digital measurement data acquisition, digital measurement data processing<br>• Measurement of process variables<br>• Sensors for gas identification<br>• Sensor monitoring<br>• Redundant measurement of safety-relevant variables |
| **Special Feature** |

| |
|---|
| **Course** |
| **Measuring in Hydrogen Plants (Lab course)** |
| **Lecturer:** |
| Prof. Dr Missbach, Prof. Dr. Wilke |
| **Content** |
| • Design, construction and operation of a measuring system in the laboratory for the acquisition of process-engineering measurands.<br>• Estimation of the measurement inaccuracies<br>• Estimation of the validity of the results<br>• Writing of a technical report<br>• Oral presentation of the results |
| **Special Feature** |
| |

| Module: 17 | | | |
|---|---|---|---|
| **Process Design and Simulation** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Winter Semester | Total Workload: 150 h<br>100 contact hours (2 semester periods per week + block course)<br>35 hours self study<br>15 hours exam preparation | 5 |
| **Module Responsibility:** Prof. Dr. Renner | | | |
| **Lecturer:** | | | |
| Dr. Rarey, Prof. Dr. Renner | | | |
| **Associated Courses** | | **Study Modes** | **Language** |
| Process Design and Simulation (2 Semester Hours per Week) | | Seminar-type Teaching, Exercises | German |
| Process Design and Simulation with CHEMCAD (Block Course 2 Semester Hours per Week)) | | Seminar-type Teaching, Exercises, Lab course | German/English |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 3rd Semester) | | | |
| Provides the basis for module(s): | Hydrogen Production (19), Hydrogen Storage, Transport and Distribution (21), Plant Operation (28), Application Project (33), Bachelor Thesis (36) | | |
| Builds on module(s): | Thermodynamics 1 (2), Thermodynamics 2 (8), Physics (9) | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| Fundamentals of Thermodynamics and Physics | | | |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Portfolio Examination | During the semester | German/English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

| **Learning outcomes after successful termination of the module** |
|---|
| The students<br>• explain special numerical methods in process simulation.<br>• describe the basics of different methods and the factors influencing these methods.<br>• analyse technical problems, simplify them if necessary or break them down into individual basic operations so that a solution is possible with a software tool.<br>• use a software package for chemical process simulation to solve the technical problems, including entering parameters, carrying out the process simulation and evaluating the results.<br>• design various components in terms of process technology (e.g. distillation column, heat exchanger, piping systems)<br>• carry out sensitivity analyses.<br>• develop their own strategies for analysing and understanding the often-complex behaviour of chemical-technical processes and for solving problems. |
| **Module Content** |
| Refer to the description of the individual courses |
| **Literature and other Learning Offers** |
| • LearnChemE.com<br>• CHEMCAD-Help<br>• Kleiber, Process Engineering: Addressing the Gap between Study and Chemical Industry<br>• Gmehling et al., Chemische Thermodynamik für die Prozesssynthese<br>• P. Stephan et al., Thermodynamik, Band 2: Mehrstoffsysteme und chemische Reaktionen, 15. neu bearbeitete Auflage, Berlin-Heidelberg: Springer, 2010<br>• A. Heintz, Thermodynamik der Mischungen, Berlin: Springer, 2017<br>• K. Sattler, H. J. Feindt, Thermal Separation Processes, Weinheim: VCH, 1995<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

| **Course** |
|---|
| **Process Design and Simulation** |
| **Lecturer:** |
| Prof. Dr. Renner |
| **Content** |
| • Fundamentals of thermodynamics of mixtures<br>• Fundamentals of thermal process engineering |
| **Special Feature** |
| |

| Courses |
| --- |
| **Block Course Process Design and Simulation with CHEMCAD** |
| **Lecturer:** |
| Dr. Rarey |
| **Content** |

- Overview of the structure and use of a chemical process simulator
    - Parameter input
    - Performing the calculation and solving any convergence problems
    - Viewing the calculation results
- Fundamentals of Chemical Thermodynamics
    - Methods for calculating the pure substance and mixture behaviour and the required substance properties
    - Input of own components and regression of model parameters on measured data (pure substance vapour pressures, vapour-liquid equilibria)
    - Data sources and estimation methods
- Special numerical methodologies in process simulation
    - Sensitivity studies
    - Optimisation
    - Numerical controller
    - Adaptation to process data
- Distillation
    - Concepts (equilibrium stages (McCabe-Thiele) and mass transfer (rate based))
    - Hydrodynamic design (sizing, costing)
    - Design of a batch distillation
    - Separation of azeotropic mixtures (extractive and azeotropic rectification)
    - Residue curves and column balances
- Dynamic simulation
    - Level control in a tank (PID controller)
    - Control of a distillation column (column pressure, profile, ...)
- Chemical reactors
    - Basic operations
    - Batch reactor
    - Regression of kinetic parameters to batch results
    - Reactive rectification
- Heat exchanger design and rating (without phase change)
    - Shortcut calculations (LMTD), utility requirements
    - Types of heat exchangers, design features
    - Design and rating of a shell and tube heat exchanger
- Liquid-liquid extraction
    - Basics of liquid-liquid equilibrium (LLE)
    - Fundamentals of design (Kremser, McCabe-Thiele, Hunter-Nash (Polpunkt))
    - Combination of extraction and distillation
- Solid-liquid equilibria, crystallisation
    - Thermodynamic basics
    - Data fitting (paracetamol solubility)
- Description of electrolyte mixtures
    - Influence of salts on VLE, gas solubility and LLE
    - Salt solubility

- Pressure influence on phase equilibria
- Design of piping systems
    - Flow rates and pressure drop
    - Design of valves and orifices
    - Two-phase flows and design of safety valves
- Pinch technology for heat integration
    - Methodology, composite and grand composite curves
    - Use of different utilities (heating and cooling fluids)
- Mechanical and thermal vapour recoveryl, use of heat pumps

| **Special Feature** |
| --- |
| |

# Module: 18

## Hydrogen safety

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** N.N.

**Lecturer:**

N.N.

| Associated Course | Study Modes | Language |
|---|---|---|
| Hydrogen safety (4 Semester Hours per Week) | Seminar-type Teaching, Exercises | English |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 3rd Semester)

| | |
|---|---|
| Provides the basis for module(s): | Hydrogen Production (19), Hydrogen Storage, Transport and Distribution (21), Plant Operation (28), Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | Thermodynamics 1 (2), Thermodynamics 2 (8), Physics (9), Electrical Engineering (12) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

Fundamentals of thermodynamics and physics

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students:

- explain possible failure mechanisms of plant components, different types of accident scenarios and the resulting risks in hydrogen plants.
- explain the structure and use of a risk matrix.
- use information sources such as safety data sheets, process descriptions or databases to prepare hazard analyses.
- prepare hazard analyses according to the Hazard and Operability (HAZOP) method using simple examples, carry out such hazard analyses and prepare the associated documentation.
- create work instructions based on älölölösimple application examples about "human performance" for internal communication.
- evaluate different methods of hazard analysis regarding their strengths and weaknesses.
- evaluate different protective devices about their effectiveness and reliability using layer of protection analysis (LOPA)
- evaluate previous incidents from industry and the resulting measures as well as recommendations about the relevance to selected application examplesas well as recommendations regarding relevance to selected application examples.

**Module Content**

- Properties of hydrogen and resulting risks
- Plant components: Design, use, potential of failure and associated risks.
- Basics of risk management
- Principles of Inherently Safer Design (ISD)
- Protective devices and measures (technical, organizational, personal) and their evaluation with the help of the Layer of Protection Analysis (LOPA)
- Methods for the preparation of hazard analyses
- Preparation, execution and documentation of hazard analyses, especially according to the Hazard and Operability (HAZOP) method
- Human performance aspects in process safety
- Change management
- Procedures for safety-related testing of plant components
- Incident scenarios
- Basics of explosion protection
- Previous incidents and lessons learned

**Literature and other Learning Offers**

- R.Wurster, U. Schmidtchen, *DWV Wasserstoff-Sicherheits-Kompendium*, DWV, 2011.
- U. Stephan, B. Schulz-Forberg, *Anlagensicherheit*, Berlin: Springer Vieweg, 2020.
- P. Badke-Schaub et al., *Human Factors Psychologie sicheren Handelns in Risikobranchen,* 2. überarbeitete Auflage, Berlin, Heidelberg: Springer, 2012.
- U. Hauptmanns, *Prozess- und Anlagensicherheit*, 2. Auflage, Berlin: Springer Vieweg, 2020.
- L. Miller, C. Grounds, *Helping humans get it right,* Process Safety Progress (Vol.38, No.2), 2019.
- N.Faulk, C. Costa da Fonseca, *MOC 101—Fundamentals for effective change management,* Process Safety Progress (Vol. 41, No.3), 2022.
- IVSS Sektion Chemie (Hrsg.), *Risikobeurteilung in der Anlagensicherheit Das PAAG- / HAZOP-Verfahren und weitere praxisbewährte Methoden,* 5. Ausgabe, Heidelberg: IVSS, 2020.
- W. Gohm, *Explosionsschutz in der MSR-Technik*, 3. überarbeitete und erweiterte Auflage, Berlin: VDE Verlag, 2019.
- Lecture notes in the THWS eLearning system

**Special Feature**

## Module: 19

### Hydrogen Production

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** N.N.

**Lecturer:**

N.N.

| Associated Course | Study Modes | Language |
|---|---|---|
| Hydrogen Production (4 Semester Hours per Week) | Seminar-type Teaching, Exercises | English |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 4th Semester)

| | |
|---|---|
| Provides the basis for module(s): | Chemical Conversion with Hydrogen (27), Plant Operation (28), Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | Thermodynamics 1 (2), Thermodynamics 2 (8), Chemistry, Electrochemistry (3), Physics (9), Electrical Engineering (12), Renewable Energy and Energy Industry (13) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

Fundamentals of thermodynamics, physics, chemistry and electrochemistry

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students:

- differentiate between the processes for producing hydrogen regarding climate protection goals.
- differentiate between the processes for hydrogen production regarding economic efficiency.
- select the appropriate plant concept for a given application.
- use information sources such as technical literature, process descriptions or databases to evaluate the processes and plant concepts about different goals.
- present the technical design parameters of the hydrogen production plant.

| Module Content |
|---|
| • Hydrogen production by electrolysis<br>• Hydrogen production by plasma lysis<br>• Hydrogen production by steam reforming<br>• Hydrogen production by methane pyrolysis<br>• Biological production of hydrogen<br>• Plant concepts for hydrogen production<br>• Energy-economic evaluation of hydrogen production processes |
| **Literature and other Learning Offers** |
| • T. Schmidt, Wasserstofftechnik, 2. Auflage, München: Hanser Verlag, 2022<br>• S. Geitmann, E. Augsten, Wasserstoff und Brennstoffzellen, 5. Auflage, Oberkrämer: Hydrogeit Verlag 2022<br>• S. Kumar, Clean Hydrogen Production Methods, Berlin: Springer Verlag 2015 https://doi.org/10.1007/978-3-319-14087-2<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

# Module: 20

## Fuel Cell

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** N.N.

**Lecturer:**

N.N.

| Associated Course | Study Modes | Language |
|---|---|---|
| Fuel Cell (4 Semester Hours per Week) | Seminar-type Teaching, Exercises | English |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 4th Semester)

| | |
|---|---|
| Provides the basis for module(s): | Plant Operation (28), Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | Thermodynamics 1 (2), Thermodynamics 2 (8), Chemistry, Electrochemistry (3), Electrical Engineering (12), Renewable Energy and Energy Industry (13) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

Fundamentals of thermodynamics, physics, electrical engineering, chemistry and electrochemistry

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students:

- identify energy utilisation profiles for fuel cell systems.
- differentiate between fuel cell systems regarding the planned utilisation profile.
- select the appropriate fuel cell system for a given utilisation profile.
- use information sources such as specialist literature, process descriptions or databases to evaluate fuel cell systems and system concepts about different objectives.
- design the fuel cell system.
- present the technical design parameters of the fuel cell system.
- list the manufacturing steps in the production of fuel cell system.

| Module Content |
| --- |
| • Fuel cell types<br>• generation of electrical energy in fuel cell systems<br>• generation of thermal energy in fuel cell systems<br>• technical design of fuel cell systems<br>• interfaces to the plant<br>• steady-state and transient operating behavior of fuel cells and peripheral equipment<br>• energy-economical evaluation of fuel cell systems<br>• manufacturing processes of fuel cell systems |
| **Literature and other Learning Offers** |
| • E. Wagner, Das System Brennstoffzelle, München: Hanser Verlag 2023<br>• T. Schmidt, Wasserstofftechnik, 2. Auflage, München: Hanser Verlag, 2022<br>• S. Geitmann, E. Augsten, Wasserstoff und Brennstoffzellen, 5. Auflage, Oberkrämer: Hydrogeit Verlag 2022<br>• M. van de Voorde, Utilization of hydrogen for sustainable energy and fuels, Berlin: De Gruyter Verlag, 2021, https://doi.org/10.1515/9783110596274<br>• P. Kurzweil, Brennstoffzellentechnik, Wiesbaden: Springer Vieweg Verlag 2016<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

## Module: 21

### Hydrogen Storage, Transport and Distribution

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Prof. Dr. Olbricht

**Lecturer:**

Prof. Dr. Olbricht

| Associated Course | Study Modes | Language |
|---|---|---|
| Hydrogen Storage, Transport and Distribution (4 Semester Hours per Week) | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 4$^{th}$ Semester)

| | |
|---|---|
| Provides the basis for module(s): | Plant Operation (28), Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | Thermodynamics 1 (2), Thermodynamics 2 (8), Chemistry, Electrochemistry (3), Electrical Engineering (12), Renewable Energy and Energy Industry (13), Fluid Mechanics (14), Control and Feedback Control Systems in Hydrogen Plants 15), Measuring in Hydrogen Plants (16) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

Fundamentals of thermodynamics, physics, chemistry and electrochemistry

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- describe the steady-state and transient behavior of storage, transport and distribution systems.
- Compare the different characteristics of storage, transport and distribution systems.
- differentiate between the various types of storage, transport and distribution systems with regard to their planned use and economic efficiency.
- select the appropriate storage, transport and distribution systems for a given use.
- use information sources such as technical literature, process descriptions or databases to evaluate the storage, transport and distribution systems with regard to different uses.
- design the storage, transport and distribution systems.
- present the technical design parameters of the storage, transport and distribution systems.

| Module Content |
| --- |
| • Thermodynamic discussion of hydrogen compression and hydrogen expansion in systems (energy demand, efficiency, temperature changes, real gas behaviour, mass and volume specific storage density, power density)<br>• stationary and mobile storage systems for hydrogen<br>• stationary and mobile transport systems for hydrogen<br>• Distribution systems for hydrogen<br>• Interfaces between stationary and mobile systems<br>• Monitoring and control of storage, transport and distribution (pipelines, interfaces, refuelling technology) |
| **Literature and other Learning Offers** |
| • T. Schmidt, Wasserstofftechnik, 2. Auflage, München: Hanser Verlag, 2022<br>• S. Geitmann, E. Augsten, Wasserstoff und Brennstoffzellen, 5. Auflage, Oberkrämer: Hydrogeit Verlag 2022<br>• G. Cerbe, B. Lendt (Hrsg.), *Grundlagen der Gastechnik,* 8. Auflage, München: Hanser Verlag, 2017<br>• C. Winter, J. Nitsch, *Speicherung, Transport und Verteilung von Wasserstoff*. In: C. Winter, J. Nitsch (Hrsg.), *Wasserstoff als Energieträger*, Berlin:Springer Verlag, 1986, https://doi.org/10.1007/978-3-642-97884-5_10<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

## Module: 22

### Plants and Vessels 2

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Prof. Dr. Olbricht

**Lecturer:**

Dipl.-Ing. Benitz

| Associated Course | Study Modes | Language |
|---|---|---|
| Plants and Vessels 2 (4 Semester Hours per Week) | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 4th Semester)

| | |
|---|---|
| Provides the basis for module(s): | Plant Operation (28), Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | Thermodynamics 1 (2), Thermodynamics 2 (8), Chemistry, Electrochemistry (3), Plants and Vessels 1 (11), Electrical Engineering (12), Fluid Mechanics (14), Control and Feedback Control Systems in Hydrogen Plants 15), Measuring in Hydrogen Plants (16), Process design and Simulation (17), Hydrogen safety (18) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

Fundamentals of thermodynamics, physics, chemistry, electrochemistry, electrical engineering, Hydrogen safety, measurement and control technology

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

| **Learning outcomes after successful termination of the module** |
|---|
| The students<br>• design hydrogen-carrying systems for specified applications.<br>• analyse and evaluate the state of the art based on current technical regulations.<br>• clarify the required operating parameters of the plants and identify the required technical regulations.<br>• design the tanks, the valves, the instrumentation, the safety devices and other plant components.<br>• describe the necessary production engineering processes.<br>• explain the technical solutions using the correct technical terminology to plant engineering specialists.<br>• illustrate the systems in technical documentation and operating instructions.<br>• develop an awareness of their responsibility for occupational safety, environmental protection, as guarantors for the safety of third parties, and for economical plant operation. |
| **Module Content** |
| • Design of plants and vessels<br>• Constructional design of plants (vessels, valves, instrumentation, safety devices, other plant components)<br>• Manufacturing processes of plants and plant components<br>• Documentation in plant construction<br>• Responsibility towards people and the environment |
| **Literature and other Learning Offers** |
| • Technical standards and regulations<br>• E. Wagner, *Das System Brennstoffzelle*, München: Hanser Verlag 2023<br>• S. Rippberger, K. Nikolaus, *Entwicklung und Planung verfahrenstechnischer Anlagen*, Berlin: Springer Verlag 2020<br>• W. Wagner, *Planung im Anlagenbau*, 4. Auflage, Würzburg: Vogel Verlag 2018<br>• G. Cerbe, B. Lendt (Hrsg.), *Grundlagen der Gastechnik,* 8. Auflage, München: Hanser Verlag 2017<br>• H. Hirschberg, *Handbuch Verfahrenstechnik und Anlagenbau*, Berlin: Springer Verlag 2014<br>• W. Wagner, *Festigkeitsberechnungen im Apparate- und Rohrleitungsbau*, 8. Auflage, Würzburg: Vogel Verlag 2012<br>• G. Scholz, *Rohrleitungs- und Apparatebau*, Berlin: Springer Verlag 2012<br>• H. Titze, H-P. Wilke, *Elemente des Apparatebaues, Grundlagen-Bauelemente-Apparate,* 3. Auflage, Berlin: Springer Verlag, 1992<br>• Y. Bock, J. Zons, Rechtshandbuch Anlagenbau, 2. Auflage, München: C. H. Beck Verlag 2021<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

| **Module: 23** | | | |
|---|---|---|---|
| **Systematical Design of Plants** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** Prof. Dr. Renner | | | |
| **Lecturer:** | | | |
| Ms. Schäfer, Prof. Dr. Wilke, Prof. Dr. Renner | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Systematical Design of Plants (2 Semester Hours per Week)<br>German in the Project (2 Semester Hours per Week) | | Seminar-type Teaching, Exercises<br>Seminar | German<br><br>Gerrman |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 4th Semester) | | | |
| Provides the basis for module(s): | Practical Module (32), Application Project (33), Bachelor Thesis (36) | | |
| Builds on module(s): | All modules of the first three semesters (1 to 18), Seminar in Engineering (31) | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| All modules of the first three semesters (1 to 18), German B2 | | | |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Project work consisting of project-accompanying attestation, final presentation and project documentation | Examination during the semester | German/English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

| **Learning outcomes after successful termination of the module** |
|---|
| The students<br>• use the tools of project management.<br>• use selected techniques of methodical design.<br>• develop solution variants, evaluate them, and recommend the further procedure.<br>• design a winning variant and work it out.<br>• present contents and results in a convincing and structured way in German.<br>• correctly evalute essential behaviour and communication structures in international business life.<br>• interpret intercultural differences of business partners and draw conclusions from them for their own adapted behaviour.<br>• use the German language understandably, correctly and appropriately. |
| **Module Content** |
| Refer to the description of the individual courses |
| **Literature and other Learning Offers** |
| • K. Ehrlenspiel, Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit, 5. Auflage. München: Hanser Verlag 2013.<br>• VDI-Richtlinien 2221 und folgende. Beuth-Verlag 2004<br>• N. Anderl, Tools für Projektmanagement, Workshops<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| Dual students work on a task in the project phase in cooperation with the practice partner |

| **Course** |
|---|
| **Systematical Design of Plants** |
| **Lecturers:** |
| Prof. Dr. Renner, Prof. Dr. Wilke |
| **Content** |
| The course is a project. It consists of seminar lessons and project work. The seminar lessons deal with selected aspects from the subject areas of project management, methodical design and product development. In the project work, the theoretically acquired knowledge must be put into practice in teamwork. The following topics are covered:<br>• Product development: clarifying the task, technical research, customer benefits, list of requirements, component-oriented design structure, FMEA, technical product description<br>• Project management: time-, deadline- and cost-appropriate processing of a complex development task with weekly results report, including the following components: project agreement, schedules according to Gantt with milestones/quality gates, task lists, VMI matrix and more<br>• Methodical design: Tools such as black box, functional structures, principles of action, morphological box, creativity technique<br>• Documentation: protocols, technical documentation in the form of a project folder, presentation<br>• Presentation techniques: all the techniques and knowledge needed to create and deliver effective presentations, including digital meetings and presentations (some aspects will be covered in this course, some in the other course) |
| **Special Feature** |
| • Guest lecture on the topic of "patents" followed by online research on student topics<br>• Separate budget for each project group, which can be used for visits to trade exhibitions and companies, small experiments or for the creation of models or prototypes<br>• Dual students work on a task in the project phase in cooperation with the practice partner |

| **Course** |
| --- |
| **German in the project** |
| **Lecturer:** |
| Ms. Schäfer |
| **Content** |
| • Presentation techniques: all the techniques and knowledge needed to create and deliver effective presentations, including digital meetings and presentations (some aspects will be covered in this course, others in the other)<br>• Expansion of general, technical and business-oriented vocabulary in the German language<br>• Strengthening of grammar structures to expand the students' ability to express themselves in the German language<br>• Awareness for intercultural differences of business partners from other nations<br>• Insight into the different language levels of business communication (formal - informal) |
| **Special Feature** |
| |

## Module: 25

### Innovation and Development Processes and Founding

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Prof. Dr. Hofmann

**Lecturer:**

Prof. Dr. Hefmann, MBA Waschik

| Associated Course | Study Modes | Language |
|---|---|---|
| Innovation and Development Processes and Founding | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module,5th Semester)

| | |
|---|---|
| Provides the basis for module(s): | Practical Module (32), Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

School knowledge physics

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- represent the terminology in innovation management and business start-up.
- implement the steps in the innovation and development process.
- evaluate the technical-economic potential of the innovation iteratively in the process.
- evaluate the consequences for society, climate and the environment of an innovation.
- explain state funding possibilities, personal financial security, rights from industrial property rights, key figures and the business plan.
- plan the necessary steps in setting up a business.
- understand the importance of team processes in the development of innovation and the founding of a company.

| Module Content |
|---|
| • Processes in innovation and idea management<br>• Creativity techniques<br>• Innovation strategy<br>• Iterative dynamic investment calculation<br>• Valuation of innovations<br>• Industrial legal rights<br>• Business administration, controlling<br>• Financing<br>• Law, legal forms, taxes and authorities<br>• Business plan |
| **Literature and other Learning Offers** |
| • K. Ehrlenspiel, *Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit, 5. Auflage*. München: Hanser Verlag 2013.<br>• VDI-Richtlinien 2221 und folgende. Berlin: Beuth-Verlag 2004<br>• J. Hauschildt, S. Salomo, C. Schultz, A. Kock, *Innovationsmanagement,* 7. Auflage, München: Verlag Franz Vahlen 2023<br>• T. Müller-Prothmann, N. Dörr, G. Kamiske, *Innovationsmanagement*, 4. Auflage, München: Hanser Verlag 2020<br>• G. Schuh, *Innovationsmanagement,* 2. Auflage, Berlin: Springer Verlag 2012<br>• A. Ternès, J. Reiber, *Gründen mit Erfolg*, Wiesbaden: Springer Gabler 2020<br>• J. Staab, *Erneuerbare Energien in Kommunen – Energiegenossenschaften gründen, führen und beraten*, 4. Auflage, Wiesbaden: Springer Gabler 2018<br>• A. Osterwalder, Y. Pigneur, *Business model generation: ein Handbuch für Visionäre, Spielveränderer und Herausforderer*, Frankfurt: Campus Verlag 2011<br>• A. Osterwalder, Y. Pigneur, et al., *Value Proposition Design: How to create Products and Services Customers Want (Strategyzers)*, Hoboken, NJ.: Wiley Verlag 2014<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

| **Module: 26** | | | |
|---|---|---|---|
| **Computational Fluid Dynamics (CFD)** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** Prof. Dr. Möbus | | | |
| **Lecturer:** | | | |
| Prof. Dr. Möbus | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Computational Fluid Dynamics (CFD) | | Seminar-type Teaching, Exercises | German |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 5th Semester) | | | |
| Provides the basis for module(s): | Practical Module (32), Application Project (33), Bachelor Thesis (36) | | |
| Builds on module(s): | Engineering Mathematics 1 (1), Engineering mathematics 2 (7), Computer Science, Digitalisation, Automation (6), Fluid Mechanics (14) | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| | | | |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- form the finite volume method to obtain the discrete equations for convection, diffusion and source terms.
- use the explicit and implicit Euler method for time discretisation and name the stability limit.
- describe the essential characteristics of turbulent flow, state the reason for using turbulence models and assess their applicability.
- name the special requirements for the simulation of incompressible and compressible flow processes and select suitable models.
- explain the principle of parallelisation of flow simulations.
- name common models for special simulation tasks such as multiphase flow, conjugate heat transfer and fluid-structure interaction and select the appropriate procedure.
- create simulations with a common flow simulation programme (e.g. Ansys Fluent) and analyse the results.

| Module Content |
|---|
| • Finite volume methods, spatial discretisation<br>• Temporal discretisation, explicit and implicit Euler method<br>• Stability and stability limit<br>• Turbulence description and turbulence models (RANS, LES, DNS)<br>• Incompressible and compressible simulation, pressure-velocity coupling<br>• Parallelisation<br>• Special modelling:<br>Multiphase flow, conjugate heat transfer, fluid-structure interaction |
| **Literature and other Learning Offers** |
| • R. Schwarze, CFD-Modellierung. Heidelberg: Springer Vieweg, 2013.<br>• F. Moukalled, L. Mangani und M. Darwish, The Finite Volume Method in Computational Fluid Dynamics. Cham: Springer, 2016.<br>• H.K. Versteeg und W. Malalasekera, An introduction to computational fluid dynamics, 2. Auflage. Harlow: Prentice Hall, 2007.<br>• J. Tu, G.-H. Yeoh und C. Liu, Computational fluid dynamics. Amsterdam: Elsevier, 2013.<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

| **Module: 27** | | | |
|---|---|---|---|
| **Chemical Conversion with Hydrogen** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** Prof. Dr. Renner | | | |
| **Lecturer:** | | | |
| Prof. Dr. Renner | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Chemical Conversion with Hydrogen (4 Semester Hours per Week) | | Seminar-type Teaching, Exercises | German |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 5th Semester) | | | |
| Provides the basis for module(s): | Practical Module (32), Application Project (33), Bachelor Thesis (36) | | |
| Builds on module(s): | Chemistry, Electrochemistry (3), Physics (9) Process design and simulation (17), Hydrogen Safety (18) | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| | | | |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- describe the reactions of hydrogen and CO2.
- describe the reaction mechanisms of hydrogen and nitrogen.
- describe the reaction mechanisms in the reduction of iron ore by hydrogen.
- describe the combustion process of hydrogen in air.
- present the plant concepts for the different processes of material conversion with hydrogen.
- assess the energetic efficiencies of the different processes.
- design process and plant concepts for material conversion with hydrogen.

| **Module Content** |
|---|
| • Processes (Sabatier reaction, Haber-Bosch process, Fischer-Tropsch synthesis)<br>• Power-to-liquids (methanol, ammonia, hydrocarbons)<br>• Power-to-methanes<br>• Use as reducing agents in steel production and branches of industry<br>• Combustion technology |
| **Literature and other Learning Offers** |
| • C. Janiak, H. Meyer, D. Gudat, P. Kurz, E. Riedel, *Moderne anorganische Chemie*, 5. Auflage, Berlin: DeGruyter Verlag 2018<br>• K. Hertwig, L. Martens, C. Hamel, *Chemische Verfahrenstechnik*, 3. Auflage, Berlin: DeGruyter Verlag 2018<br>• T. Schmidt, *Wasserstofftechnik,* 2. Auflage, München: Hanser Verlag, 2022<br>• S. Geitmann, E. Augsten, *Wasserstoff und Brennstoffzellen*, 5. Auflage, Oberkrämer: Hydrogeit Verlag 2022<br>• S. Kumar, *Clean Hydrogen Production Methods,* Berlin: Springer Verlag 2015, https://doi.org/10.1007/978-3-319-14087-2<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

## Module: 28

### Plant Operation

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Prof. Dr. Renner

**Lecturer:**
Prof. Dr. Renner

| Associated Course | Study Modes | Language |
|---|---|---|
| Plant Operation (4 Semester Hours per Week) | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**
Bachelor Programme Hydrogen Technologies (Compulsory Module, 5th Semester)

| | |
|---|---|
| Provides the basis for module(s): | Practical Module (32), Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | Chemistry, Electrochemistry (3), Physics (9), Process design and Simulation (17), Hydrogen Safety (18) |

**Compulsory Conditions of Participation**
none

**Recommended Conditions of Participation**

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**
The students
- explain the legal conditions of plant operation.
- describe the area of responsibility of the person in charge of the plant.
- characterise the operating modes of the facility.
- assess the effect of plant operating conditions on employees, society, the environment and the climate.
- evaluate the economic efficiency of plant operation.
- develop strategies for optimising plant operation

| Module Content |
|---|
| • Legal basics<br>• Commissioning, regular operation, start-up, shut-down<br>• Maintenance and repair<br>• Planned and unplanned plant shutdowns<br>• Incidents<br>• Plant monitoring<br>• Organisational principles of plant operation (plant safety, occupational safety)<br>• Economic basics of plant operation<br>• Plant optimisation |
| **Literature and other Learning Offers** |
| • I. Zenke, M. Vollmer, *Anlagenplanung, Anlagenbau, Anlagenbetrieb für Unternehmen*, Berlin: De Gruyter Verlag 2016. https://doi.org/10.1515/9783110354805<br>• D. Schmidt, *Rechtliche Grundlagen für den Maschinen- und Anlagenbetrieb*, Wiesbaden: Springer Gabler 2014<br>• M. Schenk, *Instandhaltung technischer Systeme*, Berlin: Springer Verlag, 2010<br>• K. Weber, *Inbetriebnahme verfahrenstechnischer Anlagen*, Berlin: Springer Verlag 2019<br>• K. Weber, F. Mattukat, M. Schüßler, *Dokumentation verfahrenstechnischer Anlagen,* Berlin: Springer Verlag 2020<br>• U. Stephan, B. Schulz-Forberg, *Anlagensicherheit*, Berlin: Springer Vieweg 2021<br>• U. Hauptmanns, *Prozess- und Anlagensicherheit*, Berlin: Springer Vieweg 2020<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

| **Module: 29** | | | |
|---|---|---|---|
| **General Elective** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Winter and Summer Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** | Dean of the Faculty of Applied Natural Sciences and Humanities | | |
| **Lecturer:** | | | |
| Lecturers from the Faculty of Applied Natural Sciences and Humanities or teachers appointed by the faculty | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Selection of two general electives (2 x 2 SWS) or one general elective (1 x 4 SWS) from the range of subjects offered by the Faculty of Applied Natural Sciences and Humanities | | The Faculty of Applied Natural and Human Sciences is responsible for determining and announcing the programme. | The Faculty of Applied Natural and Human Sciences is responsible for determining and announcing the programme. |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 5th Semester)<br>Bachelor Programme Mechaniical Eengineering (Compulsory Module, 6th Semester)<br><br>The module is intended to build up interdisciplinary competences ("studium generale") and is therefore not directly related to other modules of this degree programme.<br>It can be used in all other Bachelor's degree programmes, provided that there is no blocking notice for this degree programme.<br>Provides the basis for module(s):<br>Builds on module(s): | | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| Generally none; exceptions are determined and announced by the Faculty of Applied Natural Sciences and Humanities. | | | |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Each AWPF is terminated with an examination.<br>The type of examinations and their announcement are determined by the Faculty of Applied Natural Sciences and Humanities. | | |

| Learning outcomes after successful termination of the module |
|---|
| The subject-specific learning objectives depend on the general elective selected in each case.<br>The students<br>• also acquire knowledge and competences that are not subject-specific but can be significant for the desired career goal, such as special knowledge of foreign languages, in natural sciences or also in social sciences.<br>• analyse a wide variety of issues.<br>• place subject-specific knowledge in an interdisciplinary context.<br>• transfer what they have learned to their current education.<br>• have expanded their key competences and, if applicable, foreign language competences, which supports personality development, also in intercultural terms.<br>• are aware of their responsibility in personal, social and ethical terms. |
| **Module Content** |
| Subjects offered by the Faculty of Applied Natural Sciences and Humanities. in the fields of<br>• Languages<br>• Cultural studies<br>• Natural sciences and technology<br>• Politics, Law and Economics<br>• Education, psychology and social sciences<br>• Soft Skills<br>• Creativity and the Arts<br><br>Excluded from the catalogue of Faculty of Applied Natural Sciences and Humanities are courses whose content is already part of or directly related to other modules of the degree programme. The corresponding courses are marked with a blocking note in the subject catalogue.<br><br>The contents of the individual general electives are published on the homepage of the Faculty of Applied Natural Sciences and Humanities. |
| **Literature and other Learning Offers** |
| |
| **Special Feature** |
| |

## 5. Third Study Period – application and practice, 6th to 7th semester

| Module: 31 | | | |
|---|---|---|---|
| **Seminar in Engineering** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Every Semester | Total Workload: 180 h<br>75 contact hours (4 semester periods per week)<br>105 hours self study | 6 |
| **Module Responsibility:** Prof. Dr. Christel | | | |
| **Lecturer:** | | | |
| Professors of the faculty, lecturers from industry | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Seminar "Scientific Work" (1 Semester Hour per Week)<br>Seminar "Communication & Problem Solving" (1 Semester Hour per Week)<br>Seminar "Presenting & Writing" (2 Semester Hours per Week)<br>Seminar "Practice Exchange" (1 Semester Hour per Week)<br>Single skills seminars, seminar on practice exchange and individual appointments with student presentations or guest lectures in semesters 4 to 7. | | Seminar | German/English |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 6th Semester)<br>Bachelor Programme Mechanical Engineering (Compulsory Module, 6th Semester)<br>Bachelor Programme Mechatronics (Compulsory Module, 6th Semester) | | | |
| Provides the basis for module(s): | Systematical Design of Plants (23), Practical Module (32), Application Project (33), Bachelor Thesis (36) | | |
| Builds on module(s): | | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| none | | | |
| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** | |
| Presentation, Term Paper | | English | |
| The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester. | | | |

| Learning outcomes after successful termination of the module |
|---|
| The students<br>• abstract complex problems, formulate sub-goals and plan work packages (in terms of time, content, resources) with the help of IT tools.<br>• write scientifically based reports and present the results of their work (practical module, Bachelor's thesis) in a meaningful and target group-oriented manner.<br>• use online communication tools (e.g. video conferences) in the digital working world.<br>• discuss working methods and results in the group and give constructive feedback.<br>• analyse the student presentations offered and assess the procedures, working techniques and presentation techniques about their own thesis / presentation.<br>• draw conclusions from the guest lectures of the industry about the state of the art and the upcoming professional career.<br>• reflect on personal behaviour and criteria for success in the professional environment.<br>• develop their personal and social competences and thereby improve, among other things, their ability to prepare technical reports / presentations on time, to work in a team or to communicate in a target-oriented and effective manner. |
| **Module Content** |
| The seminar prepares the practical phase (32) and accompanies it through the exchange of experiences among the students. The foundations of (engineering) scientific work are laid for subsequent projects (23, 33) and the student's own Bachelor thesis (36).<br><br>Contents of the seminar:<br>• Scientific work (analysis, hypothesis, synthesis, validation).<br>• Soft skills, e.g. presentation techniques, conversation skills, problem-solving methods<br>• Project and self-management<br>• Reflection on the practical phase<br><br>Conduct of the seminar (organisation via assessment card):<br>• 4th semester: Skills seminars "Scientific work" and "Communication & problem solving". Participation in 3 individual sessions with student presentations or guest lectures from industry.<br>• 5th semester: Skills seminar "Presenting & Writing". Participation in 3 individual appointments with student lectures or guest lectures from industry.<br>• 6th semester: Seminar "Practical Exchange" to accompany the practical phase.<br>• 7th semester: Preparation of an exposé and presentation of the Bachelor's thesis. |
| **Literature and other Learning Offers** |
| |
| **Special Feature** |
| Dual students work on tasks in the seminars in cooperation with the practice partner |

| Module: 32 | | | |
|---|---|---|---|
| **Practical Module** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Every Semester | Total Workload: 720 h<br>700 hours attendance at the practical training company<br>20 hours Preparation for the industrial internship | 24 |
| **Module Responsibility:** Internshio Officer | | | |
| **Lecturer:** | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | | |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 6th Semester)

| | |
|---|---|
| Provides the basis for module(s): | Bachelor Thesis (36) |
| Builds on module(s): | Preparation and support by the engineering seminar (31)<br>Subject-related based on modules (1) to (22) |

**Compulsory Conditions of Participation**

At least 90 ECTS points from modules 1-30. must have been achieved at the time of entry.
Submission of an internship contract to the University Service Studies before the start of the internship.

**Recommended Conditions of Participation**

Specific courses (scientific work, presentation and writing) of the Seminar in Engineering (31)

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Internship certificate | | English |

Verification of successful completion of the practical phase is provided to the University Service Studies in the form of an internship certificate.

**Learning outcomes after successful termination of the module**

The students

- analyse the operational processes and (social) structures in business practice.
- transfer the learned engineering contents by applying them in practice.
- apply learned methods and soft sills (e.g. project management, communication skills, problem-solving methods) in a target-oriented manner.
- develop into a fully-fledged academic worker ("employability").

**Module Content**

The required contents of the practical phase are described in detail in the internship guidelines of the degree programme. The essential features are briefly described below:

- Familiarisation with practical work in the company under supervision appropriate to the engineering profession.
- Accompaniment and reflection of the practical phase by the engineering seminar
- Independent application of the knowledge and methods acquired during study to real problems from engineering practice.

| Literature and other Learning Offers |
| --- |
| Depending on the company (internal documentation, processes and standards) and the respective functional area (standard textbooks, scientific publications) |
| **Special Feature** |
| Dual students work on tasks in the seminars in cooperation with the practice partner |

# Module: 33

## Application Project

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Every Semester twice | Total Workload: 300 h<br>60 contact hours (4 semester periods per week)<br>240 hours self study | 10 |

**Module Responsibility:** Prof. Dr. Jung

**Lecturer:**

All professors of the Bachelor's degree programmes in Hydrogen Technologies, Mechanical Engineering and Mechatronics and lecturers for the foreign-language scopes

| Associated Course | Study Modes | Language |
|---|---|---|
| Communication Skills for Meetings, Writing Reports (2 contact hours per week during the semester lecture period) | Seminar-type Teaching, Exercises | German |
| Projektwork (2 contact hours per week during the semester lecture period) | Project | German |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 7$^{th}$ Semester)

| | |
|---|---|
| Provides the basis for module(s): | Bachelor Thesis (36) |
| Builds on module(s): | all modules from the first to the sixth semester (1) to (32) |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

For the German-language sections, German language skills at level C1

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Project | During the 7$^{th}$ semester | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

| Learning outcomes after successful termination of the module |
|---|
| The students<br>• independently apply the knowledge acquired in other modules of the Bachelor's degree programme (specialist knowledge, methods and procedures) to solve a real problem.<br>• research and analyse the current state of research and technology.<br>• work on the task cooperatively and responsibly in a team.<br>• present complex subject-related content clearly and in a way that is appropriate to the target group.<br>• prepare written project documentation in the form of a report.<br>• present the essential mid-term and final results to the client.<br>• present project contents and technical contexts in German.<br>• use the German language appropriately in a variety of business situations in the context oft he project. |
| **Module Content** |
| • Scientific work<br>• Development methodology<br>• Communication techniques<br>• Team meetings and communication<br>• Presentation techniques<br>• Project documentation<br>• German language communication and presentationsRefer to the description of the individual courses |
| **Literature and other Learning Offers** |
| • Skripte „Projektmanagement für den Studiengang Maschinenbau“ Band 1 und Band 2 (im Intranet der Fakultät verfügbar)<br>• J. Feldhusen und K.-H. Grote, Pahl/Beitz Konstruktionslehre, 8. Auflage. Berlin Heidelberg: Springer-Verlag, 2013.<br>• VDI-Richtlinie 2222, Konstruktionsmethodik - Methodisches Entwickeln von Lösungsprinzipien, VDI-Gesellschaft Produkt- und Prozessgestaltung: Düsseldorf, 1997.<br>• U. Lindemann, Methodisches Entwickeln technischer Produkte, 3. Auflage. Berlin Heidelberg: Springer-Verlag 2009.<br>• Lecture notes in the THWS eLearning system<br>• |
| **Special Feature** |
| After the mid-term presentation, an excursion to the industrial partner usually takes place. During this event, the students present the project results they have worked on up to this point to the industry or research partner under practice-relevant conditions.<br><br>Dual students work on tasks in the seminars in cooperation with the practice partner. |

# Module: 34

## Technical Lab Training

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Every Semester | Total Workload: 90 h<br>30 contact hours (2 semester periods per week)<br>60 hours self study | 3 |

**Module Responsibility:** Prof. Dr. -Ing. Vogt

**Lecturer:**

According to the list of lab exercises (eLearning course)

| Associated Course | Study Modes | Language |
|---|---|---|
| Attendance at a total of 9 experiments during the degree programme, of which a maximum of four experiments in the first three semesters | Lab course | German/English |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, formally assigned to the 7th semester)

| | |
|---|---|
| Provides the basis for module(s): | Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | Modules of the degree programme that are relevant to the experiments (see descriptions of experiments), Measuring in hydrogen plants (16) |

**Compulsory Conditions of Participation**

Certificate of safety instruction "General safety aspects of working in the laboratories" within the framework of the introductory event for first semester students (takes place every semester).

**Recommended Conditions of Participation**

The recommended participation requirements and previous knowledge can be found in the descriptions of the individual practical experiments.

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Practical courseworks | | German/English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- apply the knowledge from other modules of the degree programme in an experiment, identify the knowledge required for successful execution of the experiment and learned in different modules and link it in an interdisciplinary manner.
- analyse the processes and methods used in the experiments on a scientific basis.
- plan experiments, carry them out and document the results and the procedure in a scientifically correct way.
- interpret experimental results and draw well-founded conclusions.

| Module Content |
| --- |
| The contents can be found in the descriptions of the individual experiments. The experiments offered come from different areas of hydrogen technology and are offered in all laboratories of the Faculty of Mechanical Engineering. In addition, experiments on the basics of engineering sciences, e.g. physics, chemistry, are offered Literature and further learning opportunities |
| **Literature and other Learning Offers** |
| Experiment instructions, scripts and supplementary documents in the eLearning system of the THWS |
| **Special Feature** |
| Dual students can work on tasks in cooperation with the practice partner within the framework of the offered experiments. |

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## Module: 35

### Cost Accounting and Ethics for Engineers

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Prof. Dr. Ankenbrandt

**Lecturer:**

Prof. Dr. Ankenbrand, Prof. Dr. Kraus

| Associated Course | Study Modes | Language |
|---|---|---|
| Cost Accounting and Ethics for Engineers (4 Semester Hours per Week) | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 7th Semester)

| | |
|---|---|
| Provides the basis for module(s): | Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

The students

- classify cost accounting terms.
- interpret cost trends.
- apply cost accounting methods.
- describe the basic terms and contents of recognised catalogs of standards.
- explain the factors describing responsibility and trust.
- explain the analytical concept for world views and its elements as well as general examples.
- explain the dual character of values and their normative core functions in companies.
- analyse the potential for conflict between profit-oriented and ethical action in companies.

| **Module Content** |
| --- |
| • Basics and correlations of controlling<br>• Instruments of controlling<br>• Cost and activity accounting as an information and control system<br>• Cost type, cost centre and cost unit accounting<br>• Systems and methods of cost accounting, possible applications and limits<br>• Ethics, values, morals & norms: Functions and relevance in companies and organisations<br>• Worldview analysis: Philosophical foundations of specific value concepts<br>• Multi-rational management: professional handling of contradictions and dilemmas in companies and organisations |
| **Literature and other Learning Offers** |
| • G. Friedl, C. Hofmann und B. Pedell, *Kostenrechnung: Eine entscheidungsorientierte Einführung*, 3., überarbeitete Auflage. München: Franz Vahlen, 2017.<br>• M. Aßländer, Hrsg., *Handbuch Wirtschaftsethik*. Stuttgart: Verlag J.B. Metzler, 2011.<br>• K. Schedler, Hrsg., *Multirationales Management*. Bern: Verlag Haupt, 2013.<br>• F. Glauner, *Zukunftsfähige Geschäftsmodelle und Werte*. Berlin: Springer Gabler, 2016.<br>• Lecture notes in the THWS eLearning system |
| **Special Feature** |
| |

| **Module: 36** | | | |
|---|---|---|---|
| **Bachelor Thesis** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Every Semester | Total Workload: 360 h<br>Approx. 6 contact hours at THWS for meetings with the lecturer<br>354 hours self study | 12 |
| **Module Responsibility:** Dean of Students | | | |
| **Lecturer:** | | | |
| Examiners appointed by the examination board | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | | |
| **Applicability and Study Semester:** | | | |
| Bachelor Programme Hydrogen Technologies (Compulsory Module, 7th Semester)<br>Bachelor Programme Mechanical Engineering (Compulsory Module, 7th Semester)<br>Bachelor Programme Mechatronics (Compulsory Module, 7th Semester) | | | |
| Provides the basis for module(s): | | | |
| Builds on module(s): | All modules of the study programme | | |
| **Compulsory Conditions of Participation** | | | |
| a) has reached at least 150 CP<br>b) successfully finished all modules of the first three study semesters (modules 1 to 18)<br>c) successfully completed the practical module (32) | | | |
| **Recommended Conditions of Participation** | | | |
| Learning outcomes achieved in all modules of the study programme | | | |

| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** |
|---|---|---|
| Bachelor Thesis | Duration of work in case of continuous and exclusive work 10 weeks | German |

The boundary conditions are specified, among other things, on the registration form for the Bachelor's thesis. This is published on the faculty's intranet.

| Learning outcomes after successful termination of the module |
|---|
| The students<br>• apply their technical and methodological knowledge independently and across subjects/modules to a problem from the subject area of the degree programme in order to develop an engineering solution on a scientific basis.<br>• assess the impact of engineering solutions in the social and ecological environment and act in accordance with professional ethical principles and standards.<br>• critically evaluate their existing knowledge, recognise missing knowledge and expand their existing knowledge on their own responsibility.<br>• critically reflect on their own work.<br>• apply the methods of project management to achieve the desired goals in limited time and with limited resources and budgets.<br>• present their results and their approach in a comprehensible way and according to the principles of scientific work in a written technical report.<br>• integrate themselves into the social environment of a company (only if the work is carried out in a company). |
| **Module Content** |
| Independent solving of a problem from the subject area of the degree programme on a scientific basis. Students in the BWT dual study variant work on a problem from the cooperation company. |
| **Literature and other Learning Offers** |
| • Specialist literature according to the task of the Bachelor's thesis<br>• H. Balzert, *Wissenschaftliches Arbeiten*, 2. Auflage. Herdecke: W3L-Verlag, 2013.<br>• H. Hering, *Technische Berichte: verständlich gliedern, gut gestalten, überzeugend vortragen*, 8., überarbeitete Auflage. Wiesbaden: Springer Vieweg, 2019.<br>• H. Hering, *How to write technical reports: understandable structure, good design, convincing presentation,* 2. Auflage. Berlin, Heidelberg: Springer, 2019 |
| **Special Feature** |
| • With the approval of the examination board, the Bachelor's thesis may be carried out at an institution outside the university if supervision by the university's examiners is ensured.<br>• Dual students complete their bachelor's thesis at the practice partner. |

# 6. Second Study Period - Specialised Electives, 4th and 5th Semester

## Module: 24

### Specialised Elective 1

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Summer Semester | Total Workload: 150 h<br>60 contact hours ((<br>4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Dean of Students

**Lecturer:**

The lecturers can be identified from the descriptions in the catalogue of the individual specialised elective courses.

| Associated Course | Study Modes | Language |
|---|---|---|
| Refer to the catalogue of the individual specialised elective courses | Seminar-type Teaching, Exercises, Lab course | English |

Two of the electable courses from the catalogue specified in the curriculum must be selected for this module.

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 4th Semester)

| | |
|---|---|
| Provides the basis for module(s): | Application Project (33), Bachelor Thesis (36) |
| Builds on module(s): | |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

The recommended participation requirements and prior knowledge can be found in the descriptions of the individual courses.

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | English |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

In the subject-specific compulsory elective modules, students choose from a catalogue of courses from all subject areas of mechanical engineering and hydrogen technology according to their own preferences and professional expectations. In this way, they develop an individual focus, but this is not associated with in-depth specialisation in only one specific field of application. The students decide whether they want to intensify their knowledge in a certain field of interest or extend their knowledge in the subject.

The course-related learning objectives can be found in the descriptions of the individual courses.

**Module Content**

The contents can be obtained from the descriptions of the individual courses.

| Literature and other Learning Offers |
| --- |
| The literature references can be found in the descriptions of the individual courses. |
| **Special Feature** |
| |

# Module: 30

## Specialised Elective 2

| Duration | Semester | Workload | ECTS-Credit Points |
|---|---|---|---|
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |

**Module Responsibility:** Dean of Students

**Lecturer:**

The lecturers can be identified from the descriptions in the catalogue of the individual specialised elective courses.

| Associated Course | Study Modes | Language |
|---|---|---|
| Refer to the catalogue of the individual specialised elective courses | Seminar-type Teaching, Exercises, Lab course | German |

Two of the electable courses from the catalogue specified in the curriculum must be selected for this module.

**Applicability and Study Semester:**

Bachelor Programme Hydrogen Technologies (Compulsory Module, 5$^{th}$ Semester)

| | |
|---|---|
| This module provides the basis for the modules: | Application Project (33), Bachelor Thesis (36) |
| This module is based on the modules: | |

**Compulsory Conditions of Participation**

none

**Recommended Conditions of Participation**

The recommended participation requirements and prior knowledge can be found in the descriptions of the individual courses.

| Mode of examination / Requirements for the award of credit points | Duration of the examination | Language of the examination |
|---|---|---|
| Written exam | 90 to 120 min | German |

The specific scope of the examination and further examination boundary conditions (e.g. permitted aids) are defined in the examination conditions. These conditions are published on the faculty intranet at the beginning of each semester.

**Learning outcomes after successful termination of the module**

In the subject-specific compulsory elective modules, students choose from a catalogue of courses from all subject areas of mechanical engineering and hydrogen technology according to their own preferences and professional expectations. In this way, they develop an individual focus, but this is not associated with in-depth specialisation in only one specific field of application. The students decide whether they want to intensify their knowledge in a certain field of interest or extend their knowledge in the subject.

The course-related learning objectives can be found in the descriptions of the individual courses.

**Module Content**

The contents can be obtained from the descriptions of the individual courses.

| Literature and other Learning Offers |
| --- |
| The literature references can be found in the descriptions of the individual courses. |
| **Special Feature** |
| |

| **Module: 30a** | | | |
|---|---|---|---|
| **Transfer Seminar** | | | |
| **Duration** | **Semester** | **Workload** | **ECTS-Credit Points** |
| 1 Semester | Winter Semester | Total Workload: 150 h<br>60 contact hours (4 semester periods per week)<br>60 hours self study<br>30 hours exam preparation | 5 |
| **Module Responsibility:** Prof. Dr. Christel | | | |
| **Lecturer:** | | | |
| Lecturers of the Faculty of Mechanical Engineering and representatives of the contracting companies. | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| Transfer Seminar 2nd Semester (1 Semester Hour per Week) | | Seminar | English/German |
| Transfer Seminar 3rd Semester (1.5 Semester Hours per Week) | | Seminar | English/German |
| Transfer Seminar 5th Semester (1.5 Semester Hours per Week) | | Semina | German |
| **Applicability and Study Semester:** | | | |
| Study variant "Bachelor Hydrogen Technologies dual" (Compulsory Module, 5th Semester) | | | |
| Provides the basis for module(s): | Application Project (33), Bachelor Thesis (36) | | |
| Builds on module(s): | | | |
| **Compulsory Conditions of Participation** | | | |
| none | | | |
| **Recommended Conditions of Participation** | | | |
| The recommended participation requirements and prior knowledge can be found in the descriptions of the individual courses. | | | |
| **Mode of examination / Requirements for the award of credit points** | **Duration of the examination** | **Language of the examination** | |
| Portfolio | | English/German | |
| The specific definition of the length of the examination and other examination conditions (e.g. permitted auxiliary resources) is set out in the examination conditions. These are published at the beginning of each semester. | | | |

| Learning outcomes after successful termination of the module |
| --- |
| The students<br>• reflect on the application of theoretical knowledge in business practice.<br>• discuss the practical ways of working and methods in the companies.<br>• develop and evaluate strategies for knowledge transfer between university and companies<br>• analyse cooperation in the companies<br>• present success factors<br>• coach each other |

| Module Content |
| --- |
| • Exchange of information between students of the "Bachelor Hydrogen Technology dual" study variant<br>• Moderated exchange of information between students, university lecturers and company representatives<br>• Strategy development for knowledge transfer between companies and the university |
| **Literature and other Learning Offers** |
| • H. Mell, *Spielregeln für Beruf und Karriere*, Berlin: Springer Verlag 2013 |
| **Special Feature** |
| |

## Catalog of courses for modules 24 (FWPM 1) and 30 (FWPM 2)

| Name of the course (LV) in module 24 | **Responsible for the course** |
|---|---|
| **Flight technology (24.01)** | Möbus |
| **Quality management and production engineering (24.02)** | Sommer |
| **Special fields of internal combustion engines (24.03)** | Schlachter |
| **Combustion technology (24.04)** | Blotevogel |
| **Rolling bearing applications (24.05)** | Sommer |
| **Materials in welding technology (24.06)** | Latteier |
| **Production systematics (24.07)** | Krüger |
| **Data analysis for engineers (24.08)** | Schreiber |

| Name of the course (LV) in module 30 | **Responsible for the course** |
|---|---|
| **Additive manufacturing of metallic components (30.01)** | Versch |
| **Acoustics (30.02)** | Retka |
| **Introduction to the finite element method (FEM) (30.03)** | Mengelkamp |
| **Marketing / Technical Sales (30.04)** | Rieß |
| **Machine learning (30.05)** | Meyer |
| **Signals and systems (30.06)** | Pecher |
| **Systematic material selection in the development process (30.07)** | Spielfeld |
| **Production systematics (30.08)** | Krüger |
| **Materials and manufacturing processes in car body construction (30.09)** | Müller |
| **Systematic investigation of technical damage cases (30.10)** | Loos |

| Flight technology – 24.01 | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation | |
| **Module Responsibility:** | Prof. Dr.-Ing. Möbus | | |
| **Lecturer:** | | | |
| Prof. Dr.-Ing. Möbus | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Fluid Mechanics (14), Engineering Mechanics (5), Materials Engineering 1 and 2(4,10).

**Learning outcomes after successful termination of the module**

The students

- correctly interpret construction regulations and name the legal particularities of aircraft construction.
- describe the structure of an aircraft and the functioning of the flight controls.
- name the materials used in aviation and assess them according to suitable criteria.
- describe the structural design of the airframe and calculate individual components.
- name important aerodynamic coefficients and their relationship (polar curve) and distinguish between the properties of the airfoil and those of the finite span wing.
- describe the function of aircraft engines and name the most important components.
- calculate simple flight mechanical relationships.

**Module Content**

- International and national organization of aviation
- Construction regulations using the example of selected aircraft systems
- Structural design of the aircraft
- Materials in aviation
- Aircraft aerodynamics
- Aircraft engines
- flight performance

**Literature and other Learning Offers**

- C.-C. Rossow, *Handbuch der Luftfahrzeugtechnik*. München: Hanser, 2014
- K. Engmann, *Technologie des Flugzeugs*, 6. Auflage. Vogel Verlag, 2013.
- J. Scheiderer, *Angewandte Flugleistung*, Berlin. Springer, 2008.
- G. Gratton, *Initial Airworthiness*, 2. Auflage. Cham: Springer, 2018.
- Lehrveranstaltungsunterlagen im eLearning-System der THWS

**Special Feature**

| **Quality management and production engineering - 24.02** | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation | |
| **Module Responsibility:** Prof. Dr.-Ing. Sommer | | | |
| **Lecturer:** | | | |
| Prof. Dr.-Ing. Sommer | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Fertigungs- und Produktionstechnik, Messtechnik in Wasserstoffanlagen (16)

**Learning outcomes after successful termination of the module**

The students

- state the main areas of application, objectives and tasks of production metrology in quality management.
- apply legal metrology.
- design manual and automated measurement systems and processes.
- evaluate and validate industrial processes.
- plan acceptance tests for measurement systems and processes and carry out the acceptance tests.

**Module Content**

- Design and use of manual and automatic measurement systems and processes.
- Methods of error-free production within the framework of modern quality management systems.
- Design and conception of measuring systems and processes as autonomous working systems.
- Ensuring high reliability requirements to achieve the goals of zero-defect production.
- Integration of optical measuring methods in automated value-added processes..

**Literature and other Learning Offers**

- *Normen zum Qualitätsmanagement*, Beuth Verlag, DIN EN ISO 9000 ff jeweils aktuelle Fassung.
- G. Linß, *Qualitätsmanagement für Ingenieure*. München: Hanser Verlag, 2015.
- S. Sommer, *Taschenbuch automatisierte Montage- und Prüfsysteme*. München: Hanser Verlag, 2008.

**Special Feature**

Guest lectures from the field

| Special fields of internal combustion engines – 24.03 | | |
|---|---|---|
| **Duration** | **Semester** | **Workload** |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation |
| **Module Responsibility:** | Prof. Dr.-Ing. Schlachter | |
| **Lecturer:** | | |
| Prof. Dr.-Ing. Schlachter | | |

| Associated Course | Study Modes | Language |
|---|---|---|
| | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Engineering Mathematics 1 and 2 (1, 7), Physics (9), Thermodynamics 1 and 2 (2, 8), Fluid Mechanics (14).

**Learning outcomes after successful termination of the module**

The students

- describe and evaluate the development of specific work and rated speed over time and the associated development of engine power.
- use the correct technical terminology in group discussions as well as in questions.
- name and draw the extreme positions of the working pistons in reciprocating and Wankel engines as well as the intermediate working strokes and calculate kinematic and volumetric quantities.
- compare the structure of the cycle processes of four-stroke and Stirling engines and write down the reasons for real deviations from the ideal processes.
- name the characteristics underlying engine supercharging and construct absorption lines for supercharged engines.
- describe real technical systems and machines that can be modeled with cyclic processes.
- describe the design of turbochargers and the possibilities for controlling them.
- analyse the influence of fossil fuels on carbon dioxide emissions and specify chains of effects for the use of alternative fuels.

**Module Content**

- Historical classification of combustion engines and scientific mechanical engineering
- Wankel engine and comparative view Wankel / reciprocating engine
- Stirling engine
- Turbocharging of internal combustion engines
- Alternative fuels
- Control of the charge change
- Cam geometry and valve spring
- Components and damage (guest lecture)

| Literature and other Learning Offers |
|---|
| • R. van Basshuysen, Handbuch Verbrennungsmotor, 8. Auflage. Wiesbaden: Springer Vieweg, 2017.<br>• H. Pucher, K. Zinner, Aufladung von Verbrennungsmotoren, 4. Auflage. Heidelberg: Springer 2012.<br>• R. Teichmann, Grundlagen Verbrennungsmotoren, 8. Auflage. Wiesbaden: Springer 2018.<br>• Unterlagen im eLearning-System der THWS<br>• Sammlung zusammengestellter Lehrvideos zu Geschichte und Wankel (im Skriptum verlinkt) |
| **Special Feature** |

| Combustion technology – 24.04 | | |
|---|---|---|
| **Duration** | **Semester** | **Workload** |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation |
| **Module Responsibility:** Prof. Dr.-Ing. Blotevogel | | |
| **Lecturer** | | |
| Prof. Dr.-Ing. Blotevogel | | |

| **Associated Course** | **Study Modes** | **Language** |
|---|---|---|
| | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Engineering Mathematics 1 and 2 (1, 7), Physics (9), Chemistry (3), Thermodynamics 1 and 2 (2, 8).

**Learning outcomes after successful termination of the module**

The students

- draw the basic chain of combustion.
- name the main flame types of technical combustion.
- differentiate between the flame types based on their typical properties and state typical areas of application for the various flame types.
- list the starting conditions for combustion processes as well as technical parameters to describe these starting conditions.
- perform a basic combustion calculation and calculate the air requirement and exhaust gas composition in a combustion process with gaseous, liquid and solid fuels.
- investigate the energetics of combustion processes by applying the first law of thermodynamics to combustion processes, e.g. they calculate the heat release or the adiabatic combustion temperature.
- name the basic relationships and influencing parameters in the formation of pollutants and use them to analyse combustion processes.

**Module Content**

- Thermodynamics of combustion processes; chemistry of combustion.
- Types of technical combustion (ignition processes; laminar and turbulent premixed flame, laminar and turbulent non-premixed flame)
- Combustion calculation (including air demand, exhaust gas composition, energetics and efficiency)
- pollutant formation and reduction
- Measurement technology for combustion processes (conventional and optical)

| Literature and other Learning Offers |
| --- |
| • F. Dinkelacker und A. Leipertz, *Einführung in die Verbrennungstechnik*, 3. Auflage. Erlangen: ESYTEC, 2012.<br>• J. Warnatz, U. Maas und R. W. Dibble, *Combustion*, 4. Auflage. Berlin, Heidelberg: Springer, 2006.<br>• F. Joos, *Technische Verbrennung: Verbrennungstechnik, Verbrennungsmodellierung, Emissionen*. Berlin: Springer, 2006.<br>• S. McAllister, J.-Y. Chen und A. C. Fernandez-Pello, *Fundamentals of Combustion Processes*. New York: Springer, 2011.<br>• I. Glassman, R. A. Yetter und N. G. Glumac, *Combustion*, 5. Auflage. Amsterdam: Academic Press, 2014. |
| **Special Feature** |

| **Rolling bearing applications – 24.05** | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation | |
| **Module Responsibility:** Prof. Dr.-Ing. Sommer | | | |
| **Lecturer** | | | |
| Prof. Dr.-Ing. Sommer | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | Seminar-type Teaching, Exercises | German |
| **Applicability and Study Semester:** | | | |
| Machine elements and construction | | | |
| **Learning outcomes after successful termination of the module** | | | |
| The students<br>• differentiate between the main areas of application of rolling bearings.<br>• select rolling bearings for use in mechanical systems.<br>• interpret the calculation methods of complex rolling bearing systems.<br>• evaluate and examine special areas of application of rolling bearing systems.<br>• evaluate the diagnosis and maintenance of rolling bearing systems. | | | |
| **Module Content** | | | |
| • Design and calculation of rolling bearings<br>• Application of rolling bearing systems<br>• Measurement technology for rolling bearings<br>• Production of rolling bearings<br>• Condition monitoring of rolling bearing systems in operation<br>• Discussion of different application areas, e.g. for wind turbines, industrial gears and mobility applications | | | |
| **Literature and other Learning Offers** | | | |
| • Schaeffler AG, *Die Wälzlagerpraxis*. Mainz: Vereinigte Fachverlage, 2015.<br>• H. Wittel, D. Jannasch, J. Voßiek und C. Spura, *Roloff/Matek Maschinenelemente: Normung, Berechnung, Gestaltung,* 23. Auflage. Wiesbaden: Springer Vieweg Verlag, 2017. | | | |
| **Special Feature** | | | |
| Guest lectures from the field | | | |

| **Materials in welding technology – 24.06** | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation | |
| **Module Responsibility:** LBA Dipl.-Ing (FH) Latteier (EWE) | | | |
| **Lecturer:** | | | |
| LBA Dipl.-Ing (FH) Latteier (EWE) | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | Seminar-type Teaching, Exercises | German |
| **Applicability and Study Semester:** | | | |
| Fundamentals of materials engineering | | | |
| **Learning outcomes after successful termination of the module** | | | |
| The students<br>• describe the basic methods of material selection from a welding engineering point of view.<br>• state the factors influencing the weldability of steels and aluminum.<br>• demonstrate the influence of a point source of heat on a component or its material.<br>• recognize the problem of brittle fracture during welding, select appropriate countermeasures and apply them.<br>• name the defects that can occur in a welded joint, select suitable test procedures to find these defects and propose countermeasures.<br>• describe the structure of a weld seam and the main factors influencing the welding of the most important steel grades.<br>• use the Schaeffler diagram appropriately and predict the weld-metallurgical behavior of steels. | | | |
| **Module Content** | | | |
| • Steels and their properties<br>• Influence of the welding process on the properties of the joint<br>• Welding metallurgy of steels and non-ferrous metals<br>• Testing of welded joints | | | |
| **Literature and other Learning Offers** | | | |
| • G. Schulze, *Die Metallurgie des Schweißens*, 4. Auflage. Berlin: Springer Verlag, 2010.<br>• H. Fahrenwaldt et al., *Praxiswissen Schweißtechnik*, 5. Auflage. Berlin: Springer Verlag, 2015.<br>• J. Schuster, *Schweißen von Eisen-, Stahl- und Nickelwerkstoffen*, 2. Auflage. Düsseldorf: DVS-Media, 2009.<br>• Unterlagen auf der eLearning-Plattform der Hochschule | | | |
| **Special Feature** | | | |

| **Production system – 24.07** | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation | |
| **Module Responsibility:** | Prof. Dr.-Ing. Krüger | | |
| **Lecturer:** | | | |
| Prof. Dr.-Ing. Krüger | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | Seminar-type Teaching, Exercises | German |
| **Applicability and Study Semester:** | | | |
| Manufacturing and Production Engineering "Machining Production | | | |

**Learning outcomes after successful termination of the module**

The students

- describe order processing in the company.
- describe various planning methods in the context of production planning (operation planning, assembly planning, creation of routings) and apply these methods to typical tasks.
- describe basic planning methods of production control (capacity planning, scheduling) and apply these methods to typical tasks.
- describe methods for optimisation in manufacturing (e.g. value stream mapping and design) and apply these methods to typical tasks.

**Module Content**

- Different order fulfillment processes in the company
- Understanding the contents of routings and creating routings
- Approach to production planning and methods used
- Long and short-term planning tasks
- Production control with capacity planning and scheduling
- Value stream analysis and design

**Literature and other Learning Offers**

- Lecture notes in the THWS eLearning system

**Special Feature**

| Data analysis for engineers – 24.08 | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>20 h self-study phases<br>10 h exam preparation | |
| **Module Responsibility:** Prof. Dr.-Ing. Schreiber | | | |
| **Lecturer:** | | | |
| Prof. Dr.-Ing. Schreiber | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | Seminar-type Teaching, Exercises | German |
| **Applicability and Study Semester:** | | | |
| Engineering mathematics 1 and 2 (1, 7), physics (9), Measuring in Hyrogen Plants (16). | | | |

**Learning outcomes after successful termination of the module**

The students

- name the essential terms, definitions and procedures of explorative data analysis.
- list data sources, data types and suitable types of presentation.
- use appropriate methods for targeted data collection.
- select distribution models (uniform distribution / normal distribution / Weibull distribution / ...) and correctly assign statements about mean, median and measures of dispersion.
- name statements about confidence intervals and significance.
- analyse data from simulations, testing, production and field use and propose measures to optimize products and processes.
- apply the law of propagation of deviations and, on this basis, propose component and assembly tolerances that are suitable for production, assembly and function.
- state the special features of the interpretation of service life data and correctly assess results in this respect.

**Module Content**

- Preparation and analysis of unplanned (historical) data
- Basic principles of statistical experimental design
- Equalization calculation using polynomial regression and kriging
- Tolerance analysis and tolerance design
- Basic features of service life analysis

**Literature and other Learning Offers**

- S. Brandt, Datenanalyse für Naturwissenschaftler und Ingenieure, 5. Auflage, Heidelberg: Springer, 2013.
- W. Kleppmann, Versuchsplanung, 10. Auflage. München: Hanser, 2020
- NIST/SEMATECH: e-Handbook of Statistical Methods, http://www.itl.nist.gov/div898/handbook/
- Lehrveranstaltungsunterlagen im eLearning-System der THWS

**Special Feature**

| Additive manufacturing of metallic components – 30.01 | | |
|---|---|---|
| **Duration** | **Semester** | **Workload** |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation |
| **Module Responsibility:** Prof. Dr.-Ing. Versch | | |
| **Lecturer:** | | |
| Prof. Dr.-Ing. Versch | | |

| **Associated Course** | **Study Modes** | **Language** |
|---|---|---|
| | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Materials engineering, production engineering

**Learning outcomes after successful termination of the module**

The students

- state the special requirements for occupational health and safety when handling metal powders and lasers as well as for the workplace design of additive manufacturing areas.
- list the additive manufacturing processes for the production of metallic components and their properties including the applicable materials.
- roughly draw up the machine structure of additive manufacturing machines and their assemblies, in particular optical components
- assess the impact of the choice of technological parameters on the technical-physical processes in the construction process and their effects on the component properties
- identify economically viable fields of application and select the appropriate manufacturing process and the best manufacturing strategy for different applications according to the requirements.
- apply rules for the production-oriented design of additively manufacturable components
- use the correct procedure of data preparation from the digitized component model (CAD data) and its connection with technology data to create the construction programme
- name the process limits of the procedures and necessary reworking steps

**Module Content**

- Workplace design and occupational health and safety in additive manufacturing
- Additive technologies: powder bed and powder nozzle with complete processing
- Machine design of additive manufacturing systems for metal components, especially optics
- Possibilities of additive component design and design requirements from the technology
- Selection of manufacturing strategy
- Data preparation for the creation of build jobs
- Technological process and possibilities for in-process measurement of quality
- Post-processing of additively manufactured components to the ready-to-install part

| Literature and other Learning Offers |
|---|
| • U. Berger, A. Hartmann und D. Schmid, *Additive Fertigungsverfahren: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing*. Haan: Europa-Lehrmittel, 2013.<br>• A. Gebhardt, *Additive Fertigungsverfahren: Additive Manufacturing und 3D-Drucken für Prototyping - Tooling – Produktion*. München: Carl Hanser Verlag, 2016. |
| **Special Feature** |

| Acoustics - 30.02 | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | |
| 1 Semester | Summer Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation | |
| **Module Responsibility:** Prof. Dr.-Ing. Retka | | | |
| **Lecturer:** | | | |
| Prof. Dr.-Ing. Retka | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | Seminar-type Teaching, Exercises | German |
| **Applicability and Study Semester:** | | | |
| Engineering mathematics 1 and 2 (1, 7), physics (9) | | | |

**Learning outcomes after successful termination of the module**

The students

- state the essential basic acoustic terms and their mathematical relationships.
- list simplified models of sound generation and propagation and evaluate the effects of sound events in a practical manner.
- name the most important specific characteristics of the human auditory system and evaluate sounds objectively.
- state the common methods of noise analysis and interpret the corresponding measurement specifications.
- select suitable measurement techniques for noise analysis and identify the sources of noise disturbance.
- assess, depending on the characteristics of these sources, whether they can be eliminated or effectively combated by suitable damping or reduction measures.

**Module Content**

- Basic terms, physiological principles
- Noise sources
- Sound propagation of airborne and structure-borne sound, transmission paths
- Sound insulation and attenuation
- Noise generation in machines and systems
- Measuring instruments, sensors, analysis of measured data

| Literature and other Learning Offers |
| --- |
| • I. Veit, *Technische Akustik*, 7. Auflage. Würzburg: Vogel Business Media, 2012.<br>• G. R. Sinambari und S. Sentpali, *Ingenieurakustik*, 5. Auflage. Berlin Heidelberg: Springer Vieweg, 2014.<br>• F. G. Kollmann, T. F. Schösser und R. Angert, *Praktische Maschinenakustik*, 1. Auflage. Berlin, Heidelberg: Springer-Verlag, 2006.<br>• P. Zeller, *Handbuch Fahrzeugakustik*, 2. überarbeitete Auflage. Heidelberg: Vieweg+Teubner Verlag, 2011.<br>• H. Klingenberg, *Automobil-Meßtechnik*: Band A: Akustik, 2. Auflage 1991. Berlin Heidelberg: Springer-Verlag, Reprint 2012.<br>• Lehrveranstaltungsunterlagen im eLearning-System der THWS |
| **Special Feature** |
| |

| Introduction to the Finite Element Method (FEM)– 30.03 | | |
|---|---|---|
| **Duration** | **Semester** | **Workload** |
| 1 Semester | Winter Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation |
| **Module Responsibility:** Prof. Dr.-Ing. Mengelkamp | | |
| **Lecturer:** | | |
| Prof. Dr.-Ing. Mengelkamp | | |

| **Associated Course** | **Study Modes** | **Language** |
|---|---|---|
| | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Terms of technical mechanics, linear algebra

**Learning outcomes after successful termination of the module**

The students
- list the essential terms and relationships in the field of finite element simulation.
- state the stiffness matrix for tension/compression and torsion bars.
- derive the transformation relationships to transform the element stiffness matrices from the local to the global coordinate system.
- use the formulas for the stiffness matrix together with the transformation relations to describe the behavior of a truss, i.e., to formulate the equilibrium equations or the equations of motion.
- enumerate the most common boundary conditions.
- incorporate the boundary conditions into the equations.
- calculate the mechanical quantities stresses and deformations using the finite element method both manually and with a commercial finite element programme.
- analyse the results and draw conclusions on a design that may need to be modified.

**Module Content**

- Principle procedure of a FEM calculation
- modeling
- spatial discretization
- trusses, torsion bars
- Consideration of temperature changes
- solution of equation systems

| **Literature and other Learning Offers** |
|---|
| • B. Klein, *FEM, Grundlagen und Anwendungen der FEM im Maschinen- und Fahrzeugbau*, 10. Auflage. Berlin Heidelberg: Springer, 2015.<br>• C. Gebhardt, *Praxisbuch FEM mit Ansys Workbench*, 3. Auflage. München Wien: Hanser, 2018.<br>• C. Gebhardt, *Konstruktionsbegleitende Berechnung mit ANSYS DesignSpace*. München Wien: Hanser, 2009.<br>• Vorlesungsunterlagen im eLearning-System der THWS |
| **Special Feature** |
| Conduct accompanying FEM internship experiments |

| Marketing/Technical Sales – 30.04 | | |
|---|---|---|
| **Duration** | **Semester** | **Workload** |
| 1 Semester | Winter Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation |
| **Module Responsibility:** | LBA Dipl.-Ing. (FH) Thomas Rieß | |
| **Lecturer:** | | |
| LBA Dipl.-Ing. (FH) Thomas Rieß | | |

| **Associated Course** | **Study Modes** | **Language** |
|---|---|---|
| | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

**Learning outcomes after successful termination of the module**

The students

- describe the basic processes in industrial goods marketing and technical sales.
- recognise different types of business and analyse them about suitable market cultivation and sales strategies as well as the purchasing behavior of customers.
- name the typical sales channels in distribution.
- evaluate different organizational forms in sales regarding their quality and suggest optimizations.
- name the phases in the life cycle of a product and possible activation measures.
- state the special features of price negotiations with industrial customers.

**Module Content**

- Business types in industrial goods marketing
- Product and market positioning
- Sales channels, sales organization and control
- Phases in the sales process
- Sales psychology with industrial customers
- Negotiation and closing techniques

**Literature and other Learning Offers**

- Course materials in the eLearning system of the THWS

**Special Feature**

| Machine learning - 30.05 | | |
|---|---|---|
| **Duration** | **Semester** | **Workload** |
| 1 Semester | Winter Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation |

**Module Responsibility:** Prof. Dr.-Ing. Jean Meyer

**Lecturer:**

Prof. Dr.-Ing. Meyer

| Associated Course | Study Modes | Language |
|---|---|---|
| | Seminar-type Teaching, Exercises | German |

**Applicability and Study Semester:**

Engineering Mathematics 1 und 2 (1, 7)

**Learning outcomes after successful termination of the module**

The students

- classify machine learning as a discipline in the subject area of artificial intelligence.
- name areas of application of machine learning in engineering.
- list relevant parameters for the description of model quality.
- explain the differences between supervised and unsupervised learning.
- select basic machine learning algorithms based on the respective learning task and apply these algorithms.
- describe the structure of neural networks and the training process.
- carry out the application of neural networks in the context of image recognition.
- name areas of application of relevant software and hardware products used in the context of machine learning.

**Module Content**

- Methods of supervised and unsupervised learning
- Basic machine learning algorithms and their application
- Structure, function and learning of neural networks
- Deep Learning
- Data management in the context of machine learning
- Application of machine learning in image recognition
- Practical examples, including speech recognition and image recognition
- Software and hardware products from the field of machine learning

**Literature and other Learning Offers**


- S. Russel und P. Norvig, *Künstliche Intelligenz*, 3. Auflage. München: Pearson Studium, 2012.
- E. Alpaydin, *Maschinelles Lernen*. München: Oldenbourg, 2008.
- A.C. Müller und S. Guido, *Einführung in Machine Learning mit Python*. Heidelberg: O'Reilly, 2017.
- M. Paluszek und S. Thomas, *MATLAB Machine Learning*. New York: APRESS, 2017.

| **Special Feature** |
|---|

| Signals and systems – 30.06 | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | |
| 1 Semester | Winter Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation | |
| **Module Responsibility:** Prof. Dr.-Ing. Wilke | | | |
| **Lecturer:** | | | |
| Prof. Dr.-Ing. Wilke | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | Seminar-type Teaching, Exercises | German |
| **Applicability and Study Semester:** | | | |
| Engineering Mathematics 1 and 2 (1, 7), Control Engineering (15), Measurement Engineering (16) | | | |

**Learning outcomes after successful termination of the module**

The students

- name the basics of signal and system theory.
- list the elementary signals.
- form the Laplace and Fourier transforms of time functions.
- analyse systems with their responses to elementary signals.
- create transfer functions of linear, time-invariant systems.
- evaluate the system behaviour in the frequency and image range independently of the technical system characteristics.

**Module Content**

- Elementary signals
- Linear, time-invariant systems
- Integral transformations (Laplace, Fourier transform)
- Spectral analysis
- Transfer functions of linear, time-invariant systems

**Literature and other Learning Offers**

- R. Scheithauer, *Signale und Systeme*, 2. Auflage. Wiesbaden: Vieweg + Teubner, 2004.
- M. Meyer, *Signalverarbeitung*, 7. Auflage. Wiesbaden: Springer Vieweg, 2014.
- M. Werner, *Signale und Systeme*, 3. Auflage. Wiesbaden: Vieweg+Teubner, 2008.
- M. Werner, *Digitale Signalverarbeitung mit MATLAB*. Wiesbaden: Vieweg+Teubner, 2012.

**Special Feature**

| **Systematic material selection in the development process – 30.07** | | | |
|---|---|---|---|
| **Duration** | **Semester** | **Workload** | |
| 1 Semester | Winter Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation | |
| **Module Responsibility:** Prof. Dr.-Ing. Spielfeld | | | |
| **Lecturer:** | | | |
| Prof. Dr.-Ing. Spielfeld | | | |
| **Associated Course** | | **Study Modes** | **Language** |
| | | Seminar-type Teaching, Exercises | German |
| **Empfohlene Teilnahmevoraussetzungen und Vorkenntnisse** | | | |
| Werkstofftechnik, Festigkeitslehre | | | |

**Learning outcomes after successful termination of the module**

The students

- name the function, fixed boundary conditions, free parameters and parameters to be optimised for an application in order to prepare the material selection.
- apply their knowledge of materials engineering and strength theory and establish the basic equations for material selection for the application described.
- carry out a selection process for multi-parameter boundary conditions.
- compile diagrams of the material parameters in double logarithmic order.
- carry out the selection of the optimally suitable material for the parameter to be optimised.
- establish dimensionless geometry factors for bending and torsion and consider the influence of geometry on the choice of material.
- consider the factors "economy and ecology" when selecting materials.

**Module Content**

- Physical properties of the materials and their interrelationships
- Preparing the selection process by compiling parameters
- Application of the "Ashby diagrams" for material selection
- Material selection with several functional parameters
- Material selection and geometry: geometry factors
- Material selection, economy and ecology: economic and ecological constraints in material selection

**Literature and other Learning Offers**

- M. F. Ashby, *Materials Selection in Mechanical Design*, 5th Edition. Oxford: Butterworth-Heinemann, 2016.
- M. Reuter, *Methodik der Werkstoffauswahl: Der systematische Weg zum richtigen Material*, 2. Auflage. München: Carl Hanser Verlag, 2014.

**Special Feature**

## Materials and manufacturing processes in car frame construction – 30.08

| Duration | Semester | Workload |
|---|---|---|
| 1 Semester | Winter Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation |

**Module Responsibility:** Prof. Dr.-Ing. U. Müller

**Lecturer:**

Prof. Dr.-Ing. U. Müller

| Associated Course | Study Modes | Language |
|---|---|---|
| | Seminar-type Teaching, Exercises | German |

**Empfohlene Teilnahmevoraussetzungen und Vorkenntnisse**

Basic knowledge of mechanics, machine elements/design, manufacturing and materials technology

**Learning outcomes after successful termination of the module**

The students

- describe the main drivers of change for mobility in the next 10 years with the associated effects on car frame construction.
- name the most important chassis construction methods with the associated material concepts.
- describe the use of selected materials on some concrete car frame components.
- list the most important manufacturing and joining processes for car frame construction.
- analyse the joining processes with regard to their suitability for use depending on different parameters, e.g. number of pieces, complexity and light-weight design.
- describe the manufacturing processes, the areas of application and the special features of the use of ultra-high-strength steels in the car frame.

**Module Content**

- Drivers of change for mobility
- Body construction methods
- Materials for car frame construction, especially steels
- High-strength steels
- Manufacturing and joining processes

**Literature and other Learning Offers**


- S. Pischinger, U. Seiffert, *Handbuch Kraftfahrzeugtechnik*, 9. Auflage. Wiesbaden: Springer Vieweg, 2021.
- B. Klein, *Leichtbaukonstruktion*, 6. Auflage. Wiesbaden: Vieweg Verlag, 2005.
- F. Henning, E. Moeller, *Leichtbau, Methoden, Werkstoffe, Fertigung*, 2. Auflage. München: Carl Hanser Verlag, 2011.
- Lehrveranstaltungsunterlagen im eLearning-System der THWS


**Special Feature**

| Systematic investigation of technical cases of damage – 30.09 | | |
|---|---|---|
| **Duration** | **Semester** | **Workload** |
| 1 Semester | Winter Semester | Total: 75 h<br>30 h attendance (2 semester periods per week)<br>30 h self-study phases<br>15 h exam preparation |
| **Module Responsibility:** LB Dipl.-Ing. Loos | | |
| **Lecturer:d** | | |
| LB Dipl.-Ing. Loos | | |
| **Associated Course** | **Study Modes** | **Language** |
| | Seminar-type Teaching, Exercises | German |

**Empfohlene Teilnahmevoraussetzungen und Vorkenntnisse**

Materials engineering (4,10)

**Learning outcomes after successful termination of the module**

The students

- describe the basic methodology for investigating technical damage and apply it.
- present the classification of fractures and cracks and list them in the corresponding technical terminology.
- describe the purpose and basic functioning of the two most important types of microscopes (light microscope and scanning electron microscope).
- name the macroscopic and microscopic features of mechanically caused fractures and cracks and recognise these features on concrete damaged parts and by means of illustrative materials and exercises.
- analyse the damage pattern and assess the material and stress condition of damaged parts.
- visually examine real damaged parts, derive initial damage hypotheses from this and suggest further investigation steps that may be necessary.

**Module Content**

- Procedure for the investigation of technical damage
- Classification and characteristics of fractures and cracks
- Microscopic examination methods
- Manifestations of ductile and brittle force fracture as well as fatigue fracture
- Basics of electrochemical corrosion
- Appearances of corrosion damage

**Literature and other Learning Offers**


- A. Neidel et al., *Handbuch Metallschäden*, 2. Auflage. München: Carl Hanser Verlag, 2011.
- G. Lange und M. Pohl, *Systematische Untersuchung technischer Schadensfälle*, 6. Auflage. Weinheim: Wiley-VCH, 2014.


**Special Feature**