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 2023

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1 Study Plan

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)

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<tr><th colspan="2" rowspan="2"></th><th colspan="30">ECTS Credit Points</th></tr>
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<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>
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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>
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<tr><td>6</td><td colspan="5">Seminar in Engineering (31)</td><td colspan="21"></td></tr>
<tr><td>7</td><td colspan="4">Application Project (33)</td><td colspan="2">Technical Lab Training(34)</td><td colspan="4">Cost Accounting and Ethics for Engineers (35)</td><td colspan="16"></td></tr>
</table>

2 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 90 contact hours (6 hours per week during the semester lecture period) 30 hours self study 30 hours exam preparation	5

Module Responsibility: N.N.

Lecturer:

N.N.

Associated Course	Study Modes	Language
Engineering Mathematics 1 (6 Semester Hours per Week)	Seminar-type Teaching, Exercises	English

Applicability and Study Semester:

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

This module provides the basis for the modules:	Engineering Mathematics 2 (7), Physics (9), Engineering Mechanics (5), Thermodynamics 1 and 2 (2, 8), Elektrical Engineering (12)
This module is based on the modules:	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 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

- explain the calculation methods in the complex number space.
- explain the fundamental theorem of algebra.
- apply the basics of vector calculus.
- solve systems of linear equations.
- name the basic methods of matrix calculation.
- explain the basics of differential calculus.
- apply the rules of integral calculus.

Module Content

• Complex Numbers
  ○ Basics
  ○ Forms of representation
  ○ 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 90 contact hours (6 hours per week during the semester lecture period) 30 hours self study 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, Exercises	English

- **Applicability and Study Semester:**

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

This module provides the basis for the modules:	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)
This module is based on the modules:	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 definition of the kind and 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 • list and define the essential terms and relationships in the field of thermodynamics, in particular the process variables heat and work as well as the thermal and calorific state variables. • write down the essential basic equations (e.g. first law of thermodynamics). • describe the differences between the terms heat, temperature and internal energy. • use the correct terminology in group discussions and questions and judge each other on the correct use of terminology. • describe the material model "ideal gas" and name the limitations and boundary conditions when using this material model. • calculate thermal and caloric state variables as well as process variables in the case of changes of state of the ideal gas. • state the basic structure of left- and right-handed circular processes and define suitable evaluation parameters to describe these processes. • calculate thermal and caloric state variables, process variables, other variables (e.g. speeds, outputs) and evaluation ratios for circular processes and apply the individual methodological steps for calculating and analysing circular processes. • analyse cyclic processes with the working tool "ideal gas" for essential influencing variables. • describe real technical systems and machines that can be modelled with these circular processes. • evaluate the calculation quality (e.g. simplifications, assumptions) and the model quality (deviations of the cyclic process from the real machine). • evaluate processes and real technical systems with regard to their suitability and quality and propose 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. • use the principle of the "group of marbles" to work out answers to the teacher's questions in the course lessons. • evaluate different ways of training the careful and at the same time fast processing of tasks and filter out the most suitable method for themselves.
Module Content
• Conservation laws of thermodynamics, thermal and caloric state variables of substances and process variables. • Nature and interrelations of energy (as a generic term) and the forms of energy heat and work • Methodology for dealing with thermodynamic problems • Material model "ideal gas" and the behaviour of ideal gases • Special (idealised) changes of state of ideal gases • Left- and right-handed cyclic processes with the working medium "ideal gas" (e.g. Carnot, Joule, Ericsson, Stirling, Otto, Diesel, Seiliger process) • Introduction to the structure and mode of operation of power and working machines • 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. • H. D. Baehr und S. Kabelac, Thermodynamik: Grundlagen und technische Anwendungen, 16., aktualisierte Auflage. Berlin, Heidelberg: Springer Vieweg, 2016. • G. Cerbe und G. Wilhelms, Technische Thermodynamik: Theoretische Grundlagen und praktische Anwendungen, 18., überarbeitete Auflage. München: Hanser, 2017. • H. Herwig, C. Kautz und A. Moschallski, Technische Thermodynamik: Grundlagen und Anleitung zum Lösen von Aufgaben, 2., überarbeitete Auflage. Wiesbaden: Springer Vieweg, 2016. • W. Heidemann, Technische Thermodynamik: Grundkurs für das Bachelorstudium. Weinheim: Wiley VCH, 2016. • Online-Tests and JiTE-Tasks eLearning-System THWS • Interactive Simulations „Ideal Gas“, PhET-Website, z.B. https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties_en.html
Special Feature

<table>
<tr><td colspan="4">Module: 3</td></tr>
<tr><td colspan="4">Chemistry, Electrochemistry</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
60 contact hours (4 hours per week during the semester lecture period)
60 hours self study
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">Chemistry, Electrochemistry (4 Semester Hours per Week)</td><td>Seminar-type Teaching, Exercises, Lab course</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, 1st Semester)</td></tr>
<tr><td>This module provides the basis for the modules:</td><td colspan="3">All technical modules</td></tr>
<tr><td>This module is based on the modules:</td><td colspan="3"></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">School knowledge mathematics, chemistry and physics</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 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.</td></tr>
</table>

Learning outcomes after successful termination of the module
The students • valuate atoms in terms of their ability to form metallic, ionic or covalent bonds. • name the difference between an acid and a base and correctly assign the pH value. • analyse the polarity of molecules based on the chemical structure and identify the partial positive and negative regions in a polar molecule. • assign the correct oxidation states to the elements involved in a redox reaction. • evaluate the redox process according to the electrochemical voltage series. • explain the difference between an exothermic and an endothermic reaction, as well as the influence of the catalyst on the course of the reaction. • calculate the standard enthalpy of reaction and free enthalpy for individual molecules with the help of tables. • calculate the resulting potential of a redox reaction depending on the concentrations/partial pressures of the reactants ⇔ Apply the Nernst equation. • set up redox reaction equations for different fuel cell reactions. • name the common metals and matrix materials for alkaline and acid fuel cells, as well as the typical electrode and electrolyte poisons, such as CO2, CO, Cl ions. • explain the basic electrochemical principle of an alkaline fuel cell, a PEM fuel cell and an electrolyser.
Module Content
• Atomic structure and the periodic table • Bond types (covalent, ionic, metal bond) • Basics of oxidation chemistry • Acid-base concept • Redox reactions • Introduction to chemical thermodynamics and electrochemistry • Electrochemistry of fuel cell types • Chemistry of hydrogen
Literature and other Learning Offers
• G. Kickelbick, Chemie für Ingenieure, 1. Auflage, München: Addison-Wesley Verlag, 2008 • P. Kurzweiler, Angewandte Elektrochemie, 1. Auflage, Wiesbaden: Springer-Vieweg, 2020 • P. Kurzweiler, Brennstoffzellentechnik, 3. Auflage, Wiesbaden: Springer-Vieweg, 2016 • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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, Exercises	English

Applicability and Study Semester:	
Bachelor Programme Hydrogen Technologies (Compulsory Module, 1st Semester)	
This module provides the basis for the modules:	Materials Technoly 2 (10)
This module is based on the modules:	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 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

- name and visualise different types of metal lattices.
- evaluate different hardening mechanisms in metallurgy.
- name different methods of mechanical materials testing.
- use phase diagrams: Lever rule, alloy science.
- describe the methodology of drawing phase diagrams.
- draw the iron - carbon diagram
- name essential microstructures in the Fe-C system.
- describe the processes for the production of iron and steel

Module Content
• The structure of atoms. • The groups of materials. • Crystallographic structure of metals. • Lattice defects: 0., 1., 2. and 3. dimension. • Lattice defects and hardening mechanisms. • Phase diagrams: Making phase diagrams. Thermal analysis. • Basic types of phase diagrams. • The lever rule. • Basics of diffusion and heat treatment of metals. • Production of iron and steel. • The iron-carbon diagram. • Near-equilibrium microstructures in the Fe-C system. • Designation of steels • Steels for use in the hydrogen context: Hydrogen pressure resistant steels. • 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. • Bargel, H./Schulze, G. (Hrsg.) (2012): Werkstoffkunde, 11. Auflage, Springer-Vieweg. • Berns, H./ Theisen, W.: Eisenwerkstoffe Stahl und Gusseisen, 4. Auflage, Springer. • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)			
This module provides the basis for the modules:	Plants and Vessels 1 (11), Plants and Vessels 2 (22), Fluid Mdechanics (14)		
This module is based on the modules:			
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 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 • list the essential components of a mechanical substitute model (beams, rods, bearings, joints, types of load, etc.), recognise the symbols in the substitute models and correctly assign, for example, the bearing reactions or transferable internal forces. • name the terms static and kinematic determinacy, describe their meaning and analyse simple mechanical systems in this respect. • apply the principle of sectioning confidently and create suitable free-body diagrams for a given problem. • 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). • list the essential terms and interrelationships in the field of strength theory and define them, in particular the terms stress and strain. • define them, especially the terms stress and distortion. • calculate the stresses and deformations for the basic load cases such as tension/compression, bending, torsion and the pressure load of boilers. • analyse and optimise given constructions with regard to the strength verification, the problem of constraining forces in statically indeterminate systems and the various stability cases. • 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
• Force addition and equilibrium in central, general and spatial force systems. • Systems of rigid bodies, characteristics of selected joints and bearings, static determinacy. • Calculation of bearing reactions and internal forces. Calculation of centre of gravity • Sectional principle, Newton's laws • Calculation of stresses and deformations under tension/compression, bending and torsion • Thin-walled containers under rotationally symmetrical loading Stress and distortion state, material laws, strength hypotheses • 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. • 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. • D. Gross, W. Hauger, J. Schröder und W. Wall, Technische Mechanik 2 (Elastostatik), 13. Auflage. Berlin Heidelberg: Springer, 2017. • 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. • U. Gabbert und I. Raecke, Technische Mechanik für Wirtschaftsingenieure, 7., aktualisierte Auflage. München: Carl Hanser, 2013. • M. Mayr, Technische Mechanik, 8. Auflage. München, Wien: Carl Hanser Verlag, 2015. • O. Romberg und N. Hinrichs, Keine Panik vor Mechanik, 9. Auflage. Wiesbaden: Springer Vieweg, 2020. • R. Christel: Lecture notes, video tutorials and tests, Schweinfurt: eLearning-System, 2021. • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Application Project (33)
This module is based on the modules:	

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 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 • state basic terms and contents of information technology architectures, software tools and their fields of application. • - decide on the basis of the given task which solution approaches are best suited for digitalisation. • - analyse the significance and the optimisation potential of digitalisation measures in hydrogen technology on the basis of the use of networked sensor technology. • - name the importance of communication, independent knowledge acquisition and social interaction. • - create their own programme codes to solve various problems and use the debugger for troubleshooting. • - name the different possibilities of graphical representation, select the appropriate one for the task and apply it. • - evaluate the results with regard to their plausibility and present them graphically. • - 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 • Lecture notes in the THWS eLearning system
Special Feature

Course
Programming
Lecturer:
N.N
Content
• Basics of programming • Graphical representation of functions • Data import and export • 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. • Basics of digitalisation in hydrogen technology • Basics of project work in software development
Special Feature

Module: 7

Engineering Mathematics 2

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Summer Semester	Total Workload: 150 h 90 contact hours (6 hours per week during the semester lecture period) 30 hours self study 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)

This module provides the basis for the modules:	This module provides the basis for the modules:
This module is based on the modules:	This module is based on the modules:

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 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 • characterise the local behaviour of functions of several variables with the help of differential calculus. • 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.). • evaluate existence and uniqueness of solutions to given initial value problems using the theorems of Peano and Picard-Lindelöf. • classify differential equations and select the solution method based on this. • solve linear DGL with constant coefficients in the homogeneous and inhomogeneous case (characteristic polynomial, variation of constants, approach method) in physical-technical problems (mechanics, electrical engineering). • state the concept of a DGL system and name its geometric interpretation as well as the connection between DGL systems of 1st order and DGL of higher order. • calculate eigenvalues and eigenvectors of quadratic matrices. • state the general concept of a parameterised curve as well as the related concepts of velocity vector, acceleration vector and arc length. • state the forms of representation of plane curves and calculate tangent, normal, curvature and arc length.
Module Content

• Multidimensional differential calculus
  ○ Partial derivative
  ○ Gradient, Jacobian matrix
  ○ Directional derivative
  ○ Schwarz's theorem
  ○ Multidimensional Taylor polynomials
  ○ Total differential
  ○ Tangential plane
  ○ Implicit differentiation
  ○ Hessian matrix
• Multidimensional integral calculus
  ○ Integration over multidimensional domains
  ○ Coordinate systems and associated transformations
  ○ Fubini's theorem
• Ordinary differential equations
  ○ Concept and meaning
  ○ Direction fields
  ○ Existence and uniqueness
  ○ Separable DE
  ○ Linear DE
  ○ Linear DE with constant coefficients
  ○ DE systems
  ○ Eigenvalues and eigenvectors
  ○ Linear DE systems with constant coefficients
• Curves
  ○ Basic terms (tangent, arc length, curvature)
  ○ Plane curves

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
Special Feature

Module: 8

Thermodynamics 2

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Summer Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	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)
This module is based on the modules:	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 definition of the kind and 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

- explain the basic relationships of thermodynamics and heat transfer using sketches and diagrams.
- apply the basic equations and relationships to exercises and technical problems.
- model and calculate changes in thermodynamic systems.
- model and calculate thermodynamic cycles with the working tool "real substance with phase change".
- model thermodynamic problems and solve them analytically.
- question solutions to thermodynamic and thermotechnical problems critically.
- evaluate processes and machines with regard to their suitability and quality.
- suggest improvements to processes and machines.
- classify the relationships between the individual sub-areas of thermodynamics and heat transfer and their mutual interactions.
- evaluate the influence of boundary conditions, process variables and interactions.
- solve complex problems by separating them into sub-questions and solving them.
- solve complex thermodynamic and thermotechnical problems from engineering practice.
- evaluate plants and technical systems.
- develop new systems, plants, components and parts in a thermodynamically and thermotechnically correct way.

Module Content

- Repetition and consolidation of selected basics of thermodynamics.
  - Conservation laws of thermodynamics, state variables of substances and fundamental variables,
  - Behaviour of ideal and real substances
  - Relationships between heat, work and energy
- Introduction to changes of state of real substances under real conditions
- Introduction to the thermodynamics of mixtures using the example of humid air
- Left- and right-handed circular processes with the working medium "real substance with phase change" (Clausius-Rankine- and cold steam process)
- Introduction to the structure and mode of action of power and working machines and to the behaviour of machines under real conditions
- Basics of heat transfer
  - Stationary and transient heat conduction
  - Heat transfer and convection
  - Heat transfer by radiation
  - Heat transfer
- Applications of the fundamentals of heat transfer using problems from everyday engineering practice, idealisation of real heat engineering problems
- Introduction to hydrogen technology
  - Introduction to the production of hydrogen using the example of PEM electrolysers
  - 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. • G. Cerbe und G. Wilhelms, *Technische Thermodynamik: Theoretische Grundlagen und praktische Anwendungen,* 18., überarbeitete Auflage. München: Hanser, 2017. • H. D. Baehr und K. Stephan, *Wärme- und Stoffübertragung,* 8. Auflage. Berlin: Springer-Verlag, 2013. • H. Herwig, C. Kautz und a. Moschallski, *Technische Thermodynamik: Grundlagen und Anleitung zum Lösen von Aufgaben,* 2., überarbeitete Auflage. Wiesbaden: Springer Vieweg, 2016. • W. Wagner, *Wärmeübertragung,* 4. Auflage. Würzburg: Vogel Fachbuch Verlag, 2011. • P. Kurzweil, *Brennstoffzellentechnik,* 3. Auflage. Berlin: Springer-Verlag, 2016. • G. Reich, *Regenerative Energietechnik,* 2. Auflage. Berlin: Springer-Verlag, 2018. • Course materials in the THWS e-Learning system
Special Feature

Module: 9

Physics			
Duration	**Semester**	**Workload**	**ECTS-Credit Points**
1 Semester	Summer Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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 Programme Hydrogen Technologies (Compulsory Module, 2nd Semester)	
This module provides the basis for the modules:	Thermodynamics 2 (8), Practical Module (32), Bachelor Thesis (36)
This module is based on the modules:	
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 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

- list the basic physical terms of the topics "Waves", "Quantum Physics" and "Statistical Thermodynamics".
- state the essential basic equations of the above-mentioned topics.
- carry out calculations on the basis of these equations.
- apply the quantitative relationships expressed by the equations to technical systems.
- explain the meaning of the basic terms and equations by means of example applications.

Module Content
• General properties of waves in linear media (superposition principle, Huygens principle) • Wave functions of harmonic waves in one and multi-dimensional systems • Interference effects in the superposition of waves (incl. refraction of waves) • Natural oscillations in one-dimensional systems • Physical description of sound waves and quantification of loudness oriented to physiological perception • Fundamentals of the propagation of electromagnetic waves and their interaction with matter • Description of electromagnetic waves in the particle image (photons) • Fundamentals of the structure of atoms and quantised emission and absorption of energy • Significance of energy quantization for thermal radiation (black body) • 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. • P. A. Tipler, Physik für Wissenschaftler und Ingenieure, 7. Auflage, Berlin: Springer Spektrum, 2015. • J. Rybach, Physik für Bachlors, 4. Auflage, München: Fachbuchverlag Leipzig, 2019. • H. Kuchling, Taschenbuch der Physik, 21. Auflage, München, Fachbuchverlag Leipzig, 2014.
Special Feature

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Module: 10

Materials Technology 2

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Summer Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Hydrogen Safety (1890)
This module is based on the modules:	Materials Technology 1 (4)

Compulsory Conditions of Participation
none

Recommended Conditions of Participation
Materials Technology 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	English

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
- select the heat treatment for the use of steels.
- 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.
- assess the influence of fatigue stress on components.
- list the basics of damage analysis.
- describe measures for damage prevention.

Module Content
• Ferrous materials • Heat treatment of steels (basics) • Heat treatment processes. • Mechanical-technological material testing • Casting: steel and cast iron • Corrosion and corrosion protection • Special mechanisms of hydrogen embrittlement • Fibre composites and special manufacturing processes • Dynamic component loading: materials and fatigue. • Materials databases • Plastics and the environment, and the materials cycle • Calculation of component costs
Literature and other Learning Offers
• Ruge, J./Wohlfahrt, H. (2013): Technologie der Werkstoffe - Herstellung, Verarbeitung, Einsatz, 9. Auflage, Springer-Vieweg. • Bargel, H./Schulze, G. (Hrsg.) (2012): Werkstoffkunde, 11. Auflage, Springer-Vieweg. • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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, 2nd Semester)

This module provides the basis for the modules:	Plants and Vessels 2 (22)
This module is based on the modules:	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 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

- 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 optimise given constructions with regard to the strength verification.
- dimension and design components and verify the strength.
- use the correct technical terminology in group discussions as well as in questions and assess each other regarding the correct use of technical terminology.
- use the essential contents of the Pressure Equipment Directive and current DIN standards.
- analyse and assess new scientific findings.
- communicate with other specialists in vessel construction.
- are aware of their responsibility to design and calculate pressure vessels safely.
- describe the influence of calculation, planning and commissioning errors on occupational safety and thus on society.

Module Content
• Calculation of stresses and deformations in plane stress states. • Stress and distortion states, strength hypotheses, material laws • Thin-walled rings and vessels under rotationally symmetrical loading • Introduction to the Pressure Equipment Directive and construction regulations • Construction elements in pressure vessel construction • Requirements for pressure vessels (construction, materials, operation, maintenance, testing and safety) • Permissible stresses and stress categories • Design of pressure-bearing walls (spherical and cylindrical shells, flat and curved bottoms) • Consideration of connection loads • Performance of stability verifications
Literature and other Learning Offers
• Gross, Hauger, Schröder, Wall, Technische Mechanik 2, Elastostatik, 13. Auflage, Springer Verlag, 2017 • Mayr, M., Technische Mechanik, 8. Auflage, Hanser Verlag, 2015 • Holzmann, Meyer, Schumpich, Technische Mechanik Festigkeitslehre, 13. Auflage, Springer Verlag, 2018 • Gabbert und Raecke, Technische Mechanik, 7. Auflage, Hanser Verlag, 2013 • Titze, H., Wilke, H-P., Groß, K., Elemente des Apparatebaues, Grundlagen Bauelemente Apparate, 3. Auflage Springer Verlag, 1992 • Schwaigerer, S., Mühlenbeck, G., Festigkeitsberechnung im Dampfkessel- Behälter- und Rohrleitungsbau, 5. Auflage Springer Verlag 1997 • Wagner, W., Festigkeitsberechnungen im Apparate- und Rohrleitungsbau, 8. Auflage Vogel Fachbuch Verlag 2012, Kamprath-Reihe • DIN EN 13445-3 and AD2000 leaflets • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)			
This module provides the basis for the modules:			
This module is based on the modules:			
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 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

- use the 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 the calculation and analysis of electrical equivalent circuits.
- describe transient processes in coils and capacitors.
- assess the usability of individual motor types for different drives.
- evaluate processes and real technical systems with regard to their suitability and quality and propose 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 Ohm's law, Kirchhoff's rules, star-delta conversion, superposition theorem, real sources • Electric fields Electric potential, Gaussian theorem of electrical engineering, capacitors • Magnetic fields Lorentz force, law of induction • Alternating current technology Characteristic values, pointer representation, power in the alternating current network • Machines 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 • Lecture notes in the THWS eLearning system
Special Feature

3 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)			
This module provides the basis for the modules:	Hydrogen Production (19), Hydrogen Storage, Transport and Distribution (21), Plant Operation (28), Application Project (33), Bachelor Thesis (36)		
This module is based on the modules:	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 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 • use sketches and diagrams to explain the structure and the basic function and operation of renewable energy systems. • describe the structure and functioning of supply networks and systems (electricity, natural gas, hydrogen). • apply the appropriate equations and relationships to model and calculate energy systems. • critically question the solutions of energy engineering tasks. • solve practical problems in connection with the operation and design of control energy systems. • assess plants and technical systems and develop new systems, plants, components and parts. • explain the system services in power supply systems. • describe the analogies between electricity and gas supply systems. • explain the difficulties of feeding hydrogen 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. • G. Reich, Regenerative Energietechnik, 2. Auflage. Berlin: Springer-Verlag, 2018. • V. Wesselak et. al., Regenerative Energietechnik, 3. Auflage. Berlin: Springer-Verlag, 2016. • R. Zahoransky (Hrsg.), Energietechnik, 8. Auflage. Berlin: Springer-Verlag, 2019. • J. Unger et. al., Alternative Energietechnik, 6. Auflage. Berlin: Springer-Verlag, 2020. • K. Strauß, Kraftwerkstechnik, 7. Auflage. Berlin: Springer-Verlag, 2017. • L. Müller, Handbuch der Elektrizitätswirtschaft, 2. Auflage. Berlin: Springer-Verlag, 2001. • K. Pfleiderer, Strömungsmaschinen, 6. Auflage. Berlin: Springer-Verlag, 2004. • W. Wagner, Wärmeübertragung, 4. Auflage. Würzburg: Vogel Fachbuch Verlag, 2011. • P. Kurzweil, Brennstoffzellentechnik, 3. Auflage. Berlin: Springer-Verlag, 2016. • 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) • Basics and design principles of systems for the use of regenerative energy sources (photovoltaics, solar thermal energy, wind power, hydropower, geothermal energy) • 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) • 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) • Operation of energy supply systems (electricity, natural gas, hydrogen) • Economic evaluation and price models in energy supply systems
Special Feature

Module: 14			
Fluid Mechanics			
Duration	**Semester**	**Workload**	**ECTS-Credit Points**
1 Semester	Winter Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 30 hours exam preparation	5
Module Responsibility: N.N.			
Lecturer:			
N.N.			
Associated Course		**Study Modes**	**Language**
Fluid Mechanics (4 Semester Hours per Week)		Seminar-type Teaching, Exercises	English

Applicability and Study Semester:

Bachelor Programme Hydrogen Technologies (Compulsory Module, 2nd Semester)
Bachelor Programme Mechanical Engineering (Compulsory Module, 3rd Semester)
Bachelor Programme Technical Mathematics (Specialised Elective Technology/Computer Science 5th Semester)
Bachelor Programme Technical Mathematics (Compulsory Module in Study Version Simulation in Mechanical Engineering, 4th Semester)

This module provides the basis for the modules:	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)
This module is based on the modules:	Engineering Mechanics (5), Thermodynamics 1 (2), Engineering Mathematics 1 (1), Engineering Mathematics 2 (7)

Compulsory Conditions of Participation

none

Recommended Conditions of Participation

Fundamentals of Engineering Mechanics (5), Thermodynamics 1 (2), Engineering Mathematics 1 (1), Engineering Mathematics 2 (7)

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 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 • calculate forces on flat surfaces and immersion depths of floating bodies resulting from hydrostatic pressure distribution. • form control volumes, define current filaments and apply conservation of mass and momentum as well as Bernoulli's equation to them. They assess the consequences of necessary simplifications when using these laws. • calculate compressible flow processes (gas dynamics) in isentropic flow and for vertical compression shocks. • state the physical causes for peculiarities in compressible flow. • state the differences between frictionless idealised flow and frictional flow. • state the background of the similarity theory, select suitable ratios for the realisation of fluid mechanical similarity or for scale transfer and use them to calculate target quantities such as drag forces. • name the physical causes of laminar-turbulent transition and describe properties of turbulent flow. • state the cause of flow separation and assess flow processes with regard to the danger of flow separation. • calculate pressure losses in piping systems with different internals and develop solution strategies for non-linear relationships. • state the procedure for the discretisation and solution of the fluid mechanical conservation equations with the help of the finite volume method, state common grid types and select suitable boundary conditions. • analyse flow processes also qualitatively and evaluate them in terms of suitable variables by comparison.
Module Content
• Hydrostatics: pressure, forces on flat surfaces, hydrostatic lift. • Conservation of mass, Bernoulli equation and momentum theorem • Gas dynamics: Isentropic flow, Laval nozzle, compression impact • Frictional flow, Couette flow, Poiseuille flow • Navier-Stokes equations, similarity theory • Laminar-turbulent flow, critical Reynolds number • Flow around bodies, flow separation • Pressure loss calculation in piping systems with internals • 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. • W. Bohl, W. Elmendorf, Technische Strömungslehre, 15. Auflage, Würzburg: Vogel, 2014. • S. Bschorer, Technische Strömungslehre, 11. Auflage, Wiesbaden: Springer, 2018. • H.C. Kuhlmann, Strömungsmechanik, 2. Auflage, Hallbergmoos: Pearson, 2014. • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Application Project (33), Technical Lab Training (34), Bachelor Thesis (36)
This module is based on the modules:	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 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

- list the essential interrelationships of a regulated system for relevant hydrogen technology applications (storage, transport and distribution);
- describe the structure and mode of operation of a programmable logic controller, including plant safety aspects for hydrogen;
- classify the behaviour of elementary control loop elements and count their system-characteristic parameters;
- evaluate the control loop behaviour with regard to 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 procedures and determine 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 • Föllinger, O.: Regelungstechnik – Einführung in die Methoden und ihre Anwendung, VDE-Verlag, Berlin, 11. völlig neu bearbeitete Auflage, 2013 • Eichlseder, H., Klell, M.: Wasserstoff in der Fahrzeugtechnik, Springer Vieweg, Wiesbaden, 3. überarbeitete Auflage, 2012 • Lecture notes in the THWS eLearning system
Special Feature

Course
Control and Feedback Control Systems in Hydrogen Plants (Seminar-type Teaching)
Lecturer:
Prof. Dr. Kharitonov
Content
• Difference between control and regulation • Components of a control system and their safety aspects for hydrogen technology • Control loop elements and their modelling in the time and frequency domain • Control loop behaviour (stability, dynamics, steady-state accuracy) • Control loop design procedures • 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 • Design, set-up, start-up and operation of a control system in the laboratory • Estimation of the control performance • Writing of a technical report • Oral presentation of the results
Special Feature

Module: 16

Measuring in Hydrogen Plants

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Winter Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Plants and Vessels 2 (22), Systematic Design of Plants (23), Application Project (33), Technical Lab Training (34), Bachelor Thesis (36)
This module is based on the modules:	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 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 • state the basics of process engineering measurement technology. • plan, design and build measuring systems to record measured variables in hydrogen plants. • analyse process engineering plants as well as proposed measuring systems in order to evaluate and optimise them for the specific application purpose in the plant. • assess the uncertainty of the measurement results obtained. • form teams to work on and solve a practical task. • assess their own role in the team and reflect on their own behaviour. • produce a technical report in which the solution to the practical task is described in a way that is comprehensible to third parties. • interpret the solution and present their conclusions in a short oral 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. • M. Bantel, Grundlagen der Messtechnik. München: Hanser, 2000. • G. Strohrmann, Messtechnik im Chemiebetrieb,10. Auflage, München: Deutscher Industrieverlag, 2004 • DIN 1319-1:1995-01 Grundlagen der Messtechnik, Teil 1: Grundbegriffe • DIN 1319-2:2005-10 Grundlagen der Messtechnik, Teil 2: Begriffe für Messmittel • DIN 1319-3:1996-05 Grundlagen der Messtechnik, Teil 3: Auswertung von Messungen einer einzelnen Meßgröße, Meßunsicherheit • DIN 1319-4:1999-02 Grundlagen der Messtechnik, Teil 4: Auswertung von Messungen; Meßunsicherheit • DIN V ENV 13005 Leitfaden zur Angabe der Unsicherheit beim Messen; Deutsche Fassung ENV 13005:1999 • Lecture notes in the THWS eLearning system
Special Feature

Course
Measuring in Hydrogen Plants (Seminar-type Teaching)
Lecturer:
Prof. Dr. Wilke
Content
• Basic metrological terms, error calculation, measurement inaccuracies, transducers • Measurement system technology, digital measurement data acquisition, digital measurement data processing • Measurement of process variables • Sensors for gas identification • Sensor monitoring • 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. • Estimation of the measurement inaccuracies • Estimation of the validity of the results • WritinSg of a technical report • Oral presentation of the results
Special Feature

Module: 17

Process Design and Simulation

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Winterr Semester	Total Workload: 150 h 100 contact hours (4 hours per week during the semester lecture period) 35 hours self study 15 hours exam preparation	5

Module Responsibility: Prof. Dr. Renner

Lecturer:

Dr. Rarey, Prof. Dr. Renners

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)

This module provides the basis for the modules:	Hydrogen Production (19), Hydrogen Storage, Transport and Distribution (21), Plant Operation (28), Application Project (33), Bachelor Thesis (36)
This module is based on the modules:	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 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 • explain special numerical methods in process simulation. • describe the basics of different methods and the factors influencing these methods. • 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. • 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. • design various components in terms of process technology (e.g. distillation column, heat exchanger, piping systems) • carry out sensitivity analyses • 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 • CHEMCAD-Help • Kleiber, Process Engineering: Addressing the Gap between Study and Chemical Industry • Gmehling et al., Chemische Thermodynamik für die Prozesssynthese • P. Stephan et al., Thermodynamik, Band 2: Mehrstoffsysteme und chemische Reaktionen, 15. neu bearbeitete Auflage, Berlin-Heidelberg: Springer, 2010 • A. Heintz, Thermodynamik der Mischungen, Berlin: Springer, 2017 • K. Sattler, H. J. Feindt, Thermal Separation Processes, Weinheim: VCH, 1995 • Lecture notes in the THWS eLearning system
Special Feature

Course
Process Design and Simulation
Lecturer:
Prof. Dr. Renner
Content
• Fundamentals of thermodynamics of mixtures • 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 recompression, use of heat pumps

Special Feature

Module: 18

Hydrogen safety

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Winter Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Hydrogen Production (19), Hydrogen Storage, Transport and Distribution (21), Plant Operation (28), Application Project (33), Bachelor Thesis (36)
This module is based on the modules:	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 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:

- explain possible failure modes 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 sources of information 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
- prepare work instructions on the basis of simple examples of application with regard to "human performance
- evaluate different methods of hazard analysis with regard to their strengths and weaknesses
- evaluate different protective devices in terms of their effectiveness and reliability using layer of protection analysis (LOPA)
- evaluate previous incidents from industry and the resulting measures as well as recommendations with regard to relevance to selected application examples.

Module Content

- Characteristics of hydrogen and resulting risks
- Plant components: Design, use, potential for failure and associated risks.
- Basics of risk management
- Principles of Inherently Safer Design (ISD)
- Protective devices and measures (technical, organisational, personal) and their evaluation with the aid 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 the 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	Sommer Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Chemical Conversion with Hydrogen (27), Plant Operation (28), Application Project (33), Bachelor Thesis (36)
This module is based on the modules:	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 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:

- differentiate between the processes for producing hydrogen with regard to climate protection goals
- distinguish between the processes for hydrogen production with regard to 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 with regard to different goals
- present the technical design parameters of the hydrogen production plant..

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

Module: 20

Fuel Cell

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Sommer Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Plant Operation (28), Application Project (33), Bachelor Thesis (36)
This module is based on the modules:	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 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:

- identify energy utilisation profiles for fuel cell systems
- differentiate between fuel cell systems with regard to 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 with regard to different objectives
- design the fuel cell system
- present the technical design parameters of the fuel cell system.

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

Module: 21

Hydrogen Storage, Transport and Distribution

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Sommer Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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, 4th Semester)

This module provides the basis for the modules:	Plant Operation (28), Application Project (33), Bachelor Thesis (36)
This module is based on the modules:	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 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:

- describe the steady-state and transient behaviour of the storage, transport and distribution systems
- compare the different characteristics of the storage, transport and distribution systems
- differentiate between the various types of storage, transport and distribution systems with regard to the planned use.
- 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, efficiencies, temperature changes, real gas behaviour, mass and volume specific storage density, power density) • stationary and mobile storage systems for hydrogen • stationary and mobile transport systems for hydrogen • Distribution systems for hydrogen • Interfaces between stationary and mobile systems • 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 • S. Geitmann, E. Augsten, Wasserstoff und Brennstoffzellen, 5. Auflage, Oberkrämer: Hydrogeit Verlag 2022 • G. Cerbe, B. Lendt (Hrsg.), *Grundlagen der Gastechnik,* 8. Auflage, München: Hanser Verlag, 2017 • 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 • Lecture notes in the THWS eLearning system
Special Feature

<table>
<tr><td colspan="4">Module: 22</td></tr>
<tr><td colspan="4">Plants and Vessels 2</td></tr>
<tr><td>Duration</td><td>Semester</td><td>Workload</td><td>ECTS-Credit Points</td></tr>
<tr><td>1 Semester</td><td>Sommer Semester</td><td>Total Workload: 150 h
60 contact hours (4 hours per week during the semester lecture period)
60 hours self study
30 hours exam preparation</td><td>5</td></tr>
<tr><td colspan="4">Module Responsibility: Prof. Dr. Olbricht</td></tr>
<tr><td colspan="4">Lecturer:</td></tr>
<tr><td colspan="4">Dipl.-Ing. Benitz</td></tr>
<tr><td colspan="2">Associated Course</td><td>Study Modes</td><td>Language</td></tr>
<tr><td colspan="2">Plants and Vessels 2 (4 Semester Hours per Week)</td><td>Seminar-type Teaching, Exercises</td><td>German</td></tr>
<tr><td colspan="4">Applicability and Study Semester:</td></tr>
<tr><td colspan="4">Bachelor Programme Hydrogen Technologies (Compulsory Module, 4th Semester)</td></tr>
<tr><td>This module provides the basis for the modules:</td><td colspan="3">Plant Operation (28), Application Project (33), Bachelor Thesis (36)</td></tr>
<tr><td>This module is based on the modules:</td><td colspan="3">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)</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 thermodynamics, physics, chemistry, electrochemistry, electrical engineering, Hydrogen safety, measurement and control technology</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>German</td></tr>
<tr><td colspan="4">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.</td></tr>
</table>

Learning outcomes after successful termination of the module
The students: • design hydrogen-carrying systems for specified applications • analyse and assess the state of the art on the basis of current technical regulations • clarify the required operating parameters of the plants • identify the required technical regulations • design the tanks, the fittings, the instrumentation, the safety devices and other plant components • explain the technical solutions using the correct technical terminology to specialists in plant construction • illustrate the plants in technical documentation and operating instructions • develop an awareness of their responsibility for occupational safety, environmental protection, as guarantors for the safety of third parties and for the economic operation of the plant.
Module Content
• Design of plants and vessels • Dimensional layout of plants (vessels, valves, instrumentation, safety devices, other plant components) • Documentation in plant design • Responsibility towards people and the environment
Literature and other Learning Offers
• Technical standards and regulations • E. Wagner, *Das System Brennstoffzelle*, München: Hanser Verlag 2023 • S. Rippberger, K. Nikolaus, *Entwicklung und Planung verfahrenstechnischer Anlagen*, Berlin: Springer Verlag 2020 • W. Wagner, *Planung im Anlagenbau*, 4. Auflage, Würzburg: Vogel Verlag 2018 • G. Cerbe, B. Lendt (Hrsg.), *Grundlagen der Gastechnik,* 8. Auflage, München: Hanser Verlag 2017 • H. Hirschberg, *Handbuch Verfahrenstechnik und Anlagenbau*, Berlin: Springer Verlag 2014 • W. Wagner, *Festigkeitsberechnungen im Apparate- und Rohrleitungsbau*, 8. Auflage, Würzburg: Vogel Verlag 2012 • G. Scholz, *Rohrleitungs- und Apparatebau*, Berlin: Springer Verlag 2012 • H. Titze, H-P. Wilke, *Elemente des Apparatebaues, Grundlagen-Bauelemente-Apparate,* 3. Auflage, Berlin: Springer Verlag, 1992 • Y. Bock, J. Zons, Rechtshandbuch Anlagenbau, 2. Auflage, München: C. H. Beck Verlag 2021 • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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) German in the Project (2 Semester Hours per Week)		Seminar-type Teaching, Exercises Seminar	German Gerrman
Applicability and Study Semester:			
Bachelor Programme Hydrogen Technologies (Compulsory Module, 4th Semester)			
This module provides the basis for the modules:	Practical Module (32), Application Project (33), Bachelor Thesis (36)		
This module is based on the modules:	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 documentationf	Examination during the semester		German/English
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 • use the tools of project management. • use selected techniques of methodical design. • develop solution variants, evaluate them and recommend the further procedure. • design a winning variant and work it out. • present contents and results in a convincing and structured way in German. • correctly assess essential behaviour and communication structures in international business life. • interpret intercultural differences of business partners and draw conclusions from them for their own adapted behaviour. • 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. • VDI-Richtlinien 2221 und folgende. Beuth-Verlag 2004 • N. Anderl, Tools für Projektmanagement, Workshops • Lecture notes in the THWS eLearning system
Special Feature

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: • Product development: clarifying the task, technical research, customer benefits, list of requirements, component-oriented design structure, FMEA, technical product description. • 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. • Methodical design: Tools such as black box, functional structures, principles of action, morphological box, creativity techniques. • Documentation: minutes of meeting, technical documentation in the form of a project folder, presentation • 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).
Special Feature
• Guest lecture on the topic of "Patents" followed by online research on the student topics. • Own budget for each project group, which can be used for visits to trade fairs and companies, small experiments or to create models or prototypes.

Course
German in the project
Lecturer:
Ms. Schäfer
Content
• Presentation techniques: all the techniques and skills needed to create and deliver effective presentations, including digital meetings and presentations (some aspects will be covered in this course, others in the other). • Expansion of general, technical and business-oriented vocabulary in the German language • Consolidation of grammar structures to expand the students' ability to express themselves in the German language • Sensitisation to intercultural differences of business partners from other nations • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Practical Module (32), Application Project (33),Bachelor Thesis (36)
This module is based on the modules:	

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 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

- present the terminology in innovation management and business start-up
- implement the steps in the innovation and development process.
- assess the technical-economic potential of the innovation iteratively in the process.
- assess 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 • Creativity techniques • Innovation strategy • Iterative dynamic investment calculation • Valuation of innovations • Industrial property rights • Business administration, controlling • Financing • Law, legal forms, taxes and authorities • Business plan
Literature and other Learning Offers
• K. Ehrlenspiel, *Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit, 5. Auflage*. München: Hanser Verlag 2013. • VDI-Richtlinien 2221 und folgende. Berlin: Beuth-Verlag 2004 • J. Hauschildt, S. Salomo, C. Schultz, A. Kock, *Innovationsmanagement,* 7. Auflage, München: Verlag Franz Vahlen 2023 • T. Müller-Prothmann, N. Dörr, G. Kamiske, *Innovationsmanagement*, 4. Auflage, München: Hanser Verlag 2020 • G. Schuh, *Innovationsmanagement,* 2. Auflage, Berlin: Springer Verlag 2012 • A. Ternès, J. Reiber, *Gründen mit Erfolg*, Wiesbaden: Springer Gabler 2020 • J. Staab, *Erneuerbare Energien in Kommunen – Energiegenossenschaften gründen, führen und beraten*, 4. Auflage, Wiesbaden: Springer Gabler 2018 • A. Osterwalder, Y. Pigneur, *Business model generation: ein Handbuch für Visionäre, Spielveränderer und Herausforderer*, Frankfurt: Campus Verlag 2011 • A. Osterwalder, Y. Pigneur, et al., *Value Proposition Design: How to create Products and Services Customers Want (Strategyzers)*, Hoboken, NJ.: Wiley Verlag 2014 • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Practical Module (32), Application Project (33), Bachelor Thesis (36)
This module is based on the modules:	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 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

- create the discrete equations for convection, diffusion and source terms with the help of the finite volume method.
- 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 program (e.g. Ansys Fluent) and analyse the results.

Module Content
• Finite volume methods, spatial discretisation • Temporal discretisation, explicit and implicit Euler method • Stability and stability limit • Turbulence description and turbulence models (RANS, LES, DNS) • Incompressible and compressible simulation, pressure-velocity coupling • Parallelisation • Special modelling: Multiphase flow, conjugate heat transfer, fluid-structure interaction
Literature and other Learning Offers
• R. Schwarze, CFD-Modellierung. Heidelberg: Springer Vieweg, 2013. • F. Moukalled, L. Mangani und M. Darwish, The Finite Volume Method in Computational Fluid Dynamics. Cham: Springer, 2016. • H.K. Versteeg und W. Malalasekera, An introduction to computational fluid dynamics, 2. Auflage. Harlow: Prentice Hall, 2007. • J. Tu, G.-H. Yeoh und C. Liu, Computational fluid dynamics. Amsterdam: Elsevier, 2013. • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 30 hours exam preparation	5

Module Responsibility: Prof. Dr. Rennerk

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)

This module provides the basis for the modules:	Practical Module (32), Application Project (33), Bachelor Thesis (36)
This module is based on the modules:	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 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

- 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) • Power-to-liquids (methanol, ammonia, hydrocarbons) • Power-to-methanes • Use as reducing agents in steel production and other industries • Use in hydro-cracking plants • 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 • K. Hertwig, L. Martens, C. Hamel, *Chemische Verfahrenstechnik*, 3. Auflage, Berlin: DeGruyter Verlag 2018 • T. Schmidt, *Wasserstofftechnik,* 2. Auflage, München: Hanser Verlag, 2022 • S. Geitmann, E. Augsten, *Wasserstoff und Brennstoffzellen*, 5. Auflage, Oberkrämer: Hydrogeit Verlag 2022 • S. Kumar, *Clean Hydrogen Production Methods,* Berlin: Springer Verlag 2015, https://doi.org/10.1007/978-3-319-14087-2 • 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

This module provides the basis for the modules:	Practical Module (32), Application Project (33), Bachelor Thesis (36)
This module is based on the modules:	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 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

- explain the legal framework 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 • Start-up, regular operation, start-up, shut-down • Maintenance and repair • Planned and unplanned plant shutdowns • Incidents • Plant monitoring • Organisational principles of plant operation (plant safety, occupational safety) • Economic basics of plant operation • 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 • D. Schmidt, *Rechtliche Grundlagen für den Maschinen- und Anlagenbetrieb*, Wiesbaden: Springer Gabler 2014 • M. Schenk, *Instandhaltung technischer Systeme*, Berlin: Springer Verlag, 2010 • K. Weber, *Inbetriebnahme verfahrenstechnischer Anlagen*, Berlin: Springer Verlag 2019 • K. Weber, F. Mattukat, M. Schüßler, *Dokumentation verfahrenstechnischer Anlagen,* Berlin: Springer Verlag 2020 • U. Stephan, B. Schulz-Forberg, *Anlagensicherheit*, Berlin: Springer Vieweg 2021 • U. Hauptmanns, *Prozess- und Anlagensicherheit*, Berlin: Springer Vieweg 2020 • 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 60 contact hours (4 hours per week during the semester lecture period = 4 SWS) 60 hours self study 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)
Bachelor Programme Mechaniical Eengineering (Compulsory Module, 6th Semester)

The module is intended to build up interdisciplinary competences ("studium generale") and is therefore not directly related to other modules of this degree programme.
It can be used in all other Bachelor's degree programmes, provided that there is no blocking notice for this degree programme.

This module provides the basis for the modules:	
This module is based on the modules:	

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.
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. The students • 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. • analyse a wide variety of questions. • place subject-specific knowledge in an interdisciplinary context. • transfer what they have learned to their current education. • have expanded their key competences and, if applicable, foreign language competences, which supports personality development, also in intercultural terms. • 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 • Languages • Cultural studies • Natural sciences and technology • Politics, Law and Economics • Education, psychology and social sciences • Soft Skills • Creativity and the Arts 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. 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

4 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 75 contact hours (4 hours per week during the semester lecture period) 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) Seminar "Communication & Problem Solving" (1 Semester Hour per Week) Seminar "Presenting & Writing" (2 Semester Hours per Week) Seminar "Practice Exchange" (1 Semester Hour per Week) 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)
Bachelor Programme Mechanical Engineering (Compulsory Module, 6th Semester)
Bachelor Programme Mechatronics (Compulsory Module, 6th Semester)

This module provides the basis for the modules:	Systematical Design of Plants (23), Practical Module (32), Application Project (33), Bachelor Thesis (36)
This module is based on the modules:	

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
Presentation, Term Paper		English

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 • abstract complex problems, formulate sub-goals and plan work packages (in terms of time, content, resources) with the help of IT tools. • write scientifically sound reports and present the results of their work (practical module, Bachelor's thesis) in a meaningful and target group-oriented manner. • use online communication tools (e.g. video conferences) in the digital working world. • discuss working methods and results in the group and give constructive feedback. • analyse the student presentations offered and assess the procedures, working techniques and presentation techniques with regard to their own thesis / presentation. • draw conclusions from the guest lectures of the industry about the state of the art and the upcoming professional career. • reflect on personal behaviour and criteria for success in the professional environment. • develop their personal and social competences and thus 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). Contents of the seminar: • Scientific work (analysis, hypothesis, synthesis, validation). • Soft skills, e.g. presentation techniques, conversation skills, problem-solving methods • Project and self-management • Reflection on the practical phase Conduct of the seminar (organisation via assessment card): • 4^{th} semester: Skills seminars "Scientific work" and "Communication & problem solving". Participation in 3 individual sessions with student presentations or guest lectures from industry. • 5^{th} semester: Skills seminar "Presenting & Writing". Participation in 3 individual appointments with student lectures or guest lectures from industry. • 6^{th} semester: Seminar "Practical Exchange" to accompany the practical phase. • 7^{th} semester: Preparation of an exposé and presentation of the Bachelor's thesis.
Literature and other Learning Offers
Special Feature

thws Technical University of Applied Sciences Würzburg-Schweinfurt

Module: 32

Practical Module

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Every Semester	Total Workload: 720 h 700 hours attendance at the practical training company 20 hours pPreparation 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)

This module provides the basis for the modules:	Bachelor Thesis (36)
This module is based on the modules:	Preparation and support by the engineering seminar (31) 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)s

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 in the course of 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

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Module: 33			
Application Project			
Duration	**Semester**	**Workload**	**ECTS-Credit Points**
1 Semester	Every Semester 2 times	Total Workload: 300 h 60 contact hours (4 hours per week during the semester lecture period) 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, 7th Semester)			
This module provides the basis for the modules:	Bachelor Thesis (36)		
This module is based on the modules:	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 7th semester	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 • independently apply the knowledge acquired in other modules of the Bachelor's degree programme (specialist knowledge, methods and procedures) to solve a real problem. • research and analyse the current state of research and technology. • work on the task cooperatively and responsibly in a team. • present complex subject-related content clearly and in a way that is appropriate to the target group. • prepare written project documentation in the form of a report. • present the essential interim and final results to the client. • present project contents and technical contexts in German. • use the German language appropriately in a variety of business situations in the context oft he project.
Module Content
• Scientific work • Development methodology • Communication techniques • Team meetings and communication • Presentation techniques • Project documentation • 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) • J. Feldhusen und K.-H. Grote, Pahl/Beitz Konstruktionslehre, 8. Auflage. Berlin Heidelberg: Springer-Verlag, 2013. • VDI-Richtlinie 2222, Konstruktionsmethodik - Methodisches Entwickeln von Lösungsprinzipien, VDI-Gesellschaft Produkt- und Prozessgestaltung: Düsseldorf, 1997. • U. Lindemann, Methodisches Entwickeln technischer Produkte, 3. Auflage. Berlin Heidelberg: Springer-Verlag 2009. • Lecture notes in the THWS eLearning system
Special Feature
After the interim 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.

Module: 34

Technical Lab Training

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Every Semester	Total Workload:90 h 30 contact hours (2 hours per week during the semester lecture period) 60 hours self study	3

Module Responsibility: Prof. Dr. Vogt

Lecturer:

According to the list of lab exercises (eLearning course)

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

Applicability and Study Semester:

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

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

- 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

Module: 35

Cost Accounting and Ethics for Engineers

Duration	Semester	Workload	ECTS-Credit Points
1 Semester	Winter Semester	Total Workload: 150 h 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

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

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 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

- classify cost accounting terms.
- interpret cost trends.
- carry out methods of cost accounting.
- describe the basic terms and contents of recognised standards.
- explain which factors are used to describe responsibility and trust.
- explain the analytical concept for world views and its elements as well as generic examples.
- explain the dual character of values and their normative core functions in companies.

Module Content
• Basics and relationships of controlling • Instruments of controlling • Cost and activity accounting as an information and control system • Cost type, cost centre and cost unit accounting • Systems and methods of cost accounting, possible applications and limits • Ethics, values, morals & norms: Functions and relevance in companies and organisations • Worldview analysis: Philosophical foundations of specific value concepts • 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. • M. Aßländer, Hrsg., *Handbuch Wirtschaftsethik*. Stuttgart: Verlag J.B. Metzler, 2011. • K. Schedler, Hrsg., *Multirationales Management*. Bern: Verlag Haupt, 2013. • F. Glauner, *Zukunftsfähige Geschäftsmodelle und Werte*. Berlin: Springer Gabler, 2016. • 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 Approx. 6 contact hours at THWS for meetings with the lecturer 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) Bachelor Programme Mechanical Engineering (Compulsory Module, 7th Semester) Bachelor Programme Mechatronics (Compulsory Module, 7th Semester)			
This module provides the basis for the modules:			
This module is based on the modules:	All modules of the study programme		
Compulsory Conditions of Participation			
a) has reached at least 150 CP b) successfully finished all modules of the first three study semesters (modules 1 to 18) 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 • apply their subject 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. • assess the impact of engineering solutions in the social and ecological environment and act in accordance with professional ethical principles and standards. • critically evaluate their existing knowledge, recognise missing knowledge and expand their existing knowledge on their own responsibility. • critically reflect on their own work. • apply the methods of project management to achieve the desired goals in limited time and with limited resources and budgets. • present their results and their approach in a comprehensible way and according to the principles of scientific work in a written technical report. • 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.
Literature and other Learning Offers
• Specialist literature according to the task of the Bachelor's thesis • H. Balzert, *Wissenschaftliches Arbeiten*, 2. Auflage. Herdecke: W3L-Verlag, 2013. • H. Hering, *Technische Berichte: verständlich gliedern, gut gestalten, überzeugend vortragen*, 8., überarbeitete Auflage. Wiesbaden: Springer Vieweg, 2019. • 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.

5 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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)

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	English

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

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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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, 5th 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 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

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 60 contact hours (4 hours per week during the semester lecture period) 60 hours self study 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)			
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**	
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 • reflect on the application of theoretical knowledge in business practice. • discuss the practical ways of working and methods in the companies. • develop and evaluate strategies for knowledge transfer between university and companies • analyse cooperation in the companies • present success factors • coach each other

Module Content
• Exchange of information between students of the "Bachelor Hydrogen Technology dual" study variant • Moderated exchange of information between students, university lecturers and company representatives • 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