Module Guide
Electromobility, Autonomous Driving and Mobile Robotics

Faculty Electrical Engineering and Media Technology
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EM-34 Mobile Robotics

EM-01 Mathematics 1

Module code	EM-01
Module coordination	Prof. Dr. Reinhard Schlosser
Course number and name	EM 1101 Mathematics 1
Lecturer	Prof. Dr. Reinhard Schlosser
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	8
ECTS	9
Workload	Time of attendance: 120 hours self-study: 150 hours Total: 270 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	9/210
Language of Instruction	German

Module Objective

Primary learning objective: Students should be capable of applying mathematical concepts and methods to technical tasks in both their studies and later in their professional lives.

Students will acquire the following competencies: They have a working knowledge of symbolic fractions (equivalent fractions, distributive property, etc.). They are able to solve basic geometric tasks such as distance between point-line, point-plane, and line-line; and intersection angle of line-line, line-plane using vectors. They will have a good command of calculations with complex numbers; in particular, of conversion into various forms (cartesian, polar, exponential). Thus they are capable of applying the complex alternating current calculation. They are familiar with the definitions and definition areas, value areas, special function values, important calculation rules, and areas of differentiability of the basic functions (x^?, sin, cos, tan, cot, arcsin, arccos, arctan, arccot, sinh, cosh, tanh, coth, arsinh, arcosh, artanh, arcoth, exp, ln). In particular, they are able to sketch the appropriate graph. They are familiar with the definition of derivation and its physical, geometrical and analytical significance. They are familiar with the rules of differentiation and can apply them to expressions which are built up of elementary functions. They are familiar with basic integrals and are able to apply integration through substitution and partial integration to simple cases. They can apply integral calculation to geometric or physical questions. They are able to examine linear systems of equations with the help of Gaussian elimination. They are capable of utilising matrix calculus.

Applicability in this and other Programs

With regards to bachelor degree course: C02, C04, C06, C10, C11, C12, C13, C15, C16, C17, C18, C19, C20, C27, C28, C31, C33, C34, C35, C36, C37, C38, C39, C40, C41, C42, C43, C44, C45, C46, C47, C48, C49, C50

With regards to other degree courses: none

Entrance Requirements

Formally: none

In terms of content: none

Learning Content

- 1 Numbers and Vectors
  - 1.1 Sets and Transformations
  - 1.2 Real Numbers
  - 1.3 Planes
  - 1.4 Vectors
  - 1.5 Products
  - 1.6 Lines and Planes
  - 1.7 Complex Numbers
- 2 Functions, Tolerances, Constants
  - 2.1 Functions (Basic Concepts)
  - 2.2 Polynomials and Rational Functions
  - 2.3 Trigonometric Functions
  - 2.4 Sequences and Limits of Sequences
  - 2.5 Calculation Rules for Limits of Sequences and Convergence Tests
  - 2.6 Limits of Functions
  - 2.7 Continuous Functions
- 3 Differentiation

- 3.1 The Derivation of a Differentiable Function
- 3.2 Applications of Differentiation
- 3.3 Inverse Functions
- 3.4 The Exponential and Logarithm Function

4 Integration
- 4.1 The Definite Integral
- 4.2 Rules of Integration
- 4.3 Integration of Rational Functions
- 4.4 Improper Integrals

5 Linear Algebra
- 5.1 Systems of Equations and Matrices
- 5.2 Matrix Multiplication
- 5.3 Determinants

Teaching Methods

Seminaristic lessons. In class, the contents are worked out with the involvement of the students, documented with the help of a gap script, illustrated with examples and flanked and practiced with comprehension questions and 5-minute exercises. Exercises, controlled questions. hints and sample solutions help the student to rework and acquire the contents. Application-oriented examples and tasks demonstrate the usefulness of mathematical concepts and methods and build bridges to the foundation of electrical engineering, physics and electrodynamics.

Recommended Literature

K. Meyberg / P. Vachenauer: Höhere Mathematik I, 6. Auflage. Springer Verlag, Berlin 2001.

EM-02 Physics 1

Module code	EM-02
Module coordination	Prof. Dr. Johann Plankl
Course number and name	EM 1102 Physics 1
Lecturer	Prof. Dr. Johann Plankl
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	5
ECTS	6
Workload	Time of attendance: 75 hours self-study: 105 hours Total: 180 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	6/210
Language of Instruction	German

Module Objective

Students essentially deal with methods of classical physics of a point mass. They learn the necessary steps to work out independent solutions for corresponding problems in the field of engineering, whereby they are especially enabled to critically question the selection of the corresponding methods and calculation procedures.

The students get to know typical models, methods and problems from engineering practice, which can be processed with the kinematics and dynamics of a mass point, together with corresponding solution methods and strategies. The physical way of thinking of mechanics is anchored.

Students achieve the following learning objectives:

Professional Skills

The students have knowledge of the kinematics and dynamics of point masses in one-, two- and three-dimensional space. In addition, they know the concepts of free, forced and damped linear harmonic oscillation. Students are able to work conceptually and methodically. They know the most important physical models and correlations and have applied them in practical exercises. In particular, they know the basic assumptions and theories behind the phenomena to be described. They are also able to select suitable mathematical methods on the basis of a problem description and to systematically work out the solution on the basis of these methods. They have the knowledge to interpret the results in a subject-specific way. In summary, the students can apply their acquired knowledge to engineering tasks in a practice-oriented way.

Methodological Skills

Depending on the problem, students are able to identify and successfully apply appropriate calculation methods from a range of calculation methods. They can use scientific calculators and, if necessary, computer algebra software. The students have the ability to carry out independent research on the basis of more extensive exercises and to develop their existing knowledge independently.

Soft Skills

The students are aware of their responsibility as future engineers. They are in a position to discursively question problems among themselves, to justify the solutions argumentatively and to critically evaluate the results of their calculations.

Applicability in this and other Programs

In regards to this bachelor degree course: C02, C04, C06, C10, C11, C12, C13, C18, C19, C20, C27, C28, C32, C33, C34, C35, C36, C37, C38, C39, C41, C42, C43, C44, C46, C47, C48, C50

In regards to other degree courses: none

Entrance Requirements

Formally: none

In terms of content: none

Learning Content

1 Crash course mathematics (differential, integral and vector calculus)
2 Kinematics of a mass point
  2.1 Basic kinematic variables
  2.2 The one-dimensional motion

- 2.3 Motions in two- and three-dimensional space
- 2.4 Falling and throwing motions
- 2.5 Uniform rotation
- 2.6 Kinematics in polar coordinates

3 Dynamics of a mass point
- 3.1 Mass and force
- 3.2 Newtonian Axioms
- 3.3 Forces that are easy to describe
- 3.4 Work and energy
- 3.5 Conservative forces and potential
- 3.6 Impact and impulse
- 3.7 The problem of mass variation over time
- 3.8 Shock processes
- 3.9 Torque and angular momentum of mass points

4 Oscillations and vibrations
- 4.1 free undamped linear harmonic oscillation
- 4.2 Damped linear harmonic oscillation
- 4.3 forced linear oscillation
- 4.4 Non-linear vibration

Teaching Methods

Lectures and seminaristic lessons in alternation, solving tasks during the lecture and independent extended training of the computing competence on the basis of weekly exercise sheets, detailed solutions to the exercise sheets are each given with a time delay of one week and are to be compared with the own solutions, if questions arise these are clarified in the lecture.

The active participation of the students during the lecture and in the processing of the exercise sheets is particularly important through a discursive style. Challenge and encourage is the motto, so that they are catapulted from an initial passive attitude into a mode of activity.

Recommended Literature

F. Kuypers: Physik für Ingenieure, Band 1. Wiley-VCH 2012.

P. Tipler: Physik für Wissenschaftler und Ingenieure. Springer Spektrum 2015.

S. Roth / A. Stahl: Mechanik und Wärmelehre – Experimentalphysik anschaulich erklärt. Springer Spektrum 2016.

W. Pfeiler: Experimentalphysik, Band 1 – Mechanik, Schwingungen, Wellen. De Gruypter Verlag 2016.

EM-03 Principles of Electrical Engineering 1

Module code	EM-03
Module coordination	Prof. Dr. Günter Keller
Course number and name	EM 1103 Principles of Electrical Engineering I
Lecturer	Prof. Dr. Reinhard Schlosser
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	8
ECTS	9
Workload	Time of attendance: 120 hours self-study: 150 hours Total: 270 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	8/210
Language of Instruction	German

Module Objective

The course deals with the fundamentals of studying electrical engineering and information technology, in particular with the basic terms, network analysis and complex AC calculation. The students learn the independent analysis of DC and AC networks.

The students achieve the following learning objectives:

Professional Skills

The students work with the basic concepts and know the necessary units. They analyze both simple and complicated networks with universal procedures. The application of network theorems completes the analysis competence.

Students learn the application of complex AC calculation and can analyze AC networks, which include multiphase systems.
Furthermore, the students learn how to handle transfer functions, their mathematical description and their frequency response.

Methodological skills

The subject is strongly mathematically oriented. For this purpose, the students will get an introduction to their mathematical procedures and their application in theory and examples. The methods are each subdivided and presented in a series of process steps.

Soft Skills

Personal competence lies in the detailed application of mathematical and technical procedures.

Applicability in this and other Programs

In regards to this bachelor degree course: C02, C04, C06, C10, C11, C12, C13, C15, C16, C17, C18, C19, C20, C27, C28, C31, C32, C33, C34, C35, C36, C37, C38, C39, C40, C41, C42, C43, C44, C45, C46, C47, C48, C50

In regards to other degree courses: none

Entrance Requirements

Fornally: none

In terms of content: none

Learning Content

1 Basic terms
  1.1 Charge, current, voltage
  1.2 Power, energy, efficiency
  1.3 Sources
  1.4 Ohm's Law
2 Electrical circuits
  2.1 Kirchhoff's laws
  2.2 Series and parallel connection
  2.3 Mesh Current Analysis, Nodal Potential Analysis
  2.4 Network Theorems
  2.5 Nonlinear Networks
3 AC networks
  3.1 Characteristics of AC signals
  3.2 Linear network elements
  3.3 Complex AC calculation

3.4 Multiphase systems
3.5 Transfer functions
3.6 Frequency response analysis

Teaching Methods

Lecture, weekly supervised exercises with the possibility to reflect your own knowledge and to ask questions. The lecture introduces software tools such as LTspice and Python, which can support self-study very well.

Recommended Literature

Schüßler: Netzwerke, Signale und Systeme I. Springer Verlag 1991.

Weißgerber: Elektrotechnik für Ingenieure I, 11. Auflage. Springer/Vieweg, Wiesbaden 2018.

Weißgerber: Elektrotechnik für Ingenieure II, 10. Auflage. Springer/Vieweg, Wiesbaden 2018.

Weißgerber: Elektrotechnik für Ingenieure Klausurrechnen, 7. Auflage. Springer/Vieweg, Wiesbaden 2018.

M. und N. Marinescu: Elektrotechnik für Studium und Praxis: Gleich-, Wechsel- und Drehstrom, Schalt- und nichtsinusförmige Vorgänge. Springer/Vieweg 2016.

EM-04 Principles of Computer Engineering

Module code	EM-04
Module coordination	Prof. Dr. Andreas Grzemba
Course number and name	EM 1104 Computer Science 1 EM 1105 Principles of Digital Technology
Lecturers	Prof. Dr. Andreas Grzemba Prof. Dr. Andreas Penningsfeld
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	5
ECTS	6
Workload	Time of attendance: 75 hours self-study: 105 hours Total: 180 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	6/210
Language of Instruction	German

Module Objective

Primary learning objective: The students should be able to apply mathematical terms and methods of Boolean algebra to technical tasks in study and work.
To do this, students acquire the following skills:

1. Knowledge of the basics of digital circuits
2. Ability to synthesize and analyze digital systems.
3. Ability to program embedded systems with different programming languages (assembler, C)

4 Knowledge of the basics of digital circuits
5 Ability to synthesize and analyze digital systems
6 Understanding the basics of digital circuits
7 Develop ability to synthesize and analyze digital systems
8 Get to know and apply laws and theorems of Boolean algebra
9 Learning to solve problems of Boolean algebra

Applicability in this and other Programs

For this degree program: C08, C13, C16, C17, C27, C34, C35, C37, C44, C50
For other degree programs: none

Entrance Requirements

See submodul description

Learning Content

See submodul description

Teaching Methods

Seminar-like instruction. In class, the content is developed with the involvement of the students, documented with the help of a gap script, illustrated by examples and flanked and practiced by comprehension questions and 5-minute tasks. Exercises, control questions, suggestions and sample solutions serve the student for reworking and appropriation of the contents. Application-oriented examples and tasks demonstrate the usefulness of the mathematical concepts and methods of Boolean algebra.

Recommended Literature

See submodul description

EM-05 Mathematics 2

Module code	EM-05
Module coordination	Prof. Dr. Reinhard Schlosser
Course number and name	EM 2101 Mathematics 2
Lecturer	Prof. Dr. Reinhard Schlosser
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	6
ECTS	7
Workload	Time of attendance: 90 hours self-study: 120 hours Total: 210 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	6/210
Language of Instruction	German

Module Objective

Primary learning objective: Students should be capable of applying mathematical concepts and methods to technical tasks in both their studies and later in their professional lives.

In addition, students will acquire the following competencies:
They are able to apply differential and integral calculations to spatial curves, areas and ranges. In particular, they are capable of determining tangents and tangent planes. They are familiar with the definition of gradient, divergence, and rotation and their geometric as well as physical significance. They are thereby capable of applying these concepts in more advanced courses (electrodynamics).

Applicability in this and other Programs

In regards to this bachelor degree course: C11, C12, C13, C17, C18, C19, C27, C28, C31, C33, C34, C37, C38, C39, C40, C41, C42, C43, C45, C46, C48, C50

In regards to other degree courses: none

Entrance Requirements

Formally: none

In terms of content: C01, C03, C05

Learning Content

1 Linear Algebra
   1.1 Linear Functions and Characteristic Values
   1.2 Symmetric Matrices and Quadratic Forms
2 Functions of Multiple Variables: Differentiation
   2.1 Curves in IRn
   2.2 Real-valued Functions with Multiple Real Variable
   2.3 Applications of Differentiation
   2.4 Functions with Vectorial Values
3 Funktionen of Multiple Variables: Integration
   3.1 Parameter Integrales
   3.2 Curve Integrals
   3.3 Integration over Flat Ranges
   3.4 Integration over Areas in Space
   3.5 Integration over 3-Dimensional Spaces

Teaching Methods

Seminaristic lessons. In class, the content is developed with the involvement of the students, documented with the help of a gap script, illustrated by examples and flanked and practiced by comprehension questions and 5-minute tasks. Exercises, control questions, tips and sample solutions serve the student for reworking and appropriation of the contents. Application-oriented examples and tasks demonstrate the usefulness of mathematical concepts and methods and build bridges to the foundations of electrical engineering, physics and electrodynamics.

Recommended Literature

K. Meyberg / P. Vachenauer: Höhere Mathematik I, 6. Auflage. Springer Verlag, Berlin 2001.

EM-06 Physics 2

Module code	EM-06
Module coordination	Prof. Dr. Johann Plankl
Course number and name	EM 2102 Physics 2
Lecturer	Prof. Dr. Johann Plankl
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	5
ECTS	5
Workload	Time of attendance: 75 hours self-study: 75 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5/210
Language of Instruction	German

Module Objective

Students deal with methods of classical physics. They learn the necessary steps to work out independent solutions for corresponding problems in the field of engineering, whereby they are especially enabled to critically question the selection of the corresponding methods and calculation procedures. The module also includes a practical course in physics in which the students learn how to carry out and evaluate experiments.

In the module Physics 2 students get to know typical models, methods and problems, as well as experiments from engineering practice, which can be processed within the framework of classical physics, together with corresponding solution methods and strategies. The physical way of thinking of classical physics is anchored.

Students achieve the following learning objectives:

Professional Skills

The students have knowledge of coupled oscillations and waves (including acoustics), the mechanics of the rigid body, classical thermodynamics, and electromagnetism. In addition, they can carry out and evaluate physical experiments in a professional manner. The students are able to work conceptually and methodically. They know the most important physical models and correlations and have applied them in practical exercises. In particular, they know the basic assumptions and theories behind the phenomena to be described. They are also able to select suitable mathematical methods on the basis of a problem description and to systematically work out the solution on the basis of these methods. They have the knowledge to interpret the results in a subject-specific way. In summary, the students can apply their acquired knowledge to engineering problems in a practice-oriented way.

Methodological Skills

Depending on the problem, students are able to identify and successfully apply appropriate calculation methods from a range of calculation methods. They can use scientific calculators and, if necessary, computer algebra software. The students have the ability to carry out independent research on the basis of more extensive exercises and to further develop their existing knowledge independently. In addition, they are familiar with the interplay of theory and experiment, as well as with the procedure for carrying out and evaluating physical experiments.

Soft Skills

The students are aware of their responsibility as future engineers. They are able to discursively question problems among themselves, to argue for solutions and to critically evaluate the results of their calculations and experiments.

Applicability in this and other Programs

In regards to this bachelor degree course: C11, C12, C18, C19, C20, C28, C34, C35, C36, C37, C38, C39, C41, C42, C43, C46, C48, C50

In regards to other degree courses: none

Entrance Requirements

Formally: none

In terms of content: C01, C03, C05

Learning Content

1 Coupled oscillations and waves
    1.1 Perpendicular superpositon of oscillations: Lissajus figures

- 1.2 Parallel superposition of oscillations
- 1.3 The eigenvalue problem with coupled oscillators
- 1.4 Waves
- 1.5 Acoustics

2 The rigid body
- 2.1 Model of the rigid body
- 2.2 Center of mass
- 2.3 Motion of a free rigid body
- 2.4 Pairs of force
- 2.5 Moment of inertia
- 2.6 Motion around a fixed axis

3 Thermodynamics
- 3.1 Concept of heat
- 3.2 Temperature and model of the ideal gas
- 3.3 Thermal expansion of bodies
- 3.4 The laws of thermodynamics
- 3.5 Heat transport processes
- 3.6 Changes of state of ideal gases
- 3.7 Circular processes
- 3.8 Kinetic gas theory
- 3.9 Real gases and phase transformations

4 Students lab work: physical experiments
- 4.1 Introduction to experimental training and error calculation
- 4.2 Dielectric constant
- 4.3 Induction law for sinusoidal alternating currents
- 4.4 Hysteresis
- 4.5 Helmholtz coil pair
- 4.6 Hall Effect
- 4.7 Solar collector and heat pump
- 4.8 Natural radioactivity
- 4.9 Double pendulum
- 4.10 Gyroscope

Teaching Methods

Lecture and seminaristic lessons in alternation, plus a one-hour laboratory course, which is carried out every two hours for 14 days; solving problems during the lecture and independent extended training of the arithmetic competence on the basis of weekly exercise sheets, detailed solutions to the exercise sheets are issued with a time delay of one week each and are to be compared with one's own solutions, if questions arise these are clarified in the lecture. The execution and later evaluation of an experiment usually takes place in teams of two, the return and discussion of the evaluation also takes place with a time delay.

Recommended Literature

F. Kuypers: Physik für Ingenieure, Band 1 und 2. Wiley-VCH 2012.

P. Tipler: Physik für Wissenschaftler und Ingenieure. Springer Spektrum 2015.

S. Roth / A. Stahl: Mechanik und Wärmelehre – Experimentalphysik anschaulich erklärt. Springer Spektrum 2016.

S. Roth / A. Stahl: Elektrizität und Magnetismus – Experimentalphysik anschaulich erklärt. Springer Spektrum 2018.

W. Pfeiler: Experimentalphysik, Band 2 – Wärme, Nichtlinearität, Relativität. De Gruypter Verlag 2016.

W. Pfeiler: Experimentalphysik, Band 3 – Elektrizität und Magnetismus, De Gruypter Verlag 2016.

EM-07 Principles of Electrical Engineering 2

Module code	EM-07
Module coordination	Prof. Dr. Günter Keller
Course number and name	EM 2103 Principles of Electrical Engineering 2
Lecturers	Johann Bretzendorfer Prof. Dr. Reinhard Schlosser
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	7
ECTS	8
Workload	Time of attendance: 105 hours self-study: 135 hours Total: 240 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	8/210
Language of Instruction	German

Module Objective

The course deals with the basics of study of electrical engineering and information technology, in particular with electric filters, transformers, transients, quadripoles and state space representation.
The students learn the autonomous application of the networks as electrical filters, transients quadrupoles and state space representation.
The students achieve the following learning objectives:
Professional Skills

Students apply the fundamentals of electrical engineering I to electrical filters and transformers. They analyze both simple and complex networks in terms of transient phenomena and determine their system responses.
As an important special case of electrical networks, they become acquainted with the description of electrical quadrupoles and carry out calculations with these quadripoles.
Furthermore, the students learn the description of electrical networks using state space representation in mathematical and graphical form.

Methodological skills

The subject is strongly mathematically oriented. For this purpose, the students will get an introduction to their mathematical procedures and their application in theory and examples. The methods are each subdivided and presented in a series of process steps.

Soft Skills

Personal competence lies in the detailed application of mathematical and technical procedures.

Applicability in this and other Programs

In regards to this bachelor degree course: C11, C12, C13, C15, C17, C18, C19, C20, C27, C31, C33, C34, C36, C37, C38, C39, C40, C41, C42, C43, C45, C46, C47

In regards to other degree courses: none

Entrance Requirements

Formally: none

In terms of content: C01, C03, C05

Learning Content

1 Electric filters
    1.1 Theoretical Basics
    1.2 Transformations
    1.3 Passive realization
    1.4 Active realization
2 Transformer
    2.1 Structure and functionality
    2.2 Measurement on transformers
    2.3 Loaded transformers
3 Transients
    3.1 Linear differential equations
    3.2 Laplace transformation
    3.3 Application of the Laplace Transform

- 3.4 Impulse response, step response
- 3.5 Initial states

4 State space representation
- 4.1 Establishing the state equations
- 4.2 Structures of State Space Representation
- 4.3 Solution of state space representation
- 4.4 Applications

5 Four-pole theory
- 5.1 Four-pole equations
- 5.2 Four-pole circuits
- 5.3 Operating parameters

6 Laboratory experiments: DC and AC networks

Teaching Methods

Lecture, weekly supervised exercises with the possibility to reflect your own knowledge and to ask questions. The lecture introduces software tools such as LTspice and Python, which can support self-study very well.

Recommended Literature

Büttner: Grundlagen der Elektrotechnik II, 2. Auflage. Oldenbourg, München 2009.

Schüßler: Netzwerke, Signale und Systeme I. Springer Verlag 1991.

Weißgerber: Elektrotechnik für Ingenieure II, 10. Auflage. Springer/Vieweg, Wiesbaden 2018.

Weißgerber: Elektrotechnik für Ingenieure III, 9. Auflage. Springer/Vieweg, Wiesbaden 2015.

Weißgerber: Elektrotechnik für Ingenieure Klausurrechnen, 7. Auflage. Springer/Vieweg, Wiesbaden 2018.

U. Weber: Laplace-Transformation für Ingenieure der Elektrotechnik, 9. Auflage. Vieweg/Teubner, Wiesbaden 2012.

M. Marinescu / N. Marinescu: Elektrotechnik für Studium und Praxis: Gleich-, Wechsel- und Drehstrom, Schalt- und nichtsinusförmige Vorgänge. Springer/Vieweg 2016.

EM-08 Materials Science

Module code	EM-08
Module coordination	Prof. Dr. Michael Sternad
Course number and name	EM 2104 Materials Science
Lecturer	Prof. Dr. Michael Sternad
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

Students internalise the properties and applications of important classes of materials, as well as their manufacture, testing and potential error patterns.

Students will achieve the following learning objectives:
Professional skills

Understanding of the structure and properties of important functional and construction materials and typical fields of application in vehicle construction. Students are able to assign these materials to groups such as metals, plastics, ceramics or glasses based on their molecular structure and are able to apply their knowledge in simple example exercises.

Methodological skills

Students know important material parameters and can research such parameters for materials they have not yet encountered. Ultimately, students will have empirically internalised the most common material parameters and properties and will be able to apply them without research.

Personal skills

Students recognise their current abilities and deficits, accept their deficits and work on perfecting these deficits. Students experience recognition, e.g. through positive feedback or by solving difficult tasks. The recognition they experience motivates them to continue and intensify their work on personal deficits.

Applicability in this and other Programs

In this degree programme EM-11, EM-14, EM-19, EM-22

In other degree programmes:

Electrical Engineering and Information Technology (Bachelor): ET-11, ET-14, ET-27, ET-30, ET-34, ET-39, ET-40, ET-41, ET-42

Entrance Requirements

Formal: none

in terms of content: EM-01, EM-02, EM-03

Learning Content

1. **Metals and alloys**
   1.1. Steel
   1.2. Aluminium
   1.3. Magnesium
   1.4. Copper
2. **Glasses**
3. **Ceramics**
   3.1. Piezoceramics
   3.2. Magneto ceramics
   3.3. Solid ionic conductors
4. **Plastics**
5. **Optional chapters**

Teaching Methods

Seminar-based lesson

Blackboard/board, visualiser/video projector

Recommended Literature

Bargel, H. J.; Schulze, G., Werkstoffkunde, 12th edition. Springer-Verlag: 2018.

Gottstein, G., Materialwissenschaft und Werkstofftechnik: Physikalische Grundlagen, 4th edition. Springer-Verlag: Berlin, Heidelberg, 2014.

Furger, A. R., Antike Stahlerzeugung-Ein Nachweis der Aufkohlung von Eisen aus Augusta Raurica. 2nd ed.; Dr. h. c. Alfred Mutz-Stiftung: Basel, 2019

EM-09 Computer Science

Module code	EM-09
Module coordination	Prof. Dr. Andreas Penningsfeld
Course number and name	EM 2105 Computer Science 2 EM 3101 Realtime Systems
Lecturers	Prof. Dr. Robert Bösnecker Prof. Dr. Andreas Penningsfeld
Semester	2, 3
Duration of the module	2 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	6
ECTS	7
Workload	Time of attendance: 105 hours self-study: 105 hours Total: 210 hours
Weighting of the grade	7/210
Language of Instruction	German

Module Objective

Ability to program embedded systems with various programming languages (assembler, C).
Acquisition of knowledge and skills to use an object-oriented programming language, especially in C ++.

Applicability in this and other Programs

For this degree program: C16, C34, C35, C37
For any other degree program: none
For degree program Informatic III: C 3110

Entrance Requirements

See submodul description

Learning Content

See submodul description

Teaching Methods

See submodul description

Recommended Literature

See submodul description

EM-10 Statistics and Stochastics

Module code	EM-10
Module coordination	Prof. Dr. Franz Daiminger
Course number and name	EM 3102 Statistics and Stochastics
Lecturer	Prof. Dr. Franz Daiminger
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

Module objectives

Professional skills

Students know the concept of probability and can calculate the probability of events in different systems. They are able to recognise the importance of the parameters expected value, variance and standard deviation and to calculate them in different systems. The students are able to estimate the parameters expected value, variance and standard deviation through suitable statistical procedures. They can develop hypotheses and evaluate them by means of statistical surveys.

Methodological expertise

Students can apply their knowledge of probability and statistics to actual circumstances relevant to engineers. They abstract the system in order to be able to apply the methods they have learned. For example, one important application is the error calculation.

Personal and social skills

The students develop a self-concept as engineers, view facts critically and rationally. They are able to present facts clearly to other engineers and to discuss problems critically with them.

Applicability in this and other Programs

In regards to this bachelor degree courses: EM-12, EM-13, EM-18

Entrance Requirements

Formal: none

in terms of content: EM-01, EM-03

Learning Content

1 Descriptive statistics
 1.1 Data collection
 1.2 Graphical representation of data
 1.3 Key figures for the average
 1.4 Relationships between characteristics
2 Probability calculation
 2.1 Classic probability calculation
 2.2 Random variables and their distributions
 2.3 Frequently used distributions
 2.4 Normal distribution
3 Statistical inference
 3.1 Parameter estimation
 3.2 Hypothesis testing
4 Error analysis
 4.1 Measurement error
 4.2 Error propagation
 4.3 Least-squares method
5 Stochastic processes
 5.1 Markov processes
 5.2 Time-series analysis
 5.3 Kalman Filter

Teaching Methods

Seminar-based lesson

Recommended Literature

N. Henze, Arbeitsbuch Stochastik, 1st edition, Springer Verlag Berlin, 2019.

E. Behrends, Elementare Stochastik, 1st edition, Vieweg + Teubner Verlag, 2013.

Ch. Maas, Statistik für Ingenieure, 1st edition, Wiley, 2018.

H. Matthäus, W. G. Matthäus, Statistik und Excel, 1st edition, Springer Spektrum Wiesbaden, 2016.

R. Marchthaler, Kalman-Filter: Einführung in die Zustandsschätzung und ihre Anwendungen für eingebettete Systeme, 1st edition, Springer Fachmedien Wiesbaden, 2017.

EM-11 Electronic Devices

Module code	EM-11
Module coordination	Prof. Dr. Günther Benstetter
Course number and name	EM 3103 Electronic Devices
Lecturers	Prof. Dr. Günther Benstetter Fabian Kühnel
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

Students learn the necessary steps to understand the functioning of the most important discrete semiconductor components and passive components. They acquire the ability to depict electronic components in simplified models and to use them in practice.

Students will achieve the following learning objectives:
Professional skills

Knowledge:

1 Basic understanding of the structure of semiconductors and charge transport processes in solids

2 Understanding the elementary physical relationships in electronic devices and their effects on functioning
3 Knowledge of the typical applications of electronic devices

Skills:

1 Ability to depict the behaviour of real electronic devices in simplified models
2 Ability to calculate and dimension semiconductor devices and to use them in simple circuits

Competences:

1 Competency for the application-oriented selection and practical use of electronic devices

Methodological skills

Using acquired skills to analyse electronic devices and depict them in models during tasks and problems outside of solid-state electronics.

Personal skills

Students can solve problems individually, as well as within working groups, to understand electronic devices, to depict them in models and to use them.

Applicability in this and other Programs

In this degree programme EM-16, EM-17, EM-19

In other degree programmes:

Electrical Engineering and Information Technology (Bachelor): ET-14, ET-17, ET-19, ET-27, ET-30, ET-31, ET-34, ET-35, ET-36, ET-37, ET-38, ET-39, ET-40, ET-42, ET-44

Entrance Requirements

Lecture:

Formal: none

in terms of content: EM-01, EM-02, EM-03, EM-05, EM-06, EM-07, EM-08

Internship :

Formal: at least 42 ECTS points

Passed examinations of at least two of the modules Mathematics I (EM01), Physics I (EM02) and Basics of Electrical Engineering I (EM03)

in terms of content: EM-01, EM-02, EM-03, EM-05, EM-06, EM-07, EM-08

Learning Content

1 Passive components

1.1 Resistors

1.2 Capacitors
1.3 Coils

2 Basics of semiconductor physics

2.1 Band model
2.2 Intrinsic and extrinsic conduction
2.3 Equations for semiconductors in thermodynamic equilibrium
2.4 Charge carrier transport
2.5 Disruption of thermodynamic equilibrium
2.6 Fermi level in the case of current flow

3 p-n junction

3.1 p-n junction in thermodynamic equilibrium
3.2 p-n junction when electric voltage is applied
3.3 Current-voltage characteristic
3.4 Equivalent circuit diagrams
3.5 Switching behaviour
3.6 Temperature behaviour
3.7 Breakdown behaviour

4 Bipolar transistor

4.1 Structure and operation modes
4.2 Transistor mechanism
4.3 Transistor characteristics
4.4 Second order effects
4.5 BJT modelling

5 Field-effect transistor (FET)

5.1 Properties of the MOS structure, capacity behaviour
5.2 Structure and mechanism of FETs
5.3 Derivation of transistor equations
5.4 MOS-FET characteristics
5.6 MOS-FET modelling

6 Multilayer semiconductors

6.1 Four-layer diode
6.2 Thyristor
6.3 Triac

7 Optoelectronic components

7.1 Basics
7.2 Photo sensors
7.3 Optical emitting components

Teaching Methods

Seminar-based lesson
Blackboard/board, visualiser/video projector, pc simulations

Recommended Literature

H. Göbel: Einführung in die Halbleiter-Schaltungstechnik, 6th edition. Springer Lehrbuch 2019.

H. Göbel / H. Siemund: Übungsaufgaben zur Halbleiter-Schaltungstechnik , 4th edition. Springer Lehrbuch 2018.

M. Reisch: Halbleiter-Bauelemente, 2nd edition. Springer Lehrbuch 2011.

R. Müller: Grundlagen der Halbleiter-Elektronik, 7th edition. Springer Verlag, Berlin 1995.

R. Müller: Bauelemente der Halbleiter-Elektronik. Springer Verlag, Berlin 1995.

Streetman / Banerjee: Solid State Electronic Devices, 7th edition. Prentice Hall 2014.

S.M. Sze: Physics of Semiconductor Devices, 3th edition. Wiley 2006.

EM-12 Control Techniques 1

Module code	EM-12
Module coordination	Prof. Dr. Nikolaus Müller
Course number and name	EM 3104 Control Techniques 1
Lecturer	Prof. Dr. Nikolaus Müller
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

The aim is to make the students aware of the effects of feedback and making them familiar with the basic concepts of control technology.

After completing the module, students will have achieved the following learning objectives:

Professional skills:

1. They can graphically sketch control loops
2. They know the basic rules of model building and identification
3. They can determine control loop properties
4. They can choose a suitable controller structure

5 They can calculate controller parameters and implement them in software or hardware
6 They can use the Bode diagram for analysis and controller synthesis

Methodological skills: Students develop graphical illustrations of complex problems and in doing so achieve a breakdown into smaller and simpler issues.

Personal and professional development: Students independently organise their weekly preparation of the next teaching unit. They also carry out transfer tasks under time pressure.

Social skills: Students organise cooperation among themselves to carry out a practical experiment.

Applicability in this and other Programs

In this degree programme EM-15, EM-18, EM-19, EM-22

In other degree programmes:

Electrical Engineering and Information Technology (Bachelor): ET-15, ET-16, ET-26, ET-27, ET-30, ET-31, ET-41, ET-44

Entrance Requirements

Formal: none

in terms of content: EM-01, EM-02, EM-03, EM-05, EM-06, EM-07, EM-11, EM-13

Learning Content

1 Introduction

2 Description of dynamic systems

2.1 Block diagram
2.2 Linearisation around an operating point

3 Properties of control loops

3.1 Stationary behaviour
3.2 Stability

4 Controller design

4.1 Classic controller design
4.2 Parameter optimisation
4.3 Structure optimisation

5 Application of the Bode diagram

Teaching Methods

Blended Learning, seminar-based teaching, exercises, lab work

Recommended Literature

J. Lunze: Regelungstechnik I, 12th edition. Springer Vieweg 2020.

H. Lutz / W. Wendt: Taschenbuch der Regelungstechnik, 12th edition. Verlag Harri Deutsch 2021.

H. Mann / H. Schiffelgen / R. Froriep / K.Webers: Einführung in die Regelungstechnik, 12th edition. Hanser Verlag 2019.

M. Reuter / S. Zacher: Regelungstechnik für Ingenieure, 15th edition. Springer/Vieweg 2017.

W. Schneider / B. Heinrich: Praktische Regelungstechnik, 4th edition. Springer/Vieweg 2017.

G. Schulz / K. Graf : Regelungstechnik I. DeGruyter Studium 2015.

EM-13 Electrical Measurement Technique

Module code	EM-13
Module coordination	Prof. Dr. Stefan Zorn
Course number and name	EM 3105 Electrical Measurement Techniques EM 3106 Practical Course Electrical Measurement Technique
Lecturers	Joachim Brunner Prof. Dr. Stefan Zorn
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	undergraduate
Semester periods per week (SWS)	8
ECTS	6
Workload	Time of attendance: 120 hours self-study: 60 hours Total: 180 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	6 / 210
Language of Instruction	German

Module Objective

Students fundamentally deal with electrical metrology and sensors. They learn the necessary steps to develop independent solutions for corresponding problems from the engineering field, whereby they are also particularly enabled to critically question the selection of corresponding methods and calculation procedures.

Students learn typical models, methods and tasks from engineering practice, how different measuring tasks can be carried out, along with corresponding solution methods and solution strategies.

Students will achieve the following learning objectives:

Professional skills

Students are familiar with the linearisation of measuring instruments and sensors. They learn how to deal with error calculation and its statistics as well as possible causes of measurement errors and their compensation. The limits and tolerances of a measurement are also learnt In addition, the basics of measuring current, voltage and power are taught. The complete chain of a measuring unit is discussed. Students are able to dimension a measurement chain and know all the components. Special emphasis is placed on operational amplifiers. The handling and application of this Swiss army knife of electrical engineering is derived from the basics to simple basic circuits to frequency-dependent second-order circuits. The underlying mathematics is taught and enables students to design and calculate any operational amplifier circuit. Furthermore, measurement instruments, such as multimeters, oscilloscopes or power meters are covered. The transition from analogue measurement technology to digital is also described via analogue-digital or digital-analogue converters. The lecture is rounded off by the teaching of various sensor principles and their application in practice. Students will have the knowledge to apply what they have learned in a subject-specific manner. In summary, the students are able to apply their acquired knowledge to practical engineering tasks.

Methodological skills

Students are able to identify and successfully apply appropriate calculation methods from a range of calculation techniques, depending on the task at hand. They can handle scientific calculators and use computer algebra software, if necessary. The students solve exercises in the lecture independently and thereby gain confidence and experience in dealing with engineering problems. In addition, an atmosphere of openness is created to encourage students to question existing knowledge and to actively apply and combine their knowledge in new tasks.

Personal skills

The students are aware of their responsibility as future engineers. They are able to carry out measurement tasks cooperatively and as part of a team and can also critically evaluate the results.

Applicability in this and other Programs

In this degree programme EM-16, EM-17, EM-18

In other degree programmes:

Electrical Engineering and Information Technology (Bachelor): ET-19, ET-26, ET-27, ET-31, ET-33, ET-41, ET-42, ET-45

Entrance Requirements

Lecture:

Formal: none

In terms of content: EM-01, EM-02, EM-03, EM-05, EM-06, EM-07

Internship:

Formal: at least 42 ECTS points

Passed examinations of at least two of the modules Mathematics I (EM-01), Physics I (EM-02) and Basics of Electrical Engineering I (EM-03)

in terms of content: EM-01, EM-02, EM-03, EM-05, EM-06, EM-07

Learning Content

Introduction

1.Grundlagen

2. Characteristic curve and sensitivity of measurement instruments

3.Fehlerrechnung

4. Error correction/compensation

Analogue measurement technology

5. Measurement of current and voltage

6.Brückenschaltungen

7. Inductive transducers

8.Operationsverstärker

9. Frequency-dependent circuits / active filters

Digital measurement technology

10. Electron beam oscilloscope

11. Analogue-to-digital converter

12. Digital-to-analogue converter

13. Sensor principles

14. Strain gauges

Teaching Methods

Alternate lecture and seminar-based lessons, solving problems during the lecture, blackboard notes, prepared slides, instructions for the practical course; in addition, every second week 90 min. tutorial in which only exercises are calculated. The lecture is accompanied by a practical course in which the acquired knowledge can be directly applied in a laboratory environment.

Great importance is placed on the active participation of students in the lecture and in the processing of exercises. Instead of receiving merely teacher-centred teaching, the maxim is to participate and work on the learning content together.

Recommended Literature

W.-J. Becker (Ed.): *Handbuch elektrische Meßtechnik* . Hüthig, Heidelberg, 2nd edition, 2000.

A. Haug, F. Haug: *Angewandte elektrische Messtechnik* . 3rd edition, Vieweg, Braunschweig, 2000.

R. Lerch: *Elektrische Meßtechnik* . Springer, Berlin, Heidelberg, New York, 1st edition, 1996

R. Lerch: *Elektrische Meßtechnik* . Springer, Berlin, Heidelberg, New York, 3rd edition, 2007

Th. Mühl: *Grundlagen der elektrischen Messtechnik* . Vieweg+Teubner, Wiesbaden, 3rd edition, 2008

W. Pfeiffer: *Elektrische Meßtechnik* . VDE-Verlag, Berlin, 1999.

E. Schrüfer: *Elektrische Meßtechnik* . 9th edition, Hanser, München, 2007

H.-R. Tränkler *: Taschenbuch der Meßtechnik* . 4th edition, Oldenbourg, München, Wien, 1996

U. Tietze, Ch.Schenk: *Halbleiter-Schaltungstechnik.* 13th edition, Springer, 2009

G. Engeln-Müllges, K. Niederdrenk, R. Wodicka: *Numerik-Algorithmen.* 9th edition, Springer, Berlin, 2005

EM-14 Sensor Technology and Optics

Module code	EM-14
Module coordination	Prof. Dr. Franz Daiminger
Course number and name	EM 3107 Sensor Technology and Optics
Lecturer	Prof. Dr. Franz Daiminger
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	, written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

Professional skills

Students know the basics of technical optics including the most important optical instruments. They acquire knowledge of modern light sources, such as light-emitting diodes and lasers. They know the most important sensors for the detection of light, measurement of geometric and mechanical quantities, and in particular measurement of geometric distances for position recognition. They are familiar with the physical laws on which these sensors are based.

Methodological expertise

Students have the ability to select the right sensors for different measurement problems and to use them in an appropriate way and estimate their accuracy in the respective context.

Personal and social skills

The students develop a self-concept as engineers, view facts critically and rationally. They are able to present facts clearly to other engineers and to discuss problems critically with them.

Applicability in this and other Programs

In this degree programme EM-12, EM-13, EM-17, EM-18

Entrance Requirements

Formal: none

in terms of content: EM-01, EM-02, EM-03, EM-05, EM-06, EM-07

Learning Content

1 Basics of optical metrology
  1.1 Technical optics
  1.2 Optical instruments, telescope, magnifying glass, microscope
  1.3 Wave optics, diffraction and interference
  1.4 Quantum optics
  1.5 Aberration
  1.6 Photometry
2 Optical sensor technology
  2.1 Light emitting diodes, laser diodes, laser
  2.2 Photodiodes
  2.3 Photomultiplier
  2.4 CCD chip
  2.5 Optical fibre
  2.6 LIDAR (Light Detection And Ranging)
  2.7 Various optical sensor systems
3 Physical effects of sensor use
  3.1 Piezoelectric and piezoresistive effect
  3.2 Magnetic-field-based effect
  3.3 Effects of induction, capacitance and electrical resistance
  3.4 Thermoelectric effect
  3.5 Doppler effect
4 Sensors

4.1 Mechano-resistive sensors
4.2 Capacitive sensors
4.3 Magnetic-inductive sensors
4.4 Triangulation sensors
4.5 Interferometric sensors
4.6 Time-based sensors
4.7 Doppler-effect-based sensors

Teaching Methods

Seminar-based teaching / Practical course

Recommended Literature

E. Hering, G. Schönfelder: Sensoren in Wissenschaft und Technik, 1st edition, Vieweg + Teubner Verlag, 2012.

M. Löffler-Mang: Optische Sensorik, 1st edition, Vieweg + Teubner Verlag, 2012.

M. Wolff: Sensor Technologien Volume 1, 1st edition, De Gruyter Oldenburg, 2016.

M. Wolff: Sensor Technologien Volume 2, 1st edition, De Gruyter Oldenburg, 2018.

T. Tille: Automobil-Sensorik 2, 1st edition, Springer-Verlag, Berlin Heidelberg 2018.

EM-15 Microcomputer Technology

Module code	EM-15
Module coordination	Prof. Dr. Andreas Penningsfeld
Course number and name	EM 4101 Microcomputer Technology
Lecturer	Prof. Dr. Andreas Penningsfeld
Semester	4
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written student research project
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

Students will achieve the following learning objectives:

Professional skills

Students should be able to implement theoretical and practical contents of the lecture in a microcomputer system (?embedded system?) in a well-founded way.

This includes handling development systems, implementing them in a machine-oriented realisation, and carrying out testing and troubleshooting in real target systems.

Key component are the application of real-time operating systems and programming in the languages C and C++. The students are able to integrate functions of an operating system and understand object-oriented programming paradigms.

The learning outcomes can immediately be applied in professional life.

Methodological skills

Students are able to implement extensive projects in a goal-oriented manner. It is possible to select the most appropriate approach from various procedures and methods. Students are able to conduct independent research on the basis of extensive exercises and to further expand their existing knowledge independently.

Personal skills

The students are aware of their responsibility as future engineers. They are able to carry out development activities cooperatively and as part of a team and can also critically evaluate the results.

Applicability in this and other Programs

In this degree programme EM-33

In other degree programmes:

Electrical Engineering and Information Technology (Bachelor): ET-31

Entrance Requirements

Formal:

in terms of content:

Learning Content

1 Start

1.1 Development environment
1.2 Installation of AVRStudio4
1.3 Project creation
1.4 Programming
1.5 Fuses

2 Experimental setup

2.1 AVRBoard1
2.2 CPU ATmega 168

3 Experiments

3.1 Experiment with AVRBoard1: flashing of an LED
3.2 Experiment: read key
3.3 Experiment 2 Shift key
3.4 Experiment ON/OFF key
3.5 Experiment: Timer
3.6 Task ?HALLO?
3.7 Matrix keyboard

3.8 Task analogue/digital converter
3.9 I2C bus
3.10 Experimental set-up AVRIO1:
3.11 Stepper motor
3.12 AVRIO1 LED matrix
3.13 Rotary encoder
3.14 Software rotary encoder in C
3.15 Software LED matrix und rotary encoder in C++
3.16 Task Tresor2
3.17 Task rotary encoder on LEDs with 2C
3.18 I2C master/slave
3.19 Project master/slave
3.20 Object-oriented programming in C++
3.21 Serial interface USART

4 Project assignment SS 2016

5 Project assignment SS2018 motor control

6 Simulation

6.1 Simulator, main programme
6.2 Describe simulator port
6.3 Read simulator PIN and write PIN

Teaching Methods

Teaching consists of half seminar-based lessons and half practical classes.

After the teaching contents and theoretical background are presented, suitable sample exercises are given, and students work on them step by step; then small projects are carried out independently. The lecturer?s instructions are conveyed individually in line with the work progress of the groups.

The process of learning programming techniques in ?embedded systems? involves working on a lot of illustrative material practically on the computer. This develops a good level of independence during the course of the semester. The ability to work independently is developed through a variety of projects, which can then be solved almost independently under the guidance of the lecturer. One example is the speed control of a stepper motor.

Media forms are development set-ups with PC, programming devices and target systems, blackboard, script, collections of exercises, video projector, PC and secondary literature.

Remarks

PStA Written assignment

Students are given a project and they work on it for a week. The level of knowledge and personal active ability to solve spontaneous tasks are then tested and assessed in an oral examination.

Recommended Literature

G. Schmitt: Programmierung in Assembler und C - Schaltungen und Anwendungen. Oldenbourg-Verlag.

K. Wüst: Mikroprozessortechnik: Grundlagen, Architekturen, Schaltungstechnik und Betrieb von Mikroprozessoren und Mikrocontrollern. Vieweg/Teubner Verlag.

Prof. Penningsfeld Skript Mikrocomputertechnik.

EM-16 Electromagnetic Compatibility

Module code	EM-16
Module coordination	Prof. Dr. Günter Keller
Course number and name	EM 4102 Electromagnetic Compatibility
Lecturers	Prof. Dr. Günter Keller Prof. Dr. Matthias Wuschek
Semester	4
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

The course deals with electromagnetic compatibility (EMC) of electrical and electronic devices, with legal conditions and EMC design.

Students learn to assess and avoid electromagnetic interference between electrical devices.

Students will achieve the following learning objectives:
Professional skills

Students learn the basic correlations, such as terms, definitions and coupling mechanisms. One of the focus points is EMC-compliant device design, such as wiring, filters, shielding and ground systems.

In addition to technical aspects, students also learn about legal boundary conditions.

Methodological skills

The subject is oriented towards Maxwell?s equations. As a result, students are introduced to the application of basic equations to components, circuit boards, devices and systems. They apply the basics to application-related examples in theory and practice.

Personal skills

Personal skills lie in the detailed application of mathematical and technical methods.

Applicability in this and other Programs

In this degree programme: none

In other degree programmes: none

Entrance Requirements

Formal: none

in terms of content: EM-01, EM-02, EM-03, EM-06, EM-07, EM-11, EM-13

Learning Content

1 Basic concepts

1.1 Phenomena
1.2 Forms of depiction
1.3 Signals and properties
1.4 EMC work

2 Coupling mechanisms

2.1 Overview
2.2 Galvanic coupling
2.3 Capacitive coupling
2.4 Inductive coupling
2.5 Electromagnetic coupling

3 Standards and tests

3.1 European directives and EMC law
3.2 Standards
3.3 Emission measurements
3.4 Immunity tests

4 EMC-compatible circuit board design

4.1 Boundary conditions
4.2 Parasitic properties
4.3 Current loops
4.4 Ground systems

5 EMC-compatible device design

5.1 Zone concept
5.2 Wiring
5.3 Plugs
5.4 Shielding

6 EMC filter

6.1 Components
6.2 Filter design
6.3 Dimensioning

7 Shielding

7.1 Mechanism
7.2 Design possibilities

Teaching Methods

Lecture as seminar-based lesson, three practical experiments.

In the lectures, software tools such as LTspice and Python, which can support self-study very well, are used.

Recommended Literature

Franz: EMV, 5th edition. Springer/Vieweg 2013.

Schwab: Elektromagnetische Verträglichkeit, 6th edition. Springer/Verlag, Heidelberg 2011.

Montrose: EMC made simple. Montrose Compliance Services 2014.

Williams: EMC for Product Designers. Newnes 2017.

EM-17 Imaging

Module code	EM-17
Module coordination	Prof. Dr. Simon Zabler
Course number and name	EM 4103 Imaging
Lecturers	Prof. Dr. Martin Jogwich Prof. Dr. Simon Zabler
Semester	4
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

This module aims to provide students with a thorough knowledge of analogue and digital image acquisition, pre-processing and processing from both a device and a software perspective.

After completing the module, students will have achieved the following learning objectives:

Professional skills:

1. Ability to calculate or estimate lighting parameters.
2. Knowledge of the most important technical camera parameters and their effects on image acquisition.

3. Ability to calculate and set camera lens settings for a given image processing job.
4. Ability to apply various basic image processing algorithms.
5. Ability to apply various basic image pre-processing algorithms.

Methodological skills:

Students separately develop solutions of image acquisition, pre-processing and processing, first theoretically, then practically with appropriate hardware and software.

Personal and professional development:

Students implement the theoretical knowledge into the creation of an image processing programme (following fixed tasks) in workshops under tight time constraints.

Social skills: Students organise cooperation among themselves to carry out a practical laboratory experiment.

Applicability in this and other Programs

In this degree programme: none

In other degree programmes: none

Entrance Requirements

Formal: none

in terms of content: EM-01, EM-02, EM-03, EM-05, EM-06, EM-08, EM-11, EM-13

Learning Content

E Introduction

E.1 Literature on the lecture
E.2 Definitions of terms
E.3 Examples of non-industrial image processing applications

H Hardware

H.1 Human vision
H.2 Image acquisition
H.2.1 Light generation and photometry
H.2.2 Lighting
H.2.3 Applied optics
H.2.4 Signal generation
H.3 Industrial image processing [machine vision]
H.3.1 Areas of application
H.3.2 Market
H.3.3 Case studies

S Software

S.1 Image pre-processing
S.1.1 Image presentation
S.1.2 Homogeneous (monadic) point operations
S.1.3 Inhomogeneous (dyadic) point operations
S.1.4 Local operations (local filter)

S.2 Image processing
S.2.1 Size check
S.2.2 Location check
S.2.3 Segmentation process

If the numbering specified by Reinhard is mandatory, it would be quite short:

1 Introduction

1.1 Literature on the lecture
1.2 Definitions of terms
1.3 Examples of non-industrial image processing applications

2 Hardware

2.1 Human vision
2.2 Image acquisition
2.3 Industrial image processing

3 Software

3.1 Image pre-processing
3.2 Image processing

Teaching Methods

Slides, blackboard, PowerPoint script, video projector, image processing programmes, cameras, various lighting systems

Recommended Literature

J. Beyerer / F.P. Leon / Chr. Frese: Automatische Sichtprüfung, 2nd edition, Springer Verlag, Berlin Heidelberg 2016.

Chr. Demant / B. Streicher-Abel / A. Springhoff: Industrielle Bildverarbeitung, 3rd edition, Springer Verlag, Heidelberg 2011.

A. Erhardt: Einführung in die Digitale Bildverarbeitung, 1st edition, Vieweg + Teubner, Wiesbaden 2008.

B. Jähne: Digitale Bildverarbeitung und Bildgewinnung, 7th edition, Springer Vieweg Verlag, Berlin 2012.

L. Priese: Computer Vision - Einführung in die Verarbeitung und Analyse digitaler Bilder, 1st edition, Springer Verlag, Berlin Heidelberg 2015.

EM-18 Control Techniques 2

Module code	EM-18
Module coordination	Prof. Dr. Nikolaus Müller
Course number and name	EM 4104 Control Techniques 2
Lecturer	Prof. Dr. Nikolaus Müller
Semester	4
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 120 min.
Duration of Examination	120 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

The aim is to broaden students knowledge of control technology and to prepare them for typical tasks in industry.

After completing the module, students will have achieved the following learning objectives:

Professional skills:

- They construct root locus curves and use them to develop controllers
- They can explain the special effects of a digital controller
- They know the basic features of analysing control loops with switching controllers
- They represent controlled systems in the state space

- They model dynamic systems in Matlab/Simulink and analyse their behaviour

Methodological skills: Students work on systems engineering tasks with suitable graphical or procedural programmes.

Personal and professional development: Students independently organise their weekly preparation of the next teaching unit. They also carry out transfer tasks under time pressure.

Social skills: Students organise cooperation among themselves to carry out a practical experiment.

Applicability in this and other Programs

In this degree programme: none

In other degree programmes: none

Entrance Requirements

Formal: none

in terms of content: EM-01, EM-02, EM-03, EM-05, EM-07, EM-12, EM-13

Learning Content

1 Root locus curves

1.1 Design rules
1.2 Analysis and synthesis of control loops

2 Digital control

2.1 Description in the z-domain
2.2 Quasi-continuous design

3 Switching controller

3.1 Analysis for first-order systems
3.2 Analysis for second-order systems

4 Control in the state space

4.1 Setting up of state equations
4.2 Design as per the full state feedback method

Teaching Methods

Seminar-based teaching / Exercises

Recommended Literature

J. Lunze: Regelungstechnik 1, 12th edition. Springer/Vieweg 2020.

H. Lutz / W. Wendt: Taschenbuch der Regelungstechnik, 12th edition. Verlag Harri Deutsch 2021.

H. Mann / H. Schiffelgen / R. Froriep / K. Webers: Einführung in die Regelungstechnik, 12th edition. Hanser Verlag 2019.

M. Reuter / S. Zacher: Regelungstechnik für Ingenieure, 15th edition. Springer Vieweg 2017.

G. Schulz / K. Graf : Regelungstechnik 1 , 5th edition. DeGruyter Studium 2015.

G. Schulz / K. Graf : Regelungstechnik 2 , 3rd edition. DeGruyter Studium 2013.

R.C. Dorf / R.H. Bishop: Modern Control Systems, 13th edition. Pearson, 2017

EM-19 Power Electronics 1

Module code	EM-19
Module coordination	Prof. Dr. Otto Kreutzer
Course number and name	EM 4105 Power Electronics 1
Lecturer	Prof. Dr. Otto Kreutzer
Semester	4
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

The course deals with power electronics, its components, circuits and applications. In the Power Electronics subject, students learn how to use the components and circuits of power electronics and about their possible applications.
In the Power Electronics course, students learn how to use the components and circuits of power electronics and about their possible applications.

Students will achieve the following learning objectives:

Professional skills

Students learn the structure and mechanism of passive and active power electronics components and the basic topologies and their applications.

Circuits are subdivided into line-commutated and self-commutated circuits. Here, students learn not only about circuits but also about their mechanism and design Self-commutated circuits form the core of the course.

Methodological skills

Students learn the structural composition of components in circuit technology and system technology. They can apply the component design methodology to a variety of circuits.

Personal skills

Personal skills lie in the detailed application of mathematical and technical methods.

Applicability in this and other Programs

In this degree programme EM-29

In other degree programmes:

Electrical Engineering and Information Technology (Bachelor): ET-31

Entrance Requirements

Formal: none

in terms of content: EM-01, EM-02, EM-05, EM-06, EM-10, EM-11

Learning Content

1 Components
  1.1 Capacitors
  1.2 Inductances
  1.3 Diodes
  1.4 Circuit breakers
2 Integrated circuit packaging
  2.1 Cooling and thermal management
  2.2 Passive components
  2.3 Active components
3 Topologies of power electronics
  3.1 DC/DC conversion
  3.2 AC/DC conversion
  3.3 DC/AC conversion
  3.4 AC/AC conversion
  3.5 Isolating topologies
4 Application areas of power electronics

Teaching Methods

Lecture as seminar-based lessons

Recommended Literature

U. Probst: Leistungselektronik für Bachelors: Grundlagen und praktische Anwendungen. 3rd edition. Carl Hanser Verlag, München 2015.

R. Felderhoff / U. Busch: Leistungselektronik, 4th edition. Carl Hanser Verlag, München 2006.

J. Specovius: Grundkurs Leistungselektronik: Bauelemente, Schaltungen und Systeme. 9th edition, Springer/Vieweg Verlag, Wiesbaden 2018.

EM-20 Electric Machines

Module code	EM-20
Module coordination	Prof. Dr. Peter Firsching
Course number and name	EM 4106 Electrical Apparatuses
Lecturer	Prof. Dr. Peter Firsching
Semester	4
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5/ 210
Language of Instruction	German

Module Objective

After completing this module, the students know the relevant properties and functional principles of electrical machines as an important component of industrial and automotive applications. They are also able to configure a modern single-axis or multi-axis drive system electrically and, for essential parameters, also mechanically.

Professional skills:

Students understand the technical principles of electrical machines and the physical principles of electromagnetic power conversion. Furthermore, they understand the functional characteristics and the operating behaviour of industrially relevant variants of electrical machines and can assess their usability in different application scenarios.

Methodological skills:

Students know the physical/technical principles for the mechanical and electrical design of a drive and can apply these to the machine variants covered. Furthermore, they apply the methods for speed and torque control to all industrially relevant machine variants.

Personal skills:

Students work on content in groups, e.g. using examples of interpretation.

They can research technical issues alone or in groups and present them in a structured way.

Social skills:

Students are able to reflect on the requirements in the field of electrical machines and drives and transfer them to relevant application scenarios.

Applicability in this and other Programs

In this degree programme: none

In other degree programmes: none

Entrance Requirements

Formal: none

in terms of content: EM-02, EM-03, EM-06, EM-07, EM-12

Learning Content

1 Basics of electrical machines and drives

a. General drive system
b. Power consideration
c. Operation modes
d. Designs, nameplate, protection classes
e. Magnetic circuit
f. Torque and voltage formation in the e-machine

2 DC motor

a. Structure and functional principle
b. Equivalent circuit diagram and operating behaviour
c. Speed control, starting and braking
d. Dynamic behaviour

3 Basics of induction machines

a. Three-phase windings
b. Rotating magnetic fields

c. Space-vector description

4 Synchronous machines

a. Structure and functional principle
b. Operation as electronically commutated motor
c. Equivalent circuit diagram, operating behaviour, pointer diagram
d. Structure and functioning of brushless DC motors

5 Asynchronous motors

a. Functional principle
b. Equivalent circuit diagram and operating behaviour
c. Speed control
d. Starting and braking

6 Stepper motors

a. Functional principle
b. Designs
c. Activation

7 Servo drivers

a. Electronic drive control
b. Drive regulations

Teaching Methods

Blackboard notes, prepared slides, trial software, simulations in Matlab / Simulink

Seminar-based lessons 3.5 SWS

Practical lab course in groups 0.5 SWS

Recommended Literature

Fischer R.: Elektrische Maschinen, 17th edition. Hanser Verlag 2017.

Stölting H.: Handbuch Elektrische Kleinantriebe, 4th edition. Hanser Verlag 2011.

Schröder D., Kennel R.: Elektrische Antriebe ? Grundlagen. Springer-Vieweg-Verlag, 2021.

Probst U.: Leistungselektronik für Bachelors. Hanser-Verlag, 2015.

P. Brosch: Moderne Stromrichterantriebe. Vogel Verlag 1998.

EM-21 Internship

Module code	EM-21
Module coordination	Prof. Dr. Detlef Brumbi
Course number and name	EM 5101 Internship EM 5102 Internship Seminar
Semester	5
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	undergraduate
Semester periods per week (SWS)	2
ECTS	25
Workload	Time of attendance: 30 hours self-study: 720 hours Total: 750 hours
Type of Examination	internship certification
Weighting of the grade	25 / 210
Language of Instruction	German

Module Objective

Students are to gain experience in independent, engineering-related work.

The internship should introduce the work and working methodology of an engineer through concrete tasks. It must include engineering-related activities, e.g., from the areas of production, development (hardware, software), measurement and testing technology, commissioning, service, project planning.

The internship should primarily be carried out at companies in Germany and abroad. Students can also do internships in the form of project work at Deggendorf Institute of Technology.

Students will achieve the following learning objectives:

Professional skills

- Application of theoretical and practical knowledge in a technical project

- Work independently on a complex task in an industrial environment

Methodological skills

- Integrating personal skills and competences into a project assignment
- Dealing with realistic challenges in a company
- Development and implementation of solutions

Personal skills

- Insight into company structures
- Experiencing operational processes in a company
- Collaboration with other employees involved in the project
- Building teamwork, conversation and presentation skills

Applicability in this and other Programs

In this degree programme: in all specialisations

In other degree programmes: none

Entrance Requirements

Formal: at least 70 ECTS points

in terms of content: none

Learning Content

See subject description

Teaching Methods

See subject description

Remarks

Remarks

Before carrying out the in-company internship, students must register online in the university's internship management system and upload their internship contract, which is then approved online by the internship commissioner. After completing all required performances, the internship commissioner acknowledges the passing of the in-company internship by means of an online entry in the internship management system.

Passing the module 'Internship-supplementary specialisations' is a prerequisite for the module 'In-company internship' to be recognised.

Further details are regulated in the guidelines: Internship semester ET Bachelor

Recommended Literature

See subject description

EM 5101 Internship

Objectives

During their 18-week internships, students gain experience in independent, engineering-related work. See module description.

Learning Content

Individual topics as specified by the internship company and as approved by the internship commissioner.

Type of Examination

internship certification

Methods

Types of examination

Internship certificate from the company

Recommended Literature

Recommended reading

Varies from case to case depending on topics of the practical tasks

EM 5102 Internship Seminar

Objectives

In the practical seminar, students compose a written report about their internship and give a presentation.

Entrance Requirements

Formal: completion of the internship
in terms of content: none

Learning Content

Varies from case to case depending on the activities performed during the internship.

Type of Examination

report and presentation, course assessment

Methods

Types of examination

Report and presentation, course work certificate (LN)

Recommended Literature

Recommended reading

Hering / Heine: Technische Berichte: Verständlich gliedern, gut gestalten, überzeugend vortragen, 8th edition. Springer/Vieweg 2019.

EM-22 Practical Training Seminar

Module code	EM-22
Module coordination	Prof. Dr. Detlef Brumbi
Course number and name	EM 5103 Practical Traning Seminar 1 EM 5104 Practical Traning Seminar 2
Semester	5
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

In the complementary practice specialisation, there are four seminars from ?Study and Personal Competence? and three seminars from ?Professional Competence?.

The module spans several semesters. Students are to learn contents that are directly or indirectly related to the practical work of electrical engineers.

The students achieve the following learning objectives, depending on the selected seminars (professional skills, methodological skills and personal skills are defined there):

1. Acquisition of academic and personal skills
2. Acquisition of professional skills
3. Expanding what has been learned during the course of study
4. Establishing contacts with various companies
5. Insights into the practice of engineering activities
6. Presentation of work results

Applicability in this and other Programs

In this degree programme

In other degree programmes:

Entrance Requirements

Formal: none

in terms of content: none

Learning Content

Individual depending on the selected seminars of the Career Service of Deggendorf Institute of Technology.

Teaching Methods

Lecture, practical exercises, individual and group work, presentation

Remarks

Remarks

Successfully completing the module ?Complementary practice specialisation module? is a prerequisite for the module ?In-company internship? to be recognised.

Students must be registered online in the university?s internship administration in order to have the complementary practice specialisation subjects recognised.

Further details are regulated in the guidelines: Internship semester ET/ EM Bachelor

Recommended Literature

Individual depending on the selected seminars of the Career Service of Deggendorf Institute of Technology.

EM-23 English for Engineers

Module code	EM-23
Module coordination	Tanja Mertadana
Course number and name	EM 6101 English for Ingeneers
Lecturer	Dozierende für AWP und Sprachen
Semester	6
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 60 hours Total: 120 hours
Type of Examination	See examination schedule AWP and languages, written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	English

Module Objective

The module English for Engineers aims to equip students with specialised language skills necessary for independent and qualified professional activity in a globalised field of Electromobility, Autonomous Driving and Mobile Robotics. It aims to deepen and refine the students understanding of the English language in scientific and technical fields in order to enable them to use the language effectively and efficiently as a practical means of communication.

The module covers the four basic language skills - listening, reading, speaking and writing. Students expand their subject-specific vocabulary and deepen their knowledge of the language structures.

The main focus of the module is to optimise fluency and improve the ability to communicate in English in order to better understand complex and lengthy texts and conversations in professional context. Through task-based speaking, listening, reading and writing activities, students optimise their communicative skills and develop their ability to express themselves. This enables them to participate in expert discussions, work in a team, prepare relevant documents independently and in a competent manner and to give successful presentations in English.

On completion of the module, the students will have achieved the following learning objectives:

Subject-specific skills

At Level English B2/ C1, students should be able to:

- have a confident level of English (B2/C1, CEFR) and be able to understand and take part assertively in expert discussions and negotiations in the field of Electromobility, Autonomous Driving and Mobile Robotics.
- They will have the skills to understand and analyse specialised literature and to write texts at B2/C1 level.
- Students will have acquired the skills to express themselves at B2/C1 level in professional contexts.
- They will understand increasingly complex topics in their area of specialisation and can discuss them in a fairly spontaneous and flexible manner.
- They will develop the ability to apply grammatical structures both in a functional and targeted manner their future professional fields.
- They will be able to deliver clear and detailed presentations on relevant topics related to Electromobility, Autonomous Driving and Mobile Robotics and give comprehensive answers to relevant questions.
- They will be able to express personal opinions and different points of view, including a consideration of the pros and cons, effectively and as spontaneously as possible.

Methodological skills

Methodological skills refer to the students ability to use a variety of learning and working methods to further develop their linguistic and subject-specific knowledge.

- Students will expand their language acquisition skills by reflecting on their individual styles of learning.
- They will be able to filter information from different English sources and use it for discussions and presentations.
- They will be able to participate actively and as self-assertive as possible in subject-specific discussions and debates concerning Electromobility, Autonomous Driving and Mobile Robotics by presenting arguments and giving constructive feedback.
- Critical reflection on their own learning progress and strategies.

Social skills
Social skills refer to students' ability to conduct themselves appropriately, communicating effectively and working in groups when engaging in social interactions.

- Students will have developed their social skills of teamwork, reliability, and negotiation skills.
- They will have the communication skills necessary to collaborate with others to find solutions.
- They will reflect on their learning experiences from independent projects and teamwork.
- They are empathic and able to understand other viewpoints and opinions and to respond appropriately to these.
- They acquire the ability to resolve conflicts constructively and to liaise between deviating viewpoints.

Personal skills
Personal skills refer to students individual abilities, attitudes and traits that enable them to achieve their goals, further their personal development and work successfully.

- Students will have developed sound language skills and social skills, which are of fundamental importance for personal development and the future work environment.
- Development of problem-solving skills and the ability to explain solutions fairly fluently in English.

Applicability in this and other Programs

Applicability of the module for ET-6: English for Engineers

Entrance Requirements

The prerequisite for successful participation in the module is a command of the English language at B2 level, based on the Common European Framework of Reference for Languages (CEFR).

Learning Content

1. Introduction - What is Electrical Engineering?
2. Mathematics (e.g. mathematical models, mathematical operations)
3. Basics of Physics (e.g. atomic theory, physical forces)
4. Basics of Electrical Engineering (e.g. measurement technology, circuits, electronic components)
5. Electrical Engineering Case Studies (e.g. Maxwell, telecommunications, signal processing, the computer, AI)

6 Electromobility Case Studies (e.g. the pros and cons of electric cars, Teslas induction motor)
7 Communication Skills (e.g. presentations, constructive feedback, meetings)
8 Writing Skills (e.g. e-mails, academic writing, text cohesion and coherence)
9 Study Skills (e.g. efficient information processing, academic working methods)
10 Grammar (e.g. tenses, conditional forms, passive vs. active)

Teaching Methods

The teaching methods applied will focus on optimising the four main language skills (listening, speaking, reading and writing). Examples of the applied learning methods include various forms of group, individual and collaborative work, mini-presentations, exercises involving intensive reading and listening, role plays and grammar games, loci method, dictation exercises, translations, peer feedback, working with learning stations, and various writing activities designed to consolidate the content learnt.

Students will be given weekly assignments for self-study.

Remarks

All language courses require a compulsory attendance rate of 75% in order to be allowed to take the examination.

Recommended Literature

Astley, Peter, and Lewis Lansford. *Engineering 1: Student's Book* . Oxford: Oxford UP, 2013. Print.

Bauer, Hans-Jürgen. *English for Technical Purposes.* Berlin: Cornelson, 2000. Print.

Benford, Michael, Ken Thomson & Wolf-Rainer Windisch. *Electricity Matters: Englisch für elektrotechnische Berufe.* Berlin: Cornelson, 2013. Print

Blockley, David. *Engineering: A Very Short Introduction.* Oxford: OUP, 2012. Print.

Boden, Margaret. *Artificial Intelligence: A Very Short Introduction.* Oxford: OUP, 2018. Print.

Bonamy, David, and Christopher Jacques. *Technical English 3.* Harlow: Pearson Longman, 2011. Print.

Bonamy, David. *Technical English 4* . Harlow, England: Pearson Education, 2011. Print.

Brieger, Nick & Alison Pohl. *Technical English: Vocabulary and Grammar.* Oxford: Summertown, 2002. Print.

Büchel, Wolfram, et. al. *Englisch-Grundkurs für technische Berufe* . Stuttgart: Klett, 2001. Print.

Dasgupta, Subrata. *Computer Science: A Very Short Introduction.* Oxford: OUP, 2016. Print.

Dictionary of Electrical and Computer Engineering. 6th ed. San Francisco: McGraw-Hill, 2003.

Dummett, Paul. *Energy English: For the Gas and Electricity Industries.* Hampshire: Heinle, Cengage Learning, 2010. Print.

Emmerson, Paul. *Business English Handbook.* London: Macmillan, 2007. Print.

engine: Englisch für Ingenieure. Darmstadt. Various issues. Print.

Feynman, Ricahrd P. *Six Easy Pieces: Essentials of Physics Explained By Its Most Brilliant Teacher.* California: Basic Books, 2011. Print.

Foley, Mark, and Diane Hall. *MyGrammarLab* . Harlow: Pearson, 2012. Print.

Glendinning, Eric H., and Alison Pohl. *Technology 2* . Oxford: Oxford UP, 2008. Print.

Glendinning, Eric H. & John McEwan. *Oxford English for Information Technology.* 2nd ed. Oxford: OUP, 2006. Print.

Glendinning, Eric H. and Norman. *Oxford English for Electrical and Mechanical Engineering* . Oxford: OUP, 2001. Print.

Gowers, Timothy. *Mathematics: A Very Short Introduction.* Oxford: OUP, 2002. Print.

Greene, Anne E. *Writing Science in Plain English.* Chicago: CUP, 2013. Print.

Hammock, Bill et al. *Eight Amazing Engineering Stories.* Articulate Noise Books, 2012. Print.

Hart, Steve. *Written English: A Guide for Electrical and Electronic Students and Engineers.* Boca Raton: CRC Press, 2016. Print.

Hollett, Vicki and John Sydes. *Tech Talk: Intermediate.* Oxford: OUP, 2010. Print.

Ibbotson, Mark. *Cambridge English for Engineering.* Cambridge: Cambridge UP, 2008. Print.

Ibbotson, Mark. *Professional English in Use Engineering Technical English for Professionals.* Cambridge: Cambridge UP, 2009. Print.

Ince, David. *The Computer: A Very Short Introduction* . Oxford: OUP, 2011. Print.

Inch: Technical English. Karlsruhe. Various issues. Print.

Jayendran, Ariacutty. *English für Elektroniker: Ein Lehr- und Übungsbuch für das technische Englisch.* Wiesbaden: Vieweg, 1996. Print.

Lansford, Lewis, and Peter Astley. *Engineering 1* . Oxford: Oxford UP, 2013. Print.

Miodownik, Mark. *Stuff Matters.* London: Penguin, 2014. Print.

Möllerke, Georg. *Modern English for Mechanical Engineers.* Munich: Carl Hanser Verlag, 2010. Print.

Munroe, Randall. *What If?* London: John Murray, 2015. Print.

Praglowski-Leary, Klaus-Dieter. *Englisch für technische Berufe* . Stuttgart: Klett, 2004. Print.

Puderbach, Ulrike, and Michael Giesa. *Technical English - Mechanical Engineering* . Haan-Gruiten: Verl. Europa-Lehrmittel Nourney, Vollmer, 2012. Print.

Rovelli, Carlo. *Seven Brief Lessons on Physics.* London: Penguin, 2014. Print.

Smith, Roger H. C. *English for Electrical Engineering.* Reading: Garnet, 2014. Print.

Swan, Michael. *Practical English Usage.* 4th edition. Oxford: OUP, 2016. Print.

Tegmark, Max. *Life 3.0: Being Human in the Age of Artificial Intelligence.* London: Penguin, 2017. Print.

The Science Book: Big Ideas Simply Explained. London: DK, 2014. Print.

Schäfer, Wolfgang Dr. et al. *Electricity Milestones: Englisch für Electroberufe.* Stuttgart: Ernst Klett Verlag, 2013. Print.

Vince, Michael. *Advanced Language Practice.* London: Macmillan, 2009. Print.

Wagner, Georg, and Maureen Lloyd. Zörner. *Technical Grammar and Vocabulary: A Practice Book for Foreign Students* . Berlin: Cornelsen, 1998. Print.

Williams, Erica J. *Presentations in English.* Oxford: Macmillan Education, 2008. Print.

Winfield, Alan. *Robotics: A Very Short Introduction.* Oxford: OUP, 2012. Print.

EM-24 Automotive Bus Systems

Module code	EM-24
Module coordination	Prof. Dr. Andreas Grzemba
Course number and name	EM 6102 Automotive Bus Systems
Lecturer	Prof. Dr. Andreas Grzemba
Semester	6
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5/ 210
Language of Instruction	German

Module Objective

Primary learning objective: Students should be able to apply data networks in vehicles to technical tasks in their studies and profession.
For this purpose, students acquire the following professional skills: Knowledge of the basics of digital communication systems; automotive Ethernet systems; CAN bus systems; subordinate bus systems.

The acquisition of methodological, personal and social competences is defined by the future lecturer.

Applicability in this and other Programs

In this degree programme EM-32, EM-7105
In other degree programmes:
Electrical Engineering and Information Technology (Bachelor): ET-31

Entrance Requirements

Formal: none
in terms of content: EM-04, EM-09, EM-15

Learning Content

1 Basics of digital data communication
    1.1 ISO/OSI model
    1.2 Access method
    1.3 Error protection
2 Automotive network architectures
    2.1 Architectures with central gateway
    2.2 Switched Ethernet architectures
3 CAN bus
    3.1 Data link layer
    3.2 Physical layer
4 Automotive Ethernet physical layer Higher protocol layer in automotive Ethernet systems
    4.1 SOME/IP
    4.2 IP/UDP/TCP/DHCP
5 AVB/TSN
    5.1 Standards
    5.2 Time synchronisation protocols (IEEE1588)
    5.3 Real-time categories in Ethernet
    5.4 Shaper
6 Subordinate bus systems
    6.1 LIN
    6.2 PSI-5
    6.3 SENT

Teaching Methods

Seminar-based lessons and laboratory exercises with the corresponding bus systems.

Recommended Literature

W. Zimmermann / R. Schmidgall: Bussysteme in der Fahrzeugtechnik, 3rd edition. Vieweg 2008.

W. Lawrenz / Nils Obermöller: CAN: Controller Area Network: Grundlagen, Design, Anwendungen, Testtechnik. VDE-Verlag.

K. Matheus / T. Königseder: Automotive Ethernet. Cambridge University Press

AVB/TSN IEEE802.3 Standard-Familie

EM-25 Subject-specific Electives

Module code	EM-25
Module coordination	Prof. Dr. Nikolaus Müller
Course number and name	EM 6103 Subject-specific Elective 1 EM 7101 Subject-specific Elective 2
Semester	6, 7
Duration of the module	2 semester
Module frequency	annually
Course type	compulsory course
Level	Undergraduate
Semester periods per week (SWS)	8
ECTS	10
Workload	Time of attendance: 120 hours self-study: 180 hours Total: 300 hours
Weighting of the grade	10 / 210
Language of Instruction	German

Module Objective

The learning outcomes for this module can be found in the course description provided in the module handbook for the degree programme in question to which the course pertains.

Applicability in this and other Programs

Applicability of this module can be found in the course description provided in the module handbook for the degree programme in question to which the course pertains.

Entrance Requirements

The requirements for taking this module can be found in the course description provided in the module handbook for the degree programme in question to which the course pertains.

Learning Content

Selection of modules at Deggendorf Institute of Technology for the subject-specific compulsory elective modules FWP 1 and FWP 2:

Teaching Methods

Seminar-based lessons, exercises, seminars, internship

Recommended Literature

A list of recommended literature for this module can be found in the course description provided in the module handbook for the degree programme in question to which the course pertains.

EM-26 Compulsory Elective Subject of a General Academic Nature (AWP)

Module code	EM-26
Module coordination	Tanja Mertadana
Course number and name	EM 2106 General Elective 1 EM 7102 General Elective 2
Lecturer	Dozierende für AWP und Sprachen
Semester	2, 7
Duration of the module	2 semester
Module frequency	annually
Course type	compulsory elective course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	4
Workload	Time of attendance: 60 hours self-study: 60 hours Total: 120 hours
Type of Examination	See examination schedule AWP and languages
Weighting of the grade	4 / 210
Language of Instruction	German

Module Objective

- in a foreign language (language proficiency)
- in the didactic-pedagogical area (methodological expertise)
- in the socio-scientific area (social skills)
- in the psychological-sociological field (social skills)
- in the technical and scientific field (professional skills)
- in the philosophical-social-ethical area (personal skills)
- in the area of business administration

Students can choose their own courses from the elective courses offered and thus deepen knowledge of the fields they have an inclination for.

Applicability in this and other Programs

The applicability of the module In other degree programmes is guaranteed.

Entrance Requirements

For advanced language courses, students must have the required language proficiency (e.g. through successful completion of a lower level).

General elective (AWP) subjects may not have any content-related overlaps with the student's own course.

Learning Content

Specific contents can be found in the corresponding course description on the homepage of the Language a.
https://www.th-deg.de/language-and-electives-centre#languages

Teaching Methods

Teaching and learning methods can be found in the corresponding course description on the homepage of the Language and Electives Centre:
https://www.th-deg.de/language-and-electives-centre#languages

Remarks

Remarks

Course-specific details can be found in the corresponding course description on the homepage of the Language and Electives Centre:
https://www.th-deg.de/language-and-electives-centre#languages

Recommended Literature

A list of the reading recommendations can be found in the corresponding course description on the homepage of the Language and Electives Centre:
https://www.th-deg.de/language-and-electives-centre#languages

EM-27 Key Competencies

Module code	EM-27
Module coordination	Prof. Dr. Markus Straßberger
Course number and name	EM 7103 Business Administration EM 7104 Scientific Work Practice EM 7105 Sustainable Mobility
Lecturers	Prof. Dr. Thomas Geiß Prof. Dr. Markus Straßberger
Semester	7
Duration of the module	1 semester
Module frequency	annually
Course type	compulsory elective course, required course
Level	Undergraduate
Semester periods per week (SWS)	6
ECTS	9
Workload	Time of attendance: 90 hours self-study: 180 hours Total: 270 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	6 / 210
Language of Instruction	German

Module Objective

Primary objective

Students recognise business topics in the professional field and apply them to their profession. They are familiar with the basic theories and knowledge of business management for their own profession.

After completing the module, students will have achieved the following learning objectives:

Recognising the importance of business management mentality and action of company employees. Students can assess fundamental business management issues in a company.

Professional skills:

1. Students know the structure of the balance sheet and profit and loss account. They can distinguish between P&L figures (turnover, costs) and liquidity figures (cash, investment).
2. They can assign accounts to P&L and balance sheet and know what charts of accounts are.
3. They know how to open a balance sheet. They can also make simple entries and close the P&L and balance sheet.
4. Building on the basics of accounting, they can analyse company balance sheets and identify the most important key figures.
5. They know formulas for calculating interest, present value, future value, recovery factor and recuperation factor.
6. They can apply their knowledge for evaluating investments and calculating simple loans.
7. They can assess the effect of investment and financing measures on the balance sheet and P&L.

Methodological skills

Students

1. deal with academic texts on the respective topic
2. carry out group and individual work with the aim of a short presentation in the plenary

Personal skills:

Students

1. reflect on their own entrepreneurial perspective in the context of ?company performance and company value?
2. are made aware of the importance and meaning of ?business administration? in their future field of activity

Social skills

Students

1. develop critical faculties and the ability to discuss and work in a team
2. are able to bring their strengths into the development process
3. are creative and self-confident

Applicability in this and other Programs

In this degree programme

In other degree programmes:

Entrance Requirements

Formal:
in terms of content:

Learning Content

Subject matter of business administration
Ways to classify companies and determine their size
Basics of investment theory
Overview of the basics of company accounting
Criteria for selecting a business location
Criteria for selecting the legal form of a company
Types of organisational structures of a company
Selected aspects of strategic planning
Functional areas in a company and their essential decisions

1 Accounting

- 1.1 Balance sheet and P&L
- 1.2 Accounts and charts of accounts
- 1.3 Accounts
- 1.4 Opening and closing of accounts
- 1.5 Entries
- 1.6 Special business transactions

2 Financial mathematical basics

- 2.1 Interest calculations
- 2.2 Annuity computation

3 Investment

- 3.1 Static investment models
- 3.2 Dynamic investment models

4 Financing

- 4.1 Debt financing
- 4.2 Equity financing

5 Summary

Teaching Methods

Lecture with exercises, seminar, writing workshop, discussions, smaller case studies

Remarks

Remarks

Self-study with materials on iLearn

Submission of exercises

Recommended Literature

G. Wöhe: Einführung in die Allgemeine Betriebswirtschaftslehre, 25th edition. Vahlen Verlag, München 2013.

P. Mertens / F. Bodendorf: Programmierte Einführung in die Betriebswirtschaftslehre. Gabler Verlag, Wiesbaden 2001.

J. Drukarczyk / S. Lobe: Finanzierung, 11th edition. Stuttgart 2014.

L. Perridon / M. Steiner / A. Rathgeber: Finanzwirtschaft der Unternehmung, 16th edition. München 2012.

G. Wöhe / J. Bilstein / D. Ernst / J. Hächer: Grundzüge der Unternehmensfinanzierung, 10th edition. München 2009.

EM 7103 Business Administration

Learning Content

Type of Examination

written ex. 90 min.

EM 7104 Scientific Work Practice

Learning Content

Type of Examination

written student research project, oral examination, written examination

EM 7105 Sustainable Mobility

Learning Content

Type of Examination

written student research project, oral examination, written examination

EM-28 Bachelor Thesis

Module code	EM-28
Module coordination	Prof. Dr. Franz Daiminger
Course number and name	EM 7106 Bachelor Thesis EM 7107 Seminar
Lecturer	Prof. Dr. Günther Benstetter
Semester	7
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	undergraduate
Semester periods per week (SWS)	2
ECTS	14
Workload	Time of attendance: 30 hours self-study: 390 hours Total: 420 hours
Type of Examination	bachelor thesis
Weighting of the grade	14 / 210
Language of Instruction	German

Module Objective

Students are able to apply the knowledge and skills acquired during studies methodically and in context in a project from the field of electrical engineering and information technology. They are expected to independently structure a problem, systematically process it using scientific methods and, finally, document it transparently within a given period of time.
In the concluding presentation, the project and work results must be presented in a way that is appropriate for the target group.

Applicability in this and other Programs

In this degree programme: none
In other degree programmes: none

Entrance Requirements

Formal: at least 160 ECTS
in terms of content:

Learning Content

Individual topics

Teaching Methods

Guidance on independent work according to academic methods

Remarks

Applicability in this degree programme
EM-28 Bachelor's module
Remarks
The results of the bachelor?s thesis are to be presented as a lecture.

EM-29 Power Electronics 2

Module code	EM-29
Module coordination	Prof. Dr. Otto Kreutzer
	Elektomobilität (EM)
Course number and name	EM 6104 Power Electronics 2
Lecturer	Prof. Dr. Otto Kreutzer
Semester	6
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

The course builds on the knowledge of Power Electronics 1 and specifically deals with power electronic components in electromobility.
It deals with the individual components of electric vehicles and examines special optimisation for efficiency and construction volume, which is immanent to resource-saving usage.

Students will achieve the following learning objectives:
Professional skills

Students learn the special requirements of the automotive industry, and the design and optimisation goals of power electronic components in electric vehicles.
The basic circuits from Power Electronics 1 are extended to include the special topologies and application fields of electromobility. This should enable students to develop power electronics for electric vehicles independently.

Methodological skills

The application of fundamental knowledge to specific problems is practised by transferring the basic topologies of power electronics to the special applications of electromobility. This enables students to develop power electronic components in other industrial sectors as well and to optimise them for the respective application.

Personal skills

Personal skills primarily lie in practical intelligence, i.e., transferring the basic theoretical knowledge of mathematics and power electronics to specific hardware and practical set-ups.

Applicability in this and other Programs

In this degree programme: none

In other degree programmes: none

Entrance Requirements

Formal: 80 ECTS

in terms of content: EM-19

Learning Content

1 Supplementary components of power electronics
   - 1.1 Driver circuits
   - 1.2 Current and voltage measurement
   - 1.3 Control and regulation of power electronics
   - 1.4 Circuit feedback of power electronics

2 Optimisation potentials in electromobility
   - 2.1 Loss calculations of components
   - 2.2 Maximising efficiency
   - 2.3 Reduction of construction volume

3 Power electronic components of electric vehicles
   - 3.1 Battery chargers
   - 3.2 On-board converter
   - 3.3 Driver inverter
   - 3.4 Traction converter

3.5 Fuel cell converter
3.6 Special requirements for motor vehicles
3.7 Special requirements for hybrid vehicles

Teaching Methods

Lecture as seminar-based lessons

Recommended Literature

J. Müller / E. Schmidt / W. Steber: Elektromobilität: Hochvolt- und 48-Volt-Systeme, 1. Auflage. Vogel Business Media Verlag, Würzburg 2017.

U. Schlienz: Schaltnetzteile und ihre Peripherie: Dimensionierung, Einsatz, EMV.

M. Albach: Induktivitäten in der Leistungselektronik: Spulen, Trafos und ihre parasitären Eigenschaften, 1. Auflage. Springer/Vieweg Verlag, Wiesbaden 2017.

EM-30 Technology of Batteries

Module code	EM-30
Module coordination	Prof. Dr. Michael Sternad
	Elektomobilität (EM)
Course number and name	EM 6105 Technology of Batteries
Lecturer	Prof. Dr. Michael Sternad
Semester	6
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

Module objectives

Students internalise the properties and applications of important versions of electrochemical energy storage systems, as well as their structure, function and typical area of application.

Students will achieve the following learning objectives:
Professional skills

Knowledge of the structure, function and typical fields of application of primary and secondary electrochemical energy storage systems. Students are able to assign these energy storage systems to groups such as rechargeable and non-rechargeable systems based on their structure and are able to apply their knowledge in simple example exercises.

Methodological skills

Students know important parameters for energy storage (e.g. voltage, capacity, gavimetric and volumetric energy density) and can research these for unknown systems. Ultimately, students will have empirically internalised the most common parameters for both aqueous and non-aqueous systems and will be able to apply them without research.

Personal skills

Students recognise their current abilities and deficits, accept their deficits and work on perfecting these deficits. Students experience recognition, e.g. through positive feedback or by solving difficult tasks. The recognition they experience motivates them to continue and intensify their work on personal deficits.

Applicability in this and other Programs

In this degree programme: none

In other degree programmes: none

Entrance Requirements

Formal: 80 ECTS

in terms of content:

Learning Content

1. History, basics and definitions

2. Primary cells

- 2.1. Alkaline manganese batteries
- 2.2. Zinc air batteries
- 2.3. Lithium manganese dioxide batteries
- 2.4. Lithium carbon monochloride batteries
- 2.5. Lithium-iron sulphide batteries
- 2.6. Lithium thionyl chloride batteries
- 2.7. Lithium iodine batteries

3. Secondary cells

- 3.1. Lead acid batteries
- 3.2. Nickel metal hydride batteries
- 3.3. Lithium-ion batteries

4. Super capacitors

Teaching Methods

Seminar-based lesson

Recommended Literature

Reddy, T. B.; Linden, D., Linden's Handbook of Batteries, 4th ed. Reddy. 2011.
Daniel, C.; Besenhard, J. O., Handbook of Battery Materials. 2nd ed.; 2011.
Hamann, C. H.; Vielstich, W., Elektrochemie. John Wiley & Sons Australia, Limited: 2005.

EM-31 Charging Units and Hydrogen Technology

Module code	EM-31
Module coordination	Prof. Dr. Frank Denk
	Elektomobilität (EM)
Course number and name	EM 6106 Charging Units and Hydrogen Technology
Lecturer	Prof. Dr. Frank Denk
Semester	6
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

The worldwide political and technological topic of electromobility continues to be accelerated by the parallel digitisation and the expansion of regenerative sources As a result, there is now a need for centralised and decentralised charging infrastructure planning and its expansion in both national and international sectors. This is accompanied by the need for standardisation of the charging structure systems. This lecture forms, among other things, the foundation for this system design and its planning.

The current energy situation appears in a new frame, such as decarbonisation and hydrogen economy. In the context of the focus on necessary alternative drives and consequently the turning away from the pure use of fossil fuels with simultaneously growing global mobility of people, new concepts, such as the fuel cell vehicle, are emerging.

Professional skills

- Historical review and subsequent explanation of the state of the art of charging systems.
- The technologically different solutions such as DC, AC, conductive and inductive are analysed on the infrastructure side and structured with regard to their requirements.
- Alternative charging options such as capacitive charging offer further possibilities that are technically questioned in terms of their feasibility.
- Regenerative connection possibilities of the technical solutions are presented and analysed.
- The national and international norms and standards of electrical charging form a mesh of the most diverse requirements to be considered.
- This provides an outlook on the topic of requirement engineering.
- Understanding of the technical development of motor vehicles with electric motors and their connection with the different emission regulations worldwide, explaining the benefits and use of alternative drive systems.
- In-depth understanding of the structure of current fuel cell technologies.
- Application of the mobile fuel cell solution in the electric vehicle.
- Understanding of powertrain management

Methodological skills

- It is demonstrated that requirements/demands on the charging system methodically lead to solutions in the domains of hardware, software and mechanics.
- Based on this, different development methods are worked on in a fictitious project.
- In a cross-domain approach, the next step is to consider the economic efficiency of the system in the context of different regions.
- The methodologies of the system solutions are systematically studied through requirement engineering by forming sub-solutions in the technology areas of hardware/electronics, software and mechanics.
- As a result, the different variation possibilities of system solutions become visible to the participants.
- Within the framework of the background of series solution realisations, necessary economic efficiency considerations are realised.

Personal skills:

- The thematic discussion of the planning and development of charging systems leads technically and economically to project management which,

through the methodology, leads to a fundamental understanding of the necessity of a project team.
- This demonstrates the perception of a personnel project structure and the identification of the individual project staff.
- Participants recognise through this methodology the necessity of a project team with different role assignments in order to jointly develop a series solution.
- Individuals are enabled to perceive their own ?correct? role assignment as a project team member.

Social skills

- Technical problems and their solution through ?team building? are presented.
- Identification with the project team and their benefits for the project are promoted.

Applicability in this and other Programs

Applicability in this degree programme:
There is no dependence on the technological aspect and the topics of national and international standardisation.

Applicability in other degree programmes:
Since this module represents a key technological requirement for electromobility, it can be used for all degree programmes that deal with energy transfer, energy storage and system solutions for electric and hybrid vehicles. In addition, this module can be used for an extended representation in terms of electromobility infrastructure and hydrogen systems.

Entrance Requirements

Formal: 80 ECTS

in terms of content:

Learning Content

Charging systems

- Basics of requirement engineering
- Relationship between requirements and solutions
- Electrical basics AC, DC, 1-phase, 3-phase and their power classes
- Basic charging concepts conductive and inductive
- Alternative charging concepts
- Renewable energy and its integration possibilities

- National and international norms and standard
- Basics of project management
- Solutions at local regional level
- Site selection
- Fare concepts
- Project planning

Hydrogen technology

- Technological developments of fuel cell vehicles.
- Basics of hydrolysis.
- Current electrochemical hydrolysis systems.
- The chemistry of cold combustion of hydrogen.
- The current fuel cell systems.
- The PEFC as a reversible system in electric vehicles.
- Possibilities and limits of use in motor vehicles.
- Technical implementation for use in motor vehicles.

Teaching Methods

Seminar-based lesson

Recommended Literature

T. Gehrlein: Ladesäulen-Infrastruktur, 2. Überarbeitete Ausgabe. Praxishandbuch, 2018.
A. Karle: Elektromobilität ? Grundlagen und Praxis, 3. Akt. Auflage. Hanser Verlag, 2018.
J.Töpler / J. Lehmann: Wasserstoff und Brennstoffzelle, 2. Auflage. Springer Verlag, 2017.
P. Hofmann: Hybridfahrzeuge, 2. Auflage. Springer Verlag, 2014.

EM-32 Model-based Control Design and Testing

Module code	EM-32
Module coordination	Prof. Dr. László Juhász
	Autonomes Fahren / mobile Robotik (FR)
Course number and name	EM 6107 Modelbased Control Unit Design and Protection
Lecturer	Prof. Dr. László Juhász
Semester	6
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5/210
Language of Instruction	German

Module Objective

The course covers model-based controller design and validation according to the V-cycle, as well as parameter identification of technical systems. Students learn to independently analyse, synthesis and testing control loops using model-based methods.

Students will achieve the following learning objectives:
Professional skills

Students know the basic methods for the parameter identification of technical and mechatronic systems and have applied these in practical exercises. They know how to create parametric models of technical systems and verify them experimentally.

Students know the individual elements of model-based function design and protection according to the V-cycle and can understand the special features and commonalities of individual elements of the V-cycle. Furthermore, they can validate the designed controllers in a model-based manner using offline and real-time simulations according to the specifications of the V-cycle and thus detect design errors at an early stage.

Students learn about software tool chains from MathWorks and dSPACE and then apply them independently to tasks in the field of model-based controller design and validation.

Methodological skills

Students are familiar with the most important methods and tools of model-based digital simulation and use them appropriately. In particular, they can correctly derive and evaluate the stability conditions of digital simulation methods for continuous and discrete systems. They know the guidelines for a good foundation for functions that are realised on a model-basis ? related to their subsequent application in RCP, HIL and production code generation ? and can apply these guidelines independently. Students elucidate and consolidate the mentioned approaches through modelling, simulation and control of an exemplary application.

Students understand what real-time requirements mean and are familiar with their impact on the function design using rapid control prototyping. They are familiar with both the hardware and software requirements and application possibilities of RCP and use them successfully. They can also successfully perform and validate function development using rapid control prototyping for CPU-based systems. They pay special attention to the problems of tasking, I/O configuration and real-time conditions.

Students are aware of the challenges of production code generation and independently apply optimisation methods and number representation in the digital computer to achieve a positive impact on computing time and memory usage. They can independently convert a general simulation model into a model suitable for production code generation and successfully carry out the steps necessary for this (scaling, optimisation). They are familiar with the validation and analysis of the generated production code using code coverage, MIL, SIL and PIL simulation, as well as with the integration of the overall control unit code.

Students know the reasons for HIL simulation and the techniques used in such a simulation. They are well-versed in the creation and operation of an HIL application and know the synergies between rapid control prototyping and HIL. They also successfully apply test automation and virtualisation methods.

Students acquire knowledge of parameter identification methods in both the time and frequency domains and subsequently apply these to practical problems.

Personal skills

Students are aware of their responsibility as development engineers for model-based controller design and validation. They can justify work steps and results argumentatively and evaluate them critically. They can work together in teams and give each other feedback.

Applicability in this and other Programs

In this degree programme: none

In other degree programmes: none

Entrance Requirements

Formally: 80 ECTS

Contently: EM-03, EM-04, EM-07, EM-09, EM-12, EM-18, EM-19, EM-20

Learning Content

1 Introduction to model-based controller design and validation
    1.1 Comparison of traditional and model-based methods
    1.2 The V-model
2 Elements of the V-model
    2.1 Offline simulation
    2.2 Rapid control prototyping
    2.3 Production code generation
    2.4 Hardware-in-the-loop simulation
    2.5 Measuring and calibrating
3 Parameter identification
    3.1 Overview and classification of parameter identification methods
    3.2 Parameter identification in the time domain
    3.3 Parameter identification in the frequency domain
4 Sample projects

Teaching Methods

Lecture, practical computer work, practical exercises with real-time systems, individual and group work

Recommended Literature

D. Abel / A. Bollig: Rapid Control Prototyping -Methoden und Anwendungen, Springer Verlag, Berlin 2006.

J. Schäuffele / T. Zurawka: Automotive Software Engineering, 6. Auflage, Springer Vieweg, Wiesbaden 2016.

H. Winner / S. Hakuli / F. Lotz / C. Singer: Handbuch Fahrerassistenzsysteme, 3. Auflage, Springer Vieweg, Wiesbaden 2015.

Isermann R.: Grundlegende Methoden (Identifikation dynamischer Systeme, Bd.1), Springer-Verlag, 1992

EM-33 Autonomous Driving

Module code	EM-33
Module coordination	Prof. Dr. Nikolaus Müller
	Autonomes Fahren / mobile Robotik (FR)
Course number and name	EM 6108
Lecturers	Prof. Dr. Nikolaus Müller Prof. Dr. Markus Straßberger
Semester	6
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 / 210
Language of Instruction	German

Module Objective

The primary objective is to learn the model and data-based methods that enable automated driving.

After completing the module, students will have achieved the following learning objectives:

Professional skills:

- They know the description of vehicle and driving dynamics.
- They know the models of longitudinal and lateral movement of vehicles as well as suitable roadway models.

- They simulate movement models using suitable computer-based tools.
- They plan suitable trajectories.
- They know algorithms for model-based image sequence processing in real time.
- They know the basics of machine learning.
- They apply suitable techniques to solve a task.

Methodological skills:

Students work on tasks from this field using suitable tools, e.g. Python or Matlab

Social skills:

In the simulation of a race, teams compete against each other in fair competition.

Applicability in this and other Programs

none

Entrance Requirements

Formal: 80 ECTS

in terms of content: Basic modules EM-01 to EM-16

Learning Content

1 Overview
2 Dynamic modeling of driving
    2.1 Vehicular model
    2.2 Model of the road
    2.3 Movement model of other traffic participants
3 Recursive estimation procedures
    3.1 Kalman filter
    3.2 The 4D approach
4 Machine learning
    4.1 Approaches
    4.2 Outlook

Teaching Methods

Seminaristic lessons and exercises

Recommended Literature

M. Ersoy / S. Gies: Fahrwerkhandbuch, Springer, 2017.

E.D. Dickmanns: Dynamic Vision for Perception and Control of Motion, Springer, 2007.

M. Maurer et. al (Hrsg.): Autonomes Fahren, Springer, 2015.

M. Maurer (Hrsg.): Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte, Springer, 2015.

T. Bertram (Hrsg.): Automatisiertes Fahren, Springer, 2020.

V. Johanning: Car IT kompakt. Das Auto der Zukunft: Vernetzt und autonom fahren. Springer, 2015.

EM-34 Mobile Robotics

Module code	EM-34
Module coordination	Prof. Dr. Nikolaus Müller
	Autonomes Fahren / mobile Robotik (FR)
Course number and name	EM 6109 Mobile Robotics
Lecturer	Prof. Dr. Nikolaus Müller
Semester	6
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	Undergraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5/210
Language of Instruction	German

Module Objective

The aim is to learn the essential design methods for controlling mobile robots.
After completing the module, students will have achieved the following learning objectives:

Professional skills:

1. They know how different path planning algorithms work
2. They can calculate suitable trajectories
3. They know methods that can be used to estimate the space requirements of tugger trains
4. You know relevant standards for the design of safe mobile robots

5. They assess the requirement level for safety engineering

Methodological skills:

They can research in standardisation and literature databases

Social skills:

They form a team to solve a given task

Applicability in this and other Programs

In this degree programme: none

In other degree programmes: none

Entrance Requirements

Formal: 80 ECTS

Content related: EM-01, EM-02, EM-04, EM-05, EM-06, EM-09, EM-12, EM-13, EM-14, EM-15, EM-17, EM-18

Learning Content

1 Introduction to mobile robots
   - 1.1 Sensor technology
   - 1.2 Actuator engineering
   - 1.3 Control structure
2 Path planning
   - 2.1 Path planning with topographic maps
   - 2.2 Path planning in open spaces
3 Trajectory planning
   - 3.1 Point-to-point connections
   - 3.2 Curves with intermediate points
4 Vehicle paths
   - 4.1 Determination of space requirement
5 Introduction to safety engineering
   - 5.1 Safety regulations
   - 5.2 Calculation of safety levels

Teaching Methods

Seminar-based teaching, project work, internship

Recommended Literature

M. Haun: Handbuch Robotik: Programmieren und Einsatz intelligenter Roboter. Springer/ Vieweg 2013.

U. Nehmzow: Mobile Robotik: eine praktische Einführung. Springer 2002.

T. Bräunl: Embedded Robotics: Mobile robot design and applications with embedded systems. Springer 2008.

J.J. Craig: Introduction to Robotics, 3rd edition. Pearson Education 2014.

Telemecanique - Handbuch für Sicherheitsanwendungen. ZXHBSI01, 2003.