# Module Handbook

## Heidelberg University
## Medical Faculty Mannheim

## Master of Science “Biomedical Engineering”

**corresponding to examination regulations of October 1, 2024**

Standard period of study: 4 semesters full time (part-time option available)

ECTS credits: 120

Intake: winter term only (course starts from September 1)

Type of study: consecutive; research oriented

Established: winter term 2010/2011

Areas of study:

- Radiotherapy
- Imaging Physics in Medicine
- Computational Medical Physics
- Robotics and Automation in Medicine

Location: Heidelberg University campuses in Mannheim (mainly) and Heidelberg

Language of instruction: English

Target group:

> graduates with a degree in Physics or in a degree programme with essentially the same content, in particular Medical Technology, Computer Science (with a physics component), Biomedical Engineering, or Engineering

Latest revision: January 29, 2025

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# 1. Qualification objectives, profile and particularities of the degree programme

## 1.1 Preamble – Qualification objectives of Heidelberg University

In accordance with its mission statement and constitution, Heidelberg University's degree courses have subject-related, transdisciplinary and occupational objectives. They aim to provide a comprehensive academic education equipping graduates for the world of work.

The main points of the competence profile are the following:

- developing subject-related skills with a pronounced research orientation
- developing the ability to engage in transdisciplinary dialogue
- developing practice-related problem-solving skills
- developing personal and social skills
- promoting the willingness to assume social responsibility on the basis of the skills acquired

## 1.2 Profile of the degree programme

The Biomedical Engineering degree programme is a consecutive, research oriented and interdisciplinary degree programme that teaches a broad range of specialist knowledge and methods from physics, engineering, computer/ data science and mathematics. The aim of the degree programme is to enable its graduates to further develop technical methods and devices and to answer health science related questions that lead to the advancement of biomedical diagnostics and therapeutics. The programme is open to graduates with a degree in Physics or in a degree programme with essentially the same content, in particular Medical Technology, Computer Science (with a physics component), Biomedical Engineering, or Engineering. The contents of the programme are strongly orientated towards computer/ data science. This takes account of the growing need for IT expertise in this field, coupled with specialist knowledge of biomedical devices, their handling and further development. Graduates of this programme are well prepared for careers especially in, but not restricted to, the health-care/ life-science and technology sector such as the medical technology industry, academia and research organisations, hospitals and others.

### 1.2.1 Special features and characteristics

Courses take place in an outstanding environment, i.e. mainly inside the University Hospital Mannheim (UMM) with access to latest medical devices for diagnostics and therapeutics such as cutting-edge magnetic resonance imaging and radiotherapy systems. The Mannheim Institute for Intelligent Systems in Medicine, which provides the majority of the lecturers on the degree programme and where student research projects can be carried out, is also located on site.

The degree programme is internationally oriented with English as language of instruction and examination and with its lecturers nationally and internationally connected to leading institutions in research and education, such as Harvard University in the USA and Shanghai Jiao Tong University in China.

The Mannheim Medical Technology Cluster, established by the city of Mannheim as part of the 2011 Economic and Structural Development Plan, offers many opportunities for student research projects and graduate careers. The cluster comprises over 200 companies ranging from micro enterprises to global corporations and from start-ups to companies dating back over 100 years, plus clinics and research facilities. This creates a vibrant transfer and innovation ecosystem for medical technology in Mannheim and the region as a whole.

In addition, students have the opportunity to carry out research projects and pursue careers with regional partners inside the Health + Life Science Alliance Heidelberg Mannheim, the hub of medicine and life sciences in Germany, such as the Central Institute of Mental Health (ZI), the German Cancer Research Center (DKFZ), the European Molecular Biology Laboratory (EMBL), the University Hospital Heidelberg (UKHD), and the Max Planck Institute for Medical Research (MPIMR).

### 1.2.2 Course contents and specializations

The course provides theoretical background and practical elements where the knowledge can be applied using modern clinical equipment. All students get a broad basic education in biology, medicine, radiotherapy, imaging physics, image analysis, mathematical foundations, and mechatronics. In addition, they have to select at least two out of the following four specializations available in the programme.

- **Advanced Radiotherapy**

  This specialization focusses on advanced techniques related to radiation therapy treatment planning and treatment methods of cancer in radiation therapy (such as adaptive radiotherapy, brachytherapy or intra-operative radiotherapy), on radiation therapy equipment in detail (such as medical linear accelerators, intra-operative radiotherapy systems) and on giving insights into the clinical workflow.

- **Advanced Imaging Physics in Medicine**

  The courses in this specialization focus on advanced techniques related to the generation, reconstruction and processing of morphological and functional image data with medical modalities (such as computed tomography, magnetic resonance imaging, positron emission tomography), which can be used for diagnosis, treatment planning and monitoring.

- **Advanced Computational Medical Physics**

  In this specialization, courses focus on advanced computational methods from the fields of mathematics, computer science and physics with application to biomedical sciences (such as inverse problems for image reconstruction, restoration, analysis, simulation, modelling).

- **Advanced Robotics and Automation in Medicine**

  The courses in this specialization focus on advanced engineering techniques related to robotics and automation that can be used to control instrumentation for diagnosis and treatment (such as robotics for interventional therapy and surgery).

## 1.3 Subject-specific qualification objectives of the degree programme

Graduates of the Master's degree programme in Biomedical Engineering are able to:

- describe and explain basic terms and principles in biology, anatomy and physiology
- explain and apply basic mathematics and programming used in medical technology and medical physics
- explain, apply, analyse and evaluate radiotherapy techniques, imaging systems, methods in computational physics, or robotics and automation systems
- analyse, discuss and assess recent technological developments and advances in the field

They have acquired the ability to:

- independently tackle technical issues and current challenges and to find solutions or establish new areas of research in their field of specialization
- transfer and apply their thorough knowledge to daily practice, independently of the specialization
- present and defend their research orally using a variety of different media
- independently formulate research projects in medical technology and medical physics, including the identification of a research question, the development of a methodology for its solution, and the analysis of the impact of results on practice
- work autonomously and/or carry out independent research in medical technology and medical physics in a laboratory or clinical setting, and to participate actively in laboratory routines such as journal clubs, progress reports and academic discussions, as required, for example, for a subsequent doctoral degree programme

## 1.4 Generic qualification objectives of the degree programme

Graduates of the Master's degree programme in Biomedical Engineering are able to:

- independently identify, select and acquire knowledge and apply this knowledge in practical situations
- identify, examine and critically analyse information from different sources in order to develop innovative and creative solutions to research problems or own areas of research
- apply scientific working methods
- plan and manage projects, including appropriate timing and keeping of deadlines
- present and discuss data in scientific meetings
- provide, accept and consider constructive criticism

- work as part of a team and/or constitute, lead and motivate expert teams
- critically assess and evaluate biomedical engineering science
- talk and write in specialized scientific English language in international, multi-cultural and multi-disciplinary environments
- advance the health-related socio-economic state of their academic and non-academic environment and thus take responsibility for their fellow human beings and society

### 1.5 Career opportunities

Graduates of this programme are well prepared for careers especially in, but not restricted to, the health-care/ life-science and technology sector such as the medical technology industry, academia and research organisations, hospitals and others.

- medical technology industry: e.g. manufacturers of biomedical instrumentation and devices, health-care-oriented software companies, pharmaceutical companies, consulting companies

- academia and research organisation: e.g. doctoral degree programmes in related disciplines such as human sciences, engineering sciences, medical physics

- hospitals: e.g. further certification as a state radiation-protection commissioner (depending on the respective country; in Germany, for example, the status of a certified medical physics expert can be attained after extra qualification)

- others: e.g. patent offices

## 1.6 Particularities of the degree programme

### 1.6.1 Reason for cumulative examinations

- The reason for the requirement of two examination components in one module is due to the fact that courses from different specialist disciplines are to be chosen and that the competencies to be acquired vary considerably and cannot be properly tested in one examination.
- There are different examination formats intended in some modules (e.g. examination and written assignment) in order to check different skills. Furthermore, the curriculum offers a lot of choice with respect to the selection of seminar topics so that the acquired competencies can be assessed through several examinations - even if they have the same format, e.g. two written assignments on different topics.

### 1.6.2 Reason for modules with fewer than 5 credits

The modules in the area of interdisciplinary competencies are self-contained study units with fewer than five credits that cannot be combined appropriately with other modules.

### 1.6.3 Teaching, learning and assessment forms

The predominantly used teaching, learning and assessment forms are given in the following table.

| **Teaching Form** | **Learning Form** | **Assessment Form** (The concrete form of assessment will be announced during the first session of the semester.) |
|---|---|---|
| Lecture | The lecturer presents the course content using appropriate media. Students can interact and ask questions. Students prepare and follow up by self-study. | written or oral exam |
| Tutorial | Students process exercise sheets independently and prepare by self-study. The tutor or a student explains exercises or smaller parts of the syllabus. Students can interact, ask questions, and discuss with other students and/or the tutor to understand the exercises and the syllabus. | exercise sheets, and if required by tutor: presentation |
| Seminar | Students work independently on a scientific topic and prepare a presentation. The students give the presentation to other students, answer their questions and discuss the presentation under the guidance of the lecturer. | presentation, and if required by lecturer: written report |
| Practical | Laboratory and/or programming work on the basis of a task, independent laboratory execution and/or programming, evaluation and writing of a report. | written report, and if required by lecturer: presentation |

## 2. Model course of studies

| Module | | | | Recommended Semester | | | |
|---|---|---|---|---|---|---|---|
| **No.** | **Module Title** | **Module Type*** | **ECTS credits** | **1** | **2** | **3** | **4** |
| | **Mandatory Modules - during the course of study** | | **50** | | | | |
| 1. | *Basic Radiotherapy* | *M* | *5* | *X* | | | |
| 2. | *Basic Imaging Physics in Medicine* | *M* | *5* | *X* | | | |
| 3. | *Mathematical Foundations of Medical Technology and Medical Physics* | *M* | *5* | *X* | | | |
| 4. | *Basic Biology in Medicine and Radiobiology* | *M* | *5* | *X* | | | |
| 5. | *Basic Medical Science* | *M* | *5* | *X* | | | |
| 6. | *Basic Mechatronics in Medicine* | *M* | *5* | | *X* | | |
| 7. | *Medical Image Analysis* | *M* | *5* | | | *X* | |
| 8. | *Specialized Lab Project* | *M* | *15* | | | *X* | |
| | | | | | | | |
| | **Mandatory Elective Modules - during the course of study** | | **20** | | | | |
| 9. | *Mandatory Elective Module 1* | *ME* | *10* | | *X[1)]* | *X[1)]* | |
| 10. | *Mandatory Elective Module 2* | *ME* | *10* | | *X[1)]* | *X[1)]* | |
| | | | | | | | |
| | **Elective Modules - during the course of study** | | **10** | | | | |
| 11. | *Data Science and Artificial Intelligence for Medical Applications* | *E* | *5* | *X[1)]* | *X[1)]* | *X[1)]* | |
| 12. | *Advanced Biology in Medicine, Radiobiology, Medical Science* | *E* | *5* | | *X[1)]* | *X[1)]* | |
| 13. | *Mandatory Elective Module 3* | *E* | *10* | | *X[1)]* | *X[1)]* | |
| 14. | *Mandatory Elective Module 4* | *E* | *10* | | *X[1)]* | *X[1)]* | |
| | | | | | | | |
| | **Interdisciplinary Competencies (IC) - during the course of study** | *IC* | **10** | *X[1)]* | *X[1)]* | *X[1)]* | |
| | | | | | | | |
| | **Mandatory Module - Master's Thesis** | | **30** | | | | |
| 15. | *Master's Thesis (including the oral examination)* | *M* | *30* | | | | *X* |
| | | **Total ECTS credits:** | **120** | | | | |

* Module Types: Mandatory Module = M / Mandatory Elective Module = ME / Elective Module = E
Interdisciplinary Competencies = IC

[1)] Recommended in one or several of the indicated semesters.

### 2.1 Mobility window

Students have the opportunity to take modules at other higher education institutions in Germany or abroad without extending their period of study. Most appropriate for these endeavours are the second and the third semesters, and especially the fourth semester for an external Master's thesis in an academic group or company elsewhere. Please note that an application is required for recognition of external study and examination achievements.

## 3. Modules

### 3.1 Module overview

The modules during the course of study of the Master's degree programme in Biomedical Engineering comprise a total of 90 ECTS credits. The Master's thesis, including the oral examination, is worth 30 ECTS credits.

**A. Mandatory Modules**

80 ECTS credit points must be completed in the mandatory area. The following mandatory modules must be successfully completed.

| **Mandatory Modules** | **80 CP** |
|---|---|
| *Basic Radiotherapy* | 5 CP |
| *Basic Imaging Physics in Medicine* | 5 CP |
| *Mathematical Foundations of Medical Technology and Medical Physics* | 5 CP |
| *Basic Biology in Medicine and Radiobiology* | 5 CP |
| *Basic Medical Science* | 5 CP |
| *Basic Mechatronics in Medicine* | 5 CP |
| *Medical Image Analysis* | 5 CP |
| *Specialized Lab Project* | 15 CP |
| *Master‘s Thesis (including the oral examination)* | 30 CP |

**B. Mandatory Elective Modules**

A total of 20 ECTS credit points must be completed in the mandatory elective area. Students must choose two of the following modules:

| **Mandatory Elective Modules** | **20 CP** |
|---|---|
| *Advanced Radiotherapy* | 10 CP |
| *Advanced Imaging Physics in Medicine* | 10 CP |
| *Advanced Computational Medical Physics* | 10 CP |
| *Advanced Robotics and Automation in Medicine* | 10 CP |

## C. Elective Modules

In the elective area of elective modules, 10 ECTS credit points must be earned. Modules from the area of mandatory elective modules that were not used there can also be selected. Students can choose from the following modules:

| **Elective Modules** | **10 CP** |
|---|---|
| *Data Science and Artificial Intelligence for Medical Applications* | 5 CP |
| *Advanced Biology in Medicine, Radiobiology, Medical Science* | 5 CP |
| *Mandatory Elective Module 3 (see B.)* | 10 CP |
| *Mandatory Elective Module 4 (see B.)* | 10 CP |

## D. Interdisciplinary Competencies (IC)

| ***Interdisciplinary Competencies (IC)*** | **10 CP** |
|---|---|

In the elective area of interdisciplinary competencies, 10 ECTS credit points must be completed. The following selection is possible as an example:

- General Science Skills (3 CP)
- Shanghai Workshop (1 CP)

## 3.2 Module descriptions

### 3.2.1 Mandatory modules

| Title | **Basic Radiotherapy** | | |
|---|---|---|---|
| **Code** | RT_Bas | **Type** | Mandatory |
| **Workload** | 150 h | **Credit points** | 5 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (4 CP)<br>- practical or tutorial (1 CP) | | |
| **Learning content** | - physics of ionizing radiation, physical and technical aspects of therapeutic radiation beams<br>- dosimetry: principles of radiation measurements, detectors, dosimetric quantities and units<br>- instrumentation: medical linear accelerators system architectures and modes of operation<br>- medical foundations of radiation therapy and the radiation therapy treatment chain<br>- radiation therapy treatment planning: 3D conformal treatment planning, dose calculation algorithms, target volumes and dose prescription, normal tissue and organs at risk radiation response<br>- quality assurance: setting up and managing a quality assurance program in radiation therapy, risk analysis<br>- radiation protection: medical and personal exposure, radiation shielding, international radiation protection regulations and responsibilities<br>- practical training: basic dosimetry with different detectors and different phantoms, 3D conformal radiation therapy treatment planning | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe the basics of radiation oncology, and medical indications and apply this knowledge using their physics background<br>- describe and explain principles of radiation physics, dose curves for different types of radiation, the radiotherapy chain and aspects which have to be considered for a successful treatment<br>- describe and explain different radiation qualities<br>- describe and explain principles and basics of radiation protection<br>- explain and estimate the risks of ionizing radiation<br>- evaluate and compare radiation protection measures<br>- describe and apply legal regulations for radiation exposure<br>- describe relevant techniques in treatment planning and corresponding measurements<br>- assess the plan quality using appropriate evaluation tools (e.g. isodose lines, DVHs, statistics)<br>- describe the typical parameters and explain measurement methods for QA<br>- perform typical QA measurements with dedicated detectors and analyse the results<br>- take relevant aspects, terms and definitions into account when setting up a QA programme in a radiotherapy department<br>- apply basic dosimetry measurements<br>- perform manual treatment planning and determine the resulting doses<br>- generate basic treatment plans | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |

| | |
|---|---|
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- none |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail) |
| **Composition of the final grade of the module** | The final grade of the module is determined by the grade of the examination. |

| Title | **Basic Imaging Physics in Medicine** | | |
|---|---|---|---|
| **Code** | Img_Bas | **Type** | Mandatory |
| **Workload** | 150 h | **Credit points** | 5 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (4 CP)<br>- practical or tutorial (1 CP) | | |
| **Learning content** | - physics of imaging systems, such as conventional X-ray, Computed Tomography - CT, Magnetic Resonance Imaging - MRI<br>- practical training in imaging systems, such as MRI | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe the basic components and functionality of the imaging systems<br>- explain the underlying physical principles<br>- calculate physical parameters used for image acquisition, processing and analysis<br>- adjust standard imaging parameters, perform basic measurements with the imaging systems, process and analyse the image data | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- none | | |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail) | | |
| **Composition of the final grade of the module** | The final grade of the module is determined by the grade of the examination. | | |

| Title | **Mathematical Foundations of Medical Technology and Medical Physics** | | |
|---|---|---|---|
| **Code** | Math_Bas | **Type** | Mandatory |
| **Workload** | 150 h | **Credit points** | 5 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (4 CP)<br>- practical or tutorial (1 CP) | | |
| **Learning content** | - system modelling and description, such as numerical methods for solution of linear systems, approximation, integration, solving differential equations, optimization, Fourier transforms, systems theory<br>- exercises, such as basic programming with e.g. MATLAB | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- analyse and solve typical numerical problems in computational physics<br>- use standard programming functions and develop pieces of software for the solutions<br>- select the most appropriate techniques and perform simple mathematical proofs | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- none | | |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail) | | |
| **Composition of the final grade of the module** | The final grade of the module is determined by the grade of the examination. | | |

| Title | **Basic Biology in Medicine and Radiobiology** | | |
|---|---|---|---|
| **Code** | Bio_Bas | **Type** | Mandatory |
| **Workload** | 150 h | **Credit points** | 5 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (4 CP)<br>- practical or tutorial (1 CP) | | |
| **Learning content** | - basic molecular and cellular biology, such as replication, transcription, translation, post-translational modification, from DNA to a functional protein, cells and its organelles, cell division, cell cycle, cell death, Mendelian genetics and genetic diseases, molecular biological assays and techniques<br>- radiobiology, such as basics of biological radiation effect (physical interaction of different radiation qualities with matter, chemical reactions, biological consequences), DNA damage and repair, cell cycle regulation, proliferation, signal transduction, radiation sensitivity of cells and tissues and its modulation, clinical radiobiology of tumours and normal tissue, and biological effects of dose rate, fractionation, overall treatment time, volume<br>- theoretical and practical training in basic cellular, molecular and radiation biology, including: cell culture basics, the clonogenic survival assay, cell-cycle analysis (flow cytometry), the polymerase chain reaction (PCR), detection/ visualization of DNA damage and repair (gH2AX foci assay) and predictive assays and OMICS | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe the basic principles of classical genetics (Mendelian laws), molecular genetics (from DNA to protein) and of the structure and function of cells<br>- explain the theory of cloning, PCR and sequencing<br>- describe the physical, chemical, and biochemical processes leading to biological radiation effects,<br>- explain the biological basis of the effect of radiotherapy on tumours and normal tissue, and the strategies for modulating the therapeutic window<br>- calculate dose-modifying factors, fit mathematical models of dose-response relationships for cell inactivation, tumour control, normal-tissue complication, and volume effects<br>- calculate isoeffective changes in fractionation, and time factors<br>- use different kinds of laboratory tools and equipment<br>- work with cell cultures under sterile conditions<br>- perform molecular biology techniques, such as PCR, and agarose gel electrophoresis<br>- perform the necessary calculations of concentrations and dilutions<br>- explain the principles and interpret the results of cellular radiosensitivity assays<br>- evaluate and interpret cell-cycle analyses by flow cytometry | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- none | | |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail) | | |
| **Composition of the final grade of the module** | The final grade of the module is determined by the grade of the examination. | | |

| Title | **Basic Medical Science** | | |
|---|---|---|---|
| **Code** | Med_Bas | **Type** | Mandatory |
| **Workload** | 150 h | **Credit points** | 5 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (5 CP) | | |
| **Learning content** | - medical terminology<br>- macroscopic anatomy of the human body, such as anatomical relations, organ motion, differences in tissue structure and properties<br>- overview and modelling of the physiology, such as muscle and senses, heart and circulation, respiration and metabolism, kidney and homeostasis<br>- overview of the systems of the body, such as the digestive system, the respiratory system, the genitourinary system, the endocrine system, the nervous system | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe and explain basic terms and principles in anatomy and physiology as required for physicists and engineers<br>- recognize and describe the underlying regulatory roles and functional mechanisms of whole organs<br>- join those organ specific functions into larger regulatory circuits and construct math. models in order to simulate and predict physiological functions in healthy and pathological conditions | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- none | | |
| **Requirements for the assignment of credits** | - graded oral or written examination | | |
| **Composition of the final grade of the module** | The final grade of the module is determined by the grade of the examination. | | |

| Title | **Basic Mechatronics in Medicine** | | |
|---|---|---|---|
| **Code** | Mech_Bas | **Type** | Mandatory |
| **Workload** | 150 h | **Credit points** | 5 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (4 CP)<br>- practical or tutorial (1 CP) | | |
| **Learning content** | - components of mechatronic systems (MS)<br>- mechatronic components and medical devices<br>- concepts and design of MS for automation systems<br>- mechanical design of MS<br>- sensors and electronics for MS<br>- control systems such as closed loop systems<br>- actuator systems<br>- practical training in mechatronic systems | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe the basic components and functionality of the mechatronic systems<br>- explain the underlying physical and engineering principles<br>- design basic mechatronics systems<br>- implement simple mechatronic systems | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- none | | |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail) | | |
| **Composition of the final grade of the module** | The final grade of the module is determined by the grade of the examination. | | |

| Title | **Medical Image Analysis** | | |
|---|---|---|---|
| **Code** | MIA | **Type** | Mandatory |
| **Workload** | 150 h | **Credit points** | 5 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (4 CP)<br>- practical or tutorial (1 CP) | | |
| **Learning content** | - digitization of image information/ relevant data formats<br>- mathematical methods of image analysis and transformation, such as digital filtering (linear, non-linear), Fourier transform, segmentation, registration and pattern recognition | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- explain the principles used in image analysis and apply this knowledge in concrete practical applications<br>- solve image analysis tasks, i.e. apply the image processing workflow using the acquired concepts and techniques, formulate models, find solutions to specific problems, and to communicate them efficiently<br>- systematically study and describe current literature and thus solve new image analysis problems | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- Mathematical Foundations of Medical Technology and Medical Physics<br>- Basic Imaging Physics in Medicine | | |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail) | | |
| **Composition of the final grade of the module** | The final grade of the module is determined by the grade of the examination. | | |

| Title | **Specialized Lab Project** | | |
|---|---|---|---|
| **Code** | SLP | **Type** | Mandatory |
| **Workload** | 450 h | **Credit points** | 15 |
| **Cycle offered** | Continuously | **Duration** | 3 months |
| **Module parts and teaching methods** | - practical (15 CP) | | |
| **Learning content** | - The topic depends on the supervising department.<br>- The project introduces into a special field of application and can be a preparation for the Master's thesis. | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- independently research and evaluate the quality of a research group and interview the PI/project supervisor who offers a research project topic to determine if the research fits with the study programme, their interests and career development goals<br>- formulate a research project in biomedical engineering and identify the methods and techniques for the solution of the research question in collaboration with their supervisor<br>- work independently on a specific research project in a laboratory, industry or clinical setting, advised by their supervisor<br>- acquire knowledge independently and apply this knowledge in practical situations<br>- seek, process and critically analyse information from different sources, such as specialist literature, in order to develop innovative and creative solutions to research problems<br>- communicate questions and findings with others in their field as well as in an interdisciplinary setting using a variety of media<br>- select the relevant practical tools to answer research questions and work with these tools in a collaborative setting<br>- formulate, organize, perform and evaluate experiments<br>- plan and manage projects<br>- work in an international, multi-cultural and multi-disciplinary team, actively participating in discussion<br>- provide, accept and consider constructive criticism<br>- write a scientific manuscript in the form of a report similar to a short thesis | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of ONE of the following module(s) is recommended:<br>- Advanced Radiotherapy<br>- Advanced Imaging Physics in Medicine<br>- Advanced Computational Medical Physics<br>- Advanced Robotics and Automation in Medicine | | |
| **Requirements for the assignment of credits** | - ungraded examination (pass or fail) in form of a written report | | |
| **Composition of the final grade of the module** | The module is ungraded. | | |

| Title | **Master‘s Thesis (including the oral examination)** | | |
|---|---|---|---|
| **Code** | MT | **Type** | Mandatory |
| **Workload** | 900 h | **Credit points** | 30 |
| **Cycle offered** | Continuously | **Duration** | 6 months |
| **Module parts and teaching methods** | - practical (30 CP) | | |
| **Learning content** | - The topic depends on the supervising department. | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- independently research and evaluate the quality of a research group and interview the PI/project supervisor who offers a research project topic to determine if the research fits with the study programme, their interests and career development goals<br>- formulate a research project in biomedical engineering and identify the methods and techniques for the solution of the research question in collaboration with their supervisor<br>- work independently on a specific research project in a laboratory, industry or clinical setting, advised by their supervisor<br>- acquire knowledge independently and apply this knowledge in practical situations<br>- seek, process and critically analyse information from different sources, such as specialist literature, in order to develop innovative and creative solutions to research problems<br>- communicate questions and findings with others in their field as well as in an interdisciplinary setting using a variety of media<br>- select the relevant practical tools to answer research questions and work with these tools in a collaborative setting<br>- formulate, organize, perform and evaluate experiments<br>- plan and manage projects<br>- work in an international, multi-cultural and multi-disciplinary team, actively participating in discussion<br>- provide, accept and consider constructive criticism<br>- write a detailed scientific manuscript in the form of a thesis<br>- participate actively in lab routines such as journal clubs, progress reports and academic discussion<br>- present and defend scientific information and data<br>- demonstrate their assimilation and critical reflexion on the topics of the research project | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- Specialized Lab Project | | |
| **Requirements for the assignment of credits** | - graded written thesis<br>- graded oral examination including presentation and academic discussion | | |
| **Composition of the final grade of the module** | The final grade of the module is determined by the written thesis grade and the grade for the oral examination. The written grade is given a triple weighting and the grade for the oral examination is given a single weighting. | | |

### 3.2.2 Mandatory elective or elective modules

| Title | **Advanced Radiotherapy** | | |
|---|---|---|---|
| **Code** | RT_Adv | **Type** | Mandatory Elective or Elective |
| **Workload** | 300 h | **Credit points** | 10 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (3 CP)<br>- practical or tutorial (5 CP)<br>- seminar (2 CP) | | |
| **Learning content** | - radiation therapy treatment planning: intensity modulated radiation therapy (IMRT/VMAT), inverse treatment planning and optimization<br>- image guided radiation therapy (IGRT) techniques and motion management in radiation therapy<br>- advanced radiation therapy treatment techniques: brachytherapy (HDR/LDR), intra-operative radiation therapy (IORT), total body irradiation (TBI), stereotactic body radiation therapy (SBRT), proton therapy (PT), adaptive radiation therapy (ART)<br>- advanced quality assurance strategies (e.g. “end-to-end”-test in quality assurance)<br>- practical training: IMRT/VMAT treatment planning and approaches for patient specific quality assurance<br>- seminar topics depending on the current state of the art in radiation therapy | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe the principles and basics of image guided radiotherapy<br>- explain a typical QA process for image guidance systems<br>- explain the typical workflow for IGRT for different systems<br>- name major goals of IGRT<br>- name uncertainties during radiotherapy such as set-up errors, organ movements or organ deformations<br>- describe innovative methods and asses their practical use depending on the disease and available resources in a radiation therapy facility<br>- describe the principles of advanced radiation therapy approaches and discuss their benefits/shortcomings for a given treatment scenario<br>- independently perform CT scans for different phantoms and select appropriate scan protocols for radiation therapy applications<br>- perform all steps of an intensity modulated radiation therapy treatment in a phantom, evaluate the resulting accuracy and identify potential sources of error<br>- analyse the results of the measurements with dedicated software<br>- describe how an “end-to-end” test can be performed for checking a typical radiotherapy chain<br>- create a scientific report about a given project<br>- perform a literature search<br>- formulate a topic related to the current state of the art<br>- present a current research topic<br>- take part in scientific discussions | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- Basic Radiotherapy | | |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail)<br>- ungraded seminar (pass or fail) | | |
| **Composition of the final grade of the module** | If taken as mandatory elective module: The final grade of the module is determined by the grade of the examination.<br>If taken as elective module: The module is ungraded. | | |

| Title | **Advanced Imaging Physics in Medicine** | | |
|---|---|---|---|
| **Code** | Img_Adv | **Type** | Mandatory Elective or Elective |
| **Workload** | 300 h | **Credit points** | 10 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (3 CP)<br>- practical or tutorial (5 CP)<br>- seminar (2 CP) | | |
| **Learning content** | - physical foundations of advanced imaging techniques, such as Perfusion Imaging & Pharmacokinetic Modelling, Diffusion MRI, X-Nuclei Imaging, Dual energy CT, Iterative Reconstruction Techniques in CT/CBCT, SPECT, PET<br>- practical training in image acquisition techniques such as MRI<br>- seminar topics depending on the current state of the art in imaging techniques | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe components and functionality of advanced imaging techniques<br>- explain the underlying physical principles<br>- calculate physical parameters used for image acquisition, processing and analysis<br>- apply the imaging techniques in scientific or work-related tasks<br>- adjust imaging parameters, perform measurements with the imaging techniques, process and analyse the image data<br>- evaluate the performance and limitations of the imaging techniques<br>- perform a literature search<br>- formulate a topic related to the current state of the art<br>- present a current research topic<br>- take part in scientific discussions | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- Basic Imaging Physics in Medicine | | |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail)<br>- ungraded seminar (pass or fail) | | |
| **Composition of the final grade of the module** | If taken as mandatory elective module: The final grade of the module is determined by the grade of the examination.<br>If taken as elective module: The module is ungraded. | | |

| Title | **Advanced Computational Medical Physics** | | |
|---|---|---|---|
| **Code** | Comp_Adv | **Type** | Mandatory Elective or Elective |
| **Workload** | 300 h | **Credit points** | 10 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (3 CP)<br>- practical or tutorial (5 CP)<br>- seminar (2 CP) | | |
| **Learning content** | - computational methods in medical physics, such as biophysics of DNA/sequencing and protein/protein structure determination and prediction, simulators in (serious) games and medicine, volume visualization, inverse problems<br>- practical training in computational methods used in medical physics, such as non-linear numerical analysis, GPU programming, mathematical models<br>- seminar topics depending on the current state of the art in computational medical physics | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- explain the principles used in the field in order to develop solution strategies for given problems and apply them to concrete applications<br>- assess different methods and identify the most suited method to solve a given task in an interdisciplinary field<br>- analyse problems and data<br>- find solutions and solve typical problems in this field, and communicate them efficiently<br>- develop software applications for the solution of typical problems<br>- systematically study and describe current literature in order to apply the newly learned techniques to given or new tasks<br>- perform a literature search<br>- formulate a topic related to the current state of the art<br>- present a current research topic<br>- take part in scientific discussions | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- Mathematical Foundations of Medical Technology and Medical Physics | | |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail)<br>- ungraded seminar (pass or fail) | | |
| **Composition of the final grade of the module** | If taken as mandatory elective module: The final grade of the module is determined by the grade of the examination.<br>If taken as elective module: The module is ungraded. | | |

| Title | **Advanced Robotics and Automation in Medicine** | | |
|---|---|---|---|
| **Code** | Robo_Adv | **Type** | Mandatory Elective or Elective |
| **Workload** | 300 h | **Credit points** | 10 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture (3 CP)<br>- practical or tutorial (5 CP)<br>- seminar (2 CP) | | |
| **Learning content** | - concepts and application of robotics for interventional therapy and surgery<br>- engineering foundations and design of medical robots<br>- navigation systems for interventional robots<br>- registration and tracking systems<br>- peripheral components and technologies for embedding robots in interventional processes<br>- practical training in robotics and automation techniques<br>- seminar topics depending on the current state of the art in robotics and automation techniques | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe components and functionality of advanced robotics and automation techniques<br>- evaluate the performance and limitations of the robotics and automation techniques<br>- explain the underlying physical and engineering principles<br>- explain control systems for interventional use of robots<br>- design constructions of basic robot systems for medical application<br>- design software of basic navigation, registration and tracking systems<br>- apply the robotics and automation techniques in scientific or work-related tasks<br>- perform a literature search<br>- formulate a topic related to the current state of the art<br>- present a current research topic<br>- take part in scientific discussions | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- Basic Mechatronics in Medicine | | |
| **Requirements for the assignment of credits** | - graded oral or written examination<br>- ungraded practical or tutorial (pass or fail)<br>- ungraded seminar (pass or fail) | | |
| **Composition of the final grade of the module** | If taken as mandatory elective module: The final grade of the module is determined by the grade of the examination.<br>If taken as elective module: The module is ungraded. | | |

### 3.2.3 Elective modules

| Title | **Data Science and Artificial Intelligence for Medical Applications** | | |
|---|---|---|---|
| **Code** | DSAI | **Type** | Elective |
| **Workload** | 150 h | **Credit points** | 5 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture and/or practical and/or tutorial and/or seminar (5 CP)<br>Students select any combination of the teaching forms mentioned above to a total of 5 CP according to their preferences and availability. | | |
| **Learning content** | - topics of data science and artificial intelligence depending on the current state of the art, such as data structures and systems, data processing and software development, statistical methods and modelling, data analysis and prediction techniques, data visualization, machine learning methods such as artificial neural networks | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe, explain and utilize concepts of data science and artificial intelligence, independent of the teaching form, that can be used for medical applications in their field of specialization | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- none | | |
| **Requirements for the assignment of credits** | - ungraded examination (pass or fail) | | |
| **Composition of the final grade of the module** | The module is ungraded. | | |

| Title | **Advanced Biology in Medicine, Radiobiology, Medical Science** | | |
|---|---|---|---|
| **Code** | BioMed_Adv | **Type** | Elective |
| **Workload** | 150 h | **Credit points** | 5 |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - lecture and/or practical and/or tutorial and/or seminar (5 CP)<br>Students select any combination of the teaching forms mentioned above to a total of 5 CP according to their preferences and availability. | | |
| **Learning content** | - topics of advanced biology in medicine, radiobiology or medical science depending on the current state of the art, such as special anatomy, physiology or pathology | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- describe, explain and utilize concepts of advanced biology in medicine, radiobiology or medical science, independent of the teaching form, that can inspire and contribute to the further development of technical methods and devices for the advancement of biomedical diagnostics and therapeutics | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of ONE of the following module(s) is recommended:<br>- Basic Biology in Medicine and Radiobiology<br>- Basic Medical Science | | |
| **Requirements for the assignment of credits** | - ungraded examination (pass or fail) | | |
| **Composition of the final grade of the module** | The module is ungraded. | | |

### 3.2.4 Interdisciplinary competencies

Interdisciplinary competencies, in German “Übergreifende Kompetenzen” (ÜK) refer to study contents, key competencies and additional qualifications that go beyond subject-specific knowledge and convey personality and job-related competencies that are essential in today's professional life (in and outside of research). There are various options available (some module descriptions follow on the next pages). Within the framework of the ÜK, courses from the university's range of courses that do not belong to the Biomedical Engineering programme can be recognized. This includes scientific workshops, general science skills, language courses, entrepreneurship courses, career development courses, ethics/ ecology courses, and medical device regulation/ risk analysis courses. In these cases, the credit points of the courses are transferred. Courses offered by the Career Service in the area of ÜK can be recognized; in this case, it is essential to consult with the Biomedical Engineering Office beforehand.

| Title | General Science Skills | | |
|---|---|---|---|
| **Code** | GSS | **Type** | ÜK |
| **Workload** | 90 h | **Credit points** | 3 ÜK |
| **Cycle offered** | Yearly | **Duration** | 1 semester |
| **Module parts and teaching methods** | - tutorial (3 CP) | | |
| **Learning content** | - The students learn the following scientific skills:<br>- identifying and researching the state of the art of a project<br>- searching, describing and management of scientific literature<br>- developing a research plan/proposal<br>- identifying and avoiding plagiarism<br>- writing a scientific manuscript<br>- presenting scientific data<br>- The students choose a topic/theme (e.g. Master's thesis topic) and with the skills learned, generate and give a scientific presentation on the topic (incl. open discussion). | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- plan a scientific project<br>- perform a scientific literature search, describe and manage scientific literature<br>- write a scientific manuscript<br>- present scientific data | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- none | | |
| **Requirements for the assignment of credits** | - ungraded examination (pass or fail) | | |
| **Composition of the final grade of the module** | The module is ungraded. | | |

| Title | **Shanghai Workshop** | | |
|---|---|---|---|
| **Code** | SHW | **Type** | ÜK |
| **Workload** | 30 h | **Credit points** | 1 ÜK |
| **Cycle offered** | Yearly | **Duration** | 1 week |
| **Module parts and teaching methods** | - lecture (1 CP) | | |
| **Learning content** | The schedule of the workshop with Shanghai Jiao Tong University covers ca. one week.<br>- Lectures are provided covering topics of the Biomedical Engineering programme such as Modern Radiation Oncology, Image Guided Radiotherapy, Hyperthermia.<br>- Students join the “Annual Sino-German Radiation Oncology Symposium”. | | |
| **Learning objectives** | After completing this module, the students are able to:<br>- name and explain recent developments and current research activities in the field of Biomedical Engineering<br>- talk in specialized scientific English language in international, multi-cultural and multi-disciplinary environments<br>- use their broadened knowledge in culture in order to efficiently conduct mutual research projects between both institutions to solve typical problems in biomedical engineering | | |
| **Application of the module** | Biomedical Engineering (Master of Science) | | |
| **Requirements for participation** | For successful participation, the completion of the following module(s) is recommended:<br>- none | | |
| **Requirements for the assignment of credits** | - ungraded examination (pass or fail) | | |
| **Composition of the final grade of the module** | The module is ungraded. | | |