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## Module Handbook

Heidelberg University  
Medical Faculty Mannheim

### Master of Science “Biomedical Engineering”

Period of Study: Four semesters full time; yearly intake (winter term)

Type of Study: consecutive; research oriented

Start: Sept. 2010/2011

Areas of Study:

- Radiotherapy
- Medical Imaging
- Computational Medical physics

Location: Medical Faculty Mannheim/ UMM; Heidelberg University

ECTS-credits: 120

Language of instruction: English

Target Group:

- Physics (B.Sc. or higher)
- Engineering (with basic knowledge in physics)
- Mathematics

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## 1. Quality Objectives and Overview

### 1.1 Preamble: Qualification objectives at 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 Qualification objectives of the Master of Science programme in Biomedical Engineering

### (I) Subject-related qualification objectives

The programme aims at enabling students to work and/or carry out independent research in the field medical physics.

After completing this course, students

- will have acquired basic knowledge of anatomy, physiology, genetics and also basic knowledge of biophysics and engineering mathematics (numerically oriented), including programming
- will have learned and thus be able to translate and apply this knowledge into daily practice, independently of the specialization

Students completing electives

- will have acquired a broad knowledge of radiotherapy and radiotherapy techniques, computational physics, imaging, computer engineering or optics
- successfully tackled all technical issues arising in these fields that are related to Medical Physics
- are able to analyse and evaluate recent technological developments and advances in the field. Graduates will also be able to independently tackle current challenges and to find solutions or establish new areas of research.

### (II) Interdisciplinary qualification objectives

Based on knowledge acquired in specialized lab projects / research projects, students will

- have acquired all traits to understand scientific working and thinking,
- easily communicate and write in (foreign) specialized scientific language, and
- be able to critically assess, and evaluate medical science.

Students will not only learn how to present and discuss data in scientific meetings but will also be able to describe technical issues in layman's terms (e.g. when they will have to communicate with patients).

They will have all traits necessary to take responsibilities for their field and to constitute, lead and motivate expert teams.

The students will also be trained to independently develop new ideas and to autonomously develop their own area of research.

Ultimately, all students completing this course will be able to advance the socio-economic state of their academic and non-academic environment.

## 2. Possible career options

Graduates career prospects are best in health-care/life-science sectors, research organizations and the medical technology industry (producers of biomedical instruments/imaging systems, health-care-oriented software companies, the pharmaceutical industry, etc.). Successful completion of the course may also qualify graduates for 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 two additional years of supervised practical work in a qualified department and an additional examination specified in the German Radiation Protection Ordinance.

## 3. General requirements of the study

### Students Profile

The Master programme in Biomedical Engineering (MSc: Master of Science) is an interdisciplinary course open for candidates with undergraduate or higher education in:

- Physics (B.Sc.<sup>1</sup> or higher)
- Engineering (with basic knowledge in physics)
- Mathematics

This programme is science oriented. In particular, the programme is intended for those students planning to work in the medical field (either as medical physics expert after extra qualification in research or in instruments/software-health-orientated companies). In this respect, the courses provide theoretical background and practical elements where the knowledge can be applied using modern clinical equipment.

Also this programme has a strong bias towards computational science. This reflects the ever-increasing demand for IT competence in this field, in conjunction with knowledge of biomedical devices and their usage. Graduates from this program are well-prepared for positions in hospitals, academia and industry.

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<sup>1</sup> Bachelor of Science

## **Courses Locations**

The master courses are located mostly at Mannheim Medical Campus. However some courses are located at Heidelberg University Campus in Heidelberg

## **Course Material**

The learning material of all courses is accessible at the learning platform Moodle of the Medical Faculty Mannheim. The access to the platform is enabled for the students enrolled in the M.Sc. programme. Over this platform all administrative documents for students are managed as well, including the lecture schedule, the rules and regulations, the course selection and registration, the grades reports, etc.

[moodle.medma.uni-heidelberg.de](https://moodle.medma.uni-heidelberg.de)

## **Master Thesis**

The Master in Biomedical Engineering programme is nationally and internationally connected to leading institutions in research and education for radiotherapy and medical imaging.

The master thesis can be conducted in any of the internal research groups at the University Medical Center Mannheim or by any of the cooperation partners in a topic related to medical physics. The option to perform the master thesis in other external institution is possible provided that all the requirements stipulated by the Academic Committee are fulfilled. More information about this topic is found in the guideline available in Moodle.

## **Joint Degree with Shanghai Jiao Tong University, China**

The M.Sc. in Biomedical Engineering offers to students the possibility of a double degree through the exchange program with Shanghai Jiao Tong University in China. The contents of the programme cover all aspects of the innovative field of computational bio-photonics, i.e. all aspects of the diagnostic and therapeutic use of photons in medicine supported by advanced computing.

Students who decided to participate in the joint degree should stay in Mannheim during the first year of studies. The second year gives two options:

- Option 1 is to carry out the 3<sup>rd</sup> and 4<sup>th</sup> semester (elective taught modules or Master thesis, respectively) in Shanghai.
- Option 2 is to only perform the 3<sup>rd</sup> semester (elective taught modules) in Shanghai and complete the Master Thesis in Mannheim/Heidelberg.

To receive a joint degree diploma, students have to be at least half a year in any of both institutions.

#### 4. Specializations included in the program

To obtain any of the specialization available in the program, the students must to successfully attend all the courses of the corresponding modules.

##### 1. Module M3: Radiotherapy (16 ECTS<sup>2</sup>)

The specialization in Radiotherapy is focused on basic and advanced knowledge related to planning and treatment methods (3D, IMRT, VMAT, IORT, IGRT) of cancer in radiation therapy, to radiotherapy equipment (linear accelerators, computed tomography, intraoperative system), to give basic insight for clinical tasks as well as for advanced research work.

##### 2. Module M4: Medical Imaging (32 ECTS)

Imaging specialization is focused on oncological radiotherapy treatment planning and monitoring by using physiological and functional imaging of CT, MRI and PET. The courses are oriented to provide the student with fundamental knowledge in processing, analysis and quantification of medical images. Special attention is laid on the interdisciplinary approach to radiotherapeutic cancer treatment.

##### 3. Module M5: Computational Medical Physics (37 ECTS)

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<sup>2</sup> European Credit Transfer System. 1 ECTS is equivalent to 30 study hours.

Computational medical physics is focused on the fields of mathematics, computer engineering, computer science and physics. The aim of the advanced modules in this specialization is the knowledge in modern computational physics with application in life sciences. The courses are focused on inverse problems for image reconstruction, restoration, analysis, simulation, modelling and instrumentation.



## 5 Curriculum

### General Timetable:

1 <sup>st</sup> Semester	2 <sup>nd</sup> Semester	3 <sup>rd</sup> Semester	4 <sup>th</sup> Semester		
<u>Taught Modules/ Workshops:</u> <ul style="list-style-type: none"> <li>• M1 module</li> <li>• M2 module</li> <li>• M3 module</li> <li>• M4 module</li> <li>• M5 module</li> <li>•</li> </ul> <p>(min. 30 ECTS)</p>	<u>Taught Modules/ Labs/ Seminars:</u> <ul style="list-style-type: none"> <li>• M2 module</li> <li>• M3 module</li> <li>• M4 module</li> <li>• M5 module</li> <li>• M6 module</li> </ul> <p>(min. 30 ECTS)</p>	<u>Taught Modules/ Labs/ Seminars:</u> <ul style="list-style-type: none"> <li>• M3 module</li> <li>• M4 module</li> <li>• M5 module</li> <li>• M7 module</li> </ul> <p>(min. 30 ECTS)</p>	<p>M8 Master Thesis</p> <p>(30 ECTS)</p>		
<u>Specializations:</u> <ul style="list-style-type: none"> <li>• Radiotherapy</li> <li>• Imaging</li> <li>• Computational Medical Physics</li> </ul>	<u>Specializations:</u> <ul style="list-style-type: none"> <li>• Radiotherapy</li> <li>• Imaging</li> <li>• Computational Medical Physics</li> </ul>	<u>Specializations:</u> <ul style="list-style-type: none"> <li>• Radiotherapy</li> <li>• Imaging</li> <li>• Computational Medical Physics</li> </ul>	<u>Specializations:</u> <ul style="list-style-type: none"> <li>• Neurosciences</li> <li>• Imaging/ Biomedical Optics</li> <li>• Computer Engineering</li> </ul>	<u>Specializations:</u> <ul style="list-style-type: none"> <li>• Radiotherapy</li> <li>• Imaging</li> <li>• Computational Medical Physics</li> </ul>	<u>Specializations:</u> <ul style="list-style-type: none"> <li>• Neurosciences</li> <li>• Imaging/ Biomedical Optics</li> <li>• Computer Engineering</li> </ul>
<u>Venues:</u> Medical Faculty Mannheim Heidelberg University, Germany	<u>Venues:</u> Medical Faculty Mannheim Heidelberg University, Germany	<u>Venues:</u> Medical Faculty Mannheim Heidelberg University, Germany	<u>Venue:</u> Shanghai Jiao Tong University, Shanghai, China	<u>Venues:</u> Medical Faculty Mannheim Heidelberg University, Germany	<u>Venue:</u> Shanghai Jiao Tong University, Shanghai, China





## Modules Overview:

1 <sup>st</sup> Semester Winter Term (Mannheim/ Heidelberg)	Module	Course Number	Course Name	ECTS	Type of course
	M1 Advanced Physics and Mathematics for Medical Applications	1.1	Biophysics	1.0	Mandatory
		1.2	Engineering Mathematics + Exercises	3.0	Mandatory
	M2 Medicine and Radiobiology	2.1	Basic Molecular and Cellular Biology	1.0	Mandatory
		2.2	Basic Medical Science	2.0	Mandatory
	M3 Radiotherapy	3.1	Radiation Physics and Instrumentation	2.0	Mandatory
		3.2	Radiation Protection	1.0	Mandatory
		3.3	Radiotherapy Treatment Planning/Quality Assurance	2.0	Mandatory
		3.4	Treatment Planning and Quality Assurance Lab	1.0	Elective
		3.5	Image Guided Radiotherapy	1.0	Elective
	M4 Medical Imaging	4.1	Physics of Imaging Systems	2.0	Mandatory
		4.2	Biomedical Optics	1.0	Mandatory
		4.3	Biomedical Engineering + Exercise	2.0	Mandatory
		4.4	Basic Optics and Laser	1.0	Elective
		4.5	MR-Radiology Lab	1.0	Elective
		4.6	Seminar: MR Methods and Technology	2.0	Elective
	M5 Computational Medical Physics	5.1	Image Analysis + Exercises	4.0	Elective
		5.2	Matlab Programming	4.0	Elective



<b>2<sup>nd</sup> Semester Summer Term (Mannheim/ Heidelberg)</b>	<b>Module</b>	<b>Course Number</b>	<b>Course Name</b>	<b>ECTS</b>	<b>Type of course</b>
	M2 Medicine and Radiobiology	2.3	Radiobiology	2.0	Mandatory
		2.4	Basic Cellular Biology/Radiobiology Lab	1.0	Mandatory
		2.5	Seminar Radiobiology	1.0	Elective
	M3 Radiotherapy	3.6	Special Radiotherapy Techniques	2.0	Elective
		3.7	Lab Medical Physics in Radiotherapy	5.0	Elective
		3.8	Seminar: Radiotherapy Techniques	2.0	Elective
	M4 Medical Imaging	4.6	Seminar: MR Methods and Technology	2.0	Elective
		4.7	Nuclear Medicine + Exercises	4.0	Mandatory
		4.8	Lab Medical Physics in Imaging	5.0	Elective
		4.9	Seminar: Physics of Advanced MRI/CT Techniques	2.0	Elective
	M5 Computational Medical Physics	5.3	Simulators in Games and Medicine + Exercises	8.0	Elective
		5.4	Volume Visualization + Exercises (advanced)	8.0	Elective
		5.5	Inverse Problems + Exercises (advanced)	8.0	Elective
		5.6	Computational Medical Physics Lab (advanced)	5.0	Elective
	M6 Abroad Course	6.1	Shanghai Workshop	1.0	Elective



3 <sup>rd</sup> Semester Winter Term (Mannheim/ Heidelberg)	Module	Course Number	Course Name	ECTS	Type of course
	M3 Radiotherapy	3.4	Treatment Planning and Quality Assurance Lab	1.0	Elective
		3.5	Image Guided Radiotherapy	1.0	Elective
	M4 Medical Imaging	4.3	Biomedical Optics	1.0	Mandatory
		4.4	Biomedical Engineering + Exercise	2.0	Mandatory
		4.6	Seminar: MR Methods and Technology	2.0	Elective
		4.10	Advanced Imaging Techniques	2.0	Mandatory
		4.11	Medical Devices and Imaging Systems	4.0	Elective
		4.12	MRT Basics	2.0	Elective
	M5 Computational Medical Physics	4.13	X-Ray Diagnostics and Sonography	2.0	Elective
5.1		Image Analysis + Exercises	4.0	Elective	
5.2		Matlab	4.0	Elective	
M7 Master Thesis Preparation	7.1	General Science Skills	3.0	Mandatory	
	7.2	Specialized Lab Project	16.0	Mandatory	



	<b>Neurosciences</b>	<b>Imaging/ Biomedical Optics</b>	<b>Computer Engineering</b>
<b>3<sup>rd</sup> Semester (Shanghai)</b>	<b>Elective modules (max. 30 ECTS)</b>	<b>Elective modules (max. 30 ECTS)</b>	<b>Elective modules (max. 30 ECTS)</b>
	<ul style="list-style-type: none"> <li>• Nanotechnology (3.0)</li> <li>• BioMEMS (3.0)</li> <li>• Biomaterials (3.0)</li> <li>• Neurobiology (3.0)</li> <li>• Structure &amp; Function of Biomacromolecules (4.5)</li> <li>• Theoretical Neurosciences (4.5)</li> <li>• Experiments of modern lab animal science (1.5)</li> <li>• Bioheat &amp; Mass Transfer (4.5)</li> <li>• Neuroinformatics (3.0)</li> </ul>	<ul style="list-style-type: none"> <li>• Physical therapy technology (4.5)</li> <li>• Biomedical ultrasound (4.5)</li> <li>• Medical imaging (3.75)</li> <li>• New Technology in Medical Imaging (3.0)</li> <li>• Biomedical Sensors (4.5)</li> <li>• Laser medicine &amp; biophotonics (3.0)</li> <li>• Frontier problems of optics (4.5)</li> <li>• Non-linear optics of optical fibers (4.5)</li> <li>• Modern optics (4.5)</li> <li>• Optoelectronics (3.0)</li> <li>• Semiconductor devices (3.0)</li> <li>• Processing of optical information (3.0)</li> <li>• Principle &amp; technology of laser (4.5)</li> <li>• Non-linear optics (4.5)</li> <li>• Engineering optics (4.5)</li> </ul>	<ul style="list-style-type: none"> <li>• Application of Computers in Life Sciences (3.0)</li> <li>• Signal processing (4.5)</li> <li>• Digital signal processing (3.0)</li> <li>• Bioinformatics (3.0)</li> <li>• 3D image processing &amp; volume visualization (3.0)</li> <li>• Adaptive filtration (3.0)</li> <li>• Biomedical image processing (4.5)</li> <li>• TMS320 digital signal processor (3.75)</li> <li>• Random signal processing (4.5)</li> <li>• Opt. estimation theory &amp; system identification (4.5)</li> <li>• Computer graphics (4.5)</li> <li>• Wireless communication &amp; sensor networks (3.0)</li> <li>• Mobile &amp; wireless networking (4.5)</li> </ul>

<b>4<sup>th</sup> Semester Summer Term</b>	<b>Module</b>	<b>Course Number</b>	<b>Course Name</b>	<b>ECTS</b>	<b>Type of Course</b>
<b>(Mannheim/ Heidelberg or Shanghai)</b>	<b>M8</b>	<b>8.1</b>	<b>Master Thesis</b>	<b>30.0</b>	<b>Mandatory</b>



## 6. Overview of the Courses

Module	Part	Course Nr.	Title	ECTS
M1	Advanced Physics and Mathematics for Medical Applications	<a href="#">1.1</a>	Biophysics	1.0
		<a href="#">1.2</a>	Engineering Mathematics + Exercises	3.0
M2	Medicine and Radiobiology	<a href="#">2.1</a>	Basic Molecular and Cellular Biology	1.0
		<a href="#">2.2</a>	Basic Medical Science	2.0
		<a href="#">2.3</a>	Radiobiology	2.0
		<a href="#">2.4</a>	Basic Cellular Biology/Radiobiology Lab	1.0
		<a href="#">2.5</a>	Seminar Radiobiology	1.0
M3	Radiotherapy	<a href="#">3.1</a>	Radiation Physics and Instrumentation	2.0
		<a href="#">3.2</a>	Radiation Protection	1.0
		<a href="#">3.3</a>	Radiotherapy Treatment Planning/ Quality Assurance	2.0
		<a href="#">3.4</a>	Treatment Planning and Quality Assurance Lab	1.0
		<a href="#">3.5</a>	Image Guided Radiotherapy	1.0
		<a href="#">3.6</a>	Special Radiotherapy Techniques	2.0
		<a href="#">3.7</a>	Lab Medical Physics in Radiotherapy	5.0
		<a href="#">3.8</a>	Seminar Radiation Therapy Techniques	2.0
M4	Medical Imaging	<a href="#">4.1</a>	Physics of Imaging Systems	2.0
		<a href="#">4.2</a>	Biomedical Optics	1.0
		<a href="#">4.3</a>	Biomedical Engineering + Exercises	2.0
		<a href="#">4.4</a>	Basic Optics and Laser	1.0
		<a href="#">4.5</a>	MR – Radiology Lab	1.0
		<a href="#">4.6</a>	Seminar MR Methods and Technology: Journal Club + Presentation	2.0
		<a href="#">4.7</a>	Nuclear Medicine + Exercises	4.0
		<a href="#">4.8</a>	Lab Medical Physics in Imaging	5.0
		<a href="#">4.9</a>	Seminar: Physics of Advanced MRI / CT Techniques	2.0
		<a href="#">4.10</a>	Advanced Imaging Techniques	2.0
		<a href="#">4.11</a>	Medical Devices and Imaging Systems	4.0
		<a href="#">4.12</a>	MRT Basics	2.0
		<a href="#">4.13</a>	X-Ray Diagnostic and Sonography	2.0



M5	Computational Medical Physics	<a href="#">5.1</a>	Image Analysis + Exercises	4.0
		<a href="#">5.2</a>	Matlab Programming	4.0
		<a href="#">5.3</a>	Simulators in Games and Medicine + Exercises	8.0
		<a href="#">5.4</a>	Volume Visualization + Exercises (Advanced)	8.0
		<a href="#">5.5</a>	Inverse Problems + Exercises (Advanced)	8.0
		<a href="#">5.6</a>	Computational Medical Physics Lab (Advanced)	5.0
M6	Abroad Course	<a href="#">6.1</a>	Shanghai Workshop	1.0
M7	Master Thesis Preparation	<a href="#">7.1</a>	General Science Skills	3.0
		<a href="#">7.2</a>	Specialized Lab Project	16.0
M8	Master thesis	<a href="#">8.1</a>	Masters project and thesis writing; Public presentation of the thesis and final examination	30.0



## 6. Modules in Detail

## Module 1. Advanced Physics and Mathematics for Medical Applications

<b>Course Title</b>	<b>Biophysics</b>		
<b>Course no.</b>	<a href="#">1.1</a>	<b>Exam Regulations</b>	45 min Exam (Written/ Oral/ Exercises/ Report): Basics in Physics
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	30 h	<b>Max. Number of Participants</b>	40
<b>Type of Course</b>	Lecture (mandatory)	<b>Coordinator/ Lecturer</b>	Prof. Dr. J. W. Hesser
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block Course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Biophysics of DNA/sequencing, Protein/Protein structure determination and prediction</li> <li>• Biophysical electrophysiology</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students are able to:</p> <ul style="list-style-type: none"> <li>• read and understand papers in this field in order to repeat the experiment or apply it in new fields.</li> <li>• apply the knowledge to concrete applications.</li> <li>• solve typical questions in this field of biophysical processes.</li> <li>• develop programs for sequence alignment, protein structure classification, and prediction, find native conformations using force-fields,</li> <li>• correctly perform electrophysiological measurements.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture		
<b>Useful /Required Previous Knowledge</b>	none		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the lecture.</li> </ul>		



<b>Course Title</b>	<b>Engineering Mathematics</b>		
<b>Course no.</b>	<a href="#">1.2</a>	<b>Exam Regulations</b>	75 min Exam (Written/ Oral/ Exercises/ Report): Basics in Physics
<b>Credit Points</b>	3.0	<b>Formalities or Requirements for Participation</b>	no
<b>Workload</b>	90 h	<b>Max. Number of Participants</b>	40
<b>Type of Course</b>	Lecture (mandatory)	<b>Coordinator/ Lecturer</b>	Prof. Dr. J. W. Hesser
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• System modelling and description (numerical methods for solution of linear systems, approximation/integration, solving differential equations, optimization, Fourier transforms, and systems theory)</li> <li>• Matlab exercises (basic programming)</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students are able to:</p> <ul style="list-style-type: none"> <li>• solve typical numerical problems in computational physics.</li> <li>• program the solutions and use the preexisting Matlab functions for this purpose.</li> <li>• • select the most appropriate techniques and to perform simple mathematical proofs.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture and practical part.		
<b>Useful /Required Previous Knowledge</b>	none		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the lecture.</li> </ul>		





## Module 2. Basic Molecular and Cellular Biology

<b>Course Title</b>	<b>Basic Molecular and Cellular Biology</b>		
<b>Course no.</b>	<a href="#">2.1</a>	<b>Exam Regulations</b>	45 min Written Exam
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	no
<b>Workload</b>	30 h	<b>Max. Number of Participants</b>	40
<b>Type of Course</b>	Lecture (mandatory)	<b>Coordinator/ Lecturer</b>	Prof. Dr. M.R. Veldwijk, PD Dr. P. Maier
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Replication, transcription, translation and post-translational modification: From DNA to a functional protein</li> <li>• The cell and its organelles</li> <li>• Cell division, cell cycle and cell death</li> <li>• Mendelian genetics and genetic diseases</li> <li>• Molecular biological assays and techniques</li> </ul>		
<b>Learning Objectives</b>	<p>This course conveys the biological background for the master program. After its completion, the students are able to describe the basic principles of classical genetics (Mendelian Laws), molecular genetics (from DNA to protein) and of the structure and function of cells. Furthermore, they can explain the theory of cloning, PCR and sequencing.</p>		
<b>Course Parts and Teaching Methods</b>	Lecture		
<b>Useful /Required Previous Knowledge</b>	none		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the lecture.</li> </ul>		



Course Title	Basic Medical Sciences		
Course no.	<a href="#">2.2</a>	Exam Regulations	90 min. Written Exam
Credit Points	2.0	Formalities or Requirements for Participation	no
Workload	60 h	Max. Number of Participants	40
Type of Course	Lecture (mandatory)	Coordinator/Lecturer	Prof. Dr. W. Kriz, Prof. Dr. U. Böcker, Prof. Dr. M.R. Veldwijk, Prof. Dr. J. Maurer, Dr. T. Gloe
Turn	Yearly	Term	Winter
Language	English	Duration	Block course
Contents of Course:	<ul style="list-style-type: none"> <li>• Medical terminology</li> <li>• Macroscopic anatomy of the human body as required for physicists (anatomical relations, organ motion, differences in tissue properties and their consequences)</li> <li>• Focus on anatomical relations of truncus and CNS.</li> <li>• Main topics in physiology section are fundamental physiological mechanisms on the basis of organs as cell and membrane, muscle and senses, heart and circulation, respiration and metabolism, kidney and homeostasis.</li> <li>• Modelling of physiology</li> <li>• Basic immunology</li> </ul>		
Learning Objectives	<ul style="list-style-type: none"> <li>• In anatomy students learn: <ul style="list-style-type: none"> <li>- Conceptual basic knowledge in the structure of the cell and tissues,</li> <li>- continued with the Single functional portions of the macroscopic and microscopic anatomy, i.e. The digestive system, the respiratory system,</li> <li>- the genitourinary system, reproductive systems, and endocrine system, and Nervous system.</li> </ul> </li> <li>• After successful complementation of physiology section the students are able to recognize and describe the underlying regulatory roles and functional mechanisms of whole organs. With the acquired knowledge the students are able to join those organ specific functions into larger regulatory circuits and as a consequence, they are able to construct math models in order to simulate and predict physiological functions in normal healthy and pathological conditions.</li> <li>• This course conveys the basics of immunology. After its completion, the students are able to know and describe the key components of the immune system, their functions and interactions between them during an immune reaction.</li> </ul>		
Course Parts and Teaching Methods	Physiology: plenary lectures including seminar-like discussion Immunology: lectures Anatomy. Lecture and practical sessions		
Useful /Required Previous Knowledge	none		
Recommended Literature	<ul style="list-style-type: none"> <li>• Netter's Anatomy, Thieme Verlag</li> <li>• "Physiology", Costanzo, Saunders/Elsevier</li> <li>• "Human Physiology", Silversthorn, Pearson</li> </ul>		



<b>Course Title</b>	<b>Radiobiology</b>		
<b>Course no.</b>	<a href="#">2.3</a>	<b>Exam Regulations</b>	Presentation/ 75 min Written Exam/ Report
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in courses , 2.1 and 2.2
<b>Workload</b>	60 h	<b>Max. Number of Participants</b>	40
<b>Type of Course</b>	Lecture /Workshop (mandatory)	<b>Coordinator/ Lecturer</b>	PD Dr. C. Herskind, Prof. Dr. M.R. Veldwijk
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Basics of biological radiation effect (physical interaction of different radiation qualities with matter, chemical reactions, biological consequences)</li> <li>• DNA damage and repair; Cell cycle regulation, proliferation, signal transduction, Radiation sensitivity of cells and tissues, and its modulation</li> <li>• Clinical radiobiology of tumours and normal tissue</li> <li>• Biological effects of dose rate, fractionation, overall treatment time, volume,</li> </ul>		
<b>Learning Objectives</b>	<ul style="list-style-type: none"> <li>• Students should be able to describe the physical, chemical, and biochemical processes leading to biological radiation effects, to explain the biological basis of the effect of radiotherapy on tumours and normal tissue, and to explain strategies for modulating the therapeutic window.</li> <li>• They should be able to calculate dose-modifying factors, fit mathematical models of dose-response relationships for cell inactivation, tumour control, normal-tissue complication, and volume effects, and calculate isoeffective changes in fractionation, and time factors</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture and practical part including presentation and exercises		
<b>Useful /Required Previous Knowledge</b>	Good knowledge of nuclear physics and radiation physics. Basic knowledge of chemistry, cell and molecular biology, and oncological concepts		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Hall, E. J. and Giaccia, A. J. "Radiobiology for the Radiologist" 7th Edition. Lippincott Williams &amp; Wilkins (Philadelphia) 2012. ISBN-13: 978-1-60831-193-4</li> <li>• Joiner, M. and van der Kogel A. (Eds) "Basic Clinical Radiobiology" 4th Edition. Hodder Arnold (London) 2009. ISBN: 978 0 340 929 667</li> </ul>		



<b>Course Title</b>	<b>Basic Cellular Biology /Radiobiology Lab</b>		
<b>Course no.</b>	<a href="#">2.4</a>	<b>Exam Regulations</b>	data evaluation / presentation / Report
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in course 2.3
<b>Workload</b>	30 h	<b>Max. Number of Participants</b>	40
<b>Type of Course</b>	Practical Course/ Lab (mandatory)	<b>Coordinator/ Lecturer</b>	PD Dr. C. Herskind, Prof. Dr. M.R. Veldwijk, PD Dr. P. Maier
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block Course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>▪ Basics of cell culture</li> <li>▪ Techniques in micro biology</li> <li>▪ Basics of molecular biology techniques (Flowcytometry, PCR, plasmid purification and restriction enzyme digest)</li> </ul>		
<b>Learning Objectives</b>	<ul style="list-style-type: none"> <li>• The students are able to use different kinds of pipettes, work with cell cultures under sterile conditions, and perform molecular biology techniques such as restriction digests, PCR, and agarose gel electrophoresis.</li> <li>• They are able to perform the necessary calculations of concentrations and dilutions, to explain the principles of cellular radiosensitivity assays, and to evaluate and to interpret cell-cycle analyses by FACS.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Practical sessions and presentation		
<b>Useful /Required Previous Knowledge</b>	Basics in Biology and Chemistry		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Hall, E. J. and Giaccia, A. J. "Radiobiology for the Radiologist" 7th Edition. Lippincott Williams &amp; Wilkins (Philadelphia) 2012. ISBN-13: 978-1-60831-193-4</li> <li>• Joiner, M. and van der Kogel A. (Eds) "Basic Clinical Radiobiology" 4th Edition. Hodder Arnold (London) 2009. ISBN: 978 0 340 929 667</li> </ul>		



<b>Course Title</b>	<b>Seminar Radiobiology</b>		
<b>Course no.</b>	<a href="#">2.5</a>	<b>Exam Regulations</b>	Presentation, min. 5 times presence in seminar / Protocol
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in courses 2.3
<b>Workload</b>	30h	<b>Max. Number of Participants</b>	40
<b>Type of Course</b>	Seminar (Elective)	<b>Coordinator/ Lecturer</b>	PD Dr. C. Herskind, Prof. Dr. M.R. Veldwijk
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	The topic depends on the current state of the art.		
<b>Learning Objectives</b>	<ul style="list-style-type: none"> <li>• The students are able to perform a literature search and read, understand, summarize, and present, a scientific paper.</li> <li>• The students are able to follow a scientific oral presentation, take part in scientific discussions, and formulate critical questions based on hypotheses related to the current state of the art</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Workflow: <ul style="list-style-type: none"> <li>• Attendance in the Journal Club Radiobiology (min. 5 times)</li> <li>• Presentation in Journal Club (1 time)</li> <li>• Report submission</li> </ul>		
<b>Useful /Required Previous Knowledge</b>	Basic knowledge of chemistry, cell and molecular biology, and oncological concepts		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the course.</li> </ul>		



## Module 3. Radiotherapy

<b>Course Title</b>	<b>Radiation Physics and Instrumentation</b>		
<b>Course no.</b>	<a href="#">3.1</a>	<b>Exam Regulations</b>	90 min Written Exam
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	60 h	<b>Max. Number of Participants</b>	40
<b>Type of Course</b>	Lecture / mandatory	<b>Coordinator/ Lecturer</b>	Mr. V. Steil, PD Dr. H. Wertz, Dr. Y. Abo-Madyan
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block Course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Foundations of radiotherapy</li> <li>• Medical Foundations of radiotherapy</li> <li>• Basic radiation physics</li> <li>• Dosimetric quantities and units</li> <li>• Radiation dosimeters and Monitoring</li> <li>• Basic of Linear Accelerators (Linac)</li> <li>• Physical aspects of photon beams</li> </ul>		
<b>Learning Objectives</b>	<ul style="list-style-type: none"> <li>• In this course, students learn the basics of radiation oncology, together with the understanding of medical indications. Upon completion of the lecture they are able to apply this knowledge using their physics background.</li> <li>• They understand, 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.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<ul style="list-style-type: none"> <li>• Lecture on basic of radiation physics and radiotherapy equipment.</li> <li>• Practical sessions. Introduction to Radiotherapy Department, Linac commissioning and treatment planning systems.</li> </ul>		
<b>Useful /Required Previous Knowledge</b>	General Knowledge in Physics and Mathematics.		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Course book: Radiation Oncology Physics: a Handbook for teachers and students. E.B. Podgorsak. 2005 <a href="http://www-pub.iaea.org/mtcd/publications/pdf/pub1196_web.pdf">http://www-pub.iaea.org/mtcd/publications/pdf/pub1196_web.pdf</a> complementary bibliography</li> <li>• A century in Radiology: <a href="http://www.xray.hmc.psu.edu/rci/">http://www.xray.hmc.psu.edu/rci/</a></li> <li>• Radiotherapy Physics: in Practice, Williams/Thwaites, Oxford University Press, 2000</li> <li>• The Physics of Radiation Therapy, Faiz M. Khan, Lippincott, 2003</li> <li>• Radiation Oncology – Management Decisions, Chao, Lippincott, 2002</li> </ul>		



<b>Course Title</b>	<b>Radiation Protection</b>		
<b>Course no.</b>	<a href="#">3.2</a>	<b>Exam Regulations</b>	45 min Written Exam
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	30 h	<b>Max. Number of Participants</b>	40
<b>Type of Course</b>	Lecture /mandatory	<b>Coordinator/ Lecturer</b>	Mr. V. Steil, Dr. Simeonova-Chergou.
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• medical and personal exposure</li> <li>• radiation shielding</li> <li>• Regulations / Responsibilities</li> <li>• International Radiation Protection</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students should be able to:</p> <ul style="list-style-type: none"> <li>• Describe and explain principles and basics of radiation protection</li> <li>• Estimate the risks of radiation</li> <li>• be aware of risk of radiation</li> <li>• have the competence for evaluating radiation protection, and estimate risk of radiation,</li> <li>• know and apply legal regulations for radiation exposure.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture		
<b>Useful /Required Previous Knowledge</b>	General Knowledge Nuclear Physics, Radiation Physics		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Course book: Radiation Oncology Physics: a Handbook for teachers and students. E.B. Podgorsak. 2005 <a href="http://www-pub.iaea.org/mtcd/publications/pdf/pub1196_web.pdf">http://www-pub.iaea.org/mtcd/publications/pdf/pub1196_web.pdf</a></li> <li>complementary bibliography</li> <li>• <a href="http://www.icrp.org">www.icrp.org</a></li> <li>• <a href="http://www.icrp.org/docs/Summary_B-scan_ICRP_60_Ann_ICRP_1990_Recs.pdf">http://www.icrp.org/docs/Summary_B-scan_ICRP_60_Ann_ICRP_1990_Recs.pdf</a> resp. complete ICRP Report 60</li> </ul>		



<b>Course Title</b>	<b>Radiation Treatment Planning and Quality Assurance</b>		
<b>Course no.</b>	<a href="#">3.3</a>	<b>Exam Regulations</b>	90 min Written Exam
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	Successful Participation in module M1 and courses 3.1 and 3.2
<b>Workload</b>	60	<b>Coordinator / Lecturer</b>	PD Dr. H. Wertz, Dr. M. Polednik, Prof. Dr. J. Hesser
<b>Type of Course</b>	Lecture/ Practical Course (Mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• 3D planning</li> <li>• Computerized treatment planning</li> <li>• dose algorithms</li> <li>• inverse planning and optimization (IMRT-VMAT) / dose prescription</li> <li>• individual patient QA</li> <li>• machine calibration/ acceptance and commissioning</li> <li>• machine QA</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students:</p> <ul style="list-style-type: none"> <li>• have a basic and detailed knowledge of relevant techniques in treatment planning and about the measurements of beam data</li> <li>• can deal with terms: dose prescription, normalization and distribution</li> <li>• have the knowledge of all steps in the chain in the 3D planning</li> <li>• have a basic and detailed knowledge of relevant techniques in treatment planning</li> <li>• can judge the plan quality using evaluation tools (Isodose lines, DVHs, statistics)</li> <li>• should have the competence to describe the typical parameters which have to be checked in a linac QA program</li> <li>• will perform typical QA measurements with dedicated detectors and will be able to analyse the results</li> <li>• can explain measurement methods to check typical linac parameters</li> <li>• can take relevant aspects, terms and definitions into account when setting up a QA program in a radiotherapy department</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<ul style="list-style-type: none"> <li>• Lecture</li> <li>• .Practical sessions: 3D-planning (4h), Linac QA (4h).</li> </ul>		
<b>Useful /Required Previous Knowledge</b>	Radiation Protection		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Radiation Oncology Physics: a Handbook for teachers and students. E.B. Podgorsak. 2005 <a href="http://www-pub.iaea.org/mtcd/publications/pdf/pub1196_web.pdf">http://www-pub.iaea.org/mtcd/publications/pdf/pub1196_web.pdf</a></li> </ul> <p>complementary bibliography</p> <ul style="list-style-type: none"> <li>• A century in Radiology: <a href="http://www.xray.hmc.psu.edu/rci/">http://www.xray.hmc.psu.edu/rci/</a></li> <li>• Radiotherapy Physics: in Practice, Williams/Thwaites, Oxford University Press, 2000</li> <li>• The Physics of Radiation Therapy, Faiz M. Khan, Lippincott, 2003</li> <li>• ESTRO Publications:1. Monitor Unit Calculation for High Energy Photon Beams /2. Recommendations for a Quality Assurance Programme in External Radiotherapy /3. Practical Guidelines for the Implementation of a Quality System in Radiotherapy</li> </ul>		





<b>Course Title</b>	<b>Treatment Planning and Quality Assurance Lab</b>		
<b>Course no.</b>	<a href="#">3.4</a>	<b>Exam Regulations</b>	data evaluation /Report
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	Participation in courses 3.1, 3.2 and 3.3
<b>Workload</b>	30h	<b>Coordinator / Lecturer</b>	PD. Dr. Wertz, Dr. M. Polednik, Dr. S. Clausen
<b>Type of Course</b>	Practical Course/ Lab (elective)	<b>Max. Number of Participants</b>	20
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Person dosimetry, radiation protection from architectural side</li> <li>• Practical exercises for quality assurance of workflow and treatment planning system (system geometry, dosimetry)</li> <li>• Basic MU calculation</li> <li>• Dosimetry with different detector systems (ionization chamber, solid state detector, film dosimeter) in different measurement systems (water phantom, water equivalent solid phantom etc.)</li> <li>• 3D planning</li> <li>• QA Lab</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students are able to:</p> <ul style="list-style-type: none"> <li>• apply their theoretical knowledge by measuring in phantoms for dosimetry and quality assurance.</li> <li>• Can do basic treatment and dose calculation for patient delivery.</li> <li>• Can understand the whole 3D planning chain.</li> <li>• Is able to prescribe dose in different ways</li> <li>• Can generate plans with fix SSD and isocentric techniques</li> <li>• Can homogenize dose using different wedge thicknesses</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Practical session at the Radiotherapy Department.		
<b>Useful /Required Previous Knowledge</b>	Students should apply basics in radiation protection in real situation / perform treatment planning / apply dosimetry / and perform quality assurance		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Radiation Oncology Physics: a Handbook for teachers and students. E.B. Podgorsak. 2005 <a href="http://www-pub.iaea.org/mtcd/publications/pdf/pub1196_web.pdf">http://www-pub.iaea.org/mtcd/publications/pdf/pub1196_web.pdf</a></li> </ul> <p>complementary bibliography</p> <ul style="list-style-type: none"> <li>• A century in Radiology: <a href="http://www.xray.hmc.psu.edu/rci/">http://www.xray.hmc.psu.edu/rci/</a></li> <li>• Radiotherapy Physics: in Practice, Williams/Thwaites, Oxford University Press, 2000</li> <li>• The Physics of Radiation Therapy, Faiz M. Khan, Lippincott, 2003</li> <li>• ESTRO Publications:1. Monitor Unit Calculation for High Energy Photon Beams /2. Recommendations for a Quality Assurance Programme in External Radiotherapy /3. Practical Guidelines for the Implementation of a Quality System in Radiotherapy</li> </ul>		



<b>Course Title</b>	<b>Image Guided Radiotherapy</b>		
<b>Course no.</b>	<a href="#">3.5</a>	<b>Exam Regulations</b>	45 min Written Exam
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	Successful Participation in module M1 and courses 3.1, 3.2 and 3.3.
<b>Workload</b>	30 h	<b>Coordinator / Lecturer</b>	PD Dr. H. Wertz, Dr. A. Arns, Dr. L. Jahnke
<b>Type of Course</b>	Lecture / Elective	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Techniques of patient positioning and target location in radiation therapy (simulation, portal imaging, positioning support systems/mask systems), inaccuracies herein concerning positioning accuracy and dosimetry)</li> <li>• Localization by ultrasound margin concepts</li> <li>• Localization by 2D X-ray (portal imaging, Fiducial markers)</li> <li>• 3D-CT (Cone Beam CT, Gantry Mounted Volume Imaging)</li> <li>• Motion management techniques</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students are be able to:</p> <ul style="list-style-type: none"> <li>• Describe the principles and basics of image guided radiotherapy and adaptive RT</li> <li>• Explain a typical QA process for image guidance systems</li> <li>• Explain the typical workflow for IGRT for different systems</li> <li>• Name major goals of IGRT and ART</li> <li>• Name uncertainties during radiotherapy such as set-up errors, organ movements or organ deformations</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture Practical session (4h)		
<b>Useful /Required Previous Knowledge</b>	General Knowledge Nuclear Physics, Radiation Physics, imaging systems, radiation therapy		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the lecture.</li> </ul>		



<b>Course Title</b>	<b>Special Radiotherapy Techniques</b>		
<b>Course no.</b>	<a href="#">3.6</a>	<b>Exam Regulations</b>	90 min Written Exam
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	Successful Participation in courses 3.1, 3.2 and 3.3.
<b>Workload</b>	60	<b>Coordinator / Lecturer</b>	Dr. F. Stieler, Dr. L. Jahnke, Dr. J. Fleckenstein, Dr. M. Polednik; Dr. S. Clausen; PD. Dr. Wertz
<b>Type of Course</b>	Lecture /elective	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Brachytherapy</li> <li>• Intra Operative Radiotherapy (IORT)</li> <li>• Total Body Radiation (TBI)</li> <li>• Stereotactic radiotherapy</li> <li>• advanced delivery methods</li> <li>• Particle therapy</li> <li>• Adaptive therapy</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students:</p> <ul style="list-style-type: none"> <li>• have a thorough knowledge and understanding of innovative radio-oncologic methods for cancer treatment.</li> <li>• are be able to asses a practically use of them depending on the disease of patient and available resources in a radiotherapy facility.</li> <li>• Describe the principles and basics of Seeds implantations and Afterloading.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture		
<b>Useful /Required Previous Knowledge</b>	General Knowledge radiation physics, radiation planning, Dosimetry and quality assurance in radiology and radiotherapy		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• The GEC/ESTRO Handbook of Brachytherapy, Gerbaulet, ESTRO Publishing, 2002</li> <li>• Intensity-Modulated Radiation Therapy, Webb, Institute of Physics Publishing, 2001</li> <li>• Inverse planning algorithms for external beam radiation therapy, Chui, Med. Dosim, 2001</li> <li>• AAPM Report on IMRT, Ezzell et al., Med. Phys. 30, 2003</li> <li>• Radiation Oncology Physics: A Handbook for Teachers and Student, E.B. Podgorsak, INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2005</li> </ul>		



<b>Course Title</b>	<b>Lab Medical Physics in Radiotherapy</b>		
<b>Course no.</b>	<a href="#">3.7</a>	<b>Exam Regulations</b>	Presentation/Report/Exercises
<b>Credit Points</b>	5.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in course 3.1, 3.2, 3.3 and 3.4
<b>Workload</b>	150 h	<b>Coordinator / Lecturer</b>	PD Dr. H. Wertz; Dr. A. Arns, Dr. C. Nwankwo, Dr. L. Jahnke, Dr. J. Fleckenstein.
<b>Type of Course</b>	Lab / elective	<b>Max. Number of Participants</b>	15
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Practical exercises for quality assurance of workflow and treatment planning system (system geometry, dosimetry) – “end-to-end”-test.</li> <li>• Dosimetry with different detector systems (ionization chamber, solid state detector, film dosimeter) in different measurement systems (water phantom, water equivalent solid phantom etc.)</li> <li>• Patient Treatment planning (different tumour sites).</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students are able to:</p> <ul style="list-style-type: none"> <li>• Describe the typical workflow for external radiotherapy with linacs</li> <li>• Perform CT scans for different phantoms</li> <li>• Design treatment plans and QA plans for different phantoms</li> <li>• Deliver the QA plans with a linac</li> <li>• Measure the QA plans with dedicated detector systems</li> <li>• Analyse the results of the measurements with dedicated software</li> <li>• Describe how an “End-to-End” test can be performed for checking a typical radiotherapy chain</li> <li>• Create a scientific report about a given project</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Practical session at the Radiotherapy Department including the dedicate computer tomography, the linear accelerator and the treatment planning systems available. A report must be submitted at the end of the lab.		
<b>Useful /Required Previous Knowledge</b>	General Knowledge radiation physics, radiation planning, Dosimetry and quality assurance in radiology and radiotherapy		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the course.</li> </ul>		



<b>Course Title</b>	<b>Seminar Radiation Therapy: Journal Club + Presentation</b>		
<b>Course no.</b>	<a href="#">3.8</a>	<b>Exam Regulations</b>	Presentation, min. 5 times presence in seminar
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in courses 3.1, 3.2, 3.3
<b>Workload</b>	60 h	<b>Coordinator / Lecturer</b>	PD Dr. H. Wertz
<b>Type of Course</b>	Seminar / elective	<b>Max. Number of Participants</b>	15
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<p>The topic depends on the current state of the art and the supervising lab. Workflow:</p> <ul style="list-style-type: none"> <li>• Attendance in the Journal Club Radiation Therapy (min. 5 times)</li> <li>• Presentation in Journal Club (1 time)</li> <li>• Report submission</li> <li>•</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students:</p> <ul style="list-style-type: none"> <li>• are able to take part in scientific discussions</li> <li>• is capable to work on literature research for a topic related to current state of the art in radio therapy and related fields and present it.</li> <li>• Create a suitable scientific presentation</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<p>Workflow:</p> <ul style="list-style-type: none"> <li>• Attendance in the Journal Club Radiobiology (min. 5 times)</li> <li>• Presentation in Journal Club (1 time)</li> </ul> <p>Report submission</p>		
<b>Useful /Required Previous Knowledge</b>	General Knowledge radiation physics, radiation planning, Dosimetry and quality assurance in radiology and radiotherapy		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the course.</li> </ul>		



## Module 4. Medical Imaging

<b>Course Title</b>	<b>Physics of Imaging Systems</b>		
<b>Course no.</b>	<a href="#">4.1</a>	<b>Exam Regulations</b>	90 min Written Exam
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	60 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad
<b>Type of Course</b>	Lecture (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	6 week course
<b>Contents of Course:</b>	<p>physical basics of imaging systems:</p> <ul style="list-style-type: none"> <li>• conventional X-ray</li> <li>• Computer Tomography CT</li> <li>• Magnetic Resonance Imaging MRI</li> <li>• Sonography/ Ultrasound</li> <li>• Medical Equipment</li> </ul>		
<b>Learning Objectives</b>	<p>After completion of this course students will:</p> <ul style="list-style-type: none"> <li>• be able to describe the physical basics of the imaging systems mentioned</li> <li>• capable to apply gained knowledge image acquisition, processing and analysis</li> <li>• gain skills to optimize or/and to develop further imaging technology</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture on imaging systems ( 4h/per week)		
<b>Useful /Required Previous Knowledge</b>	General basics in physics.		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Medical Imaging Physics, Hende/Ritenour, Wiley-Liss, 2002</li> <li>• Bildgebende Systeme für die medizinische Diagnostik, Morneburg, 1995</li> <li>• Computertomographie. Grundlagen, Gerätetechnologie, Bildqualität, Anwendungen, Kalender, 2006</li> <li>• Magnetic Resonance Imaging Theory and Practice, Vlaardingerbroek/den Boer, 2003</li> </ul>		



<b>Course Title</b>	<b>Biomedical Optics</b>		
<b>Course no.</b>	<a href="#">4.2</a>	<b>Exam Regulations</b>	45 min Written Exam
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in module 4.4
<b>Workload</b>	30 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad
<b>Type of Course</b>	Lecture (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	6 week course
<b>Contents of Course:</b>	<p>physical basics of biomedical optics</p> <ul style="list-style-type: none"> <li>basics of geometrical optics: reflection- and refraction law, dispersion, polarization</li> <li>physical basics of optics: particle/wave dualism, Maxwell laws</li> <li>basics of laser physics: principals, interaction with matter, laser-properties and – systems</li> <li>biomedical applications: lasers in medicine, microscopy, etc.</li> </ul>		
<b>Learning Objectives</b>	<p>After completion of this course students will be able to:</p> <ul style="list-style-type: none"> <li>describe basic physical principles in optics and lasers</li> <li>select appropriate hardware for biomedical experiments using optics</li> <li>experiment with laser systems in medical applications</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture and exercises.		
<b>Useful /Required Previous Knowledge</b>	General basics in physics and optics		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>E. Hecht and A. Zajac, Optics, Addison Wesley, International 4<sup>th</sup> ed., 2003</li> <li>M. Born and E. Wolf, Principles of optics: Electromagnetic theory of propagation, Cambridge University Press, 2002</li> <li>M.H. Niemz, Laser-Tissue Interactions: Fundamentals and Applications (Biomedical and Medical Physics, Biomedical Engineering), Springer, 3<sup>rd</sup> enlarged ed., 2003</li> <li>L.O. Björn, Photobiology, Springer, 2008</li> </ul>		



<b>Course Title</b>	<b>Biomedical Engineering + Exercises</b>		
<b>Course no.</b>	<a href="#">4.3</a>	<b>Exam Regulations</b>	90 min Written Exam
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in course 1.1.
<b>Workload</b>	60 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad, PD Dr. F. Zöllner
<b>Type of Course</b>	Lecture (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	7 weeks course
<b>Contents of Course:</b>	Basic Physics of biomedical engineering: <ul style="list-style-type: none"> <li>• Blood Pressure &amp; Flow</li> <li>• High Frequency Radio Pulses</li> <li>• Electrophysiology Measurements Techniques and Modelling</li> <li>• Ultrasound</li> <li>• Elastography</li> </ul>		
<b>Learning Objectives</b>	After completing this course the students will be able to: <ul style="list-style-type: none"> <li>• describe fundamental principles of biomedical engineering topics</li> <li>• design and perform experiments in this field</li> <li>• model and solve simple systems in the biomedical field</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<ul style="list-style-type: none"> <li>• Lecture to teach the basic concepts</li> <li>• Exercise to learn and rehearse the topics of the lecture</li> </ul>		
<b>Useful /Required Previous Knowledge</b>	Basics in Physics and Mathematics		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Medical Physics and Biomedical Engineering, Brown et al., 1999</li> <li>•</li> </ul>		





<b>Course Title</b>	<b>Basic Optic</b>		
<b>Course no.</b>	<a href="#">4.4</a>	<b>Exam Regulations</b>	45 min Written Exam
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	Successful Participation in M1, course 2.1, 2.2
<b>Workload</b>	30	<b>Coordinator / Lecturer</b>	Prof. Dr. J. Bille
<b>Type of Course</b>	Lecture /elective	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Geometric optics: reflection, refraction, dispersion, polarization</li> <li>• Optical aberration</li> <li>• Gauss-optics</li> <li>• Diffraction optics</li> <li>• Interferometry</li> <li>• Optical resolution, human eye, optical instruments</li> </ul>		
<b>Learning Objectives</b>	<p>After completing this course the students:</p> <ul style="list-style-type: none"> <li>• Have a thorough knowledge of the basic elements of geometric optics apply lens equations for optical systems, diffraction theory.</li> <li>• perform interfereometrical measurement methods.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture on optics		
<b>Useful /Required Previous Knowledge</b>	General knowledge in optics		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• E. Hecht, Physics, Brooks/Cole Publishing Company, 1994</li> <li>• P. Tipler, Physics, Worth Publishers Inc., 1982</li> <li>• M. Born and E. Wolf, Principles of optics: Electromagnetic theory of propagation, Cambridge University Press, 2002</li> </ul>		



<b>Course Title</b>	<b>MR-Radiology Lab</b>		
<b>Course no.</b>	<a href="#">4.5</a>	<b>Exam Regulations</b>	presentation and data evaluation
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in course 4.1
<b>Workload</b>	30 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad
<b>Type of Course</b>	Practical Course/ Lab (elective)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	4 weeks course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Practical training in image acquisition with MRI (phantom experiments)</li> <li>• Characteristics of conventional imaging sequences regarding tissue contrast, artefacts (T1, T2)</li> <li>• Characteristics of fast imaging sequences</li> <li>• Application of special sequences (angiography, diffusion tensor imaging, functional MRI)</li> <li>• Practical training in MR- spectroscopy</li> </ul>		
<b>Learning Objectives</b>	<p>Students will be able to:</p> <ul style="list-style-type: none"> <li>• describe the technique of MR- spectroscopy</li> <li>• apply gained experimental knowledge on MRI in their own scientific or work related projects</li> <li>• perform MRI scans</li> <li>• process and to analyse MR images and spectra</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<ul style="list-style-type: none"> <li>• Lab will be performed at a clinical whole body scanner</li> </ul>		
<b>Useful /Required Previous Knowledge</b>	General basics in physics and MRI		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Medical Imaging Physics, Hende/Ritenour, Wiley-Liss, 2002</li> </ul>		

<b>Course Title</b>	<b>Seminar MR Methods and Technology: Journal Club + Presentation</b>		
<b>Course no.</b>	<a href="#">4.6</a>	<b>Exam Regulations</b>	Presentation, min. 5 times presence in seminar
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in courses 4.1
<b>Workload</b>	60 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad
<b>Type of Course</b>	Seminar (elective)	<b>Max. Number of Participants</b>	6
<b>Turn</b>	Half-yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Weekly course
<b>Contents of Course:</b>	The topic depends on the current state of the art in imaging techniques and the supervising lab (M4).		
<b>Learning Objectives</b>	<p>The students will be able to:</p> <ul style="list-style-type: none"> <li>• take part in scientific discussions,</li> <li>• formulate a topic related to the current state of the art.</li> <li>• present current research topics .</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<p>Workflow:</p> <ul style="list-style-type: none"> <li>• Attendance in the Journal Club Imaging (min. 5 times)</li> <li>• Presentation in Journal Club (1 time)</li> <li>• Report submission.</li> </ul>		
<b>Useful /Required Previous Knowledge</b>	Basic understanding in physics and mathematics		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the course.</li> </ul>		



<b>Course Title</b>	<b>Nuclear Medicine + Exercises</b>		
<b>Course no.</b>	<a href="#">4.7</a>	<b>Exam Regulations</b>	90 min Written Exam
<b>Credit Points</b>	4.0	<b>Formalities or Requirements for Participation</b>	Successful participation in courses 3.1: Radiation Protection, and 3.2: Radiation Physics and Instrumentation, and 4.1: Physics of Imaging Systems
<b>Workload</b>	120 h	<b>Coordinator / Lecturer</b>	Prof. Dr. Gerhard Glatting
<b>Type of Course</b>	Lecture with Exercises (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Summer semester
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Basic physics of imaging and therapy with radioactive substances</li> <li>• Nuclear Medicine instrumentation (gamma camera, SPECT, PET)</li> <li>• Basic radiochemistry / radiopharmacy</li> <li>• Clinical nuclear medicine (scintigraphy, immunoscintigraphy, SPECT, PET)</li> <li>• Modelling in nuclear medicine</li> <li>• Molecular radiotherapy (radioiodine therapy, radioimmunotherapy, peptide receptor radionuclide therapy)</li> <li>• Evaluation of diagnostic systems</li> <li>• Combination of nuclear medicine and other modalities (PET/CT, SPECT/CT)</li> <li>• Applications</li> </ul>		
<b>Learning Objectives</b>	<p>After completing the course the students should be able to:</p> <ul style="list-style-type: none"> <li>• describe and explain the principles used in nuclear medicine and the function of the imaging devices</li> <li>• describe the desired characteristics of radionuclides for nuclear medicine</li> <li>• analyse malfunctions of imaging devices using the acquired concepts and techniques, to formulate models and find solutions to specific problems, and to communicate them efficiently,</li> <li>• perform a basic dosimetry and treatment planning in molecular radiotherapy,</li> <li>• evaluate diagnostic systems with respect to basic imaging characteristics.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<ul style="list-style-type: none"> <li>• Lecture on Medical Physics in "Nuclear Medicine" (16 hours)</li> <li>• Exercises (8 hours)</li> </ul>		
<b>Useful /Required Previous Knowledge</b>	Knowledge in radiation physics and medical imaging.		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Physics in Nuclear Medicine. SR Cherry, JA Sorenson, ME Phelps. 4<sup>th</sup> ed. Philadelphia, Pennsylvania: Saunders/Elsevier 2012.</li> <li>• Medical Imaging Physics, Hendee/Ritenour, Wiley-Liss, 2002</li> <li>• Announced by the lecturer</li> </ul>		



<b>Course Title</b>	<b>Lab Medical Physics in Imaging</b>		
<b>Course no.</b>	<a href="#">4.8</a>	<b>Exam Regulations</b>	Presentation/ Report/ Exercises/ Exam
<b>Credit Points</b>	5.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in courses 4.1.
<b>Workload</b>	150 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad
<b>Type of Course</b>	Lab (mandatory)	<b>Max. Number of Participants</b>	20
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• MRI hardware setup</li> <li>• Basic settings and preparation of MRI system (Frequency adjusts, flip angle, shim)</li> <li>• Recording FID signal, influence on the signal, etc.</li> <li>• Relaxation time measurements and data analysis in probes of water and oil</li> </ul>		
<b>Learning Objectives</b>	<p>Students will be able to:</p> <ul style="list-style-type: none"> <li>• describe the principle of the MR signal generation and relaxation concept.</li> <li>• apply gained experimental knowledge on MRI in their own scientific or work related projects.</li> <li>• perform MRI scans.</li> <li>• calculate relaxation time constants from MR datasets</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<p>Introductory lecture to introduce the content of the lab and to introduce the handling of the MRI system Exercises in small groups using a table top MRI system</p>		
<b>Useful /Required Previous Knowledge</b>	Basic Knowledge in Physics		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• A dedicated script describing the experiments to be performed by the students will be provided at the start of the course</li> </ul>		



<b>Course Title</b>	<b>Seminar Physics of Advanced MRI / CT Techniques</b>		
<b>Course no.</b>	<a href="#">4.9</a>	<b>Exam Regulations</b>	Presentation, Report and 75% attendance
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in courses 4.1
<b>Workload</b>	60 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad, PD Dr. F. Zöllner, Dr. J. Zapp, Dr. A. Neubauer, Dr. J Charcon, Dr. S. Domsch, Dipl. phys. M. Ruttorf
<b>Type of Course</b>	Seminar (Elective)	<b>Max. Number of Participants</b>	20
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Weekly course
<b>Contents of Course:</b>	The topic depends on the current state of the art in physical basics of imaging and/or diagnostic techniques including MRI and CT. Respective papers are selected and distributed among the attendees.		
<b>Learning Objectives</b>	<p>The students will be able to:</p> <ul style="list-style-type: none"> <li>• take part in scientific discussions,</li> <li>• formulate a topic related to the current state of the art</li> <li>• present current research topics .</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<p>Workflow:</p> <ul style="list-style-type: none"> <li>• Attendance in the Journal Club Imaging (75%)</li> <li>• Presentation in Journal Club (1 time)</li> <li>• Report submission.</li> </ul>		
<b>Useful /Required Previous Knowledge</b>	Basic Knowledge in Physics and medical imaging systems.		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the course.</li> </ul>		

<b>Course Title</b>	<b>Advanced Imaging Techniques</b>		
<b>Course no.</b>	<a href="#">4.10</a>	<b>Exam Regulations</b>	90 min Written Exam
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in module M1 and course , 4.1, 4.5 or 4.9
<b>Workload</b>	60 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad, PD Dr. F. Zöllner
<b>Type of Course</b>	Lecture (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<p>Physical foundations of advanced imaging techniques:</p> <ul style="list-style-type: none"> <li>a) Perfusion Imaging &amp; Pharmacokinetic Modelling</li> <li>b) Diffusion MRI</li> <li>c) X-Nuclei Imaging</li> <li>d) Cone Beam CT</li> <li>e) Iterative Reconstruction Techniques in CT/CBCT</li> </ul>		
<b>Learning Objectives</b>	<p>After completing the course the students will be able to:</p> <ul style="list-style-type: none"> <li>• describe thoroughly advanced MRI and CT imaging methods.</li> <li>• apply these techniques in scientific or work related tasks.</li> <li>• To analyse imaging data previously acquired</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture with exercises		
<b>Useful /Required Previous Knowledge</b>	General knowledge in medical imaging		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the course.</li> </ul>		



<b>Course Title</b>	<b>Medical Devices and Imaging Systems</b>		
<b>Course no.</b>	<a href="#">4.11</a>	<b>Exam Regulations</b>	120 min Written Exam
<b>Credit Points</b>	4.0	<b>Formalities or Requirements for Participation</b>	successful attendance in course 4.1 and 4.5
<b>Workload</b>	120 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad
<b>Type of Course</b>	Lecture (elective)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Weekly course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Basic Physics of MRI</li> <li>• Concept of spin relaxation</li> <li>• Preparation of Magnetization, Pulses etc.</li> <li>• Hardware for MRI</li> <li>• Image coding using gradient system. k-space</li> </ul>		
<b>Learning Objectives</b>	<p>Students will be able to:</p> <ul style="list-style-type: none"> <li>• describe and report on the fundamental details of MRI</li> <li>• describe advanced imaging concepts in MRI</li> <li>• apply this knowledge in their scientific projects or work related duties</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<p>Lecture to teach the theoretical aspects          Exercises to rehearse the lectures          Labs including experiments on a table top MRI and a visit at a clinical whole body systems</p>		
<b>Useful /Required Previous Knowledge</b>	General basics in physics.		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Spin Dynamics: Basics of Nuclear Magnetic Resonance, Levitt, Wiley, 2001.</li> <li>• Magnetic Resonance Imaging Theory and Practice, Vlaardingerbroek/den Boer, 2003</li> </ul>		





<b>Course Title</b>	<b>MRT Basics</b>		
<b>Course no.</b>	<a href="#">4.12</a>	<b>Exam Regulations</b>	90 min Written Exam
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	successful attendance in module 4.1 and 4.2
<b>Workload</b>	Lecture 30 h Self-Study 20 h Preparation for Exam 10 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad
<b>Type of Course</b>	Lecture (elective)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	weekly course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Advanced techniques of Imaging in MRI</li> <li>•</li> </ul>		
<b>Learning Objectives</b>	<p>Students will be able to:</p> <ul style="list-style-type: none"> <li>• describe and report on the fundamental details of MRI</li> <li>• describe advanced imaging concepts in MRI</li> <li>• apply this knowledge in their scientific projects or work related duties</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture		
<b>Useful /Required Previous Knowledge</b>	General basics in physics.		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Magnetic Resonance Imaging Theory and Practice, Vlaardingerbroek/ den Boer, 2003</li> </ul>		



<b>Course Title</b>	<b>X-Ray Diagnostic and Sonography</b>		
<b>Course no.</b>	<a href="#">4.13</a>	<b>Exam Regulations</b>	90 min Written Exam
<b>Credit Points</b>	2.0	<b>Formalities or Requirements for Participation</b>	successful attendance in module 4.1
<b>Workload</b>	Lecture 30 h Self-Study 20 h Preparation for Exam 10 h	<b>Coordinator / Lecturer</b>	Prof. Dr. L. Schad/ PD Dr. F. Zöllner
<b>Type of Course</b>	Lecture (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Weekly course
<b>Contents of Course:</b>	Advanced techniques of Imaging Systems/ Diagnostics <ul style="list-style-type: none"> <li>• Conventional X-ray</li> <li>• Sonography/ Ultrasound</li> </ul>		
<b>Learning Objectives</b>	After completing the course the students will be able to describe or report on the physical basics of conventional X-ray and Sonography		
<b>Course Parts and Teaching Methods</b>	Lecture		
<b>Useful /Required Previous Knowledge</b>	General basics in physics.		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Medical Imaging Physics, Hende/Ritenour, Wiley-Liss, 2002</li> </ul>		



## Module 5. Computational Medical Physics

<b>Course Title</b>	<b>Image Analysis + Exercises</b>		
<b>Course no.</b>	<a href="#">5.1</a>	<b>Exam Regulations</b>	Oral Exam
<b>Credit Points</b>	4.0	<b>Formalities or Requirements for Participation</b>	Successful attendance in course 1.2 and 4.1
<b>Workload</b>	120 h	<b>Coordinator / Lecturer</b>	Prof. Dr. J.W. Hesser
<b>Type of Course</b>	Lecture (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Weekly course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Digitalization of image information/ relevant data formats</li> <li>• Mathematical methods of image transformation, digital filtering (linear, non-linear), Fourier- transform, segmentation, registration and pattern recognition</li> </ul>		
<b>Learning Objectives</b>	<p>After completing the course the students</p> <ul style="list-style-type: none"> <li>• have a thorough knowledge and understanding of the principles using image analysis and should be able to apply this knowledge in concrete practical applications</li> <li>• have competence in the solution of image analysis tasks covered by this course, i.e. the ability to apply the image processing workflow using the acquired concepts and techniques, to formulate models and find solutions to specific problems, and to communicate them efficiently,</li> <li>• are able to broaden their knowledge and competence in this field on their own by systematic study of the literature and thus solving new image analysis problems.</li> </ul>		
<b>Course Parts and Teaching Methods</b>			
<b>Useful /Required Previous Knowledge</b>	none		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Medical Image Processing, Gonzalez/Woods/Eddin, Pearson, 2004</li> </ul>		



<b>Course Title</b>	<b>Matlab Programming</b>		
<b>Course no.</b>	<a href="#">5.2</a>	<b>Exam Regulations</b>	Exam (Written/Oral/Exercises/Report)
<b>Credit Points</b>	4.0	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	120 h	<b>Coordinator / Lecturer</b>	Prof. Dr. J.W. Hesser
<b>Type of Course</b>	Lecture / Practical Course (elective)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• User interfaces</li> <li>• Advanced Matlab programming skills</li> <li>• Typical applications where Matlab is applied in the master thesis</li> </ul>		
<b>Learning Objectives</b>	<p>After completing the course the students</p> <ul style="list-style-type: none"> <li>• have a thorough knowledge and understanding of the principles using advanced programming techniques and should be able to apply this knowledge in concrete practical applications</li> <li>• have competence in the solution of programming tasks covered by this course, i.e. the ability to apply numerical methods using the acquired concepts and techniques, to formulate models and find solutions to specific problems, and to communicate them efficiently,</li> <li>• are able to broaden their knowledge and competence in this field on their own by systematically studying of the literature and solving new problems with this extended knowledge.</li> <li>•</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Lecture with practical sessions. The exercises should be solve with tutoring advice.		
<b>Useful /Required Previous Knowledge</b>	Basic knowledge of programming in Matlab		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• <a href="http://www.lmsc.ethz.ch/Teaching/ipss_2010/advancedProgramming.pdf">http://www.lmsc.ethz.ch/Teaching/ipss_2010/advancedProgramming.pdf</a></li> <li>• <a href="http://jagger.berkeley.edu/~pack/e177/">http://jagger.berkeley.edu/~pack/e177/</a></li> <li>• <a href="http://www.mathworks.cn/programs/downloads/presentations/MasterClassA_AdvancedProgramming.pdf">http://www.mathworks.cn/programs/downloads/presentations/MasterClassA_AdvancedProgramming.pdf</a></li> </ul>		



<b>Course Title</b>	<b>Simulator in Games and Medicine + Exercises (advanced)</b>		
<b>Course no.</b>	<a href="#">5.3</a>	<b>Exam Regulations</b>	Exam (Written/Oral/Exercises/Report)
<b>Credit Points</b>	8.0 3 (Lecture) 5 (Exercises)	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	240 h	<b>Coordinator / Lecturer</b>	Prof. Dr. J. Hesser
<b>Type of Course</b>	Lecture and Exercise (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Basic components of simulation engine (games)</li> <li>• Architecture of games engines</li> <li>• Introduction of OGRE as an open-source game engine</li> <li>• Overview: graphics and computer games</li> <li>• Collision engine</li> <li>• Animation and physics engine (open-source library Bullet)</li> <li>• Path planning engine</li> <li>• AI (artificial intelligence) engine</li> <li>•</li> </ul>		
<b>Learning Objectives</b>	<p>After completing the course the students</p> <ul style="list-style-type: none"> <li>• have a thorough knowledge and understanding of the principles used in computer game engines in order to be able to develop an own game engine</li> <li>• have acquired the necessary knowledge and competence for an understanding of this research field and hence being able to assess efficient and suited solutions for given problems</li> <li>• have competence in the interdisciplinary field of computer games covered by this course, i.e. the ability to develop serious game applications including graphics systems, physics systems, and AI-systems, and to communicate this efficiently,</li> <li>• are able to broaden their knowledge and competence in this field on their own by systematically studying of the literature in order to apply the newly learned techniques to given or new tasks.</li> <li>•</li> </ul>		
<b>Course Parts and Teaching Methods</b>			
<b>Useful /Required Previous Knowledge</b>	Previously gained background in C++.		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Gregory et al: Game Engine Architecture</li> <li>• Ericson: Real-Time Collision Detection</li> <li>• Eberly: Game Physics</li> <li>• Millington: Artificial Intelligence for Games</li> </ul>		



<b>Course Title</b>	<b>Volume Visualization + Exercises (advanced)</b>		
<b>Course no.</b>	<a href="#">5.4</a>	<b>Exam Regulations</b>	Exam (Written/Oral/Exercises/Report)
<b>Credit Points</b>	8.0 2 (Lecture) 6 (Exercises)	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	240 h	<b>Coordinator / Lecturer</b>	Prof. Dr. J. Hesser
<b>Type of Course</b>	Lecture (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Computer Graphics basics</li> <li>• Conversion into surface and volume grids</li> <li>• Sampling and approximation theory</li> <li>• Volume rendering</li> <li>• Vector and information visualization</li> <li>• Programming technique: GPU- programming</li> </ul>		
<b>Learning Objectives</b>	<p>After completing the course the students</p> <ul style="list-style-type: none"> <li>• have a thorough knowledge and understanding of the principles used in visualizing scalar scientific data in order to develop visualization strategies for given problems</li> <li>• have acquired the necessary knowledge and competence for an understanding of this research field and being able to assess the most appropriate technique for a given problem</li> <li>• have competence in the interdisciplinary field of volume visualization covered by this course, i.e. the ability to analyse data, interpolate data and extract useful information using the acquired concepts and techniques, to formulate models and find solutions to specific problems, and to communicate them efficiently,</li> <li>• are able to broaden their knowledge and competence in this field of volume visualization on their own by systematically studying of the literature in order to apply the newly learned techniques to given or new tasks.</li> <li>•</li> </ul>		
<b>Course Parts and Teaching Methods</b>			
<b>Useful /Required Previous Knowledge</b>	Previously gained background in C++		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Engel et al: Real-Time Volume Graphics: <a href="http://www.real-time-volume-graphics.org">www.real-time-volume-graphics.org</a>,</li> <li>• Schroeder et al: VTK Textbook: <a href="http://www.kitware.com/products/books/vtkbook.html">http://www.kitware.com/products/books/vtkbook.html</a></li> </ul>		



<b>Course Title</b>	<b>Inverse Problems + Exercises (advanced)</b>		
<b>Course no.</b>	<a href="#">5.5</a>	<b>Exam Regulations</b>	Exam (Written/Oral/Exercises/Report)
<b>Credit Points</b>	<b>8.0</b> 2 (Lecture) 6 (Exercises)	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	240 h	<b>Coordinator / Lecturer</b>	Prof. Dr. J. Hesser
<b>Type of Course</b>	Lecture and Exercise (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Examples of inverse problems, especially tomography and deblurring</li> <li>• Deterministic approaches, Tikhonov regularization</li> <li>• Stochastic methods (Bayesian techniques)</li> <li>• Estimating the regularization parameter</li> <li>• Compressed sensing</li> </ul>		
<b>Learning Objectives</b>	<p>After completing the course the students</p> <ul style="list-style-type: none"> <li>• have a thorough knowledge and understanding of the principles used in inverse problems and are able to apply this to a given problem</li> <li>• have acquired the necessary knowledge and competence for an understanding of this research field and to correctly identify the most suited method for a given task</li> <li>• have competence in the interdisciplinary field of inverse problems covered by this course, i.e. the ability to analyse given inverse problems and find appropriate solvers and regularization techniques,</li> <li>• are able to broaden their knowledge and competence in this field of inverse problems on their own by systematically studying of the literature in order to apply the new techniques to given or new problems.</li> </ul>		
<b>Course Parts and Teaching Methods</b>			
<b>Useful /Required Previous Knowledge</b>	none		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Vogel: Computational Methods for Inverse Problems</li> <li>• <a href="http://www.math.montana.edu/~vogel/Book/">http://www.math.montana.edu/~vogel/Book/</a></li> </ul>		



<b>Course Title</b>	<b>Computational Medical Physics Lab (advanced)</b>		
<b>Course no.</b>	<a href="#">5.6</a>	<b>Exam Regulations</b>	Presentation/ Report/Exercises/Exam
<b>Credit Points</b>	5.0	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	150 h	<b>Coordinator / Lecturer</b>	Prof. Dr. J. Hesser
<b>Type of Course</b>	Lab (mandatory)	<b>Max. Number of Participants</b>	12
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>• Methods of non-linear numerical analysis – eLearning-course</li> <li>• GPU programming – hands-on-course with examples</li> <li>• Mathematical models in medical physics and biomedical optics such as – eLearning course</li> </ul>		
<b>Learning Objectives</b>	<p>After completing the course the students</p> <ul style="list-style-type: none"> <li>• have a thorough knowledge and understanding of the principles used in computational medical physics and are able to apply this to a given problem</li> <li>• have acquired the necessary knowledge and competence for an understanding of this research field and to correctly identify the most suited method for a given task</li> <li>• are able to broaden their knowledge and competence in this field in order to apply the new techniques to given or new problems.</li> </ul>		
<b>Course Parts and Teaching Methods</b>			
<b>Useful /Required Previous Knowledge</b>	none		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the course.</li> </ul>		





## Module 6. Abroad Courses

<b>Course Title</b>	<b>Shanghai Workshop</b>		
<b>Course no.</b>	<a href="#">6.1</a>	<b>Exam Regulations</b>	presentation / Oral exam
<b>Credit Points</b>	1.0	<b>Formalities or Requirements for Participation</b>	none
<b>Workload</b>	30 h	<b>Coordinator / Lecturer</b>	Prof. Dr. F. Wenz, Prof. Dr. J. Hesser,
<b>Type of Course</b>	workshop (elective)	<b>Max. Number of Participants</b>	20
<b>Turn</b>	Yearly	<b>Term</b>	Summer
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<p>The schedule of the workshop in Shanghai covers one week. Both Shanghai Jiao Tong University and Mannheim Faculty, University of Heidelberg, provide about 8-hour lectures.</p> <p>The lectures cover the topics:</p> <ul style="list-style-type: none"> <li>• Radiotherapy, Nuclear Medicine: <ul style="list-style-type: none"> <li>• Modern Radiation Oncology (Shanghai Jiao Tong University)</li> <li>• Image Guided Radiotherapy (University of Heidelberg)</li> <li>• Hyperthermia (University of Heidelberg)</li> </ul> </li> <li>• Biomedical Optics (Shanghai Jiao Tong University)</li> </ul> <p>Additionally, the students join the "Annual Sino-German Radiation Oncology Symposium".</p>		
<b>Learning Objectives</b>	<p>After completing the course the students can:</p> <ul style="list-style-type: none"> <li>• name and explain recent developments and current research activities in radiotherapy and biomedical optics.</li> <li>• communicate with students from other institutions about radiotherapy and biomedical optics</li> <li>• use their broadened knowledge in culture in order to efficiently conduct mutual research projects between both institutions to solve typical problems in biomedical engineering.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	Attendances of lecture and the Sino-German workshop in Shanghai, China. At the end of the workshop will be done an oral examination.		
<b>Useful /Required Previous Knowledge</b>	Basic knowledge of programming in Radiotherapy		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>• Will be given at the beginning of the workshop.</li> </ul>		



## Module 7. Master Thesis Preparation

<b>Course Title</b>	<b>General Sciences Skills</b>		
<b>Course no.</b>	<a href="#">7.1</a>	<b>Exam Regulations</b>	Presentation / Report /Protocol
<b>Credit Points</b>	3.0	<b>Formalities or Requirements for Participation</b>	The course 7.1. should be running simultaneously or before this course.
<b>Workload</b>	90 h	<b>Coordinator / Lecturer</b>	Prof. Dr. M.R. Veldwijk, Prof. Dr. J. Sleeman
<b>Type of Course</b>	Workshop (mandatory)	<b>Max. Number of Participants</b>	20
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<p>The students receive a topic/theme (i.e. future master thesis topic).</p> <ul style="list-style-type: none"> <li>Following the theme, the students work on the state of the art, write a short report and present it.</li> <li>The students learn how to get new ideas through special techniques like brainstorming. They have to structure these ideas and develop a research plan/proposal. A report has to be written.</li> </ul> <p>A tutor will introduce the students to each task and will guide them through their work.</p>		
<b>Learning Objectives</b>	<p>After completing the course the students:</p> <ul style="list-style-type: none"> <li>gain knowledge to plan a scientific work</li> <li>are capable to gain information about the state of the art in an specific scientific field related to any of the three specialization offered in the master program</li> <li>are able to write and review grant proposals and how to gain new ideas in a research field.</li> </ul>		
<b>Course Parts and Teaching Methods</b>	<p>Lecture Report Presentation</p>		
<b>Useful /Required Previous Knowledge</b>	none		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>Will be given at the beginning of the course.</li> </ul>		



<b>Course Title</b>	<b>Specialized Lab Project</b>		
<b>Course no.</b>	<a href="#">7.2</a>	<b>Exam Regulations</b>	Protocol to Practical Course
<b>Credit Points</b>	16.0	<b>Formalities or Requirements for Participation</b>	Formal registration / Successful attendance in General Science Skills (course 7.1.) and the course 3.7 and 4.9as well as, if possible, another specialized seminar in order to know the basics of planning and control of scientific lab projects.
<b>Workload</b>	480 h	<b>Coordinator / Lecturer</b>	
<b>Type of Course</b>	Scientific Lab (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	The topic depends on the supervising department.		
<b>Learning Objectives</b>	After completing the course the students are able to apply the knowledge learned in theoretical courses in a practical application that is related to the foci of the BME-study program. The project should introduce into a special field of application, where the students should show that they are able to apply given techniques to solve practical problems including e.g. the scientific approach, protocol writing of experiments. Thereafter, they have the knowledge and experience to perform a scientifically oriented master thesis.		
<b>Course Parts and Teaching Methods</b>	This course could be joined with the final master thesis. The students should search by him/her self for a topic of his/her interests approaching any of the research groups belonging to any of specializations offered in the Master Program. External projects or internship are also possible after competition of internal requirements.		
<b>Useful /Required Previous Knowledge</b>	none		
<b>Recommended Literature</b>	Depending on the topic of the project.		



## Module 8. Master Thesis

<b>Course Title</b>	<b>Master Thesis</b>		
<b>Course no.</b>	<a href="#">8.1</a>	<b>Exam Regulations</b>	Written Thesis, colloquium (public Oral presentation with discussion), final Oral examination about thesis and whole content of the attended lectures
<b>Credit Points</b>	30.0	<b>Formalities or Requirements for Participation</b>	Formal registration / Successful attendance in all Modules M1, M 2, M7 and specialized courses from M3, M4, M5 (related to the individual specialization of the student)
<b>Workload</b>	4 months (daily)	<b>Coordinator / Lecturer</b>	Independent scientific work (supervised)
<b>Type of Course</b>	Thesis (mandatory)	<b>Max. Number of Participants</b>	40
<b>Turn</b>	Yearly	<b>Term</b>	Winter
<b>Language</b>	English	<b>Duration</b>	Block course
<b>Contents of Course:</b>	<ul style="list-style-type: none"> <li>The topic and contents depend on the supervising department.</li> </ul>		
<b>Learning Objectives</b>	After completing the course the students are able to work independently on a scientific topic, guided by a tutor. They can search and analyse literature as well as formulate/organize and perform an experiment.		
<b>Course Parts and Teaching Methods</b>			
<b>Useful /Required Previous Knowledge</b>	none		
<b>Recommended Literature</b>	<ul style="list-style-type: none"> <li>Topic-related.</li> </ul>		

