Module handbook for the study program

Master of Science
Medical Physics and Physics of Living Systems
(MMP-PLS)

of TU Dortmund University

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Contents

General remarks

To avoid inconsistencies, each module offered by the faculty appears in the module handbook of only one (!) degree program.

Responsible Person
As is common in most physics departments and faculties, required courses and major electives rotate among instructors; therefore, module descriptions do not include instructor names but responsible Persons.

Work Load
The work load of one credit point corresponds to 30 hours of work. The work load quoted in the description of the modules below represents the typical work load associated with the modules.

Mode of delivery
All courses are planned to be delivered face-to-face, but the mode of delivery can be changed in agreement with the students or external constraints. While distance learning is possible for most lectures and seminars, it is difficult to maintain for laboratory courses.

Examinations
Most modules are completed by an examination. If the type of examination is not fixed in the module description it has to be specified by the examiner no later than two weeks after the start of the course. Details about the examinations, e.g. the length and the announcement procedure, are detailed in §9 of the Master's Examination Regulation.

Teaching methods
The teaching methods used depend on the type of course:
- “Lecture” (L)for lecture-type courses and seminars given by invited speakers
- “Problem-based learning” (T) for tutorials/exercise sessions, e.g. in theoretical physics
- “Seminar” (S) for presentations prepared by students
- “Directed discussion” for an in-class discussion of the presented material organized by the teacher
- “Laboratory method” (P) for lab experiments conducted by the students and under supervision
- “Research” for the Master thesis and internships

Teachers can deviate from the teaching methods indicated given personal preferences

Description of the study program

The Master of Science in Medical Physics and Physics of Living Systems program has a standard period of study of 4 semesters and a total number of 120 credit points (CP). It is divided into a study phase (1^{st} - 3^{rd} semester) with 75 CP and a research phase (3^{rd} - 4^{th} semester) with 45 CP.

The program offers two tracks, from which one has to be chosen:

Track A: Medical Physics

Track B: Physics of Living Systems

Each Track combines a number of mandatory courses (core curriculum) as well as electives. While the core curriculum assures a high standard in order to pass the program, a wide range of electives enables the students to match their individual interests in this fast-growing field.

All students are divided into one of three study pathways according to their previous training in medical physics before starting the Master programme. To align students' basic knowledge of medical physics, there are “synchronisation courses”, which are credited in the elective area.

Study Phase

During the study phase, modules from four different areas must be taken.

1. Synchronisation (9 CP)

   Students are assigned to one of three course plans (1, 2, 3) based on their subject-specific prior knowledge (i.e., their Bachelor’s degree). A synchronisation course is assigned to each of these course plans. For students assigned to course plan 2 or 3, the synchronisation course is compulsory. For students assigned to the course plan 1, the synchronisation course is optional and they can choose elective courses instead to reach their full CPs.

Plan	**Bachelor’s degree**	**Synchronisation course**	**CP**
1	Medical Physics	*Free electives*	9
2	Physics	Biomedical Physics	9
3	Biomedical Engineering, Biophysics or related subjects	Theoretical Physics	9

   Exception: If the assigned synchronisation course has been successfully attended within the Bachelor’s program, students have to choose elective courses instead to reach their full CPs.

2. Fundamentals of thermodynamics and statistics (Mandatory) (13/14 CP)

   Within the Fundamentals of thermodynamics and statistics the students need to select courses in statistics and thermodynamics. Students have to choose one of the following two courses:

Modules	**CP**
Wahrscheinlichkeitsrechnung und mathematische Statistik	4

(German)	
Statistical methods of data analysis A (English)	5

As well as one of the courses thermodynamics/statistical physics:

Modules	**CP**
Thermodynamik und Statistik (German)	9
Thermodynamics and Statistical Physics (RUB, English)	9

Exception: If any of the courses has been successfully attended within the Bachelor’s program, students have to choose elective courses instead to reach their full CPs.

3. Area of specialization (39 CP)

In the master of Medical Physics and Physics of Living Systems, a specialisation track must be taken:

Track	**CP**
A) Medical Physics	39
B) Physics of Living Systems	39

The module representatives are:

Track	**Module representative**
A) Medical Physics	Prof. Dr. Armin Lühr
B) Physics of Living Systems	Prof. Dr. Matthias Schneider

4. Free electives (13-14 CP)

Free electives can be chosen from a large selection of courses. Students can explore their interest within both possible tracks, i.e., every course that is part of a specialisation track can also be chosen as a free elective. Additionally, a variety of modules with different topics is provided. An overview of courses can be found below. The division into subject areas is for clarity purposes only.

Research Phase

In the 3rd and 4th semester, the focus shifts to research. Parallel to remaining courses in the 3rd semester, there is a research internship to prepare for the Master's thesis. The 4th semester is dedicated to the Master’s thesis.

Module	**CP**
Research internship for the Master's thesis	15
Master’s thesis and presentation	30
Sum	45

Typical Course Timelines (Examples)

*Table 1: Example for students with a **B. Sc. in Medical Physics** (**NO** Synchronisation Course) studying **Track A Medical Physics***

	Semester	**Fundamentals of Thermo-dynamics and statistics**	**Track A: Medical Physics**	**Electives/ Synchroni-sation courses**	**Master‘s thesis**	**Total**
Study Phase	**1**		Advanced Clinical Medical Physics 6 CP	Radiation Applications in the Clinic 3 CP		29 CP
			Advanced Medical Imaging 6 CP	Ultrasound in Medicine 5 CP		
			AI for Medical Applications 9 CP			
	2	Statistical Methods of Data Analysis A 5 CP	Medical Physics and Technology in Particle Therapy 3 CP	Methods of Clinical Research 5 CP		31 CP
		Thermo-dynamics and Statistical Physics 9 CP	Advanced Magnetic Resonance Imaging 6 CP			
			Fundamentals of Detector Physics 3 CP			
Research Phase	**3**		TPS - Practical Course on Treatment-Planning 6 CP	Applications of Machine Learning in Medical Physics 3 CP	Research Internship 15 CP	30 CP
				Physics of Life 6 CP		
	4				Master’s thesis 30 CP	30 CP
	Sum:	14 CP	39 CP	22 CP	45 CP	120 CP

*Table 2: Example for students with a **B. Sc. in Medical Physics** studying **Track A Medical Physics**.*

	Semester	Fundamentals of Thermo-dynamics and statistics	Track A: Medical Physics	Electives/ Synchroni-sation courses	Master's thesis	Total
Study Phase	1		Advanced Clinical Medical Physics 6 CP	Modern Radiation Therapy 6 CP		33 CP
			Advanced Medical Imaging 6 CP	Physics of life 6 CP		
			AI for Medical Applications 9 CP			
	2	Statistical Methods of Data Analysis A 5 CP	Applied Proton Therapy 6 CP	Computational Physics 9 CP		30 CP
		Thermo-dynamics and Statistical Physics 9 CP		Basic radiation protection regulation for medical physics experts 1 CP		
Research Phase	3		Radiation Applications in the Clinic 3 CP		Research Internship 15 CP	27 CP
			TPS - Practical Course on Treatment-Planning 6 CP			
			Applications of Machine Learning in Medical Physics 3 CP			
	4				Master's thesis 30 CP	30 CP
	Sum:	14 CP	39 CP	22 CP	45 CP	120 CP

*Table 3: Example for students with a **B. Sc. in Biomedical Engineering** (Synchronisation Course **Theoretical Physics** (WS)) studying **Track A Medical Physics**.*

	Semester	**Fundamentals of Thermo-dynamics and statistics**	**Track A: Medical Physics**	**Electives/ Synchroni-sation courses**	**Master's thesis**	**Total**
Study Phase	**1**		Advanced Clinical Medical Physics 6 CP	**Synch. Course** Theoretical Physics 9 CP		29 CP
			Advanced Medical Imaging 6 CP	Ultrasound in Medicine 5 CP		
				Applied Physics in Clinical Medicine 3 CP		
	2	Statistical Methods of Data Analysis A 5 CP	Advanced Magnetic Resonance Imaging 6 CP	Methods of Clinical Research 5 CP		31 CP
		Thermo-dynamics and Statistical Physics 9 CP	Applied Proton Therapy 6 CP			
Research Phase	**3**		Radiation Applications in the Clinic 3 CP		Research Internship 15 CP	30 CP
			AI for Medical Applications 9 CP			
			Applied Dosimetry 3 CP			
	4				Master's thesis 30 CP	30 CP
	Sum:	14 CP	39 CP	22 CP	45 CP	120 CP

*Table 4: Example for students with a **B. Sc. in Physics** (Synchronisation Course **Biomedical Physics** (WS)) studying **Track B Physics of Living Systems**.*

	Semester	Fundamentals of Thermo-dynamics and Statistics	Track B: Physics of Living Systems	Electives/ Synchroni-sation courses	Master's thesis	Total CP
Study Phase	1		Physics of Life 6 CP	**Synch. Course** Biomedical physics 9 CP		30 CP
			AI for Medical Applications 9 CP	Advanced Medical Imaging 6 CP		
	2	Thermodynamic and Statistical Physics 9 CP	Lab PLS 5 CP			29 CP
		Statistical methods of data analysis A 5 CP	Tissue Engineering 4 CP			
			Soft Matter 6 CP			
Research Phase	3		MD – Soft Matter and Biomaterials 6CP	Detector systems in particle and medical physics 3 CP	Research Internship 15 CP	32 CP
			Biomaterials 4 CP	Applied Phys in Clinical Med 3 CP		
	4				Master's thesis 30 CP	30 CP
	Sum:	14 CP	40 CP	21 CP	45 CP	120 CP

Table 5: Example for students with a ***B. Sc. Biomed Eng*** *(Synchronisation Course* ***Theoretical Physics*** *(WS)) studying* ***Track B Physics of Living Systems****.*

	Semester	Fundamentals of Thermo-dynamics and Statistics	Track B: Physics of Living Systems	Electives/ Synchroni-sation courses	Master's thesis	Total CP
Study Phase	**1**		Physics of Life 6 CP	**Synch. Course** Theoretical Physics 9 CP		30 CP
			AI for Medical Applications 9 CP	Advanced Medical Imaging 6 CP		
	2	Thermodynamic and Statistical Physics 9 CP	Lab PLS 5 CP			29 CP
		Statistical methods of data analysis A 5 CP	Fundamental Immunology 4 CP			
			Soft Matter 6 CP			
Research Phase	**3**		MD – Soft Matter and Biomaterials 6CP	Detector systems in particle and medical physics 3 CP	Research Internship 15 CP	32 CP
			Biomaterials 4 CP	Applied Phys in Clinical Med 3 CP		
	4				Master's thesis 30 CP	30 CP
	Sum:	14 CP	40 CP	21 CP	45 CP	120 CP

Detailed module descriptions

Synchronisation courses

Module: Biomedical Physics (Synch Course)				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. sem.	**Credits** 9	**Work load** 270 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture	L	6	4
		Tutorial	T	3	2
2	**Language: English**				
3	**Content**				

I. **Physics of Physiology & Biophysics**

1) History of the Role of Physics in Medicine. How Biology stimulated physics and how physics stimulated biology
2) Thermodynamics: The first and 2nd Law and its statistical interpretation. Diffusion
   Math Section: Probability Theory
3) Energetics and physical chemistry in living systems, chem. Potential and puffer systems; Blood oxygenation (Allostery)
4) Biomolecules and The Cell: From Material to Protein Folding
5) Hydrodynamics of Blood flow, viscosity, FL Effect and Blood Clotting
   Math Section: The Navier Stokes Equation
6) The Heart as a mechanical pump; The heart as a muscle
   Math Section: Elasticity Theory
7) Membranes & Introduction to Neuroscience
8) Physics of hearing; resonance, impedance and non-linear oscillators
   Math Section: The Wave Equation
9) Physics of the eye

II. Medical Physics: Imaging tools

1) X-Ray and Computed Tomography (CT)
   Math Section: Fourier Transformation, Convolution
2) Magnetic Resonance Imaging (MRI)
3) Ultrasound
4) EKG and Blood Pressure
5) Modern Tools: Cell Mechanics, Microfluidics, PCR, CTC, DNA-Squeezing, FACS…
6) Tool in challenging Environments: Socioeconomic Considerations

4	**Learning outcome** After successfully completing the module students – recognize the complexity of biological processes and the necessity of having multiple physical concepts ready to understand these processes quantitively. – are able to transform physical principles and knowledge to problems of living systems and medical applications. – can apply physical concepts of elasticity theory in membrane mechanics and the physics of hearing. – can apply the principles of hydrodynamics to understand physical foundation of blood flow and blood clotting. They understand blood as a complex fluid in contrast to “simple” fluids like water and air. – will have an overview of diagnostically relevant tools and their physical principles. – are able to apply mathematical tools to reconstruct an image from x-ray, MRI and ultrasound studies. – are up to date on recent developments in diagnostic tools. – can apply physical concepts to minimize effort, prerequisites and costs of modern medical tools as may (for instance) become necessary in socioeconomic challenged communities.	
5	**Examination** Graded exam (120 min) or oral exam (30 min), will be announced at the beginning of the course	
6	**Participation Requirements** No	
7	**Module type** Elective module/ mandatory module	
8	**Responsible** Prof. Dr. Matthias Schneider	**Faculty in charge** Department of Physics

Module: Theoretical Physics (Synch Course)				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. sem.	**Credits** 9	**Work load** 270 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture	L	6	4
		Tutorial	T	3	2
2	**Language: English**				

3 **Content**

I. Theoretical Mechanics

1) Elements of classical Newtonian mechanics, conservation laws (momentum, angular momentum energy), 2-body problem with central force
2) Stationary action principle, Lagrangian mechanics, Hamiltonian mechanics
3) Conservation laws, dynamics in phase space, Poisson brackets, overview nonlinear dynamics

II. Quantum Mechanics

1) Limits of classical physics
2) 5 postulates, wave functions, operators, uncertainty relation, Hamiltonian, Schrödinger equation, correspondence principle, Ehrenfest theorem
3) Harmonic oscillator, potential well, potential step, tunneling
4) Angular momentum operator, spin, normal Zeeman effect
5) Hydrogen atom
6) Perturbation theory, hyperfine structure, Stark, anomalous Zeeman effect

4 **Learning outcome**

The students are familiar with the principles and laws of classical theoretical mechanics and quantum mechanics as outlined in the course content and can apply them, i.e. they can classify phenomena of physics and microphysics in the context of abstract models and establish connections to the appropriate concepts of mathematics.

5 **Examination**
Study achievements: homework
Graded exam (180 min) or oral exam (30 min), will be announced at the beginning of the course

6 **Participation Requirements**
No

7 **Module type**
Elective module/ mandatory module

8	**Responsible**	**Faculty in charge**
	Prof. Dr. Jan Kierfeld	Department of Physics

Fundamentals of thermodynamics and statistics

Module: Statistical Methods of Data Analysis / SMD A (PHY523a)
Degree Program: B.Sc. Physik, B.Sc. Medizinphysik, M.Sc. Physics, MMPPLS

https://physik.tu-dortmund.de/en/study/courses-and-qualification/bachelor-physik/module-handbook/

Module: Wahrscheinlichkeitsrechnung und mathematische Statistik (Informatik) (**GW02**)				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: in WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 4	**Work load** 120 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture + Tutorial	L+T	4	4
2	**Language:** Deutsch				
3	**Content** Characteristics and data types, statistical key figures for univariate and bivariate data (location, scatter, connection). Probability spaces and basics of statistical modeling. Random variables and their distributions, important probability distributions. Conditional probabilities and stochastic independence. expected value and variance; Markoff chains. Estimation, statistical tests and confidence intervals				
4	**Learning outcome** After successfully completing the module – Students understand the basics of statistical modeling – Students can apply the statistical methods presented				
5	**Examination** Study achievements: homework, module examination: graded exam (max. 120 min)				
6	**Participation Requirements** No				
7	**Module type** Elective module/ mandatory module				
8	**Responsible** Dean of the Faculty of Statistics	**Faculty in charge** Department of Statistics			

Module: Thermodynamik und Statistik (**PHY531**)
Degree Program: Bachelor Physics (B.Sc.), B.Sc. Medizinphysik, IMAPP, Lehramt, MMPPLS

https://physik.tu-dortmund.de/en/study/courses-and-qualification/bachelor-physik/module-handbook/

Module: Thermodynamics and Statistical Physics (RUB)				
Degree Program: Master Physics (M. Sc.), RUB				
Frequency: in SS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 9	**Work load** 180 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture + Tutorial	L+T	6	4+2
2	**Language:** English				
3	**Content** Quantum statistics and classical statistical mechanics, thermodynamics, applications. Starting point is the simple statistics of many particles, thermodynamics is derived from this. Afterwards quantum statistics with applications				
4	**Learning outcome** After successfully completing this module, the students – Have a basic understanding of the concepts of statistical mechanics – Know the fundamental concepts of quantum statistics – Are familiar with fundamental definitions of classical and quantum mechanical statistical physics – Can solve typical problems of non-interacting multi-particle physics				
5	**Examination** Written examination of 120 min				
6	**Participation Requirements** Formal: None Content: Knowledge of the contents of “Introduction to Quantum Mechanics and Statistics” (Bachelor) will be expected Preparation: None				
7	**Module type** Elective module/ mandatory module				
8	**Responsible** Prof. Dr. Sulpizi	**Faculty in charge** Department of Physics (RUB)			

https://www.physik.ruhr-uni-bochum.de/en/studies/degree-programs/bachelor-of-science/modulhandbuecher-b-sc/

Track A: Medical physics

Mandatory courses	**Sem.**	**CP**
Advanced Clinical Medical Physics	WS	6 CP
Advanced Medical Imaging	WS	6 CP
AI for Medical Applications	WS	9 CP
Elective courses		
Radiotherapy and Dosimetry		
Radiation applications in the clinic	WS	3 CP
Modern Radiation Therapy	WS	6 CP
Medical Physics and Technology in Particle Therapy	SS	3 CP
Applied Proton Therapy	SS	6 CP
TPS – Practical Course on Treatment Planning	WS + SS	6 CP
Basic radiation protection regulation for medical physics experts	SS	1 CP
Fundamentals of Detector Physics	SS	3 CP
Angewandte Dosimetrie	SS	3 CP
Medical Imaging and Machine Learning		
Advanced Magnetic Resonance Imaging	SS	6 CP
Image Processing in Medicine	SS	5 CP
Ultrasound in Medicine	WS	5 CP
Applications of Machine Learning in Medical Physics	WS	3 CP

The following modules are of particular interest with regard to a later career as a clinical medical physics expert:

- Advanced Clinical Medical Physics
- Advanced Medical Imaging
- Radiation applications in the clinic
- Modern Radiation Therapy
- Medical Physics and Technology in Particle Therapy
- Applied Proton Therapy
- TPS – Practical Course on Treatment Planning
- Basic radiation protection regulation for medical physics experts (German)
- Applied Dosimetry

Mandatory courses

Module: Advanced Clinical Medical Physics				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 6	**Work load** 180 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture	L	6	4
2	**Language: English**				
3	**Content** Dosimetry and radiation therapy: 1) Dosimetry: basic terms and definitions of clinical dosimetry, secondary electron balance, cavity theory, Bragg-Gray theory, detectors, types clinical. Dosimeter, dosimeter for special applications, water absorbed dose concept incl., calorimetric representation, calibration of dosimeters teletherapy and brachytherapy, legal basis for metrological controls, dose measurement method according to DIN 6800-2 2) Physics and technology of the electron linear accelerator 3) Introduction to the basics of the therapeutic forms of brachytherapy and proton therapy on the eye: Modalities of brachytherapy, therapy indications, target volume localization, therapy planning, therapy implementation, applicators and forms of application, afterloading brachytherapy, intravascular brachytherapy, eye tumor brachytherapy, proton therapy on the eye, research projects in the field of brachytherapy 4) Introduction to the basics and implementation of radiotherapy (teletherapy) for tumor patients: Biological basics: types of radiation, dose-effect relationships, cell survival curves, linear-quadratic model, fractionation. Radiation therapy treatment chain: patient positioning and immobilization, 3D imaging as the basis for radiation planning, concept of contouring of target volumes and organs at risk, radiation planning (choice of technique, dose calculation, plan assessment), patient positioning on the device, verification procedures. Conformational radiotherapy: requirements, possibilities, limits. Intensity-modulated radiation therapy as a modern development: Inverse radiation planning, method for implementing intensity-modulated techniques on conventional linear accelerators. Helical tumor therapy as an alternative concept. Dosimetric verification of intensity-modulated irradiations. Approaches to improve the accuracy of beam application: Stereotactic radiation therapy. Image-guided radiation therapy. Problems and possible solutions in the irradiation of respiratory tumors. Practical demonstration at the University Hospital Essen: Implementation of image-guided, intensity-modulated radiation therapy on the phantom. 5) Quality assurance in radiotherapy Imaging procedures and radiation protection: 6)X-ray imaging: Generation and absorption of X-rays, image formation, detectors and films, applications of X-ray imaging, e.g. DEXA, mammography, classic X-ray image 7) Tomographic methods CT, PET, SPECT: Functional principle, technical basics, combination devices, radiation detectors, image acquisition and reconstruction, basics of contrast agent application, basics for the comparability and quantification of CT examinations based on HU values, quantification methods (PET), Production, use and effects of radiopharmaceuticals, 8) Radiation protection: How can patients and staff be protected from the ionizing radiation from imaging procedures? The dose exposures of the various imaging procedures are presented.					
4	**Learning outcome** After successfully completing the module, students will have acquired knowledge in the field of radiation therapy and imaging, which is typically one of the requirements for medical physics experts. The students 1. are familiar with the basics of dosimetry and its applications, 2. have acquired in-depth knowledge of the physical and technical fundamentals of radiation therapy and the functional principles of imaging techniques, 3. know the advantages and disadvantages and the technical limitations of teletherapy and brachytherapy and imaging methods, 4. are familiar with the biological and technical requirements as well as the process of treatment with ionizing radiation and the physical principles of imaging procedures using ionizing radiation. 5. understand the connections between ionizing radiation. Radiation protection, diagnostic methods, dosimetry, biological effectiveness of ionizing radiation and radiation therapy.					

5	**Examination** will be announced at the beginning of the course	
6	**Participation Requirements** Basic knowledge of radiation physics and the interaction of radiation and matter is required. These can be acquired, for example, by successfully participating in the "Strahlungsphysik I" module of the bachelor's degree program in Medical Physics at TU Dortmund University.	
7	**Module type** Elective module/ mandatory module	
8	**Responsible** Prof. Dr. Andreas Block (Klinikum Dortmund)	**Faculty in charge** Department of Physics

Module: Advanced Medical Imaging				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 6	**Work load** 180 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture + Tutorial	L+T	6	4
2	**Language: English**				

3 Content

The "Advanced Medical Imaging" module provides students with advanced concepts, technologies and applications of medical imaging. It covers a wide range of imaging techniques used in modern clinical diagnostics and research. The focus is on the theoretical foundations of image processing, the functioning of the various imaging procedures, including the meaning and clinical relevance of the imaged quantities, their clinical application and their current limitations.

The module will cover the following key topics:

- Introduction to imaging technologies: Historical development and current technologies.
- Basics of image processing: image quality, filtering, noise reduction, reconstruction.
- Imaging techniques and their clinical relevance:
  - Magnetic resonance imaging (MRI) and functional MRI
  - Computed tomography (CT)
  - Positron emission tomography (PET) and single photon emission tomography (SPECT)
  - Ultrasound (US) and optical imaging (OI)
  - Hybrid imaging techniques (e.g. PET/CT, PET/MRI)
- Image analysis and interpretation: quantitative analysis, image segmentation and registration and 3D modeling.
- Clinical applications: Tumor diagnostics, cardiology, neurology, radiology, minimally invasive surgery.
- Future of medical imaging: artificial intelligent (AI) and machine learning in image processing, new imaging techniques and their potential applications.

4 Learning outcome

Upon successful completion of this module, students will be able to:

- Explain the principles and technologies behind advanced medical imaging techniques.
- Compare the advantages and limitations of imaging modalities such as MRI, CT, PET, SPECT, US, and OI.
- Apply image processing and analysis techniques to interpret medical images and assist in clinical decision-making.
- Understand the role of imaging in personalized medicine and clinical research.
- Discuss current trends and future directions in medical imaging, including the use of AI and machine learning.

5 Examination

Will be announced at the beginning of the course

6 Participation Requirements

Basic knowledge on physics and technology of medical imaging as provided by the courses "Medical Physics II" or "Biomedical Physics (Synch Course)" is desirable, but not mandatory for understanding the topics in this course.

7 Module type

Elective module/ mandatory module

8	**Responsible** Prof. Dr. A. Lühr PD Dr. habil rer. nat. Mona Salehi Ravesh	**Faculty in charge** Department of Physics

Module: AI for Medical Applications				
Degree Program: MMPPLS, M.Sc. Physics, M.Sc. Computer Science, M.Sc. Applied Computer Science				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 9	**Work load** 270 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture (2h) + Tutorial (4h)	L+T	9	6
2	**Language: English**				
3	**Content** • Motivation – What are the goals and what tools are required to attain them? • Medical Data – Types, Standards & Multimodality • Machine Learning Basics I & II • Basic and advances Computer Vision with Deep Learning. What does the computer see? • Natural Language Processing – From Basics to Large Language models. How does the computer read? • Introduction to Generative AI – GAN and Diffusion models • Timeseries Analysis with classical methods and AI • Introduction to AI Agents • What else is there? Pointers to other methods and bleeding edge developments. Exercises accompanying the lecture content. The algorithms and approaches are implemented and evaluated using real medical data sets. Students will have access to a learning platform with GPUs to train their models.				
4	**Learning outcome** • Participants will be able to assess the importance of AI in medicine • Know about types of medical data and how to handle it • Understand how to apply classic machine learning and AI algorithms to medical images and clinical text • After the course, participants will be able to familiarize themselves independently with more advanced AI procedures and apply (i.e. programming) them to the medical domain				
5	**Examination** Graded exam (120 min) or oral exam (30 min), will be announced at the beginning of the course				
6	**Participation Requirements** • Solid programming skills in Python or similar language • Experience with git, ssh and command line tools desirable				
7	**Module type** Mandatory module				
8	**Responsible** Prof. Dr. Dr. Jens Kleesiek, Prof. Dr. Michael Kamp		**Faculty in charge** Medical Faculty UDE / Department of Physics		

Elective courses

Module: Radiation applications in the clinic				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 3	**Work load** 90 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Seminar	S	3	Single appointments + block course
2	**Language:** English				
3	**Content** Basics, clinical applications and current developments in research in the areas of radiation therapy, nuclear medicine, radiology and medical radiation protection. An overarching focus topic is determined for each seminar series. Possible topics include, for example, the biological effects of radiation, physical measurement methods in clinical environments or current treatment and diagnostic options and their limitations. In addition to technical aspects of the methods, their relevance and requirements in the clinical environment should also be discussed.				
4	**Learning outcome** By completing the module, students have acquired in-depth knowledge of clinical aspects of medical physics that are used in the areas of radiation therapy, nuclear medicine, radiology and medical radiation protection. You can identify the basic physical principles of diagnostic and therapeutic methods and understand their interaction as well as practical limitations in applying the principles due to the complex patient situation. You are able to familiarize yourself with a complex subject area independently and present the essential content in an understandable and convincing manner. You have knowledge of modern presentation techniques and can use them. They can defend their point of view in a scientific discussion.				
5	**Examination** Provision of academic achievement. The coursework is achieved in the form of a lecture and participation in the discussion of other lectures.				
6	**Participation requirements** Basic knowledge of medical physics and radiation physics is required. These can be acquired, for example, by successfully participating in the “Medizinphysik II” or “Strahlungsphysik I” module of the bachelor's degree program in Medical Physics at the TU Dortmund.				
7	**Module type** Elective module				
8	**Responsible** Prof. Dr. Armin Lühr (TUDo)			**Faculty in charge** Department of Physics	
9	**Teachers** Prof. Dr. Armin Lühr (TUDo), Prof. Dr. Andreas Block and Dr. Katharina Loot (Klinikum Dortmund)				

Module: Modern Radiation Therapy				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 6	**Work load** 180 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture + Tutorial	L+T	6	4
2	**Language: English**				
3	**Content** Radiotherapy is multifaceted, and the complexity of tumor treatment requires the use of different radiotherapy modalities and technical solutions to achieve optimal treatment results. The lecture provides an introduction to modern radiotherapy: - Imaging procedures in radiotherapy (repetition) - Structure recognition, segmentation and registration in radiotherapy - State of the art of photon therapy - Stereotaxy and radiosurgery - Radiotherapy with charged particles - Temporal-spatial fractionation in radiotherapy - FLASH therapy - 4D radiotherapy (for mobile tumors) - Adaptive radiotherapy - MRI-based radiotherapy - Boron neutron capture therapy - Brachytherapy and intraoperative radiotherapy - Radiotherapy for pregnant patients				
4	**Learning outcome** After successfully completing the module, students can: - Describe and differentiate the various modern radiation techniques such as Intensity Modulated Radiation Therapy (IMRT), Volumetric Modulated Arc Therapy (VMAT), helical tomotherapy, sterotaxy, image-guided radiation therapy (IGRT), adaptive radiation therapy, charged particle therapy and brachytherapy for optimal cancer treatment and for different tumor types. - Differentiate the conceptual applications of imaging techniques and in vivo dosimetry procedures in modern radiation techniques. - Evaluate the risk of secondary tumors after radiotherapy.				
5	**Examination** Course credits: active participation Module examination: oral examination or written examination				
6	**Participation Requirements**				
7	**Module type** Elective module				
8	**Responsible** Dr. A. Hammi		**Faculty in charge** Department of Physics		

Module: Medical physics and technology of particle therapy				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: SS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 3	**Work load** 90 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture	L	3	2
2	**Language: English**				
3	**Content** Radiation effect of higher-energy protons and other nuclei, radiobiological effect, beam generation by cyclotron or synchrotron, Bragg peak, range calculation, spread out Bragg peak, functional principle and design of the systems with gantry and radiator head, different beam types and corresponding radiator heads for proton therapy, radiation planning: concepts and clinical case studies				
4	**Learning outcome** After successfully completing the module, students will be able to understand and categorize the basics and applications of particle therapy. They know the difference in lateral and depth dose profiles due to the completely different nature of interactions in tissue between photons and particles (protons). You are familiar with the various beam generation techniques. In addition, they understand the methods for beam expansion and depth modulation. You can name the essential elements of the complex irradiation systems and explain their function. They can apply the principles of appropriate biological and physical radiation treatment planning.				
5	**Examination** will be announced at the beginning of the course				
6	**Participation Requirements** Basic knowledge of radiation physics and the interaction of radiation and matter is required. These can be acquired, for example, by successfully participating in the “Strahlungsphysik I” module of the bachelor’s degree program in Medical Physics at TU Dortmund University.				
7	**Module type** Elective module/ mandatory module				
8	**Responsible** Dean of the Department of Physics		**Faculty in charge** Department of Physics		
9	**Teacher** Dr. C. Bäumer (WPE)				

Module: Applied Proton Therapy				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.), M.Sc. Physics				
Frequency: in SS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 6	**Work load** 180 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Computer Lab	P	6	4
2	**Language:** English				
3	**Content** Basics of the Monte Carlo simulation method • Interaction of ionizing radiation and description by means of computer simulations • Focus: Proton radiation and field shaping for clinical applications in radiation therapy • Simulation of patient irradiation by integration of CT image data sets • other changing topics: e.g. radiation protection or biological effectiveness In each course, a compact introduction to the topic is followed by its direct implementation in simulations to be created by the students themselves. In a final project work, a complete irradiation is simulated and evaluated from a clinical point of view.				
4	**Learning outcome** After successful completion of the module, students can • Name the basics of Monte Carlo (MC) simulation techniques and apply them to specific problems involving ionizing radiation. • Interpret and process results from simulations and present them in an appropriate manner. • Explain the effect of individual components of different beam shaping techniques for clinical treatment fields and recreate them using computer simulations. • Recognize and explain differences in the physical dose distribution of various types of radiation and irradiation techniques. • Explain the data structure of the clinical standard file format (DICOM) and display, read and process content in suitable software. • Describe the creation of simple proton irradiation plans, evaluate them from a clinical perspective, and apply what they have learned to a specific project.				
5	**Examination** Course achievement: written project report Module exam: will be announced at the beginning of the course.				
6	**Participation requirements** No				
7	**Module type** Elective module				
8	**Responsible** Prof. Dr. A. Lühr		**Faculty in charge** Department of Physics		

Module: TPS - Practical Course on Treatment-Planning (KM05)				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency WS+SS	**Duration** 1 semester	**Semester** 1. – 3. sem.	**Credits** 6	**Work load** 180 h

1	**Module structure**				
	No.	**Element / course**	**Type**	**Credits**	**Contact hours per week**
	1	Practice	P	6	2
2	**Language:** German / English				
3	**Content** Introduction to the basics of radiation planning, carrying out contouring and radiation planning on simple phantoms, but also interactive or inverse creation of individual radiation plans for patients based on anonymized patient data.				
4	**Learning outcome** The students are familiar with the modules of a radiation planning system and various dose calculation methods. You know the volume concept in radiation therapy, the use of the most important imaging procedures with multimodal image registration and fusion, as well as the essential principles of plan optimization (protection of organs at risk, homogeneous irradiation of the target volume). You can operate a modern 3D/4D treatment planning system, evaluate isodose curves and interpret dose-volume histograms.				
5	**Examination** Coursework: Attendance; Preparation of protocols for the internship experiments; final oral group examination (30 min)				
6	**Participation Requirements** Basic knowledge of radiation physics and the interaction of radiation and matter is required. These can be acquired, for example, through successful participation in the module “Strahlungsphysik I”, “Medizinphysik I & II” and “Medizinphysikalisches Klinikpraktikum” of the Medical Physics bachelor’s degree program at the TU Dortmund.				
7	**Module type** Elective module				
8	**Responsible** Dean of the Department of Physics	**Faculty in charge** Department of Physics			
9	**Teachers** Christian Mehrens and Prof. Dr. Andreas Block (Klinikum Dortmund), Dr. Anne Bialek (TUDo)				

Module: Basic radiation protection regulation for medical physics experts				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: SS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 1	**Work load** 30 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture and practice	S	1	Block course
2	**Language:** German				
3	**Content** Basics: radiation physics, radioactivity, radiation biology, dosimetry, radiation planning. Dose estimates, personal dosimetry. Radiation use on humans: justifiable indication Natural and civilizational radiation exposure. Radiation protection: basics, structural and equipment radiation protection, applications (e.g. in nuclear medicine). Legal basis.				
4	**Learning outcome** The students have acquired the knowledge that is imparted in a basic radiation protection course in accordance with legal regulations.				
5	**Examination** will be announced at the beginning of the event				
6	**Participation requirements** Basic mathematical and physical knowledge from the bachelor's degree program				
7	**Module type** Elective module				
8	**Responsible** Dean of the Department of Physics	**Faculty in charge** Department of Physics			
9	**Teachers** Prof. Dr. Andreas Block (Klinikum Dortmund), Jun.-Prof. Dr. Armin Lühr (TUDo)				

Module: Fundamentals of Detector Physics (PHY825)
Degree Program: Physics (M.Sc.), B.Sc. Physik, B.Sc. Medizinphysik, M.Sc. Physics, IMAPP, MMPPLS

https://physik.tu-dortmund.de/en/study/courses-and-qualification/master-physics/module-handbook/

Module: Angewandte Dosimetrie (PHY629)
Degree Program: Physik (B. Sc.), B.Sc. Physik, B.Sc. Medizinphysik, M.Sc. Physics, MMPPLS

https://physik.tu-dortmund.de/en/study/courses-and-qualification/bachelor-physik/module-handbook/

Module: Advanced MRI				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.), B.Sc. Physik, M.Sc. Physics, IMAPP				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 6	**Work load** 180 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture (1h)	L	6	4
	2	Exercise Session (1h)	E		
	3	Seminar (1h)	S		
	4	Clinical Training (1h)	T		
2	**Language:** English				

3

Content

Magnetic resonance imaging (MRI) is a non-ionizing imaging technique. MRI enables multidimensional (2D, 3D, 4D,...) and multicontrast (T_1-, T_2, T_2*, diffusion, perfusion, susceptibility,...) in-vivo (human or animals) or ex-vivo (forensic, various substances, cell culture) imaging using either exogenous contrast agents or endogenous substances (blood, tissue components).

The well-functioning combination of different hardware and software components based on physical and mathematical principles allows the creation of an MRI image that can be used for both scientific and diagnostic purposes. The MRI images can be evaluated either qualitatively or quantitatively. A quantitative evaluation enables both an objective assessment of the MRI images independent of the user's professional experience and the use of appropriate MRI methods in the context of long-term examinations and drug treatments.

The focus of this four-part course is on 1) understanding the formation of different image contrasts from a physical point of view, 2) analyzing quantitative MRI images using different programming languages, 3) preparing a scientific presentation on an MRI-related topic based on current literature, and 4) practical experience with the MRI techniques and contrasts presented in the course.

Literature:

- Mona Salehi Ravesh; Lecture notes, TU Dortmund University, 2024.
- Bernstein M. et al; "Handbook of MRI pulse sequences", Academic Press
- Haacke M. et. Al.; "Magnetic Resonance Imaging: Physical Principle and Sequence Design", Wiley
- Schlegel W. et. Al.; "Medical Physics", Springer
- www.pubmed.org
- https://mriquestions.com/index.html

4

The lecture covers the basics of magnetic resonance imaging and MRI weighting (T_1, T_2, T_2*, perfusion, diffusion weighting), which are necessary for understanding quantitative MRI techniques.

As part of exercises, students will implement mathematical-physical methods in a programming language of their choice, which will be used for the quantitative analysis of the MRI methods covered in the lecture.

In a seminar, students will be able to extract the essence of selected research articles and present recent advances in the application of quantitative MRI techniques to human imaging. This gives students practical experience and develops their presentation skills, which are essential for future research activities and international conferences.
As part of a subsequent practical course, students will be able to perform in vitro (phantom) examinations on a human MRI machine, giving them hands-on experience of the techniques covered and the image contrasts within this course. In addition, they will gain their first experience in producing a phantom that can be used for a specific question (quantitative relaxometry). This will provide students with practical experience and develop their decision-making skills, which are essential for future research activities.

5

Examination

Course credit: Active participation in the exercises, 20-minute seminar presentation, 2-3-page practical report.
Module exam: oral exam (30 min)

6	**Participation Requirements** Knowledge from the courses "Theoretical Physics II" and "Experimental Physics III" is desirable, but not mandatory for understanding the topics in this course.	
7	**Module type** Elective module/ mandatory module	
8	**Responsible** PD Dr. habil rer. nat. Mona Salehi Ravesh	**Faculty in charge** Department of Physics

Module: Image processing in medicine				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: SS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 5	**Work load** 150 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture+ Tutorial	L+T	5	
2	**Language:** English				
3	**Content** Reception by the human visual system, definition and basics of image processing (e.g. discretization, sampling theorem, global parameters of images), operations in the spatial domain (histogram modulation, filtering, morphological operations, geometric Image operations, distance transformation), information extraction methods (segmentation, texture analysis, shape description), classification and machine learning (support vector machines, deep learning), image restoration, image registration, visualization.				
4	**Learning outcome** After successfully completing the module - Can students confidently apply the basics of two- and multi-dimensional signal processing. - The students master techniques and strategies in order to be able to solve typical tasks in image processing independently. - The students have in-depth programming knowledge in MATLAB through exercises. - The students are qualified to analyze cross-disciplinary, interdisciplinary questions through the application area of medical image processing. - The students are prepared to work on further questions in medical image processing in the research phase.				
5	**Examination** will be announced at the beginning of the event				
6	**Participation requirements** Confident handling of Fourier transformation and description of systems in the frequency domain (time frequencies / spatial frequencies)				
7	**Module type** Elective module				
8	**Responsible** Prof. Dr.-Ing. Georg Schmitz		**Faculty in charge** RUB		

Module: Ultrasound in medicine				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 5	**Work load** 150 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture+ Tutorial	L+T	5	
2	**Language:** English				
3	**Content** Linearized acoustic field equations in fluid media and elastic solids, scattering and attenuation in biological tissues, the piezoelectric effect, ultrasonic transducers (structure, equivalent circuits), imaging methods with ultrasonic transducer arrays, flow measurement and Doppler methods, ultrasound contrast agents, selected special areas (elastography, photoacoustics, harmonic imaging, HIFU therapy, superresolution imaging)				
4	**Learning outcome** After successfully completing the module - Students know the basic linear acoustic equations and can explain the linearizations used and derive the linear wave equation in inhomogeneous media. - The students know the basic quantities and relationships for the propagation of ultrasound waves in solid bodies. - Students can model the acoustic properties of biological tissue (scattering, attenuation). - The students know how conventional clinical ultrasound devices work, can describe the structure of ultrasound transducers and are able to implement simple reconstruction procedures (delay-and-sum). - The students are prepared to work on further questions regarding imaging and therapeutic ultrasound systems in the research phase.				
5	**Examination** will be announced at the beginning of the event				
6	**Participation requirements** Confident handling of Fourier transformation and description of systems in the frequency domain (time frequencies / spatial frequencies)				
7	**Module type** Elective module				
8	**Responsible** Prof. Dr.-Ing. Georg Schmitz		**Faculty in charge** RUB		

Module: Applications of Machine Learning in Medical Physics				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 3	**Work load** 90 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Seminar	S	3	2
2	**Language:** English				
3	**Content** Machine learning has been increasingly used in many areas of medicine for years and even has the potential to change them completely. Already today, machine learning methods are of great importance, for example, in diagnostics with the help of imaging procedures. There, machine learning methods help physicians to evaluate the highly complex data in order to make a diagnosis more precisely and faster. But machine learning can also be used efficiently in other areas, such as therapy planning, treatment or even in the development of effective drugs, not only to save costs and time, but ultimately to provide patients with the best possible care. In this seminar, you will first get an overview of the diverse applications of machine learning in medicine. In addition, you will scientifically research a selected topic, gain a deeper insight and understanding, and clearly prepare and present it as a lecture. The central focus of these seminar lectures is on the medical-physical applications, less on the technical aspects of machine learning. In addition to the seminar lectures, we prepare short lecture inserts in which we take a closer look at the technical aspects of machine learning in the respective applications and explain them without any necessary prior knowledge.				
4	**Learning outcome** The participants get an overview of current topics in medicine, in which modern machine learning methods are used. You will learn how to research a scientific topic and present it to an audience in a comprehensible lecture. In addition, you will gain insights into how modern machine learning algorithms work.				
5	**Examination** Course Credits: Active participation in the discussions during the seminar hours. Module examination: Graded, independently researched and elaborated seminar presentation.				
6	**Participation requirements** Basic knowledge in medical physics, desirable is the lecture 'Statistical Methods of Data Analysis'.				
7	**Module type** Elective module				
8	**Responsible** Prof. Dr. Kevin Kröninger	**Faculty in charge** Department of Physics			

Module: Modern Techniques of Radiation Therapy				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.) (and B.Sc.), Physics M.Sc. (and B.Sc.)				
Frequency: in SS/WS	**Duration:** 1 semester	**Semester:** 5.-6. Sem (B.Sc) 1.-3. Sem (M.Sc)	**Credits:** 3	**Work load** 90 h

1	**Module Structure:**				
	No.	**Element / Seminar**	**Type**	**Credits**	**Contact hours per week**
	1	Seminar	S	3	1
2	**Language:** German/English				

3 **Content**

This seminar complements the lecture "Modern Radiation Therapy" by providing a discussion- and project-oriented deep dive into modern technologies used in clinical radiation oncology. Students will assess and discuss the current clinical workflows, technological trade-offs, and implementation barriers, based on state-of-the-art literature and clinical case scenarios.

Core technology blocks include:

- State-of-the-art photon therapy
- Image guidance and motion management
- Adaptive radiotherapy
- MRI-guided radiotherapy
- Charged particle therapy (IMPT robust optimization, range verification)
- Proton Arc therapy
- Temporal and spatial fractionation concepts
- FLASH radiotherapy
- Boron neutron capture therapy
- Brachytherapy and intraoperative radiotherapy

Seminar format:

- Presentation

4 **Learning outcome**

Participants will:

- understand the operating principles and clinical workflows of key modern radiation therapy technologies,
- be able to compare technologies in terms of plan quality, robustness, imaging burden, delivery constraints, and uncertainties,
- understand the challenges and the evidence behind "new" technologies: identify what the limitations are, and what is still unknown then translate that into realistic clinical use case.
- communicate technology assessments clearly in oral presentations.

5 **Examination**

Module exam: graded individual seminar presentation.
(Active participation in discussions is expected as part of the seminar performance.)

6 **Participation Requirements**

For bachelor's students, the successful completion of the lecture Medical Physics II

7 **Module type**

Elective module

8	**Responsible** Dr. Abdelkhalek Hammi	**Faculty in charge** Department of Physics

Module: Introduction to radiation physics and proton therapy				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: in SS/WS	**Duration:** 1 semester	**Semester:** 5.-6. Sem (B.Sc) 1.-3. Sem (M.Sc)	**Credits:** 3	**Work load** 90 h

1	**Module Structure:**				
	No.	**Element / Seminar**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture with practical course (exercise)	L+E	3	2
2	**Language:** German/English				
3	**Content** This lecture introduces basic concepts of radiation physics, the radiation therapy workflow, and in particular proton therapy for medical physics and physics students. It is also suitable for students without a physics background or non-physics PhD candidates working at the interface with proton therapy. The aim is to make the physical principles behind proton therapy and radiation therapy in general accessible and directly relevant for biologists, chemists and non-physics PhD candidates working in projects related to proton therapy. **Topics include:** - Interaction of photons, electrons, and heavy charged particles - Dosimetry basics - Biological relevance of radiation therapy: DNA damage, radiation chemistry, repair pathways - Overview of medical imaging modalities used in radiotherapy - Physical and biological advantages of proton therapy - Proton therapy: workflow and clinical applications - Patient-specific dose calculation: proton vs. photon- treatment plans - Assessment of dosimetric effects of radiotherapy - Proton therapy: uncertainties and challenges - Alternative radiation therapy techniques Practical sessions include simplified hands-on interpretation of imaging data, proton dose calculations, and case-based comparisons between photon and proton therapy, linking the underlying physics to biological effects.				
4	**Learning outcome** After completing the lecture, participants will: - Understand the fundamental physical mechanisms underlying radiation therapy and be able to connect these physical principles with biological and chemical mechanisms relevant for research or clinical practice. - Understand how radiation affects molecules, cells, and tissues. - Understand the need for multi-modal imaging in radiotherapy and its use in radiotherapy. - Understand the basic clinical workflow of radiation therapy in general, with a particular focus on proton therapy. - Be able to perform basic patient-specific proton-based treatment plan calculations. - Be able to assess and interpret basic dosimetric quantities and related effects in patient cases (e.g., dose, dose rate, LET, RBE, NTCP). - Understand the need for new technologies and assessment tools to improve the outcomes of future proton therapy.				
5	**Examination** Module exam: Oral exam				
6	**Participation Requirements** Own laptop				
7	**Module type** Elective module				
8	**Responsible** Dr. Abdelkhalek Hammi	**Faculty in charge** Department of Physics			

Module: Challenges of Future Radiation Oncology				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: in SS/WS	**Duration:** 1 semester	**Semester:** 5.-6. Sem (B.Sc)	**Credits:** 3	**Work load** 90 h

		1.-3. Sem (M.Sc)		

1	**Module Structure:**				
	No.	**Element / Seminar**	**Type**	**Credits**	**Contact hours per week**
	1	Seminar	S	3	1
2	**Language:** German/English				
3	**Content** This seminar is built around the European Society for Radiotherapy and Oncology task-group on the future challenges for medical physics in the era of precise radiation oncology and focuses on four tightly connected dilemmas that will shape future practice: 1) Target definition as inherent problem in the radiation oncology: moving from expert-driven contours to evidence- and data-driven target concepts (including uncertainty-aware / probabilistic thinking). 2) AI and automation: implementing AI safely as a clinical tool not as a black box. 3) Biology and individualized radiotherapy: developing interpretable bio-mathematical models that combine standard matrices with clinical, imaging and biological information to support precision decisions. 4) Side effects versus benefit of radiation therapy: managing normal-tissue toxicity and immune-related effects as a central constraint of personalization to define how far we can boost treatment, push margins, and adapt treatment without causing avoidable toxicity? Seminar format: • Presentation				
4	**Learning outcome** By the end of the seminar, participants will be able to: • explain why defining the target is still hard and uncertain in clinical practice, and how newer methods aim to make contours more consistent and avoid unnecessary treatment • judge when AI/automation is ready for clinical use by checking data, validation, failure modes, and QA requirements. • connect dose and fractionation decisions to biological response and toxicity models and discuss what individualized radiotherapy would require in practice. • frame the core dilemma of future RT: maximizing tumor control while minimizing side effects (including immune-related effects), and argue for balanced, evidence-based decisions.				
5	**Examination** Module exam: graded individual seminar presentation. (Active participation in discussions is expected as part of the seminar performance.)				
6	**Participation Requirements** For bachelor's students, the successful completion of the lecture Medical Physics II				
7	**Module type** Elective module				
8	**Responsible** Dr. Abdelkhalek Hammi		**Faculty in charge** Department of Physics		

Track B: Physics of Living Systems

Mandatory courses	Sem.	CP
Physics of life	WS	6 CP
Lab course: Physics of Living Systems	SS	5 CP
AI for Medical Applications	WS	9 CP
Elective courses		
Soft Matter	SS	6 CP
MD Simulation of Biological Materials	WS	6 CP
Neuroinformatics	WS/SS	6 CP
Biomaterials	WS	4 CP
Tissue Engineering	SS	4 CP
Medicinal Chemistry 1	WS	4 CP
Medicinal Chemistry 2	SS	4 CP
Fundamental Immunology	SS	4 CP
Biomolecular Modelling	WS	4 CP

Note: Electives can also be suggested proactively. An informal proposal including the description of the course should be send to the secretary of the chair of the program.

Mandatory courses

Module: Physics of life (**BP12**)				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.), B.Sc. Physik, B.Sc. Medizinphysik, M.Sc. Physics				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 6	**Work load** 180 h

<table>
<tr><td rowspan="3">1</td><td colspan="5">Module structure</td></tr>
<tr><td>No.</td><td>Element / Course</td><td>Type</td><td>Credits</td><td>Contact hours per week</td></tr>
<tr><td>1</td><td>Lecture + Tutorial</td><td>L+T</td><td>6</td><td>4</td></tr>
<tr><td>2</td><td colspan="5">Language: English</td></tr>
<tr><td>3</td><td colspan="5">Content
i) Thermodynamics, phase transformations and critical phenomena in biology. Role of fluctuations, Landau-Ginzburg, connection to all other areas
ii) Mechanics of the cell: elasticity of shells, Helfrich theory, wetting, cell adhesion according to Sackmann, budding line tension.
iii) Electrostatics on biopolymers and membranes: Poisson-Boltzmann, Gouy Chapmann, coupling to phase transformations
iv) Polymer Theory: Gauss and Flory Chain, Dynamics (Rousse and Zimm), De Gennes, Reptation, Semiflexible Polymer
v) Viscoelasticity theory of biopolymer networks/cytoskeleton. Affine networks, scale arguments, rubber plateau, dynamics and elasticity
vi) Life at small Reynolds numbers. Microswimmer, reversibility, slender body theory (sperm, bacteria, paramecium, lungs,...)
vii) Non-linear phenomena. (coupled) nonlinear oscillators (hearing), solitons, application nerves, heart...
viii) Evolution theory</td></tr>
<tr><td>4</td><td colspan="5">Learning outcome
After successfully completing the module
– Students can apply physical concepts of hydrodynamics, elasticity theory, thermodynamics/statistics and electrodynamics in an interdisciplinary manner to questions of biological and medical physics (especially) on a mesoscopic and macroscopic scale.
– In the exercises, students learned to independently understand problems from the interdisciplinary subject area of biological physics and physiology as physical problems, to solve them and to discuss them in the group.</td></tr>
<tr><td>5</td><td colspan="5">Examination
Course work: Exercises
Graded exam (120 min) or oral exam (30 min), will be announced at the beginning of the course</td></tr>
<tr><td>6</td><td colspan="5">Participation Requirements
No</td></tr>
<tr><td>7</td><td colspan="5">Module type
Elective module/ mandatory module</td></tr>
<tr><td>8</td><td colspan="2">Responsible
Prof. Dr. Matthias Schneider</td><td colspan="3">Faculty in charge
Department of Physics</td></tr>
</table>

Module: Lab course to Physics of Living Systems				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: SS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 6 CP	**Work load** 180 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lab	P		
2	**Language: English**				
3	**Content** Experimental introduction to central working methods from biophysical research i.e. • Electrophysiology • Lipids and Membrane Biophysics • Fluorescence microscopy • FRET • Contraction Force microscopy The respective experiment instructions only contain a brief outline of the theoretical and experimental basics. The necessary knowledge must be acquired through self-study.				
4	**Learning outcome** The students earn the practical knowledge that is necessary for successful independent experimental work in the field of biophysical research. The students are familiar with different techniques and their respective theoretical background.				
5	**Examination** Oral Exam (30min)				
6	**Participation Requirements** Physics of Life				
7	**Module type** Elective module/ mandatory module				
8	**Responsible** Prof. Dr. Matthias Schneider		**Faculty in charge** Department of Physics		

Module: AI for Medical Applications
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)

To avoid copying errors and discrepancies, each entry is printed only once. Detailed information about the module can be found in the section on Track A.

Elective courses

Elective courses	
Soft Matter	6 CP
MD Simulation of Biological Materials	6 CP
Neuroinformatics	6 CP
Biomaterials	4 CP
Tissue Engineering	4 CP
Biomolecular Modelling	4 CP
Mediclinal Chemistry 1	4 CP
Mediclinal Chemistry 2	4 CP
Fundamental Immunology	4 CP

Module: Theory of Soft and Biological Matter (**PHY633**)
Degree Program: Physik (B. Sc.), B.Sc. Physik, M.Sc. Physics, M.Ed. Lehramt (Gym/Ge, BK)

https://physik.tu-dortmund.de/en/study/courses-and-qualification/bachelor-physik/module-handbook/

Module: Molecular Simulation of Soft Matter and Biological Materials **(PHY714)**
Degree Program: Physics (M. Sc.)

https://physik.tu-dortmund.de/en/study/courses-and-qualification/master-physics/module-handbook/

Neuroinformatics.

This subject area offers a variety of courses offered primarily by the Institute for Neuroinformatics at RUB. An overview of the courses currently offered can be found here:
https://www.ini.rub.de/teaching/courses/

Examples of courses offered include:

Introduction to Data Science	WS
Deep Learning	WS
Natural Language Processing with Deep Leaning	WS
Supervised Methods	SoS
Unsupervised Methods	WS
Introduction to Computational Neuroscience	SoS
Single-Neuron Models	SoS
Neural Dynamics	WS

* the selection of courses offered varies to some degree each year.

Module: Biomaterials: From Cells to Tissues				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: annual, WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 4	**Work load**

1 Module structure

No.	Element / Course	Type	Credits	Contact hours per week
1	Biomaterials: From cells to tissues	L	3	2
2	Exercise for Biomaterials: From cells to	T	1	1

2 Language: English

3 Content

1) Introduction to biological tissues
− properties at the cellular scale
− properties at the macromolecular scale: composition of the extracellular matrix
2) Interactions between cells and their native tissue environment
− soluble signals
− matrix-bound cues
− matrix mechanics
− cell-cell interactions
3) Biomaterials and scaffolds: definitions and fundamental properties
− biocompatibility, biodegradability, structural and functional support for cells
4) Types of biomaterial scaffolds
− natural biomaterials (decellularized tissues, ECM protein hydrogels)
− synthetic polymeric biomaterials
5) Scaffold design and biomaterial properties
− structure (porosity, fibrous)
− mechanical and degradative properties
− biochemical composition
− topography
6) Scaffold fabrication techniques
− hydrogel synthesis and functionalization
− techniques to introduce porosity
− fiber electrospinning
− 3D printing
7) Biomaterials in 2D versus 3D cell culture: applications
8) Regulation of cell function by biomaterial properties
− cell-matrix interactions (e.g. cell adhesion, mechanotransduction)
− cell migration
− stem cell proliferation and differentiation

4 Learning outcome

After module completion, students will be able to

- explain basic design principles in modern biomaterials and cell culture scaffolds
- understand how properties of biomaterials regulate cell function and apply this knowledge to custom-design biomaterials for specific cell culture applications
- develop design strategies for biomedical applications at the interface of chemistry, materials science and cell biology
- independently familiarize themselves with a biomedical topic/problem in a scientific manner
- present complex interdisciplinary biomedical topics in spoken and written language using the correct scientific terminology

5 Examination

Coursework: seminar presentation,
module examination: oral or written examination.

6 Participation Requirements

None,
Basic knowledge of cell biology, comparable to courses on cell biology in the Bachelor's program in chemical biology and basic knowledge on biochemistry are recommended.

7 Module type

Elective module/ mandatory module

8	**Responsible** Prof. Dr. B. Trappmann	**Faculty in charge** Department of Chemistry and Chemical Biology

Module: Tissue Engineering				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: annual, SS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 4	**Work load**

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Tissue Engineering	L	3	2
	2	Exercise for Tissue Engineering	T	1	1
2	**Language: English**				
3	**Content** 1. Basic principles of tissue engineering 2. Biomaterials in tissue engineering − Scaffolds: design, materials, fabrication and characterization 3. Cell source: isolation, expansion, differentiation 4. In vitro control of tissue development − Microfluidic platforms − Principles of bioreactor design 5. Gene therapy 6. Current applications − Skin − Heart − Bone − Muscle − Nervous system 7. Fundamentals of drug delivery 8. In vivo transplantation of engineered tissues 9. Clinical translation 10. Applications of engineered tissues in drug testing/ replacement of animal models 11. Current challenges of tissue engineering and outlook on future possibilities				
4	**Learning outcome** After module completion, students will be able to – explain basic design principles in tissue engineering and regenerative medicine – understand the criteria for choosing an appropriate combination of cell source, scaffolds and bioreactors to engineer specific tissues – apply tissue engineering principles to address clinical problems – demonstrate knowledge of already existing clinical applications of tissue engineering and their limitations – independently familiarize themselves with a biomedical topic/problem in a scientific manner – present complex interdisciplinary biomedical topics in spoken and written language using the correct scientific terminology				
5	**Examination** Coursework: seminar presentation, module examination: oral or written examination.				
6	**Participation Requirements** None, Basic knowledge of cell biology, comparable to courses on cell biology in the Bachelor's program in chemical biology and basic knowledge on biochemistry are recommended.				
7	**Module type** Elective module/ mandatory module				
8	**Responsible** Prof. Dr. B. Trappmann		**Faculty in charge** Department of Chemistry and Chemical Biology		

Module: Biomolecular Modeling				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: annual	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 4	**Work load**

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Biomolecular Modeling	L	3	2
	2	Exercises for Biomolecular Modeling	T	1	1
2	**Language: English**				
3	**Content** 1. Basics − Molecular coordinate systems − Classical mechanics − Statistical mechanics − Principles of Monte Carlo simulation − Principles of molecular dynamics simulations − Optimization methods/vibration analysis 2. Atomic models for biological systems − Intra- and intermolecular potential functions − Potential parametrization − Construction principles of complex molecular models − Efficient calculation methods 3. Calculation of observables − Thermodynamic quantities − Structural variables, distribution functions − Dynamic quantities, time correlation functions − Comparison with experimental data 4. Special simulation techniques − Creation of different ensembles − Free energy simulations − The Potential of Mean Force − Advanced methods 5. Applications − Biological membranes − Protein dynamics − Protein-ligand binding				
4	**Learning outcome** Upon successful completion of the module, students will be able to, – explain different simulation and modeling methods for biological systems, – propose suitable calculation methods for given applications and questions and to estimate the limits of their predictive power and the effort required, – select and apply appropriate programming techniques for problem solving, – use acquired knowledge to develop methodical solution strategies for biochemical and biophysical problems and to logically analyze the results, – develop solution strategies, discuss, present their own point of view appropriately orally and in writing as well as cooperate with others.				
5	**Examination** Oral examination				
6	**Participation Requirements** None				
7	**Module type** Elective module/ mandatory module				
8	**Responsible** Prof. Dr. S. M. Kast	**Faculty in charge** Department of Chemistry and Chemical Biology			

Module: Medicinal Chemistry 1				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: annual, WS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 4	**Work load**

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Medicinal Chemistry 1	L	3	2
	2	Exercise for Medicinal Chemistry 1	T	1	1
2	**Language: English**				
3	**Content** 1. Fundamentals of protein-ligand interaction: - Methods for understanding protein-ligand interactions as a basis for the rational design of W agents. 2. Basic concepts of medicinal/pharmaceutical chemistry: - Definition of active substance - Drug substance and medicinal product, how do active substances work? - Phase I-IV clinical trials 3. Basic concepts of the description of pharmacokinetics: - LADME concept and terms - Application routes 4. Independent pharmacokinetic characteristics: - Understanding of clearance parameters, - Volume of distribution - Bioavailability - Half-life - Elimination 5. Structural properties and possibilities for optimising pharmacokinetic properties: - Lipinsky Rules and Innovations - Metabolic processes - Prediction of ADME properties on the basis of calculated parameters 6. Prediction of human PK properties: - Transporter properties - Microsomal stability - Caco 2 assay - Scaling methods 7. Structure-based drug design and computer methods of modern drug discovery: - Visualisation of physicochemical properties of active substances - molecular modelling - virtual screening - Database searches 8. Case studies: - Factor Xa inhibitors - MMP inhibitors - Kinase inhibitors - Lipid 2 antagonists - PDE5 inhibitors - Adenosine agonists - sGC stimulators - sGC activators - DPP4 inhibitors				
4	**Learning outcome** By successfully completing this module, students will be able to, – explain basic principles of protein-ligand interaction and modern drug discovery. – comprehend structure-based, rational and computer-based methods for the development of active substances – explain factors that influence the interplay of pharmacokinetics and pharmacodynamics and understand the possibilities for influencing these processes through chemical modification and apply them in problem solving. – develop interdisciplinary solution strategies for practical problems at the interface between chemistry, pharmacology and biophysics for basic research and biomedical applications. – discuss, communicate their own point of view appropriately and cooperate with others when developing solution strategies.				

5	**Examination** Written exam	
6	**Participation Requirements** None, knowledge of bioorganic chemistry and organic chemistry is recommended	
7	**Module type** Elective module/ mandatory module	
8	**Responsible** Prof. Dr. D. Rauh	**Faculty in charge** Department of Chemistry and Chemical Biology

Module: Medicinal Chemistry 2				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: annual, SS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 4	**Work load**

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Medicinal Chemistry 2	L	3	2
	2	Exercise for Medicinal Chemistry 2	T	1	1
2	**Language: English**				
3	**Content** 1. History of drug research and discovery: - Active plant ingredients - Aspirin - Process of synthesis of the active substance 2. Targets for pharmacologically active agents: - Distribution of target classes for commercial agents 3. Protein-ligand interactions: - Significance of the individual energy contributions - Strength of different types of interaction 4. Enzyme inhibitors: - Types of enzyme inhibition and their kinetic description - Types of enzyme inhibition and their kinetic description - Mechanisms of different protease types - Proteasome and proteasome inhibitors 5. Industrial pharmaceutical research: - Screening process - Screening by selection - Computational chemistry methods in the hit finding and hit-to-lead process - Optimisation cycles 6. Case studies: - Factor Xa inhibitors - MMP inhibitors - Kinase inhibitors - Lipid 2 antagonists - PDE5 inhibitors - sGC stimulators - sGC activators - DPP4 inhibitors 7. Biological drugs such as oligonucleotides and antibodies				
4	**Learning outcome** By successfully completing this module, students will be able to, – explain the processes of pharmaceutical research and industrial applications. – understand the underlying principles for the action of biological drugs – understand different technologies for drug identification – describe different types of enzyme inhibition and to draw conclusions about possible consequences of enzyme inhibition from chemical structural features. – develop interdisciplinary solution strategies for practical problems at the interface between chemistry, pharmacology and biophysics for basic research and biomedical applications. – discuss, communicate their own point of view appropriately and cooperate with others when developing solution strategies.				
5	**Examination** Written exam				
6	**Participation Requirements** None, knowledge of bioorganic chemistry and organic chemistry is recommended				
7	**Module type** Elective module/ mandatory module				
8	**Responsible** Prof. Dr. D. Rauh		**Faculty in charge** Department of Chemistry and Chemical Biology		

Module: Fundamental Immunology				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: annual, SS	**Duration:** 1 semester	**Semester:** 1. – 3. sem.	**Credits** 4	**Work load**

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Fundamental Immunology	L	3	2
	2	Exercises for Fundamental Immunology	T	1	1
2	**Language: English**				
3	**Content** 1. organs and cell types of the immune system 2. immunological processes during viral or bacterial infections 3. immunological effector mechanisms of infection control 4. basics of immunological anti-tumor response 5. novel immunologic therapeutic approaches - therapy with monoclonal antibodies, - cell therapy, - immunosuppressive drugs, - bone marrow transplantation 6. basics of signal transduction in immune cells - Signal transduction of cytokines, - T cell receptor, - inhibitory receptors				
4	**Learning outcome** By successfully completing this module, students will be able to, – understand the different cell types and organs of the immune system and their functions based on their knowledge acquired in the course. – understand the interaction of the different components of the immune system in a successful immune response. – understand and evaluate experimental approaches for the investigation of immunological processes. – explain various manipulations of the immune system for therapeutic purposes. – present scientific facts in technically correct terms in speech and in writing and to discuss them with others.				
5	**Examination** Written exam				
6	**Participation Requirements** None, basic knowledge of cell biology comparable to courses on cell biology in the bachelor's degree program in chemical biology is recommended.				
7	**Module type** Elective module/ mandatory module				
8	**Responsible** Prof. Dr. Carsten Watzl		**Faculty in charge** Department of Chemistry and Chemical Biology		

Free Electives

Every course that is part of specialization Track A and B can also be chosen as a free elective. For these courses, the module descriptions can be found under the descriptions of Track A and Track B.
Courses provided by the Department of Physics of the TU Dortmund University are also eligible as Free Electives. The module descriptions can be found in the respective module handbooks

Examples of electives are listed below

Subject area Clinical Medical Physics

Module	CP	Module handbook
Advanced Clinical Medical Physics	6	MMPPLS
Radiation applications in the clinic	3	MMPPLS
Modern Radiation Therapy	6	MMPPLS
Medical Physics and Technology in Particle Therapy	3	MMPPLS
Applied Proton Therapy	6	MMPPLS
TPS – Practical Course on Treatment Planning	6	MMPPLS
Basic radiation protection regulation for medical physics experts	1	MMPPLS
Introduction to radiation physics and proton therapy	3	MMPPLS
Fundamentals of Detector Physics	3	M. Sc. Physics
Detector systems in particle and medical physics	3	M. Sc. Physics

Subject area Medical Imaging

Module	CP	Department
Advanced Medical Imaging	6	TU Phys/ MMPPLS
Advanced Magnetic Resonance Imaging	6	TU Phys/ MMPPLS
Image Processing in Medicine	5	RUB ET
Ultrasound in Medicine	5	RUB ET
Tomographic imaging methods	5	RUB ET
Master's internship in medical technology	3	RUB ET
Master's seminar in medical technology	3	RUB ET
Biomedical Optics	3	RUB ET
Applied data visualization for medical physicists	6/9	TU Comp
Medical image processing	6/9	TU Comp
Seminar - Medical Image and Signal Processing	6/9	TU Comp

Module: Tomographic imaging methods				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: SS	**Duration:** 1 semester	**Semester:** 1st/2nd sem.	**Credits** 5	**Work load** 150 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture+ Tutorial	L+T	5	
2	**Language:** English?				
3	**Content** Generation and detection of X-rays, interactions of X-rays with matter, CT reconstruction methods (Fourier slice theorem, filtered back projection), practical aspects of image reconstruction, nuclear magnetic resonance effect, FID/spin echoes/gradient echoes, spatial coding in MRI, k-space description the MRI, simple basic sequences (spin echo, TSE, EPI, GRASE, BOLD), acoustic wave equation and Fourier diffraction theorem.				
4	**Learning outcome** After successfully completing the module ● Students know the basic tomographic reconstruction methods for X-ray computed tomography (CT), magnetic resonance imaging (MRI) and acoustic diffraction tomography. ● Can the students compare the tomographic imaging methods and explain their imaging properties (contrast mechanism, spatial and time resolution). In particular, they can describe the imaging properties in the spatial frequency space. ● The students know the basic technical structure of the systems for CT and MRI. ● Students can practically implement simple reconstruction algorithms. ● The students are prepared to work on further questions for imaging systems in the research phase.				
5	**Examination** will be announced at the beginning of the event				
6	**Participation requirements** Confident handling of Fourier transformation and description of systems in the frequency domain (time frequencies / spatial frequencies)				
7	**Module type** Elective module				
8	**Responsible** Prof. Dr.-Ing. Georg Schmitz	**Faculty in charge** RUB			

Module: Master's internship in medical technology				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1st/2nd sem.	**Credits** 3	**Work load** 90 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Practice	P	3	
2	**Language:** English?				
3	**Content** The internship includes four experiments, each of which is carried out on several dates. In addition to recording measurement data, it is often necessary to evaluate algorithms that have to be programmed as part of the internship. The four experiments have the topics: - Basics of ultrasound pulse-echo imaging - Optimization of ultrasonic transducers with the Finite Element Method (FEM) with a professional commercial FEM program that is used, among others, by the most important manufacturers of medical ultrasound devices. - Design and optimization of array systems for imaging, complete simulation of imaging ultrasound devices from data acquisition to image. - Registration of medical image data using the example of computer-assisted surgery.				
4	**Learning outcome** After successfully completing the module - Students can practically solve exemplary questions about imaging systems. - The students have acquired in-depth knowledge of programming with Matlab. - Using an example, the students learned how to technically optimize a system based on finite element methods. - The students can present a test result in the form of a technical report correctly in terms of content and form. - The students practiced sensibly dividing complex activities into small teams.				
5	**Examination** Test certificate after successful completion of the test and submission of the test report. Before the experiment is carried out, the knowledge required for the experiment is asked (10 minutes) and must be available in sufficient quantity.				
6	**Participation requirements** Confident handling of Fourier transformation and description of systems in the frequency domain (time frequencies / spatial frequencies)				
7	**Module type** Elective module				
8	**Responsible** Prof. Dr.-Ing. Georg Schmitz		**Faculty in charge** RUB		

Module: Master's seminar in medical technology				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: SS	**Duration:** 1 semester	**Semester:** 1st/2nd sem.	**Credits** 3	**Work load** 90 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Seminar	S	3	
2	**Language:** English?				
3	**Content** The seminar basically covers topics from the area of imaging and image processing of medical image data. The main topic is chosen anew every semester and announced on the website of the Chair of Medical Technology at the beginning of the semester or in the preliminary discussion of the event.				
4	**Learning outcome** After successfully completing the module - Students can independently review literature on a given topic and grasp and reproduce the essential content. - The students master key skills for presenting their results, such as the written summary of the research results (literature study) and the presentation of the results. - Students are enabled to express constructive criticism of the work of colleagues (peer review) and to formulate questions regarding content.				
5	**Examination** The coursework is achieved in the form of a lecture and participation in the discussion of other lectures.				
6	**Participation requirements** no				
7	**Module type** Elective module				
8	**Responsible** Prof. Dr.-Ing. Georg Schmitz			**Faculty in charge** RUB	

Module: Biomedical Optics (BV07)				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1st/2nd sem.	**Credits** 3	**Work load** 90 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Seminar	S	3	
2	**Language:** English				
3	**Content** Basics of the interaction of light and biological tissues, instrumentation for biomedical optical imaging, microscopy, optical coherence tomography (OCT), other tomographic optical methods, treatment of diseases with light (e.g. laser surgery).				
4	**Learning outcome** After successfully completing the module - The students have learned to follow a lecture in English - The students know the essential interaction mechanisms between light and biological tissue. - Students understand various methods of optical imaging of biological tissue and the treatment of diseases with light.				
5	**Examination** The coursework is achieved in the form of a lecture and participation in the discussion of other lectures.				
6	**Participation requirements** no				
7	**Module type** Elective module				
8	**Responsible** Prof. Dr. rer. nat. Martin Hofmann			**Faculty in charge** RUB	

Module: Applied data visualization for medical physicists				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: SS	**Duration:** 1 semester	**Semester:** 1st/2nd sem.	**Credits** 6 or 9	**Work load** 180 h or 270h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture	L	6	4
	2	Exercise (optional)	T	3	2
2	**Language:** English?				
3	**Content** With the increasing size of data volumes in practically all areas as well as their complexity and changeability, visualization is becoming increasingly important. It serves both for intuitive representation and as a means of analysis. Corresponding visualizations are often achieved by mapping onto graphic scenes, which are then displayed efficiently using graphic data processing methods. The first part of the module covers basic concepts for visualizing and analyzing data of different types. Data types considered are in particular one- and two-dimensional functions, multi-dimensional functions, graphs and scattered point sets. Methods of graphical data processing, statistical data analysis, efficient discrete algorithms and data structures as well as applied mathematics are presented, on which the concepts and their realizations are based. Furthermore, existing visualization/analysis systems that provide corresponding concepts are discussed. The second part of the module presents advanced visualization concepts that are specifically relevant to medical physics. These concern volume data, as occurs in various imaging procedures, as well as vector and tensor fields. Furthermore, the use of visualization techniques in the analysis and prognosis of biomedical signals will be discussed, taking existing systems of computer-assisted diagnosis into account.				
4	**Learning outcome** After successfully completing the module - Students have methodological knowledge that enables them to solve complex visualization and analysis tasks on data, e.g. B. result in connection with medical-physical requirements - Students have applied methods that are available in existing systems and are based on original literature in their given form, but have also adapted them to new, possibly expanded questions and identified application limits and specific features				
5	**Examination** Coursework: none; Module examination or two partial achievements. If you only take the lecture: graded oral module examination. If the exercises are also completed: two partial achievements, for the lecture: graded, oral exam, exercises: ungraded, written				
6	**Participation requirements** No				
7	**Module type** Elective module				
8	**Responsible** Priv.-Doz. Dr. F. Weichert			**Faculty in charge** Department of Computer Science	

Module: Medical image processing				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1st/2nd sem.	**Credits** 6 or 9	**Work load** 180 h or 270h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture	L	6	4
	2	Exercise (optional)	T	3	2
2	**Language:** English?				
3	**Content** The capture and processing of images (generally sensor data) with computers and mobile devices is spreading rapidly due to the inexpensive availability of the technical equipment. The subject of the course is methods of digital image analysis. One focus is the classic processing chain of image analysis, which is divided into the parts discretization, image restoration, image enhancement and segmentation. Basic concepts such as the sampling theorem, the Fourier transform and other transformations as well as methods for solving optimization problems are presented. Another focus is the introduction to machine learning methods (deep learning), image compression and 3D computer vision, which are the basis for important applications of digital image processing.				
4	**Learning outcome** After successfully completing the module - Students have basic knowledge that enables them to recognize and master tasks that can be solved using digital image analysis methods. - Students find their way around the field in such a way that they are able to identify, understand and apply related methods and procedures that go beyond those of the lecture, depending on the task				
5	**Examination** Coursework: none; Module examination or two partial achievements. If you only take the lecture: graded oral module examination. If the exercises are also completed: two partial achievements, for the lecture: graded, oral exam, exercises: ungraded, written				
6	**Participation requirements** No				
7	**Module type** Elective module				
8	**Responsible** Priv.-Doz. Dr. F. Weichert		**Faculty in charge** Department of Computer Science		

Module: Seminar - Medical Image and Signal Processing				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: WS	**Duration:** 1 semester	**Semester:** 1st/2nd sem.	**Credits** 6 or 9	**Work load** 180 h or 270h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Lecture	L	6	4
	2	Exercise (optional)	T	3	2
2	**Language:** English?				
3	**Content** Medical image and signal processing is developing into a key technology in the diagnosis and therapy of various clinical pictures, both through more complex and efficient algorithms and through new imaging and processing hardware. As part of the seminar, relevant concepts and techniques will be examined. The lectures will cover, among other things, current methods of image analysis and pattern recognition for computer-aided diagnostics and therapy, for two- and three-dimensional reconstruction and visualization, as well as numerical and analytical methods for simulating and describing the relevant processes in the context of diagnostics and therapy. In addition, work on experimental and imaging procedures (e.g. MRI) is also discussed. Within the seminar should - Machine learning methods (e.g. CNNs) for classifying relevant structures or predicting processes, - Visualization methods for representing static and dynamic processes, - Techniques for simulating medical and biological processes, - Concepts for generating realistic models via synthesis or additive manufacturing processes, - Algorithms for the photorealistic spatial representation of anatomical structures, - Measurement techniques (e.g. CT, MRT) to determine processes (e.g. flow processes) and anatomical structures be treated as lecture topics				
4	**Learning outcome** After successfully completing the module - Students can independently review literature on a given topic and grasp and reproduce the essential content. - The students master key skills for presenting their results, such as the written summary of the research results (literature study) and the presentation of the results. - Students are enabled to express constructive criticism of the work of colleagues (peer review) and to formulate questions regarding content.				
5	**Examination** The coursework is achieved in the form of a lecture and participation in the discussion of other lectures.				
6	**Participation requirements** No				
7	**Module type** Elective module				
8	**Responsible** Priv.-Doz. Dr. F. Weichert		**Faculty in charge** Department of Computer Science		

Subject area Medical Physics

Module: Innovations in Medical Physics: From AI to Precision Medicine				
Degree program: MMPPLS				
Frequency By the semester	**Duration** 1 Semester	**Semester** 1st/2nd semester	**Credits** 5	**Work load** 150h

1	**Module structure**				
	No.	**Element / course**	**Type**	**Credits**	**Contact hours per week**
	1	Seminar and flipped-classroom lecture	L+S	3	
	2	Preparation of a Research Paper on a Scientific Topic	T	2	
2	**Language:** English				
3	**Content** This course adopts a flipped-classroom format in which students explore recent scientific publications and emerging technologies in medical physics. Topics include AI for inverse problems and advanced imaging, single-cell diagnostics, spatial omics, bioprinting, precision medicine, and other cutting-edge developments from academia and industry. The course aims to provide students with an up-to-date understanding of modern technologies, foster critical analysis of current research, and prepare them for careers in both scientific research and industry.				
4	**Learning outcome** After completing this course, students will be able to: • critically analyze and discuss recent scientific publications in medical physics; • describe the principles, opportunities, and limitations of the most prominent emerging technologies • evaluate the scientific and clinical relevance of technological innovations; • present and communicate current research topics effectively to an expert audience				
5	**Examination** Module examination: Graded presentation on a Scientific topic of choice.				
6	**Coursework and examination requirements** Preparation of a Research Paper on the chosen Scientific Topic (see Examination). Regular active participation in the course.				
7	**Prerequisites** Basic knowledge of Python and Medical Physics				
8	**Module type** Elective module				
9	**Responsible** Benedikt Sabaß	**Organization** Department of Physics			

Subject area Biophysics

Module	**CP**	**Module handbook**
Theory of Soft and Biological Matter II	5	M. Sc. Physics
Soft Matter and Biophysics: Experiment and Theory	3	M. Sc. Physics
Structural Analysis with X-rays	5	M. Sc. Physics

https://physik.tu-dortmund.de/en/study/courses-and-qualification/master-physics/module-handbook/

Subject area Applied Physics in Medicine

Module	CP	Module handbook
Accelerator Physics I (PHY712)	6	M. Sc. Physics
Accelerator Physics II (PHY812)	6	M. Sc. Physics
Fundamentals of Detector Physics (PHY825)	3	M. Sc. Physics
Detector systems in particle and medical physics (PHY826)	3	M. Sc. Physics
Laser – Arten und Anwendungen (deutsch) (PHY729)	3	M. Sc. Physics
Physical-Chemical Analytics 1a, Applied Spectrometry (PHY7219a	3	M. Sc. Physics
Quantum Optics	3	M. Sc. Physics
Modern Optics	3	M. Sc. Physics
Advanced Solid State Physics II: Magnetism and Superconductivity	6	M. Sc. Physics

https://physik.tu-dortmund.de/en/study/courses-and-qualification/master-physics/module-handbook/

Module: Applied Physics in Clinical Medicine (PHY7226)				
Degree Program: Physics (M.Sc.), B.Sc. Medizinphysik, MMPPLS				
Frequency: in WS	**Duration:** 1 semester	**Semester:** 1st/2nd sem.	**Credits** 3	**Work load** 90 h

1	**Module structure**				
	No.	**Element / Course**	**Type**	**Credits**	**Contact hours per week**
	1	Seminar	S	3	2
2	**Language:** English				
3	**Content** 1. Physics as a duty for the physician (radiation protection, Medical Devices Act) 2. Technical devices in diagnostics and therapy 3. Brain, eye, ear 4. Neck 5. Lung 6. Heart 7. Visceral surgery I (esophagus, gastrointestinal) 8. Visceral surgery II (liver, gall bladder, pancreas) 9. Trauma surgery 10. Orthopedics 11. Angiology				
4	**Learning outcome** Basic knowledge of applied physics in the clinical medicine according to the course content. The seminars are structured so that first the anatomy and physiology, the pathophysiology and then the typical diseases are discussed and to what extent physics is applied in diagnostics and therapy. When possible, particular reference is made to the possible field of activity of the medical physicist.				
5	**Examination** Written or oral module final examination: the requirements. will be announced by the instructor at the beginning of the course.				
6	**Participation requirements** no				
7	**Module type** Elective module				
8	**Responsible** Dr. A. Schilling (Klinikum Westfalen)		**Faculty in charge** Department of Physics		

Subject area Physics

Module	CP	Module handbook
Einführung in die Festkörperphysik (deutsch) (PHY521)	9	B. Sc. Physics
Statistical Methods of Data Analysis/ SMD B	5	B. Sc. Physics
Practical Aspects of Instrumentation (PHY7233)	3-9	M. Sc. Physics
Computational Physics (PHY632)	9	B. Sc. Physics
Einführung in die Kern- und Elementarteilchenphysik (deutsch) (PHY522)	9	B. Sc. Physics
Advanced Solid State Physics I: Semiconductors and Light-Matter Interaction	6	B. Sc. Physics
Methoden der klinischen Forschung (deutsch) (PHY6210)	5	B. Sc. Medizinphysik
Applications of Synchrotron Radiation	3	M. Sc. Physics
Applications of Synchrotron Radiation (Seminar) (PHY8211b)	3	M. Sc. Physics
Machine Learning for Physicists (PHY626)	4	B. Sc. Physics
Anwendungen des maschinellen Lernens in der Medizinphysik (PHY6211)	3	B. Sc. Medizinphysik
Superconducting Technology applied to particle accelerators	3	M. Sc. Physics
Vorlesung Magnetismus (deutsch) (PHY5210V)	6	B. Sc. Physics
Seminar Magnetismus (deutsch) (PHY5210S)	3	B. Sc. Physics
Photovoltaik (deutsch) (PHY5216)	3	B. Sc. Physics
Stochastic dynamics – from Brownian motion to field theory (PHY7322)	6	M. Sc. Physics
Principles and Applications of Nonlinear Optical Spectroscopy (PHY7245)	3	M. Sc. Physics

https://physik.tu-dortmund.de/en/study/courses-and-qualification/master-physics/module-handbook/

Modules in the research phase

Module: Research Internship (FP02)				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: every semester	**Duration:** 1 semester	**Semester:** 3rd sem.	**Credits** 15	**Work load** 450 h

1	**Module structure** Research internship	
2	**Language:** English	
3	**Content** Literature research Familiarization with theoretical procedures or experimental procedures Discussion of problems of current research Preparation of a short (approx. 5 p.) report or presentation Literature: Current literature on the respective research area In addition, e.g. Ascheron, Kickuth: Make Your Mark in Science, Alley: The Craft of Scientific Presentation, Alley: The Craft of Scientific Writing.	
4	**Learning outcome** Students will be able to work independently in a current area of research with the associated experimental or theoretical methods. The students can summarize their work in a report. In addition to the technical deepening, the students have further developed their written presentation skills as well as their media skills and communication skills.	
5	**Examination**	
6	**Participation requirements**	
7	**Module type** Mandatory module	
8	**Responsible** Dean of the Department of Physics	**Faculty in charge** Department of Physics

Module: Master's thesis (FP03)				
Degree Program: Master Medical Physics and Physics of Living Systems (M. Sc.)				
Frequency: every semester	**Duration:** 6 months	**Semester:** 4th Sem.	**Credits** 30	**Work load** 900 h

1	**Module structure** Supervised research	
2	**Language:** English	
3	**Content** Work on a current scientific problem in experimental or theoretical medical or bio-physics in an international research environment and final presentation of the results. Literature: Monographs, review articles and original publications on the respective scientific problem.	
4	**Learning outcome** The students are able to work independently on a current scientific project in an international research environment in accordance with a project plan they have developed, i.e. carry out the corresponding experiments or calculations. In addition to the technical competence required for the research project, the students will have developed their methodological competence, team competence, communication competence, oral presentation skills, self-competence (ability to work under pressure, flexibility, time management) and often also intercultural competence.	
5	**Examination**	
6	**Participation requirements** Module "Research Internship"	
7	**Module type** Mandatory module	
8	**Responsible** Dean of the Department of Physics	**Faculty in charge** Department of Physics

List of modules included in this MHB