Faculty of Science

MSFN02, Medical Radiation Physics: Hospital Physics, 60 credits

Medicinsk strålningsfysik: Sjukhusfysik, 60 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2021-12-09 and was last revised on 2024-11-12 by The Education Board of Faculty of Science. The revised syllabus comes into effect 2024-11-12 and is valid from the autumn semester 2025.

General information

The course is included in the later part of the medical physicist education (semester 7-8), and introduces clinical applications of medical radiation physics. The course is compulsory for the degree of Master of Science in Medical Physics according to The Higher Education Ordinance 2006:1324 (Degree of Master of Science in Medical Physics 300 credits).

Language of instruction: Swedish and English
The teaching is mainly given in Swedish but certain lectures and exercises can be held in English. A predominant part of the reading list is in English.

Main field of study	*Specialisation*
Medical Radiation Physics	A1F, Second cycle, has second-cycle course/s as entry requirements

Learning outcomes

The course covers clinically applied radiation physics and consists of 7 modules. The included modules contain both diagnostic and therapeutic applications of ionising radiation, including related mathematical and statistical methods.

- Module 1. Image processing and mathematical methods (12 credits)
- Module 2. Imaging and functional diagnostics: MR - physics (9 credits)
- Module 3. Imaging and functional diagnostics: nuclear medical physics (13.5 credits)

- Module 4. Imaging and functional diagnostics: X-ray physics (6 credits)
- Module 5. Radiotherapy physics (13.5 credits)
- Module 6. Biostatistics (4.5 credits)
- Module 7. Reflective writing 2 (1.5 credits)

Knowledge and understanding

Module 1. Image processing and mathematical methods

After completed module, the student should be able to:

- explain digital images in mathematical terms and describe alternatives for their representation such as histograms, profiles and the use of colour bars
- define and explain the operations convolution and Fourier transform for continuous and discrete signals in one or more dimensions, their application on common functions and their application in theoretical models and practical applications
- describe the imaging process as a translation-invariant system and image properties such as spatial resolution, image contrast and signal-to-noise ratio
- give a mathematical description of sampling of continuous signals and how this operation influences the information content in discrete data
- explain the reconstruction problem formulated via the Radon transform and its solution with filtered back projection
- describe basic probaility theory, principles for problem solution with neural networks, methods for image analysis such as coregistration, image segmentation, and fundamental concepts for evaluation of diagnostic image quality.

Module 2. Imaging and functional diagnostics: MR physics

After completed module, the student should be able to:

- describe and explain the phenomenon nuclear magnetic resonance (NMR) from a quantum physical as well as a semi-classical perspective, including excitation, relaxation, signal generation and recieval
- describe basic types of pulse sequences (gradient echo, spinn echo, and inversion recovery) and account for how radio-frequent excitation and relaxation influences the contrast properties in the resulting MR images
- describe the principles of how magnetic field gradients are applied (in space and time) to achieve spatial resolution, and mathematically describe the transition from acquired signal to morphological MR image from a k-space perspective
- describe the basic principles of the essential components of clinical pulse sequences and give account of their most typical properties as well as advantages and disadvantages
- describe the technical construction of the MR camera at a general level, and the ongoing technical/mathematical development (including use of AI)
- describe mechanisms at a general level for and use of MR - contrast medium

- describe the most common medical applications of MR diagnostics at a general level, as well as contrast mechanisms and types of pulse sequences in MR methods for quantitative, functional, micro-structural and molecular imaging, and principles of MR spectroscopy.

Module 3. Imaging and functional diagnostics: nuclear medical physics

After completed module, the student should be able to:

- describe and explain the structure and the function of imaging detector systems (gamma camera and PET camera), and have a general knowledge of other types of imaging systems (including pre-clinical systems)
- give an account of how different physical effects influence nuclear medical images and explain the corrections that can be carried out
- identify, describe and explain the origin of common artefacts in nuclear medical images
- give an account of the use of single detector system (e.g. for monitoring, uptake measurement and activity measurement)
- have a good overview of radionuclides and radioactive drugs (radiopharmaceuticals) for diagnostics and therapy, and have basic knowledge of uptake mechanisms and a general knowledge of the clinical use of common radiopharmaceuticals
- give an account of common methods for quality control of radiopharmaceuticals
- give an account of the formalism for internal dosimetry, and connect this formalism to basic physical quantities and nuclear medicine methods for measurement and pharmacokinetic models
- explain basic quantities in image quality analysis, understand the principle of ROC analysis, and have knowledge of how clinical studies are carried out and evaluated in the field
- describe applications of AI in nuclear medicine diagnostics and therapy, at a general level
- describe and explain the basics of the medical use of ultrasound and how this diagnostic method can be compared with other diagnostic methods based on ionising and non-ionising radiation.

Module 4. Imaging and functional diagnostics: X-ray physics

After completed module, the student should be able to:

- describe and explain the structure and function of an X-ray generator, X-ray tube and detector for conventional examinations, mammography and for different types of tomography (CT/CBCT)
- describe the principle of digital detectors and explain their function
- explain how exposure parameters and exposure conditions for different systems influence X-ray spectra, image quality (noise, resolution and contrast), scattered radiation and absorbed dose to the patient
- have knowledge of different methods and instrumentation for measuring image quality and absorbed dose

- explain basic quantities in image quality analysis and understand the principles of ROC analysis, and have basic knowledge in how clinical studies are performed and evaluated in the subject area
- have knowledge of the most common medical applications in diagnostic radiology and describe applications of AI at a general level
- provide an overview of current radiation protection legislation and radiation protection recommendations in the area.

Module 5. Radiotherapy physics

After completed module, the student should be able to:

- describe the structure of medical linear accelerators and explain their structure and function
- describe the structure and function of after loading equipment and radiation sources in brachytherapy
- describe radiation fields with regard to absolute and relative dose distributions, both for external radiation sources and around radioactive sources for brachytherapy
- give an account of international recommendations for reporting of radiotherapy
- give an account of the treatment process from diagnosis to completed treatment, including diagnostic imaging systems, fixation system, assessment of optimised treatment plans, and documentation
- describe medical applications of AI in radiotherapy at a general level.

Module 6. Biostatistics

After completed module, the student should be able to:

- give an account of experimental trial design
- give an account of the basic concepts of hypothesis testing such as null hypothesis, significance testing, p-value and statistical power.

Module 7. Reflective writing 2

After completed module, the student should be able to:

- in written reports give a clear account of experimental observations, and to explain complex underlying relationship in connection with the laboratory exercises that are carried out in the included course modules.

Competence and skills

Module 1. Image processing and mathematical methods

After completed module, the student should be able to:

- independently analyse and solve computational tasks related to image processing and the principles of neural nets, present solutions and set them in relation to the underlying theory
- independently apply methods for processing and analysis of discrete signals in one, two and three dimensions, structure and implement them in computer programs, and present and discuss the own and others' results in relation to the underlying theory
- individually interpret theoretical and mathematical descriptions of different image processing operations.

Module 2. Imaging and functional diagnostics: MR physics

After completed module, the student should be able to:

- independently carry out calculations of how imaging time and image quality parameters (SNR, spatial resolution, image field, artifact sensitivity, etc.) are influenced when different machine settings and other practical preconditions are changed
- identify, describe and explain (from a mathematical/physical perspective) common artifacts in MR images
- apply an optimal safety awareness based on acquired knowledge of practical risks and possible biological effects
- set up and carry out a practical MR experiment.

Module 3. Imaging and functional diagnostics: nuclear medical physics

After completed module, the student should be able to:

- discuss methods for quality control of detector systems and radioactive drugs, and analyse and evaluate the results of the controls
- handle open radiation sources in a safe manner
- give an overview of radiation protection legislation and radiation protection recommendations in the field, and discuss and analyse radiation protection related issues specific for nuclear medicine
- independently carry out internal dosimetric calculations and discuss how different factors influence the uncertainty in the result related to the aim of the dosimetry.

Module 4. Imaging and functional diagnostics: X-ray physics

After completed module, the student should be able to:

- carry out calculations of patient radiation doses for different radiological examinations (including computed tomography and mammography)
- suggest the choice of appropriate radiation shielding in different clinical situations and exposure environments
- suggest which detector (direct/indirect) is best suited for various clinical examinations in diagnostic radiology.

Module 5. Radiotherapy physics

After completed module, the student should be able to:

- carry out experimental determination of dose distributions and use this information to independently carry out dose calculations in simple treatment cases
- carry out clinical treatment planning and optimisation with regard to biological and physical aspects, in both conventional and intensity modulated external radiotherapy, as well as brachytherapy, and to describe which computational models that can be used
- discuss and analyse radiation protection related issues specific for radiotherapy.

Module 6. Biostatistics

After completed module, the student should be able to:

- describe and apply different estimation methods
- carry out calculations using statistical programs corresponding to the course content.

Module 7. Reflective writing 2

After completed module, the student should be able to:

- produce comprehensive written text, with a correct language and subject-specific terminlogy
- use tables and graphs in a way that clarify the information in a written report.

Judgement and approach

Module 1. Image processing and mathematical methods

After completed module, the student should be able to:

- evaluate factors that influence the reliability of image information, based on the characteristics of the image
- evaluate the applicability of a given image processing method, based on a proposed situation
- use a critical approach to exisiting software, based on knowledge of digital images and AI and the theoretical and technical problems that must be solved in the implementation and application of different types of methods.

Module 2. Imaging and functional diagnostics: MR physics

After completed module, the student should be able to:

- analyse, interpret and evaluate quantitative results as well as image quality from experimental MR measurements, and report relevant methods, results and conclusions in writing
- suggest and implement appropriate practical safety arrangements in a clinical MR environment.

Module 3. Imaging and functional diagnostics: nuclear medical physics

After completed module, the student should be able to:

- evaluate the information in a nuclear medicine image, based on the physical limitations of the different imaging systems and discuss suitable reconstruction, compensation and postprocessing methods, based on which information that should be inferred
- relate the clinical applicability of nuclear medicine methods compared to other alternatives, e.g. ultrasound
- discuss and evaluate different radiation protection situations in nuclear medicine.

Module 4. Imaging and functional diagnostics: X-ray physics

After completed module, the student should be able to:

- discuss and analyse radiation protection-related matters specific to diagnostic radiology
- compare the most common medical applications in diagnostic radiology with alternative diagnostic imaging methods.

Module 5. Radiotherapy physics

After completed module, the student should be able to:

- evaluate and discuss appropriate treatment technique and modality in brachytherapy and external-beam radiotherapy
- evaluate and suggest methods for quality assurance including control of both equipment and procedures, such that each patient is ensured that the absorbed dose in the target volumes correspond to the prescribed radiation dose within acceptable limits.

Module 6. Biostatistics

After completed module, the student should be able to:

- choose and evaluate applicability of common parametric and non-parametric hypothesis tests, e.g. t-test, Chi-2 test and Mann-Whitney U-test, Wilcoxon rank sum test.

Module 7. Reflective writing 2

After completed module, the student should be able to:

- discuss and critically review experimental results in relation to known facts and models
- master to receive and respond to constructive criticism from reviewers.

Course content

Module 1. Image processing and mathematical methods (12 credits)

The definition of digital images, matrix size, pixel and voxel, image depth, grey and colour bars, window settings, gamma correction, histogram equalisation, continuous and discrete convolution, continuous and discrete Fourier transform, the convolution theorem, the delta- and shah-functions, sampling theory, the Nyqvist theorem, weighting artefacts, interpolation, linear translation-invariant systems, spatial resolution, point-spread function, modulation transfer function, image contrast, signal-to-noise level, filtering, ringing artefacts, tomographic reconstruction with filtered back projection, the Radon transform, sinogram, back projection, the Fourier slice theorem, the noise problem in filtered back projection, coregistration, image geometry, segmentation, neural networks and deep learning.

Module 2. Imaging and functional diagnostics: MR physics (9 credits)

General history. NMR-related nuclear physics, including the concepts of magnetic fields, nuclear spin, resonance, spin population and signal generation. Basic contrast parameters: Proton density as well as T1, T2 and T2* relaxation. Basic pulse sequences, i.e. spin echo, gradient echo, inversion recovery, as well as their typical contrast properties at different machine settings. The basic principles of pulse sequence optimisation. Clinical pulse sequences such as rapid gradient echos, fast spin echos, combination sequences and echo planar sequences. Application of magnetic field gradients in time and space for receiving spatial resolution (slice selection, frequency encoding, phase encoding, gradient refocusing). Signal detection, digitisation and image reconstruction (via Fourier transform) based on k-space formalism. Image quality parameters such as image field, spatial resolution, signal-to-noise ratio, bandwidth. Common MR artifacts' origin and appearance. Review of contrast agents for MRI. Overview of the MR systems technical structure and development potential. Introduction to MR methods for quantitative, functional, microstructural and molecular imaging, as well as MR spectroscopy, including technology and applications. Overview of clinical applications and diagnostics. MR safety including short-term and long-term biological effects, limits and public authority directives, and practical risks with MR studies (metal implant, missiles, effects on surrounding equipment, etc.).

Module 3. Imaging and functional diagnostics: nuclear medical physics (13.5 credits)

General history. Structure and function of the gamma camera for systems based on scintillation and semi-conductors. Collimation principles. Structure and function of SPECT-systems, PET-systems, and combination systems (SPECT-CT, PET-CT) for image fusion. Detectability, Artifacts. Image-based activity quantification. Correction methods for attenuation, scatter and non-perfect collimation. Image artefacts at high count rates. Iterative reconstruction methods. Clinical applications and image processing. ROC analysis. Pre-clinical imaging systems (micro-SPECT, micro-PET).

Other detectors in nuclear medicine (e.g. uptake meters abd probes). Activity meters and traceability. Production of radionuclides. Radiopharmaceuticals for diagnostics and treatment. Mechanisms for the localisation of radiopharmaceuticals. Pharmacological requirements. Generator systems. Quality control of radioactive drugs. Clinical applications of radioactive drugs. Pharmacokinetic models and compartment analysis. Formalism for internal dosimetry and applications with software. Patient-specific dosimetry and dosage planning. Radionuclide therapy. Dosimetry at the tissue and cell level. Patient and staff radiation protection. Optimisation. Ultrasound, including basic physical methods and clinical applications. Applications of AI in the field.

Module 4. Imaging and functional diagnostics: X-ray physics (6 credits)

General history. X-ray generator. X-ray tubes. The heel effect. X-ray spectrum and filtration. The X-ray image. Radiation fields, radiation quality parameters (HVL, spectra). Primary and secondary radiation, reduction of secondary radiation. Object contrast, contrast mediums. Detectors (image panels, image intensifiers, direct digital systems, photon counters). Computed tomography, spectral-CT, conebeam-CT, reconstruction algorithms, CT number. Mammography. Tomosynthesis. Synchrotron imaging. Quantification of image quality: PSF, MTF, Wiener spectrum, ROC & other methods. Quality control: periodic monitoring & delivery monitoring, reject analysis, clinical applications of X-rays. Optimisation, image quality versus the patient's absorbed dose. Staff and patient radiation protection. Applications of AI in the field.

Module 5. Radiotherapy physics (13.5 credits)

General history. General clinical external radiotherapy and brachytherapy. Clinical radiobiology and bioeffect models. Medical linear accelerators. Radiation sources in radiotherapy. Characteristics of radiotherapy. Treatment planning and calculation of absorbed dose in external radiotherapy, uncertainties in radiotherapy, use of the Monte Carlo method in radiotherapy. Intensity-modulated radiotherapy and optimisation theory. Tomotherapy, 4D radiotherapy and IGRT. Radiotherapy with protons, light ions, and neutrons. Dosimetry guidelines (IAEA) and radiation quality concepts. Clinical dosimetry. Total body irradiation. Image-fusion in treatment planning. Quality assurance (QA) and quality control (QC): acceptance testing/commissioning and periodic monitoring of radiotherapy machines. Radiation protection. Accidents and incidents in radiotherapy. Applications of AI in the field.

Module 6. Biostatistics (4.5 credits)

Experimental design: group size, matched/unmatched monitoring. Hypothesis testing: null hypothesis, hypothesis testing, p-value and statistical power, parametric and non-parametric hypothesis testing, e.g. t-tests, Chi2-test and Mann-Whitney U-test, Wilcoxon rank sum test. Analysis and presentation of survival data. Multivariate analysis: regression, correlation, ANOVA, cluster analysis, factor analysis. Estimation: regression, the least squares method, risk analysis.

Module 7. Reflective writing 2 (1.5 credits)

Compilation of reports from laboratory excersises on the included course modules, and revision after recieval of constructive criticism from reviewers.

Course design

The course is divided into modules. The teaching consists of a varying combination of lectures, calculation exercises, as well as auscultations and study visits linked to clinical activities or current research in medical radiation physics. Strong emphasis is placed on student active learning and training in oral and written communication. To each module, there is a considerable element of written assignments and seminars, as well as laboratory exercises, including computer simulations and field exercises. Participation in advanced assignments and laboratory exercises, including preparatory components such as e.g. laboratory follow-ups, is compulsory.

Assessment

Each module includes one or more examinations. Examinations are carried out in writing as well as orally. Advanced assignments and laboratory exercises are assessed through written and oral presentations.

Unless otherwise specified by the examining teacher, the use of tools based on generative artificial intelligence (GAI tools) is not permitted for creation of the final version that is submitted or presented for examination. For cases where the examining teacher states that the use of GAI tools is permitted, the use must be clearly declared by the student.

For students who have not passed the regular examination, an additional occasion for re-examination is offered. The number of examination sessions is limited to five. A student who has failed five examinations is not given any additional examination session.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Grades

Grading scale includes the grades: Fail, Pass, Pass with distinction
To pass a module, approved examinations are required for each of the included assignments, as well as participation in compulsory parts, as described above.

To pass the whole course, at least the grade Pass is required on all included modules, as well as passed presentations of all laboratory exercises in the course. To pass the course with distinction, the grade Pass with distinction is required on at least two thirds of the modules.

Entry requirements

Admission to the course requires a Pass grade on all previous courses (180 credits) according to the programme syllabus of Degree of Master of Science in Medical Physics (NASJF) 300 credits (25/5/2023 U 2023/626).

Further information

Apart from the aim and contents of the course as above, the qualification descriptor for professional qualification as medical physicists (The Higher Education Ordinance 2006:1324) is used as a basis for the aim of the course, contents and implementation.

The course can not be included in the exam qualification together with MSFM21 Medical radiation physics: Medical physics, 60 credits, or RAF320 Medical radiation physics, Medical Physics, 40 p (60 credits).

The course is given at the department of medical radiation physics, Lund university.