LUND UNIVERSITY

Faculty of Science

MSFM21, 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 2007-09-12 to be valid from 2007-09-13, spring semester 2008.

General Information

The course is a compulsory second-cycle course (semester 7–8) in the medical physics programme and 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

Main field of studies	*Depth of study relative to the degree requirements*
Medical Radiation Physics	A1F, Second cycle, has second-cycle course/s as entry requirements

Learning outcomes

On completion of the course students shall have acquired the following knowledge and skills (distributed across the following modules):

Module 1 Image processing and its mathematical methods (9 credits)

- independently be able to analyse and explain the relationship between different ways to represent discrete distributions, and operations involving these, using mathematical formalism, in computer programming language, and in oral and written form
- be able to explain how methods function – in particular convolution, Fourier transform, discrete sampling, interpolation, filtration and tomographic reconstruction) for processing of discrete data (digital images) – to both

colleagues (medical physicists) and other professional categories in healthcare as well as how different factors limit the reliability of results from using these methods
- independently be able to analyse and explain the effects that limitations in the properties of camera equipment have on image quality, in particular limited spatial resolution, image noise and contrast definition
- demonstrate an understanding of theoretical descriptions of image analysis methods in e.g. instruction books or research articles
- be able to explain different magnitudes in image quality analysis and understand the principle of Receiver Operating Characteristic (ROC) analysis
- independently be able to write short programs for the analysis of discrete signals in one, two and three dimensions, and
- be able to evaluate and state an opinion on the applicability of discrete data processing methods in different technical applications.

Module 2 Imaging and functional diagnostics (31 credits)
The module includes the physics and technology behind ultrasound, magnetic resonance, X-rays and nuclear medicine (including radiopharmaceuticals and internal dosimetry).

Ultrasound physics

- have a good overview of application fields for ultrasound diagnostics
- be very familiar with the fundamental concepts of ultrasound physics and be able to explain these to healthcare staff
- have a good understanding of the basic technical principles that are utilised in a diagnostic ultrasound machine
- know and discuss the safety aspects of medical ultrasound, and
- be able to interpret a medical ultrasound image as well as identify artifacts

MR physics

- be able to describe in detail and explain Nuclear Magnetic Resonance (NMR) based on a quantum physics as well as a semiclassical perspective including excitation, relaxation, signal generation and reception
- be able to describe basic pulse sequence types (gradient echo, spin echo and inversion recovery) and account for how radio-frequent excitation and relaxation influence contrast qualities in corresponding MR images
- be able to describe in detail the principles of how magnetic field gradients are applied (in space and in time) for receiving spatial resolution, and describe in mathematical terms the transition from collected signals to morphological MR images from a k-space perspective.
- independently be able to carry out computations on how imaging time and image quality parameters (SNR, spatial resolution, image field, artifact sensitivity, etc) are influenced when different machine settings and other practical conditions change
- have knowledge about the basic principles of the essential components in clinical pulse sequences as well as be able to account for their most typical properties and their advantages and disadvantages
- have a basic knowledge of mechanisms for MR contrast agents as well as have general knowledge of their clinical use
- be able to identify, describe and explain (from a mathematical/physical perspective) common artifacts in MR images
- have general knowledge of the most common medical applications of MR diagnostics and be familiar with contrast mechanisms and pulse sequence types

in functional MR methods as well as the principles of MR spectroscopy, and
- can apply an optimal approach to safety based on acquired knowledge of the practical risks and possible biological effects, as well as set up and carry out a practical MR experiment focusing on quality control and quality assurance

Nuclear medical physics

- be able to describe in detail and explain the structure and function of imaging detection systems (scintillation camera, SPECT and PET), and be familiar with and have general knowledge of other types of imaging system (including SPECT and PET)
- be able to account for how attenuation and dispersion influence images and explain the corrections that can be performed
- be able to identify, describe and explain the origin of common artifacts in scintigraphical images
- be familiar with the use of simple detection systems (e.g. for monitoring, uptake measurements, intraoperative probes and activity meters)
- have a good overview of radionuclides and radiopharmaceuticals for diagnostics and treatment, have basic knowledge of uptake mechanisms and a general knowledge of common radiopharmaceuticals' clinical use, as well as the ability to perform simple quality monitoring
- be familiar with quality control methods for equipment and be able to discuss and design programmes to regularly monitor, analyse and evaluate results of quality control procedures, as well as discuss and suggest measures
- be able to explain the different magnitudes in image quality analysis, understand the principle of ROC analysis, as well as be familiar with how clinical studies are performed and evaluated in the subject area
- be able to present an overview of radiation protection legislation and radiation protection recommendations in the field and discuss and analyse radiation protection-related issues specific to nuclear medicine, and
- know the principles of internal dosimetry, biokinetic models and compartmental analysis, as well as in accordance with MIRD formalism independently carry out internal dosimetric calculations for diagnostic and therapeutic radiopharmaceuticals

X-ray physics

- be able to describe in detail and explain the structure and function of radiography equipment (X-ray generators, X-ray tubes, image receivers) for conventional (planar) examinations, mammography and for different types of tomography (CT)
- be able to understand the principle for analogue and digital detectors and account for their function and advantages and disadvantages, as well as explain how they are used clinically
- be able to explain how exposure parameters and exposure conditions for different systems influence X-ray spectra, image quality (image noise, resolution and contrast), spread of radiation and the patient's absorbed dose
- be able to explain the different magnitudes in image quality analysis, understand the principle of ROC analysis, as well as be familiar with how clinical studies are performed and evaluated in the subject area
- be familiar with the different instruments for dosage measurement, know the principle for their function and independently be able to perform calculations for patient's radiation doses for different radiography examinations (including computed tomography and mammography) both in routine procedures and in

unplanned events of significance from a radiation protection perspective
- be able to present an overview of radiation protection legislation and radiation protection recommendations in the field and discuss and analyse radiation protection-related issues specific to nuclear medicine
- be able to discuss and prepare quality management programmes for regular monitoring of both radiography equipment and working methods, as well as analyse results from monitoring and suggest possible measures, and
- have general knowledge of the most common medical applications in diagnostic radiology and alternative methods in imaging and functional diagnostics.

Module 3 Radiotherapy physics (16 credits)

- have good knowledge of medical linear accelerators and be able to explain their structure and function
- have good knowledge of afterloading equipment and radiation sources in brachytherapy
- be able to describe radiation fields with regard to absolute and relative dosage distribution both for external radiation sources and around radioactive sources for brachytherapy
- master experimental determination of dosage distribution and use this information to independently perform dosage calculations in simple treatment cases
- be able to evaluate and discuss appropriate treatment techniques and modality in brachytherapy and external radiotherapy
- be able to perform clinical dosage planning and optimisation with regard to biological and physical aspects in both conventional and intensity-modulated external radiotherapy such as brachytherapy, as well as have a degree of familiarity with the computing models that can be used
- be able to account for international recommendations for the reporting of radiotherapy
- be familiar with the treatment process from diagnosis to completed treatment including diagnostic imaging systems, fixation systems, assessment of optimised dosage plans, as well as documentation
- be able to discuss and analyse radiation protection-related issues specific to radiotherapy
- be able to discuss and prepare programmes for quality assurance including monitoring of both equipment and working methods so that each patient is assured that the absorbed dose in the target volume corresponds to the prescribed radiation dose within accepted limits.

Module 4 Biostatistics (4 credits)

- have basic knowledge of experimental design
- be able to account for the basic concepts of hypothesis testing such as the null hypothesis, significance testing, p-value and statistical strength, as well as choose and apply common parametric and non-parametric hypothesis testing e.g. t-test, 2-test and Mann-Whitney U test, Wilcoxon's rank sum test, presentation of survival data
- be able to describe and apply different estimation methods, and
- be able to perform computations in a statistical program package suitable for the course content.

Course content

The course consists of the modules *image processing and its mathematical methods, imaging and functional diagnostics (ultrasound, HR, X-ray and nuclear medicine) and radiotherapy physics.*

Module 1 Image processing and its mathematical methods (9 credits)

History. Image theory: definition of an image. Convolution. The DELTA function. The Fourier transform. Sampling. Interpolation. Linear systems. Contrast. Image noise. ROC analysis. Filtration methods. Image reconstruction, filtered back projection and iterative methods. IDL script programming.

Module 2 Imaging and functional diagnostics (31 credits)

Imaging and functional diagnostics includes the physics and technology behind ultrasound, magnetic resonance, X-rays and nuclear medicine (including radiopharmaceuticals and internal dosimetry).

Ultrasound physics
History, ultrasound technology, sensor technology, diagnostic machine technology, presentation methods, doppler, field characterisation, safety, artifacts, power ultrasound, special techniques in areas such as brachytherapy in gynaecological cancer and prostate cancer, cardiology, urology and prenatal diagnosis.

MR physics
General history. The foundations of NMR-related nuclear physics including concepts such as magnetic fields, 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. Clinical pulse sequences such as the fast gradient echo. 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 system's technical design. Review of methods for functional MR as well as MR spectroscopy including technology and applications. Quality control and quality assurance of MR equipment. Overview of clinical applications. MR safety including short-term and long-term biological effects, limits and public authority directives as well as the practical risks of MR examinations (metal implants, projectiles, effects on surrounding equipment, etc).

Nuclear medical physics
General history. Scintillation camera: structure and function Collimators Structure and function of SPECT systems, PET systems as well as combination systems (SPECT-CT, PET-CT) for image fusion. Detectability, Artifacts. Activity quantification in planar and tomographic studies. Correction methods for attenuation, dispersion, collimator resolution. Downtime. Transmission SPECT. Reconstruction methods. Clinical applications and image processing. ROC analysis. Mathematical modelling of detection systems using Monte Carlo (methods for calculation of photon transport, mathematical phantoms and examples of common Monte Carlo programs). Systems for small animal imaging (micro-SPECT, micro-PET). Other detectors in nuclear

medicine (e.g. uptake meters, probes, activity meters). Production of radionuclides. Radiopharmaceuticals for diagnostics and treatment. Mechanisms for localisation. Pharmacological requirements. Generator systems. Quality control: in vitro and in vivo. Clinical applications. The basis for internal dosimetry. Biokinetic models and compartmental analysis. MIRD formalism and applications using software. Patient-specific dosimetry and dosage planning. Radionuclide therapy. Dosimetry at the tissue and cell level. Patient and staff radiation protection. Optimisation. Monte Carlo simulation of electron transport for dosimetric calculations. Dosimetric calculations using Monte Carlo (methods for calculation of photon/electron transport, mathematical phantoms and examples of common Monte Carlo programs).

X-ray physics
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 (film, intensifying screens, image plates). Image intensifiers. Direct digital detectors. Computed tomography, reconstruction algorithms, CT numbers. Mammography. Tomosynthesis.
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.

Module 3 Radiotherapy physics (16 credits)

General history. General clinical external radiotherapy and brachytherapy. Clinical radiobiology and bioeffect models. Medical linear accelerators. Radiation sources in radiotherapy. Characteristics of radiotherapy. Dosage planning and dosage calculation 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 using protons, light ions and neutrons (BNCT). Dosimetry guidelines (IAEA) and radiation quality concepts. Clinical dosimetry. Total body irradiation. Image-fusion in dosage planning. Quality assurance (QA) and quality control (QC): acceptance testing/commissioning and periodic monitoring of radiotherapy machines. Radiation protection. Accidents and incidents in radiotherapy.

Module 4 Biostatistics (4 credits)

Experimental design: group size, matched/unmatched monitoring. Hypothesis testing: the null hypothesis, significance testing, p-value and statistical strength, parametric and non-parametric hypothesis testing e.g. t-test, 2-test and Mann-Whitney U test, Wilcoxon's 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.

Course design

Teaching consists of lectures with many group exercises, laboratory sessions, auscultations, student seminars and feedback sessions. A strong emphasis is placed on thematic teaching and students' activities and training in oral and written communication. Internet resources are used as a natural part of teaching sessions. Compulsory attendance applies to all course components.

Continuous assessment is applied in the course. Summative assessment (examinations at the end of modules) is oral, in writing or a combination of the two. Formative assessment during the course takes the form of problem-solving, written assignments and special advanced assignments with report writing and seminar presentations.

Assessment

For students who have not passed the regular examination, an additional examination is offered by agreement with the course coordinator or director of studies. Student assessments are carried out after each module.

Subcourses that are part of this course can be found in an appendix at the end of this document.

Grades

Marking scale: Fail, Pass, Pass with distinction.
The final grade is determined by combining the results of the various assessed course components.

Entry requirements

Admission to the course requires passes on courses in accordance with the programme syllabus for the Medical Physics programme (NASJF) 300 credits (30/05/2007, Reg. no NG 211-352/2006).

Further information

In addition to course's learning outcomes and content as outlined above, the course applies the qualification description for professional qualification as medical physicists (The Higher Education Ordinance 2006:1324) and The Swedish National Board of Health and Welfare's "Competencies for medical physicists" (SOS 2001-105-1) as a basis for the course's learning outcomes, content and implementation.

The course may not be credited towards a degree together with RAF320.

Subcourses in MSFM21, Medical Radiation Physics: Hospital Physics

Applies from H07

0701 Digital Image Processing and its Mathematics, 9,0 hp
Grading scale: Fail, Pass, Pass with distinction
0702 Physics of Ultrasonics, 3,0 hp
Grading scale: Fail, Pass, Pass with distinction
0703 Physics of MR-physics, 8,0 hp
Grading scale: Fail, Pass, Pass with distinction
0704 Physics of Radiology, 8,0 hp
Grading scale: Fail, Pass, Pass with distinction
0705 Physics of Nuclear Medicine, 12,0 hp
Grading scale: Fail, Pass, Pass with distinction
0706 Physics of Radiation Therapy, 16,0 hp
Grading scale: Fail, Pass, Pass with distinction
0707 Biostatistics, 4,0 hp
Grading scale: Fail, Pass, Pass with distinction