LUND UNIVERSITY

Faculty of Science

MSFM02, Medical Radiation Physics: Basic Course, 60 credits

Medicinsk strålningsfysik: Grundkurs, 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 physics program (semester 5-6), and initiates the specialisation in 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	A1N, Second cycle, has only first-cycle course/s as entry requirements

Learning outcomes

The course covers basic radiation physics and consists of 8 modules. The included modules include both ionising and non-ionising radiation and its biological effects, as well as scientific methodology and medical orientation.

- Module 1. Ionising radiation: production, interaction and detection (8.5 credits, 6.5 credit, 6 credits)
- Module 2. Ionising radiation: dosimetry (7.5 credits)
- Module 3. Scientific methodology (3 credits)
- Module 4. Medical orientation (4.5 credits)

- Module 5. Radiation biology (7.5 credits)
- Module 6. Non-ionising radiation (7.5 credits)
- Module 7. Environmental radiology and radiation protection (7.5 credits)
- Module 8. Reflective writing 1 (1.5 credits)

Knowledge and understanding

Module 1. Ionising radiation: production, interaction and detection

After completed module, the student should be able to:

Production

- explain quantities for radioactive decay and radiation fields
- explain different radioactive decays, as well as primary and secondary radiation
- explain activation and production of radionuclides
- give an account of different accelerators and radiation sources in health care and society at a general level
- give an account of basic radiation protection.

Interaction

- describe and explain the most common scatter and energy transfer mechanisms in interactions of light and heavy charged particles with matter, as well as account for the dependence of the interaction processes on energy and material composition
- describe and explain the most common scatter and energy absorption mechanisms in interactions of photons with matter, as well as account for the dependence of the interaction processes on energy and material composition
- account for the energy classification of neutrons, describe and explain common scattering processes and reactions that lead to energy transfer and slowing down of neutrons as they interact with matter, as well as account for the dependence of the interaction processes on energy and material composition at a general level
- describe and explain relevant atomic interaction cross-sections and define and explain related macroscopic units that are used to describe how interaction with a given material influences am incident beam of photons or particles in terms of attenuation or stopping power
- describe and explain the basic principles of Monte Carlo simulation of the interaction of photons and charged particles, and how the Monte Carlo method can be used to simulate radiation transport in a medium.

Detection

- describe the principles of gas-filled detectors, scintillation detectors and semiconductor detectors, and give an account of the design, materials, properties and function of the different detector systems
- give an account of the use of different detector types in research and health care.

Module 2. Ionising radiation: dosimetry

After completed module, the student should be able to:

- describe and explain the dosimetric quantities and their relationship
- explain the meaning of radiation equilibrium and its importance for the determination of absorbed dose
- account for micro dosimetric quantities
- give an account of basic cavity theories and the use of perturbation factors, and explain the importance of the Monte Carlo method in this context.

Module 3. Scientific methodology

After completed module, the student should be able to:

- explain fundamental concepts in the theory and methods of science
- describe the processes of scientific publication
- explain different kinds of research design in clinical research
- describe the fundamental principles of good research practice
- be aware about the organisation of the research landscape.

Module 4. Medical orientation

After completed module, the student should be able to:

- briefly describe the human anatomy
- explain briefly the physiology of the largest organ systems
- describe the basic processes in cell and tumour biology
- give an account of symptoms, diagnostics and treatment for diseases relevant to the fields of the medical physicist
- describe the basic structure in the organisation of the health care and in the legislation in the health care system.

Module 5. Radiation biology

After completed module, the student should be able to:

- explain the biological effects that ionising radiation causes on the molecular, cellular, tissue, organs and organism level, their mutual relations and time dynamics for different types of effects after exposure to low and high and high absorbed dose levels
- explain how radiobiological effects are quantified and describe how they can be examined with different experimental techniques
- explain how different factors can influence radiobiological effects such as e.g. type of radiation, oxygenation level, dose rate, fractionation, and explain the quantities that are used to describe these effects

- explain stochastic and teratogenic effects, independently analyse and describe data and the scientific foundation whereupon prevailing models for risk estimation are based.

Module 6. Non-ionizing radiation

After completed module, the student should be able to:

- account for the electromagnetic spectrum as well as classify its components
- account for the difference between electromagnetic fields and electromagnetic radiation
- describe how static and time-varying electromagnetic fields and electromagnetic radiation interact with biological matter
- describe how optical radiation, including laser, interacts with biological matter
- account for international and national recommendations and laws in the field.

Module 7. Environmental radiology and radiation protection

After completed module, the student should be able to:

- describe the occurrence of radioactive substances in the environment (including radon), its dispersion, deposition, accumulation as well as transfer to plants, animals and man in marine and terrestrial ecosystems
- give an account of fundamental principles of nuclear power reactors and the structure of boiling and pressurised water reactors
- account for and give examples of fundamental radioecological concepts as food chain, critical group, bioindicator etc
- describe the use of radionuclides as tracers for biogeochemical processes
- account for different measuring techniques and mathematical models including absorbed dose calculations for man and radiation effects on ecosystems
- account for the work of the different radiation protection organisations
- explain the regulatory framework for radiation protection based on current radiation protection recommendations and give an account of the society's radiation protection preparedness for nuclear energy accidents (international, national and local).

Module 8. Reflective writing 1

- in written reports give an account of experimental observations and explain underlying relationship in connection to the laboratory exercises that are carried out in the included modules.

Competence and skills

Module 1. Ionising radiation: production, interaction and detection

After completed module, the student should be able to:

Production

- apply available data for radioactive decay and for primary and secondary radiation
- carry out calculations related to radioactive decay and activation, and discuss solution methods and present result.

Interaction

- acquire and use quantitative tabulated values that describe how incident radiation interacts with matter, for different types of radiation, energies and materials
- independently analyse and solve computational problems related to the interaction of ionising radiation with matter, as well as be able to present and discuss solution methods and results
- use detector systems commonly occurring in laboratory environment to carry out measurements of the effects of ionising radiation interactions with matter, and thereby apply basic practical radiation protection
- use Monte Carlo methods to supplement interaction related measurement data
- both qualitatively and quantitatively analyse and evaluate experimental and Monte Carlo generated data from interaction processes in materials, and present relevant methods, results and conclusions in writing.

Detection

- independently identify and choose relevant detector type and detector system to carry out precise measurements in different situations
- set up and carry out practical measurements with commonly occurring detector systems, analyse and evaluate measurement data both qualitatively and quantitatively, and carry out and present calculations (including uncertainty analysis) based on the measurement results
- independently analyse and solve computational problems related to detection of ionising radiation, as well as be able to present and discuss solution methods and results
- use different common detector systems in the laboratory environment to analyse effects depending on choice of detector type and the resolution of the detector.

Module 2. Ionising radiation: dosimetry

After completed module, the student should be able to:

- analyse and solve concrete problems in dosimetry
- carry out simple calculations in accordance with the most common cavity theories.

Module 3. Scientific methodology

After completed module, the student should be able to:

- carry out search and retrieval of scientific literature and critical review
- write a scientific report according to established structure
- design a research study and discuss ethical aspects
- present scientific data and results with relevance and rigour.

Module 4. Medical orientation

After completed module, the student should be able to:

- present the plans and directions of the body with a medically relevant terminology
- discuss the basic cell biological factors behind the origin of cancer
- discuss disease progression and treatment options for common cancer diagnoses.

Module 5. Radiation biology

After completed module, the student should be able to:

- discuss the function of laboratory technologies for studying radiobiological effects, as well as quantify and analyse the results
- carry out simple laboratory procedures for the study of radiobiological effects
- apply cell survival models and discuss the assumptions that underlie the models
- use scientifically established concepts and terminologies.

Module 6. Non-ionizing radiation

After completed module, the student should be able to:

- discuss possible mechanisms for how static and time varying electromagnetic fields and radiation, including optical radiation and laser, may cause biological effects
- solve simple problems regarding static and time varying electromagnetic fields and radiation, including optical radiation and laser.

Module 7. Environmental radiology and radiation protection

After completed module, the student should be able to:

- discuss reasons for disequilibrium in the natural decay chains and the radiological consequences of this, as well as discuss causes of historical changes in our radiation environment
- present and discuss radiation protection issues and risks in a relevant way for different target groups
- use simple sampling techniques and radiochemical analytical methods
- carry out simple radiation protection measurements in the field

- analyse and present collected data in writing and orally
- use concepts as biological half-life uptake, secretion and residence time in compartment modelling
- perform measures in radiation protection preparedness situations that require medical physics competence
- apply ICRP's three principles of different exposure situations.

Module 8. Reflective writing 1

- 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. Ionising radiation: production, interaction and detection

After completed module, the student should be able to:

Production

- evaluate experimental data from own measurements of radioactive decay
- make a proper choice of accelerator for production of ionising radiation and radionuclides
- assess and suggest suitable applications of radiation sources in healthcare and society.

Interaction

- suggest choice of radiation protection barrier (with respect to material and design) in different exposure situations and environments
- interpret and evaluate measurement data from radiation interactions in laboratory exercises
- use Monte Carlo simulated data as an aid to interpret experimental results and identify relevant sources of errors in experimental measurements
- suggest appropriate practical radiation protection measures in laboratory environment.

Detection

- suggest choice of detector type (with respect to materials and design) in different detection situations
- interpret and evaluate measurements of ionising radiation in laboratory exercises.

Module 2. Ionising radiation: dosimetry

After completed module, the student should be able to:

- suggest which detector/dosimeter that is most suited for measurement of absorbed dose in common situations
- discuss the concept of absorbed dose with regard to its physical and biological use and its limitations.

Module 3. Scientific methodology

After completed module, the student should be able to:

- assess relevance and credibility of different sources of information
- interpret the validity and relevance of measured data
- argue for the scientific method as a foundation for the search for new knowledge
- discuss ethical aspects and misconduct in research.

Module 4. Medical orientation

After completed module, the student should be able to:

- demonstrate an understanding of the role of the medical physicist in a hospital
- discuss patient safety questions in connection with medical physics applications.

Module 5. Radiation biology

After completed module, the student should be able to:

- evaluate different dose levels in relation to the risk to induce different types of radiobiological effects for cells, tissues, organs and the individual
- justify how different factors such as type of radiation, oxygenation level, dose rate, fractionation, cell- and tissue type, can influence radiobiological effects on a short and long term
- discuss risk estimation at low radiation doses based on its scientific foundation.

Module 6. Non-ionizing radiation

After completed module, the student should be able to:

- relate to electromagnetic fields and radiation occurring in society, including optical radiation and laser, as well as respond to inquiries on how these interact with biological matter
- discuss and argue for the risks of injuries associated with electromagnetic fields and radiation in a popular way to the public.

Module 7. Environmental radiology and radiation protection

After completed module, the student should be able to:

- suggest appropriate radiation protection instrument for different unknown situations
- suggest necessary measurements to decide appropriate measures based on radiation type, activity, possible dispersion as well as influence on man and environment
- suggest appropriate radiochemical methods in different analysis situations
- interpret and communicate measurement result to expertise and the public in an understandable and relevant way
- assess risks and suggest measures based on current recommendations and legislation
- assess entitling the use of ionising radiation, suggest optimisation measures and apply dose restrictions and reference levels.

Module 8. Reflective writing 1

- critically discuss and review experimental results in relation to known facts and models
- master the receival and response to constructive criticism from reviewers.

Course content

Module 1. Ionising radiation: production, interaction and detection (8.5 credits, 6.5 credits, 6 credits)

Introduction to laboratory work with radiation sources.

Production

The history of radiation physics. Introduction to radiation safety. Overview of basic quantities for activity, radiation fields and dosimetry. The origin and occurrence of ionising radiation. Atomic processes: characteristic X-ray radiation and Auger emission. Nuclear processes: alfa decay, beta decay, electron interception and metastabile state, isomeric transition, gamma radiation and internal conversion. The radioactive decay, serial decay, activation. Natural decay chains. Commonly occurring radiation sources in medicine, industry and society. Tabulated data for radioactive decay and atomic radiation. Overview of and principles of accelerators in medicine and research.

Interaction

Processes of heavy and light charged particles passing through matter (including the dependence on energy, mass and charge of the particle as well as the properties of the medium): Inelastic collision with atomic electrons, inelastic collision with atomic nucleus, elastic collision with atomic nucleus, elastic collision with atomic electrons. Energy transfer mechanisms, ionisation, stopping power, dispersion, energy-range relations, bremsstrahlung. Interaction processes and cross-sections for ionising photons radiation (X-ray and gamma): Photoelectric effect, Compton-scattering, and pair production, including the energy of the processes and Z-dependency. Photon attenuation including narrow and broad-beam conditions, build-up and radiation barriers. Description and energy classification of interaction processes and cross-sections for neutrons including scatter and nuclear reactions. Stopping and moderation of neutron radiation. Thermal neutrons. Neutron attenuation and radiation barriers. Methods for determination of cross-sections and its uncertainties as well as use of tables for interaction coefficients. Use of interaction theory in mathematical Monte Carlo simulations of radiation transfer in different experimental situations.

Detectors

General basic principles of detection of ionising radiation. Structure, design and function for gas-filled detectors (ionisation chamber, proportional counters, Geiger-Müller counters), inorganic and organic scintillation detectors and semiconductor detectors for spectroscopy and imaging. Principles of energy resolution and spectrometry for photons and charged particles. Neutron detection. Principles of image quality and methods for measurement of noise, contrast, signal and resolution. Pulse counting statistics, the statistical nature of the measurement result, systematic errors, the concepts precision and precision. Monte Carlo simulation as an aid for the interpretation of measurements. Calibration, low activity measurements and background radiation. Orientation in the use of radiation detectors in healthcare. Choice of appropriate detector and optimisation of measurement setup.

Module 2. Ionising radiation: dosimetry (7.5 credits)

Dosimetric quantities and definitions according to the ICRU. Basic microdosimetry and microdosimetric units. Radiation transport. Charged particle equilibrium. Fano's theorem. Interface dosimetry. Cavity theories: Bragg-Gray, Spencer-Attix and Burlin. Monte Carlo calculations. Calculation of stopping-power ratios and track-ends. Perturbation factors. Absolute and relative dosimeters. Introduction to applied dosimetry.

Module 3. Scientific methodology (3 credits)

Theory and history of science. The scientific method. Knowledge resistance and pseudoscience. Information competence with scientific literature search, source criticism and reference management. Scholarly publishing and academic writing. Presentation of measured data and figures. Research trial planning and evidence hierarchy within medicine. Good research ethics and misconduct in research. The history of universities and academic freedom. The Swedish research landscape, funding and legislation.

Module 4. Medical orientation (4.5 credits)

Basic cell and tumour biology, the cell cycle, mutations, oncogenes and apoptosis. Basic anatomy and physiology: the structure of the body and the physiology of the most important organs as well as the interplay between different organ systems. Medical terminology: the plan of the body and directions, Latin/Greek names of the most common organs/organ system. The symptoms and treatment of diseases, with an emphasis on cancer. The role of the medical physicist in health care. Legislation in health care. Medical ethics and the relation between different professional groups in health care. Patient security.

Module 5. Radiation biology (7.5 credits)

Basics of radiobiology: DNA damage, chromosome aberrations, cell survival curves. Radiation sensitivity, repair mechanisms, dose rate effects, the oxygen effect, LET, RBE, radiation-effect modifiers. The quantities equivalent dose and effective dose. Methods and applications in radiobiological research. Radiation effects: Dose-response relationships for cells, tissues, organs, individuals, relations between radiation dose and biological effects, deterministic tissue reactions and stochastic effects (somatic and hereditary), as well as teratogenic effects. Radiation epidemiological data underlying the knowledge of late effects of radiation. Radiobiological models. Experimental techniques to study radiobiological effects. Organisations involved in radiation protection.

Module 6. Non-ionising radiation (7.5 credits)

The electromagnetic spectrum. Static and time varying electric and magnetic fields (EMF), as well as radio frequent radiation and microwaves. Optical radiation: IR, UV and laser. The interaction of electromagnetic fields and non-ionizing electromagnetic radiation with matter, as well as its effect on and absorption in medium. Production of EMF and non-ionizing radiation. Electromagnetic fields around devices and power generation. Measuring instruments as well as principles of detection of different types of EMF and non-ionizing radiation. Biological effects: dose-response relations for cells, organs, individuals, and relations between non-ionizing radiation and biological effects. Results of radiobiological research with respect to the effect of EMF and non-ionizing radiation. Epidemiology and risk issues with respect to current public debate in relevant subjects (mobile telephony, power lines, etc). Orientation in non-ionizing radiation for diagnostics and treatment in healthcare. Radiation protection work, radiation protection recommendation, and legislation, as well as international and national organisations.

Module 7. Environmental radiology and radiation protection (7.5 credits)

Environmental radiology

Composition and importance of our natural radiation environment with dominating mechanisms and transport paths to humans. Principles of the use of natural and artificial radioisotopes as tracers for processes. Basic kinetic models. Elementary concepts in reactor physics and potential reasons for exposure from nuclear reactors in normal operation and at accidents, as well as the different stages in the nuclear fuel cycle. Historical overview of events and potential future scenarios, their extent and influence on humans and the environment. Occurrence of radon, its decay, detection, dosimetry as well as risk estimation for different groups. Measurements in field with mobile detection systems and hand held radiation protection instruments for surveillance, identification and quantification of radiation sources and field contamination. Calculation and evaluation of relevant radiation protection quantities from measurement data.

Radiation protection

Basic concepts in radiation protection based on ICRP's recommendations, the relation between physical and measurable units to radiation protection quantities in different exposure situations. Methods of measurement for estimating efficient dose, prospective and retrospective. Application of ICRP's three principles (justification, optimisation, dose limits) in different exposure situations including ALARA and the LNT-model. The relation between radiation protection organisations on global, regional, and national levels, as well as radiation protection preparedness: organisation, resources, measurements in the field, assessment and reporting. Communication of risks in view of earlier events.

Module 8. Reflective writing 1 (1.5 credits)

Compilation of reports from laboratory excersises for the different included modules and revision after reception of constructive criticism from reviewer.

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, 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 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 for at least two thirds of modules.

Entry requirements

Admission to the course requires at least a Pass grade on all previous courses (120 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 MSFM01 Medical radiation physics: Basic course, 60 credits or MSFM11 Medical radiation physics: Basic course, 60 credits.

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