LUND UNIVERSITY

Faculty of Science

MSFM01, 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 2017-08-24 to be valid from 2017-08-24, autumn semester 2017.

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 studies	*Depth of study relative to the degree requirements*
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 7 modules. The included modules cover the properties and the biological effects of both ionising and non-ionizing radiation, as well as scientific methodology and medical orientation.

- Module 1. Ionising radiation: production, interaction and detection (19.5 credits)
- Module 2. Ionising radiation: dosimetry (7.5 credits)
- Module 3. Scientific methodology (3 credits)
- Module 4. Medical orientation (6 credits)
- Module 5. Radiation biology (7.5 credits)
- Module 6. Non-ionizing radiation (9 credits)
- Module 7. Environmental radiology and radiation protection (7.5 credits)

Knowledge and understanding

Module 1. Ionising radiation: production, interaction and detection

After completed module, the student should be able to:

Production

- describe and explain the decay processes for radioactive nuclides
- describe the radiation that is produced by radioactive decay and explain its properties
- describe and explain the accelerators that are used for production of ionising radiation and production of radioactive nuclides
- account for the atomic and nuclear processes involved in radioactive decay
- describe and explain decay chains by means of nuclear data tables

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, as well as define and explain related macroscopic quantities that are used to describe how interactions in a given material affects an incident beam of photons/particles

Detection

- describe the principles of gas-filled detectors, scintillation detectors and semiconductor detectors as well as account for the design, properties and function of the different detector systems
- account for the use of different detector types in research and healthcare

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
- account for basic cavity theories and the use of perturbation factors

Module 3. Scientific methodology

After completed module, the student should be able to:

- explain fundamental scientific concepts
- describe the historical development of natural sciences and clinical research
- describe the process of publication of research
- account for the institutionalised science and research

Module 4. Medical orientation

After completed module, the student should be able to:

- describe human anatomy briefly

- explain briefly the physiology of the largest organ systems
- describe the basic processes in cell and tumour biology
- account for symptoms, diagnostics and treatment for diseases with relevance to the fields of the medical physicist
- describe the basic structure in the organisation of the healthcare as well as in the legislation in health care

Module 5. Radiation biology

After completed module, the student should be able to:

- describe and explain the biological effects that ionising radiation causes on molecular, cellular, tissue, organs and organism level, explain their mutual relations as well as the dynamics with which different effects appear after low and high absorbed doses
- describe and explain how radiobiological effects are quantified as well as how they can be examined with different experimental techniques
- describe and explain factors that modify radiobiological effects such as e.g. radiation type, oxygen, dose rate, as well as explain such measures that are used to quantify these effects
- explain stochastic and teratogenic effects, analyse and describe data as well as the scientific basis for prevailing models for risk estimation

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 current international and national recommendations and laws in the area

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
- account for fundamental principles of nuclear power plants 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, as well as account for the radiation protection preparedness with respect to nuclear energy accidents (international, national and local)

Competence and skills

Module 1. Ionising radiation: production, interaction and detection

After completed module, the student should be able to:

Production

- acquire and use quantitative values of units that describe how radioactive nuclides decay
- calculate produced activity in a product from an activation process
- analyse and solve computational problems related to radioactive decay and the production of ionising radiation, as well as be able to present and discuss solution methods and results
- both qualitatively and quantitatively analyse and evaluate experimental data from practical measurements of radioactive decay

Interaction

- acquire and use quantitative values of units that describe how incident radiation is slowing down or attenuated in interactions with matter for different radiation types, 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
- both qualitatively and quantitatively analyse and evaluate experimental data from practical measurements on interaction effects, as well as present relevant methods, results and conclusions in writing

Detection

- 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 as quantitatively, as well 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

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:

- independently carry out information retrieval in databases and in scientific literature
- use reference management systems in written reports
- write a report that follows the format for a scientific article
- discuss the practical implementation of pre-clinical and clinical studies and their ethical aspects
- present and discuss current scientific findings and results in a popular way

Module 4. Medical orientation

After completed module, the student should be able to:

- present the plan of the body and directions 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 study of radiobiological effects
- apply cell survival models and discuss the assumptions that underlie the models
- use 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 for different exposure categories

Judgement and approach

Module 1. Ionising radiation: production, interaction and detection

After completed module, the student should be able to:

Production

- interpret and evaluate decay data for radioactive nuclides
- suggest choice of accelerator type for production of ionising radiation

Interaction

- suggest choice of radiation protection barrier (with respect to materials and design) in different exposure situations and environments
- interpret and evaluate measurement data from radiation interactions in laboratory exercises
- suggest appropriate practical radiation protection measures in laboratory environments

Detection

- suggest choice of detector type (with respect to materials and design) in different detection situations
- interpret and evaluate measurement data from detected 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

- evaluate the concept 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
- demonstrate an understanding of the concept of risk, both in an administrative and a practical way
- independently suggest new issues in the work as a medical physicists and assess possible ways to answer these in a scientific way
- demonstrate an understanding of academic integrity and medical ethics

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 issues in connection with radiophysical 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
- discuss risk estimation at low radiation doses in relation to its scientific basis

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 issues of how these interact with biological matter
- discuss and argue for the risks of injuries with electromagnetic fields and radiation in a popular way for 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 method 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 justification of using ionising radiation, suggest optimization measures, as well as apply dose limitations/reference levels

Course content

Module **1.** Ionising radiation: production, interaction and detection, 19.5 credits

Introduction to laboratory work with radiation sources.

Production
Historical introduction and overview of basic units for radiometry. Different types of ionising radiation, its origin and occurrence. Atomic processes: transitions between the electron shells, characteristic X-ray radiation and Auger electrons. Nuclear processes: alpha decay, beta decay, electron capture, metastable states, isomeric

transition, gamma radiation, internal conversion. Semiempirical mass formula. Radioactivity, the time course of the decay, serial decay, activation. Commonly occurring radionuclides for medicine and industry. Tables for decay data and interpretation of decay schemes. Production of radionuclides. Fission and fusion. Nuclear reactions. Principles of accelerators and radiation sources in medicine, research and industry. Neutron sources.

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-dispersion, pair production, including energy and Z-dependence. 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 dispersion and nuclear reactions. Braking 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.

Detectors
General basic principles of detection of ionising radiation. Structure, design and function for gas-filled detectors (ionisation chamber, proportional counter, Geiger-Müller counter), inorganic and organic scintillation detectors, semiconductor detectors, and neutron detectors. Principles of energy resolution and spectrometry for photons and charged particles. Neutron detection. Orientation in methods for measurement of small currents and charges, pulse detection, pulse amplification, pulse electronics and pulse height analysis. Pulse counting statistics, the statistical nature of the measurement result, systematic errors, the concepts precision and precision. Absolute and relative measurements, calibration, coincidence techniques, low activity measurement, 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 units and definitions according to 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

Scientific fundamental concept and theory. Scientific method. Basic history of science. Research institutions and funding. Information retrieval and databases of the university library. Scientific literature and publication. Evidence-based medicine. Academic integrity. Medical Ethics. Research-ethical questions. Medical information and confidentiality. Literature search and reference management. The concept of risk. Epidemiology.

Module 4. Medical orientation, 6 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 medical physicist and the role of the medical physicist in health care. Legislation in health care. Medical Ethics and the relation between different professional groups in healthcare. Patient security.

Module 5. Radiation biology, 7.5 credits

Basics of radiobiology: injuries on DNA, chromosome aberrations, cell survival curves. Radiation sensitivity, repair mechanisms, dose rate effects, the oxygen effect, LET, RBE, radiation effect modifiers. The units equivalent dose and efficient dose. Methods and applications in radiobiological research. Radiation effects: Dose-reponse relations 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 technologies to study radiobiological effects. Organisations involved with radiation protection issues.

Module 6. Non-ionizing radiation, 9 credits

The electromagnetic spectrum; static and time dependent electric and magnetic fields (EMF) as well as radio frequent radiation and microwaves; optical radiation: IR, UV and laser. Electromagnetic field and non-ionizing electromagnetic radiation interaction 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. Simple 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, its 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 the field with mobile detection systems and hand held radiation protection instruments for search, 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.

Course design

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 biophysics. In addition, there is a considerable element of laboratory exercises, which can also consist of computer simulations or field exercises, as well as written assignments and seminars. Strong emphasis is placed on student active learning and training in oral and written communication. Participation in laboratory exercises and advanced assignments, including preparatory components such as e g laboratory follow-ups, is compulsory.

Assessment

Examination takes place by both oral and written exams during the course. Laboratory exercises and advanced assignments are assessed through written reports or oral presentations. For students who have not passed the regular examination, an additional examination is offered in close connection to the regular occasion, or by agreement with the course coordinator and the director of studies.

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.

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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.
To pass the whole course, at least the grade pass is required on all included examinations, as well as passed compulsory components. To pass the course with distinction, it is additionally required that the grade pass with distinction has been achieved on at least two thirds of the included exams.

Entry requirements

For admission to the course, passed courses according to the programme syllabus of Degree of Master of Science in Medical Physics (NASJF) are required 300 credits (19/11/2015, Dnr Fail 2016/82).

Further information

The course may not be included in qualification together with MSFM11 Medical radiation physics: Basic course, 60 credits, or RAF310 Medical radiation physics, basic course, 40 p (60 credits).

Subcourses in MSFM01, Medical Radiation Physics: Basic Course

Applies from H17

1701 Ionizing Radiation: Production and Interaction (Theory), 8,0 hp
Grading scale: Fail, Pass, Pass with distinction
1702 Ionizing Radiation: Detection (Theory), 6,0 hp
Grading scale: Fail, Pass, Pass with distinction
1703 Ionizing Radiation: Problem Solving, 5,5 hp
Grading scale: Fail, Pass, Pass with distinction
1704 Ionizing Radiation: Dosimetry, 7,5 hp
Grading scale: Fail, Pass, Pass with distinction
1705 Introduction to the Scientific Method, 3,0 hp
Grading scale: Fail, Pass, Pass with distinction
1706 Introductory Medicine, 6,0 hp
Grading scale: Fail, Pass, Pass with distinction
1707 Radiobiology, 7,5 hp
Grading scale: Fail, Pass, Pass with distinction
1708 Non-ionizing Radiation, 9,0 hp
Grading scale: Fail, Pass, Pass with distinction
1709 Environmental Radiology and Radiation Protection, 7,5 hp
Grading scale: Fail, Pass, Pass with distinction