MASTER OF ADVANCED STUDIES IN MEDICAL PHYSICS

Jointly organised by ICTP and Trieste University

(rev 05/02/2024)

The Master is addressed to students with a MSc in Physics (or equivalent academic degree).

The course, taking into account IAEA and IOMP recommendations, is organised in two years of activities:

- A first year of academic courses and exercises
- A second year of supervised Clinical Training

After the Master, the recommendation is to follow other 1-2 years of Clinical training to reach the competences of a Clinically Qualified Medical Physicist (CQMP) or a different path according to the requirements of the competent authorities in the Country.

The Certification/Registration as Clinically Qualified Medical Physicist (CQMP) has to follow existing State registration rules. IAEA and IOMP are recommending that the competences have to be maintained with a CPD (Continuous Professional Development) programme.

The programme has been re-accredited by the IOMP (International Organisation on Medical Physics) in August 2023.

Year 1: Academic programme

The academic programme of the first year is covering the relevant areas of medical physics, to provide a solid backgrouns on medical physics and to prepare the student to enter in a formal clinical medical physics residency (second year). It will also provide the student with the basic knowledge needed to embark on a career in the regulatory, industry, metrology, research and development or innovation through research sectors, for instance.

The major outcome of the academic programme would be to provide students with a thorough grounding in the physiological basis, analytical methods and fundamental aspects of medical physics and instil an attitude of integrity, professionalism, critical-thinking and scientific rigor.

Teaching is provided by full time academic staff, clinical medical physicists, dosimetrists, radiation protection experts and health care professionals, like radiologists and radiation oncologist physicians.

Master of Advanced Studies in Medical Physics

CORE MODULES

The following table lists the courses and the practicals module of the first year.

Code	Name of course or practicals	ECTS*	No. hours of lectures or supervised exercises	Type of activity	Examination type
	Common course				
L1	Anatomy and Physiology as applied to Medical Physics	4	32	lesson	Oral
L2	Radiobiology	1	12	lesson	written
L3	Radiation Physics	4	36	lesson	written
L4	Radiation Dosimetry	4	32	lesson	written
L5	Medical Imaging Fundamentals	4	32	lesson	written
L6	Physics of Imaging Detectors	1	8	lesson	written
L7	Physics of Diagnostic and Interventional Radiology with X-ray 1	2	16	lesson	written
L8	Physics of Diagnostic and Interventional Radiology with X-ray 2	2	20	Lesson/lab	written
L9	Physics of Diagnostic Radiology with US and MRI	4	32	lesson	written
L10	Radiology exercise	1	12	laboratory	written
L11	Physics of nuclear medicine	5	48	Lesson/lab	written
L12	Physics of Radiation Oncology 1	9	92	lesson/lab	written
L13	Physics of Radiation Oncology 2	6	56	lesson/lab	written
L14	Radiation Protection 1	2	16	lesson	written
L15	Radiation Protection 2	1	8	lesson	written
L16	Technology of Information Technology for MP	1	8	lesson	written
L17	Information technology and software tools	1	12	laboratory	written
L18	Statistics for medicine	1	12	Lesson	written
L19	Monte Carlo simulation methods	1	12	lesson	written
L20	At hospital in radiology, nuclear medicine, radiotherapy and medical physics depts. and at the University , Physics department lab	2	24	laboratory	reports
	Only for diagnostic imaging track				
LI1	Physics of diagnostic and interventional radiology with X ray: projection radiology including mammography and fluoroscopy	2	20	lesson/lab	written
LI2	Nuclear medicine 3: dosimetry in therapy, reconstruction algorithms, procedure optimisation	2	20	lesson/lab	written
	Only for radiation oncology track				

LT1	Commissioning linac and TPS	2	20	lesson/lab	written
LT2	Small photon field dosimetry	1	8	lesson/lab	written
LT3	Brachytherapy (exercise)	1	12	laboratory	written
	TOTAL ECTS AND HOURS	**60**	**560**		

European Credit Transfer and Accumulation System (**ECTS**) is a standard for comparing the study attainment and performance of students of higher education across the European Union and other collaborating European countries. For successfully completed studies, ECTS credits are awarded. One academic year corresponds to 60 **ECTS-credits** that are equivalent to 1500–1800 hours of study in all countries irrespective of standard or qualification type and is used to facilitate transfer and progression throughout the Union. Typically, a ECTS is equivalent to 25-30 hours of study.

L1. Anatomy and Physiology as applied to Medical Physics

- Anatomical Nomenclature
  - Origin of anatomical names
  - Prefixes and suffixes
  - Anatomical position and body plane terminology
- Structure, Physiology, Pathology, and Radiographic appearance (x-ray, CT, MRI and nuclear medicine imaging) of:
  - Bones and Bone Marrow
  - Brain and CNS
  - Thorax
  - Abdomen
  - Pelvis
  - Respiratory, Digestive, Urinary, Reproductive, Circulatory, Lymphatic, Endocrine Systems

L2. Radiobiology

- Classification of Radiation in radiobiology
- Cell-Cycle and cell death
- Effect of cellular radiation, oxygen effect
- Type of radiation damage
- Cell survival curve
- Dose-response curve
- Early and late effects of radiation
- Modelling, Linear Quadratic Model, α/β Ratio
- Fractionation, EQD_{2Gy}
- Dose Rate Effect
- Tumour Control Probability (TCP), Normal Tissue Complication Probability (NTCP), Equivalent Uniform Dose (EUD)
- Tolerance Doses and Volumes, Quantitative Analysis of Normal Tissue Effects in the Clinic (QUANTEC) [10]
- Normal and tumour cell therapeutic ratio
- Radio-sensitizers, Protectors

L3. Radiation Physics

- Brief review of quantum mechanics and modern physics
- X-rays radiology - introduction
- Passage of the radiation though matter; microscopic treatment
  - coherent and incoherent scattering on atoms
  - photoelectric effect
  - characteristic x-rays
- Passage of x-rays through matter: macroscopic treatment
  - Filtering
  - X-rays instrumentation
  - Contrast and scattered radiation
- X-rays detectors
  - Image intensifiers
  - Image screens
  - Digital detectors: computed radiography; the f-centers, direct radiography, indirect conversion methods, direct conversion methods
  - Other digital detectors

L4. Radiation Dosimetry

- Interactions of charged and uncharged particles and related quantities
- Stochastic, non-stochastic quantities
- Radiation fields and dosimetry quantities
- Radiation and charged particle equilibrium
- Cavity theories and Fano theorem
- Radiation dosimeters and instrumentation
- Radiation primary standards
- Calibration Chain
- Code of practice for dosimetry in diagnostic and interventional and for dosimetry in radiation therapy

L5. Medical Imaging Fundamentals

- Mathematical Methods
- Tomographic Reconstruction Techniques
- Linear Systems
- Acquisition, formation, processing and display of medical images
- Perception
- Evaluation of Image Quality

L6. Physics of Imaging Detectors

- Basics: Introduction to Poisson statistics

- Physics of generic photon detectors
  - Quantum efficiency
    - Direct conversion detectors
    - Indirect conversion detectors
  - Integrating detectors
  - Counting detectors
  - Spectroscopic detectors
  - Sampling (Space and Time)
  - Noise considerations (Signal to noise ratio)
- Photon transfer curve
  - Concept of spatial frequency depending detective quantum efficiency (Integrating detectors, Counting detectors)

L7-L8. Physics of Diagnostic and Interventional Radiology with X-Ray 1 & 2

- Overview of Imaging Modalities (ionizing and non-ionizing)
- X ray Imaging
  - Generation of x-rays , x-ray spectra
  - Detectors
  - Image Parameters
  - Image quality, Noise, contrast, resolution
  - Interventional Radiology
  - Dual energy imaging and absorptiometry
  - Patient dose and system optimization
- Computed tomography, QA, dosimetry andoptimisation
- Dual and Multi-modality Imaging
- Quality Management of Diagnostic and Interventional Radiology

L9. Physics of Diagnostic Radiology with US and MR

- Ultrasound Imaging
  - Acoustic properties of biological tissues
  - Wave, motion and propagation, acoustic power
  - Modes of Scanning
  - Transducers
  - Doppler
  - Safety
- Magnetic Resonance Imaging (MRI)
  - Physics of Magnetic Resonance
  - MR Image formation
  - MR Instrumentation
  - MRI methods
  - MR contrast and image quality

- Clinical applications and artefacts
- Safety

L11. Physics of Nuclear Medicine

- Short elements of nuclear decays
- Radioisotope imaging generalities
- Images from radioisotopes
- Radioisotopes production
  - Bateman equations
- Radionuclides administration
- The most frequently used radioisotopes
- Imaging Instrumentation
  - Planar, Whole-body
  - SPECT
  - PET
  - Hybrid Imaging
- Medical applications of SPECT and PET
- Image Quality and noise
- Non-imaging Instrumentation
  - Dose calibrators, Well counters
  - Probes
- Internal Dosimetry
- Quantitative Imaging
- Radionuclide Therapy
- Acceptance testing and commissioning
- Quality assurance and management of Nuclear Medicine

L12-L13. Physics of Radiation Oncology 1 & 2

- Overview of clinical radiotherapy
- Radiation therapy equipment (accelerators, cobalt 60, cyclotrons, kV generators)
- Basic photon radiation therapy (dosimetric functions, etc.)
- MU calculation
- Basic treatment planning (3D) and TPS exercises
- Simulation, virtual simulation, DRR's, image registration and TPS exercises
- Image guidance and verification in radiotherapy (Cone beam CT, ultrasound, Portal imaging, in-vivo dosimetry, image registration)
- Patient setup, including positioning and immobilization
- ICRU Reports 50, 62 and 83
- Basic electron radiation therapy, ICRU Report 71
- Dose calculation algorithms and heterogeneity corrections
- Inverse Planning, optimization, IMRT/VMAT and TPS exercises

- Brachytherapy, ICRU Report 38 , AAPM TG 43 formalism
  - HDR/LDR, radioactive seed implant, Equipment, Treatment Planning
- Introduction and applications of AI to radiation therapy
- Radiation therapy information systems
- Acceptance testing and commissioning
- Health technology procurement and maintenance

- Small field dosimetry (fundamental aspects, protocols)
- Small-field radiotherapy equipment and techniques

L14-L15. Radiation Protection 1 & 2

- Elements of radiobiology for radiation protection
- Sources of radiation in medical area and applications
- Radiation protection dose quantities
- Legal framework for radiation protection (IAEA BSS)
  - Occupational, public exposure and annual limits
  - Medical exposure
- Radiation protection instrumentation
- External and internal personal and ambient monitoring
- Shielding calculation of medical facilities
- Radioactive transport and waste management
- Emergency procedures
- Radiation protection programme design, implementation and management in the medical applications

L16. Technology of Information Technology for Medical Physics

- Introduction to HIS, RIS and PACS
- International standards (IEC, DICOM, IHE)
- Diagnostic imaging systems (RDSR and patient dosimetry tracking systems)
- Radiotherapy R&V systems

L18 Statistics for Medicine: Statistics as a useful and necessary tool for the health professions.

- Descriptive statistics:
  - Charts /tables, box-plot, measures of central tendency, measures of dispersion and their 'critical' use. Examples and exercises with R in the field of bio-medical.
  - Elements of probability theory: definitions and problems, the conditional probability.
  - Diagnostic tests and ROC curve: Examples and exercises with R
  - Populations of Gaussian data and their properties.
- Elements of statistical inference:
  - Point estimates, estimates of intervals, the 'confidence intervals'. Estimation of the mean of a population of Gaussian data. Examples and exercises with R;

  - Statistical tests: the chi-square test, Fisher's exact test, the t test Student, Mann-Whitney test and the Wilcoxon test. Examples and exercises with R
  - Risk measures: relative risk (RR) and odds ratio (OR)
  - Linear regression: Examples and exercises with R
- Critical reading of a scientific article

L19 Monte Carlo simulation methods for medical physics

- General Introduction to Monte Carlo methods
- Use of Monte Carlo methods in Medical Physics
- Basic of Monte Carlo simulation within the Geant4 framework
- Practical session of Geant4 simulation
- Basic information about other MC tools

Seminars, workshops covering following topics:

- ICTP and ICTP/IAEA training courses and workshops
- Professional and Scientific Development
- Ethics , professionalism
- Presentation Skills (scientific communication)

PRACTICAL SESSIONS

L10. Diagnostic and interventional radiology exercises

- General radiology: QA, patient dosimetry (software tools)
- Interventional radiology:
  - Equipment for interventional radiology
  - Procedure optimisation: DRLs, equipment set-up, protocol optimisation
  - Prevention of skin burns: skin dosimetry, trigger level, protocol optimisation, clinical follow-up of high dose patients, radiochromic film dosimetry
  - Organ dose assessment (Monte Carlo tool)

L20. Practical sessions with a hospital facilities

Sessions to be held at the Trieste Hospital facilities.

Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
Interventional and Diagnostic Radiology	Interventional and Diagnostic Radiology	Interventional and Diagnostic Radiology	Interventional and Diagnostic Radiology	Nuclear Medicine	Nuclear Medicine
Conventional radiography	Mammography	Interventional Radiology	Computed Tomography	Non-imaging Instrumentation QC	Imaging Instrumentation (SPECT) QC

Session 7	Session 8	Session 9	Session 10	Session 11	Session 12
Radiation Dosimetry	Radiation Protection	Radiation Oncology	Radiation Oncology	Radiation Oncology	Radiation Oncology
Radiochromic Film Dosimetry	Radiation Survey of a clinical installation	Water Tank Scanning of Photons clinical beams	Water Tank Scanning of Electrons clinical beams	QC on Linac	QC on MLC

L17 Information technology and software tools for medical physics

- Data analisys
- ImageJ programming: quantitative image quality assessment

Year 2 – Supervised clinical training

Year 2 is devoted to a supervised full time clinical training to be performed in one accredited Medical physics department.
The Resident will practice mainly in a specific area of medical physics: medical physics for diagnostic imaging or medical physics for radiation therapy.
Activities to perform, assessment of the skills and competences acquired in each field are adapted from the IAEA and AFRA clinical training of medical physicists guidelines.

Activity type	ECTS*	Minimum No. Of hours
Clinical training in a hospital of the network	55	1200
Final thesis	5	125
TOTAL ECTS AND HOURS	**60**	**1325**

The assignment to hospital will be not less than 45 weeks (about 1700 hours) that includes the work for the development of the thesis work.

Clinical training content and assessment agreement
Two clinical traiing programmes are developed:

- training in radiation oncology,
- training in diagnostic and interventional radiology and nuclear medicine.

A personalised Portfolio of activities is developed by the Clinical Medical Physicist Supervisor tailored to the Resident background and knowledge before the beginning of the clinical training.

Sugegsted number of weeks to spend in developing the different modules.

Radiotherapy

Module	Duration (weeks)	Range (weeks)
Clinical environment in radiotherapy	Entire programme 46 weeks	
External beam radiotherapy (EBRT) reference dosimetry	4	2-6
EBRT relative dosimetry	7	4-10
Imaging equipment	3	2-4
EBRT	17	14-20
Brachytherapy	2.5	1-4
Radiation protection and safety	3	2-4
Equipment specification and acquisition	1.5	1-2
Quality management	8	6-10
Professional ethics	Entire programme 46 weeks	
Total weeks	46	

Diagnostic and interventional radiology & nuclear medicine

Module	Duration (weeks)	Priorities
Clinical awareness	Entire programme 23 wks	
Radiation protection and safety	3	
Dosimetry instrumentation and calibration	1	
Performance testing of imaging equipment	13	1
Patient dose audit	2	4
Technology management of imaging equipment	1	2
Optimisation of clinical procedure	3	3
Professional ethics	Entire programme 23 wks	
Total weeks	23	
(The training can be expanded up to 36 wks including angiography units and MRI imaging and safety. The remaining 10 weeks will be devoted to performance testing modules of nuclear medicine equipment) – Priorities: 1 basic – 4 highest competences		

Module	Duration (weeks)	Priorities
Clinical awareness	Entire programme 23 wks	
Radiation protection and safety	4	4*
Technology management in NM	2	
Radioactivity measurement and internal dosimetry	3	
Performance testing of NNM equipment	7	1
Preparation and quality control of radiopharmaceuticals	1	
Radionuclide therapy using unsealed sources	2	3
Optimisation in clinical application	4	2
Professional ethics	Entire programme 23 wks	
Total weeks	23	
(The training can be expanded up to 36 wks including also PET/CT. The remaining 10 weeks will be devoted to performance testing modules of diagnostic radiology equipment) – Priorities: 1 basic – 4 highest competences (*) design of the NM Dpt		

For diagnostic and interventional radiology & nuclear medicine it is stated that the 2 sub-programmes can share equally the time or, in the case of specific resident training needs, a sub-programme can be enlarged maintaining some modules of the second programme that has to be included following the indicated priorities (priority 1 indicate the mandatory module)

(the content of this sillabi refers to the courses and activities developed in the AA 2023-24)