MASTER OF ADVANCED STUDIES IN MEDICAL PHYSICS

Jointly organised by ICTP and Trieste University

COURSE SYLLABI

(rev 10/01/2022)

The Master of Advanced Studies in Medical Physics (MMP), a Master after Master, is addressed to students with a MSc in Physics (or an equivalent academic degree).
The course, taking into account IAEA, AFRA and IOMP recommendations, is organised in two years of activities:

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

After the MMP, the graduated as reached the knowledge, skill and competences required by the AFRA recommendations. According to the IOMP and IAEA recommendations, when the country has an advanced health system, another year of clinical training is necessary. Different requirements to reach the competences of a Clinically Qualified Medical Physicist (CQMP) can be required by the rules of the competent authorities of the country. Some countries are requiring a Certification/Registration to act as clinical medical physicist and these requirements have to be known before to enrol in this programme.
The programme is under re-accreditation by the IOMP.

Learning objectives

- Have extended fundamental and research based modern knowledge in radiation physics, radiation measurements, dosimetry, and radiation protection;
- Are able to use obtained knowledge and skills for problem solving in medical environment, especially related to dose assessment and radiation protection;
- Have sufficient knowledge on anatomy and physiology, radiobiology and know the radiobiological impact of ionizing radiation on tissues and organs
- Know state of the art equipment and technologies used in radiotherapy, diagnostic imaging and information technologies;
- Know modern physical methods, that are used for examination and treatment of patients in clinical praxis, as well as mathematical modelling based dose planning and experimental dosimetry methods;
- Have fundamental knowledge on radiation protection of the individuals and environment, know legal basis of radiation protection and under specific circumstances may act as radiation protection instructors;
- Know quality assurance programme, understand their importance and are able to implement and perform quality control measurements on site.

Medical Physics Master - Year 1

The academic education of the first year is covering the relevant specialties of medical physics, 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.

CORE MODULES

The core modules are provided below, including an outline of their content:

Code	Name of course or practical	ECTS	No. hours of lectures or supervised exercises	Type of activity	Examination type
L1	Anatomy and Physiology for Medical Physics	4	32	lesson	O
L2	Radiobiology	1	12	lesson	W

L3	Radiation Physics	4	36	lesson	W/O
L4	Radiation Dosimetry	4	32	lesson	W/O
L5	Medical Imaging Fundamentals	4	32	lesson	W/O
L6	Physics of Imaging Detectors	1	8	lesson	W
L7	Physics of Nuclear Medicine:				
	- Physics of nuclear medicine 1	2	24	lesson	W/O
	- Physics of nuclear medicine 2 and exercises	2	20	lesson/lab	W
	- Physics of nuclear medicine exercises 3	2	12	lesson/lab	W
L8	Physics of Diagnostic and Interventional Radiology:				
	- Diagnostic radiology with x-ray	2	16	lesson	W
	- Computed tomography	2	20	lesson/lab	W/O
	- Diagnostic imaging with US and MR	4	32	lesson	W/O
	- Exercises on optimisation in interventional radiology	1	12	lab	W/lab
L9	Physics of Radiation Oncology:				
	- Radiation therapy and exercises 1	9	92	lesson/lab	W/O/lab
	- Radiation therapy and exercises 2	6	56	lesson/lab	W/O/lab
L10	Radiation Protection:				
	- Fundamentals and application in medicine	2	18	lesson	W/O
	- Internal dosimetry and radiation protection in nuclear medicine	1	8	lesson	W/O
L11	Information Technology in medicine:				
	- Standards and main applications	1	8	lesson	W
	- Information technology: software tools	1	12	lab	W
L12	Statistics for medicine	1	12	lesson	W
L13	Introduction to Monte Carlo simulation	1	12	lab	W
P1	Hospital exercises in radiology, nuclear medicine and radiotherapy	2	24	lab	W
	Courses for the diagnostic imaging track				
L7.1	Physics of nuclear medicine 4	2	16	lesson	W
L8.1	Physics of Diagnostic Radiology with X-ray 3: projection radiography & mammography	2	20	lesson/lab	W
	Courses for the radiation oncology track				
L9.1	Commissioning of linac and TPS	2	20	lesson/lab	W
L9.2	Small photon field dosimetry	1	8	lesson/lab	W
L9.3	Brachytherapy exercise	1	12	lab	W
	TOTAL ECTS	**60**			

ECTS: European Credit Transfer and Accumulation System 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.
W: written exam; O: oral exam; lab: supervised exercises with software tools or in physics laboratory or on hospital installations.

L1. Anatomy and Physiology for 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)
- 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
  - Pair/triplet production
- 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

- Charged and uncharged particle interactions with matter and relevant quantities
- Stochastic, non-stochastic quantities
- Fluence, Exposure, KERMA, Absorbed dose
- Radiation and charged particle equilibrium
- Fano theorem and cavity theories
- Radiation dosimetry instrumentation
- Radiation Standards and calibration chain
- Dosimetry protocols and IAEA codes of practice for diagnostic and interventional radiology and for 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
- Integrating detectors
- Counting detectors
- Spectroscopic detectors
- Sampling: Space, Time
- Noise considerations; Signal to noise ratio
- Photon transfer curve

L7. & 7.1 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 management of Nuclear Medicine

L8. Physics of Diagnostic and Interventional Radiology
Diagnostic and Interventional Radiology with X-ray
- 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
  - Radiographic, Mammography, Fluoroscopic,
  - CT, DECT
  - Interventional Radiology
  - Dual energy imaging and absorptiometry
  - Patient dose and system optimization
- Dual and Multi-modality Imaging
- Quality Management of Diagnostic and Interventional Radiology

Diagnostic Radiology with US and MRI
- 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

L8.1 Physics of Diagnostic Radiology with X-ray 3: optimisation in projection radiography & mammography

L9. Physics of Radiation Oncology
- Overview of clinical radiotherapy
- Radiation therapy equipment (accelerators, cobalt 60, cyclotrons, kV generators)
- Basic photon radiation therapy (dosimetric functions, etc.)
- Basic treatment planning
- Simulation, virtual simulation, DRR's, image registration
- Patient setup, including positioning and immobilization

- ICRU Reports 50, 62 and 83
- Basic electron radiation therapy, ICRU Report 71
- Kilovoltage radiotherapy
- Dose calculation algorithms and heterogeneity corrections
- Brachytherapy, ICRU Report 38 , AAPM TG 43 formalism
    - HDR/LDR, Equipment, Treatment Planning
- Inverse Planning, optimization, IMRT
- Image guidance and verification in radiotherapy (Cone beam CT, ultrasound, Portal imaging, in-vivo dosimetry, image registration)
- Radiation therapy information systems
- Health technology assessment and management of radiotherapy equipment

L9.1 Linac and treatment planning system commissioning
L9.2 Small field dosimetry (fundamental aspects, protocols)
L9.3 Advanced brachytherapy techniques and exercises

L10. Radiation Protection

- Sources of Radiation
- Biological Effects of Radiation
- Radiation Quality factor, Equivalent dose, Effective dose, Operational quantities
- Legal framework for radiation protection (BSS)
- Occupational, public exposure and regulatory dose limits
- Radiation protection instrumentation
- External and internal personal monitoring and ambient dosimetry
- Shielding calculation
- Radioactive transport and waste management
- Emergency procedures
- Radiation protection programme design, implementation and management in the medical applications

L11. Information Technology in Medicine

- International standards: IEC, DICOM, IHE
- Implementations: HIS, RIS, PACS
- Radiotherapy R&V systems
- Patient monitoring standards

L12 Statistics for Medicine

- 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

L13. Introduction to Monte Carlo simulation

- 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

Workshops, Seminars covering following topics:

- ICTP and Joint ICTP/IAEA advanced workshops
- Professional and Scientific Development
- Ethics , professionalism
- Presentation Skills
- Scientific Communication

PRACTICAL SESSIONS

P1. Practical sessions at hospital facilities

3-hour 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

P2. Radiology

- General radiology: QA, patient dosimetry (software tools)
- Interventional radiology:
  - Equipment QA
  - 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

P3. Nuclear Medicine

- Image quality assessment
- QC of nuclear medicine instrumentation
- Patient internal dosimetry (use of software tools)

P4. Radiation Oncology

- Linac and TPS Commissioning
- Manual MU calculation
- QA of a TPS (AAPM TG43)
- TPS exercises on image for radiation therapy, 3DCRT and VMAT planning
- Simulation, virtual simulation, DRR's, image registration, patient setup, including positioning and immobilization
- Multimodality: image registration, motion management
- Brachytherapy planning and QA

P5 Information technology and software tools for medical physics

- Programming with ImageJ: quantitative image quality assessment

<u>Medical Physics Master - Year 2</u>

Year 2 is devoted to a supervised full time clinical training to be performed in one accredited hospital.
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 programmes are identified:

- the first for the training in radiation oncology,
- the second for diagnostic radiology and nuclear medicine.

An individual Portfolio will be developed by the Clinical Medical Physicist Supervisor tailored to the Resident background and knowledge before the beginning of the clinical training.

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)