MASTER'S PROGRAMME IN MEDICAL PHYSICS

Jointly organised by ICTP and Trieste University

(ver 10/12/2016)

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 practical exercises in Medical Physics
- A second year of supervised Clinical Training

After the Master, the recommendation is to follow other 1-2 years of Clinical Training in order to be recognised as 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.

Medical Physics Master - Year 1

The academic education of the first year is covering all 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 both by full time academic staff and by clinical medical physicists and other health care professionals, like radiobiologists, clinicians and regulators.

CORE MODULES

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

Code	Name of course or practicals	ECTS*	No. hours of lectures or supervised exercises	Type of activity	Examination type
L1	Anatomy and Physiology as applied to Medical Physics	4	32	lesson	Oral
L2	Radiobiology	1	8	lesson	Oral
L3	Radiation Physics	4	32	lesson	Oral
L4	Radiation Dosimetry	4	32	lesson	Oral

L5	Medical Imaging Fundamentals	3	24	lesson	Oral
L6	Physics of Imaging Detectors	1	8	lesson	Oral
L7	Physics of Nuclear Medicine	3	24	lesson	Oral
L8	Physics of Diagnostic and Interventional Radiology with X-ray 1	2	16	lesson	Oral
L9	Physics of Diagnostic and Interventional Radiology with X-ray 2	2	16	lesson	Oral
L10	Physics of Diagnostic Radiology with US and MR	4	32	lesson	Oral
L11	Physics of Radiation Oncology 1	4	32	lesson	Oral
L12	Physics of Radiation Oncology 2	4	32	lesson	Oral
L13	Radiation Protection 1	2	16	lesson	Oral
L14	Radiation Protection 2	1	8	lesson	Oral
L15	Technology of Information Technology for Medical Physics	2	16	lesson	Oral
	Guided exercises and practicals (228 h):				
P1	At hospital in radiology, nuclear medicine, radiotherapy and medical physics depts	3	36	laboratory	written
P2	Radiology	3	36	laboratory	written
P3	Nuclear medicine	2	24	laboratory	written
P4	Radiation oncology	8	96	laboratory	written
P5.1	Information technology and software tools: exercises with ImageJ	1	12	laboratory	written
P5.2	Statistics for medicine	1	12	laboratory	written
P6	Montecarlo simulation methods	1	12	laboratory	written
	TOTAL ECTS AND HOURS	**60**	**556**		

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

- Quantities and Units

- Stochastic, non-stochastic quantities
- Fluence, Exposure, KERMA, Absorbed dose
- Radiation, charged particle equilibrium
- Neutron Interactions
- Multiple scattering theories
- Stopping Power
    - Restricted, Unrestricted
    - Linear Energy Transfer (LET)
- Transport Equation
    - Charged Particle slowing down
    - Continuous Slowing Down Approximation (CSDA)
- Fano theorem
- Cavity Theory
    - Large, small cavity
- Radiation Dosimeters and instrumentation
- Radiation Standards
- Calibration Chain
- Absolute dosimetry protocols and IAEA codes of practice

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
            - Charge generation and charge collection
        - Indirect conversion detectors
            - Scintillators
    - Integrating detectors
    - Counting detectors
    - Spectroscopic detectors
- Sampling
    - Space
    - Time
- Noise considerations

        - Signal to noise ratio
    - Photon transfer curve
    - Concept of spatial frequency depending detective quantum efficiency
        - Integrating detectors
        - Counting detectors

L7. Physics of Nuclear Medicine

- Short elements of nuclear decays
- Radioisotope imaging generalities
- Images from radioisotopes
- Radioisotopes production
    - Bateman equations
- Radionuclides administration
- The most frequenty 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-L9. Physics of 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, Tomosynthesis
    - Interventional Radiology
    - Dual energy imaging and absorptiometry
    - Patient dose and system optimization

- Dual and Multi-modality Imaging
- Quality Management of Diagnostic and Interventional Radiology

L10. 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-L12. 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
- Small field dosimetry (fundamental aspects, protocols)
- Small-field radiotherapy equipment and techniques (Stereotactic Radiotherapy and Radiosurgery, Stereotactic Body Radiotherapy, Intensity Modulated Radiotherapy, Tomotherapy™, Cyberknife™, Gammaknife™, etc.)
- Image guidance and verification in radiotherapy (Cone beam CT, ultrasound, Portal imaging, in-vivo dosimetry, image registration)
- Radiation therapy information systems
- Acceptance testing and commissioning

- Quality management of radiotherapy

L13-L14. Radiation Protection

- Sources of Radiation
- Activity, half-life, exponential attenuation, half-value layer (HVL), inverse square law, tenth-value layer (TVL)
- Biological Effects of Radiation
- Radiation Quality factor, Equivalent dose, Effective dose
- Legal framework for radiation protection (BSS)
- As low as reasonably achievable (ALARA) concept
- Occupational, public exposure and annual limits
- Radiation protection detectors (Ionization chambers, Geiger-Mueller, Proportional counters, Scintillators, Thermoluninescent Dosimeters (TLDs), neutron detectors)
- Personal and environmental dosimetry
- Shielding calculation
- Radioactive transport and waste management
- Emergency procedures
- Radiation protection programme design, implementation and management in the medical sector

L15. Technology of Information Technology for Medical Physics

- International standards
    - IEC, DICOM, IHE
- HIS/RIS/PACS
- Radiotherapy R&V systems
- Navigation systems
- Registration, segmentation

Seminars covering following topics:

- ICTP and ICTP/IAEA training courses
- Professional and Scientific Development
    - Ethics , professionalism
- Presentation Skills
    - Scientific Communication
    - Techniques of Instruction

PRACTICAL SESSIONS

P1. Practical sessions with a hospital facilities

3 hours 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
- Introduction and use of IDL tools for image analysis

P3. Nuclear Medicine

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

P4. Radiation Oncology

- Commissioning and basic QC
  - Linac (AAPM TG 106 and 142)
  - Simulators (AAPM RPT 83)
  - Epid
  - kV Imager, R&V
- MU calculation (ESTRO)
- QA of a TPS (AAPM TG43)
- External beam photon therapy planning (ICRU 50 & 62)
- Electron beam electron therapy planning (ICRU71)
- 3DCRT planning

- IMRT/VMAT: Planning (ICRU 83) and QA (included AAPM TG 142)
- Simulation, virtual simulation, DRR's, image registration, patient setup, including positioning and immobilization
- Image guidance and verification in radiotherapy: cone beam CT, ultrasound, portal imaging, (AAPM TG 179 and 95)
- Multi modality: image registration, motion management
- Brachytherapy planning and QA

P5.1 Information technology and software tools for medical physics

- Programming with ImageJ: quantitative image quality assessment

P5.2 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

P6. 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

Medical Physics Master - Year 2

Year 2 is devoted to a supervised full time clinical training to be performed in one accreditated hospitals.
The student should \practices covering mainly 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 hospitals will be not lees 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 radiotherapy,
- the second for diagnostic radiology and nuclear medicine.

The content and duration of the clinical training will be tailored to the background and knowledge of the Resident taking into account the following tables.
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)

The students, at the end of the first year of the Course will be assigned to a hospital of the Network of accredited hospitals.

Head of the Medical Physics Departments and Hospitals of the Network of Hospitals for the Clinical Training

Head MP Dpt	**Hospital name**	**Town**
Stefania Maggi	Az. Ospedaliero Universitaria Ospedali Riuniti	Ancona
Elvira Capra	Centro di Riferimento Oncologico	Aviano
Andreoli Stefano	Az. Ospedaliera Papa Giovanni XXIII	Bergamo
Alessandro Turra	Az. Ospedaliero Universitaria “Arcispedale Sant’Anna”	Ferrara
Busoni Simone	Az. Ospedaliera Careggi	Firenze
Alberto Torresin	Ospedale Niguarda Ca' Granda	Milano
Gabriele Guidi	Az.Ospedaliero-Universitaria di Modena	Modena
Andrea Crespi	Az. Ospedaliera S. Gerardo	Monza
Marco Brambilla	Az. Ospedaliero Universitaria Osp. Maggiore della Carità	Novara
Marta Paiusco	Istituto Oncologico Veneto	Padova
Antonio Traino	Az. Ospedaliero Universitaria Pisana	Pisa
Lidia Strigari	Ist. Nazionale Tumori Regina Elena	Roma
Roberto Ropolo	A.O.U. Citta della Salute e della Scienza	Torino
Aldo Valentini	Ospedale S. Chiara	Trento
Mario De Denaro	Az. Ospedlaiero Universitaria Ospedali Riuniti	Trieste
Maria Rosa Malisan	Az. Ospedaliero Universitaria S. Maria della Misericordia	Udine
Carlo Cavedon	Az. Ospedaliero Universitaria Integrata	Verona
Paolo Francescon	ULSS 6 Vicenza, Ospedale San Bortolo	Vicenza
Hrvoje Hrsak	University Hospital Centre Zagreb (KBC)	Zagreb