MASTER’S PROGRAMME IN MEDICAL PHYSICS

Jointly organised by ICTP and Trieste University

(Version 10/01/2018)

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 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 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 accredited by the IOMP in November 2019.

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:

<table>
<thead>
<tr>
<th>Code</th>
<th>Name of course or practicals</th>
<th>ECTS*</th>
<th>No. hours of lectures or supervised exercises</th>
<th>Type of activity</th>
<th>Examination type</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>Anatomy and Physiology as applied to Medical Physics</td>
<td>4</td>
<td>32</td>
<td>lesson</td>
<td>Oral</td>
</tr>
<tr>
<td>L2</td>
<td>Radiobiology</td>
<td>1</td>
<td>8</td>
<td>lesson</td>
<td>Oral</td>
</tr>
</tbody>
</table>
L1. Anatomy and Physiology as applied to Medical Physics

-o Anatomical Nomenclature
  ▪ Origin of anatomical names
  ▪ Prefixes and suffixes
  ▪ Anatomical position and body plane terminology
-o Structure, Physiology, Pathology, and Radiographic appearance (x-ray, CT, MRI and nuclear medicine imaging) of:
  ▪ Bones and Bone Marrow
  ▪ Brain and CNS
  ▪ Thorax
  ▪ Abdomen
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, $\alpha/\beta$ 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 through 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
L5. Medical Imaging Fundamentals
  o Mathematical Methods
  o Tomographic Reconstruction Techniques
  o Linear Systems
  o Acquisition, formation, processing and display of medical images
  o Perception
  o Evaluation of Image Quality

L6. Physics of Imaging Detectors
  o Basics: Introduction to Poisson statistics
  o Physics of generic photon detectors
    ▪ Quantum efficiency
      • Direct conversion detectors
      • Indirect conversion detectors
    ▪ Integrating detectors
    ▪ Counting detectors
    ▪ Spectroscopic detectors
  o Sampling
    ▪ Space
    ▪ Time
  o Noise considerations
    ▪ Signal to noise ratio
  o Photon transfer curve
  o Concept of spatial frequency depending detective quantum efficiency
    ▪ Integrating detectors
    ▪ Counting detectors

L7. Physics of Nuclear Medicine
  o Short elements of nuclear decays
  o Radioisotope imaging generalities
  o 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-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

  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
- 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
- Health technology assessment and management of radiotherapy equipment

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, TL and OSL Dosimeters, 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.

<table>
<thead>
<tr>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
<th>Session 4</th>
<th>Session 5</th>
<th>Session 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interventional and Diagnostic Radiology</td>
<td>Interventional and Diagnostic Radiology</td>
<td>Interventional and Diagnostic Radiology</td>
<td>Interventional and Diagnostic Radiology</td>
<td>Nuclear Medicine</td>
<td>Nuclear Medicine</td>
</tr>
<tr>
<td>Conventional radiography</td>
<td>Mammography</td>
<td>Interventional Radiology</td>
<td>Computed Tomography</td>
<td>Non-imaging Instrumentation QC</td>
<td>Imaging Instrumentation (SPECT) QC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 7</th>
<th>Session 8</th>
<th>Session 9</th>
<th>Session 10</th>
<th>Session 11</th>
<th>Session 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation Dosimetry</td>
<td>Radiation Protection</td>
<td>Radiation Oncology</td>
<td>Radiation Oncology</td>
<td>Radiation Oncology</td>
<td>Radiation Oncology</td>
</tr>
<tr>
<td>Radiochromic Film Dosimetry</td>
<td>Radiation Survey of a clinical installation</td>
<td>Water Tank Scanning of Photons clinical beams</td>
<td>Water Tank Scanning of Electrons clinical beams</td>
<td>QC on Linac</td>
<td>QC on MLC</td>
</tr>
</tbody>
</table>
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

- Commissioning and basic QC
  - Linac (AAPM TG 106 and 142)
  - Simulators (AAPM RPT 83)
  - EPID
  - kV Imager, R&V
- Manual MU calculation
- 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

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**Medical Physics Master - Year 2**

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.

<table>
<thead>
<tr>
<th>Activity type</th>
<th>ECTS*</th>
<th>Minimum No. Of hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical training in a hospital of the network</td>
<td>55</td>
<td>1200</td>
</tr>
<tr>
<td>Final thesis</td>
<td>5</td>
<td>125</td>
</tr>
<tr>
<td><strong>TOTAL ECTS AND HOURS</strong></td>
<td><strong>60</strong></td>
<td><strong>1325</strong></td>
</tr>
</tbody>
</table>

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

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

Diagnostic and interventional radiology & nuclear medicine

<table>
<thead>
<tr>
<th>Module</th>
<th>Duration (weeks)</th>
<th>Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical awareness</td>
<td>Entire programme 23 wks</td>
<td></td>
</tr>
<tr>
<td>Radiation protection and safety</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Dosimetry instrumentation and calibration</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Performance testing of imaging equipment</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Patient dose audit</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Technology management of imaging equipment</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Optimisation of clinical procedure</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Professional ethics</td>
<td>Entire programme 23 wks</td>
<td></td>
</tr>
<tr>
<td>Total weeks</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

(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
<table>
<thead>
<tr>
<th>Module</th>
<th>Duration (weeks)</th>
<th>Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical awareness</td>
<td>Entire programme 23 wks</td>
<td></td>
</tr>
<tr>
<td>Radiation protection and safety</td>
<td>4</td>
<td>4*</td>
</tr>
<tr>
<td>Technology management in NM</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Radioactivity measurement and internal dosimetry</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Performance testing of NNM equipment</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Preparation and quality control of radiopharmaceuticals</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Radionuclide therapy using unsealed sources</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Optimisation in clinical application</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Professional ethics</td>
<td>Entire programme 23 wks</td>
<td></td>
</tr>
<tr>
<td>Total weeks</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

(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)
Network of accredited hospitals for the clinical training

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

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