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International Atomic Energy Agency

# Postgraduate Medical Physics Academic Programmes

*Endorsed by the International Organization for Medical Physics (IOMP)*

VIENNA, 2021

TRAINING COURSE SERIES 56 (Rev. 1)

# POSTGRADUATE MEDICAL PHYSICS ACADEMIC PROGRAMMES

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TRAINING COURSE SERIES No. 56 (Rev. 1)

# POSTGRADUATE MEDICAL PHYSICS ACADEMIC PROGRAMMES

## ENDORSED BY THE INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS (IOMP)

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2021

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# FOREWORD

The application and management of quality, safe and effective radiation medicine is the result of a team effort of different professionals, such as medical specialists, technologists and medical physicists. In order to fulfil their duties, medical physicists working as health professionals are expected to acquire competency in their area of specialization by completing appropriate educational qualifications and structured and supervised clinical training in one or more specialities of medical physics.

Guidelines on the requirements, outline and structure of postgraduate level academic programmes in medical physics were published by the IAEA in 2013 in Training Course Series No. 56 (TCS-56), which was endorsed by the International Organization for Medical Physics. These guidelines and accompanying handbooks have been used by Member States as a template to support regional efforts to harmonize medical physics education and by an increasing number of Member States with a critical mass of medical physicists that wish to initiate national postgraduate academic education programmes. The 18th biennial Secondary Standards Dosimetry Laboratories Scientific Committee, which evaluates the IAEA's programme relating to dosimetry and medical radiation physics, suggested that the IAEA publications that facilitate professional education in Member States be updated. The present publication is an update of TCS-56 to include more recent core resources and provide clarifications on student admission, assessment and quality management to promote best practices and sustainability of programmes.

To become clinically qualified medical physicists, the graduates of the academic programmes are expected to then undergo specialized clinical training as described in IAEA Human Health Series No. 25. The IAEA has published three Training Course Series publications providing guidelines and references for clinical training programmes for medical physicists specializing in radiation oncology (TCS-37), diagnostic radiology (TCS-47) and nuclear medicine (TCS-50). In 2021, the IAEA published guidance on certification of clinically qualified medical physicists (TCS-71), which was endorsed by the International Organization for Medical Physics and the International Medical Physics Certification Board, to further promote the recognition of the profession.

The International Organization for Medical Physics has endorsed this publication. The IAEA officers responsible for this publication were G. Loreti and D. van der Merwe of the Division of Human Health.

EDITORIAL NOTE

## CONTENTS

# 1. INTRODUCTION

## 1.1. BACKGROUND

Medical physics was classified among the healthcare professions by the International Labour Organization [1]. The International Basic Safety Standards [2] specifically refers to medical physics professionals with respect to medical exposure, patient protection and safety. The roles and responsibilities of medical physicists working in a hospital are given in detail in the IAEA's Human Health Series No. 25 [3], which also specifies the requirements in terms of academic education and clinical training to become a CQMP, and to work independently in one or more specialties of medical physics. A diagram summarizing such pathways is provided in Fig. 1. Similar to other health professionals, it is expected that CQMPs are certified nationally; the IAEA has published guidelines to support Member States in the establishment of certification bodies [4].

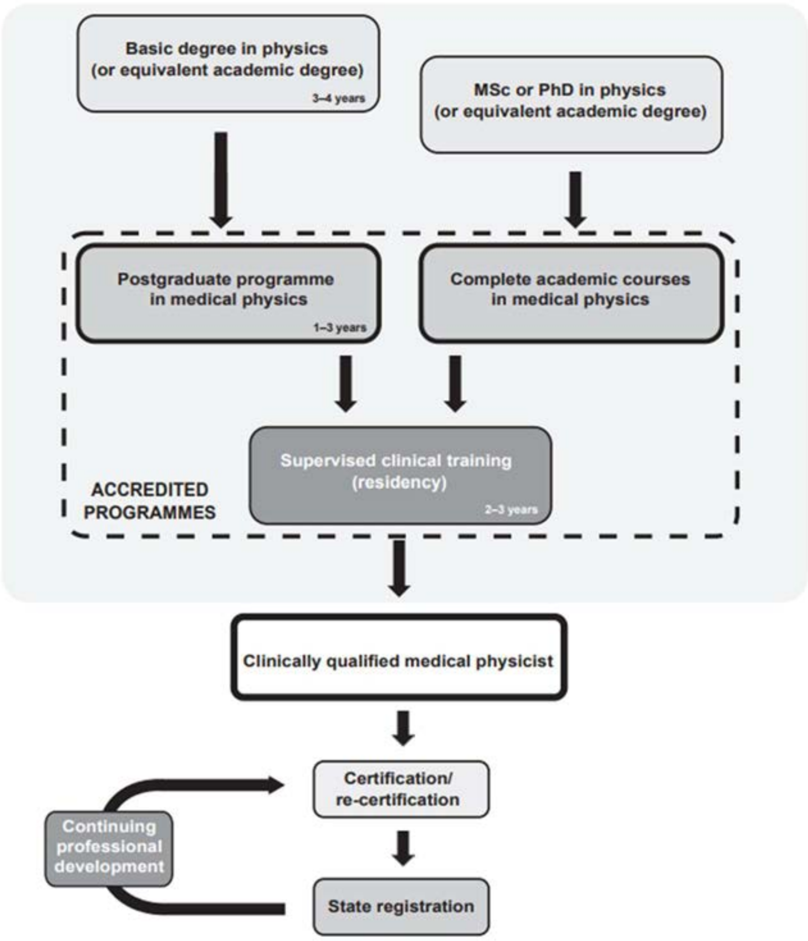


*FIG. 1. The recommendations on minimum requirements for the academic education and clinical training of clinically qualified medical physicists [4]. Successful completion of accredited programmes as shown within the dashed line in the figure, equips a medical physicist with the necessary knowledge, skills and competence to provide a safe and effective medical physics clinical service.*

The postgraduate academic education programme in medical physics provides a student with the foundational knowledge to enter a formal clinical medical physics residency [5-7]. It also provides the student with the knowledge needed to embark on a career for instance in the industry and metrology sectors, or to continue the academic studies at the doctoral level.

It is expected that the academic programme is hosted by an academic institution capable of awarding postgraduate-level degrees, in order to remain sustainable by offering academic career development pathways. Ideally, the academic institution offering the academic programme would additionally be linked to a university teaching hospital(s), to facilitate the collaboration of clinical medical physicists in the postgraduate programme, as well as to facilitate access of the graduates to a clinical training programme after the academic degree.
Additionally, a collaboration in between the university and the hospital can foster the development of research activities in the field of dosimetry and medical physics.

### 1.2. OBJECTIVE

The major objective of a postgraduate medical physics academic programme is to provide the students with a thorough grounding in medical physics, critical thinking, scientific rigor, and adequate professional ethics, to facilitate the integration of the graduates in a healthcare profession, where the benefit of the patient is at the centre of all activities.

### 1.3. SCOPE

This document aims to guide Member States in structuring a postgraduate-level academic programme in medical physics, and includes considerations pertaining to admission criteria, quality management and sustainability. The document comprises a list of knowledge sources for the core modules.

### 1.4. STRUCTURE

Section 2 provides insights on the admission criteria, to facilitate the process of appropriate student selection into the programme; this is complemented by examples provided in the Annex.
Section 3 describes the academic faculty and facilities to underpin and sustain the implementation of the programme.
Section 4 describes the content of the core modules and lists possible elective modules and practical sessions.
Section 5 highlights the importance of assessment in the framework of the programme.
Sections 6 and 7 aim respectively at providing considerations on quality management and sustainability of the programme.

## 2. ADMISSION CRITERIA

The undergraduate degree of students entering a postgraduate medical physics academic programme is preferably in physics or an equivalent relevant quantitative physical or physics-engineering science core degree.
Because there is significant variation in the level and composition of university-level education worldwide, it is often necessary for qualifications authorities to determine the local degree equivalence, prior to student admission. For admission to the medical physics programme, it will in addition be necessary to interrogate the academic transcripts of the degree.

While all components of transcripts provide meaningful information, specific elements have been identified as tenets in such evaluation and as pre-requisites to be admitted to a postgraduate-level academic degree in medical physics:

- At least 2 years of undergraduate level mathematics need to be completed successfully including:
  - Advanced Calculus
  - Complex Variables
  - Differential Equations
  - Numerical methods
  - Applied Linear Algebra

- The following physics topics are typically covered during undergraduate study. If not, they will need to be completed prior to entry into the medical physics programme:
  - Electricity and Magnetism
  - Atomic Physics/Nuclear Physics
  - Classical Mechanics
  - Quantum Mechanics
  - Solid State Physics
  - Modern Physics and Relativity
  - Thermodynamics / Statistical Physics
  - Signal Processing
  - Physics of Fluids and Gases
  - Optics
  - Computational Physics/Computer programming

The admission requirements for other individuals, who have already completed a graduate or postgraduate degree in any other field, is the same.
Generally, universities have well-established autonomous criteria to recognize prior learning. Examples on how to assess the qualifications of students seeking admission to a postgraduate medical physics programme are provided in the Annex.

## 3. INFRASTRUCTURE

### 3.1. ACADEMIC FACULTY

It is important that the academic faculty includes at least one instructor holding a PhD in the medical physics field, who is active in research. In cases where this is not achievable at the moment of the establishment of the programme, it is expected that a plan to strengthen the faculty is devised in a defined timeframe. In the interim, an established researcher with a PhD in a relevant related specialty (e.g. applied physics) could be considered. The lack of faculty with a PhD and substantial scientific research activities, will most likely limit the ability of the institution to offer a strong research component, and to foster independent and original research in medical physics (e.g. final thesis/report). Teaching is usually provided both by full time academic staff and by medical physicists and other health professionals working in the healthcare sector. Ideally, an appropriate number of CQMPs working in hospitals are involved in the postgraduate programme and hold formal faculty appointments in the university hosting the programme. The structure of the academic programme would therefore typically include a formal link with a clinical medical physics department in a hospital, with a teaching mandate. This serves the purposes of providing formal recognition of the contribution of CQMPs to the programme and encourages their commitment to the academic programme by promoting dedicated time to educational tasks. Radiobiologists, radiation metrologists, clinicians and regulators may also contribute by providing instruction in appropriate modules. In turn, they could also hold reciprocal honorary academic appointments.

To ensure the involvement of hospital staff is sustainable and does not detract from the workforce needed to support the clinical activities of diagnosis and treatment of patients, the clinical department(s) supporting the academic programme need to monitor their medical physics staffing levels, e.g. in accordance with national, international or IAEA guidelines [8-10].

## 3.2. FACILITIES

As part of the formal link between the academic institution and the hospital(s), it is important that an agreement or Memorandum of Understanding (MoU) is established. The existence of this link between hospital(s) and the university might provide students with supervised access to the clinical environment. The clinical radiation oncology, radiology and nuclear medicine services need to be equipped with at least the standard resources recommended by the national guidelines for the clinical training of medical physicists or in accordance with international best practice guidelines (e.g. IAEA clinical training guidelines [5-7]).

It would be advantageous if, as part of the research and practical work, the student, if fully supervised, could observe activities on the following equipment, systems and modalities related to the following services:

- Radiation oncology services:
  - Megavoltage teletherapy
  - 3D treatment planning
  - Radiotherapy simulation (conventional and/or computed tomography (CT))
  - Brachytherapy
  - Quality control, reference and relative dosimetry equipment, including a water phantom
- Radiology services:
  - General radiography
  - Fluoroscopy
  - CT
  - Magnetic Resonance Imaging (MRI)
  - Ultrasound
  - Dual energy X ray Absorptiometry (DXA)
  - Mammography
  - Dental radiography, if available
  - Quality control and dosimetry equipment
- Nuclear medicine services:
  - Gamma camera systems
  - Positron Emission Tomography (PET) or PET/CT, if available
  - Dose calibrator, probes and counters
  - Quality control equipment and calibration sources
  - Survey meters and contamination probes
  - Nuclear medicine therapy services, and dosimetry software and equipment

Exposure to the hospital environment can be complemented by offering the students the opportunity to become familiar with a metrology institution, a radiobiology laboratory, specialized facilities and other dosimetry-relevant services where available.

In case students are exposed to the clinical environment, all local liability issues concerning equipment, health and safety, radiation safety and protection, professional, research and education ethics, and patient confidentiality issues need to be clarified in the MoU. In some countries, students need to register with a certification body in order to observe or participate in any supervised clinical activity.

It is expected that the academic programme will offer its students the following elements, considered of crucial importance to support the programme and its related educational and research activities:

- Internet connectivity and access to computer workstations with basic computational software.

- Library access, including electronic journal access, and the relevant reports and publications from the major medical physics international reference organizations (e.g. International Committee for Radiological Units and Measurements (ICRU), International Commission on Radiological Protection (ICRP), etc.). The list of core reference textbooks associated with the recommended medical physics modules is given in the next section.

## 4. MEDICAL PHYSICS MODULES

The academic modules contained within the medical physics programme aim at preparing a student to understand the principles of physics applied to radiation medicine, conduct research and apply critical and innovative thinking to problem solving. An ability to perform research is expected to be acquired as part of the postgraduate programme; consequently, it is strongly advised that a research project is included as part of the academic programme. Typically, the project will provide the student with an opportunity to demonstrate an ability to conduct a literature review, apply statistical methods, present a description of methods and a discussion of results. An opportunity for oral and written presentation of the project would be beneficial, e.g. presentation at a scientific conference.

### 4.1. CORE MODULES

The core modules are provided below, including an outline of their content. It is expected that the course contents are taught to the level of quantitative detail indicated by the references provided and consistent with postgraduate-level education in basic science. Some overlaps can occur between different core modules; however, the different perspectives can be beneficial in providing complementary points of view.

- Anatomy and Physiology as applied to Medical Physics
  - Anatomical nomenclature
    - Origin of anatomical names
    - Prefixes and suffixes
    - Anatomical position and nomenclature; surface anatomy

- Structure, physiology, pathology and/or diagnostic image appearance (e.g. X ray, Computed Tomography (CT), MRI and nuclear medicine imaging) of:
    - Skeleton and bone marrow
    - Brain and Central nervous system
    - Thorax
    - Abdomen
    - Pelvis
- Respiratory, digestive, urinary, reproductive, circulatory, lymphatic and endocrine systems

- Radiobiology
  - Basics of cancer and the role of radiation therapy
    - Hallmarks of cancer
    - Oncogenes, tumour suppression genes and genome caretakers
  - Ionizing radiation interaction with biological systems:
    - Time-scale of effects
    - Classification of effects
    - Cell cycle and radiosensitivity
    - Linear Energy Transfer (LET)
  - Radiation-induced damage and DNA damage response:
    - Single strand break and double strand breaks
    - DNA damage sensors
    - DNA damage signalling
    - Effector pathways
  - Cell death after irradiation
    - How, when and why cells die
  - Quantification of cell survival: clonogenic assays
    - Cell survival curves
    - Models (e.g. linear quadratic model, Lethal-Potential Lethal etc.)
  - Relative Biological Effectiveness (RBE):
    - RBE and dose, dose rate and LET
    - RBE for tumours and normal tissue
  - Oxygen effect
  - Radiobiological dose models:
    - Tumour Control Probability (TCP)
    - Normal Tissue Complication Probability (NTCP)
    - Tolerance doses and volumes (Quantitative Analysis of Normal Tissue Effects in the Clinic - QUANTEC)
    - Equivalent Uniform Dose (EUD)
  - Fractionation:
    - The linear quadratic approach
    - Equivalent dose in 2 Gy fractions EQD2
    - Biologically Effective Dose (BED)

    - Incomplete repair and continuous irradiation
    - Hypo- and hyper-fractionation in radiotherapy

- Radiation Physics
  - Overview of Modern Physics
    - Historical overview
    - Atomic and nuclear structure
    - Radioactive decay
    - Concept of cross section
    - Elementary quantum mechanics
  - Atomic models (multi-electron), transition selection rules, atomic relaxation and radiation production
  - Radiation production by accelerated charges
  - Photon interactions
  - Neutron interactions
  - Charged particle interactions
  - Multiple elastic scattering
  - Mass scattering power
  - Mass stopping power
    - Unrestricted mass electronic stopping power for heavy charged particles
    - Unrestricted mass electronic and radiative stopping power for electrons and positrons
    - Restricted mass stopping power, linear energy transfer (LET)
  - Boltzman Transport Equation
    - Charged particle slowing down under the Continuous Slowing Down Approximation (CSDA)
    - Secondary electrons
  - Introduction to Monte Carlo techniques
  - Overview of non-ionizing radiation physics

- Radiation Protection
  - Introduction, historical perspective and sources of radiation
  - Radiation protection detection and measurement (Geiger-Mueller (GM), proportional counters, scintillators)
  - Exponential attenuation, half-value layer (HVL), inverse square law, tenth-value layer (TVL)
  - Shielding calculations
  - Safety assessment for facilities and activities [11]
  - Operational dosimetry, e.g. equivalent dose, effective dose, etc. [12]
  - Legal framework for radiation protection
  - Planned exposure situations [13]
    - General requirements
    - Occupational exposure

    - Public exposure
    - Medical exposure
  - Emergency exposure situations [13]
  - Radioactive transport and waste management
  - Risk assessment and communication of risk

- Professional and Scientific Development
  - Ethics
    - The World Medical Association Declaration of Helsinki
    - Basis of clinical trials
    - Ethics review/committees
    - Ethical principles: beneficence, non-maleficence, autonomy (respect), justice (impartiality), prudence (precaution), honesty (transparency), accountability, inclusiveness, etc.
  - Professionalism
    - Clinical governance
    - Quality management
    - Code of conduct
    - Management of medical equipment
    - Conflict of interest
  - Peer review/Journal club
  - Presentation skills
    - Scientific communication
    - Techniques of instruction

- Research Methodology
  - Research planning
  - Literature review
  - Data gathering and processing
  - Statistical methods in research
  - Computational tools and analysis
  - Critical analysis
  - Scientific writing
  - Authorship, integrity, plagiarism

- Medical Imaging Fundamentals
  - Mathematical methods
  - Tomographic reconstruction techniques
  - Linear systems
  - Introduction to image acquisition
  - Measures of image quality
    - Linear systems
    - Sampling theory, e.g. Nyquist-Shannon Sampling Theorem
    - Contrast, contrast detail assessment, contrast-to-noise ratio (CNR)

    - Signal, sensitivity, receptor response curves, dynamic range
    - Spatial resolution (e.g. Point Spread Function (PSF), Line Spread Funtion (LSF), Modulation Transfer Function (MTF))
    - Noise, Noise Power Spectra (NPS)
    - Detective Quantum Efficiency (DQE)
  - Introduction to image processing
    - Image filtering (smoothing, restoration)
    - Image segmentation
    - Image registration
    - Statistical techniques (optimisation, classification)
    - Volumetric techniques (rendering, modelling)
  - Image perception and assessment
    - Theory of human vision (Barton model)
    - Specifications of observer performance (decision outcomes, ROC)
    - Experimental methodologies
    - Design of display systems

- Radiation Dosimetry
  - Dosimetric quantities and units
  - Radiation equilibrium, partial charged particle equilibrium
  - Fano theorem
  - Cavity theory
  - Primary radiation standards for air kerma and absorbed dose
  - Radiation dosimeters for diagnostic and therapy applications
  - Calibration traceability
  - Absorbed dose to air ($N_{D,air}$) concept, detector response, e.g. absorbed dose to water calibration coefficient ($N_{D,w}$)
  - Reference dosimetry protocols and codes of practice
  - Small field dosimetry (fundamental aspects, recommendations)

- Physics of Radiation Oncology
  - Overview of clinical radiotherapy
  - Radiation therapy equipment ($^{60}$Co teletherapy, cyclotrons, kV generators, particle accelerators and waveguide theory)
  - Physics of megavoltage photon radiation therapy (dosimetric functions and basic treatment planning, Monitor Unit (MU) calculations)
  - Physics of kV photon radiation therapy (dosimetric functions and basic treatment planning, MU calculations)
  - Patient setup, including positioning and immobilization
  - Simulation, virtual simulation, Digitally Reconstructed Radiographs (DRRs), image registration
  - Dose calculation algorithms and heterogeneity corrections
  - Prescribing, recording and reporting according to the relevant ICRU Reports

- Physics of megavoltage electron radiation therapy according to relevant ICRU or American Association of Physicists in Medicine (AAPM) reports
- Brachytherapy according to relevant ICRU and AAPM reports:
  - High Dose Rate (HDR) and Low Dose Rate (LDR)
  - Equipment and sources
  - Treatment planning
- Inverse planning and optimization for Intensity Modulated Radiation Therapy (IMRT)
- Small field radiotherapy equipment and techniques (stereotactic radiotherapy (SRT) and radiosurgery (SRS), stereotactic body radiotherapy (SBRT), IMRT, Volumetric Arc Therapy (VMAT), Magnetic Resonance Guided Radiotherapy (MRgRT)
- Image guidance and verification in radiotherapy (Cone beam CT (CBCT), ultrasound (US), portal imaging, in-vivo dosimetry (IVD)), affine and deformable image registration
- Adaptive radiotherapy principles
- Radiation therapy information systems
- Principles of quality management in radiation oncology

- Physics of Nuclear Medicine
  - Production of radionuclides and radiopharmaceuticals
  - Radioactive decay and choice of radionuclides
  - Detectors and electronics
  - Non-imaging instrumentation
    - Dose calibrators, Well counters
    - Probes
  - Imaging Instrumentation
    - Planar, whole-body
    - Single Photon Emission Computed Tomography (SPECT)
    - Photon Emission Tomography (PET)
    - Hybrid imaging
  - Internal dosimetry (Medical Internal Radiation Dose (MIRD) formalism, biokinetic modelling and compartmental analysis)
  - Quantitative imaging
  - Dosimetry for radiopharmaceutical therapy
  - Image quality and noise
  - Principles of quality management in nuclear medicine
  - Radiation protection specific to nuclear medicine
  - Diagnostic applications and interpretation of radionuclide images

- Physics of Diagnostic and Interventional Radiology
  - X ray production including spectra
  - Exposure parameters and influence on image quality
  - X ray imaging and image reconstruction

    - Radiography
    - Mammography
    - CT
    - Fluoroscopy and interventional radiology
    - Digital radiography
    - Dual energy X ray absorptiometry, dental panoramic and tomographic imaging
    - Contrast enhancement
    - Patient dose and system optimization
- Ultrasound imaging
    - Ultrasound generation
    - Ultrasound interaction
    - Acoustic properties of biological tissues
    - Wave, motion and propagation, acoustic power
    - Image artifacts and image quality
    - Modes of scanning
    - Therapeutic applications
    - Transducers
    - Doppler techniques
    - Safety
- MRI
    - Physics of MRI
    - MR image formation
    - Nuclear Magnetic Resonance (NMR) and MRI
        - Magnetism, spins and NMR signal generation
        - The spin echo
        - T1 and T2 relaxation
        - NMR Spectroscopy
    - MRI imaging and reconstruction
        - Magnetization transfer
        - MRI hardware
        - k-space formalism, Fast Fourier Transform (FFT) and image formation (MRI)
        - Gradient echoes
        - Fast imaging (echo-planar imaging (EPI), k-space filling, parallel imaging)
    - MR instrumentation
    - MRI methods
    - MR contrast and image quality
    - Safety
- Clinical applications and artefacts
- Dual and multi-modality imaging
- Principles of quality management in radiology

## 4.2. PRACTICAL SESSIONS

Practical sessions or laboratory work is possible in all modules however, one laboratory session could cover multiple topics. Examples of laboratory exercises are given below and the academic modules to which they apply are provided:

- Anatomy and Physiology as applied to Medical Physics
  - Anatomy and function using different imaging modalities
- Radiation Physics and Radiation Dosimetry:
  - Measurements with ionization chambers in Co-60, X ray, and accelerator beams
  - Water Tank Scanning
  - Measurements with solid state and chemical dosimeters (Thermoluminescent Dosimeters (TLD), Metal-Oxide Semiconductor Field-Effect Transistors (MOSFET), Optically Stimulated Luminescent Dosimeters (OSLD), film, etc.)
- Radiation Physics:
  - Simple Monte Carlo code development to illustrate principle and sampling
  - Monte Carlo Transport Calculations using general purpose code
- Radiation Protection
  - Radiation survey of a clinical installation and shielding calculation
- Medical Imaging Fundamentals
  - Digital Imaging and Communications in Medicine (DICOM) practical
  - Experiments in perception
- Radiation Dosimetry
  - Reference dosimetry calibration of clinical beams using an International protocol, e.g. IAEA TRS 398 [14]
  - Small field dosimetry
- Physics of Radiation Oncology
  - A basic treatment planning exercise
- Physics of Nuclear Medicine
  - Calibration of the sensitivity of a gamma camera
  - Gamma ray spectroscopy
- Physics of Interventional and Diagnostic Radiology
  - X ray tube output dependence on HVL, tube voltage, tube current, exposure time, beam filtration and distance
  - Image quality assessment (contrast, resolution, modulation transfer function)
- Radiobiology
  - Measurement of a survival curve

## 4.3. CORE RESOURCES

A list of core knowledge sources that could be used to develop the programme is provided below, noting that many are examples of the current major textbooks in the field. Some are available electronically. A fully developed programme makes use of a far more extensive list of textbooks, e.g. the official IOMP CRC Press book series, and software, e.g. EMITEL e-Encyclopedia of Medical Physics and Multilingual Dictionary of Terms (http://www.emitel2.eu/emitwwwsql/index-login.aspx). All IAEA material is available online and most of the syllabus is covered in the three IAEA handbooks [15-17]. In addition, the IAEA Human Health Campus Web site [https://humanhealth.iaea.org] contains a substantial range of texts and downloadable teaching aids. There are freely downloadable treatment planning systems for education purposes that can also be considered (e.g. MATRAD, Plunc 3D etc.).

- Anatomy and Physiology as applied to Medical Physics:
  – TORTORA, G.J., DERRICKSON, B.H., Principles of Anatomy and Physiology. John Wiley & Sons, Inc., New Jersey, USA (2011).
  – WEIR, J., ABRAHAMS, P.H., SPRATT J.D., SALKOWSKIET L.R., Imaging Atlas of Human Anatomy, 4th Edition. Mosby, Maryland, USA (2010).

- Radiobiology
  – JOINER, M.C., VAN DER KOGEL, A.J., (Eds), Basic Clinical Radiobiology 5th edition, CRC Press (2019).
  – HALL, E.J., AND GIACCIA, A. Radiobiology for the Radiologist, Lippincott Williams & Wilkins, Philadelphia, US, 8th Ed. (2018).
  – LEHNERT, S., Biomolecular Action of Ionizing Radiation (Series in Medical Physics and Biomedical Engineering), Taylor and Francis, USA (2007).
  – INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Biology: A Handbook for Teachers and Students, Training Course Series, No. 42, IAEA, Vienna (2010).
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- Radiation Physics
  – PODGORSAK, E. B., Radiation Physics for Medical Physicists (Biological and Medical Physics, Biomedical Engineering), Springer, New York, USA (2010).
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## 4.4. ELECTIVE TOPICS

The following additional topics are recommended and are likely to be offered where relevant specialist expertise and resources exist:

- Health Technology Assessment
- Information and Communications Technology

- Particle Therapy or Special Techniques
- Accuracy requirements and uncertainties in radiation medicine
- Optical Imaging
- Microdosimetry
- Targeted Therapies
- Theranostics
- Management Principles
- Advanced statistical methods

## 5. STUDENT KNOWLEDGE EVALUATION AND TESTING

The knowledge acquired by the students needs to be formally assessed, in alignment with similar programmes in the host university, for instance science-focused postgraduate programmes. Typically, this includes final knowledge testing (also called high-stakes assessments) in the individual modules composing the programme. Nevertheless, the evaluation of the knowledge may include more regular and less formal types of assessments (also called low-stakes, formative assessments) [18]. The mechanisms of assessment could include one or a combination of written examinations, oral examinations, laboratory reports, presentations, attendance registers, small research projects and progress reports. When observing group work (e.g. laboratory-based exercises), it is important that each student's assessments are predominantly (70% or more) representative of individual (rather than group) performance or effort. Research ethics and integrity may be verified through a variety of methods, for instance the use of invigilation, plagiarism software or oral performance assessment.

Results reflecting the knowledge acquired by students (typically a numerical grading system) in each module are usually externally moderated and then stored in an organized manner, maintaining confidentiality and privacy of personal data. Such results are made available to graduates in the form of official university academic transcripts.

## 6. PROGRAMME QUALITY MANAGEMENT

In alignment with international best practices [19, 20], it is expected that educational programmes at all levels are subject to management mechanisms to ensure their quality is established, evaluated and maintained over time. This can include periodic collection, analysis and recording of feedback from the students, recent graduates and faculty. Additionally, the academic programme can undergo other types of periodic reviews, which may include but are not limited to:

(a) Review of the content of the syllabus and related references, to ensure alignment to scientific and professional developments and requirements,
(b) Analysis of the programme syllabus against international best practices (for instance IAEA guidelines)
(c) Comparison of the programme syllabus against similar programmes, to enhance harmonization at the national, sub-regional or regional level
(d) self-assessment, audit or peer review of the programme (for instance, Annex A of [19])
(e) accreditation of the programme.

A postgraduate-level programme in medical physics aims to provide students with the option to proceed to a clinical training residency in a hospital. After successfully completing clinical training, residents would be certified as qualified health professionals, with a certification to practice independently as CQMPs [4]. Consequently, when addressing point (a) and (e) above, consultations with the appropriate medical physics professional organization(s) is of crucial importance.

For point (c), a national qualifications authority can help coordinate and harmonize education, training, assessment and quality assurance of qualifications awarded in the country; with the view to improving quality and international comparability. As a consequence, national and foreign certificates and qualifications can be processed to determine recognition and/or verify international equivalence.

For points (a), (b), (d) and (e), experienced auditors and international organizations are available to provide advice and validation e.g. IOMP, the Commission on Accreditation of Medical Physics Educational Programs (CAMPEP). Accreditation of programmes is a structured mechanism that is typically national but can also rely on regional or international benchmarking or review. For medical physics programmes which are required to prepare students for clinical training in the health professional environment, consultations with the national professional bodies and the input of the National Health Authority (NHA) that is responsible for certification, are highly recommended.

## 7. PROGRAMME SUSTAINABILITY

It is expected that the standard university course assessment and evaluation takes place on a regular basis, as applied to all other academic programmes. The sustainability of a postgraduate level academic programme in medical physics is typically evaluated with respect to its purpose, which includes two main outputs:

1) providing the appropriate knowledge to graduates who aim to become CQMPs;

2) providing adequate preparation of graduates to embark on medical physics research.

For point 1), the sustainability of the programme is linked to the progression of graduates into a structured and supervised clinical training programme [5-7] first, followed by their employment as CQMPs in a hospital. It is therefore important that the academic programme stakeholders work closely with the national medical physics professional organization, certification body and other authorities to ensure the establishment and recognition of the medical physics profession, according to international recommendations [4].

For point 2), it is also important that a sustainable research team is developed and maintained. The research programme will ideally also include the CQMPs working in hospitals and other related collaborators.

To ensure its sustainability, it is expected that a programme will:

a) produce sufficient numbers of graduates that are gainfully absorbed into remunerated employment after completion of the programme;

b) facilitate access of its graduates to structured and supervised clinical training programmes in medical physics. In cases where the academic programme feeds clinical training programmes at the sub-regional, regional or international levels, the entrance criteria and quality of the various clinical training programme(s) needs to be taken into account. This information can be obtained through consultations with national professional organizations and certification bodies;

c) plan to produce an adequate number of medical physics graduates in view of the estimated future needs of the country (or region). This can be ensured through close collaboration with national or regional medical physics professional organizations and with the health authorities of the countries. Models for predicting CQMP staffing levels can be beneficial for this process [9, 10];

d) operate in a setting where the medical physics profession exists and is recognized or where a clear and realistic action plan and timeframe for the establishment of the medical physics profession has been devised;

e) Systematically request feedback and follow up on the graduates' professional status.

## Annex

## APPLYING ADMISSION CRITERIA

### A–1. INTRODUCTION

It is expected that students entering a postgraduate medical physics academic programme hold an undergraduate degree in physics or an equivalent relevant quantitative physical science or physics-engineering science core degree. However, many universities offer undergraduate degrees with a hybrid mix of subjects and it is sometimes difficult to establish equivalence and relevance. This Annex provides a sample of three transcripts of undergraduate degrees and corresponding guidance related to their equivalence for meeting the admission criteria of a postgraduate-level programme in medical physics.

The first example, shown in Table A–1, provides an excerpt of a course where the quantitative physics background of the candidate is clear, although the transcript is a physical-chemistry field (honours degree). While the course may not include some specific topics (e.g. optics, and relativity), in this case the candidate has the quantitative physical science background necessary for entry into a postgraduate medical physics programme.

TABLE A–1. EXAMPLE OF AN EVALUATION OF A TRANSCRIPT FROM A PHYSICAL CHEMISTRY DEGREE FOR THE PURPOSE OF ACCEPTANCE INTO A POSTGRADUATE MEDICAL PHYSICS PROGRAMME

| **Course name (extracted from the transcript)** | **Correspondence to requirements for admission (postgraduate medical physics programme)** |
|---|---|
| Introduction to physical chemistry + laboratory component | Thermodynamics |
| Advanced calculus, ordinary differential equations (2 courses) | Advanced calculus, differential equations |
| Classical mechanics | Classical Mechanics |
| Introduction to physical chemistry 2 + laboratory | Thermodynamics |
| Applied linear algebra, complex variables, ODE’s (3 courses) | Advanced calculus, complex variables |
| Computers in engineering | Computational physics/computer programming |
| Electricity and magnetism | Electricity and magnetism |
| Quantum physics 1 | Quantum mechanics, atomic physics, modern physics |
| Quantum physics 2 | Quantum mechanics, atomic physics, modern physics |
| Advanced quantum physics | Quantum mechanics, atomic physics, modern physics |
| Statistical thermodynamics | Thermodynamics/statistical physics |
| Signal processing | Signal processing |
| Inorganic chemistry | Atomic physics, modern physics |
| Molecular properties and structure | Atomic physics, modern physics |
| Electromagnetic waves | Electricity and magnetism, modern physics |
| Solid state physics | Solid state physics |
| Statistical mechanics | Thermodynamics/statistical physics |
| Introduction to computer science | Computational physics/computer programming |
| Advanced biophysics | Some aspects of the physics of fluids and gases |

The second example, shown in Table A–2, provides a case where the candidate has not completed a quantitative physical science programme (physics or engineering physics programme). In this case, it is likely that the assessment of the transcripts will reveal an insufficient physics background. This particular undergraduate programme was a radiation technology diploma/degree.

TABLE A–2. EXAMPLE OF A TRANSCRIPT FROM A RADIATION TECHNOLOGY DIPLOMA/DEGREE THAT WOULD NOT RESULT IN ACCEPTANCE INTO A POSTGRADUATE MEDICAL PHYSICS PROGRAMME

| **Course name** |
|---|
| Biological systems |
| Anatomy in radiation oncology |
| Fundamentals of radiation oncology |
| General physics |
| Radiation effects and safety |
| Equipment in radiation oncology |
| Applied radiation dosimetry |
| Applied ethics |
| CT simulation |
| Introduction to medical imaging |

The third case, shown in Table A–3, relates to an undergraduate degree in “Allied Health Sciences”. Although several courses can be found that correspond to the nuclear medicine specialty of medical physics, the background of the individual in basic quantitative physical sciences is inadequate for medical physics postgraduate studies.

TABLE A–3. EXAMPLE OF A TRANSCRIPT FROM A DEGREE IN ALLIED HEALTH SCIENCES THAT WOULD NOT RESULT IN ACCEPTANCE INTO A POSTGRADUATE MEDICAL PHYSICS PROGRAMME

| **Course name** |
|---|
| Anatomy |
| Physiology |
| Biochemistry |
| Psychology |
| Elements of health and nursing principles |
| Clinical examination of visual system |
| English |
| Microbiology |
| Pathology |
| Pharmacology |
| Medical physics |
| Medical sociology |
| Hospital operation management |
| Community medicine |
| Basics of human genetics |
| Medical electronics |
| Intermediate organic chemistry |

| **Course name** |
| --- |
| Intermediate mathematics |
| Introduction to biophysics |
| Environmental science |
| Anatomy, physiology, pathology related to nuclear medicine |
| Nuclear physics and Introduction to radiation protection |
| Nuclear medicine instrumentation and quality control |
| Radio chemistry and radio pharmacy |
| 1st aid management and splinting techniques |
| Clinical posting 1 |
| Nuclear medicine techniques |
| Radiobiology and radiation safety in nuclear medicine |
| Physical health |
| Basics of research methodology |
| Basics of biostatistics |
| Clinical posting 2 |
| Diagnostic and therapeutic procedures in nuclear medicine |
| Molecular imaging |
| Medical ethics and law |
| Trauma life support |
| Cardiac life support |
| Clinical posting 3 |

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## ABBREVIATIONS

| | |
|---|---|
| AAPM | American Association of Physicists in Medicine |
| CQMP | Clinically Qualified Medical Physicist |
| ICRU | International Commission on Radiation Units and Measurements |
| IMPCB | International Medical Physics Certification Board |
| IOMP | International Organization for Medical Physics |
| SSDL | Secondary Standards Dosimetry Laboratories |

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