C A M P E P

Commission on Accreditation of Medical Physics Educational Programs, Inc.

Standards for Accreditation of Professional Doctorate Educational Programs in Medical Physics

Revised February 2023

Preamble

Medical Physics is a branch of physics that applies the concepts and principles of physics to the diagnosis and treatment of human diseases. Medical Physics encompasses four fields: Imaging Physics, Nuclear Medicine Physics, Radiation Oncology Physics and Medical Health Physics. This document focuses on the essential educational and experience requirements needed to engage in medical physics research and development, and to enter a residency program in preparation for clinical practice of one of the first three fields.

Terms such as “shall”, “must”, “require”, “should”, “may” and “recommend” are frequently used in these standards. The terms “shall”, “must”, and “require” denote items or activities that CAMPEP believes are mandatory components of an educational program. That is, they are required components. The terms “should”, “may” and “recommend” are considered desirable but not essential components of an educational program.

Contents

1. Program Objective and Goals 1
2. Program Structure and Governance 2
3. Program Director 4
4. Program Faculty/Staff 5
5. Institutional Support 5
6. Educational Environment 5
7. Scholarly Activities 6
8. Didactic Curriculum 6
9. Clinical Curriculum 10

3. Program Goal and Objective

The program objectives shall, at a minimum, include the development in the student of:

- an understanding of the role of patient safety in the clinical practice of medical physics;
- an understanding of the physics, mathematics and other physical science required for a career in medical physics;
- an understanding of how research and inquiry lead to the creation of new knowledge;
- the technical knowledge, skills and competency required for the safe application of the technologies used in the practice of medical physics;
- an appreciation of the clinical purpose and applications of sophisticated technologies;
- an understanding of the protocols and practices essential to the employment of technologies to detect, diagnose and treat various illnesses and injuries;
- the ability to use analytical and research methods to solve problems arising in the clinical environment;
- the ability to deploy new strategies within the clinical environment;
- the ability to critically evaluate research and scholarship in medical physics;
- the competent use of research to pose new questions and to solve problems in research and clinical settings;
- the communication and interpersonal skills that are necessary to function in a collaborative, multidisciplinary environment;
- the professional attributes and the ethical conduct and actions that are required of medical physicists; and
- a valuing of career-long continuing education to keep scientific knowledge and skills current.

1.1 The program shall state its mission and objectives.

4. Program Structure and Governance

2.1G Institutions in the United States offering graduate education in medical physics must be accredited by an accreditation organization recognized by the US Department of Education or the Council for Higher Education Accreditation. Programs in other jurisdictions must hold appropriate equivalent recognition.

2.1R The institution in which the clinical training is conducted must be accredited by the appropriate healthcare accreditation organization.

2.2G Professional doctorate programs in medical physics shall be sited in a well-defined university structure where the term “university” refers to an institute of higher learning and research, with standing in the academic community, a full-time faculty, frequently multiple schools and departments offering study in a comprehensive range of multidisciplinary areas and generally with a reputation for distinct areas of research. Although a Medical Physics Graduate Program may be newly established within the institution, it is expected that the institution be well-established with a history of stability, an infrastructure to support students through their studies, and with well-defined services for protecting students’ interests, e.g., an ombudsman.

2.2R The clinical training must be located in an appropriately structured, well-established clinical environment, with a history of stability and with the infrastructure to support resident education and training.

2.3 The Professional Doctorate program shall be overseen by an appropriate steering committee, which is chaired by the program director or delegate and meets at least twice a year.

2.4 The steering committee's membership shall include the program director and other faculty and staff members who are involved in medical physics education.

2.5 The process for appointment of the members of the steering committee shall be documented.

2.6 Minutes of the steering committee meetings, including a summary of any actions that are proposed or taken, shall be recorded.

2.7 A mechanism for students to communicate with the steering committee shall be available.

2.8 The steering committee shall establish a process for evaluating the quality of the educational program and annually assess the quality of the educational program based on this process, taking appropriate action to address improvements when needed.

2.9 The steering committee shall assess and monitor the strengths, weaknesses, needs, and long-term goals of the program.

2.10 A procedure shall be in place to appropriately counsel, censure, and, after due process, dismiss students who fail to achieve acceptable learning metrics or clinical competence, or who behave unethically.

2.11 All courses and clinical practica, including distance learning courses, shall use well-defined and consistently applied metrics for evaluating student progress and performance.

2.12G A program that has tracks that are not CAMPEP-accredited must clearly identify those students who are enrolled in the accredited program. The mechanism by which the program designates the graduates of the accredited track, e.g., an attestation of completion or a unique notation on the diploma, must be clearly stated on the program's website.

2.12R A program may consist of a single institution or of a primary site plus one or more affiliated institutions. An affiliated site is a participating site that is physically separated from the primary site such that it would be impractical for the program director at the primary site to directly supervise the resident's training at the affiliated site. Residency programs with multiple physical locations that are reasonable commuting distance, and where the program director can exercise direct supervision of the resident's training at all physical sites, may be considered to be a single site.

For programs with affiliated sites, a formal agreement must be in place between the main site and the affiliate site(s) describing liability, responsibility, accountability and any financial arrangements.

2.13 An accredited program must publicly describe the program and the achievements of its graduates and students, preferably through a publicly accessible web site, readily accessible from the program website home page. This information must be updated no less often than annually and must include the numbers of applicants to the program, of students offered admission, of students matriculated, and of graduates. Where possible, information on the

subsequent positions of graduates must also be provided, i.e., clinical practice, industrial positions, etc. This information should not identify individuals.

2.14 A professional doctorate program shall consist of at least two years of full-time equivalent clinical training, with progressively increasing responsibilities under the supervision of qualified medical physicists. *Students' responsibilities shall, under appropriate supervision, rise to the level of actual clinical activities.* The educational experience may take place at one or more affiliated institutions.

2.15 The clinical component of a professional doctorate program shall clearly identify the program type (therapy, imaging, imaging + nuclear medicine, etc.). If that is not clearly delineated in the program name, then the program must identify the program type on the home page of its website.

3. Admissions

3.1 Students entering a professional medical physics doctorate program shall have a strong foundation in basic physics. This shall be demonstrated either by an undergraduate or graduate degree in physics, or by a degree in an engineering discipline or another of the physical sciences and with coursework that is the equivalent of a minor in physics (i.e., one that includes at least three upper-level undergraduate physics courses that would be required for a physics major).

3.2 If a professional doctorate program conditionally admits applicants with deficiencies in their academic backgrounds, the remedial physics education of such students shall be well-defined.

3.3 Admission standards for incoming students are clearly stated.

3.4 The method of processing an application, including evaluating the application and informing the applicant of actions taken, shall be clearly stated.

4. Program Director

4.1 The process for the appointment of the program director shall be documented.

4.2 A sole program director shall be responsible and accountable for ensuring that the professional doctorate program satisfies the CAMPEP standards and shall ensure that all students receive a high-quality education in all courses and practica.

4.3 The program director must possess a PhD or other doctoral degree in medical physics or a closely-related discipline, and hold an appropriate academic appointment at the institution hosting the program. In addition, the program director must be certified to practice medical physics by the American Board of Radiology, the Canadian College of Physicists in Medicine, or another appropriate certifying agency.

4.4 The program director shall have at least five years of full-time post-graduate experience in medical physics.

4.5 The program director shall be responsible for coordinating the faculty, recruiting students into the program, advising the students, and evaluating and promoting the program.

4.6 The program director shall be responsible for determining and documenting that each student offered entry into the professional doctorate program satisfies the CAMPEP

admission standards for graduate education in medical physics or completes rigorous remedial education to meet the standards.

4.7 The program director shall ensure that all student statistics, annual reports, and other information that is required by CAMPEP are reported accurately and in a timely fashion.

4.8 The program director shall ensure that student progress is regularly monitored. During the clinical component of the program, the program director shall meet periodically with each student to assess the student's clinical progress, and minutes of the meeting shall be maintained. A copy of the minutes shall be provided to the student.

5. Program Faculty and Staff

5.1 The process for the appointment of the program faculty and staff shall be documented.

5.2 An adequate number of qualified program faculty and staff members shall be available and have sufficient time for teaching and mentoring professional doctorate students.

5.3G A majority of the program faculty shall have an academic appointment at an accredited educational institution.

5.3R The number of program staff shall exceed the number of residents in the program plus 1.

5.4G Some of the program faculty members shall be licensed to practice medical physics by an appropriate jurisdiction or be certified in a branch of medical physics by an appropriate certifying agency.

5.4R The number of program staff shall exceed the number of clinical students in the program plus 1.

5.5 Program faculty members shall be engaged in scholarly activities such as participation in scientific societies and meetings, scientific presentations and publications, and continuing education.

6. Institutional Support

6.1 The institution sponsoring the professional doctorate program shall provide administrative support, including educational resources, budget, office/cubicle space, conference room(s), audiovisual facilities, and office support (e.g., copiers, internet access, e-mail accounts, and telephone).

6.2 The institution must express its intention to support the program both financially and administratively for the term of the accreditation.

6.3 Any financial support of students, including benefits, shall be described clearly to prospective applicants prior to their application to the program.

6.4 Entering students shall be provided with orientation information to ensure their efficient integration into the program.

6.5 The program shall instruct its students on the potential hazards that they might encounter and on the appropriate measures for them to take to minimize risks to themselves, others, and equipment.

6.6 The program shall instruct its students regarding the professional, ethical, and regulatory issues in the responsible conduct of research and in the protection of the confidentiality of patient information.

7. Educational Environment

7.1 The program shall have mechanisms that encourage open discussion and communication, and facilitate the exchange of knowledge, experience and ideas.

7.2 Conference, seminar, and journal club activities shall be used for students to practice their presentation and oral communication skills.

7.3 Students shall have access to a variety of journals, books, and appropriate resource materials.

7.4 Students shall have access to appropriate clinical and research facilities and the program shall demonstrate that clinical facilities and equipment are used in the teaching of practical aspects of core topics in imaging physics and radiation oncology physics.

7.5 Students shall be provided with a mechanism for regular feedback concerning the quality of their instruction and the diligence of their teachers and mentors. The students shall be protected from unwarranted retribution.

7.6 Feedback on the overall effectiveness of the program and recommendations for improvement should be sought from graduates.

7.7 Issues and concerns that are identified through feedback shall be evaluated by the steering committee and remedial action shall be taken where appropriate.

7.8G Professional doctorate students shall engage in research projects to develop a systematic approach to solving problems and to gain a familiarity with scientific method.

7.8R All clinical, educational and scholarly activities engaged in by the clinical student shall be recorded in an activities journal using any appropriate format maintained personally by each student and examined regularly by the program director

8. Didactic Curriculum

The structure of course work in a professional doctorate education program in medical physics may be defined by the program but shall, as a minimum, include the topics listed below. These core topic courses will, for example, typically require about 18 semester credit hours or more. Additional courses provided by the professional doctorate program to fulfill institutionsl requirements may vary widely from program to program. For example some programs may require graduate level physics courses, while others may offer advanced courses in medical physics, statistics, or other allied topics. These additional courses may be required or elective at the discretion of the program.

Typically, the didactic component of a professional doctorate program will take two academic years. Significant deviations from this period should be justified.

8.1 Radiological physics and dosimetry

8.1.1 Atomic and nuclear structure
8.1.2 Classification of radiation
8.1.3 Quantities and units to describe radiation fields
8.1.4 Quantities and units to describe radiation interactions

8.1.5 Indirectly ionizing radiation: photons
8.1.5.1 Exponential attenuation
8.1.5.2 Photon interactions
8.1.6 Indirectly ionizing radiation: neutrons
8.1.6.1 Neutron interactions
8.1.7 Directly ionizing radiation (electrons, protons, others)
8.1.7.1 Interactions of directly ionizing radiation
8.1.8 Radioactive decay
8.1.9 Charged particle equilibrium
8.1.10 Radiation dosimetry – general
8.1.11 Radiation dosimetry – calorimetry
8.1.12 Radiation dosimetry – chemical
8.1.13 Cavity theory
8.1.14 Ionization chambers
8.1.14.1 Calibration of photon and electron beams with ionization chambers
8.1.15 Dosimetry and phantoms for special beams
8.1.16 *In vivo* dosimetry (TLD, OSL)
8.1.17 Relative dosimetry methods
8.1.18 Neutron dosimetry
8.1.19 Pulse mode detectors

8.2 Radiation protection and safety

8.2.1 Introduction and historical perspective
8.2.2 Interaction physics applied to radiation protection
8.2.3 Protection principles (time, distance, shielding)
8.2.4 Handling radiation and radioactive sources
8.2.5 Radiation survey/contamination equipment
8.2.6 Personnel monitoring
8.2.7 Radiation dose limits
8.2.8 Protection regulations
8.2.9 Shielding Principles: beams and sources
8.2.10 Application of statistics
8.2.11 External exposure
8.2.12 Internal exposure
8.2.13 Environmental dispersion
8.2.14 Radioactive waste

8.3 Fundamentals of medical imaging

8.3.1 History of medical imaging
8.3.2 Mathematical Models
8.3.3 Reconstruction mathematics
8.3.4 Radiography
8.3.4.1 X-ray tube construction and X-Ray beam production; kV, mA, pulse width
8.3.4.2 X-ray beam properties and interactions in matter
8.3.4.3 Sources of image contrast and noise; detector efficiency and dose, noise power spectrum analysis
8.3.4.4 Spatial and temporal resolution
8.3.4.5 Detector technologies and anti-scatter grids

8.3.4.6 Digital radiography and computed radiography
8.3.4.7 Mammography
8.3.4.8 Performance testing and equipment QA

8.3.5 Fluoroscopy
8.3.5.1 Detector technologies; Flat panel imager, image intensifier/TV
8.3.5.2 Radiographic contrast agents
8.3.5.3 Automatic exposure control and basic imaging modes
8.3.5.4 Digital angiography and digital subtraction angiography
8.3.5.5 Operating technique and dose to patient and staff
8.3.5.6 Performance testing and equipment QA

8.3.6 Computed tomography
8.3.6.1 Basic data acquisition principles and scanning modes
8.3.6.2 Basic reconstruction modes
8.3.6.3 In-plane spatial resolution, slice thickness, image noise, dose
8.3.6.4 Artifacts
8.3.6.5 Cone-beam computed tomography
8.3.6.6 Performance testing and equipment QA
8.3.6.7 CT scanning technique and patient dose

8.3.7 Nuclear medicine imaging
8.3.7.1 Modes and processes of radioactive decay
8.3.7.2 Basics of nuclear reactions and radioactivity
8.3.7.3 Nuclear counting statistics
8.3.7.4 Counting systems and gamma cameras
8.3.7.5 Image quality and reconstruction
8.3.7.6 Physics of SPECT and PET systems
8.3.7.7 Radiotracer techniques
8.3.7.8 Radiopharmaceutical design and mechanisms of localization
8.3.7.9 Performance testing and equipment QA

8.3.8 Magnetic resonance imaging
8.3.8.1 Magnetization, precession, Larmor equation, rotating frame of reference, spin tipping
8.3.8.2 T1 and T2 relaxation
8.3.8.3 Pulse sequences and image formation (slice selection, phase encoding, frequency encoding)
8.3.8.4 Spin echo image formation
8.3.8.5 Image contrast (proton density, T1, T2 and T2*)
8.3.8.6 Definition of common acquisition parameters (TE, TR, field of view, spatial resolution) and signal-to-noise ratio
8.3.8.7 Rapid imaging techniques (gradient echo, fast spin echo)
8.3.8.8 Magnetization preparation techniques (inversion recovery, saturation)
8.3.8.9 Artifacts
8.3.8.10 Performance testing and equipment QA
8.3.8.11 MR contrast agents
8.3.8.12 Safety and biological effects

8.3.9 Ultrasound
8.3.9.1 Propagation of ultrasound through tissue; sources of contrast
8.3.9.2 Diagnostic transducers, including materials and probe types

8.3.9.3 2-D, 3-D ultrasound imaging
8.3.9.4 Spatial and temporal resolution
8.3.9.5 Doppler and color flow imaging
8.3.9.6 Performance testing and equipment QA
8.3.9.7 Elasticity imaging methods
8.3.9.8 Artifacts
8.3.9.9 US contrast agents
8.3.9.10 Safety and biological effects

8.4 Radiobiology

8.4.1 History of radiation injuries in humans
8.4.2 Radiation interactions in cells/tissues
8.4.3 Radiation injury to DNA
8.4.4 Repair of DNA damage
8.4.5 Indirect effects of radiation
8.4.6 Chromosomal damage and repair
8.4.7 Target theory and cell survival curves
8.4.8 Free radical formation
8.4.9 Apoptosis, reproductive cell death
8.4.10 Cell kinetics
8.4.10.1 Cell recovery processes
8.4.10.2 Cell cycle sensitivity
8.4.11 Radioprotectors, radiosensitizers
8.4.12 RBE, OER, LET
8.4.13 Tissue injuries
8.4.13.1 Acute effects of radiation
8.4.13.2 Delayed effects of radiation
8.4.13.3 Radiation carcinogenesis
8.4.13.4 Radiation mutagenesis
8.4.13.5 Radiation teratogenesis
8.4.13.6 Other embryo/fetal effects
8.4.14 Risk estimates of radiation
8.4.15 History of linear no-threshold theory
8.4.16 Predictions of cancers in populations
8.4.17 Radiation epidemiology
8.4.18 Evidence of cancers in populations
8.4.19 Concept of radiation hormesis
8.4.20 Tumor radiobiology
8.4.21 Time, dose, fractionation
8.4.22 Molecular mechanisms
8.4.23 Drug/radiation interactions

8.5 Medical Anatomy & Physiologic Processes

8.5.1 General Terminology
8.5.1.1 Anatomical reference terminology
8.5.1.2 Imaging planes and orientations
8.5.1.3 Diagnostic Radiology terminology and conventions
8.5.1.4 Radiation Therapy terminology and conventions

8.5.2 Sectional and Radiographic Anatomy
- 8.5.2.1 Breast
- 8.5.2.2 Cardiovascular
- 8.5.2.3 Digestive System
- 8.5.2.4 Musculoskeletal
- 8.5.2.5 Neurological System
- 8.5.2.6 Reproductive/Endocrine
- 8.5.2.7 Thoracic Cavity
- 8.5.2.8 Urinary System
- 8.5.2.9 Lymphatic System

8.5.3 Human Physiology
- 8.5.3.1 Nervous system
- 8.5.3.2 Musculoskeletal system
- 8.5.3.3 Cardiovascular system
- 8.5.3.4 Respiratory system
- 8.5.3.5 Digestive system
- 8.5.3.6 Integumentary system
- 8.5.3.7 Urinary system
- 8.5.3.8 Reproductive system
- 8.5.3.9 Immune system
- 8.5.3.10 Endocrine system

8.5.4 Pathology
- 8.5.4.1 Neoplastic Diseases
- 8.5.4.2 Benign Disease
- 8.5.4.3 Trauma
- 8.5.4.4 Cardiovascular Diseases
- 8.5.4.5 Neurological

8.6 Radiation therapy physics

8.6.1 History of radiation oncology

8.6.2 Principles of radiation oncology

8.6.3 External beam treatments
- 8.6.3.1 Sources of external beams
- 8.6.3.2 Calibration of external beams
- 8.6.3.3 Acquisition of external beam data
- 8.6.3.4 Treatment planning principles
- 8.6.3.5 Multifield radiation therapy
- 8.6.3.6 IMRT, VMAT
- 8.6.3.7 Image fusion, registration, segmentation, quantitation
- 8.6.3.8 Motion management
- 8.6.3.9 Performance testing and equipment QA

8.6.4 Brachytherapy
- 8.6.4.1 Brachytherapy sources
- 8.6.4.2 Storing and shielding brachytherapy sources
- 8.6.4.3 Brachytherapy delivery devices
- 8.6.4.4 Brachytherapy treatment planning principles
- 8.6.4.5 Performance testing and equipment QA

8.6.5 Special techniques in radiotherapy
8.6.6 Radiation therapy with neutrons, protons, light ions
8.6.7 Radiation protection in radiation therapy

8.7 Professionalism and Ethics

These topics should be introduced in the didactic component of the educational program and taught in greater detail in the clinical component of the educational program.

Professionalism

8.7.1 Definition of a profession and professionalism
8.7.2 Elements of a profession
8.7.3 Definition of a professional
8.7.4 Elements of professionalism (altruism, honesty, integrity, excellence, duty, accountability, respect for others)
8.7.5 How is professionalism judged?
8.7.6 Do's and don'ts of professionalism
8.7.7 Physician's charter and applicability to physicists

Leadership

8.7.8 Qualities of leaders
8.7.9 Rules of leadership
8.7.10 Causes of leadership failure

Ethics

8.7.11 Ethics of a profession
8.7.12 Ethics of an individual
8.7.13 Interactions with colleagues and co-workers
8.7.14 Interactions with patients and the public
8.7.15 Confidentiality
8.7.16 Peer review
8.7.17 Negotiation skills
8.7.18 Relationships with employers
8.7.19 Conflicts of interest (recognition and management)
8.7.20 Ethics in research (fabrication, fraudulence, plagiarism)
8.7.21 Use of animals in research
8.7.22 Use of humans in research
8.7.23 Relationships with vendors
8.7.24 Publication ethics

9. Clinical Curriculum

9.1 The self-study document shall include written expectations of student clinical performance and behavior as well as the training schedule that is given to students. This training schedule shall include:

1. Duration of each clinical rotation
2. Clinical rotation objectives
3. Didactic educational expectations

4. Optional research opportunities that complement clinical training (The Self-Study should describe how the integrity of clinical training is maintained.)

9.2 The elements of clinical training shall be consistent with the curriculum described below.

9.3 The self-study document shall include a summary of the elements of clinical training of each clinical rotation to include:

1. Documentation of specific training objectives;
2. Documentation of student progress evaluation with student name removed;
3. Documentation of any required remedial didactic education;
4. List of clinical conferences, seminars and/or journal reviews including their frequency that the resident is expected to attend.
5. An appropriate reading list.

9.4 The process for creating or modifying training objectives shall be described.

9.5 All facilities used by the students including their location, availability, and capacity shall be listed.

9.6 Ethics and Professional Curriculum

The topics identified in 8.7 should be introduced in the didactic component of the educational program and taught in greater detail in the clinical component of the educational program.

9.7 Imaging Physics Clinical Curriculum

Minimum requirements are described below for completing clinical education in imaging physics. For tests to be conducted, the number of systems to be tested to demonstrate competency is left to the discretion of the program director and the supervising physicist, except for systems where facility accrediting agencies define the minimum number of systems that must be tested for an individual to be considered a qualified medical physicist. In these cases, the minimum number of systems to be tested shall be at least the number specified by the accrediting agency. For topics that define quantities that may be measured or computed, the resident should perform actual measurements or computations to demonstrate familiarity with the quantities and their uses.

- Conduct system performance evaluations and quality control, safety and compliance tests, including vendor recommendations, under supervision of a qualified physicist
  - Radiography
  - Computed radiography
  - Fluoroscopy
  - Interventional/angiography
  - Mammography
  - Stereotactic breast biopsy
  - Computed tomography (CT)
  - Magnetic resonance
  - Ultrasound
  - Image processors/printers
- Safety evaluations
  - Entrance exposure estimates
  - Organ dose estimates

  - Computed tomography dose index (CTDI) and dose-length product (DLP)
  - Mean glandular dose
  - Effective dose
  - Risk estimates
  - Personnel exposure estimates and reduction
  - Fetal dose
  - Contrast agents
  - Protocol optimization
  - MRI hazards
  - Organ/fetal doses with MIRD system
  - Radiopharmaceutical applications and risks
  - Site considerations and shielding design
  - Personnel shielding/monitoring
  - Calibration and survey instruments
  - Radiation surveys
  - Safety policies/procedures
  - Compliance audits
  - Dose limits
- Informatics
  - Picture archiving and communications systems (PACS) and radiology information systems (RIS) systems and their integration
  - Digital imaging and communication systems (DICOM) standards
  - Health Level 7 (HL7)
  - Information acquisition from PACS/images
  - Informatics variations among modalities
  - Dose reporting features
  - Use of Integrating the Healthcare Enterprise (IHE) radiology profiles
  - Open source software resources
  - Quality/maintenance of imaging workstations
  - Evaluation of viewing conditions
  - Image registration, fusion, segmentation, processing
  - Computer-aided detection (CAD) and computer-aided diagnosis (CADx) systems

9.8 Nuclear Medicine Physics Clinical Curriculum

Minimum requirements are described below for completing clinical education in nuclear medicine physics. For tests to be conducted, the number of systems to be tested to demonstrate competency is left to the discretion of the program director and the supervising physicist, except for systems where facility accrediting agencies define the minimum number of systems that must be tested for an individual to be considered a qualified medical physicist. In these cases, the minimum number of systems to be tested shall be at least the number specified by the accrediting agency. For topics that define quantities that may be measured or computed, the resident should

perform actual measurements or computations to demonstrate familiarity with the quantities and their uses.

- Conduct system performance evaluations and quality control, safety and compliance tests, including National Electrical Manufacturers Association (NEMA) and vendor specifications, under supervision of a qualified physicist
    - Gamma camera, including intrinsic/extrinsic/SPECT performance
    - PET/CT, including ACR accreditation tests
    - Sufficient tests to achieve ACR qualified medical physicist status
    - Non-imaging equipment (e.g. dose calibrators, uptake probes, well counters)
    - Image processors/printers
    - Computer systems
- Safety evaluations
    - Organ/fetal doses with MIRD system
    - CTDI and DLP
    - Effective dose
    - Risk estimates
    - Personnel exposure estimates and reduction
    - Radiopharmaceutical applications and risks
    - Site considerations and shielding design
    - Personnel shielding/monitoring
    - Unsealed source management (storage, inventory, packaging, transportation, personnel protection)
    - Calibration and survey instruments
    - Radiation and contamination surveys
    - Radiopharmacy considerations
    - Radionuclide therapy/personnel safety/patient release criteria/public safety
    - Safety policies/procedures
    - Compliance audits
    - Occupational and public dose limits
    - National and state regulations
    - Radiation exposure to the public
    - Waste handling and disposal
    - Radioactive spills
    - Radiation signage
    - Medical events (definition and reporting requirements)
- Informatics
    - PACS and RIS systems and their integration
    - HL7
    - DICOM standards
    - Information acquisition from PACS/images
    - Informatics variations among modalities

- Dose reporting features
- Use of IHE radiology profiles
- Open source software resources
- Quality/maintenance of imaging workstations
- Evaluation of viewing conditions
- Image registration, fusion, segmentation, processing
- Quantitative analysis
- Kinetic modeling/computer analysis

9.9 Radiation Oncology Physics Clinical Curriculum

Minimum requirements are described below for completing clinical education in radiation oncology physics. For tests to be conducted, the number of systems to be tested to demonstrate competency is left to the discretion of the program director and the supervising physicist, except for systems where facility accrediting agencies define the minimum number of systems that must be tested for an individual to be considered a qualified medical physicist. In these cases, the minimum number of systems to be tested shall be at least the number specified by the accrediting agency. For topics that define quantities that may be measured or computed, the resident should perform actual measurements or computations to demonstrate familiarity with the quantities and their uses.

- Conduct system calibrations, performance evaluations and quality control, safety and compliance tests, including vendor specifications, under supervision of a qualified physicist
  - Megavoltage photons
  - Electron beams
  - Small field systems (SRS, SBRT)
  - Gamma knife (if available)
  - ^{60}Co (if available)
  - Brachytherapy implants (temporary/permanent)
  - Brachytherapy applicators, LDR, HDR
  - CT simulators
  - SPECT (if available)
  - PET/CT (if available)
  - MRI/CT (if available)
  - Protons (if available)
  - Dose scanning systems
  - In vivo dosimetry systems (e.g. diodes, thermoluminescence dosimeters (TLD), optically stimulated luminescence dosimeters (OSLD)
  - External beam dose measuring systems
  - 3D external beam treatment planning workstations
  - Immobilization devices
  - Organ motion-correction methods
  - Inhomogeneity correction algorithms

  - Image-guided radiation therapy equipment/techniques [e.g., planar MV and kV imagers, cone beam CT, non-radiographic localization (e.g., ultrasound (US), surface camera, radiofrequency (RF) beacon tracking)]
  - US in therapy
  - MRI
  - Total body photon irradiation (TBI)
  - Total skin electron therapy (TSET)
  - Optional: Conduct evaluations and tests of other therapy items (e.g. fluoro simulation, SPECT, PET/CT, MRI/PET, proton accelerators if in clinical use at the educational institution
- Treatment planning and delivery
  - Treatment simulation techniques (e.g. patient positioning, immobilization)
  - Beam properties (photons, electrons)
  - Beam modifiers [e.g., bolus, compensators, wedges (i.e., physical, dynamic, universal)]
  - Step-and-shoot and sliding window IMRT
  - Treatment planning algorithms
  - Monitor unit calculations/influencing factors
  - Monitor unit calculations/configurations (e.g. SSD setup, SAD setup, extended distance setup, off axis calculations, and rotational beams)
  - Tumor localization and International Commission on Radiation Units and Measurements (ICRU) target definitions [e.g. gross tumor volume (GTV), clinical target volume (CTV), planning target volume (PTV)]
  - Normal tissue anatomical contouring
  - 2D and 3D treatment planning
  - IMRT/VMAT planning/optimization/QA
  - Small field planning/optimization/QA
  - Site specific treatment planning – multiple applications
  - Plan evaluation [e.g., dose volume histogram (DVH), conformity index, homogeneity index, biological evaluators]
  - Treatment records
  - Dose limits to sensitive structures
  - Brachytherapy treatment plans and QA
  - Clinical applications of various radiation treatments
- Safety
  - Failure mode effects analysis (FMEA) principles/applications
  - Root cause analysis (RCA) principles/applications
  - Sealed source storage/safety/protection
  - Sealed source inventory/check in/out procedures
  - Sealed source packaging/transportation (e.g., Title 19 CFR)
  - Calibration of sealed sources

- Exposure and contamination surveys
- Radiation signage
- Definition and reporting requirements for medical events
- Radiation safety of personnel during radionuclide therapy
- Patient release criteria following radionuclide therapy and radiation safety for the public
- Safety policies/procedures
- Compliance audits
- Occupational and public dose limits
- National and state regulations
- Radiation exposure to the public
- Site design and shielding (primary and secondary barrier computations)
- Neutron shielding
- Facility radiation surveys
- Personnel dosimetry

- Informatics
  - Beam data acquisition/management
  - Beam modeling
  - Validation of imported images
  - PACS systems and their integration
  - HL7
  - DICOM standards
  - DICOM in radiation therapy (DICOM-RT)
  - Information acquisition from PACS/images
  - Quality/maintenance of imaging workstations
  - Evaluation of viewing conditions
  - Image registration, fusion, segmentation, processing
  - Quantitative analysis
  - Record and verify systems
  - Treatment record design/maintenance
  - IHE – Radiation Oncology (IHE-RO)
  - Network integration/management, and roles of physics and information technology staff
- Therapeutic radiopharmaceutical training should be included in the curriculum of professional doctorate students.