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INTERNATIONAL MEDICAL PHYSICS CERTIFICATION BOARD (IMPCB)
Medical Physics Certification Process – Requirements

Contents

INTRODUCTION

Background:

IMPCB is developing a program that allows:

I. Accreditation of National or Regional Boards that provide certification of Medical Physicists in their jurisdiction
II. Certification of individuals in countries where no National Boards exist.

In the first instance the documentation pertains to the first objective above even though it is recognised that the processes are informed also by the second objective.

In the process of developing the required procedures and guidelines, IMPCB has developed a Model Program (http://www.impcbdb.org/model-program/) to guide the initial set-up of the examination program. The present document is informed by this model.
It is acknowledged, that this is by no means the only model that will be acceptable when evaluating certification Boards for accreditation. The IMPCB recognizes that there are national/regional variations to certification in medical physics based on differences in national/regional legislation and educational traditions. Consequently, IMPCB will give to national and regional certification bodies considerable freedom to decide on the manner in which a given organization seeking IMPCB accreditation conducts the certification process. The present document lays our requirements that IMPCB is considering using for its own examinations and which other certification Boards might like to use.
IMPCB is committed to work on other model programs in the future and/or provide links to other established Boards that use different models.

Accreditation of National or Regional Organisations or certification of individuals will be provided to several specialties of medical physics such as Radiation Oncology Physics; Diagnostic and Interventional Radiological Physics; Nuclear Medicine Physics; Non-ionizing Radiation Physics; Medical Health Physics and Physiological Measurement. Given the current demands and workforce requirements the first three specialties to be considered are Radiation Oncology Physics, Diagnostic and Interventional Radiological Physics and Nuclear Medicine Physics.

Accreditation or certification procedures and the examination of medical physicists through IMPCB consist in general of three parts:

a. Part I is designed to accredit or certify in fundamental aspects of medical physics (General Medical Physics).
b. Part II is designed to accredit or certify in a specialty area of medical physics, (such as Radiation Oncology Physics; Diagnostic and Interventional Radiological Physics; Nuclear Medicine Physics; Non-ionizing Radiation Physics; Medical Health Physics; Physiological Measurements)
c. Part III is designed to accredit or certify fitness to practice clinical medical physics in a designated specialty, (such as Radiation Oncology Physics; Diagnostic and Interventional Radiological Physics; Nuclear Medicine Physics; Non-ionizing Radiation Physics; Medical Health Physics; Physiological Measurement).
d. Parts I and II are assessed in a written examination process while Part III should be conducted as an oral examination. Candidates are expected to pass both Part I and Part II before taking Part III.

It is anticipated that candidates progress through the three parts in sequence. Persons who may qualify only for Part I or Parts I and II may undergo these examinations only. IMPCB can provide a ~~certificate~~ record to candidates who have only passed either Part I or Part I and II on request.

Purpose of the present document

The present document details requirements for certification of individuals and provides one possible model for certification boards established by National or Regional Organisations that apply for accreditation. It is structured into three separate parts pertaining to the three parts of the examination detailed above. The criteria were developed by the Accreditation Committee (AC) of IMPCB through three subcommittees which were dealing with the three parts of the examination. An attempt was made to 'harmonise' the documentation for the three parts. However, given the difference in scope, the difference in examination approach and the differences of other existing relevant documents for the three parts some differences remain.

The IMPCB recognizes that there are national/regional variations to certification in medical physics based on differences in national/legislation and educational traditions, so it gives national and regional certification bodies considerable freedom to decide on the manner in which a given organization seeking IMPCB accreditation conducts the certification process. Thus, IMPCB describes the examination process only in general terms; however, the certification body, in order to gain and maintain IMPCB accreditation, must comply with the examination process for which it obtained accreditation. In assessing an application for accreditation IMPCB will take into consideration IOMP Policy Statements 1 and 2 as well as the local circumstances of the respective certification board.
Individuals will be certified after fulfilling the requirements set out in the present document.

Several important issues are not covered in the present document. They pertain to:

- Requirements for Continuing Professional Development (CPD) and 'Re-certification Requirements
- Consideration of interim or temporary certification
- Consideration of languages other than English
- Provisions for 'grandfathering in' medical physicists who have appropriate credentials
- Guidelines for training and education programmes

Structure of the document

The document is divided into three main parts detailing the requirements for the three parts of the examination process.

Parts I and II are similar in their format and consist of three sections: General considerations and format; Process of examination; and, Subjects covered. The latter is typically listed for the three specialties and divided into 'knowledge' and 'skills' sections. Part III requires a slightly different structure.

The document concludes with a bibliography and some examples for questions in an appendix. For additional examples please also refer to http://www.theabr.org/ic-rp-sample .

PART I:
Requirements for successful completion of Part I of the exam

The following requirements list both undergraduate and postgraduate requirements for candidates who wish to be examined for Part I of the IMPCB certification. The weighting of the different components may vary from country to country depending on the general physics education and other local considerations. It is assumed that the examination will be conducted in a written format.
Commensurate with the nature of the contents of Part I, the requirements distinguish between required knowledge and skills which are detailed in the following sections.

A. General considerations and format

The Part I written examination will be based on questions presented in one or more of the following formats:

i. Multiple choice (MC).
ii. Short answer.
iii. Essay type.
iv. Computational type.
v. Random choice from a large question bank available to candidates ahead of the examination. The examination committee determines the random choice of a predetermined number of questions from the examination booklet.

Multiple choice questions are deemed an appropriate approach to written examinations since they offer reliability, result in objective testing of a candidate's knowledge and skills, are cost-effective, and provide a record of a candidate's performance. They are easy to use in an examination setting; however, they are also time consuming and difficult to compose in an un-ambiguous form. MC questions typically fall into one of the following three MC question types: (a) Traditional MC questions, (b) Multiple True – False MC questions, and (c) Matching MC questions.
MC-based examinations also suffer several disadvantages in contrast to standard written and oral examinations, such as: (a) They contain the correct answer to each question allowing for the choice of the correct answer instead of asking for the formulation of the correct answer, (b) It is possible to stumble upon the correct answer to a MC question through guesswork, (c) They are purely binary and no partial marks are possible. Additional comments on multiple choice questions are provided in appendix 1.

Short answer and essay type (long answer) questions can be defined well and allow the candidate to explain succinctly the salient features of the correct answer. These questions are most suitable for candidates with average or superficial knowledge of the subject, but present problems for candidates with either no knowledge of the subject (zero marks) or extensive knowledge of the subject (full marks but exam time can be lost by delving too deep into the question). Partial marks are possible.

A computational question expects the candidate to calculate the final numerical answer to a specific problem through formulating the general solution based on physical principles involved in the question. Partial marks are possible.

Random choice from a question bank is based on an examination booklet available to candidates prior to the examination. This examination format has been used successfully by the Canadian College of Physicist in Medicine (CCPM) for the past 30 years and the CCPM examination committee updates the booklet every few years. The booklet is quite extensive, covers all the important specialties of medical physics, and serves as an excellent syllabus

for candidates preparing for their specific specialty examination. The questions can be quite elaborate and consist of several sub-questions covering a specific subject with a mixture of many formats such as short and long essays, drawing of schematic diagrams as well as computational problems. Partial marks are possible.

B. Process of examination

The IMPCB recommends that Part I certification examination consist of several components each component containing questions presented in one or more of the formats given above.

National or regional bodies seeking IMPCB accreditation would be expected to decide on the format used for their certification examination and present their proposed examination format to the IMPCB for evaluation. Upon receiving an IMPCB accreditation, the certification body would be obliged to make examination candidates fully aware of the examination format and rules governing marking of the examination papers. The IMPCB recommends that Part I of the IMPCB-accredited certification examination contain several sections, with each section containing questions presented in one or more of the formats listed above.

Typical duration of the Part I IMPCB-accredited written examination will be 4 – 6 hours split into two sittings.

C. Subjects covered in the Part I examination shall be as follows

The subjects are distinguished between undergraduate subjects that would generally be expected as entry requirements into a medical physics program and postgraduate subjects that are specific to a medical physics course. The examination focuses on the postgraduate aspects only.

C1. Undergraduate Pre-requisites

Applicants are expected to have taken the following undergraduate courses to the level necessary for following a postgraduate Masters programme in Medical Physics:

1. Physics
    - Classical and Relativistic Mechanics
    - Electricity and Magnetism
    - Optics
    - Physics of Fluids and Gases
    - Quantum Mechanics
    - Atomic and Nuclear Physics
    - Solid State Physics
    - Thermodynamics and Statistical Physics
    - Measurement, Instrumentation and Signal Processing
    - Computational Physics and Computer Programming

2. Mathematics
    - Applied Linear Algebra
    - Advanced Calculus
    - Complex Variables
    - Differential Equations
    - Numerical methods

Ref: IAEA (2013) TCS56 Postgraduate Medical Physics Academic Programmes

C.2. Biophysics and Basic Biomedical Sciences for Medical Physicists

Knowledge

1. Explain the basic biophysics (e.g., diffusion, osmosis, hemodynamics, biopotentials) and biochemistry necessary for an understanding of human anatomy and physiology.
2. Describe and explain cell structure, function, division and differentiation.
3. Describe using a systems approach the major systems of the human organism and the anatomy and physiology of component organs.
4. Explain the basis of human health, aetiology of disease (in particular carcinogenesis and heritable processes) and trauma.
5. Understand medical terminology and anatomical positions
6. Describe human development, growth and ageing
7. Describe normal anatomy /physiology and trauma / pathology in medical images

Skills

1. Recognize body organs and basic pathologies in medical images.

C.3. Clinical Medical Devices & Protection from Physical Agents

Knowledge

1. Overview of the following areas of physics applied in medicine:
    a. Properties, measurement, instrumentation and interaction with matter of ionizing and non-ionizing radiations,
    b. The principles of ionizing radiation dosimetry
2. Understand relevant international, regional and national legislation, standards and documentation regarding medical devices and risk from associated physical agents (with particular emphasis on radiological devices and ionizing radiation).
3. Describe the principles of protection from physical agents, with emphasis on ionizing radiation, with respect to patient, occupational and public risks.
4. Explain how to protect oneself from physical agents (particularly ionizing radiation)
5. Present an overview of the range of medical devices used in contemporary healthcare including: overview of commonly used medical devices, overview of the various imaging modalities, physiological measurement devices, therapeutic devices.
6. Utilize medical device and DICOM standard terminology.
7. Explain the principles of medical device management including planning, evaluation of clinical needs, preparation of technical specifications for tender purposes, evaluation of tendered devices, procurement, acceptance testing, commissioning, constancy testing, maintenance, decommissioning and service contract management.
8. Explain the principles of service quality development as applied to the use of medical devices and protection from physical agents.
9. Explain the effects of physical agents on the workings of medical devices (e.g. electromagnetic compatibility).
10. Describe procedures for the handling of adverse incidents related to medical devices and physical agents.

Skills

1. Demonstrate basic skill in the use of image processing software (e.g., Basic features of ImageJ).

Notes:

i. The material in this section of the syllabus is meant to lay a generic foundation for a more in-depth application specific to the specialty of Medical Physics chosen by the candidate in Part 2.

ii. The level for ionising radiation physics and dosimetry required is for example that in the first 4 chapters of EB Podgorsak et al. Radiation Oncology Physics: A handbook for teachers and students. IAEA Vienna 2005.
iii. In the case of students with a first degree in Engineering there may be the need to provide for lack of sufficient previous knowledge in quantum mechanics and atomic and nuclear physics.

C.4. Ionizing Radiation Physics and Dosimetry

The topics in this section of the syllabus are an elaboration of what is expected in Section C.3. (1) in the case of ionising radiation:

Basic Radiation Physics
Electron interactions
Photon interactions
Dosimetric principles
Cavity theory
Ionization chamber dosimetry
Film dosimetry
Luminescence dosimetry
Semiconductor dosimetry
Other dosimetry systems
Primary standards
Radiation monitoring instruments
Operation quantities for radiation monitoring
Area survey instrumentation
Individual monitoring instrumentation

The level for ionising radiation physics and dosimetry required is for example that in the first 4 chapters of EB Podgorsak et al. Radiation Oncology Physics: A handbook for teachers and students. IAEA Vienna 2005.

C.5. Research Methods and Statistics for the Physical and Health Sciences and Medical Informatics

Knowledge

1. Review a particular area of research interest in own specialty of medical physics including associated professional, ethical, legal and educational issues.
2. Identify research objectives worthy of study.
3. Apply the main research designs used by physicists involved in biomedical and health sciences research.
4. Appreciate the strengths and limitations of each research design and select a particular research design for a given study.
5. Appreciate the importance of both qualitative and quantitative data in biomedical and health sciences research.
6. Discuss the following topics in Medical Informatics:

   The Organization of Medicine
   The Organization of Health Information
   The Paper-based and Electronic Medical Record
   Hospital Information Systems
   Radiology Information Systems

Systems in Public Health:
- Disease Surveillance
- Chronic Disease Management
- Disease Registries
- Epidemiology
- Health Indicators
- Statistical reporting

eHealth
Information for the Healthcare Professional and Patient.
Issues in Telemedicine:
- Systems for Clinical Decision Making
- Artificial Intelligence in Medicine
- Expert Systems in Medicine
- Bioinformatics and the Genome Project

Measuring Quality and Outcomes
- Standards
- Quality Improvement

The Personal Health Record
Ethical and political issues

Skills

1. Demonstrate use of statistical methods for the analysis of physical, biomedical and health science data.

C.6. Principles of Biomedical Signal Processing for Medical Physics

Knowledge

1. Understand the origin and nature of biomedical signals.
2. Understand and apply the following signal processing principles to biomedical signals:
    a. Signal sampling and quantisation
    b. LTI systems
    c. Frequency domain analysis of signals
    d. Signal filtering
3. Use of appropriate signal processing software

Skills

1. Demonstrate use of basic signal processing software.
2. Demonstrate basic use of MATLAB for signal processing.

Note: There may be the need to provide for lack of sufficient previous knowledge in signal processing and use of Matlab.

C.7. Principles of Biomedical Image Processing for Medical Physics

Knowledge

1. Understand the origin and nature of biomedical images.
2. Understand and apply the following image processing principles to biomedical images:
    a. Generation of digital images,
    b. Intensity transformation in digital images,
    c. Spatial filtering,

d. Frequency domain filtering of images,
e. Image segmentation,
f. Classification of objects of interest in images,
g. Review of image compression techniques,

3. Use appropriate image processing software.

Skills

1. Demonstrate advanced skill in the use of image processing software (e.g., more advanced features of ImageJ).
2. Demonstrate basic use of MATLAB for image processing.

PART II
Requirements for successful completion of Part II of the exam

The following details the postgraduate requirements for candidates who wish to be examined for Part II of the IMPCB certification.
Part II of the IMPCB-accredited certification examination, similarly to Part I, will be given in the format of a written examination. In contrast to Part I that covers the basic aspects of medical physics with which all medical physicists should be familiar regardless of their chosen specialty. Part II concentrates on the candidate's specialty.
Currently IMPCB is focusing only on requirements for Radiation Oncology Medical Physics, Diagnostic and Interventional Radiological Physics and Nuclear Medicine Physics.

A. General considerations and format

The format of the examination process is similar to Part I and the information provided in section I A. applies.

B. Process of the examination

The IMPCB recommends that Part II certification examination consist of several components each component containing questions presented in one of the formats given above. Examples for this are provided in the appendix to the present document.

National or regional bodies seeking IMPCB accreditation would be expected to decide on the format used for their certification examination and present their proposed examination format to the IMPCB for evaluation. Upon receiving an IMPCB accreditation, the certification body would be obliged to make examination candidates fully aware of the examination format and rules governing marking of the examination papers. The IMPCB recommends that Part II of the IMPCB-accredited certification examination contain several sections, each section with questions presented in one or more of the formats listed above.

Typical duration of the Part II IMPCB-accredited written examination will be 4 – 6 hours split into two sittings.

C. Subjects that may be covered in the Part II examination shall be as follows
As for Part I of the examination these are separated in required knowledge and skills.

C.1. RADIATION ONCOLOGY MEDICAL PHYSICS

Knowledge

1. Explain in detail the statutory and institutional requirements for Medical Physics Services and the roles of the Medical Physicist, MPE, RPE and RPO in the establishment and management of systems for effective clinical use of medical devices and radiation protection of patient/staff/public in Radiation Oncology.
2. Interpret qualitatively and quantitatively anatomical and functional 2D/3D images from the various imaging modalities and recognise specific anatomical, functional and pathological features to a level necessary to be able to contribute effectively to the work of the Radiation Oncology team.
3. Describe the perspectives of the patient and other healthcare professionals in the Radiation Oncology team.
4. Explain in detail the design and functioning of medical devices used in Radiation Oncology and the design variables which impact device performance indicators and clinical effectiveness and including:

a. external beam devices: kV therapy devices, cobalt units, medical linear accelerators (linacs) and other systems for MV X-ray / gamma-ray /electron beams (tomotherapy devices, robotic linacs, mobile linacs, intra-operative radiation oncology devices, gamma knife, cyberknife), cyclotrons and synchrotrons (protons and heavier ion beams) and brachytherapy afterloading systems,
b. imaging devices: e.g., EPID, kV, CBCT, in-room CT,
c. treatment planning system software and calculation algorithms.

5. Explain in detail and quantitatively methods for quality control of medical devices in Radiation Oncology, including methods for acceptance testing and commissioning.
6. Explain in detail and quantitatively dose-bioeffect relationships relevant to Radiation Oncology.
7. Describe quantitatively and in detail the process and practical implementation of patient/occupational/public risk assessments, dose optimization and limitation in Radiation Oncology.
8. Discuss ethical issues related to the protection of patients and volunteers in Radiation Oncology research.
9. Apply national/regional laws, regulations, recommendations, acceptance criteria and standards (including IEC standards where relevant) related to device performance and patient/occupational/ public protection in Radiation Oncology.
10. Describe present and envisaged future developments of medical devices and protection from associated ionising radiations in Radiation Oncology.
11. Explain pedagogical methods used for the training of other healthcare professionals in patient and personal protection in Radiation Oncology.
12. Explain in detail and quantitatively:
    a. the physical principles, capabilities and limitations of the different external beam irradiation techniques: 3D conformal, rotational techniques (conformal arcs, conformal dynamic arcs), non-coplanar techniques,
    b. the principles of beam and brachytherapy treatment planning systems and dose calculation and optimization algorithms,
    c. the use of conventional techniques to optimize dose distributions,
    d. recommended national / international absorbed dose measurement protocols based on absorbed dose in water/solid phantoms for photon and electron beams (including brief description/discussion of proton and heavier ion beams),
    e. the various approaches to in-vivo dosimetry for Radiation Oncology beams and discuss choice of appropriate sensors,
    f. the calibration chain for dosimetry sensors used in Radiation Oncology,
    g. theoretical and practical aspects of reference dosimetry for high-energy photons, electrons and brachytherapy sources,
    h. recommended methods for reference air kerma (RAK) determination for brachytherapy sources.

Skills

1. Operate at a basic level selected medical devices used in Radiation Oncology as appropriate to the role of a medical physicist.
2. Use selected methods for quality assurance/control of medical devices in Radiation Oncology (including TPS and manual/remote after-loading systems) and prepare a plan for acceptance testing and commissioning (including acquiring beam data for commissioning the TPS).
3. Use Information and Communication Technologies (ICT) standards and infrastructures applied in Radiation Oncology.
4. Apply quantitatively and in a detailed manner the concepts of justification, optimization and dose limitation with respect to patient / occupational-public protection in Radiation Oncology.

5. Use selected quantitative methods of patient and personal dosimetry and workplace / individual / environmental monitoring in Radiation Oncology and for the establishment of dose delivery prescriptions and dose constraints.
6. Optimize quantitatively patient /occupational protection in high risk practices in Radiation Oncology.
7. Design arrangements for prevention of accidents and incidents, preparedness and response in emergency exposure situations and disposal of any sources/waste in Radiation Oncology.
8. Prepare basic technical specifications for medical device procurement and new installation design in Radiation Oncology.
9. Survey at a basic level Radiation Oncology installations with regard to patient /occupational/public protection including the categorization of areas, classification of workers and any protective apparel and barriers.
10. Use a TPS for patient specific treatment plan generation and optimization and conventional techniques for creating optimized patient specific dose distributions.
11. Operate selected radiation measurement devices/detectors and interpret the results.
12. Select the most appropriate detector for measuring absolute and relative dose distributions in different irradiation conditions for photon and for electron beams,
13. Use the local recommended Code of Practice for the determination of absorbed dose to water from external radiotherapy photon beams.
14. Perform selected dose measurements to support radiation treatment.
15. Perform at a basic level brachytherapy source calibration.
16. Perform constancy checks on ionization chambers and calibrate diode dosimeters.
17. Perform at a basic level in-vivo dosimetry with appropriately chosen protocols and sensors including verification of the delivered dose at single points or planes (e.g., transit dosimetry using portal imaging).
18. Apply International, and national regulations for the transport, handling, storage and use of radioactive sources in Radiation Oncology.
19. Produce a basic plan for the design of new treatment, simulator and, sealed / unsealed source storage rooms with respect to occupational/public protection.
20. Use at a basic level selected immobilization (including stereotactic) devices for the immobilization of patients.
21. Use at a basic level selected conventional and CT/CBCT simulators for patient specific planning and plan verification.
22. Acquire multimodality imaging data and perform image fusion for target volume delineation and planning.
23. Archive, back-up and restore treatment plans.
24. Perform plan optimization and evaluation using uniformity criteria, constraints, DVHs and biological parameters (TCP, NTCP).
25. Use classical dose distribution calculation systems for LDR (e.g., Paris and Manchester systems) and extension to HDR, PDR.
26. Participate at a basic level in the verification of the different steps of treatment: patient positioning, target localisation, and dosimetric verification of the irradiation plan.
27. Perform independent monitor unit calculation for dosimetric verification of treatment plans.

C.2. DIAGNOSTIC AND INTERVENTIONAL RADIOLOGICAL PHYSICS

Knowledge:

1. Explain in detail statutory and institutional requirements for Medical Physics Services and the roles of the Medical Physicist, MPE, RPE and RPO in the establishment and management of systems for effective clinical use of medical devices and radiation protection of patient/staff/public in Diagnostic and Interventional Radiology.

2. Interpret qualitatively and quantitatively anatomical and functional 2D/3D images from the various imaging modalities and recognise specific anatomical, functional and pathological features to a level necessary to be able to contribute effectively to the work of the Diagnostic and Interventional Radiology team.
3. Describe the perspective of the patient and other healthcare professionals in the Diagnostic and Interventional Radiology team.
4. Explain in detail and quantitatively the design and functioning of medical devices used in Diagnostic and Interventional radiology and the design variables which impact device performance indicators and clinical effectiveness.
5. Explain in detail and quantitatively methods for quality assurance of medical devices in Diagnostic and Interventional Radiology, including methods for acceptance testing and commissioning.
6. Explain quantitatively and in detail dose-bioeffect relationships (particularly but not exclusively ionising radiation) relevant to Diagnostic and Interventional Radiology.
7. Describe in detail and quantitatively the process and practical implementation of patient/occupational/public risk assessments, dose optimization (including foetal risk) and limitation in Diagnostic and Interventional Radiology.
8. Discuss in detail ethical issues related to the protection of patients and volunteers from physical agents (particularly but not exclusively ionising radiation) in Diagnostic and Interventional Radiology research.
9. Apply national/regional laws, regulations, recommendations, acceptance criteria and standards (including IEC standards where relevant) related to device performance and patient/occupational/ public protection in Diagnostic and Interventional Radiology.
10. Describe present and envisaged future developments of medical devices and protection from associated physical agents in Diagnostic and Interventional Radiology.
11. Explain pedagogical methods used for the training of other healthcare professionals in patient and personal protection in Diagnostic and Interventional Radiology.
12. For each imaging modality (all variants of x-ray projection imaging, CT, ultrasound and MRI):
    a. explain quantitatively target image quality outcomes relevant to diagnostic effectiveness,
    b. explain quantitatively the physical properties of tissues which the device measures and images, including any variables impacting the value of these properties and associated tissue contrast,
    c. explain in detail image quality assessment criteria and the relationship with device performance indicators (e.g., unsharpness (LSR, PSF, LSF, MTF), noise (noise power spectra, noise propagation in image subtraction, NEQ, DQE), image contrast (CNR) etc,
    d. predict the effect on image quality outcomes, diagnostic accuracy, patient and occupational risk when changing scanning and image reconstruction parameters,
    e. explain in detail the structure of acquisition protocols, pre-processing of image data, mathematics of image reconstruction methods and post-processing of images,
    f. explain the strengths and limitations of the imaging modality and impact on diagnostic efficacy,
    g. define patient/occupational protection related indicators/quantities suitable for ensuring adherence to safety limits and reference levels (e.g., KAP, DLP, D, E, Hp, SAR, MSD) including methods for measurement or calculation,
    h. explain the physical basis of any contraindications in the use of the device and procedures for avoiding adverse events,

i. explain the impact on performance indicators arising from device malfunction, inappropriate protocol and device misuse including any artefacts arising from these and local procedures for reporting such malfunctions,
j. Apply quantitatively the theory of human image perception/observer performance to the optimization of image reading,

Skills:

1. Operate at a basic level selected medical devices used in Diagnostic and Interventional Radiology as appropriate to the role of a medical physicist.
2. Use selected methods for quality assurance/control of medical devices in Diagnostic and Interventional Radiology, and prepare a plan for acceptance testing and commissioning.
3. Use Information and Communication Technologies (ICT) standards and infrastructures applied in Diagnostic and Interventional Radiology.
4. Apply quantitatively and in a detailed manner the concepts of justification, optimization and dose limitation with respect to patient / occupational-public protection from physical agents in Diagnostic and Interventional Radiology.
5. Use selected quantitative methods of patient and personal dosimetry and workplace / individual / environmental monitoring in Diagnostic and Interventional Radiology and for the establishment of diagnostic reference levels and dose constraints.
6. Optimize imaging methods and acquisition parameters to fulfil clinical needs.
7. Optimize quantitatively patient /occupational physical agent protection in high risk practices in Diagnostic and Interventional Radiology.
8. Design arrangements for prevention of accidents and incidents, preparedness and response in emergency exposure situations and disposal of any sources/waste in Diagnostic and Interventional Radiology.
9. Prepare technical specifications for medical device procurement and new installation design in Diagnostic and Interventional Radiology.
10. Survey Diagnostic and Interventional Radiology installations with regard to patient/occupational/public protection from physical agents including the categorization of areas, classification of workers and any protective apparel and barriers.
11. For each imaging modality (x-ray projection imaging, CT, ultrasound and MRI):
    a. apply quantitative image processing techniques to increase the diagnostic value of images,
    b. identify possible causes of device malfunctioning, below target imaging quality and suggest appropriate action,
    c. design protective barriers, accessories and personal protective equipment with regard to occupational/public safety including shielding calculations.

C.3. NUCLEAR MEDICINE MEDICAL PHYSICS

Knowledge

1. Explain in detail statutory and institutional requirements for Medical Physics Services and the roles of the Medical Physicist, MPE, RPE and RPO in the establishment and management of systems for effective clinical use of medical devices and radiation protection of patient/staff/public in Nuclear Medicine.
2. Interpret qualitatively and quantitatively anatomical and functional 2D/3D images from the various imaging modalities and recognise specific anatomical, functional and pathological features to a level necessary to be able to contribute effectively to the work of the Nuclear Medicine team.
3. Describe the perspective of the patient and other healthcare professionals in the Nuclear Medicine team.

4. Explain in detail and quantitatively the design and functioning of medical devices used in Nuclear Medicine and the design variables which impact device performance indicators and clinical effectiveness.
5. Explain in detail and quantitatively methods for quality assurance of medical devices in Nuclear Medicine, including acceptance testing and commissioning.
6. Explain quantitatively and in detail dose-bioeffect relationships relevant to Nuclear Medicine.
7. Describe in detail and quantitatively the process and practical implementation of patient/occupational/public risk assessments, dose optimization (including foetal risk) and limitation in Nuclear Medicine.
8. Discuss in detail ethical issues related to the protection of patients and volunteers from ionising radiation in Nuclear Medicine research.
9. Apply national/regional laws, regulations, recommendations, acceptance criteria and standards (including IEC standards where relevant) related to device performance and patient/occupational/ public protection in Nuclear Medicine.
10. Describe present and envisaged future developments of medical devices and protection from associated ionising radiations in Nuclear Medicine.
11. Explain pedagogical methods used for the training of other healthcare professionals in patient and personal protection in Nuclear Medicine.
12. For each Nuclear Medicine imaging modality (gamma camera, SPECT, PET, hybrid systems):
    a. list and explain target image quality outcomes relevant to diagnostic effectiveness.
    b. explain in detail image quality assessment criteria and the relationship with device performance indicators
    c. predict the effect on image quality, diagnostic accuracy, patient and occupational risk when changing scanning and image reconstruction parameters and radiopharmaceutical.
    d. explain in detail the structure of acquisition protocols, pre-processing of image data, mathematics of image reconstruction methods and post-processing of images. Describe the influence of the reconstruction method and processing parameters used in PET/SPECT (e.g. cut-off frequency, number of iterations, number of subsets, post-filtering type and parameters) on activity measurements.
    e. apply quantitative image processing techniques to increase the diagnostic value of images,
    f. explain the strengths and limitations of the imaging modality and impact on diagnostic efficacy,
    g. define patient/occupational protection related indicators/quantities suitable for ensuring adherence to safety limits and reference levels including methods for measurement or calculation.
    h. explain the physical principles underpinning the methods for the prevention of contamination, protective barriers, accessories and personal protective equipment with regard to occupational/public safety including shielding calculations (including PET systems and cyclotrons),
    i. identify possible causes of device malfunctioning, below target imaging quality and suggest appropriate action in simple situations.
13. Describe and explain in detail the structure of a radiopharmacy with particular reference to radiation protection and quality control of radiopharmaceuticals.
14. Explain in detail the structure, functioning and use of devices required within the context of patient dosimetry e.g., well counters, dose calibrators.
15. Explain the MIRD scheme and the fundamental characteristics and limitations of the formalism, and how this governs its usage.
16. Explain the fundamental limitations of dosimetry at the organ level, for instance in deriving tumour dosimetry, taking into account activity and density heterogeneities.

17. Describe how Dose-Volume-Histograms or isodose curves are calculated and what results should be provided.
18. Describe how diagnostic and therapeutic exposures are managed in the context of Nuclear Medicine, including optimization of dose through prescription of recommended administered activities and protocols.
19. Describe the process and practical implementation of radiation risk assessments in the context of Nuclear Medicine arising from both external and internal sources of exposure.
20. Describe the key considerations when designing a new facility to optimise radiation safety of workers and the public including radionuclide therapy, and radiopharmaceutical production and PET cyclotron.
21. Describe the requirements for regulatory compliance with respect to the management and use of sealed and unsealed radiation sources including security considerations, requirements for storage, shielding, record-keeping, disposal, transportation and audit.
22. Explain the nature and sources of internal and external radiation exposure and the relevant dose limits in Nuclear Medicine for the worker, including extremity doses and dose limits for pregnant and lactating workers, and young workers, and the public, and dose constraints for comforters and carers.

Skills

1. Operate at a basic level selected medical devices used in Nuclear Medicine as appropriate to the role of a medical physicist and adjust equipment settings (e.g., choice of energy windows, collimators, scan duration, count statistics) for optimum activity results.
2. Use selected methods for quality assurance/control of medical devices in diagnostic Nuclear Medicine, and prepare a plan for acceptance testing and commissioning.
3. Use Information and Communication Technologies (ICT) standards and infrastructures applied in Nuclear Medicine.
4. Apply quantitatively and in a detailed manner the concepts of justification, optimization and dose limitation with respect to patient / occupational-public protection from external radiation and internal contamination in Nuclear Medicine.
5. Use selected quantitative methods of patient and personal dosimetry and workplace / individual / environmental monitoring in Nuclear Medicine and for the establishment of recommended activities and dose constraints.
6. Optimize quantitatively patient /occupational physical agent protection in high risk practices in Nuclear Medicine.
7. Design arrangements for prevention of accidents and incidents, preparedness and response in emergency exposure situations and disposal of any sources/waste in Nuclear Medicine.
8. Prepare technical specifications for medical device procurement and new installation design in Nuclear Medicine.
9. Survey at a basic level Nuclear Medicine installations with regard to patient/occupational/ public protection including the prevention of contamination, categorization of areas, classification of workers and any protective apparel and barriers.
10. For each imaging modality (gamma camera, SPECT, PET, hybrid systems):
    a. apply quantitative image processing techniques to increase the diagnostic value of images,
    b. identify possible causes of device malfunctioning, below target imaging quality and suggest appropriate action in simple situations,
    c. design methods for the prevention of contamination, protective barriers, accessories and personal protective equipment with regard to occupational/public safety including shielding calculations.
    d. Extract parametrical information

11. Design optimal dosimetry protocols and calculation procedures for molecular radiotherapies.
12. Perform dosimetric calculations using the MIRD formalism.
13. Determine whole body, organ and effective doses using tools such as OLINDA.

PART III:
Requirements for successful completion of Part III of the exam

The following are suggested Oral Examination processes and Accreditation Requirements as compiled by Accreditation subcommittee III charged with providing guidance on and develop additional requirements for the IMPCB oral examination and accreditation process. The nature of this part of the examination differs from the two previous ones as it does require the examiners and the candidates to meet.

A. General considerations

In developing such requirements, the committee took the following into consideration:

1. Knowing that education and training resources may vary significantly between countries and regions, every effort will be made to provide a credentialing process that is amenable to work with the variety of medical physics environments without compromising the integrity of the board certification objectives.

2. A candidate enrolment in training to prepare for the oral boards, requires the candidate successful completion of Parts I and II of the board training and exams requirements.

3. The Oral exam will mainly test the candidate clinical skills and how to operate as an independent and safe medical physicist.

4. There will be three Oral Exam certification boards covering the three clinical medical physics specialties currently under consideration, namely: Radiation Oncology, Diagnostic and Interventional Radiological, and Nuclear Medicine Medical Physics.

B. Process of examination

There are five categories in this exam, details of which will depend on the sub-speciality (radiation therapy or diagnostic imaging physics), as outlined in C.4

The total exam duration shall be 150 minutes (5 questions per category, 6 minutes per question, total of 30 minutes per category) divided equally between the panels and panel members. The exam can be conducted in one full session or split the exam time into two successive sessions, depending on the exam format.

B.1. The oral exam shall be conducted in one of the following formats:

1. A single examination panel including 3-5 examiners asking competency questions listed in the five categories listed in C.4.

   OR

2. Multiple examination panels like one-on-one (need five examiners) or two-on-one (need 4 examiners). One of the examiners shall be selected as the exam Panels chair. All panels will ask competency questions on all five categories listed in C.4.

3. Examiners in each panel will alternate on asking the questions. They should initially average the scores given per question in each category then discuss the candidate performance and decide on Pass, Fail or Conditioned.

4. A “Conditioned” candidate is only required to repeat the failed category. Candidates failing two or more categories fail the examination and must repeat the entire exam.

5. Pass/Fail per category: one example of a scoring system per question asked is 1-5 with 1 being poor performance and 5 being outstanding performance. The Pass score for each category shall be an average of 3 or above. A score of 2 in one category can be raised to 3 IF the examination panel discussion leads to such a conclusion. The panel can raise only one category from 2 to 3. A 1 average score in any category cannot be raised. All averages will be truncated, i.e. average of 2.9 becomes 2.

C. Specifics:

1. Additional training requirements for a candidate to be eligible for admission to the specialty oral examination means: training in an IMPCB recognized accredited program to obtain specific competences in a specialty area.

2. The duration over which such competences are obtained shall be two years.

3. The IAEA education of medical physicists program, IAEA TCS-37, TCS-47, TCS-50 and the AAPM report 197 and 249 on the same subject shall be considered when outlining the following details:

    a. The type and extent of supervision and guidance needed during the clinical training.

    b. Suggestion of specific implementation steps like the use of didactic courses (class room), tests, research, thesis, residency, paper publication, lab work, specific clinical tasks, specific clinical skills, rotation in other specialties

    c. The extent of each competency in length and depth, and time to be spent to cover each of the competences in the two year program.

4. The list of competences a candidate should obtain for each medical physics specialty includes the following categories. It is expected that each specialty will select and configure the appropriate items in each category that are relevant to that specialty.

    a. Patient-Related Measurements
    Calculation of dose from photon and particle beams and radionuclide sources; radiotherapy treatment planning; physical factors affecting dose (e.g., beam intensity, field size, depth, thickness, filtration, half-life, screens, grids, concentration, etc.); special techniques and devices (e.g., rotational therapy, stereotactic radiosurgery; IMRT; wedge filters, infusion techniques, grids, radiography, fluoroscopy, mammography, tomography, CT, ultrasound, computers and their applications, etc.); preparation of applicators; low-dose-rate (LDR) and high-does-rate (HDR) brachytherapy; in vivo and in-phantom dose measurements; and related subjects.

    b. Image Acquisition, Processing and Display
    Principles of and techniques for image acquisition; image formation; digital imaging; computer-based image reconstruction; methods for image display; image analysis; image processing, image enhancement, fusion and segmentation; image artefacts; modulation transfer function; signal-to-noise

ratio; informatics; picture archiving and communication systems; and related subjects.

c. Calibration, Quality Control and Quality Assurance
Characteristics and use of calibration equipment; measurements of radiation quantity and quality; calibration and evaluation of ionizing and nonionizing radiation sources and installations; calibration and evaluation of measuring, recording, and imaging devices; acceptance testing, commissioning, quality control and quality assurance; and related subjects.

d. Equipment
Principles and properties of radiation generating equipment; radiation sources; radiation receptors; radiation therapy equipment; diagnostic radiological equipment; nuclear medicine equipment; ultrasound equipment; nuclear magnetic resonance equipment; and related subjects.

e. Radiation Protection and Patient Safety
Time, distance and shielding; workload, use and occupancy factors; shielding design for primary, scatter, and leakage radiation; barrier calculation; report preparation; air concentrations of radioactivity; department design; radiation standards and units; radiation protection principles; radiation regulations and requirements; responsibilities of the radiation protection office; radiation surveys in diagnostic radiology, nuclear medicine, and radiation therapy; characteristics of survey equipment; evaluation of radiation hazards; personnel monitoring; and related subjects.

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Appendices:

1.a Notes on multiple choice questions for part I and II of the medical physics written certification examination

Typical examinations based on multiple choice (MC) questions employ several question types to test the breadth and depth of candidate's knowledge and skills. Most frequently multiple choice exam questions fall into one of the following three MC question types:

I. Traditional multiple choice question is referred to as Type A multiple choice question and consists of an item stem and five plausible answers containing one correct answer and four distractors.

II. Multiple True – False multiple choice question is referred to as Type K multiple choice question and tests the candidate's in-depth understanding of several aspects of a concept, process, or procedure.

III. Matching multiple choice question is referred to as Type B multiple choice question and consists of a set of directions, a set of 5 premises, i.e., items to be matched, as well as a set of 4 options associated with the premises.

Many recommendations, some of dubious value, are available on strategies for writing MC examinations. They are often presented in the form of rules of thumb that border on gambling or guesswork and have little or no connection with the examination format and examination material. For example, assuming that the correct answer to a MC question is the answer option with the longest text or with the most scientific-sounding language or simply option B out of five possible options is neither an advisable nor a reliable MC examination strategy. The candidates must understand that the basic requirements for doing well in a MC exam are: (i) having solid background in examination material, (ii) studying hard, (iii) knowing the subject material, and (iv) understanding the subject material.

Some useful strategies for candidates writing MC examinations are:

1. Carefully read all instructions provided with the examination paper.
2. Determine how much time you have for each MC question, leaving some time at the end of exam for verification of answers.
3. Read each MC question carefully and try to anticipate the correct answer before getting distracted by all the possible options. Remember that all distractors generally look plausible, yet among the five options there is only one correct or best answer.
4. For a given MC question read all the possible options before committing yourself to an answer.
5. For MC questions involving calculations verify the decimal points as well as the units of physical quantities.
6. Start the MC examination with questions that you find easy and return to difficult questions once you run out of the easy ones.
7. There is no adequate substitute for knowing the correct answer to a MC question.
8. At the beginning of the examination verify whether or not penalty is assigned for incorrect answers and proceed accordingly.
9. Relying on lucky guesses or mystical "rules of thumb" is not a good MC examination strategy, especially, if a penalty is assigned for incorrect answers.
10. In MC examinations graded without a penalty for incorrect answers, making an educated guess to a difficult question is an acceptable strategy.
11. Be prepared for the MC examination emotionally, physically, as well as intellectually.
12. Keep calm during the examination.

1.b Notes on certification examination models based on random choice questions from an examination booklet.

While the format of multiple choice questions is appropriate for both part I. and part II of the written certification examinations, part II. examination can also be given in a format based on a random choice from a large question bank available to candidates several months prior to the examination session. In this model, the examination committee of the national or regional certification body determines the random choice of a predetermined number of long questions from the examination booklet. The long questions usually consist of a combination of various components, all components dealing with a specific aspect of a broad medical physics subject and falling into one of the following categories: short question, essay type question, or computational question.

Excellent examples of random choice long medical physics questions for several specialties of medical physics as well as examination rules are available from the Canadian College of Physicists in Medicine (CCPM) on-line at: www.ccpm.ca

2. Examples for questions in Part I:

a) Multiple Choice (MC)

I. EXAMPLES OF TRADITIONAL MULTIPLE CHOICE QUESTION:

(circle the appropriate answer A., B., C., D., or E.)

Example 1: [Correct answer is option C. (0.44 MeV) obtained from the Compton graph]

A mono-energetic 1 MeV photon beam has a Compton interaction with a lead absorber. The mean energy transferred to electrons in lead is:

A. 1 MeV

B. 0.511 MeV

C. 0.440 MeV

D. 0.255 MeV

E. negligible

Example 2: [Correct answer is option B. (13.6 eV) obtained from theory of Bohr atom]

The binding energy of a n = 2 electron in a singly ionized helium atom is:

A. 3.4 eV

B. 13.6 eV

C. 27.2 eV

D. 54.4 eV

E. 108.8 eV

Example 3: [Correct answer is option E. based on alpha particle scattering on atomic nuclei, Geiger-Marsden experiment, and Rutherford model of the atom]

Rutherford scattering refers to an interaction between:

A. energetic electron and orbital electron.

B. photon and loosely bound electron.

C. neutron and heavy nucleus.

D. photon and nucleus.

E. alpha particle and heavy nucleus.

Example 4: [Correct answer is option B.]

Fluorescence yield is defined as:

A. number of photons emitted in a bremsstrahlung interaction.

B. number of characteristic photons emitted per vacancy in atomic shell.

C. number of Auger electrons emitted per vacancy in atomic shell.

D. number of photons emitted in gamma decay

E. number of electrons emitted in internal conversion.

Example 5: [Correct answer is option A.]

In an air-filled ionization chamber used in radiation dosimetry:

A. positive ions and negative ions are collected.

B. positrons and electrons are collected.

C. positive ions and electrons are collected.

D. neutral atoms are collected.

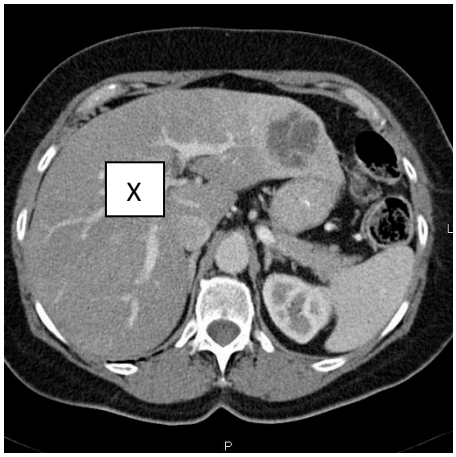
E. characteristic photons and Auger electrons are collected.

Example 6. Which statement best describes the phenomenon of pair production?

A. The electrons and positrons are emitted at 180° to each other.
B. Positrons and antineutrinos are produced when the interactions occur.
C. Photons with energies greater than 1.02 MeV are necessary for the interactions to occur.
D. The total energy of the incident photon is evenly divided between the kinetic energy of the pair of particles.

Example 7. The organ marked X in the image below is the:

A. Liver
B. Spleen
C. Kidney
D. Aorta



Example 8. Which of the following is non-probability sampling?

A. Snowball sampling
B. Random sampling
C. Cluster sampling
D. Stratified sampling

II. EXAMPLES OF TRUE – FALSE MULTIPLE CHOICE QUESTIONS:

(circle the appropriate answer A., B., C., D., or E.)

Example 1: [Correct answer is option E. based on the Bohr theory of the atom]

The validity of the Bohr/Rutherford atomic model is supported by results from the following experiments:

(1) Franck-Hertz experiment.

(2) Davisson-Germer experiment.

(3) Moseley experiment.

(4) absorption and emission spectra of gases.

A. all are correct.

B. (1) and (4) only are correct.

C. (1), (2), and (4) only are correct.

D. (2) and (3) only are correct.

E. (1), (3) and (4) only are correct.

Example 2: [Correct answer is option B. Note: in nuclear pair production no electronic vacancies are produced in atomic shells]

Electronic vacancies are produced in atomic shells through various effects, such as:

(1) photoelectric effect.

(2) nuclear pair production.

(3) electron capture.

(4) Auger effect.

A. all are correct.

B. (1), (3), and (4) only are correct.

C (1) and (2) only are correct.

D. only (1) is correct.

E. (3) and (4) only are correct.

Example 3: [Correct answer is option D. The emitted electron is called an Auger electron and it is emitted with energy of 58 keV].

The K, L, and M energy levels in a hypothetical multi-electron atom are –80 keV, –20 keV and –2 keV, respectively. A vacancy is produced in the K shell and is filled by an electron from the L shell and the L – K transition is followed by an emission of an M shell electron.

(1) Emitted M-shell electron is called an internal conversion electron.

(2) Emitted M-shell electron is called an Auger electron.

(3) Emitted M-shell electron is called a Compton electron.

(4) M-shell electron is emitted with energy of 60 keV.

(5) M-shell electron is emitted with energy of 58 keV.

A. only (1) is correct.

B. (1) and (4) only are correct.

C. (2) and (4) only are correct.

D. (2) and (5) only are correct.

E. only (4) is correct.

III EXAMPLES OF MATCHING MULTIPLE CHOICE QUESTIONS:

[match statements (001), (002), (003), and (004) with appropriate statement labeled A., B., C., D., or E.]

Example 1: [Correct answers are as follows: for (001) – option E.; for (002) – option B.; for (003) – option A.; and for (004) – option D.]

Match each year listed in (001) through (004) with appropriate discovery listed in A. through E.

A. electron by Thomson.

B. natural radioactivity by Becquerel.

C. neutron by Chadwick.

D. nuclear fission by Hahn, Strassmann, Meitner, and Frisch.

E. x rays by Röntgen.

(001)	1895	A.	B.	C.	D.	E.
(002)	1896	A.	B.	C.	D.	E.
(003)	1897	A.	B.	C.	D.	E.
(004)	1939	A.	B.	C.	D.	E.

Example 2: [Correct answers are as follows: for (001) – option D.; for (002) – option A.; for (003) – option C.; and for (004) – option E.]

Match the given interaction listed in (001) through (004) with the appropriate effect listed in A. through E.

A. photoelectric effect.

B. Rutherford scattering.

C. bremsstrahlung.

D. Compton scattering.

E. nuclear pair production.

(001)	photon interaction with free electron.	A.	B.	C.	D.	E.
(002)	photon interaction with bound electron.	A.	B.	C.	D.	E.

(003) electron interaction with nucleus. A. B. C. D. E.

(004) photon interaction with nucleus. A. B. C. D. E.

Example 3: [Correct answers are as follows: for (001) – option A.; for (002) – option D.; for (003) – option B.; and for (004) – option E.]

Match the values listed in (001) through (004) with appropriate parameter listed in A. through E.

A. classical radius of the electron.

B. Compton wavelength of the electron.

C. distance of closest approach for an 8 MeV alpha particle undergoing Rutherford scattering on a gold (A = 197) foil.

D. radius of gold nucleus.

E. radius of hydrogen atom.

(001) 2.82 fm. A. B. C. D. E.

(002) 5.82 fm. A. B. C. D. E.

(003) 0.024 A. B. C. D. E.

(004) 0.53 A. B. C. D. E.

Example 4: [Correct answers are as follows: for (001) – option A.; for (002) – option C.; for (003) – option E.; and for (004) – option B.]

Match the major linac components listed in (001) through (004) with appropriate linac

operational system listed in A. through E. below:

A. injection system.

B. radiofrequency power generation system.

C. beam transport system.

D. acceleration waveguide.

E. beam monitoring system.

(001) electron gun. A. B. C. D. E.

(002) bending magnet. A. B. C. D. E.

(003)	ionization chamber.	A.	B.	C.	D.	E.
(004)	klystron.	A.	B.	C.	D.	E.

b. Short answer:

1. Distinguish between absorbed dose, equivalent dose and effective dose.

2. Explain the sharp discontinuities (absorption edges) in the variation of the photoelectric component of the mass linear attenuation coefficient with incident photon energy.

3. The dead time of a GM counter is 100 □s. Find the true counting rate if the measured counting rate is 12,000 counts per minute.

c. Essay type:

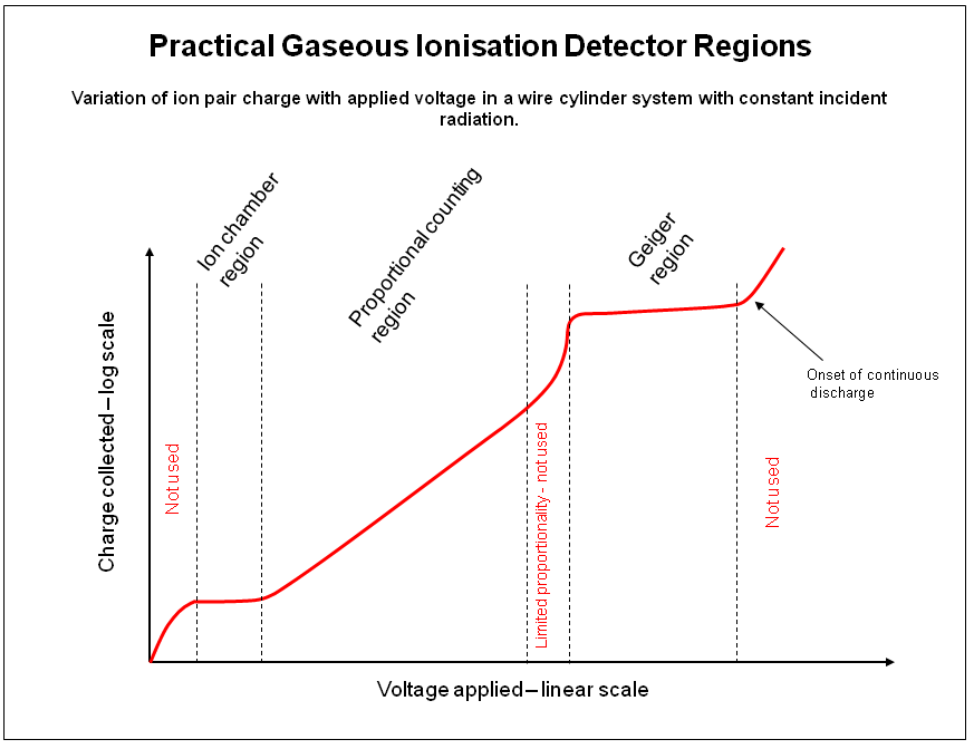
The mission statement of the medical physicist can be stated as follows: “Medical Physicists will contribute to maintaining and improving the quality, safety and cost-effectiveness of healthcare services through patient-oriented activities requiring expert action, involvement or advice regarding the *specification, selection, acceptance testing, commissioning, quality assurance/control and optimised* clinical use of *medical devices* and regarding *patient protection from associated physical agents*; all activities are to be based on current best evidence or own scientific research when the available evidence is not sufficient. The scope includes risks to volunteers in biomedical research, carers and comforters; and occupational/public when impacting patient safety (EC Guidelines on the Medical Physics Expert project)” Explain the above mission statement (in particular the terms in italics) and discuss its application to ONE of the specialties of medical physics i.e., EITHER Diagnostic and Interventional Radiology OR Radiation Oncology OR Nuclear Medicine.

d. Computational type:

1. This question is about gas-filled detectors

   (a) The diagram below shows the variation of output pulse size from a gas-filled ionization detector with variation in the bias voltage. Describe and explain the main regions of the diagram and their use.

   (10)



(b) The dead time of a GM counter is 100 □s. Find the true counting rate if the measured counting rate is 12,000 counts per minute.

(c) An ionization chamber and an electrometer are used to carry out measurements on an electron beam of energy 0.50 MeV. Assuming that the chamber is being used in the saturation region and that all photons produced are stopped within the chamber, calculate the number of incident electrons per second that would produce an electrometer reading of 200 pA given that the ionization energy W of the gas is 35 eV.

2. Calculate the total effective dose for a chest x-ray of a female patient from the following data:

Absorbed dose at the entrance point to the patient's skin (entrance skin absorbed dose) = 500 □Gy

Organ/tissue	Absorbed dose to organ / tissue as percentage of entrance skin absorbed dose (%)
gonads	2
breast	2
bone marrow (red)	1

lung	30
thyroid	1
bone surface	1
stomach	5
liver	10
Remainder tissues	10

The ICRP 103 (2007) tissue weighting factors:

Organ / Tissue	Tissue Weighting Factor
Bone-marrow (red), Colon, Lung, Stomach, Breast, Remainder tissues*	0.12
Gonads	0.08
Bladder, Oesophagus, Liver, Thyroid	0.04
Bone surface, Brain, Salivary glands, Skin	0.01

* Remainder tissues: Adrenals, Extrathoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Small intestine, Spleen, Thymus, Prostate (♂), Uterus/cervix (♀)

3. Distinguish between a Gaussian, lognormal and Poisson distribution commenting on the circumstances of their use in medical physics.

The table below gives the number of background counts x for 50 intervals each of 1 minute duration in a nuclear medicine facility.

Calculate the mean count

Calculate the measured fractional frequencies

For each count value x, calculate the expected fractional frequency assuming a Poisson distribution with the mean calculated above

Draw a scatter diagram with measured fractional frequency on the x-axis and the expected fractional frequency based on the assumption of a Poisson distribution on the y-axis. Comment on the result.

x	Measured frequency (number of intervals with the given count)
0	21
1	18
2	7
3	3

4	1
> & = 5	0
Total	50

4. The following question involves an application of Laplacian filtering in image processing.

(a) Laplacian filtering can be used to detect edges in an image. Specify a Laplacian filter mask and compute the image that results when Laplacian filtering is applied to the image **B** where

$$\mathbf{B} = \begin{pmatrix} 240 & 243 & 220 & 200 & 50 \\ 230 & 223 & 215 & 53 & 45 \\ 228 & 225 & 59 & 54 & 45 \\ 214 & 61 & 54 & 49 & 42 \end{pmatrix}$$

The border pixels of the resulting image can be ignored.

(b) Describe how the performance of Laplacian filtering for edge detection compares to that of first derivative filters such as Prewitt or Sobel operators.

(c) Write a MATLAB program that filters an image **B** using a Laplacian filter. The program must provide plots of the resulting image as well as its centred magnitude and phase spectrum.

2. Examples for questions in Part II:

To come

Comment: Good examples for multiple choice questions: http://www.theabr.org/ic-rp-sample

3. Examples for questions in Part III:

To come