RADIATION PROTECTION

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Status	Organisation	Responsible person(s)
Lead contractor (Chair)	Dept. Radiology. University Complutense of Madrid, UCM, Spain.	Eduardo Guibelalde
Main Partner	European Federation of Organisations for Medical Physics, EFOMP.	Stelios Christofides Carmel J. Caruana Wil Van der Putten Teresa Eudaldo Jacob Geleijns Renato Padovani
Partner/s	Institute of Physics and Engineering in Medicine, IPEM, United Kingdom.	Stephen Evans
	Dept. of Physics. “Enrico Fermi” University of Pisa, Italy.	Alberto del Guerra
	North East Strategic Health Authority, North East Yorkshire and the Humber Quality Assurance Reference Centre, NHS, United Kingdom.	Keith Faulkner Jim Malone John Blenkinsopp Robin Bunton Alex Gillett
	German Society of Medical Physics, DGMP, Germany.	Klemens Zink
Observer/s	World Health Organisation, WHO	Ferid Shannoun
	Working Party on Medical Exposures. Art. 31 Euratom	Eliseo Vañó
Experts who have collaborated in the drafting of some items of the guidelines	M. Bardies (FR), A. Beavis (UK), N. Belcari (IT), E. Breatnach (EI), N. Burton (UK), A. Calzado (ES), M. Chevalier (ES), J. Damilakis (GR), P. P. Dendy (UK), W Enghardt (DE), P. Erba (IT), P François (FR), C Garibaldi (IT), C. Gori (IT), M. Josipovic (DK), I-L. Lamm (SE), M. Lassmann (DE), M. N. Lonsdale (DK), T. Major (HU), O. Morrish (UK), S. Nikoletopoulos (GR), D.R. Olsen (NO), M. Wasilewska-Radwanska (PL), A. Rindjers (BE), J.C. Rosenwald (FR), B. Sattler (USA), W. Waddington (UK), M. Waligorski (PL), R. Wirestam (SE)	

Core team responsible of elaborating present document:

E. Guibelalde
S. Christofides
C. Caruana
S. Evans
W. van der Putten

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List of abbreviations

AAPM	American Association of Physicists in Medicine
BSS	Basic Safety Standard
CPD	Continuing Professional Development
CR	Computed Radiography
CT	Computed Tomography
DDR	Direct Digital Radiography
DGMP	Deutsche Gesellschaft für Medizinische Physik
DR	Diagnostic Radiology
EANM	European Association of Nuclear Medicine
EC	European Commission
ECTS	European Credit Transfer System
EFOMP	European Federation of Organisations for Medical Physics
EHEA	European Higher Education Area
EQF	European Qualification Framework
ESR	European Society of Radiology
ESTRO	European Society for Therapeutic Radiology and Oncology
EU	European Union
FTE	Full Time Equivalent
HTA	Health Technology Assessment
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IMRT	Intensity-Modulated Radiation Therapy
IOMP	International Organisation for Medical Physics
IPEM	Institute of Physics and Engineering in Medicine
IR	Interventional Radiology
ISTISAN	Istituto Superiore di Sanità
KSC	Knowledge, Skills and Competences
LO	Learning Outcome
MED	Medical Exposure Directive
MP	Medical Physicist
MPE	Medical Physics Expert
MPS	Medical Physics Service
NM	Nuclear Medicine
PET	Positron Emission Tomography
QA	Quality Assurance
QMP	Qualified Medical Physicist
R&D	Research & Development
RO	Radiation Oncology
RP	Radiation Protection
RPA	Radiation Protection Adviser
RPE	Radiation Protection Expert
RT	Radiotherapy
R&D	Research and Development
SEFM	Sociedad Española de Física Médica
SPECT	Single-Photon Emission Computed Tomography
UCM	University Complutense of Madrid
UK	United Kingdom
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WHO	World Health Organisation
WTE	Whole-Time-Equivalent

1. Introduction

1.1. Background

Council Directive 97/43/Euratom (Medical Exposures Directive, MED) (European Commission, 1997) defines the Medical Physics Expert (MPE) as "an expert in radiation physics or radiation technology applied to exposure, within the scope of this Directive, whose training and competence to act is recognized by the competent authorities; and who, as appropriate, acts or gives advice on patient dosimetry, on the development and use of complex techniques and equipment, on optimization, on quality assurance, including quality control, and on other matters relating to radiation protection, concerning exposure within the scope of this Directive".

Article 6.3 of MED requires that the MPE be closely involved in radiotherapeutic practices, be available in nuclear medicine practices and be involved, as appropriate, in other radiological practices, for consultation and giving advice on radiation protection issues including optimisation of protection, patient dosimetry, QA, etc.

Article 7.1 of MED requires Member States to ensure that MPEs have adequate theoretical and practical training for the purpose of radiological practices, as well as relevant competence in radiation protection. For this purpose Member States shall ensure that appropriate curricula are established and shall recognise the corresponding diplomas, certificates or formal qualifications.

The European Commission is aware of the present situation in many Member States, where there is an insufficient number of adequately trained MPEs to address the needs of medical procedures applying ionising radiation; this situation is especially startling in today's context of constantly growing use of higher-dose medical equipment (e.g. CT, PET). One possible solution to address this situation and bring forward the effective implementation of EU legislation and initiatives is to support the harmonisation of MPE education in the Member States, aiming at easier mutual recognition and improved mobility of these professionals. For this purpose, in 2010, the European Commission launched a 2-year project on the MPE to provide for improved implementation of the MED and to facilitate the harmonisation of the MPE among the Member States aiming at their cross-border mobility. This project has been supervised by the Working Party on Medical Exposure (WP MED) established by the Group of Experts referred to in Article 31 of the Euratom Treaty.

The project included the following tasks, eventually assigned to the Consortium led by the Complutense University of Madrid[1]:

1. an EU-wide study on the status and the legal and practical arrangements in the Member States regarding the training, education and recognition of the MPE (European Commission Project, 2012),
2. organisation of a European Workshop on the MPE (European Commission Workshop, 2012),

[1] http://lacomplutense.ucm.es/web/medical-physics-expert-project

3. development of a European Guidance document on the MPE containing appropriate recommendations on harmonising education, training and recognition requirements for the MPE in the European Union within the existing EU legislative network.

Soon after the publication of the 2007 Recommendations of the International Commission on Radiological Protection (ICRP, 2007) the EC launched a revision of the Euratom BSS. This also involves a simplification of the Community legislation on radiation protection by integrating five current Euratom Directives[2], the Medical Exposure Directive (MED) included, into a single revised Euratom BSS Directive. The Commission adopted the proposal for revised Euratom BSS in September 2011 and sent it to the European Economic and Social Committee, the European Parliament and the Council of the European Union (European Commission, 2011).

The proposal for council directive defines the roles and responsibilities of services and experts who should be involved in ensuring that technical and practical aspects of radiation protection are managed with a high level of competence. It defines the role of the Radiation Protection Expert (RPE) and the Medical Physics Expert (MPE). The requirements for information, training and education are also addressed and strengthened in a specific title in order to highlight the importance of education and training in radiation protection

1.2. Purpose and scope

The purpose of this European Guidance on Medical Physics Expert (MPE) is to provide for improved implementation of the Medical Exposure Directive and revised BSS provisions related to the MPE and to facilitate the harmonisation of the education and training of medical physicists to MPE level among the Member States aiming at an improvement in cross-border mobility.

This European Guidance contains appropriate recommendations on harmonising education, training and recognition requirements for MPEs in the European Union within the existing EU legislative framework. It makes recommendations for the most appropriate education and training structure, based on the European Higher Education Area and on the European Qualifications Framework for Lifelong Learning (European Parliament and Council, 2008) , to achieve the defined required professional competences. It proposes detailed syllabi for the education and training of MPEs. The Guidance also contains

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- Council Directive 96/29/ Euratom of 13 May 1996, laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation,
- Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionising radiation in relation to medical exposure,
- Council Directive 89/618/Euratom of 27 November 1989 on informing the general public about health protection measures to be applied and steps to be taken in the event of a radiological emergency,
- Council Directive 90/641/Euratom of 4 December 1990 on the operational protection of outside workers exposed to the risk of ionising radiation during their activities in controlled areas,
- Council Directive 2003/122/Euratom of 22 December 2003 on the control of high-activity sealed radioactive sources and orphan sources.

recommendations on the MPE staffing levels necessary to ensure adequate radiation protection of patients and, where appropriate, staff, depending on the size and type of the radiological practice.

2. The Role of the Medical Physics Expert (MPE)

2.1. Role of the MPE in the revised Basic Safety Standard (BSS)

Medical Physics Experts are defined and their roles are specified in the revised BSS. The pertinent articles are:

Article 4: Meaning of Terms

(40) *Medical physics expert* means an individual having the knowledge, training and experience to act or give advice on matters relating to radiation physics applied to medical exposure, whose competence to act is recognised by the competent authorities;

Article 57: Procedures

(3) In medical radiological practices, *a medical physics expert* shall be appropriately involved, the level of involvement being commensurate with the radiological risk posed by the practice. In particular:

> (a) in radiotherapeutic practices other than standardised therapeutic nuclear medicine practices, a medical physics expert shall be closely involved;
> (b) in standardised therapeutical nuclear medicine practices as well as in radiodiagnostic and interventional radiology practices, a medical physics expert shall be involved;
> (c) for other simple radiodiagnostic procedures, a medical physics expert shall be involved, as appropriate, for consultation and advice on matters relating to radiation protection concerning medical exposure.

Article 59: Equipment

(2) Member States shall ensure that:

> (d) acceptance testing, involving the medical physics expert, is carried out before the first use of the equipment for clinical purposes, and performance testing is carried out thereafter on a regular basis, and after any major maintenance procedure.

Article 85: *Medical physics expert*

(1) Within the health care environment, *the medical physics expert* shall, as appropriate, act or give specialist advice on matters relating to radiation physics as applied to medical exposure

(2) Depending on the medical radiological practice, the medical physics expert shall take responsibility for dosimetry, including physical measurements for evaluation of the dose delivered to the patient, give advice on medical radiological equipment, and contribute in particular to the following:

(a) optimisation of the radiation protection of patients and other individuals subjected to medical exposure, including the application and use of diagnostic reference levels;
(b) the definition and performance of quality assurance of the medical radiological equipment;
(c) the preparation of technical specifications for medical radiological equipment and installation design;
(d) the surveillance of the medical radiological installations with regard to radiation protection;
(e) the selection of equipment required to perform radiation protection measurements;
(f) the training of practitioners and other staff in relevant aspects of radiation protection.

Where appropriate, the task of the medical physics expert may be carried out by a medical physics service.

2.2. Mission statement and key activities for MPEs

In order to make the role more understandable to decision makers and management of healthcare institutions and provide direction for stakeholders a mission statement was formulated by the consortium based on the above articles of the revised BSS. The mission statement is the following:

"Medical Physics Experts 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 radiological devices and regarding patient risks from associated ionising radiations[3]; all activities will 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" (Legido-Quigley H, McKee M, Nolte E, Glinos IA, 2008) (European Commission. DG Health and Consumer Protection, 2005) (European Commission, 2007) (CPME, 2005) (Caruana CJ, 2011).

2.3. Areas of medicine involving the MPE

MPEs are traditionally located in departments of diagnostic and interventional radiology (D&IR), nuclear medicine (NM) and radiation oncology/radiotherapy (RO). MPEs also provide services in other areas of medicine ranging from dentistry to cardiology and neurology.

[3] This document concerns the medical use of *ionising* radiation; however, if during the process of justification or at other times, alternatives to the use of ionising radiations are proposed which involve other physical agents (e.g., radio-frequencies and field gradients in magnetic resonance imaging or tumour ablation) there must be an assessment of the relative "efficacy, benefits and risks" (Article 80 of the revised BSS). It is therefore highly recommended that an MPE is appropriately knowledgeable regarding the medical use of such other physical agents to be able to participate fully in such an assessment.

2.4. Key activities of the MPE

The mission of the MPE is expressed in many aspects of medical radiological practice. The consortium has identified and defined the key activities of MPEs. These are shown in Table 1:

Table 1: Definition and elaboration of the Key Activities of MPEs

Key Activity	Main Actions
Scientific problem solving service.	Comprehensive problem solving service involving recognition of less than optimal performance or optimised use of medical radiological devices, identification and elimination of possible causes or misuse, and confirmation that proposed solutions have restored device performance and use to acceptable status. All activities are to be based on current best scientific evidence or own research when the available evidence is not sufficient.
Dosimetry measurements.	Measurement of doses suffered by patients, volunteers in biomedical research, carers, comforters and persons subjected to non-medical imaging exposures; selection, calibration and maintenance of dosimetry related instrumentation; independent checking of dose related quantities provided by dose reporting devices (including software devices); measurement of dose related quantities required as inputs to dose reporting or estimating devices (including software). Measurements to be based on current recommended techniques and protocols.
Patient safety / risk management (including volunteers in biomedical research, carers, comforters and persons subjected to non-medical imaging exposures).	Surveillance of medical radiological devices and evaluation of clinical protocols to ensure the ongoing protection of patients, volunteers in biomedical research, carers, comforters and persons subjected to non-medical imaging exposures from the deleterious effects of ionising radiations in accordance with the latest published evidence or own research when the available evidence is not sufficient. Includes the development of risk assessment protocols.
Occupational and public safety / risk management (*when there is an impact on medical exposure or own safety*)[4].	Surveillance of medical radiological devices and evaluation of clinical protocols with respect to protection of workers and public when impacting the exposure of patients, volunteers in biomedical research, carers, comforters and persons subjected to non-medical imaging exposures or responsibility with respect to own safety. Includes the development of risk assessment protocols in conjunction with the radiation protection expert.
Clinical medical device management.	Specification, selection, acceptance testing, commissioning and quality assurance/ control of medical devices in accordance with the latest published European or International recommendations and the management and supervision of associated programmes. Testing to be based on current recommended techniques and protocols.
Clinical involvement.	Carrying out, participating in and supervising everyday radiation protection and quality control procedures to ensure ongoing effective and optimised use of medical

[4] When the reduction of occupational and public risk would have an impact on medical exposure (e.g., in interventional radiology in which patient and occupational exposure are correlated, or nuclear medicine in which patient, occupational and public risk are correlated) optimisation may require input from both an MPE and a radiation protection expert (or an individual recognised as both). The MPE is also required to have knowledge and skills in occupational radiation protection sufficient to take responsibility for own protection. Competences (which in the EQF framework refer to responsibility) in occupational and public safety / risk management are the responsibility of the Radiation Protection Expert.

	radiological devices and including patient specific optimisation.
Development of service quality and cost-effectiveness.	Leading the introduction of new medical radiological devices into clinical service, the introduction of new medical physics services and participating in the introduction/development of clinical protocols/techniques whilst giving due attention to economic issues.
Expert consultancy.	Provision of expert advice to outside clients (e.g., clinics with no in-house medical physics expertise).
Education of healthcare professionals (including medical physics trainees)	Contributing to quality healthcare professional education through knowledge transfer activities concerning the technical-scientific knowledge, skills and competences supporting the clinically-effective, safe, evidence-based and economical use of medical radiological devices. Participation in the education of medical physics students and organisation of medical physics residency programmes.
Health technology assessment (HTA)	Taking responsibility for the physics component of health technology assessments related to medical radiological devices and /or the medical uses of radioactive substances/sources.
Innovation	Developing new or modifying existing devices (including software) and protocols for the solution of hitherto unresolved clinical problems.

3. Qualification and Curriculum Frameworks for the MPE in Europe

3.1. Introduction

This section presents the qualification and curricular frameworks for the MPE in Europe. Use of the frameworks will facilitate harmonisation of MPE qualifications, education and training leading to improved mobility. All qualification frameworks in Europe should be referred to the European Qualifications Framework (EQF) for lifelong learning (European Parliament and Council, 2008). In the EQF, learning outcomes are expressed as inventories of knowledge, skills and competences (KSC).

3.2. Qualification Framework

The proposed qualification framework (figure 1) is based on the results of the project survey; the various systems of qualifications used in Europe were evaluated and a framework developed based on the best features of each system taking into account the modernisation of scientific careers envisaged in the field. Owing to the rapid expansion of medical device technology and research results, it is not possible for an MPE to be competent in more than one specialty of medical physics covered by the BSS (i.e., diagnostic and interventional radiology, nuclear medicine and radiation oncology/radiotherapy); therefore, the MPE should be independently recognised in each specialty of medical physics. The KSC for the recognition of MPE status by the competent authorities are to be gained initially through learning in an institution of higher education and *structured* clinical training in a residency within an accredited healthcare institution and subsequently developed further through *structured advanced* experience and CPD. Explanatory notes to the qualification framework diagram plus associated rationales are shown in Table 2.

Figure 1: The Qualification Framework for the MPE in Europe

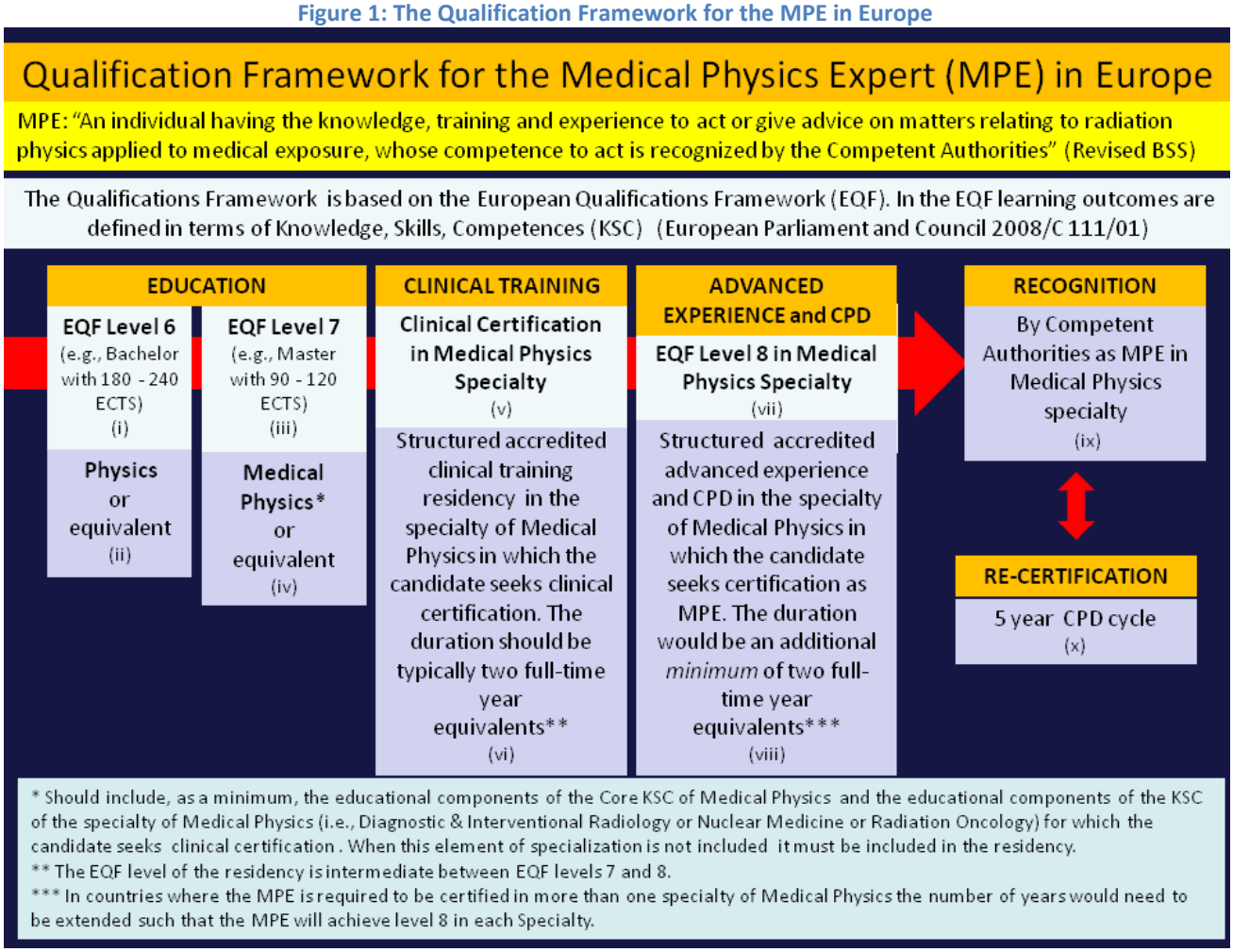


Table 2: Notes to the Qualification Framework diagram

	Note	Rationale
(i)	The fundamental educational level for medical physics professionals is a level 6 in physics and associated mathematics (Eudaldo T, Olsen K, 2010).	Medical physics professionals need to have good foundations in physics and mathematics as Medical Physics is a physical, numeric and exact science.
(ii)	'Equivalent' here meaning EQF level 6 with a high level of physics and mathematics content.	This will make it possible for graduates from other Level 6 programmes which include a high level of physics and mathematics (e.g., engineering, biophysics) to enter the field.
(iii)	The educational entry level for the medical physics professional has been set at EQF level 7. (Eudaldo T, Olsen K, 2010).	At entry level the medical physics professional needs to have highly specialised knowledge, critical awareness of knowledge issues in the field, specialised problem-solving skills, ability to manage work contexts that are complex and ability to review the performance of teams. (European Parliament and Council, 2008) Medical physics professionals require highly specialised knowledge in radiation protection and the medical devices covered by the BSS and specialised problem-solving and troubleshooting skills. The medical physics professional is involved in clinical contexts that may be very complex and reviews the performance of radiation protection and quality control teams in own specialty of medical physics.

(iv)	'Equivalent' here meaning EQF level 7 with a high level of physics and mathematics content *plus* the educational component of the core KSC of medical physics and the educational component of the KSC specific to the specialty of medical physics for which the candidate would be seeking clinical certification (as specified in this document). This additional education can be concurrent with the training.	This will make it possible for candidates with Masters in physics, biophysics, engineering etc to enter the field; however, such candidates need to undertake an *additional* educational programme which includes the educational component of the core KSC of medical physics and the educational component of the KSC specific to the specialty of medical physics for which the candidate would be seeking clinical certification.
(v)	The medical physics professional at entry level is a professional with clinical certification in medical physics at a level intermediate between EQF levels 7 and 8.	The education and training to clinical certification in medical physics is a necessary foundation for further development to MPE EQF Level 8.
(vi)	Structured accredited residency based training for clinically based development of the core KSC of medical physics and the KSC specific to the specialty of medical physics for which the candidate would be seeking clinical certification. The duration of this structured training is typically *two* full-time year equivalents.	The IAEA recommends that clinical certification would need a training period of *two* full-time year equivalents for any one specialty of medical physics (IAEA, 2009) (IAEA, 2010) (IAEA, 2011).
(vii)	The MPE in a given specialty of medical physics is a professional with clinical certification in a specialty of medical physics who has achieved the highest level of expertise in that particular specialty. The medical physics professional through *structured advanced* experience, ongoing extensive CPD and commitment places the KSC at the highest possible level i.e., EQF level 8.	The qualification level for the MPE has been set at EQF Level 8 because the MPE requires knowledge at the most advanced frontier of a field of work and at the interface between fields, the most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research / innovation and to extend / redefine existing professional practice, demonstrate substantial authority, innovation, autonomy, professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work contexts including research (European Parliament and Council, 2008). To carry out activities requiring expert action, involvement or advice with authority and autonomy and which are based on current best evidence (or own scientific research when the available evidence is not sufficient), the MPE requires frontier knowledge in own specialty of medical physics and at the interface between physics and medicine. The MPE requires specialised skills and techniques in radiation protection and comprehensive experience regarding the effective and safe use of the medical devices in own specialty, and the synthesis and evaluation skills required to solve critical problems in service development, research, innovation and the extension and redefinition of existing professional practice.
(viii)	This will mean that to reach MPE status (Level 8) in the specialty area requires a *minimum* total of *four* years equivalent clinical training (2 years equivalent of foundation training in the specialty area to clinical certification and a *further* two years equivalent of *advanced, structured*	It should be emphasised that the *further* 2 years to reach MPE status must consist of *advanced, structured* experience and CPD and not simply CPD designed to maintain competence. The two years minimum of advanced experience must be measured from the time *when the advanced experience commences*. The advanced experience and CPD might not follow immediately the 2 years of basic training if the candidate is not deemed to be sufficiently

	experience and CPD in the specialty).	prepared.
(ix)	A person who is currently recognised as an MPE and is in possession of the core KSC of medical physics and the KSC specific to the specialty for which recognition is sought should be deemed to satisfy the requirements for recognition as an MPE if they are currently on active duty as an MPE and are deemed to have reached level 8.	This is a grand parenting clause.
(x)	This is the requirement for an MPE to maintain recognition.	A five year cycle of re-certification and re-recognition is recommended.

3.3. Curriculum Framework for MPE programmes in Europe

The curriculum framework (figure 2) consists of a structured inventory of KSC underpinning the role, mission and key activities of the MPE. The proposed curriculum framework is intended to be comprehensive yet concise. It is designed to make the commonalities between the various specialties of medical physics apparent and emphasise common terminology - hence facilitating collaboration between MPEs from the different specialties (e.g., in hybrid imaging, radiotherapy planning).

The KSC are classified in two categories: generic skills and subject specific KSC (EC Tuning Project, 2008). Generic skills consist of transferable skills which are expected of all professionals at a particular level of the EQF. In this case the relevant levels are level 7 (EC Tuning Project, 2008) and level 8 (Tuning Physics Subject Area Group, 2007). Subject specific KSC are specific to a profession. These are further classified into sub-categories as determined by the particular profession. The following classification is based on proposals by EFOMP (Christofides S. et al., 2009), and Caruana (Caruana CJ, 2011):

(a) *Medical physics core KSC*: these KSC are expected of all MPEs irrespective of their specialty:

i. KSC for the MPE as *physical scientist*: these are fundamental physics KSC expected of all physical scientists
ii. KSC for the MPE as *healthcare professional*: these are KSC expected of all healthcare professionals
iii. KSC for the MPE as expert on the clinical use of medical radiological devices and protection from associated ionising radiations (and other physical agents as appropriate): these represent medical device and safety KSC common to all specialties of medical physics.

(b) *Medical physics specialties KSC*: these KSC are highly specific to each specialty of medical physics (i.e., diagnostic and interventional radiology or nuclear medicine or radiation oncology/radiotherapy) and therefore cannot be included in the core.

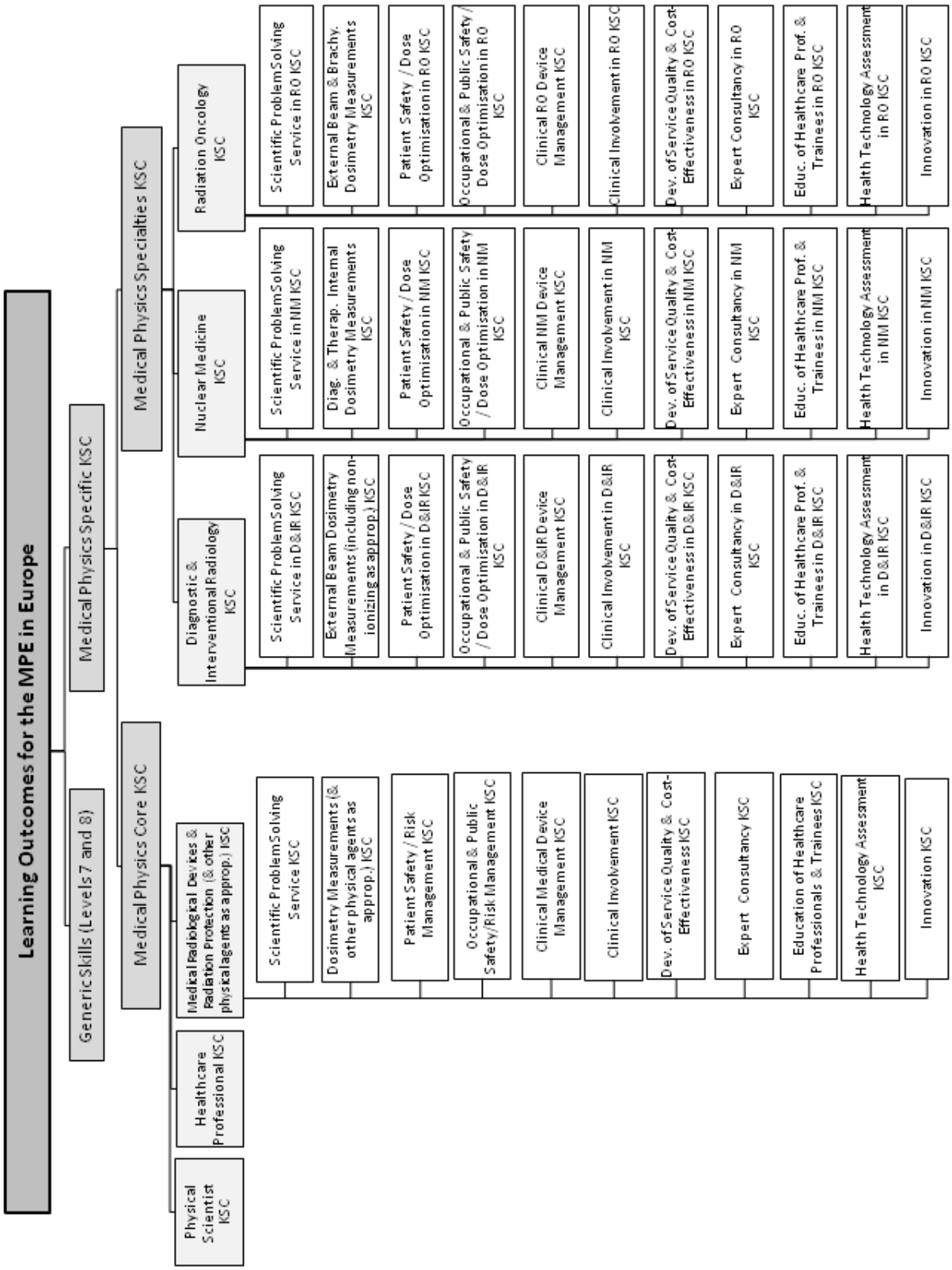
The core KSC inventory and three specialty KSC inventories are given in Appendix A. A candidate seeking recognition by the competent authorities as an MPE in a given specialty of medical physics should reach level 8 in the core KSC and the KSC specific to that particular specialty.

Education and training programmes should be based on the most updated textbooks and reports in the literature such as:

a. Medical physics textbooks such as the handbooks and training manuals produced by the IAEA for physics in radiation oncology, nuclear medicine and diagnostic radiology,
b. International, European and national legislation including all EU directives relevant to radiation protection, medical devices, physical agents and personal protective equipment,
c. Relevant EC reports, recommendations and protocols (e.g., Radiation Protection series http://ec.europa.eu/energy/nuclear/radiation_protection/publications_en.htm),
d. Reports, recommendations and protocols from relevant International organisations (e.g., IAEA, IEC, ICRP, ICRU, WHO, UNSCEAR),
e. Reports, recommendations and protocols from International, European and national medical physics professional bodies (e.g., IOMP, EFOMP, AAPM, IPEM),
f. Reports, recommendations and protocols from European professional and scientific bodies associated with the specific areas of medical physics practice (e.g., ESTRO, ECR, EANM),
g. Reports, recommendations and protocols from relevant national authorities (e.g., HPA (UK), STUK (FI))
h. Primary research reports and review articles from the research literature.

Educational and training methods should take into account modern developments in education and be based on approaches specific to adult learning (e.g., case-based learning).

Figure 2: Curriculum Framework for MPE programmes in Europe



4. Recognition of the MPE

4.1. Introduction and Background

In the definition of the MPE as given both by Directive 97/43/Euratom (European Commission, 1997)and the current version of the draft revised BSS (European Commission, 2011), it states that the "training and competence to act is recognised by the competent authorities". Both these documents specify in various articles the roles and responsibilities of the Competent Authorities. The Directive 97/43/Euratom also defines Competent Authorities as "any authority designated by a Member State".

This definition clearly allows Member States to designate different authorities to deal with specific aspects of Directive 97/43/Euratom, which has led to variation in said designation for the recognition of the MPE in the Member States.

Within the work carried out by this project, the Medical Physics Expert survey (European Commission Workshop, 2012) results identified differing interpretations of the MPE role and of the level of training and competence required for the designation of the MPE across The European Union. This may have arisen because the definition of MPE does not define the word 'expert'.

The survey results also showed that recognition of the MPE is achieved mainly through registration, and that the existing registers recognise the competence of medical physicists but only a few explicitly recognise the competence of the MPE. The survey and professional interviews carried out during the project also showed that there was confusion in many Member States about how professional registration operates, but it was clear that a system in which MPEs need to have some formal accreditation or registration was seen as positive.

The results of the survey and interviews also indicated that there is no harmonisation between Member States in the recognition of the MPE. An additional factor contributing to this and the above discrepancies is that the level of expertise that an MPE should have is mainly dictated by the level and sophistication of the technology available in each Member State. This hinders harmonisation of competence and hence the mobility of the MPE between Member States.

4.2. Recommendations

In order to reach harmonisation in the recognition of the MPE and to allow free mobility of the MPE between the Member States it is recommended that a formal mechanism for recognising an individual's status as an MPE should be put in place in each Member State:

1. Each Member State should consider designating, through a legal instrument, a Competent Authority specifically for the recognition of the MPE.
2. Recognition should be achieved by registration. It is highly recommended that a professional register should be kept by an official authority (e.g. Ministry of Health or Radiation Protection Authority). This task could also be delegated to a professional body such as professional medical physics societies if an official mandate is given.

3. The Competent Authority designated for the recognition of the MPE, should use the Qualifications Framework and KSC of the MPE specified in the present document, for the recognition of the MPE to Level 8 of the EQF.
4. The educational establishments of each Member State involved in medical physics education and training should use the KSCs of the present guidelines.
5. To allow the mobility of the MPE between Member States, it is recommended that the education and training of each MPE be recorded in a document that can be used as proof of the recognised competence.
6. MPE education and training requires formal steps that should be implemented by the competent authorities as recommended in the Qualification and Curriculum Frameworks to be found in this document.
7. It is highly recommended that MPE recognition should be overseen by a joint board of experts from the various stakeholders (i.e. Ministry of Education, Ministry of Health, Radiation Protection Authorities and Professional Societies, as appropriate).

The implementation of the above recommendations will ensure that the recognition of the MPE is harmonised throughout the Member States and will facilitate the mobility of MPEs from one Member State to the other.

5. Medical Physics Expert Staffing Levels in Europe

5.1. Introduction

To ensure adequate protection of the patient it is essential to have the appropriate number of MPEs and supporting staff. This section provides factors that allow the numbers of MPEs required for radiotherapy, radiology (diagnostic and interventional) and nuclear medicine to be calculated. The numbers will relate to the need to assure that the key activities of the MPE derived from Article 59 of the revised BSS be achieved identifying the scope of the MPE from Article 85 of the revised BSS and as identified by this project. The factors presented below should be used by relevant stakeholders such as healthcare decision makers and hospital administrators to identify the number of MPEs required. It is not practicable to provide guidelines for all types and complexity of clinical services (e.g. very specialised procedures, advanced clinical research etc.) and services involved in such activities will therefore have additional MPE requirements.

In deriving the factors use was made of comprehensive literature reviews and data collected from surveys to inform the group of experts associated with this project. In deriving the factors it was noted that the number of standard working hours per year varies between different Member States. For instance, the working hours per year in Ireland are around 1710 compared with around 1650 hours in the UK. However, due to the uncertainties in the factors, it is recommended that no adjustments to the factors be attempted unless staff are specifically employed to work long hours or overtime.

The MPE staffing factors required in radiotherapy, nuclear medicine and radiology are dealt with separately below. To obtain the required staffing levels, the factors have to be multiplied by the number of elements associated with each factor and the results summed together to calculate the total WTE (Whole Time Equivalent) of MPEs and staff in the medical physics service (MPS).

Comparisons using these factors to calculate staffing levels with other data available in the literature were found to be difficult, particularly for nuclear medicine and radiology, due to the differing ways in which staffing numbers can be derived. Only the total medical physics staffing levels in an MPS could be compared since there was no data in the literature found relating specifically to the staffing levels associated with the MPE.

For radiotherapy, the MPE factors were based on the report by IPEM (IPEM 2002). The calculated MPS staffing levels required for a typical radiotherapy department was shown to be in reasonably good agreement with the total staffing levels associated with a range of other literature (ISTISAN, 2002), (Klein EE, 2010), (SEFM, 2002), (IAEA, 2010).

For nuclear medicine and radiology, the MPE factors were based on the survey results and analysis by the relevant Special Interest Groups in IPEM and from expert opinion by the core working group associated with the Guidelines on Medical Physics Expert Project (European Commission Project, 2012).

The MPS staffing levels associated with a range of diagnostic equipment found in typical nuclear medicine and radiology departments appeared to be in reasonably good agreement with the total staffing levels suggested by the AAPM (AAPM, 1991). However, they resulted in greater levels compared to those suggested by some other literature (EFOMP, 1997), (IAEA, 2010), (SSRMP, 2009), (DGMP, 2010). Reasonable agreement with these reports did exist, however, if the factors associated only with just routine work were used.

The factors associated specifically with patient activity for high dose radiology procedures have not normally been assessed separately in other reports. These have been specifically included in the present work because of the increased attention placed on the hazards associated with CT and interventional radiology studies.

A person recognised to act as an MPE may also separately be recognised to act as a Radiation Protection Expert (RPE). However, the staffing requirements associated with the work of an RPE are outside the scope of this project.

5.2. Medical Physics Staffing levels in Radiotherapy

The number of MPEs required for a radiotherapy service will depend on the number and type of equipment and also the number of patients treated (or planned).

The MPE factors are indicated for external beam and brachytherapy and include additional components for special procedures such as IMRT, IGRT and SBRT. The factors also take into account MPE involvement in education, administration, computer support and developmental time.

The number of MPEs required for the radiotherapy departments depends upon: the amount and complexity of used equipment, the number of patients treated and the complexity of treatments together with departmental working arrangements.

The specific MPE tasks taken into account for deriving the WTE factors were: ensuring the accurate calibration of the treatment equipment, having full responsibility for the scientific aspects of the treatment planning process including setting up protocols for standardised treatments, being closely involved in the establishment of all new techniques and with any deviation from standard practice, providing appropriate supervision in order to be closely involved in the treatment, and being involved in various procedures to retain a considerable amount of practical experience.

Other tasks taken into account in deriving the WTE factors for the MPE were: management, development and scientific direction of the MPS, ensuring the accuracy of radiotherapy treatment through scientific supervision of dose, calculation procedures and of ongoing quality control of both equipment and treatment planning, design and implementation of new and innovative treatments, leadership of research and development - especially in the technological basis of radiotherapy, providing advice on appropriate treatment techniques, ensuring radiation safety, management of computer systems, equipment management and procurement, and teaching and training of staff.

An estimate of the number of MPEs required as a function of WTE is shown in Table 3.

Table 3: MPE Staffing Factors for Radiotherapy

Equipment Dependent Factors		**Item**	**MPE WTE**	**MPS WTE**
	Linear Accelerator	Multi-mode	0.6	1.2
	Linear Accelerator	Single-mode	0.2	0.9
	IGRT	Unit	0.1	0.2
	HDR	Unit	0.2	0.4
	CT Simulator	Unit	0.2	0.4
	Planning	System	0.1	0.4
	IMRT	Unit	0.2	0.4
	RT Data/Imaging	Data Network	0.1	0.4
	Simulator	Unit	0.1	0.4
	MLC	Unit	0.05	0.2
	EPID	Unit	0.05	0.2
	Advanced/Brachy TPS	Unit	0.1	0.2
	300 kV	Unit	0.05	0.2
	150 kV	Unit	0.05	0.2
	Low Dose After-loading	Unit	0.1	0.4
	Block Cutter	Unit	0.05	0.2
	Automatic Outlining	Unit	0.05	0.2
	SBRT (new)	Unit	0.2	0.2
	SBRT (established)	Unit	0.1	0.2
Patient Dependent Factors		**No. of Courses**	**MPE WTE**	**MPS WTE**
New patients	External	1000	0.5	1.8
	3D Conformal	100	0.1	0.4
	TBI	100	0.4	0.8

	SBRT	100	0.4	0.8
	IMRT	100	0.4	0.8
	Total Skin Electrons	100	0.4	0.8
New patients	Brachytherapy	100	0.4	0.8
	I-125	100	0.4	0.8
Service Dependent Factors		***Notes***	**MPE WTE**	**MPS WTE**
Radiation Protection Advice		Per centre	0.1	0.1
Quality System		Per centre	0.2	0.5

Notes
a. The minimum number of MPEs should be made at least two in order to cover for absences. Similarly, the number of staff within the other groups must be adequate to cover for absences.
b. The number of staff in the MPS does not include Clinical Engineers/Technologists for equipment support and maintenance since this will depend upon the extent to which maintenance is carried out in-house.

These factors include all elements such as education and training, committees and meetings, administration and management.

At the start of a procurement process it should be noted that a significant time is required to appropriately specify and evaluate the equipment. Acceptance testing and commissioning will require additional staffing to ensure this is undertaken in a timely manner and to ensure the integrity of the process.

National and international trials involving radiotherapy require detailed implementation by an MPE. It is recommended that one WTE MPE is associated with every 8 clinical trials for initial set-up and maintenance of the trials.

An example of the staffing requirements associated with a typical radiotherapy centre is given in Appendix B1.

5.3. Medical Physics Staffing levels in Nuclear Medicine

The core duties and responsibilities of the MPE in a nuclear medicine department are related to: equipment design, defining the technical specification of the equipment, establishing procedures, providing equipment quality control, ensuring adequate image quality is obtained in the most dose efficient way, optimisation of the medical exposures, and the radiological protection of the patient and other service related factors. Other activities include: teaching, staff education, administrative activities, committees, and attending meetings.

The MPE deals with patients in two groups: diagnostic studies and radionuclide therapy. In some departments, radionuclide therapy is undertaken by radiotherapy services.

Additional factors associated with the MPE for service delivery are: ongoing service development, clinical governance, audits, practical radiation protection support, environmental protection, delivery of regulatory compliance, research and development including clinical trials, education and training within service and management of scientific service.

An estimate of the number of MPEs required as a function of WTE is shown in the Table 4.

Table 4: MPE Staffing Factors for Nuclear Medicine

Equipment Dependent Factors	**Item**	**MPE WTE**	**MPS WTE**
Planar Gamma Camera	unit	0.02	0.05
Multi-head SPECT Gamma Camera - 99mTc only	unit	0.05	0.1
Multi-head SPECT CT Gamma Camera – 99mTc only	unit	0.05	0.1
Multi-head SPECT CT Gamma Camera - range of radionuclides	unit	0.1	0.2
PET/CT Camera – new installation	unit	0.3	0.5
PET/CT Camera – established installation	unit	0.1	0.2
Image Processing and Review on first Workstation	unit	0.05	0.1
Image Processing and Review on subsequent Workstations	unit	0.01	0.03
IT support for simple networked systems and workstations	unit	0.02	0.05
IT support for complex networked systems and workstations	unit	0.05	0.1
Automatic Gamma Counter	unit	0.01	0.05
Radionuclide Calibrator	unit	0.01	0.03
DXA Bone Densitometry	unit	0.01	0.05
Patient Dependent Factors	**No. of procedures**	**MPE WTE**	**MPS WTE**
Planar imaging procedures not involving data processing	3 types	0.005	0.01
Imaging procedures involving data processing (e.g. renogram) with quantification or tomographic reconstruction (SPECT or SPECT/CT)	100	0.01	0.02
FDG oncology PET/CT imaging procedures	100	0.02	0.05
Any other PET/CT imaging procedures, without post-processing/quantification	100	0.02	0.05
Outpatient radionuclide therapy (e.g. 131-Iodide for ca. thyrotoxicosis)	50	0.01	0.03
Simple inpatient radionuclide therapy (e.g. 131-Iodide for ca. thyroid)	10	0.005	0.01
Complex radionuclide therapy (e.g. 131-mIBG, 177Lu, 90Y agents, monoclonal antibodies, novel bone pain palliation agents, labelled microspheres)	10	0.07	0.1
Non-imaging, laboratory procedures	100	0.01	0.03
Service Dependent Factors (3 Gamma Camera Department)	***Notes***	**MPE WTE**	**MPS WTE**
Ongoing service development	Per department	0.2	0.3
Clinical Governance including ongoing audits	Per department	0.2	0.3
Practical radiation protection support	Per department	0.05	0.1
Radiation protection role for delivery of regulatory compliance	Per department	0.05	0.1
Environmental protection	Per department	0.05	0.1
Management of scientific service	Per department	0.1	0.1
Research and Training Dependant Factors	***Notes***		
Research and Development including clinical research	Per department	0.2	0.3
Delivering training – internal	Per trainee	0.2	0.3
Education and training within service	Per department	0.04	0.05
Clinical Trials with trial specific QA requirements	Per department	0.04	0.05

Notes

a. *Adequate provision must be made to cover for absences.*
b. *The installation of cyclotrons was considered to be outside the scope of this work and will need to be considered separately.*

An example of the staffing requirements associated with a typical nuclear medicine department is given in Appendix B2.

5.4. Medical Physics Staffing levels in Radiology

The core duties and responsibilities of the MPE associated with a radiology service are related to installation design, defining the technical specification of the equipment, establishing procedures, equipment quality control and the radiological protection of the patient and (often) the workers.

The types of tasks associated with each category of equipment are: QA (on site), QA (analysis and reporting), optimisation: troubleshooting protocols flagged by users, optimisation: troubleshooting protocols flagged by dose audit, dose audit/calculation, acceptance/commissioning of systems, acceptance/commissioning of component e.g. x-ray tube/detector, optimisation: setting up exposure protocols, examination of newly installed equipment for the purposes of ensuring the safety features and warning devices operate correctly and there is sufficient protection provided, together with other support/advice.

Other activities associated with the MPE are: advising on and reviewing clinical research studies, delivering teaching and training, research and development, equipment specification and evaluation, radiation protection for new installations, audit of facilities for regulatory compliance, review of personal monitoring, testing protocol development and management.

An estimate of the number of MPEs required as a function of WTE is shown in Table 5.

Table 5: MPE Staffing Factors for Radiology

Equipment Dependent Factors	Item	MPE WTE	MPS WTE
CT scanners (portable, dual or single source excluding radiotherapy)	unit	0.02	0.07
CT scanners - multi-modal (e.g. PET-CT, SPECT-CT etc.)	unit	0.01	0.03
Digital mammography systems (computed radiography and direct digital)	unit	0.02	0.07
Analogue mammography systems (film based)	unit	0.01	0.04
Fixed radiography systems (number of x-ray generators installed in a room)	unit	0.01	0.03
Portable radiography systems	unit	0.004	0.02
Fixed fluoroscopy systems (single or bi-plane systems)	unit	0.01	0.04
Fixed interventional systems (including cath labs)	unit	0.01	0.04
Mobile C-arms	unit	0.006	0.03
Digital radiography detectors (excluding mammography)	unit	0.006	0.02
Computed radiography readers(excluding mammography)	unit	0.004	0.02
Conventional dental x-ray equipment (intra-oral, panoramic systems)	unit	0.002	0.01
Dental cone-beam CT scanners	unit	0.003	0.02
Bone density scanners (all types including peripheral quantitative CT)	unit	0.001	0.01
Image display device (CRT and LCD primary/reporting monitors)	pairs of monitors	0.0005	0.003
Imaging specimen cabinets (e.g. those used in breast imaging)	unit	0.0005	0.003
MV imagers in radiotherapy	unit	0.02	0.05

kV imagers in radiotherapy (for planar imaging and CBCT)	unit	0.01	0.04
CT scanners used in radiotherapy	unit	0.02	0.06
Radiotherapy simulators	unit	0.01	0.03
Other integrated radiotherapy imaging equipment (e.g. tomotherapy)	unit	0.001	0.005
Patient Dependent Factors	**No. of patients**	**MPE WTE**	**MPS WTE**
Patient dosimetry in Interventional Radiology and Cardiology	1000	0.02	0.04
Estimation of skin dosimetry and follow up (high doses)	50	0.005	0.01
Patient dosimetry in CT	1000	0.01	0.02
Risk assessment in pregnant patients	10	0.005	0.01
Service Dependent Factors	***Notes***	**MPE WTE**	**MPS WTE**
Equipment specification	Per procurement	0.007	0.01
Equipment evaluation	Per procurement	0.01	0.02
Radiation protection advice for new installations	Per installation	0.005	0.01
Audit of facilities for regulatory compliance	Per facility	0.005	0.01
Review of personal monitoring results	Per service	0.05	0.1
Testing protocol development	Per service	0.08	0.2
Research and Training Dependent Factors	***Notes***	**MPE WTE**	**MPS WTE**
Lead MPE assessment for application to Research Ethics Committee	Per project	0.004	0.004
Local MPE review of approved research studies	Per project	0.002	0.002
Delivering training – external	Per attendee	0.0007	0.001
Delivering training – internal	Per trainee	0.2	0.3
Delivering academic teaching	Per attendee	0.003	0.004
Carrying out research lead by your service	Per project	0.08	0.2
Support provided to research projects external to your service	Per project	0.02	0.03

Notes

a. *Adequate provision must be made to cover for absences.*

An example of the staffing requirements associated with a typical diagnostic radiology department is given in Appendix B3.

5.5. Conclusions and Recommendations

Recommended staffing factors have been set for estimating the number of MPEs required for a given medical physics service involving the use of ionising radiations for radiotherapy, nuclear medicine and diagnostic x-ray services. The factors are both equipment and task/patient based.

They provide methods that can be used by departmental managers and administrators to obtain the number of MPEs that should be employed to provide a high quality, safe, efficient and productive service with the innovation necessary for the introduction of new equipment and techniques. Additional elements for research and development have been identified separately but the amount of staff

employed within pure research will be mainly a function of additional external funding and is not within the scope of this report.

For radiotherapy, the nature of the involvement of medical physics will require the presence of MPEs, recognised in the relevant specialties, to be on site for at least part of the standard working day and available for consultation during extended working days and weekends. It is expected that at least two MPEs will be required to provide this assurance. Outside normal working hours and for satellite sites, an MPE must be available for consultations at all times the service is operating, and if circumstances require, can be on-site quickly to take adequate measures to assure the radiation protection of the patient.

For nuclear medicine and radiology, the nature of this involvement will require the presence of MPEs, recognised in the relevant specialties, to carry out measures related to radiation protection of the patient and quality assurance of the equipment, to optimise practices, to respond appropriately to individual patient-specific issues, to assist in matters of organisation and to be available for consultations at all other times the service is operating.

The number of MPEs required will depend upon the number of equipment and their complexity together with the amount of patient activity.

All MPEs should have time allocated for CPD some of which may take the form of in-house training, and service development projects to meet the needs of the department.

When the WTE is not a whole number, an MPE may be employed to carry out other duties commensurate with their experience. Alternatively, an MPE may be employed part time or form partnerships with other services.

In an MPS there should be one or more MPEs within each specialty who assumes responsibility for the service provision in that specialty. The MPS should employ other medical physics staff to support the work of the MPE. The skill-mix for the support staff should be decided in consultation between the employer and the MPE. Without the appropriate level of experience and supervision of staff within an MPS there is an increased risk of failure in patient safety standards. Inadequate staff resources may directly impact on the quantity and quality of the service provided to patients. Where there is a shortfall of staff compared to these guidelines there is a potential for under usage of expensive equipment, non-optimal exposures, patients not receiving state of the art care and an increase in patient overexposures. For all MPSs some form of management and administration will be required. The amount required will depend upon the size and complexity of the service and may contribute a further one WTE per service.

For staff working at multiple locations, an additional WTE component may need to be factored into the calculated staffing levels to account for the time it takes staff to travel to the different locations.

Healthcare decision makers and hospital administrators should audit the staffing levels at intervals of no more than two years and ensure reasonable compliance with this guidance is achieved.

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APPENDIX A: Inventory of Learning Outcomes for the MPE in Europe

Table A. 1: Generic Skills

Generic Skills Required at Level 7 (MP Level and MPE Level)	Generic Skills Required at Level 8 (MPE Level only)
Instrumental 1. Retrieve information from different sources. 2. Analyze and synthesize. 3. Solve problems. 4. Use general productivity software. 5. Organize, plan and manage one's workload. 6. Communicate effectively (orally and in writing) in two European languages. 7. Take decisions in a timely manner.	1. Demonstrate a systematic understanding of a field of study and mastery of the skills and methods of research associated with that field. 2. Find, select and define problems of interest. 3. Reflect upon the questions raised, the types of knowledge produced and the impact their knowledge might have on society 4. Organize a number of relevant facts in a coherent framework, which allows the development of an "economy of knowledge, based on experimental facts and overarching ideas". 5. Apply the acquired knowledge and understanding in different contexts and to innovate. 6. Conceive, design, implement and adapt a substantial process of research with integrity. 7. Make a contribution through original research that extends the frontier of knowledge some of which merits national or international refereed publication. 8. Demonstrate critical analysis, evaluation and synthesis of new and complex ideas. 9. Communicate with peers, the larger professional community and with society in general about their areas of expertise. 10. Promote within professional contexts, technological, social or cultural advancement in a knowledge based society.
Interpersonal 1. Communicate orally and in writing with both experts in the field and non-experts. 2. Respect diversity and multiculturalism. 3. Exhibit aptitude to work in an international context. 4. Demonstrate ongoing ethical commitment. 5. Work productively in both mono-disciplinary and multi-disciplinary teams. 6. Criticise constructively and accept constructive criticism.	
Systemic 1. Generate new ideas (creativity). 2. Design and manage projects. 3. Adapt to new situations. 4. Learn autonomously and take responsibility for one's own learning. 5. Reflect and evaluate one's own practice and learning. 6. Apply research skills and use published evidence to develop and improve the quality of one's own practice. 7. Work within the scope of one's practice and abilities. 8. Seek advice when a task is outside one's ability. 9. Be entrepreneurial. 10. Display a will to succeed. 11. Display leadership and initiative. 12. Assume responsibility for one's own actions.	

Table A. 2: KSC for the MPE as Physical Scientist

Knowledge (facts, principles, theories, practices)	**Skills** (cognitive and practical)	**Competence** **(responsibility and autonomy)**
K1. List the fundamental quantities and dimensions of physics, including use in checking consistency of equations. K2. List the common fundamental and derived constants of physics. K3. List the base and derived SI units. K4. List and describe the properties of the common fundamental particles, including mass, charge and spin. Particle-antiparticle annihilation (in depth treatment of positron-electron annihilation). K5. List the various forms of energy and types of forces in nature and the properties of their carrier particles. K6. Explain the basic principles of quantum theory and relativistic mass-energy (sufficient for medical physics). K7. Describe the structure of the atom and nucleus and define the terms 'isotope' and 'isobar'. K8. Explain nuclear and electron energy levels, ionization, nuclear isomers and the auger effect. K9. Describe and explain the structure of the periodic table and chart of the nuclides. K10. List and describe the various forms of chemical bonding. K11. Explain the forms of spectroscopy / spectrometry (including MRS and EPR) K12. Describe the band theory of solids with particular emphasis on semiconductors. K13. Discuss nuclear stability, list and describe quantitatively the various common modes of radioactive decay (alpha, beta, positron decay, gamma, isomeric transition, electron capture, internal conversion), explain decay schemes, gamma and beta spectra, use of decay and secular / transient equilibrium equations. K14. List and describe the main types of nuclear reactions including phototransmutation. K15. Describe and explain processes for the production of medical radionuclides using cyclotrons, reactors and generators, including quantities of generated activities in thin and thick targets. K16. List and describe the basic characteristics of common electronic components and integrated circuits. K17. Describe the general design of a measuring instrument K18. Utilize the ISO international vocabulary of metrology (VIM). K19. List and explain the specifications of measuring instruments including accuracy, SNR, precision, range of measurement, resolution, reliability (repeatability, reproducibility, consistency, stability, ruggedness), sensitivity, specificity, linearity, response time. K20. Explain the meaning of calibration (relative, absolute, calibration coefficients...), traceability and primary / secondary standards. K21. Describe in detail and quantitatively the main types of sensors, their mode of action and response: mechanical (position, velocity, force, pressure, sound and ultrasound), temperature, electric and magnetic fields, voltage, ionizing electromagnetic radiation (include gas-filled (including cavity theory, Bragg-Gray principle, conversion of charge to absorbed dose), semiconductor, scintillation-optical systems (solids and liquids), storage TL phosphor systems, optically stimulated luminescence (OSL), films (including radiochromic), non-ionizing electromagnetic radiation, ionizing particles, chemical and biochemical. K22. Explain quantitatively the following characteristics of ionizing radiation sensors / detectors: pulse height spectrum and energy resolution, counting curves and plateau, detection efficiency and energy response, dead time, detection threshold and temporal resolution. K23. Describe and explain in detail equipment used for gamma and x-ray spectrometry. K24. Explain the electronic modules used in radiation sensing systems. K25. Explain how signals are classified (dimensionality, periodicity, continuity, determinism), acquired, converted to digital form and processed (signals function of time, spatial coordinates or both, include both continuous and pulse signals). K26. Describe and explain at a basic level the following: temporal / frequency domain representation of signals, Fourier transform, statistical description of signals, power spectral density, autocorrelation function, sample (discrete) signals,	S1. Manage the acquisition, editing, analysis, interpretation, presentation, and reporting of measurement data. S2. Communicate clearly results to peers (in the form of notes, resumes, reports, poster, article, oral presentation) at local and international meetings and for research journals. S3. Use statistical techniques / tests and software to analyse measurement data and manage associated uncertainties. S4. Able to analyze critically the international literature within a given area of research S5. Design and evaluate systems for the rigorous and safe conduct of physical measurements and experiments.	C1. Manage the conduct of experimental work autonomously and in a safe manner. C2. Assume responsibility to autonomously: - List a set of research objectives worthy of attention and which are realizable given the available resources. - Write a literature review article concerning the area of interest. - Realize the research objectives by integrating and applying knowledge and skills. - Communicate clearly results to peers (in the form of notes, resumes, reports, poster, journal/conference article, oral presentation) at local and international meetings and for research journals. - Defend results in front of peers. C3. Organise networks for research and development within own scientific community. C4. Assume responsibility for ethical issues associated with research.

delta function and its Fourier transform, Fourier transform of discrete signal (DFT), the FFT, the effect of finite sample intervals, linear processors, impulse response, convolution integral and theorem, various types of filters used in the processing of medical signals. K27. Describe and explain the main electronic modules used to acquire and process signals from ionising and non-ionising radiation sensors (e.g., amplification, pulse shaping, discriminators, pulse height analyzers, counters, coincidence and veto logic gates). K28. Describe the various ways in which signals which are functions of spatial coordinates can be spatially encoded, decoded and displayed. K29. Discuss the advantages and disadvantages of imaging as a means of displaying spatially dependent signals and variables. K30. Explain the way that signals and images are processed to facilitate the extraction of information (continuous & pulse signals). K31. Explain the difference between lossy/ lossless compression of digital images and describe standard compression schemes. K32. Explain the function, procedures and types of documentation produced by International and European standard setting bodies for electro-technical devices. K33. List and describe quantitatively and in detail the properties and means of production and control of ionising and non-ionising electromagnetic radiations, particulate radiation beams and ultrasound including the characteristics of the radiation fields in both air and tissue. K34. Distinguish between ionising radiations with a direct or indirect mechanism for energy transfer and deposition. K35. List and describe quantitatively and in detail the interactions of ionising and non-ionising electromagnetic radiations, particulate radiation, ultrasound, static electric and magnetic fields with inanimate and animate matter (including energy absorption/deposition), including: - electron-orbital electron and electron-nucleus interactions, stopping power, mass scattering power. - photon beam attenuation, photoelectric absorption, Rayleigh and Compton scatter, pair-production. and the variation of cross-section/angular distribution of scattered photons/secondary electrons with photon energy, atomic number and density of the attenuating materials, kerma, attenuation coefficients. - proton and heavier ion interactions: stopping power, Bethe formula, Bragg peak, range, straggle. - neutron interactions: including activation. - ultrasound interactions: absorption, reflection, scatter, acoustic impedance, non-linear propagation. - static electric / magnetic and RF fields. - optical radiation including laser. K36. Explain the meaning of build-up. K37. Describe the properties of neutron beams including moderation and attenuation. K38. Discuss the characteristics of the common statistical distributions: normal, log-normal, t, Poisson. K39. List and describe the various forms of uncertainties in the measurement of data and their treatment (GUM approach). K40. Explain the concept of bias in measurement and ways to avoid it. K41. Explain how quantitative statistical techniques are used to describe and handle data, including the calculation of confidence intervals, combined uncertainties, correlation, regression and hypothesis testing including the influence of sample size. K42. Describe the statistics of nuclear decay, photon / particle interactions with matter and ionizing radiation measurement. K43. Explain the basic principles of modelling and simulation including statistical modelling based on Monte-Carlo techniques. K44. Discuss the principles and processes of physics research.		

Table A. 3: KSC for the MPE as a Healthcare Professional

Knowledge (facts, principles, theories, practices)	**Skills** **(cognitive and practical)**	**Competence** **(responsibility and autonomy)**
K1. List and explain the functions of healthcare organizations, the way healthcare is organized (internationally, nationally and locally), principles of clinical governance and developments in healthcare policy. K2. Describe the function of the various healthcare entities (including own institution) within the local healthcare organization and their role within the national framework for healthcare provision. K3. Explain the role of Medical Physics Services in healthcare. K4. Utilise accurate medical terminology in communication with other healthcare professionals. K5. Explain those sections of the human biological sciences (anatomy, physiology, pathology, cellular and biomolecular science, radiological anatomy) relevant to own area of medical physics practice. K6. Explain and discuss the concepts of quality, safety / risk and cost-effectiveness as applied to healthcare. K7. Explain and discuss ethical and legal issues in healthcare relevant to the scope of the profession (e.g., research ethics, data protection, privacy, dignity, ethical governance). K8. Discuss those aspects of healthcare psychology and sociology relevant to the profession. K9. Explain the technological infrastructure required for quality service within own future area of medical physics. Describe and explain the European and national legal frameworks, regulations, guidelines and codes-of-practice impacting the role of the MPE. K10. Explain briefly European and national legal frameworks, regulations, guidelines and codes-of-practice impacting the practice of other professions with whom the MPE interacts. K11. Discuss the development of the MPE profession in both the local and European context. K12. Discuss the principles of healthcare management. K13. Discuss the principles of epidemiology. K14. Discuss the principles and processes of quantitative and qualitative research involving human subjects.	S1. Communicate effectively clinical information, advice, instruction and professional opinion to patients, colleagues, other healthcare professionals, support staff, service users, relatives, carers, comforters and volunteers in medical research within own area of medical physics practice using appropriate terminology. S2. Establish the necessary communication links and relations with other healthcare professionals and organizational units related to own area of medical physics practice. S3. Recognize and respond appropriately to own, patients' and relatives' emotional responses. S4. Acquire EU Directives, national regulations and guidelines and recommendations from national and international organizations related to own area of medical physics. S5. Make best use of available resources in the interest of patients and society.	C1. Practise responsibly within the legal, regulatory and ethical boundaries of the profession. C2. Maintain fitness to practise in an autonomous manner. C3. Collaborate with other healthcare professionals, support staff and service users, relatives, carers and comforters within own area of medical physics practice. C4. Take responsibility for the management of own workload to ensure effective and efficient input to the work of the healthcare team in own area of medical physics practice. C5. Organise the various aspects of the routine service within own area of medical physics practice. C6. Work responsibly within national / local professional codes of practice and own competence limitations. C7. Take responsibility for appropriate behaviour towards colleagues, patients and relatives as stipulated by organizational policies and national legislation. C8. Take responsibility for own input within mono-disciplinary and multi-disciplinary research teams. C9. Take responsibility for making the best use of available resources to provide optimum healthcare to patients and members of society. C10. Assume responsibility for timely action (within own limitations) to prevent and respond to adverse events. C11. Assume responsibility to ensure that all activities are based on current best evidence or own scientific research when the available evidence is not sufficient. C12. Take responsibility to maintain one's knowledge and skills current through an appropriate continuous professional development programme. C13. Facilitate learning of peers, other healthcare professionals, students (including Medical Physics trainees). C14. Take responsibility for the development of effective, safe and efficient teams (including multi-professional teams) in own area of medical physics practice. C15. Show respect towards the ethical, religious and cultural perspectives of patients. C16. Adhere to the Code of Ethics of the profession. C17. Assume responsibility for ethical issues associated with research involving human subjects.

Table A. 4: KSC for the MPE as Expert in Clinical Medical Radiological Devices & Radiation Protection (and other physical agents as approp.)

	Knowledge (facts, principles, theories, practices)	**Skills** **(cognitive and practical)**	**Competence** **(responsibility and autonomy)**
Scientific Problem Solving Service	K1. List statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Scientific Problem Solving Service. K2. Use physics, concepts, principles and theories to describe in detail and quantitatively, the structure, functioning, characteristics, strengths and limitations and use of the medical devices used in own area of medical physics. K3. Describe in detail and quantitatively the properties of ionising radiations (electromagnetic,electrons, ions, neutrons) and other physical agents (e.g., electrical energy, static electric / magnetic fields, non -ionising electromagnetic radiation, vibration, sound and ultrasound, heat energy and laser) to be found in the healthcare environment. K4. Explain quantitatively using biological models the beneficial and/or adverse biological effects of ionizing radiations and the various physical agents associated with medical devices, the factors influencing the magnitude of the biological effect and the way these can be manipulated to improve clinical outcomes e.g., in the case of ionizing radiation this would include radiobiological models, radiation epidemiology, mutagenesis, carcinogenesis (including leukaemogenesis), genetic effects on offspring from irradiation of gametes, teratogenic effects on the conceptus, skin effects, eye cataracts, cell survival curves, linear-quadratic model, absorbed dose, type of radiation (RBE, radiation weighting factor), tissue radiosensitivity (LET, RBE, tissue weighting factor), dose rate, presence of radiosensitisers, oxygen and radioprotectors, age, dose-effect relationships. K5. Explain the application of the terms deterministic/stochastic, early/late and teratogenic/genetic effects in relation to each physical agent. K6. List the main sources of evidence from within the general physics, medical physics and healthcare literature (e.g., the Cochrane Collaboration) essential for the carrying out of a systematic survey in own area of medical physics practice.	S1. Apply the general concepts, principles, theories and practices of physics to the solution of clinical problems concerning the optimised clinical use of medical devices and safety / risk management with respect to associated ionizing radiations and other physical agents. S2. Use the general concepts, principles, theories and practices of physics to analyze the research literature concerning the optimised use of medical devices and safety / risk management with respect to ionizing radiations and other associated physical agents. S3. Use physics research skills to develop the experimental evidence base for the optimal use of medical devices and safety / risk management from associated ionizing radiations and physical agents when present evidence is insufficient. S4. Use the general concepts, principles, theories and practices of physics to ensure effective and safe practice in own area of medical physics practice. S5. Use the general concepts, principles, theories and practices of physics for the transfer of new medical devices and associated techniques to the clinical environment in an effective, safe and economical manner. S6. Design quantitative clinical and biomedical studies based on rigorous statistical design. S7. Use statistical packages for the analysis of clinical and biomedical data.	C1. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Scientific Problem Solving Service. C2. Take responsibility for the setting-up and organization of a Medical Physics Service in own area of medical physics practice. C3. Take responsibility for applying the general concepts, principles, theories and practices of physics to the solution of clinical problems concerning the optimal use of medical devices and management of risk from associated ionizing radiations and other physical agents in own area of medical physics practice. C4. Take responsibility for using the general concepts, principles, theories and practices of physics to analyze the research literature concerning the optimal use of medical devices and management of risk from associated ionizing radiations and other physical agents and to transfer relevant published research results to the clinical environment in own area of medical physics practice. C5. Take responsibility to use the general concepts, principles, theories and practices of physics for the selection and insertion of new medical devices within own area of medical physics practice and to facilitate the effective, safe and economical use of said devices. C6. Take responsibility to use physics research skills to develop the evidence base for the optimal use of medical devices in own area of medical physics practice when present evidence is insufficient.

Dosimetry Measurements (and other physical agents as approp.)	K7. List and explain the statutory and institutional requirements of Medical Physics Services with respect to Dosimetry Measurements (including non-ionising radiations as appropriate). K8. Define and explain the dosimetric quantities (including units and inter-relationships) used to assess beneficial or adverse biological effects for ionizing radiations and the various types of physical agents in own area of medical physics practice (*use ICRU 85, 2011 definitions for ionizing radiation*). K9. Define patient dosimetric quantities for each clinical procedure in own area of medical physics practice and explain the method used for their measurement / calculation. K10. Explain the relationship between the various dosimetric quantities used (e.g., between energy fluence, kerma and absorbed dose for photon beams including the concept of charged particle equilibrium). K11. Define operational quantities (including units and inter-relationships) used in personal dosimetry e.g., ambient H*(10), directional H'(0.07, angle) and personal dose equivalents i.e., depth dose equivalent $H_p(10)$ and skin dose equivalent $H_p(0.07)$ for external photon radiation and explain the method used for their measurement / calculation. K12. Describe and explain in detail and quantitatively the structure, operation and advantages / disadvantages of the various types of patient and personal dosimeters and area monitors available for the various types of ionising and non-ionising radiation including criteria for selection (e.g., accuracy, precision, uncertainties, linearity, any dose rate / energy / directional dependence, spatial resolution, physical size, read out convenience and convenience of use), management, calibration, traceability (including international traceability framework) and user protocols (in the case of ionizing radiation dosimetry include cavity theory). K13. Explain the principles of biological monitoring / dosimetry.	S8. Select and use instruments for dosimetric quantities for the various types of ionizing radiations and other physical agents for patients, workers and public in own area of medical physics practice. S9. Develop rigorous dosimetry protocols in own area of medical physics practice. S10. Interpret the results of dosimetry measurements. S11. Maintain calibration of dosimetry instruments. S12. Implement cross-calibration procedures for dosimetry instruments. S13. Convert dosimetry quantities measured in air or other medium to relevant dosimetric quantities in tissue.	C7. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Dosimetry Measurements (including non-ionising radiations as appropriate). C8. Equip an appropriate laboratory for the measurement of dosimetric quantities for the various types of ionizing radiations and physical agents for patients, workers and public in own area of medical physics practice. C9. Take responsibility for the selection, acceptance testing, commissioning and quality control of instruments for the measurement of dosimetric quantities for ionizing radiations and other physical agents in own area of medical physics practice. C10. Take responsibility for the handling, management, calibration and maintenance of dosimetry instruments in own area of medical physics practice. C11. Take responsibility for dosimetric investigations and the supervision of dosimetry measurements.

Patient Safety / Risk Management	K14. Explain the statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Patient Safety / Risk Management. K15. Explain the classification of medical devices based on patient risk. K16. Explain the principles of patient risk management as applied to medical devices and associated ionizing radiations and other physical agents in own area of medical physics practice. K17. Describe the beneficial and possible adverse biological effects (including mechanisms) to patients of ionizing radiations and other physical agents including the factors impacting the magnitude of the biological effect. K18. Explain the possible impact of human factors with regard to patient safety in the use of medical devices and associated ionizing radiations and other physical agents. K19. Explain the difference between deterministic/stochastic, early/late and teratogenic/genetic effects of the various ionizing radiations and other physical agents in relation to patient risk. K20. Explain relevant international, EU, national and local legislation, recommendations and documentation regarding risk from ionizing radiations and other physical agents with the purpose of hazard prevention and emergency preparedness in the healthcare environment with regard to patient safety / risk management. K21. Describe and explain the procedures for the prevention, investigation and handling of adverse incidents (including use of Root Cause Analysis / Failure Modes and Effects Analysis or alternative methodology; recommendations of appropriate remedial actions) with respect to patients in own area of medical physics practice. K22. Describe the process and practical implementation of patient risk assessments in own area of medical physics practice, using techniques for the qualitative and quantitative assessment of risk. K23. Name and explain the function of the main National, European and International organizations concerned with protection of patients from ionizing radiations and other physical agents (e.g., ICRP, ICNIRP, IAEA, EC, WHO, UNSCEAR). K24. Explain how research exposures are managed in own area of medical physics practice including the processes of ethical review and including the use of dose constraints where appropriate. K25. Describe the requirements for, and the practical implementation of, appropriate systems for the monitoring of doses to patients from ionizing radiations and other physical agents in own area of medical physics practice.	S14. Calculate patient risk from measurement data of the dosimetry quantities used to assess adverse biological effects for the various types of ionizing radiations and other physical agents. S15. Assess patient risks from given procedures in own area of medical physics practice from measured patient dose data and dose-effect relationships. S16. Apply the principles of justification (risk / benefit assessment), optimization (including ALARA) and the setting up of reference levels to protect the patient from unnecessary risk from ionizing radiations and other physical agents. S17. Apply the various means of dose reduction (appropriate source strengths, exposure time, distance, shielding) in protocol optimization. S18. Calculate risks to the unborn child in the case of exposure to ionizing radiations and other physical agents. S19. Develop an organisational policy to achieve regulatory compliance for patient safety from ionizing radiations and other physical agents in own area of medical physics practice. S20. Investigate incidents to determine the cause(s) and recommending appropriate remedial action with respect to patient safety in own area of medical physics practice. S21. Conduct critical examinations (interlocks, warning systems, safety design features and barriers) related to patient safety in own area of medical physics practice.	C12. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Patient Safety / Risk Management. C13. Inventorise sources of ionizing radiations and other physical agents present in the hospital environment with respect to patient safety. C14. Take responsibility for the ongoing optimization of existing and newly introduced protocols in own area of medical physics practice with respect to patient protection and in accordance with the latest published evidence or own research when the available evidence is not sufficient. C15. Carry out an ionizing radiation and other physical agent dose audit with respect to patient safety in own area of medical physics practice. C16. Take responsibility for the development of patient safety teams in own area of medical physics practice. C17. Implement corrective procedures with regard to patient safety in own area of medical physics practice. C18. Take responsibility for the planning for emergency situations with regard to patient safety in own area of medical physics practice. C19. Implement a detailed organisational policy to support the safety of patients in own area of medical physics practice. C20. Take responsibility for the establishment and use of appropriate reference levels with respect to risks from ionizing radiations and other physical agents. C21. Develop contingency plans for emergency procedures with respect to patient safety in own area of medical physics practice. C22. Take responsibility for the design of a new facility (including waiting and resting rooms) in own area of medical physics practice taking into consideration patient safety. C23. Take responsibility for the surveillance of installations with respect to protection of patients from ionizing radiations and other physical agents.

Patient Safety / Risk Management (cont.)	K26. Describe the principles and practice of contingency planning and the implementation of emergency procedures with respect to patient safety in own area of medical physics practice. K27. Describe the key considerations for the design of a new facility (including waiting and resting rooms) with regards to patient safety in own area of medical physics practice. K28. List and explain the functioning of safety systems (e.g., interlocks) found in own area of medical physics practice with respect to patient safety. K29. Explain how the application of good safety practices and the use of appropriate devices and techniques are used to optimize clinical protocols. K30. List and describe quantitatively and in detail the interactions with organic matter of ionising and non-ionising electromagnetic radiations, particulate radiation, ultrasound and electric and magnetic fields at the molecular, cellular, tissue and macroscopic levels in relation to patient risks. K31. Define the radiation dosimetry quantities used in patient risk assessment and their use in the radiation protection of patients. K32. Explain the principles of the design of radiation safety plans with respect to patient safety in own area of medical physics practice. K33. Explain the fundamental characteristics and limitations of the various models / algorithms used in the quantification of patient doses from external sources of ionising radiation. K34. Explain compartmental / bio-kinetic models and the fundamental characteristics and limitations of the MIRD model and algorithms for internal radionuclide patient dosimetry.	S22. Give advice on the choice and use of protective equipment related to patient safety in own area of medical physics practice. S23. Assess patient risks for a given experimental procedure.	C24. Take responsibility for the management of good and safe practice in the use of ionising radiation beams and sealed / unsealed sources in own area of medical physics practice in relation to patient safety.

Occupational & Public Safety / Risk Management (*when there is an impact on medical exposure or own safety*)	K35. List and explain statutory and institutional roles of Medical Physics Services with respect to Occupational and Public Safety / Risk Management in own area of medical physics practice *when there is an impact on medical exposure or own safety*. K36. Describe the possible adverse biological effects (including mechanism) to workers / public from ionizing radiations (and other physical agents if approp) including the factors impacting the magnitude of the biological effect. K37. Explain the principles of occupational risk audit and management, hazard prevention and emergency preparedness as applied to ionizing radiations (and other physical agents if approp) associated with the use of medical devices in own area of medical physics practice. K38. Explain relevant international, European, national and local legislation, recommendations and documentation regarding risk from ionizing radiations and other physical agents with regard to occupational and public safety in own area of medical physics practice. K39. Explain how the principles of justification, optimization (including ALARA), and risk limitation are used for occupational and public protection from the deleterious effects of ionizing radiations and other physical agents. K40. Name and explain the function of the main National, European and International organizations concerned with protection of workers and the general public from ionizing radiations and other physical agents (e.g., ICRP, ICNIRP, IAEA). K41. Explain how sites and facilities are designed to ensure protection of workers and the general public. K42. Describe and explain the procedures for the prevention, investigation and handling of adverse incidents with respect to workers/public in own area of medical physics practice. K43. Explain quantitatively and in detail the interactions with organic matter of ionising and non-ionising electromagnetic radiations, particulate radiation, ultrasound and electric and magnetic fields at the molecular, cellular, tissue and macroscopic levels in relation to occupational / public risks. K44. Define and measure or calculate the operational quantities (including units and inter-relationships) used in personal dosimetry in own area of medical physics practice (e.g., ambient, directional and personal dose equivalents at recommended depth, annual limit on intake, derived air concentration).	S24. Perform occupational / public risk assessment based on facility survey and estimated / measured dosimetry data in own area of medical physics practice. S25. Assess occupational risk from given procedures in own area of medical physics practice from ionizing radiations and other physical agents using measured occupational dose data and dose-effect relationships. S26. Carry out a risk audit with respect to occupational / public safety from ionizing radiations and other physical agents in own area of medical physics practice. S27. Evaluate facilities/systems/procedures in terms of occupational / public safety from ionizing radiations and other physical agents in own area of medical physics practice. S28. Assess occupational risks for a given experimental procedure.	C25. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Occupational and Public Safety / Risk Management *when there is an impact on medical exposure or own safety*.

Occupational & Public Safety / Risk Management (cont.)	K45. Explain the possible impact of human factors with regard to occupational / public safety in use of medical devices and associated ionizing radiations and other physical agents. K46. Explain the roles of occupational / public safety personnel associated with ionizing radiations and other physical agents such as Radiation Protection Expert and Radiation Protection Officer as defined in European, national and local legislation / documentation. K47. Explain the scope, objectives, structure and content of formal systems of work ('local rules'). K48. Explain in quantitative terms the various means of dose reduction for external radiation (source strengths, exposure times, distance, shielding) and internal radionuclides with respect to occupational / public safety. K49. State current dose limits and constraints for workers / public. K50. Describe the process and practical implementation of occup./ public risk assessments in own area of medical physics practice, using techniques for the qualitative and quantitative assessment of risk. K51. Describe the key considerations for the design of a new facility (including waiting and resting rooms) with regards to occupational / public safety in own area of medical physics practice. K52. Describe the principles and practice of contingency planning and the implementation of emergency procedures with respect to occupational / public safety in own area of medical physics practice. K53. Describe suitable processes for the reporting of radiation incidents involving workers / members of the general public in the context of own area of medical physics practice, using root cause analysis and/or other tools to determine the underlying cause(s). K54. Describe the requirements for, and the practical implementation of, appropriate systems for the monitoring of radiation dose to the worker, including extremity doses and dose limits for pregnant and lactating workers, and young workers; and for the public; including selection, management and calibration of devices used to measure such doses, dose records and techniques for dose measurement. K55. Explain how the application of good radiation safety practice and the use of appropriate personal protective equipment minimises worker and public doses in medicine. K56. Explain the principles radiation safety plan design with respect worker / public safety in own area of medical physics practice. K57. List and explain the functioning of safety systems found in own area of medical physics practice vis-a-vis occupational / public safety.		

Clinical Medical Device Management	K58. Explain the purpose and practical implementation of formal systems of work ('local rules') with regard to safety in own area of medical physics practice. K59. List and explain statutory and institutional requirements for Medical Physics Services with respect to Clinical Medical device Management in own area of medical physics practice. K60. Define / explain medical device terminology. K61. List the medical devices used in own area of medical physics practice and explain their purpose, modular structure and detailed functioning. K62. Explain the scope and function of national, European and International medical device standard setting bodies. K63. Explain the Medical Device Directives and associated documentation. K64. Explain the meaning of 'acceptability criteria' as applied to medical devices. K65. Describe and discuss the principles of medical device design with respect to clinical effectiveness and safety, including human-factors. K66. Explain the function of ICT hardware and software associated with devices including digital communications networks (LAN, WAN, network typologies, protected subnets for 'mission critical' devices including firewalls) and systems (e.g., PACS) and data exchange standards used in medicine (e.g., DICOM, DICOM-RT). Include discussions regarding hardware configuration, operating systems, IP terminology, port assignment, ftp, telnet, ping testing, network gates/ router procedures, virus infection risks (types, routes of propagation, and precautionary measures). K67. Describe relevant data and ICT security standards for collection, storage and transmission of data and Data Protection Legislation K68. Describe the operational relationships between hospital information systems (HIS) and information systems specific to own area of medical physics practice (e.g., RIS for imaging). K69. Describe and explain in detail the DICOM standard including its application to own area of medical physics practice. K70. Explain data warehousing for archiving and storage and relevant legislation regarding time such information must be kept. K71. Discuss medical device software standards and types of software licensing. K72. Explain the principles of medical device connectivity, connectivity standards and problems with interoperability.	S29. Use appropriate physical / software test objects / phantoms, data acquisition protocols, data recording forms, national / European / international protocols to measure the performance indicators of medical devices in own area of medical physics, assess deviations from acceptable values (as indicated by manufacturer and international / European / national standard setting bodies), evaluate the relevance of deviations for clinical practice and suggest actions for restoring default performance. S30. Evaluate technical specifications of commercial devices in own area of medical physics practice. S31. Carry out acceptance testing, commissioning and constancy testing procedures in own area of medical physics practice. S32. Adapt national and international acceptance testing, commissioning and QC standards to specific devices/device limitations where appropriate. S33. Evaluate whether medical device service agreements (including software updates) are adequate to ensure service continuity and patient and occupational safety in own area of medical physics practice.	C26. Take responsibility for statutory and institutional requirements for Medical Physics Services with respect to Clinical Medical Device Management in own area of medical physics practice. C27. Take responsibility for medical device (including software, information systems, PACS) management including planning, evaluation of clinical needs, specification for tender purposes, evaluation of tendered devices, acceptance testing, commissioning, constancy testing (including setting of warning and suspension levels), maintenance, decommissioning and service contract management in own area of medical physics practice. C28. Participate in the procurement of new devices in own area of medical physics practice. C29. Take responsibility for the maintenance of quality control records. C30. Organize infrastructures for distribution, archiving and retrieval of images. C31. Organize infrastructures for display and reading of images and for the reporting and archiving of findings. C32. Pursue corrective actions with minimum interference with departmental functionality. C33. Establish and plan QA/QC procedures in appropriate support of the specific activity in own area of medical physics practice. C34. Take responsibility for the development of an institutional quality assurance / quality control medical device service as required by European and national medical device standard setting bodies in own area of medical physics practice. C35. Take responsibility for the development and ongoing update of departmental quality control protocols for medical devices in own area of medical physics practice.

Clinical Medical Device Management (cont.)	K73. Explain the effects of ionizing radiations and other physical agents on the workings of medical devices in general and in own area of medical physics practice (e.g., electromagnetic interference / compatibility). K74. Define and explain the principles of quality, quality assurance, quality control, performance indicators, constancy testing, quality control tests, test frequency, tolerances, and action criteria with respect to medical devices. K75. Explain the principles of medical device (including associated software) management including planning, evaluation of clinical needs, specification for tender purposes, evaluation of tendered devices, procurement, acceptance testing, commissioning, constancy testing, maintenance and decommissioning; service contract management. K76. List and explain the functions of the major International and European standard (e.g., IEC, CENELEC) setting bodies (and others such as NEMA) for medical devices and describe the various types of documentation issued by these bodies and their use in medical device management. K77. Describe and explain in detail international, national and local protocols for assessing the performance of medical devices in own area of medical physics practice. K78. Explain the principles of business planning, inventory control, auditing, benchmarking and handling of service contracts as applied in medical device management. K79. Explain and discuss the main properties of biomaterials relevant to medical device design.	S34. Analyze the medical devices used in own area of medical physics practice and investigate their design, functioning, associated signal / image processing, safety features, typical specifications and performance indicators. S35. Design and test physical and technical methods for quality control of devices in own area of medical physics practice. S36. Identify sources of device malfunctioning in own area of medical physics practice. S37. Autonomously acquire and analyze in detail the literature and user / technical manuals for medical devices in own area of medical physics practice. S38. Interpret and apply local occupational protection rules as applicable to medical device QC procedures. S39. Evaluate and participate in the selection of medical devices in a tender in own area of medical physics practice. S40. Utilize PACS and DICOM in own area of medical physics practice. S41. Apply available systems resources (e.g., RIS, PACS, DICOM data) to QA data elaboration and record. S42. Implement cross-institutional quality control procedures for devices. S43. Perform a documented risk assessment for devices not within suspension levels. S44. Design rooms to accommodate specific devices in own area of medical physics practice.	C36. Participate in the installation of new devices in own area of medical physics practice. C37. Negotiate device acceptance with provider and own department management following acceptance tests. C38. Organize, manage and train quality control teams in own area of medical physics practice. C39. Decide if actions are required on a medical device to restore default performance. C40. Define warning and suspension levels for devices.

Clinical Involvement	K80. List and explain statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Clinical Involvement. K81. Describe and explain the principles of anatomy, physiology, biology (including radiobiology), pathology as related to the main clinical applications in own area of medical physics practice. K82. Describe trauma / development of diseases, diagnosis, treatment and follow-up relevant to own area of medical physics practice, including primary healthcare and screening programmes. K83. Explain the International Classification of Diseases (ICD). K84. Explain how medical devices/ ionizing radiations and other physical agents are used for the solution of clinical problems in own area of medical physics practice. K85. Describe the clinical applications and target clinical outcomes in the use of medical devices in own area of medical physics practice. K86. Explain clinical guidelines in own area of medical physics practice. K87. Describe the patient's perspective in clinical processes in own area of medical physics practice. K88. Explain the risk/benefit justification of procedures in own area of medical physics practice. K89. Explain protocol optimization principles in own area of medical physics practice. K90. Explain the design principles, the relevant legislation issues and approval procedures for clinical trials. K91. Explain the principles and implementation of Good Clinical Practice (GCP), Good Manufacturing Practice (GMP) and Good Laboratory Practice (GLP) in own area of medical physics practice. K92. Describe general indications and contra-indications for the use of devices in own area of medical physics practice. K93. Understand the nature of anatomical/ pathological medical images as the visualization of the 3D distribution of physical variables. K94. List the main sources of evidence from within the general physics, medical physics and general healthcare (e.g., the Cochrane Collaboration) literature essential for the carrying out of a systematic survey in own area of medical physics practice. K95. Explain basic concepts in health informatics such as unique patient identifier, medical record and disease coding (e.g., ICD10). K96. Explain safety and risk related issues associated with the use of ICT in own area of medical physics practice.	S45. Recognize basic anatomical / pathological structures of the human body in projection / tomographic and 3D medical images relevant to own area of medical physics practice. S46. Recognize basic physiological processes in nuclear / molecular images. S47. Participate in clinical discussions within multidisciplinary teams in own area of medical physics practice. S48. Participate in the design of patient plans in own area of medical physics practice when appropriate. S49. Adhere to procedures regarding hygiene. S50. Participate in patient preparation and positioning prior to data acquisition when appropriate. S51. Analyze critically protocol proposals in terms of feasibility, effectiveness and safety. S52. Handle and analyze medical images including the extraction of parametric data / images. S53. Set up devices, experiments and protocols for the measurement of physical variables relevant to clinical practice. S54. Operate medical devices in own area of medical physics practice effectively and safely.	C41. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Clinical Involvement. C42. Oversee daily patient safety / risk management involving medical devices and associated ionizing radiations and other physical agents in own area of medical physics. C43. Participate in the evaluation and optimization of clinical procedures and protocols and risk elimination / reduction in own area of medical physics practice in both routine and non-routine procedures. C44. Advise physician in image interpretation and quantification when appropriate. C45. Take responsibility for semi-quantitative and quantitative data for clinical application. C46. Advise on different patient diagnosis / treatment schedule options when appropriate. C47. Participate in the definition of the limits of acceptability of clinical procedures. C48. Advise on the most appropriate procedure with respect to risk/benefit ratio. C49. Supervise procedures for paediatric investigations in relation to dose optimization. C50. Advise other healthcare professionals on optimization and safety of individual patient examination / treatment and examination / treatment protocols. C51. Live up to demands imposed by duty of confidentiality, professional secrecy, ethical standards. C52. Represent medical physics in clinical conferences. C53. Take responsibility for the prevention, investigation and handling of adverse incidents (including use of Root Cause Analysis / Failure Modes and Effects Analysis or alternative methods; recommendations of appropriate remedial actions) with respect to patients in own area of medical physics practice.

Clinical Involvement (cont.)	K97. Describe patient flows and management of clinical processes in own area of medical physics practice. K98. Explain the use of information / communication standards in medicine such as HL7, SNOMED, IHE. K99. Explain the use of Patient Administration Systems, the Electronic Patient Record and Order Communication systems. K100. Explain security and privacy issues related to electronic patient information systems. K101. Describe the purpose and implementation of local systems for formal incident reporting and internal review with regard to risk management.		
Development of Service Quality and Cost-Effectiveness	K102. List statutory and institutional requirements for Medical Physics Services with respect to development of Service Quality and Cost-effectiveness in own area of medical physics practice. K103. Explain the principles of business, strategic planning and cost effectiveness in the case of Medical Physics Services. K104. Define and explain the principles of quality, continuous quality improvement, quality audit and total quality management systems as applied to aspects of clinical audits involving medical devices and associated ionizing radiations and other physical agents. K105. Explain why the holistic development of a service depends on the quality assurance of the parts. K106. Explain why the development of service quality for an area of medical practice requires input from various healthcare professionals. K107. Describe responsibilities of other healthcare professionals involved in QA activities in own area of medical physics practice. K108. Describe the intentions and principles of QA systems like ISO 9000 and formal systems for external accreditation by expert/professional bodies. K109. Define quality objectives in own area of medical physics practice. K110. Describe the institutional framework of QA activity and regulation in own area of medical physics practice. K111. List and explain the functions of the major International and European standard setting bodies for healthcare quality; describe the various types of documentation issued by these bodies and explain its use for service quality development. K112. Explain the principles of Evidence Based Medicine and describe how the evidence base can be used to improve service quality. K113. Describe the purpose and implementation of local systems for formal incident reporting and internal review with regard to improvement of service quality.	S55. Participate in development of service quality and cost-effectiveness in own area of medical physics practice. S56. Define quality objectives in own area of medical physics practice. S57. Define, measure and optimize appropriate quality indicators in own area of medical physics practice. S58. Set up a service quality development strategy for own area of medical physics practice. S59. Prepare a business and strategic plan for the development of Medical Physics Services in own area of medical physics practice. S60. Apply the principles of business, strategic planning and cost effectiveness in own area of medical physics practice. S61. Set up and continuously develop a feedback system for ongoing improvement of quality (based on assessment of non-conformities and accident analysis) in own area of medical physics practice. S62. Apply available resources (such as those in RIS/PACS systems) to elaboration and recording of quality related data. S63. Measure quality management performance and improvements in own area of medical physics practice. S64. Participate in the reporting, review and analysis of incidents.	C54. Take responsibility for statutory and institutional requirements for Medical Physics Services with respect to Development of Service Quality and Cost-Effectiveness in own area of medical physics practice, whilst being aware that improvement of the service as a whole depends on the inputs of other healthcare professionals. C55. Advise on the technical aspects impacting the clinical effectiveness and safety of new medical devices or techniques prior to their introduction into clinical practice. C56. Participate in the design and implementation of QA systems in own area of medical physics practice. C57. Take responsibility for using the methodologies of Evidence Based Medicine to investigate ways of improving service quality within own area of medical physics practice. C58. Assume responsibility for quality management audits involving medical devices and associated ionizing radiations and other physical agents. C59. Take responsibility for the design and implementation of a monitoring system for Medical Physics Services in own area of medical physics practice. C60. Take responsibility for the development and implementation of a business and strategy plan for Medical Physics Services in own area of medical physics practice. C61. Take responsibility for the formal review and analysis of incidents within own area of medical physics practice.

Expert Consultancy	K114. List and explain statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Expert Consultancy. K115. Explain the role of a consultant. K116. Explain the role of scientists as consultants in healthcare. K117. Describe the general role of the MPE as consultant in own area of medical physics practice. K118. Discuss the specific ethical issues involved in delivering a consultancy service in own area of medical physics practice (including conflict of interest issues).	S65. Apply MPE consultancy skills to specific scenarios in own area of medical physics practice. S66. Identify and manage ethical issues involved in delivering a consultancy service in own area of medical physics practice (including conflict of interest issues).	C62. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Expert Consultancy including responsibility for associated ethical issues commensurate with level of personal expertise. C63. Produce and/or audit reports as an independent provider for organizations other than one's own. C64. Design and evaluate continuous professional courses in own area of medical physics practice for organizations other than one's own.
Educ. of Healthcare Professionals (including Medical Physics trainees)	K119. List statutory and institutional requirements for Medical Physics Services with respect to the education and training of healthcare professionals (including Medical Physics trainees) in own area of medical physics practice. K120. Discuss the application of the principles of knowledge transfer to the case of healthcare professionals. K121. Discuss the principles of modern adult pedagogy and apply them to the medical device and ionizing radiations and other physical agents educational needs of healthcare professionals (including continuous professional development activities) and including training associated with the introduction of new devices and techniques. K122. Discuss methods for developing and delivering ionizing radiations and other physical agents education and training learning outcomes for addressing the learning needs of specific healthcare professionals in specific clinical environments. K123. Discuss the factors which impact the choice of learning outcomes and methods of knowledge transfer to the case of medical device and ionizing radiations and other physical agents knowledge for specific healthcare professionals in specific clinical environments (such as previous education and training and the usability and safety features of devices). K124. Describe the content of appropriate programmes for healthcare professionals involving the optimised clinical use of medical devices and protection from ionizing radiations and other physical agents in own area of medical physics practice .	S67. Set up an inventory of learning outcomes tailored to the specific learning needs of specific healthcare professionals in specific clinical environments in conjunction with the leaders of the respective healthcare professions. S68. Prepare effective and efficient modes of knowledge transfer activities specific to the specific learning needs of specific healthcare professionals in specific clinical environments in conjunction with the leaders of the respective healthcare professions. S69. Prepare effective modes of assessment appropriate for the various healthcare professions. S70. Carry out own pedagogical research when the evidence base for education and training of healthcare professions is insufficient.	C65. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to the Education (including continuous professional development) of Healthcare Professionals (including Medical Physics trainees). C66. Take responsibility for the education of healthcare professionals (including Medical Physics trainees) regarding the optimised clinical use of medical devices and safety from ionizing radiations and other physical agents in specific clinical environments in own area of medical physics practice. C67. Take responsibility for the education of healthcare professionals (including Medical Physics trainees) in performing QC procedures related to medical devices in own area of medical physics practice. C68. Take responsibility for the education of healthcare professionals (including Medical Physics trainees) regarding protection from ionizing radiations and other physical agents including the use of personal dose monitors and personal protection equipment. C69. In conjunction with other healthcare professionals take responsibility for ensuring that referrers are knowledgeable of current referral criteria in own area of medical physics practice. C70. Take responsibility for raising public awareness of safety issues regarding ionizing radiations and other physical agents in own area of medical physics practice.

Health Technology Assessment	K125. List and explain statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Health Technology Assessment (HTA). K126. Explain the principles of HTA as applied to medical devices and procedures in own area of medical physics practice. K127. List and explain the steps for the carrying out a HTA, including use of primary data and secondary sources. K128. Define the roles and responsibilities of all professionals involved in an HTA project in own area of medical physics practice. K129. List the issues that should be considered in an HTA project in own area of medical physics practice. K130. Explain the value of HTA reports for policy makers at the European, national, regional and facility levels. K131. Explain the importance of HTA reports in controlling cost in relation to benefit for the considered technology in own area of medical physics practice. K132. Apply research methodologies and statistical techniques used at the interface between physical and biomedical science in clinical trials involving medical devices and/or ionizing radiations and other physical agents. K133. Discuss the ethical issues associated with clinical trials involving medical devices and/or ionizing radiations and other physical agents. K134. Describe how to apply for approval from a hospital and /or university based ethics committee for a clinical trial involving medical devices and /or ionizing radiations and other physical agents. K135. Describe the fundamentals and design models of clinical trials in own area of medical physics practice.	S71. Perform a systematic review of the existing evidence base to evaluate the clinical effectiveness and safety of a new medical device or new procedure involving medical devices / ionizing radiations and other physical agents. S72. Communicate HTA reports to policy makers. S73. Interpret the statutory and institutional requirements of Medical Physics Services in HTA activities. S74. Design and monitor the medical physics components of clinical trial protocols in own area of medical physics practice. S75. Perform statistical analysis and report on clinical trials involving medical physics services. S76. Assemble a suitable physics team for a specific HTA project. S77. Conduct the technical components of an HTA project in own area of medical physics practice.	C71. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Health Technology Assessment (HTA). C72. Use the methodologies of HTA to carry out a HTA in conjunction with other healthcare professionals. C73. Take responsibility for the technical component of a HTA related to medical devices and /or ionizing radiations and other physical agents. C74. Take responsibility for the technical component of a clinical trial related to medical devices and /or ionizing radiations and other physical agents. C75. Take responsibility and communicate with relevant authorities with regards to safety from ionizing radiations and other physical agents in the case of clinical trials. C76. Apply for approval from a hospital and /or university based ethics committee for a clinical trial involving medical devices and /or ionizing radiations and other physical agents. C77. Take responsibility for the evaluation of a clinical trial protocol. C78. Ensure good clinical practice (GCP) compliance of activities within clinical trials. C79. Advise on and take responsibility for the preclinical device aspects of the ethical review of a clinical trial. C80. Assume the responsibility of statistical and other mathematical data processing and recording in a clinical trial.
Innovation	K136. List and explain statutory and institutional requirements for Medical Physics Services with respect to Innovation in own area of medical physics practice. K137. Define innovation as the development of new devices (including software), modification of existing devices (including software) and the development of new techniques using devices for the solution of hitherto unresolved clinical problems. K138. Explain the importance of ongoing horizon scanning for new and emerging technologies. K139. Describe the methodology of horizon scanning for new and emerging technologies. K140. Discuss the opportunities for innovation in own area of medical physics practice.	S78. Apply the methodology of horizon scanning (including listing of specific information sources) for new and emerging technologies to own area of medical physics practice.	C81. Take responsibility for statutory and institutional requirements for Medical Physics Services with respect to Innovation in own area of medical physics practice. C82. Take responsibility for the development of new devices (including software) and modification of existing devices (including software), including their implementation and evaluation in response to clinical needs in own area of medical physics practice. C83. Take responsibility for legal issues involved in the development of medical devices (including software) in own area of medical physics practice.

Table A. 5: KSC Specific for the MPE in Diagnostic & Interventional Radiology

	Knowledge (facts, principles, theories, practices)	**Skills** **(cognitive and practical)**	**Competence** **(responsibility and autonomy)**
Scientific Problem Solving Service	K1. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Scientific Problem Solving Service. K2. List the common imaging modalities (general projection x-ray imaging (DDR, CR and film-screen where this is still valid), chest systems, mammography, dental systems (intra-oral, OPG, cephalometric systems), mobile, flat panel / image intensifier fluoroscopes including C-arms, interventional systems, tomosynthesis, paediatric systems, radiostereometric (RSA) systems, stereotactic systems, dual energy X-ray absorptiometry (DXA), axial and helical mode CT, cone-beam CT, MRI, ultrasound) and explain their function as instruments for the measurement, mapping and imaging of the spatial distribution of different physical variables within the human body. Each imaging modality/dedicated device has its utility in the various applications of medical imaging i.e., diagnosis, population screening, patient monitoring, intervention and specialised use such as paediatric. K3. Discuss the advantages and disadvantages of imaging as a means of displaying spatially dependent signals and variables. K4. Explain in detail the principles of image quality measurement: linear systems theory, types of contrast (subject, image and display), unsharpness (LSR, PSF, LSF, MTF), lag, noise (including sources, noise power spectra, effect of lag on noise, noise propagation in image subtraction), SNR (including Rose model, Wagner's taxonomy, CNR, relation to dose, NEQ, DQE. K5. Explain inverse problem mathematical techniques used in image reconstruction (including both convolution and iterative methods and the advantages and disadvantages of each). K6. Describe and explain at an advanced level the following: temporal / frequency domain representation of signals, Fourier transform, statistical description of signals, power spectral density, autocorrelation function, sampled (discrete) signals, delta function and its Fourier transform, Fourier transform of aperiodic discrete signal (DFT), the FFT, the effects of finite sample intervals, linear processors, impulse response, convolution integral and theorem, various types of filters used in the processing of medical signals. K7. Explain in detail the way that acquisition data is processed to facilitate the extraction of information. K8. Explain the principles and methods of image post-processing including knowledge based image analysis, pattern theory, deterministic image processing and feature enhancement, image segmentation, image registration and co-registration / fusion. K9. Discuss the limitations of image post-processing.	S1. For each modality, operate imaging devices at the level necessary for give advice on optimization of imaging protocols, quality control, image quality manipulation, and carry out research when the available evidence for advice is not sufficient. S2. For each modality predict the effect on image quality and diagnostic accuracy when changing scanning and reconstruction parameters. S3. Manipulate acquisition parameters for all forms of projection x-ray imaging devices (e.g., kV, filtration, mAs, sensitivity ('speed'), collimation, magnification, SID, SSD, frame rate, screening time, manual/AED modes, compression), explain the effect on image quality and relevant patient dose quantities (and occupational dose particularly when this is correlated with patient dose) and relevance to specific clinical studies.	C1. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Scientific Problem Solving Service. C2. Carry out or supervise as appropriate the measurement of physical quantities relevant to the effective, safe and economical use of medical devices / ionizing radiations and other physical agents in Diagnostic and Interventional Radiology.

Scientific Problem Solving Service (cont.)	K10. For each imaging modality, define and explain in detail and quantitatively the physical property / properties of tissues which the device measures and images, including any variables impacting the value of these properties and associated tissue contrast (e.g., attenuation coefficient for CT which is dependent on beam energy/kV, tissue contrast in CT dependent on kV). K11. For each imaging modality, list and explain sources of measurement inaccuracy, uncertainty and artefacts. K12. For each imaging modality, describe quantitatively the static / time-varying fields used and their clinical specification. K13. For each imaging modality, list and define device performance indicators relevant to image quality outcomes (e.g., limiting spatial and contrast resolutions, SNR, geometric accuracy) including discussion of accuracy, precision and stability. K14. For each imaging modality, explain the relationship between target image quality outcomes and imaging device performance indicators. K15. For each imaging modality, explain in detail the application of the following concepts / techniques for the improvement of the diagnostic value of medical images: reconstruction algorithms, image processing, image display, image visualisation, quantitative image analysis, computer aided diagnosis, vision and perception, image registration. K16. Explain in detail the DICOM standard for all modalities including the meaning of the terminology used in the DICOM header of images from the various modalities. K17. Explain the meaning and the concepts of sensitivity and specifity in medical imaging. K18. Explain the use of Signal Detection and Psychophysical theories(including concepts of sensitivity, specificity and ROC analysis) in medical imaging. K19. For each imaging modality, explain the special requirements for quantitative imaging. K20. For each imaging modality define explain in detail the structure and functioning of the various components of the imaging device (e.g., high voltage generator, timers, various types of x-ray tubes and their characteristics, tube cooling, flat filters and shaped filters, beam limiting devices, detector, anti scatter grids, operator console, patient support, computer, display, workstation in the case of projection x-ray imaging). K21. For each imaging modality, explain in detail the operation, technical principles and geometry of imaging equipment. K22. For each imaging modality, explain device design variables which impact device performance indicators (e.g., focal spot size in the case of x-ray imaging). K23. For each imaging modality, list and explain user controlled variables/settings and their impact on image quality/diagnostic efficacy and patient risk. K24. For each imaging modality, explain strengths and limitations and their impact on image quality / diagnostic efficacy (including any artefacts).	S4. Manipulate acquisition parameters for all forms of CT imaging (e.g., kV, bowtie filter, mA, rotation time, tube current modulation, noise index, pitch, collimation, scanned field of view, slice thickness, beam collimation, over beaming, over scanning), explain the effect on image quality and relevant patient dose quantities (and occupational dose particularly when this is correlated with patient dose) and relevance to specific clinical studies. S5. Acquire MRI images and manipulate user parameters (e.g., pulse-sequence selection, TE, TR, flip angle, FOV, matrix size etc.) to optimise image quality and acquisition time. S6. Acquire ultrasound images and manipulate user parameters (e.g., choice of transducer frequency, depth gain compensation, dB output etc.) to optimise image quality. S7. Apply first-order motion compensation for flow effects in MR images. S8. For each imaging modality, use electronic callipers / imager software to measure distances, areas and organ volumes. S9. Use specialised test tools e.g., contrast-detail test objects, to evaluate imaging systems. S10. For each imaging modality elicit information from DICOM file headers. S11. Use modelling and simulation software (e.g. Matlab, SimuLink) to solve problems in the processing of imaging data.	

Scientific Problem Solving Service (cont.)	K25. For each imaging modality, explain in detail acquisition protocols, pre-processing of image data, image reconstruction principles, post-processing of images. K26. For each imaging modality, describe and explain differences in device design and their effects on image quality and patient safety for dedicated devices (e.g., mammography, dental systems for projection x-ray imaging). K27. Describe in detail x-ray projection and CT imaging devices for general projection x-ray imaging (DDR, CR and film-screen where this is still valid), chest systems, mammography (including tomosynthesis), dental systems (intra-oral, OPG, cephalometric systems), mobile, dual energy projection x-ray imaging, flat panel/image intensifier/mobile/over/under table fluoroscopes and C-arms, interventional systems, paediatric systems, radiostereometric (RSA) systems, stereotactic / biopsy systems (e.g., mammography), dual energy X-ray absorptiometry (DXA), sequential/axial and helical mode CT, multidetector CT, dual source/energy CT, volumetric CT scanners, CT scanners for radiotherapy planning, CT fluoroscopy and cone-beam CT, including: - physics principles, geometry, functioning, structure, strengths and limitations - image reconstruction and automatic pre-processing - image quality related performance indicators - device design for image quality and patient/occupational dose optimization, including special features for dedicated systems - user determined parameters and their manipulation for optimising image quality and patient dose K28. Define and explain the effect of variation of the following performance indicators on image quality in projection x-ray imaging (spatial resolution, contrast resolution, contrast to noise ratio, point spread function, modulation transfer function, noise power spectrum, detective quantum efficiency, noise equivalent quanta). K29. Define and explain the following detector dose requirements: speed class (film-screen), speed index (CR), DQE (DR).		

Scientific Problem Solving Service (cont.)	K30. Explain in detail the following features of fluoroscopes: flat-panel / image intensifier detectors (including problems with image intensifiers such as geometric distortion, environmental magnetic field effects), continuous and pulsed acquisition including frame rate, automatic brightness control, high dose rate fluoroscopy, digital spot imaging, cine runs, last image hold, roadmapping, 3D - cone beam CT acquisition. K31. Explain in detail the following aspects of CT scanning: algebraic (iterative) and integral transformation (convolution, filtered back projection) methods of reconstruction, CT numbers /Hounsfield units, z-interpolation in helical acquisition, retrospective image reconstruction (reconstruction kernel, slice width, reconstructed field of view), bolus tracking, prospective triggering (ECG, respiratory), retrospective gating (ECG, respiratory), CT perfusion. K32. Explain the following MRI concepts/principles: MR nuclei in a static magnetic field (B_0), Larmor frequency, radiofrequency field (B_1), relaxation mechanisms and times (T1, T2, T2*), Bloch equation (without and with relaxation terms), rotating frame, intrinsic and extrinsic MRI contrast parameters. K33. Describe and explain the following MRI devices: static magnetic field subsystem, radiofrequency field subsystem, gradient field subsystem (amplitudes, rise times, slew rate and eddy current effects), computer and control sub-system, the various types of RF coils and RF shielding. K34. Explain the MRI spatial encoding using linear magnetic field gradients including the k-space formalism. K35. Explain the following pulse sequences: spin echo, gradient echo, fast spin echo, inversion recovery (STIR, FLAIR), spatial and chemical saturation techniques, ultrafast techniques (echo-planar and spiral), steady-state free precession sequences. K36. Explain the physics principles underpinning MR angiography (MRA) and flow, perfusion and diffusion imaging, functional MR imaging (fMRI) and BOLD contrast, MR spectroscopy (MRS), parallel imaging, DCE-MRI. K37. Explain the formation of common artefacts e.g., motion artefact, aliasing ('wrap-around' artefact), metal and susceptibility artefact, chemical shift artefact, truncation artefact, B_0 / B_1 inhomogeneity, RF distortions and coil problems, ghosting (non-motion). K38. Explain the mechanisms of tissue contrast enhancement using paramagnetic / ferromagnetic contrast agents and hyperpolarized substances. K39. Explain contrast mechanisms, protocols and post-processing tools for perfusion, diffusion and fMRI studies. K40. List and explain the user determined MRI parameters influencing image contrast, SNR, CNR, spatial resolution and acquisition time. K41. Explain the special requirements and challenges associated with MRI-guided interventions.		

Scientific Problem Solving Service (cont.)	K42. Explain harmonic and non-linear solutions to the ultrasound wave equation, parameters (pressure, displacement, density, particle velocity), energy fluence rate (intensity) and power, acoustic impedance (soft tissue, gas and bone), pulse repetition frequency, demodulation, logarithmic compression, frame rate. K43. Explain the various interactions of ultrasound with tissue (including gas in tissues: absorption (including frequency dependence), Rayleigh scatter (including frequency dependence), reflection, behaviour at interfaces (including angular dependence), and refraction. K44. Explain the formation of ultrasound image 'speckle'. K45. Describe in detail the following ultrasound modes: 2D/3D/4D B-Mode scanning, A-Mode , M-Mode , Colour Flow Pulsed Doppler, Duplex/triplex scanners, Pulsed Doppler, Continuous Wave (CW) Doppler, Spectral Doppler, Power Doppler, Tissue Harmonic imaging (THI), Contrast Harmonic Imaging (CHI), Transient Contrast Imaging, Compound imaging, Extended FOV imaging, Coded and chirp excitation, elastography, including: - physics principles, geometry, functioning, structure, strengths and limitations - image reconstruction and automatic pre-processing - image quality related performance indicators - device design for image quality and patient safety, including special features for dedicated systems - user determined parameters and their manipulation for optimising image quality and patient safety. K46. Explain the piezo-electric effect, the structure and characteristics of transducers (resonance, bandwidth, backing and matching layers, near and far field beam patterns), continuous and pulsed operation, duty factor, linear array transducers, side lobes, transmit beam focusing/forming, receive focusing, apodisation and dynamic aperture, curvilinear arrays, phased array (off axis focusing), multi-frequency transducers and 1.5/2D arrays. K47. Define and explain performance indicators for ultrasound imaging devices e.g., spatial resolution (axial , lateral, slice thickness), contrast resolution (including dynamic range), SNR, range, dead zone, geometric accuracy for B-mode imaging. K48. Explain the formation of common artefacts in B-mode imaging (e.g., distal enhancement, shadowing, reverberation, flaring, mirror image, beam width and side lobe artefacts). K49. Explain the principles of computer aided diagnosis. K50. DXA: principles, BMD, phantom calibration, normal range (including precision and reproducibility), HSA, least significant change, T-scores and Z-scores, QCT, QUS		

External Beam Dosimetry Measurements *(and other physical agents as approp.)*	K51. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to patient /occupational / public Ionizing and Non-ionizing Radiation Dosimetry Measurements. K52. For each imaging modality define patient safety /dosimetry related indicators/quantities (use *both ICRU 74 and commonly used terminology for x-radiation*): - projection radiography: photon / energy fluence and fluence rate, absorbed dose, terma, kerma, KAP (P_{KA}, DAP), IAK (K_i), ESAK (K_e),ESD, effective dose, glandular dose in mammography - fluoroscopy: cumulative fluoroscopy time, cumulative fluoroscopy KAP, cumulative fluorography KAP, total cumulative KAP, cumulative air kerma at the international reference point, peak skin dose, organ absorbed dose, effective dose … - CT: $CTDI_{air}$ ($C_{a,100}$), $CTDI_W$ (C_W), $CTDI_{vol}$ (C_{VOL}), KLP ($P_{KL,CT}$), organ absorbed dose, effective dose … - MRI: SAR - Ultrasound: mechanical and thermal indices, acoustic output K53. Define and explain methods of measurement of occupational / public dose indicators suitable for ensuring adherence to exposure limit values and dose constraints: - x-ray imaging: ambient H*(10), directional H'(0.07, angle) and personal dose equivalents i.e., depth dose equivalent HP(10) and skin dose equivalent HP(0.07) - MRI: current density, whole body / localised SAR, power density	S12. For each imaging modality, identify and carry out appropriate patient / occupational / public safety related dosimetric measurements and calculations. S13. For each imaging modality measure / calculate patient safety /dose related indicators/quantities and wherever possible verify independently values supplied by manufacturers. S14. For each imaging modality, select appropriate phantoms/phantom materials for dosimetry. S15. Use specialized dosimetry software / conversion coefficients to calculate effective doses and organ absorbed doses from dosimetry measurements. S16. Measure static-field levels in the vicinity of MR units. S17. Measure the output of ultrasound units using.	C3. Take responsibility for statutory and institutional requirements for Medical Physics Services with respect to Ionizing and Non-ionizing Radiation Dosimetry Measurements. C4. For each imaging modality, take responsibility for the measurement of appropriate patient / occupational / public safety related dosimetric monitoring quantities. C5. Carry out a dose assessment for the foetus in the case of pregnant patients.

Patient Safety / Dose Optimisation	K54. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Patient safety / Dose Optimization. K55. Explain radiobiological dose-effect relationships relevant to Diagnostic and Interventional Radiology with respect to patient safety including discussion of the physical and biological background, response of tissues to radiation on molecular, cellular and macroscopic level, models of radiation induced cancer and hereditary risks and radiation effects on humans in general, children and the conceptus. K56. Explain the meaning of justification and optimization as applied to medical imaging practices. K57. For each imaging modality, list and explain the target patient safety outcomes with respect to hazards from ionizing radiations and other physical agents. K58. For each imaging modality, list and explain in detail and whenever possible quantitatively protocol design variables (e.g., appropriate device settings, accessories, safety procedures, patient instructions) which impact patient safety and optimization of practices, procedures and acquisition protocols. K59. Explain the methodology for the setting up of diagnostic reference levels (DRL). K60. For each imaging modality explain the physical principles underpinning the use of protective barriers, accessories and apparel with regard to patient safety. K61. For each imaging modality, describe the key considerations for the design of a new facility with respect to patient safety (including waiting and resting rooms). K62. Describe the process and practical implementation of patient safety / dose audits in the context of Diagnostic and Interventional Radiology. K63. For each imaging modality, explain the physical basis of any contraindications in the use of the device and procedures for avoiding adverse events. K64. Explain the bioeffects of MRI with regard to patient safety including static field effects (projectile, effects on implants, physiological effects), RF field (Tissue heating, SAR, burn injuries) and gradient field considerations (peripheral nerve stimulation, sound pressure levels). K65. Explain the biological effects of ultrasound at the molecular, cellular and tissue levels (e.g., risks from thermal effects, cavitation and micro-streaming). K66. Explain safe operating levels in ultrasound imaging including thermal and mechanical indices and their use in reducing patient risk. K67. Discuss in detail ethical issues related to the protection of patients and volunteers in biomedical research.	S18. Use radiobiological dose-effect relationships relevant to Diagnostic and Interventional Radiology to estimate patient risk (including adverse incidents involving high exposures). S19. Apply the concepts of justification, optimization and diagnostic reference levels to patient protection. S20. For each imaging modality, apply local European laws, regulations, recommendations and standards related to patient safety. S21. Optimize patient radiation protection in high dose or high risk practices: interventional radiology, CT, health screening programmes, irradiation of children, neonates or the foetus, genetic predisposition for detrimental radiation effects.	C6. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Patient Safety / Dose Optimization. C7. Take responsibility for the protection of patients by optimization of practices, procedures and acquisition protocols. C8. Take responsibility for establishment of diagnostic reference levels. C9. Take responsibility for ensuring that doses in a facility are measured, are consonant with European, national and local diagnostic reference levels and advise management and imaging professionals on means of reducing doses when necessary. C10. Participate in the establishment of referral criteria and justification of practices.

Occupational & Public Safety / Dose Optimisation (*when there is an impact on patient safety)*	K68. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Occupational & Public Safety / Dose Optimization *when there is an impact on medical exposure or own safety*. K69. For each imaging modality list and explain target occupational/public safety outcomes with respect to hazards from ionizing radiations and other physical agents. K70. Explain the practical application of ALARA to promote the radiation safety of the worker and public in Diagnostic and Interventional Radiology. K71. Explain radiobiological dose-effect relationships relevant to Diagnostic and Interventional Radiology with respect to occupational/public safety including discussion of the physical and biological background, response of tissues to radiation on molecular, cellular and macroscopic level, models of radiation induced cancer and hereditary risks and radiation effects on humans in general, children and the conceptus. K72. For each imaging modality, explain the physical principles underpinning the use of protective barriers, accessories and personal protective equipment with regard to occupational/public safety. K73. For each imaging modality list and explain the protocol design variables (including appropriate device settings, accessories, safety measures) which occupational/public safety. K74. Explain the principles of time, distance and shielding with respect to external radiation exposure, and the practical application of these principles to the radiation safety of the worker and public in Diagnostic and Interventional Radiology. K75. Define and describe the role of the RPE and RPO in the establishment and management of systems for radiation safety in Diagnostic and Interventional Radiology. K76. For each imaging modality define and explain appropriate occupational/public ionizing radiations and other physical agents dose monitoring quantities. K77. Explain the use of occupational / public dose indicators used in x-ray imaging: ambient H*(10), directional H'(0.07, angle) and personal dose equivalents i.e., depth dose equivalent HP(10) and skin dose equivalent HP(0.07). K78. Explain the special requirements with respect to occupational radiation protection in fluoroscopy (e.g., particularly in paediatrics and interventional procedures). K79. List and explain in detail occupational/public hazards related to MRI.	S22. Use radiobiological dose-effect relationships relevant to Diagnostic and Interventional Radiology to estimate occupational/public. S23. For each modality apply local European laws, regulations, recommendations and standards related to occupational/public safety. S24. Verify that radiation protection and risk management is in compliance with guidelines, directives, and legislation (including dose limits).	C11. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Occupational / Public Safety /Dose Optimization *when there is an impact on medical exposure or own safety*.

Clinical D&IR Device Management	K80. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Medical Device Management. K81. Demonstrate an understanding of the required technological infrastructure for a Diagnostic and Interventional Radiology department and knowledge of how to establish the necessary interactions with the infrastructures of other medical specialities within the hospital that utilize medical imaging (e.g., nuclear medicine, radiation oncology; cardiology, surgery). K82. Describe the components/subsystems of medical devices in each imaging modality. K83. For each imaging modality list and explain acceptability criteria and tender specifications. K84. Explain in detail the structure and the application of Information and Communication Technologies (ICT) for healthcare including Hospital Information Systems, Radiology Information System and Picture Archiving and Communication System in Diagnostic and Interventional Radiology. K85. Describe combined modality imaging systems and their clinical applications. K86. For each imaging modality, explain EU and national legislation, recommendations and regulations impacting the use of the modality.	S25. Evaluate imaging device performance for each imaging modality, from the measurement of suitable performance indicators using suitable test objects / phantoms. S26. For each imaging modality, carry out acceptance testing, commissioning and QC procedures. S27. For each imaging modality, recognize technical deficiencies in device user / technical manuals, documentation and legislation. S28. Utilize PACS and DICOM in Diagnostic and Interventional Radiology. S29. For each imaging modality, identify device malfunctioning and take appropriate action. S30. Calibrate the various types of devices used in Diagnostic and Interventional Radiology. S31. Conduct critical examinations for each imaging modality (interlocks, warning systems, safety design features and barriers). S32. Safely transfer, archive and retrieve images and data across software and hardware interfaces.	C12. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Medical Device Management. C13. Advise on the purchase of the most appropriate image modality / device model for a specific clinical application. C14. For each imaging modality, select hardware / software systems for image display and image processing (including integration of both). C15. Take responsibility for the acceptance, commissioning and constancy testing of image display and processing systems. C16. For each imaging modality, take responsibility to ensure conformity with European and national laws, regulations, recommendations and standards (including acceptability criteria).

Clinical Involvement in D&IR	K87. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Clinical Involvement. K88. Explain the use of the various modalities for anatomical and functional imaging. K89. Explain the uses of medical imaging in diagnosis and therapy. K90. Interpret anatomical and functional 2D/3D images from the various modalities and recognise specific anatomical, functional and pathological features. K91. Describe the various clinical applications of each imaging modality and their significance for patient management. K92. Give an overview of major diseases and trauma including their signs and symptoms K93. Explain and discuss the general principles of clinical diagnosis and the standards for reporting of diagnostic accuracy (STARD). K94. Explain the various types of screening programs and the importance of collective dose. K95. Explain the principles and use of in vivo MR spectroscopy / spectrometry. K96. Describe the relative technical strengths and limitations of the various imaging modalities and their impact on image quality outcomes / clinical effectiveness. K97. For each imaging modality, list and explain target imaging outcomes (e.g., in terms of image quality criteria) relevant to diagnostic effectiveness. K98. For each imaging modality, list and explain the protocol design variables (including appropriate device settings, accessories, and safety measures) which impact image quality and discuss possible effects on diagnostic accuracy. K99. For each imaging modality, explain the physical principles underpinning the effective and safe use of any ancillary medical devices and the safe disposal of non-reusable ancillary medical devices. K100. For each imaging modality, 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. K101. For each imaging modality, explain the specific medical terminology necessary for effective clinical involvement in each (e.g., in pulsatility Index, resistance Index in Doppler ultrasound). K102. For each imaging modality explain the mode of contrast enhancement, use and risks of contrast media. K103. Explain contrast enhanced fluoroscopy and CT studies including digital subtraction angiography. K104. Explain the action and use of contrast agents in ultrasound (e.g., blood pool contrast agents: microbubbles, inert gas bubbles, resonance, non-linear behaviour).	S33. For each imaging modality, recognize normal anatomy as well as pathology in images to a level necessary for the clinical involvement role of the MPE. S34. For each imaging modality, apply the theory of image formation for the analysis and optimization of clinical acquisition protocols. S35. For each imaging modality, manipulate acquisition parameters (e.g., tube voltage, filtration, contour filters, tube current, exposure time, field size, magnification in projection x-ray imaging) to optimize image quality and patient dose. S36. For each imaging modality, explain the effect of operator selectable parameters on image quality and hence clinical utility. S37. Apply theory of image reconstruction and post-processing to achieve optimal image quality for a specific clinical task. S38. For each imaging modality, assess imaging device performance levels requirements and scanning settings for specific clinical tasks. S39. Apply the theory of human image perception/observer performance to the optimization of image reading. S40. For each imaging modality, evaluate image quality from psychophysical studies with human observers. S41. For each imaging modality identify and correct causes of below target image quality and safety criteria. S42. For each imaging modality, recognize images from routine examinations.	C17. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Clinical Involvement. C18. Apply the theory of image formation to advise on the selection of the most appropriate imaging modality. C19. For each imaging modality, give advice regarding the adjustment of protocols to the needs of particular clients in studies which are complex, unusual, beyond-protocol and non-predictable. C20. For each imaging modality, advise on protocol modifications for paediatric imaging with respect to diagnostic effectiveness and safety.

Clinical Involvement in D&IR (cont.)	K105. For each imaging modality describe the patient's perspective in the entire process examination. K106. Explain the use of image guided treatment in the various specializations of medicine such as surgery, interventional radiology and cardiology. K107. For each imaging modality explain the different acquisition protocols used to perform common types of examinations (e.g., obstetrics and gynaecology, cardiac, abdominal, small parts- breast, testes, thyroid, musculo-skeletal, paediatric and vascular in ultrasound imaging).	S43. For each modality recognize, explain and give advice regarding image artefacts.	C21. For each imaging modality, give advice on the different types of processing of images for specific clinical applications. C22. For each imaging modality, advise on routine and advanced visualisation techniques. C23. Supervise image reconstruction and image handling procedures. C24. For each imaging modality advise on the implementation and application of systems for computer aided diagnosis. C25. For each imaging modality, provide practical safety-related guidelines. C26. Give advice on selection of appropriate RF coils for specific clinical applications in MRI. C27. Give advice regarding choice of appropriate transducers for B-mode and Doppler imaging.
Development of Service Quality and Cost-Effectiveness in D&IR	K108. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Development of Service Quality and Cost-Effectiveness. K109. Explain why development of service quality and cost-effectiveness in Diagnostic and Interventional Radiology necessitates the participation of the various professions. K110. Explain the role of the various professions involved in Diagnostic and Interventional Radiology with respect to the development of service quality and cost-effectiveness.		C28. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Development of Service Quality - Cost Effectiveness.
Expert Consultancy in D&IR	K111. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Expert Consultancy. K112. Discuss the particular ethical issues involved in expert consultancy in areas involving a high level of collective dose.		C29. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Expert Consultancy.

Education of Healthcare Professionals (including Medical Physics trainees) in D&IR	K113. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Education of Healthcare Professionals (including Medical Physics trainees). K114. Discuss the particular ethical issues involved in expert consultancy in the education of healthcare professionals (including Medical Physics trainees) in areas involving a high level of collective patient doses.		C30. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Education of Healthcare Professionals (including Medical Physics trainees).
Health Technology Assessment in D&IR	K115. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Health Technology Assessment. K116. Discuss the particular ethical issues involved in HTA in areas involving radiation, in particular ionizing radiation. K117. Explain how research medical exposures are managed in the context of Diagnostic and Interventional Radiology including the processes of ethical review and clinical trials administration and governance (GCP) and the use of appropriate dose constraints.		C31. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Health Technology Assessment.
Innovation in D&IR	K118. List statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Innovation.		C32. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Innovation.

Table A. 6: KSC Specific for the MPE in Nuclear Medicine

	Knowledge (facts, principles, theories, practices)	**Skills** **(cognitive and practical)**	**Competence** **(responsibility and autonomy)**
Scientific Problem Solving Service	K1. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Scientific Problem Solving Service. K2. Describe the application of beta decay, electron capture, positron decay, positron annihilation, isomeric transitions in Nuclear Medicine. K3. List and describe the radiation detectors specific to Nuclear Medicine. K4. Illustrate the characteristics of a Nuclear Medicine counting system including the effect of background counts and minimum detectable counts. K5. Discuss the characteristics of electronics related to Nuclear Medicine devices K6. Describe the concepts of fundamental detector properties like energy resolution, sensitivity, spatial resolution and temporal resolution and how they affect the performance of Nuclear Medicine devices. K7. Explain how statistical techniques are used for radiation measurement in Nuclear Medicine K8. Explain the physical and technological working principles of the imaging devices used in Nuclear Medicine including gamma camera systems, single photon and positron emission tomography systems, combined modality systems and dedicated scanner design. K9. List and describe the application of Information and Communication Technology (ICT) to Nuclear Medicine including image storage, image acquisition and processing and file format and secure file transfer K10. Describe the basic concepts of image reconstruction in Nuclear Medicine including analytical and iterative reconstruction techniques. K11. Illustrate the basic mathematical concepts used in Nuclear Medicine including linear systems, Fourier analysis and FFT, convolution/deconvolution, curve fitting and function optimization. K12. Describe the basic procedures for correction and quantitation, and fundamental limits in Nuclear Medicine. K13. Explain the concepts of compartmental analysis and its use in Nuclear Medicine. K14. List and explain the main types of computer codes used for dose calculation. K15. Describe up to date Nuclear Medicine literature, scientific reports and national and international recommendations.	S1. Identify measurable physical quantities relevant to Nuclear Medicine and realize experiments for their measurement. S2. Operate radiation measurement devices/detectors and interpret the results in the context of Nuclear Medicine. S3. Design and test physical and technical aids for physical measurements relevant to Nuclear Medicine. S4. Realize experiments for the measurement of properties relevant for instrument specific performance assessment, especially with reference to established national and international standards (NEMA, IEC). S5. Develop, assess and implement new methods and technologies in Nuclear Medicine. S6. Analyze and handle images from a Nuclear Medicine imaging device. S7. Extract parametrical information/image from Nuclear Medicine data. S8. Calculate biological parameters from Nuclear Medicine images using compartmental modelling.	C1. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Scientific Problem Solving Service. C2. Take responsibility for good practice in the use of sealed/unsealed sources of ionizing radiation. C3. Take responsibility for inventory of sealed radiation sources present in the laboratory and in the hospital environment. C4. Support the measurement of physical quantities relevant to Nuclear Medicine. C5. Take responsibility for the handling, management and maintenance of radiation measurement devices.

Diag.& Therap. NM Internal Dosimetry Measurements	K16. List statutory and institutional requirements for Medical Physics Services with respect to Diagnostic and Therapeutic Nuclear Medicine Internal Dosimetry Measurements. K17. List the various equipments and devices required within the context of patient dosimetry including probes, well counters, dose calibrators, gamma cameras & PET scanners (including hybrid systems) K18. Describe calibration factors including phantoms, phantom setup and measurements for dosimetry specific image quantification. K19. Describe and explain the role and influence of attenuation, background and scatter corrections / geometry / shielding / collimators/ dead time correction, partial volume effect, cross-talk, when relevant, in all devices involved in activity measurements. K20. Explain how cumulated activity is calculated from time-activity curve data by appropriate methods, including curve fitting algorithms and compartmental analysis. K21. Describe the influence of the equipment settings (e.g. choice of energy windows, collimators, scan duration, count statistics) on activity results and how temporal sampling (scheduling of image acquisition) affects the results obtained. K22. 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. K23. List methods for determining patient-specific organ masses including the respective errors and explain the difference between morphological and functional volume of organs or lesions. K24. Describe the principles of tumour dosimetry. K25. Explain the fundamental limitations of dosimetry at the organ level, for instance in deriving tumour dosimetry, taking into account activity and density heterogeneities. K26. Describe the application and use of techniques for the estimation of dose at the sub-organ, voxel and cellular level, in the context of radionuclide therapy (including radioimmunotherapy). K27. Describe device QC for dosimetry specific image quantification. K28. Describe how Dose-Volume-Histograms or isodose curves are calculated and what results should be provided.	S9. Distinguish between requirements for radiation protection dosimetry and the need for patient-specific dosimetry in a therapeutic setting. S10. Design optimal dosimetry protocols and calculation procedures for molecular radiotherapies. S11. Assess the requirements for quantitative imaging and/or other measurements for dosimetric purposes. S12. Calculate cumulative activities (incl. curve-fitting techniques and use of compartmental modelling). S13. Develop methods for ensuring reproducibility of dosimetry assessments. S14. Perform dosimetric calculations using the MIRD formalism. S15. Delineate the differences between methods used for calculating dose factors (point-kernel vs. Monte-Carlo). S16. Determine organ masses using different imaging modalities. S17. Determine whole body, organ and effective doses using tools such as OLINDA. S18. Apply correct radiobiological concepts. S19. Determine when voxel-based dosimetry and use of dose-volume histograms are appropriate. S20. Understand the concept of reference sources, both internal and external for absolute radioactivity determination (e.g., traceability, reference laboratories, accuracy).	C6. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Diagnostic and Therapeutic Nuclear Medicine Internal Dosimetry Measurements. C7. Take responsibility for dosimetric measurements necessary for dosimetric investigations. C8. Take responsibility and supervise the development of appropriate dosimetry protocols including quantitative imaging aspects, time-sampling, time-activity curves derivation and dose calculations.

Patient Safety / Dose Optimisation	K29. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Patient Safety / Dose Optimization for both diagnostic & therapeutic procedures. K30. Explain the concepts of absorbed dose and effective dose and the ALARA principle as applied to Patient Safety / Dose Optimization in Nuclear Medicine. K31. Explain the MIRD scheme, understanding its development and the fundamental characteristics and limitations of the formalism, and how this governs its usage. K32. Explain the role of the ICRP in the development of the dosimetric formalism, including use of the ICRP reference phantom. K33. Explain how standard geometric models may be made patient-specific by scaling to individual body mass, organ volume/mass and tissue density. K34. Explain how the main types of computer codes used for dose calculation can be used for dose optimization. K35. Describe how diagnostic and therapeutic medical exposures are managed in the context of Nuclear Medicine, including the application of Diagnostic Reference Levels and optimization of dose through prescription of activity and protocol. K36. Explain how research medical exposures are managed in the context of Nuclear Medicine, including the processes of ethical review and clinical trials administration and governance and the use of appropriate dose constraints. K37. Describe the process and practical implementation of radiation risk assessments in the context of Nuclear Medicine; using techniques for the qualitative and quantitative assessment of risk, and the assessment of dose to the patient arising from both internal and external sources of exposure.	S21. Participate in the development of optimized imaging and therapeutic protocols. S22. Systematize the inclusion of dosimetry reports based on injected activity and ICRP data for diagnostic procedures in patient medical records. S23. Apply relevant guidance document in dosimetry reporting for molecular radiotherapy. S24. Interpret radiation dose quantities related to CT devices as part of hybrid systems and apply these appropriately to dose optimization.	C9. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Patient safety / Dose Optimization for diagnostic & therapeutic procedures. C10. Take responsibility for patient dose optimization within the Nuclear Medicine facility. C11. Advise on the optimization of clinical protocols for Nuclear Medicine (including software aspects).

Occupational & Public Safety / Dose Optimisation (*when there is an impact on medical exposure or own safety)*	K38. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Occupational & Public Dose Optimization *when there is an impact on medical exposure or own safety*. K39. Describe the key considerations in the design of a Nuclear Medicine facility that optimise radiation safety of workers and the public (including classification of radiation areas); to include diagnostic Nuclear Medicine imaging with PET and multi-modality imaging, non-imaging or in-vitro laboratory procedures, radionuclide therapy, and radiopharmaceutical production including cyclotron PET tracer production. K40. Explain the need for, and use of radiation risk assessments in Nuclear Medicine using qualitative and quantitative risk assessment, and the assessment of dose to workers and public arising from internal and external exposure. K41. 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 and audit. K42. Describe the requirements for regulatory compliance with regard to the management and disposal of radioactive waste and the transportation of radioactive substances. K43. 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. K44. Explain how therapeutic exposures are managed in both inpatient and outpatient contexts. K45. Describe factors for optimizing acquisition/processing procedures to decrease CT dose in combined modalities. K46. Describe and explain the ALARA principle as applied to occupational and public dose optimization in Nuclear Medicine. K47. Describe appropriate systems for monitoring dose to pregnant and lactating workers, young workers, and the public, including selection, management and calibration of devices used to record doses and practical techniques for dose measurement. K48. Explain the practical application of the principles of time, distance and shielding to the radiation safety of the worker and public from Nuclear Medicine practices. K49. Explain how good radiation safety practice and appropriate personal protective equipment minimises internal radiation exposure of the worker and public in Nuclear Medicine. K50. Describe the role of designated radiation protection officers in the management of systems for radiation safety in Nuclear Medicine.	S25. Classify appropriately radiation areas within a Nuclear Medicine facility. S26. Apply the concept of ALARA and the principles of time, distance and shielding to the radiation safety of the worker and public in Nuclear Medicine. S27. Apply good radiation safety practice and the appropriate use of personal protective equipment to minimise internal and external radiation exposure of workers and the public arising from Nuclear Medicine. S28. Develop formal systems of work ('local rules') with regard to radiation safety in Nuclear Medicine.	C12. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Occupational & Public Dose Optimization *when there is an impact on medical exposure or own safety*.

Clinical Medical Device Management in NM	K51. Explain the purpose and implementation of formal systems of work ('local rules') with regard to radiation safety in Nuclear Medicine. K52. Explain the nature of contamination and practical measures required to affect environmental and personal decontamination in Nuclear Medicine; its relevance to radiation safety of the worker and public, and the principles, systems and precautions required to minimise the hazard. K53. Describe the principles of contingency planning and emergency procedures in Nuclear Medicine. K54. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Clinical Nuclear Medicine Device Management. K55. List the fundamental components of medical devices used in Nuclear Medicine. K56. Define the specifications of a Nuclear Medicine imaging device for tender purposes, generally and as tailored to particular clinical requirements. K57. Specify acceptability criteria for medical devices used in Nuclear Medicine both generally and with respect to their specific clinical usage. K58. List combined modality imaging systems and illustrate possible applications in Nuclear Medicine. K59. Describe the principles of QC for Nuclear Medicine devices, such as gamma probes, well counters, dose calibrators, gamma cameras, SPECT, PET, hybrid systems etc. K60. List the physical and chemical properties of radionuclide compounds selected to implement Quality Control (QC) and their radioprotection implications. K61. Describe the institutional framework for Quality Assurance (QA) activity and regulation in a Nuclear Medicine department. K62. Describe duties and responsibility of other health professionals involved in QA activities K63. Explain the principles of Quality Control for production of isotopes and synthesis of radiopharmaceuticals. K64. Describe QC measures in sequential imaging (several patient visits). K65. Describe QC for synergistic use of data from various modalities.	S29. Design a Nuclear Medicine facility. S30. Evaluate Nuclear Medicine devices in a tender both generally and as required with respect to particular clinical requirements. S31. Design and test physical and technical aids for examination/ treatment of patients. S32. Adapt QC protocols to the specific types/models of devices used in a particular Nuclear Medicine dept. S33. Analyze results of QC procedures, assess device performance by comparison to reference values as indicated by the manufacturer and/or local, national, European and other authorities/bodies. S34. Design and test physical and technical methods for the assessment of devices used in Nuclear Medicine S35. Interpret and apply local radioprotection rules as applicable to QC procedures. S36. Adapt national and international QC standards to specific equipment limitations, where appropriate. S37. Assess accuracy / reproducibility of radionuclide solution preparation. S38. Assess deviations of performance parameters from reference levels and interpret their relevance. S39. Implement cross-calibration procedures between devices. S40. Perform a documented risk assessment for equipment not within suspension levels.	C13. Take responsibility for the statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Clinical Medical Device Management. C14. Organize infrastructures for distribution, archiving and retrieval of Nuclear Medicine images. C15. Organize infrastructures for display and reading of examinations and for the reporting and archiving of findings. C16. Organize and supervise the preparation of radioactive sources for QC procedures.

Clinical Involvement in NM	K66. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Clinical Involvement. K67. Describe the general role of Nuclear Medicine procedures in diagnosis, therapy (including radioimmunotherapy) and treatment response evaluation. K68. Explain how the Nuclear Medicine devices are used for the solution of a clinical problem. K69. Describe the principle of radiopharmaceutical preparation and associated quality control. K70. Describe the principles of radiopharmaceutical biodistribution in normal organ and target tissues. K71. Describe the fundamentals of molecular radiotherapy (including radioimmunotherapy). K72. Explain the fundamentals of the use of PET in EBRT planning. K73. Describe general indications and contra-indications for Nuclear Medicine procedures. K74. Describe diagnostic procedure and clinical procedure guidelines. K75. Describe protocol optimization principles. K76. Describe the risk/benefit justification of Nuclear Medicine diagnostic and therapeutic procedures as related to the radiation exposure risk. K77. Explain the interactions/synergism between chemotherapy, EBRT and molecular radiotherapy. K78. Illustrate methodologies for the measurement of the lesion response to therapy. K79. List laboratory and imaging procedures to evaluate organ toxicity. K80. Illustrate dose limiting toxicity classification and quantification. K81. Describe how dosimetric calculations may be made in diagnostic and therapeutic practice, and how this conditions the level of accuracy required. K82. Explain how standard geometric models (e.g., MIRD) may be made patient-specific by scaling to individual body mass, organ volume/mass and tissue density. K83. Explain how standard exposures and procedures can be modified in special cases e.g., the pregnant patient, the lactating patient, paediatric patients. K84. Define the reproducibility of the patient positioning and list methods for ensuring reproducibility of image quality. K85. Explain the radiation protection principles underpinning current referral criteria for Nuclear Medicine procedures.	S41. Participate in the design of a patient specific treatment plan. S42. Estimate relevant activity to inject to paediatric patients according to international recommendations. S43. Analyze how molecular radiotherapy could impact on other treatment modalities. S44. Analyze critically new protocol proposals (i.e. feasibility, safety…). S45. Analyze the limits of acceptability of clinical Nuclear Medicine procedures. S46. Calculate patient and operator doses and consequent risks for a given clinical or experimental procedure. S47. Perform dosimetric calculations using the MIRD formalism, including the appropriate adaptation of standard models and data to achieve patient-specific estimates.	C17. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Clinical Involvement. C18. Advise Nuclear Medicine physicians in imaging interpretation and quantification. C19. Take responsibility for deriving semi-quantitative and quantitative data for clinical application. C20. Advise on different treatment schedule options. C21. Advise on the most appropriate procedure with respect to risk/benefit ratio. C22. Advise on and take responsibility for daily optimization of clinical acquisition protocols for individual patients in both standard and non-standard situations and their adaptation for particular patients. C23. Supervise procedures for paediatric investigations. C24. Advise on the use of Nuclear Medicine data for radiotherapy planning. C25. Assume responsibility for data handling / recording. C26. Support Nuclear Medicine staff with physical-technical guidelines. C27. Supervise image reconstruction and image handling procedures.

Development of Service Quality and Cost-Effectiveness in NM	K86. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Development of Service Quality and Cost-Effectiveness.	S48. Setup a feedback system for improving quality after non-conformities, deviations and accidents. S49. Measure quality management performance and improvements. S50. Implement cross-institutional quality control procedures.	C28. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Development of Service Quality and Cost-Effectiveness.
Expert Consultancy in NM	K87. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Expert Consultancy.	S51. Apply MPE consultancy skills to specific scenarios in Nuclear Medicine.	C29. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Expert Consultancy. C30. Take responsibility for clinical consultancy services in Nuclear Medicine commensurate with level of personal expertise.
Education of Healthcare Professional (including Medical Physics trainees) in NM	K88. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Education of Healthcare Professionals (including Medical Physics trainees). K89. Describe appropriate programmes for staff training in radiation safety in Nuclear Medicine.	S52. Develop appropriate programmes for staff training in radiation safety with regard to Nuclear Medicine.	C31. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Education of Healthcare Professionals (including Medical Physics trainees). C32. In conjunction with other healthcare professionals in Nuclear Medicine, take responsibility for ensuring that referrers are knowledgeable of current referral criteria for Nuclear Medicine procedures. C33. Take responsibility for the delivery of appropriate programmes for staff training in radiation safety with regard to Nuclear Medicine. C34. Teach healthcare professionals the physical principles of radionuclide decay, production and handling and the working principles of devices used in Nuclear Medicine. C35. Train healthcare professionals in the optimized use of medical devices used in Nuclear Medicine. C36. Supervise and train healthcare professionals in the use of new devices and/or methods. C37. Train staff to implement patient dose optimization within the Nuclear Medicine facility.

Health Technology Assessment in NM	K90. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Health Technology Assessment. K91. Explain the principles of business and strategic planning for Medical Physics Services in Nuclear Medicine. K92. Illustrate the cost effectiveness of the Medical Physics Services in Nuclear Medicine. K93. Describe the design principles, relevant legislation issues and approval procedures for clinical trials in Nuclear Medicine. K94. Explain the principles of Health Technology Assessment (HTA) as applied to medical device technologies and procedures used in Nuclear Medicine. K95. Define the roles and responsibilities of all the professionals involved in a Nuclear Medicine HTA project. K96. List the issues that should be considered in a Nuclear Medicine HTA project. K97. Explain the importance of HTA reports in controlling cost in relation to benefit for the considered technology in Nuclear Medicine. K98. Explain the value of a Nuclear Medicine HTA report to the relevant policy makers at the European, national, regional and facility levels.	S53. Develop a business and strategy plan for Medical Physics Services in Nuclear Medicine S54. Design and monitor the medical physics components of clinical trial protocols in Nuclear Medicine S55. Perform statistical analysis and report on clinical trials involving medical physics services in Nuclear Medicine S56. Assemble a suitable technical team for a specific HTA project in Nuclear medicine S57. Conduct the technical components of an HTA project in Nuclear medicine.	C38. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Health Technology Assessment. C39. Take responsibility for the development and implementation of a business and strategy plan for the Medical Physics Services in Nuclear Medicine C40. Advise and participate in the design of clinical trials involving medical devices in Nuclear Medicine C41. Take responsibility for the technical components of an HTA project in Nuclear Medicine. C42. Evaluate clinical trial protocols. C43. Share responsibility for conducting clinical trials. C44. Advise on relevant aspects of ethical review of a clinical trial
Innovation in NM	K99. List statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Innovation. K100. Describe the methodology of horizon scanning for new and emerging technologies in Nuclear Medicine.	S58. Integrate new devices (incl. software) in an existing infrastructure S59. Apply the methodology of horizon scanning (including listing of specific information sources) for new and emerging technologies in Nuclear Medicine.	C45. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Innovation. C46. Take responsibility for the development of new devices (including software) or modification of existing devices (including software) in response to clinical needs in Nuclear Medicine. C47. Take responsibility for definition of new experimental set-ups and the development of new phantoms for performance assessment of existing / new devices.

Table A. 7: KSC Specific for the MPE in Radiation Oncology/Radiotherapy

	Knowledge (facts, principles, theories, practices)	**Skills** **(cognitive and practical)**	**Competence** **(responsibility and autonomy)**
Scientific Problem Solving Service	K1. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to Scientific Problem Solving Service. K2. Explain the functioning, characteristics, strengths and limitations of the various types of available treatment devices: kV therapy devices, cobalt units, medical 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. K3. Explain the physical principles, capabilities and limitations of the different external beam irradiation techniques: 3D conformal, rotational techniques (conformal arcs, conformal dynamic arcs), non-coplanar. K4. Explain the functioning and characteristics of the various types of in-room imaging devices available on the market (e.g., EPID, kV-MV CBCT, stereoscopic X-ray imaging systems, in-room CT, MRI, USI). K5. Explain the importance of geometrical accuracy (includ. its repeatability and stability) of imaging devices for Radiation Oncology. K6. Explain the functioning and characteristics of devices for accelerating / delivering protons and heavier ions for Radiation Oncology. K7. Explain the techniques of field formation (passive, active) with protons and heavier ions include. intensity modulation and organ motion compensation. K8. Explain the function of treatment planning system (TPS) software as a virtual treatment system with dose distribution calculator (including associated features e.g., BEV, DRR, DVH). K9. Discuss the limitations of dose calculation algorithms for heterogeneity corrections in low density tissue and tissue interfaces where electronic equilibrium is not fully established. K10. Describe and explain source and points position reconstruction algorithms for brachytherapy (radiographic films, CT and other image based algorithms). K11. Explain the AAPM TG-43 dose calculation algorithm and modern model based algorithms for brachytherapy. K12. Explain the physical and radiobiological advantages of protons and heavier ions for Radiation Oncology and clinical indications for use. K13. Explain methods of cancer treatment using non-ionising radiations (e.g., RF ablation) and explain their relative efficacy, benefits and risks with respect to ionising radiation.	S1. Operate devices used in radiation oncology. S2. Operate radiation measurement devices/detectors and interpret the results in the context of radiation oncology.	C1. Take responsibility for statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to a Scientific Problem Solving Service. C2. Carry out or supervise the measurement of physical quantities relevant to the effective, safe and economical use of medical devices / radiation in radiation oncology. C3. Realize experiments for the measurement of properties relevant to instrument specific performance assessment with reference to national and international standards (e.g., IEC). C4. Evaluate and implement new methods and technologies in radiation oncology.

External Beam & Brachy. Dosimetry Measurements	K14. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to External Beam & Brachytherapy Dosimetry Measurements. K15. Explain the terminology used in photon, electron and proton Radiation Oncology dosimetry (e.g., PDD, TMR, TPR, OAR). K16. Describe and explain recommended national and international (e.g., IAEA) absorbed dose measurement protocols based on absorbed dose in water/solid phantoms for photon, electron, proton and heavier ion beams using different sensors types of sensors (ionisation chambers, diodes, film, TLD). K17. Explain the various approaches to in-vivo dosimetry for Radiation Oncology beams and discuss choice of appropriate sensors. K18. Describe the calibration chain for dosimetry sensors used in Radiation Oncology. K19. Explain the theoretical and practical aspects of reference dosimetry for high-energy photons, electrons and brachytherapy sources. K20. Explain the concepts of in-vivo dosimetry for ion beam Radiation Oncology including range verification methods using PET. K21. Describe and explain recommended methods for reference air kerma (RAK) determination for LDR/HDR/PDR brachytherapy sources. K22. Describe and explain the functioning, characteristics, strengths and limitations of sensors used for RAK measurement. K23. Define reference conditions for fixed-SSD and isocentric approaches. K24. Explain basic dosimetry in non-reference conditions (e.g. extended SSD, off-axis). K25. Explain the following concepts and methods of relative dosimetry: central axis dose distribution in water, output factors (effects of head scatter and phantom scatter, dependence on treatment parameters), 3D dose distribution, beam profiles (e.g., penumbra region, flatness, and symmetry), effects of beam modifiers such as hard and virtual wedges, compensators and bolus.	S3. Select the most appropriate detector for measuring absolute and relative dose distributions in different irradiation conditions for photon and for electron beams. S4. Calculate uncertainties in Radiation Oncology dosimetry measurements. S5. Use the national recommended Code of Practice for the determination of absorbed dose to water from external radiotherapy photon beams. S6. Measure absorbed dose in external radiotherapy beams under both reference and non-reference conditions. S7. Cross-calibrate ionization chambers and diode dosimeters at the local facility. S8. Perform brachytherapy source calibration (including measurement uncertainties). S9. Interpret source calibration certificates from manufacturers. S10. Perform constancy checks (e.g., strontium-90 based) on ionization chambers and calibrate diode dosimeters. S11. Perform 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).	C5. Take responsibility for Medical Physics Services in Radiation Oncology with respect to External Beam & Brachytherapy Dosimetry Measurements. C6. Take responsibility for in-vivo dosimetry in external beam and brachytherapy Radiation Oncology. C7. Set up a program for acceptance testing, calibration and quality control of dose measurement systems used in Radiation Oncology. C8. Carry out a Radiation Oncology dose audit. C9. Take responsibility for the calibration of ionizing chambers in a traceable dosimetry laboratory. C10. Determine brachytherapy source strengths according to national and international (e.g., IAEA) protocols and recommendations. C11. Perform pre-treatment dosimetric verification of treatment plans for standard and sophisticated Radiation Oncology techniques (such as standard 3D-CRT plans, special technique plans, IMRT) in a phantom.

Patient Safety / Dose Optimisation	K26. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to Patient Safety / Dose Optimization. K27. Explain dose-effect relationships relevant to Radiation Oncology with respect to patient safety including discussion of the physical and biological background, response of tissues to radiation on molecular, cellular and macroscopic level, models (including limitations of existing models) of radiation induced cancer and hereditary risks and radiation effects on humans in general, children and the conceptus. K28. Describe and explain the principles and structure of treatment planning and dose optimization (including limitations) in the case of patients undergoing treatment with photon, electron, proton and heavier ion beams (including special techniques such as stereotactic treatments, IMRT, IMAT). K29. Describe and explain the principles and structure of brachytherapy treatment planning systems, dose calculation algorithms (TG 43, model based algorithms) and optimization algorithms for HDR, LDR and PDR. K30. Explain the limitations in existing models for treatment planning systems. K31. Explain how conventional techniques are used to optimize dose distributions. K32. Explain P+, utility function and other appropriate models used in optimization of treatment outcomes. K33. Explain the use of Artificial Intelligence (e.g., Bayesian statistics and artificial neural networks) to the management of cancer. K34. Explain how comforters and carers are managed in the context of radiation oncology and the use of appropriate dose constraints.	S12. Use radiobiological dose-effect relationships relevant to Radiation Oncology to estimate patient risks (including potential adverse incidents involving high exposures). S13. Assess sources and levels of uncertainty in geometry and dose delivery and apply methods for their monitoring and control. S14. Evaluate the clinical implications of the strengths and limitations of the locally available afterloading systems and sources.	C12. Take responsibility for Medical Physics Services in Radiation Oncology with respect to Patient Safety / Dose Optimization. C13. Take responsibility for patient dose optimization within the Radiation Oncology facility. C14. Investigate radiation incidents involving patients to determine the cause(s) and recommend appropriate remedial action. C15. Take responsibility for good practice in the use of sealed/unsealed sources of ionizing radiation with respect to patient safety. C16. Evaluate critical radiobiological calculations performed by commercial treatment planning systems. C17. Set the requirements of PET studies specifically for Radiation Oncology planning.

Occupational & Public Safety / Dose Optimisation (***when*** *there is an impact on medical exposure or own safety)*	K35. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to occupational / public dose optimization *when there is an impact on medical exposure or own safety*. K36. Explain dose-effect relationships relevant to Radiation Oncology with respect to occupational/public safety including discussion of the physical and biological background, response of tissues to radiation on molecular, cellular and macroscopic level, models of radiation induced cancer and hereditary risks and radiation effects on humans in general and the conceptus. K37. Explain the principles of risk management as applied to Radiation Oncology devices and ionising radiation in the case of workers / public with respect to external beam therapy and brachytherapy. K38. Explain international, European and local radiation protection regulations regarding the use of radiation producing devices and sealed radioactive sources. K39. Explain the principles underpinning the design of radiation safety plans for radiation producing devices in Radiation Oncology.	S15. Use radiobiological dose-effect relationships relevant to Radiation Oncology to estimate occupational/public risks (including adverse incidents involving high exposures). S16. Apply International, European and National regulations for the transport, handling, storage and use of radioactive sources in Radiation Oncology.	C18. Take responsibility for Medical Physics Services in Radiation Oncology with respect to occupational / public dose optimization *when there is an impact on medical exposure or own safety*.

Clinical Medical Device Management in RO	K40. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to Clinical Medical Device Management. K41. Describe the hardware and software components of a treatment planning system (TPS) and associated networking standards (e.g., DICOM, DICOM-RT). K42. Explain the principles of quality control of external beam, brachytherapy, TPS and associated imaging systems.	S17. Specify, justify and rank the criteria for specifying and selecting treatment and in-room imaging devices. S18. Import measured beam data into a TPS. S19. Specify, justify and rank the criteria for selecting a TPS. S20. Evaluate the specifications for external beam therapy devices. S21. Perform acceptance testing, commissioning and quality control of treatments units, TPS, imaging systems and networks in Radiation Oncology. S22. Perform acceptance testing, commissioning and constancy testing of treatment units and in-room imaging devices. S23. Perform acceptance testing, commissioning and QC of after-loading equipment (LDR, HDR, PDR), treatment planning systems, sources and applicators, imaging systems in brachytherapy, networks, etc. using national, international recommendations and local protocols.	C19. Take responsibility for Medical Physics Services in Radiation Oncology with respect to Clinical Medical Device Management. C20. Take responsibility for acceptance testing, commissioning and quality control of treatments units, TPS, imaging systems and networks in Radiation Oncology. C21. Take responsibility for acceptance testing, commissioning and constancy testing of treatment and in-room imaging devices. C22. Take responsibility for acceptance testing, commissioning and QC of after-loading equipment (LDR, HDR, PDR), treatment planning systems, sources and applicators, imaging systems in brachytherapy, networks, etc. using national, international recommendations and local protocols. C23. Manage brachytherapy sources including source specification, source security, procedures in case of source loss and source disposal. C24. Setup and manage a quality control program for brachytherapy sources (including leakage tests), source calibration equipment, applicators and treatment planning systems. C25. Take responsibility for inventory of sealed radiation sources present in the brachtherapy laboratory and in the hospital environment.

Clinical Involvement in RO	K43. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to Clinical Involvement. K44. Describe and explain oncogenesis, the development of cancer, the role of oncogenes and suppressor-genes, the nature of the various forms of cancers and their molecular and cellular features. K45. Explain at an appropriate level the clinical advantages / disadvantages of the various diagnostic options for the various forms, stages and body location of cancer. K46. List and explain the clinical advantages / disadvantages of surgical, chemotherapeutic and radiation options for the treatment of the various forms, stages and body location of cancer. K47. Explain models for DNA damage, cell survival, repair and fractionation models. K48. Explain the mechanisms involved in novel drugs commonly used in combination with radiation. K49. Describe the radiosensitivity of relevant tissues and tolerance doses for normal tissues (e.g., QUANTEC). K50. Explain how the radiosensitivity of tumour and normal tissues is influenced by combinations of chemotherapy and radiation therapy. K51. Explain the radiobiological rationale underpinning the various treatment strategies (fractionation, dose rate, radiosensitization and reoxygenation) in radiation therapy. K52. Explain therapeutic ratio, tumour control probability, normal tissue complication probability, tolerance doses, dose-volume effects. K53. List and describe the major signalling pathways of importance for response to radiation. K54. Explain the response to therapeutic levels of X-ray, electrons, protons and heavier ions at the molecular, cellular, tissue and macroscopic levels for tumour and normal tissue. K55. Explain and use ICRU terminology and recommendations regarding target volumes (e.g., GTV, CTV, PTV, PRV), organ at risks and specification of dose and volumes, margin decisions, including international recommendations (ICRU 50, 62, 83). K56. Describe quantitatively the radiation fields produced by external beam devices and their clinical specification. K57. Specify beam quality in terms of quality index for photons beams and range / energy parameters for electron beams. K58. Describe the characteristics of clinical beams in air and water / solid phantoms. K59. Explain the use of the various imaging modalities (including PET/CT, PET/MRI, and ultrasound) in the different stages of the radiation oncology process. K60. Explain the methods for management of patient organ motion in radiation oncology.	S24. Use a TPS for patient specific treatment plan generation and optimization. S25. Use conventional techniques for creating optimized patient specific dose distributions using beam combinations, beam shaping, weighting and normalization, wedges, bolus, compensators, MLCs, field matching. S26. Analyze acquisition protocols in CT and MR imaging and the effect of user set parameters on the appearance of the image and its clinical utility for Radiation Oncology. S27. Operate treatment devices and in-room imaging devices available at own institution effectively and safely. S28. Use immobilization (including stereotactic) devices for the immobilization of patients. S29. Design and test physical and technical aids for simulation/treatment of patients. S30. Perform detailed dose-response analysis from clinical data and patient series. S31. Analyze dose specifications and volume definitions according to national and international protocols and recommendations (including ICRU 38 and 58, GEC ESTRO, ABS). S32. Use conventional and CT/CBCT simulators for patient specific planning and plan verification. S33. Acquire multimodality imaging data and perform image fusion for target volume delineation and planning. S34. Use IMRT techniques (forward / inverse planning, fluence map optimization) for creating optimized patient specific dose distributions: fixed-gantry IMRT (static / dynamic MLC), rotating-gantry IMRT (serial / helical tomotherapy, intensity-modulated arc therapy). S35. Archive, back-up and restore treatment plans. S36. Evaluate how normal tissue tolerances are set up in own department.	C26. Take responsibility for Medical Physics Services in Radiation Oncology with respect to Clinical Involvement. C27. Take responsibility for patient specific patient treatment plan optimization and minimizing absorbed doses to organs at risk. C28. Take responsibility for the accuracy of MU calculations and treatment MU verification using suitable measurements or independent calculation. C29. Evaluate image quality acquired during the Radiation Oncology process. C30. Give advice on optimization and safety of individual patient simulation/treatment and simulation/treatment protocols. C31. Optimise treatment parameters and perform specific dose measurements for pregnancy cases. C32. Advise on fractionation and dosimetry for completion of a Radiation Oncology treatment following omission of a wedge in early fractions. C33. Give advice regarding the most appropriate technique according to tumour site and intent of the treatment. C34. Advise on need of follow-up visits. C35. Record and report dosimetric parameters according to international recommendations. C36. Take responsibility for the evaluation of magnitudes and sources of day-to-day treatment variability / uncertainties in radiation oncology and their clinical implications, set tolerances and action levels. C37. Involve oneself closely in the overall clinical process of brachytherapy from operating theatre through simulator localization, treatment planning, source preparation and delivery. C38. Take responsibility for independent verifications of calculated treatment times of intra-cavitary insertions and interstitial implants using manual methods. C39. Take responsibility to verify, optimize and QA treatment plans for individual patients. C40. Implement techniques for minimizing errors due to target motion resulting from respiration (respiratory gating, breath hold and tumor tracking). C41. Take responsibility for the verification of correct data transfer from the TPS to the treatment unit.

Clinical Involvement in RO (cont.)	K61. Explain how CT patient simulators provide a virtual (immobilized) patient for treatment plan generation and optimization purposes. K62. Compare national and international treatment protocols for different irradiation techniques with those used at own institution. K63. Describe the effect of various beam arrangements, beam modification devices (hard and virtual wedges, compensators, blocks, MLCs, bolus) and beam weights on dose distribution. K64. Explain the various meanings of the term 'normalization'. K65. Explain how IMRT techniques are used for creating optimized dose distributions: fixed-gantry IMRT (static or dynamic MLC), rotating-gantry IMRT (serial and helical tomotherapy, intensity-modulated arc therapy). K66. Discuss the use of 4D treatment planning systems. K67. Compare different levels of treatment planning complexity in relation to clinical requirements and the uncertainties involved. K68. List and describe the various radionuclides and types of sealed sources used in brachytherapy and their clinical use. K69. Describe permanent and temporary implants and associated techniques used in clinical applications. K70. Describe in mathematical terms dose calculation algorithms (correction-based, model-based and Monte Carlo) for photon and electron beams. K71. Explain pre-planning models for intracavitary and interstitial brachytherapy (GEC ESTRO, Manchester, Paris, image based dosimetry). K72. Explain how research medical exposures are managed in the context of radiation oncology, including the processes of ethical review and clinical trials administration and governance (GCP) and the use of appropriate dose constraints.	S37. Perform fractionation calculations, response calculations (using NTCP/TCP models), effective dose calculations and volume effect corrections using established models. S38. Perform plan optimization and evaluation using uniformity criteria, constraints, DVHs and biological parameters (TCP, NTCP). S39. Operate imaging systems used in brachytherapy. S40. Use classical dose distribution calculation systems for LDR (e.g., Paris and Manchester systems) and extension to HDR, PDR. S41. Participate in special brachytherapy techniques (e.g., permanent prostate seeds, stereotactic brain implants, eye plaques, partial breast irradiation). S42. Participate in the verification of the different steps of treatment: patient positioning, target localisation, and dosimetric verification of the irradiation plan. S43. Perform conformal 3D and IMRT treatment plans of a suitable set of the most representative tumour sites. S44. Perform optimised plans for LDR/HDR/PDR. S45. Perform optimised plans for permanent seeds prostate brachytherapy implantation. S46. Use the 'record and verify' system available at the institution to verify data transfer from the TPS to the treatment unit. S47. Apply the principles of optimization in daily routine in a Radiation Oncology facility with respect to patient dose optimization.	

Clinical Involvement in RO (cont.)		S48. Create o Perform independent monitor unit calculation for dosimetric verification of treatment plans. S49. Implement different IGRT on-line or off-line correction protocols to improve accuracy of patient positioning, target localization, and minimize intra and inter-fraction set-up errors. S50. ptimized dose distributions for sophisticated and special radiation oncology techniques: stereotactic radiation oncology (SRT) / radiosurgery (SRS), intraoperative radiation therapy (IORT), total body irradiation (TBI), total skin electron irradiation (TSEI), gated irradiation of mobile targets. S51. Perform manual monitor unit or time calculations for MV and kV X-ray beams, gamma rays and electron beams for a variety of clinical situations S52. Check computer calculations of monitor units on treatment plans using the institution‘s charts or independent monitor unit calculation program, taking into account field-size factors, wedge factors and other relevant factors.	
Development of Service Quality & Cost-Effectiveness in RO	K73. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to the development of service quality and cost-effectiveness. K74. Explain why development of service quality and cost-effectiveness in radiation oncology involves the development of all steps of treatment i.e., simulation, planning, verification, delivery and reporting.		C42. Take responsibility for statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to the development of service quality and cost-effectiveness. C43. Share responsibility of the leadership of a multi-disciplinary team managing the quality development of all steps of treatment i.e., simulation, planning, verification, delivery and reporting.

Expert Consultancy in RO	K75. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to expert consultancy. K76. Discuss the particular nature of consultancy and ethical issues involved in the clinical use of high levels of ionising radiation.		C44. Take responsibility for statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to expert consultancy. C45. Take responsibility for the particular nature of consultancy and ethical issues involved in Radiation Oncology and the clinical use of high levels of ionising radiation.
Education of Healthcare Professional (including Medical Physics trainees) in RO	K77. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to the education of Healthcare Professionals (including Medical Physics trainees). K78. Discuss the particular education and training issues associated with the clinical use of high levels of ionising radiation.		C46. Take responsibility for statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to the education and training of Healthcare Professionals (including Medical Physics trainees). C47. Take responsibility for the particular education and training issues associated with the clinical use of high levels of ionising radiation.
Health Technology Assessment in RO	K79. List statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to HTA. K80. Discuss the particular issues associated with HTA activities involving the clinical use of high levels of ionising radiation. K81. Explain how research medical exposures are managed in the context of radiation oncology, including the processes of ethical review and clinical trials administration and governance (GCP) and the use of appropriate dose constraints.		C48. Take responsibility for statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to HTA.
Innovation in RO	K82. Discuss the particular issues associated with innovation involving Radiation Oncology and in particular the clinical use of high levels of ionising radiation.		C49. Take responsibility for the particular issues associated with innovation involving Radiation Oncology and in particular the clinical use of high levels of ionising radiation.

APPENDIX B: Examples of MPE Staffing Levels for Radiotherapy, Nuclear Medicine and Radiology services

B.1 Examples of MPE Staffing Levels for Radiotherapy

In order to provide clarity with the above recommendations, it is useful to consider a radiotherapy service that has:

- 3 multi-energy linear accelerators with MLC's, virtual wedge and portal imaging systems,
- 1 with IMRT
- 1 with stereotactic body radiotherapy (SBRT)
- 1 CT-simulator;
- 1 3D treatment planning system with advanced modules (IMRT, SBRT);
- 1600 treatments per year,
- 600 of them with 3D planning,
- 100 with IMRT and
- 100 with SBRT.

Table B. 1: Calculation of staffing levels in Radiotherapy

	MPE WTE	**MPS WTE**
Equipment Dependent	2.7	5.8
Patient Dependent	2.2	6.9
Service Dependent	0.3	0.6
TOTAL	**5.2**	**13.3**

For a department consisting of the above units and patient activity 5.2 WTE MPEs are required. This may be rounded to 5 WTE MPEs but the total staffing levels must be kept as calculated. In this example it is possible 1 MPE will be the lead for external beam, 1 for brachytherapy, 1 for treatment planning, 1 for unsealed therapies and 1 for advanced, highly complex and novel treatments and those involving clinical trials.

B.2. Example of MPE Staffing Levels for Nuclear Medicine

In order to provide clarity with the above recommendations we consider a Nuclear Medicine department that has:

- 3 SPECT cameras;
- 3 computerised systems for image analysis;
- 4 non-imaging systems;
- 5000 SPECT studies per year
- 200 outpatient radionuclide treatments.

Table B. 2: Calculation of staffing levels in Nuclear Medicine

	MPE WTE	MPS WTE
Equipment Dependent	0.4	0.9
Patient Dependent	0.5	1.1
Service Dependent	0.6	0.9
Research and Training*	0.5	0.7
TOTAL	**2.0**	**3.6**

** multiplying each factor in this section by 1*

B.3. Example of MPE Staffing Levels for Radiology

In order to provide clarity with the above recommendations we consider an x-ray department that has:

- 2 CT scanners,
- 10 fixed x-ray units,
- 2 interventional fluoroscopy units,
- 3 analogue mammography units, and
- analysis of patient doses in Interventional Radiology and Cardiology involving 5,000 patients,
- estimations of patient skin doses and follow up for high doses on 50 patients,
- analysis of patient doses in CT involving 10,000 patients,
- risk assessments for 10 pregnant patients.

Table B. 3: Calculation of staffing levels in Radiology

	MPE WTE	MPS WTE
Equipment Dependant	0.2	0.6
Patient Dependant	0.2	0.4
Service Dependant	0.2	0.4
Research and Training*	0.5	0.7
TOTAL	**1.1**	**2.1**

**** multiplying each factor in this section by 1***

For a department consisting of the above units and patient activity 1.1 WTE MPEs are required. This may be rounded to 1 WTE MPE but the total staffing levels must be kept as calculated.