EUROPEAN COMMISSION

RADIATION PROTECTION

No. 174

EUROPEAN GUIDELINES ON MEDICAL PHYSICS EXPERT

ANNEX 1

Inventory of Learning Outcomes for the MPE in Europe

Project: “Guidelines on Medical Physics Expert"
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The statements and recommendations of this report do not necessarily reflect the position of the European Commission.

Contents

Curriculum Framework for MPE programmes in Europe

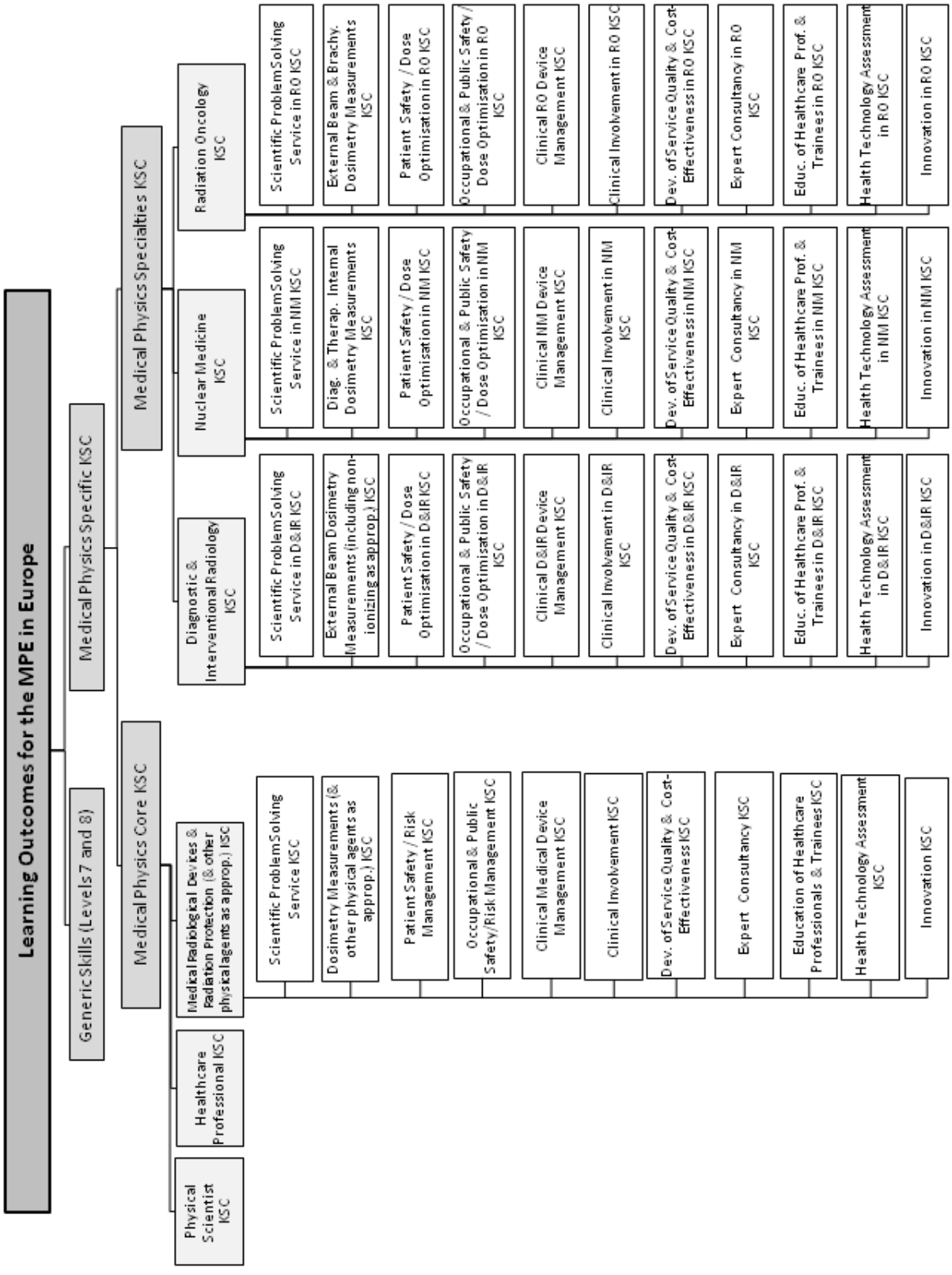

Table 1: Generic Skills

Generic Skills Required at Level 7	Generic Skills Required at Level 8 (MPE Level)
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 2: KSC for the MPE as Physical Scientist

Knowledge **(facts, principles, theories, practices)**	**Skills** **(cognitive and practical)**	**Competence** **(responsibility and autonomy)**
K1. Explain the fundamental quantities and dimensions of physics, including use in checking consistency of equations. K2. Explain the common fundamental and derived constants of physics. K3. Explain the base and derived SI units. K4. Explain the properties of the common fundamental particles, including mass, charge and spin. Particle-antiparticle annihilation (in depth treatment of positron-electron annihilation). K5. Explain the various forms of energy and types of forces in nature and the properties of their carrier particles. K6. Explain the principles of quantum theory and relativistic mass-energy. K7. Explain 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. Explain the structure of the periodic table and chart of the nuclides. K10. Explain the various forms of chemical bonding. K11. Explain the forms of spectroscopy / spectrometry (including MRS and EPR) K12. Explain the band theory of solids with particular emphasis on semiconductors. K13. Discuss nuclear stability, explain 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. Explain the main types of nuclear reactions including phototransmutation. K15. Explain processes for the production of medical radionuclides using cyclotrons, reactors and generators, including quantities of generated activities in thin and thick targets. K16. Explain the characteristics of common electronic components and integrated circuits. K17. Explain the general design of a measuring instrument K18. Utilize the ISO international vocabulary of metrology (VIM). K19. 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. Explain 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. 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. Explain: temporal / frequency domain representation of signals, Fourier transform, statistical description of signals, power	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: - Explain 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.

spectral density, autocorrelation function, sample (discrete) signals, 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. 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. Explain 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 explain 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. Explain 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. Explain 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 properties of neutron beams including moderation and attenuation. K37. Discuss the characteristics of the common statistical distributions: normal, log-normal, t, Poisson. K38. Explain the various forms of uncertainties in the measurement of data and their treatment (GUM approach). K39. Explain the concept of bias in measurement and ways to avoid it. K40. Explain how quantitative statistical techniques are used to interpret and handle data, including the calculation of confidence intervals, combined uncertainties, correlation, regression and hypothesis testing and the influence of sample size. Include specific techniques of relevance to the particular specialty of medical physics (e.g., sensitivity, specificity, ROC, VGA, model observers in diagnostic studies). K41. Explain the statistics of nuclear decay, photon / particle interactions with matter and ionizing radiation measurement. K42. Explain the principles of modelling and simulation including statistical modelling based on Monte-Carlo techniques. K43. Discuss the principles and processes of physics research.		

Table 3: KSC for the MPE as a Healthcare Professional

Knowledge **(facts, principles, theories, practices)**	**Skills** **(cognitive and practical)**	**Competence** **(responsibility and autonomy)**
K1. 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. Explain 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. K10. Explain the European and national legal frameworks, regulations, guidelines and codes-of-practice impacting the role of the MPE. K11. Explain briefly European and national legal frameworks, regulations, guidelines and codes-of-practice impacting the practice of other professions with whom the MPE interacts. K12. Discuss the development of the MPE profession in both the local and European context. K13. Discuss the principles of healthcare management. K14. Discuss the principles of epidemiology. K15. 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. Survey 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 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. Explain 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 explain 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. Explain 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. Explain 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 applying 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 apply 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 apply 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. Explain 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. 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. Design and equip an appropriate space 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. In the case of acceptance testing this should be done in cooperation with the vendor. 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. Explain 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. 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. Explain 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. Explain 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. C24. Investigate in conjunction with the vendor technical factors leading to accidental/unintended exposures.

Patient Safety / Risk Management (cont.)	K26. Explain 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. Explain 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. 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. 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 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.	C25. 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. 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. Explain 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. Explain 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.	C26. 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain 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. 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. 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. Survey 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. Explain 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. Explain relevant data and ICT security standards for collection, storage and transmission of data and Data Protection Legislation K68. Explain 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. Explain 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.	C27. 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. C28. 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, installation design and surveillance, and service contract management in own area of medical physics practice. In the case of acceptance testing this should be done in cooperation with the vendor. C29. Participate in the procurement of new devices in own area of medical physics practice. C30. Take responsibility for the maintenance of quality control records. C31. Organize infrastructures for distribution, archiving and retrieval of images. C32. Organize infrastructures for display and reading of images and for the reporting and archiving of findings. C33. Pursue corrective actions with minimum interference with departmental functionality. C34. Establish and plan QA/QC procedures in appropriate support of the specific activity in own area of medical physics practice. C35. 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. C36. 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. 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 explain the various types of documentation issued by these bodies and their use in medical device management. K77. 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.	C37. Participate in the installation of new devices in own area of medical physics practice. C38. Negotiate device acceptance with provider and own department management following acceptance tests. C39. Organize, manage and train quality control teams in own area of medical physics practice. C40. Decide if actions are required on a medical device to restore default performance. C41. Define warning and suspension levels for devices.

Clinical Involvement	K80. Explain statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Clinical Involvement. K81. 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. Explain 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. Explain 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. Explain 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. Explain 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. Survey 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 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 anatomical / pathological structures of the human body in projection / tomographic and 3D medical images relevant to own area of medical physics practice. S46. Recognize 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.	C42. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Clinical Involvement. C43. Oversee daily patient safety / risk management involving medical devices and associated ionizing radiations and other physical agents in own area of medical physics. C44. 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. C45. Advise physician in image interpretation and quantification when appropriate. C46. Take responsibility for semi-quantitative and quantitative data for clinical application. C47. Advise on different patient diagnosis / treatment schedule options when appropriate. C48. Participate in the definition of the limits of acceptability of clinical procedures. C49. Advise on the most appropriate procedure with respect to risk/benefit ratio. C50. Supervise procedures for paediatric investigations in relation to dose optimization. C51. Advise other healthcare professionals on optimization and safety of individual patient examination / treatment and examination / treatment protocols. C52. Live up to demands imposed by duty of confidentiality, professional secrecy, ethical standards. C53. Represent medical physics in clinical conferences. C54. 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. Explain 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. Explain 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. Explain 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. Explain responsibilities of other healthcare professionals involved in QA activities in own area of medical physics practice. K108. Explain 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. Explain the institutional framework of QA activity and regulation in own area of medical physics practice. K111. Explain the functions of the major International and European standard setting bodies for healthcare quality; explain 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 explain how the evidence base can be used to improve service quality. K113. Explain 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.	C55. 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. C56. Advise on the technical aspects impacting the clinical effectiveness and safety of new medical devices or techniques prior to their introduction into clinical practice. C57. Participate in the design and implementation of QA systems in own area of medical physics practice. C58. Take responsibility for using the methodologies of Evidence Based Medicine to investigate ways of improving service quality within own area of medical physics practice. C59. Assume responsibility for quality management audits involving medical devices and associated ionizing radiations and other physical agents. C60. Take responsibility for the design and implementation of a monitoring system for Medical Physics Services in own area of medical physics practice. C61. Take responsibility for the development and implementation of a business and strategy plan for Medical Physics Services in own area of medical physics practice. C62. Take responsibility for the formal review and analysis of incidents within own area of medical physics practice.

Expert Consultancy	K114. 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. Explain 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).	C63. 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. C64. Produce and/or audit reports as an independent provider for organizations other than one's own. C65. 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. Explain 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. Explain 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.	C66. 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). C67. 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. C68. 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. C69. 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. C70. 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. C71. 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. 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. 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. Explain 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. Explain 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. Explain 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.	C72. 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). C73. Use the methodologies of HTA to carry out a HTA in conjunction with other healthcare professionals. C74. Take responsibility for the technical component of a HTA related to medical devices and /or ionizing radiations and other physical agents. C75. Take responsibility for the technical component of a clinical trial related to medical devices and /or ionizing radiations and other physical agents. C76. Take responsibility and communicate with relevant authorities with regards to safety from ionizing radiations and other physical agents in the case of clinical trials. C77. 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. C78. Take responsibility for the evaluation of a clinical trial protocol. C79. Ensure good clinical practice (GCP) compliance of activities within clinical trials. C80. Advise on and take responsibility for the preclinical device aspects of the ethical review of a clinical trial. C81. Assume the responsibility of statistical and other mathematical data processing and recording in a clinical trial.
Innovation	K136. 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. Explain 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 survey of specific information sources) for new and emerging technologies to own area of medical physics practice.	C82. Take responsibility for statutory and institutional requirements for Medical Physics Services with respect to Innovation in own area of medical physics practice. C83. 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. C84. Take responsibility for legal issues involved in the development of medical devices (including software) in own area of medical physics practice.

Table 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. Explain statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Scientific Problem Solving Service. K2. Explain 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, NPS etc). K5. Explain inverse problem mathematical techniques used in image reconstruction (including both convolution and iterative methods and the advantages and disadvantages of each). K6. 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, explain sources of measurement inaccuracy, uncertainty and artefacts. K12. For each imaging modality, explain quantitatively the static / time-varying fields used and their clinical specification. K13. For each imaging modality, define and explain 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, 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, 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. Explain 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. 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. 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. Explain 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. Explain 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.	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. Explain 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, explain the target patient safety outcomes with respect to hazards from ionizing radiations and other physical agents. K58. For each imaging modality, 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, explain the key considerations for the design of a new facility with respect to patient safety (including waiting and resting rooms). K62. Explain 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. Explain 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 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 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. Explain 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. Explain 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. Explain 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. Explain the components/subsystems of medical devices in each imaging modality. K83. For each imaging modality 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. Explain 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. For each imaging modality take responsibility for the acceptance, commissioning and constancy testing of imaging devices and image display and processing systems. In the case of acceptance testing this should be done in cooperation with the vendor. 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. Explain 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. Explain 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. Explain 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, explain target imaging outcomes (e.g., in terms of image quality criteria) relevant to diagnostic effectiveness. K98. For each imaging modality, 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 explain 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain 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 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. Explain statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Scientific Problem Solving Service. K2. Explain the application of beta decay, electron capture, positron decay, positron annihilation, isomeric transitions in Nuclear Medicine. K3. Explain the functioning of 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. Explain 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. Explain 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. Explain the concepts of image reconstruction in Nuclear Medicine including analytical and iterative reconstruction techniques. K11. Illustrate the mathematical concepts used in Nuclear Medicine including linear systems, Fourier analysis and FFT, convolution/deconvolution, curve fitting and function optimization. K12. Explain the 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. Explain the main types of computer codes used for dose calculation. K15. Explain 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. Explain statutory and institutional requirements for Medical Physics Services with respect to Diagnostic and Therapeutic Nuclear Medicine Internal Dosimetry Measurements. K17. Explain 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. Explain calibration factors including phantoms, phantom setup and measurements for dosimetry specific image quantification. K19. Explain 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain device QC for dosimetry specific image quantification. K28. Explain 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain factors for optimizing acquisition/processing procedures to decrease CT dose in combined modalities. K46. Explain and explain the ALARA principle as applied to occupational and public dose optimization in Nuclear Medicine. K47. Explain 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. Explain 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. Explain the principles of contingency planning and emergency procedures in Nuclear Medicine. K54. Explain statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Clinical Nuclear Medicine Device Management. K55. Explain 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. Explain combined modality imaging systems and illustrate possible applications in Nuclear Medicine. K59. Explain the principles of QC for Nuclear Medicine devices, such as gamma probes, well counters, dose calibrators, gamma cameras, SPECT, PET, hybrid systems etc. K60. Explain the physical and chemical properties of radionuclide compounds selected to implement Quality Control (QC) and their radioprotection implications. K61. Explain the institutional framework for Quality Assurance (QA) activity and regulation in a Nuclear Medicine department. K62. Explain 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. Explain QC measures in sequential imaging (several patient visits). K65. Explain 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. C17. Take responsibility for acceptance testing, commissioning and QC of nuclear medicine devices using national, international recommendations and local protocols. In the case of acceptance testing this should be done in cooperation with the vendor.

Clinical Involvement in NM	K66. Explain statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Clinical Involvement. K67. Explain 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. Explain the principle of radiopharmaceutical preparation and associated quality control. K70. Explain the principles of radiopharmaceutical biodistribution in normal organ and target tissues. K71. Explain the fundamentals of molecular radiotherapy (including radioimmunotherapy). K72. Explain the fundamentals of the use of PET in EBRT planning. K73. Explain general indications and contra-indications for Nuclear Medicine procedures. K74. Explain diagnostic procedure and clinical procedure guidelines. K75. Explain protocol optimization principles. K76. Explain 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. Explain laboratory and imaging procedures to evaluate organ toxicity. K80. Illustrate dose limiting toxicity classification and quantification. K81. Explain 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 explain 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.	C18. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Clinical Involvement. C19. Advise Nuclear Medicine physicians in imaging interpretation and quantification. C20. Take responsibility for deriving semi-quantitative and quantitative data for clinical application. C21. Advise on different treatment schedule options. C22. Advise on the most appropriate procedure with respect to risk/benefit ratio. C23. 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. C24. Supervise procedures for paediatric investigations. C25. Advise on the use of Nuclear Medicine data for radiotherapy planning. C26. Assume responsibility for data handling / recording. C27. Support Nuclear Medicine staff with physical-technical guidelines. C28. Supervise image reconstruction and image handling procedures.

Development of Service Quality and Cost-Effectiveness in NM	K86. Explain 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.	C29. 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. Explain 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.	C30. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Expert Consultancy. C31. 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. Explain statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Education of Healthcare Professionals (including Medical Physics trainees). K89. Explain 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.	C32. 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). C33. 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. C34. Take responsibility for the delivery of appropriate programmes for staff training in radiation safety with regard to Nuclear Medicine. C35. Teach healthcare professionals the physical principles of radionuclide decay, production and handling and the working principles of devices used in Nuclear Medicine. C36. Train healthcare professionals in the optimized use of medical devices used in Nuclear Medicine. C37. Supervise and train healthcare professionals in the use of new devices and/or methods. C38. Train staff to implement patient dose optimization within the Nuclear Medicine facility.

Health Technology Assessment in NM	K90. Explain 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. Explain 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. Explain 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.	C39. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Health Technology Assessment. C40. Take responsibility for the development and implementation of a business and strategy plan for the Medical Physics Services in Nuclear Medicine C41. Advise and participate in the design of clinical trials involving medical devices in Nuclear Medicine C42. Take responsibility for the technical components of an HTA project in Nuclear Medicine. C43. Evaluate clinical trial protocols. C44. Share responsibility for conducting clinical trials. C45. Advise on relevant aspects of ethical review of a clinical trial
Innovation in NM	K99. Explain statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Innovation. K100. Explain 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 survey of specific information sources) for new and emerging technologies in Nuclear Medicine.	C46. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Innovation. C47. 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. C48. Take responsibility for definition of new experimental set-ups and the development of new phantoms for performance assessment of existing / new devices.

Table 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain and explain recommended methods for reference air kerma (RAK) determination for LDR/HDR/PDR brachytherapy sources. K22. Explain 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 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. In the case of acceptance testing this should be done in cooperation with the vendor. 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. Explain 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. Explain 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. Explain 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. Explain 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. Explain statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to Clinical Medical Device Management. K41. Explain 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. In the case of acceptance testing this should be done in cooperation with the vendor. C21. Take responsibility for acceptance testing, commissioning and constancy testing of treatment and in-room imaging devices. In the case of acceptance testing this should be done in cooperation with the vendor. 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. In the case of acceptance testing this should be done in cooperation with the vendor. 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. Explain statutory and institutional requirements for Medical Physics Services in Radiation Oncology with respect to Clinical Involvement. K44. 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. 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. Explain 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. Explain 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. Explain 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. Explain 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.	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. 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.)	K60. Explain the methods for management of patient organ motion in radiation oncology. 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. Explain 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. Explain the various radionuclides and types of sealed sources used in brachytherapy and their clinical use. K69. Explain permanent and temporary implants and associated techniques used in clinical applications. K70. Explain 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.	S36. Archive, back-up and restore treatment plans. 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. Explain 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. Explain 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. Explain 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. Explain 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.