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Clinical Training of Medical Physicists Specializing in Diagnostic Radiology

VIENNA, 2010

TRAINING COURSE SERIES 47

CLINICAL TRAINING OF MEDICAL PHYSICISTS SPECIALIZING IN DIAGNOSTIC RADIOLOGY

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INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

The application of radiation in human health, for both diagnosis and treatment of disease, is an important component of the work of the IAEA. The responsibility for the increasing technical aspects of this work is undertaken by the medical physicist. To ensure good practice in this vital area, structured clinical training programmes are required to complement academic learning. This publication is intended to be a guide to the practical implementation of such a programme for diagnostic radiology.

There is a general and growing awareness that radiation medicine is increasingly dependent on well trained medical physicists based in the clinical setting. However, an analysis of the availability of medical physicists indicates a large shortfall of qualified and capable professionals. This is particularly evident in developing countries. While strategies to increase academic educational opportunities are critical to such countries, the need for guidance on structured clinical training was recognized by the members of the Regional Cooperative Agreement (RCA) for Research, Development and Training related to Nuclear Sciences for Asia and the Pacific. Consequently, a technical cooperation regional project (RAS6038) under the RCA programme was formulated to address this need in the Asia–Pacific region by developing suitable material and establishing its viability.

Development of a clinical training guide for medical physicists specializing in diagnostic radiology started in 2007 with the appointment of a core drafting committee of regional and international experts. The publication drew on the experiences of clinical training programmes in Australia and New Zealand, the UK and the USA, and was moderated by physicists working in the Asian region. This publication follows the approach of the IAEA publication Training Course Series No. 37, Clinical Training of Medical Physicists specializing in Radiation Oncology. This approach to clinical training has been successfully tested in Thailand, with two other Member States currently undergoing testing, and is believed to be applicable to the medical physics community in general.

The IAEA acknowledges: the special contribution of the drafting committee, including L. Collins (Australia), J. E. Gray (United States of America), K.-H. Ng (Malaysia), D. Sutton (United Kingdom) and B. J. Thomas (Australia). The IAEA officers responsible for this publication were I. D. McLean of the Division of Human Health and M. P. Dias of the Department of Technical Cooperation.

EDITORIAL NOTE

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CONTENTS

1. INTRODUCTION

1.1. The need for physicists in diagnostic radiology

Medical physicists fulfil an essential role in modern medicine. Medical physicists working in the field of diagnostic radiology are specialised in that role and are generally called "Diagnostic Radiology Medical Physicists". They are part of an interdisciplinary team in the Diagnostic Radiology Department dedicated to providing safe and effective diagnosis using a variety of medical imaging modalities. Other members of the team include radiologists and diagnostic radiographers.

Medical physicists make a major contribution to the safe and effective diagnosis of patients. Their knowledge of physics, particularly in imagining science dealing with image formation and characterization and radiation physics and how it interacts with human tissue and of the complex technology involved in modern imaging equipment are essential to the successful application of medical imaging. The diagnostic radiology medical physicist's responsibilities include the areas of: dosimetry, image quality, optimization, research and teaching, radiation safety, quality assurance and equipment management [1].

1.2. The need for structured and supervised clinical training of medical physicists specializing in diagnostic radiology

The role of the medical physicist specialized in diagnostic radiology is built on a foundation in university level general physics which then requires specialized knowledge and processes to understand the technical complexities of medical imaging. However to be clinically qualified to practice alone in a medical facility, the medical physics professional must have experience in a wide range situations and be able to make professional judgements, based on sound scientific principles and experience. To gain this ability the new graduate needs to be supervised by one or more senior competent medical physicists and to be extended through a structured training programme that ensures the widest possible set of relevant experiences. While similar knowledge and training principles have existed for many years in other professions, such as medicine, it is only recently that this approach has been recognised as essential for medical physicists [2–4]. In summary a clinically qualified medical physicist specialized in diagnostic radiology physics should have:

- A university degree in physics, engineering or equivalent physical science
- Appropriate academic qualifications in medical physics (or equivalent) at the postgraduate level [5],
- At least two years (full time equivalent) structured and supervised clinical training[1] undertaken in a hospital[2].

Member States that do not have a Masters program with the required content in place are strongly encouraged to formulate a strategy to achieve this.

It is emphasized that the holder of a university degree in medical physics without the required hospital training cannot be considered clinically qualified.

The above standard for the education and training of medical physicists should be recognised by a nationally responsible authority. The lack of recognition of medical physics standards is

[1] The period of clinical training would include service delivery and research and development.
[2] A hospital or clinical centre approved for the purpose by the nationally responsible authority.

a problem common to almost all countries. However a national accreditation (or certification) process, ideally through a professional organization, is seen as vital in raising the standard of the practice of medical physics. The continuing professional development of the practicing medical physicist through short courses, conference attendance, access to the scientific literature etc should then follow.

Postgraduate courses in medical physics at the Masters level are offered by many universities. To enrol in these courses, students are normally required to have completed an undergraduate (bachelor level) degree in physics or an acceptable alternative. These Master's courses are typically of 18–24 months duration and provide the graduate with knowledge of the physics and technology underpinning the practice of medical imaging, however in order to independently and safely perform the roles and responsibilities of a medical physicist a significant period of structured in-service clinical training is required.

The duration of this clinical training is agreed to be at least 24 months full time and can only be provided in a hospital with access to full diagnostic radiology services[3] under the supervision of a medical physicist qualified in diagnostic radiology. Hence the total time required for education and clinical training of a medical physicist is at least 4 years (2 years postgraduate university education plus at least 2 years clinical training) following completion of a bachelor degree in physics or acceptable alternative.

1.3. Why this programme?

While the shortage of clinically qualified medical physicists is a worldwide problem it is most acute in developing nations. One important reason for this is the migration of promising physics professionals from developing countries to more developed countries where the recognition of the medical physicists is better established. The introduction of a programme of clinical training to supplement academic qualifications has the dual purpose of providing skilled professionals for the developing country as well as providing standards that can be used to raise the recognition on medical physicists.

In an increasing number of countries Master level courses in medical physics are offered by universities. The clinical in-service training component however is in many cases missing. This has resulted in incomplete preparation of the medical physicists to practice independently as important aspects of training cannot be completed in the university setting. A structured in-service clinical training programme provides a better preparation for medical physicists to ensure that they are capable of independent, safe and effective practice. Such a programme should reduce the total time needed for medical physicists, referred to as Residents in this programme, to reach clinical competence and also to prepare them to undertake the more advanced methodologies which are being rapidly introduced in medical imaging.

The resident medical physicist in this programme is expected to be an employee of a clinical facility or hospital with responsibility in a suitable diagnostic radiology facility and would contribute to the routine duties of medical physicists within that department. This contribution would initially be in the role of an assistant but would, as the resident's level of knowledge and skills progressed, become more and more substantial. In the final 6–12 months of training the resident would make an independent contribution to many of the

[3] The term 'full diagnostic radiology services' will be defined by the nationally responsible authority to be consistent with the services available in the country.

roles of the medical physicist, and require only limited supervision. Hence the investment of time and effort in training residents is repaid as they become more competent and increase their contribution back to the department.

The IAEA has a long history of involvement in medical physics education and training. This publication has been recently developed as a guide to be used in the clinical training of the next generation of medical physicists specializing in diagnostic radiology. This guide is a companion to a previous publication for the clinical training of medical physicists specializing in radiation oncology [6].

2. OBJECTIVE OF THE CLINICAL TRAINING PROGRAMME

The objective of the clinical training programme for medical physicists specializing in diagnostic radiology is to produce an independent practitioner who is a life long learner and who can work unsupervised within a multidisciplinary team at a safe and highly professional standard.

The clinical training programme is seeking to assist this objective through:

- Provision of detailed guidance on clinical training
- Provision of an implementation strategy to allow effective clinical training.
- Forming a basis for a national or regional qualification (education and clinical training) standard
- Providing assistance to national bodies and departments to deliver the training programme through a pilot programme
- Promoting quality improvement of the programme, and
- Strengthening of the national capacity to sustain such a clinical training programme after initial introduction.

3. ESSENTIAL REQUIREMENTS FOR IMPLEMENTATION OF THE CLINICAL TRAINING PROGRAMME[4].

3.1. Programme management

On the level of an individual resident, the concept of clinical training can be relatively simple. However as a programme begins to involve many individual residents spread over a number of medical facilities, it grows in complexity and importantly it also needs clear assessment standards which need to be established and maintained[5]. This calls for a defined management structure.

This structure would normally be most effective on a national level[6] and usually needs to be placed within an established body or institution (such as a professional body for example). Relatively few countries have developed structures for clinical training currently in place. To assist in cases with limited existing management structures and limited resources, external assistance is advocated.

[4] Please see Appendix III for more detail on this section
[5] See Appendix V Assessment criteria, page 143.
[6] Regional clinical training programmes might also be possible in some circumstances

3.1.1. National

The programme should be under the direction of a national authority such as the Ministry of Education, Ministry of Health, relevant professional body or the National Atomic Energy Authority. It will have overall responsibility for the programme and is referred to, in this publication, as the **National Responsible Authority**.

The National Responsible Authority provides **formal recognition** of the qualification "Diagnostic Radiology Medical Physicist" (or equivalent) and the requirements to become one.

In managing the programme the National Responsible Authority has a responsibility to:

- Establish a ***National Steering Committee*** to oversee the programme. The National Steering Committee is the working arm of the National Responsible Authority. The Committee comprises of representatives from the relevant professional body (where one exists) and other relevant interest groups and stake holders (such as ministry of health, universities, radiation protection authority, allied professional societies etc.). It is highly recommended that representatives from the relevant professional body should form the majority of members. It is expected that the National Steering Committee will delegate its day to day responsibilities to a National Programme Coordinator.
- Appoint a ***National Programme Coordinator*** to oversee the implementation of the programme (appointment of several Programme Coordinators may be justified in large countries where regional coordination is necessary). The National Programme Coordinator should, ideally, be a person engaged in the practice of diagnostic radiology medical physics. The Coordinator will normally report to the National Steering Committee.
- Ensure that the ***Professional Body*** sets the professional standards required to define competency, provides professional support for the programme and has overall responsible for the assessment processes. This may involve the forming of an assessment committee.
- Establish a ***Support Group*** of individuals who agree to assist with resident training. The support group may include radiologists, diagnostic radiology medical physicists and personnel from educational institutions. Preferably one person external to the country should be a member of the support group.
- Ensure that the programme is financially viable. Ideally the employer and/or government authorities benefiting from the improvement in the medical physicist workforce resulting from the clinical training should contribute financially to the programme.

3.1.2. External

One form of external assistance involves the pilot testing of the clinical training programme in selected countries for a trial period of several years. For these pilot programmes an external management structure has been formed to coordinate external support and to oversee the general conduct of the programme. An external coordinator has been appointed to work closely with the National Programme Coordinator and National Steering Committee to ensure the smooth operation and success of the programme. External experts may also be

utilised to assist departments with aspects of the programme and to monitor standards of assessment.

3.2. Minimum recommended requirements for departments to undertake a clinical training programme

The minimum recommended requirements for a department to undertake a clinical training programme are:

- To provide the residents with a supervisor who is experienced and clinically competent in diagnostic radiology medical physics[7].
- To have (on-site) a specified range of diagnostic radiology and dosimetry equipment with appropriate established QA processes. For some equipment a preparedness to rotate residents to other departments with that equipment is acceptable.
- To offer a significant range of diagnostic radiology services and employ medical practitioners trained in diagnostic radiology.
- To provide resident's with access to textbooks and other relevant resources such as the internet.

4. ELEMENTS OF THE CLINICAL TRAINING PROGRAMME

Documents to assist countries in implementing a structured clinical training programme for Diagnostic Radiology Medical Physicists have been developed by the IAEA. These are included as appendices to this text as seen below:

- Appendix I: A handbook for Residents in the programme
- Appendix II: A handbook to assist clinical supervisors in the performance of their important role in this programme
- Appendix III: An implementation manual to assist a country and departments with the introduction of the programme
- Appendix IV: A guide which is divided into modules and sub-modules relating to the essential elements of the roles and responsibilities of medical physicists specializing in diagnostic radiology. Each sub-module contains suggested items of training to assist the resident in acquiring necessary knowledge and skills in the area.
- Appendix V: A guide to the assessment of competency in the areas of these sub-modules and other aspects of the programme.
- Appendix VI: Supplementary forms and documents

[7] In some situations it may be possible to utilise a form of remote supervision with the use of a suitable communication system.

APPENDIX I. HANDBOOK FOR RESIDENTS

This appendix has been based on the Handbook for Residents developed in New South Wales (NSW) for use in the Training, Education and Accreditation Programme (TEAP) of the ACPSEM for registrars in radiation oncology medical physics. The input of NSW Health is gratefully acknowledged.

I.1. INTRODUCTION

The shortage of clinically qualified medical physicists in all specialties of radiation medicine is a worldwide problem that is well recognised and is most acute in developing nations. The increasing complexity of both diagnostic and treatment equipment coupled with the raising of the expectations of good health care in all parts of the world, as well as the implementation of radiation safety standards, are contributing to worsen this shortage.

Resolution of this shortage can be approached by supporting existing medical physicists and by ensuring appropriate training for those seeking to enter the profession. The IAEA has a long history of involvement in medical physics education and clinical training and has participated in both aspects with the support of practicing medical physicists through workshops, training courses and fellowship programmes. More recently the IAEA have committed to raising the standard of the next generation of medical physicists through educational and clinical training initiatives and support programmes.

The fundamental problem of providing competent medical physicists in a clinical environment cannot be fully realised until the education and clinical training of the entry practitioner is at a suitable standard.

According to IAEA standards a clinically qualified medical physicist must have

- a university degree in physics, engineering or equivalent physical science
- appropriate academic qualifications in medical physics (or equivalent) at the postgraduate level,
- a minimum of two years (full time equivalent) structured clinical in-service training undertaken in a hospital.

This standard also states “It is emphasized that the holder of a university degree in medical physics without the required hospital training cannot be considered clinically qualified.”

Ideally, this education and training should be recognised by a national accreditation body. A national accreditation process, ideally through a professional organization, is seen as vital in raising the standard of the practice of medical physics. The continuing professional development of practicing medical physicists through short courses, conference attendance, access to the scientific literature etc should then follow.

To partially address the problem of providing clinical training for the next generation of medical physicists specializing in diagnostic radiology a clinical training guide and other resources to assist in the implementation of a clinical training programme for residents has been developed. Persons undergoing training in this programme are referred to as Residents.

The current publication has been developed to assist Residents with their understanding of the nature of the programme as well as the roles and responsibilities that they and others have in ensuring optimum clinical training.

It is important that this publication is carefully read before commencing clinical training.

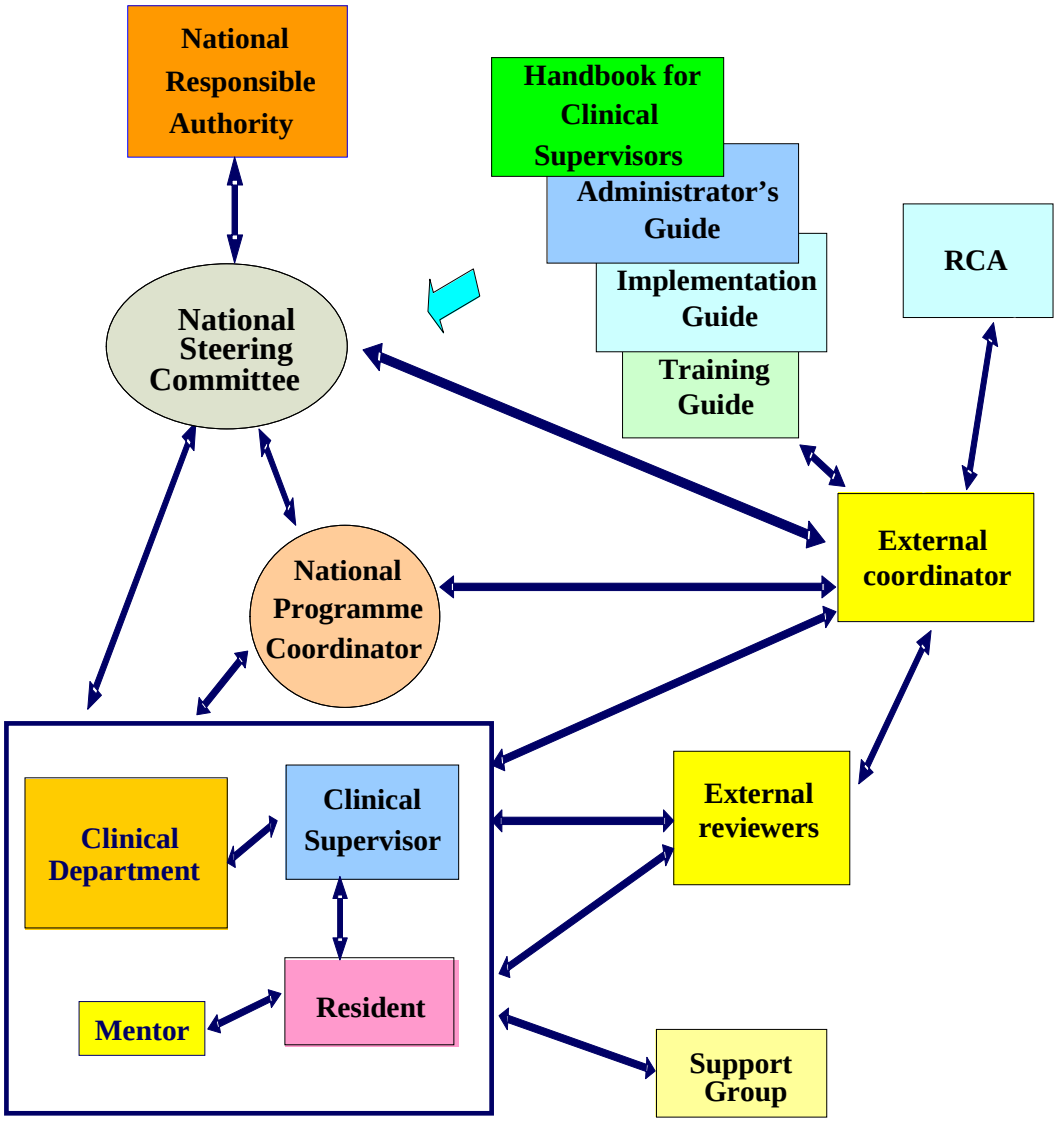

FIG. I.1. Schematic showing the management structure and lines of communication within the RCA pilot clinical training programme. Some lines of communication (e.g. department-resident) have been omitted for simplicity.

I.2. STRUCTURE OF THE CLINICAL TRAINING PROGRAMME

The structure and lines of communication within the pilot of the clinical training programme are shown schematically in Fig. I.1. Following is a brief explanation of the roles of the some of the groups/persons indicated in Fig. I.1. Further details can be found in the publication Appendix III *Implementation guide*.

- The ***National Responsible Authority*** such as the relevant professional body, Ministry of Education, Ministry of Health or the National Atomic Energy Authority, has overall responsibility for the programme. It provides formal recognition of the qualification provided by the program. It will form a National Steering Committee and appoint a National Programme Coordinator. The National Responsible Authority will normally delegate authority to a National Steering Committee to oversee the program.

- The ***National Steering Committee*** is comprised of the Professional Body and representatives from relevant interest groups and stake holders. The National Steering Committee is responsible for maintaining standards in the programme by ensuring that guidelines for participation are strictly followed by Departments and Residents. It deals with complaints and appeals. It supervises the National Programme Coordinator.

- The ***Professional Body*** is responsible for setting the professional standards required to define competency and providing professional support for the programme. It would normally have overall responsibility for the assessment processes.

- The ***National Programme Coordinator*** is responsible for coordination of the project and liaises with Residents and their Clinical Supervisors to ensure that the quality of training is appropriate and that Residents develop adequate skills and professional attitudes.

- The ***Clinical Supervisor*** is a suitably qualified and experienced medical physicist specializing in diagnostic radiology who, ideally, is working in the same department as the resident. In some cases it may be possible for the clinical supervisor to be external provided good communication with the registrar is possible. He or she has a pivotal role in ensuring the success of the clinical training of a Resident. See Section 3.1 for more detail on the roles and responsibilities of the Clinical Supervisor.

- The ***Mentor*** may be the Clinical Supervisor or other person or a support group may serve a mentorship role. It is important that the "mentor" is someone that the resident chooses to perform this role. The Mentor may provide advice on professional and personal issues and particularly can help in establishing a work – life balance. For more involved personal issues however the resident should be referred to the hospital counsellor or other suitable professionals.

- The ***Support Group*** is made up of individuals who agree to assist with Resident training. The support group may include radiologists, diagnostic radiology medical physicists and personnel from educational institutions. Ideally, at least one person, external to the country, is also a member of the support group.

- The ***External Coordinator*** monitors the progress of Residents and the programme in general. He/she works closely with the National Programme Coordinator and National Steering Committee to ensure the smooth operation and success of the programme.

- The ***External Reviewers*** monitor the progress of individual Residents and review their work plan or items of assessment.

I.3. ROLES AND RESPONSIBILITIES OF RESIDENTS

Success of the clinical training programme relies on you, the Resident, undertaking self-directed study including, in consultation with the Clinical Supervisor, determining deadlines. You must also take individual responsibility for meeting those deadlines. Difficulty completing the programme is expected to be encountered when a Resident has low initiative and/or is slow to accept responsibility.

Termination of the clinical training position may be considered if you fail to meet the standards required in the programme following a period of supportive and corrective feedback and opportunity to improve.
Your responsibilities include:

- Meeting regularly with your Clinical Supervisor to discuss progress and to review deadlines.
- Accepting the supportive **and** corrective feedback provided by your Clinical Supervisor and other experienced medical physicists in your department. You need to accept this feedback in the spirit that it is provided, i.e. to assist in improving your performance in the programme.
- Maintaining necessary documentation. An important example is to ensure that your Clinical Supervisor "signs off" after completing a competency assessment. A second important example is keeping your portfolio up-to-date.
- Preparing in a thorough manner for all assessments required as part of the programme.
- Taking every opportunity to develop your knowledge and skills and, once acquired, maintaining the knowledge and skills.

I.4. ROLES AND RESPONSIBILITIES OF CLINICAL SUPERVISORS

The clinical supervisor's responsibilities include:

- Ensuring that the Resident is trained in all significant aspects of diagnostic radiology medical physics by facilitating a structured training programme in keeping with the guide and with the scope of modules and assessment levels to be completed as determined by the National Steering Committee. Note that this does not mean that all the training is done by the supervisor. It is the responsibility of the supervisor to ensure that suitably qualified specialists undertake the training of the Resident in the various facets of the programme.
- Meeting regularly with the Resident to discuss progress (including reviewing deadlines) and to provide adequate supportive and corrective feedback to the Resident such as the level of competency achieved and competency achievements which have fallen behind. (Note: in this document a "meeting" may be face-to-face or by videoconference or other means as the circumstances allow or require.)
- Providing a six monthly report on the Resident's progress to the National Programme Coordinator.
- Ensuring that the Resident's clinical training and performance is monitored, documented, assessed and reported as required.
- Ensuring that the in-service clinical training is provided to a standard acceptable to the National Steering Committee and providing to the Resident support where required.
- Ensuring that the Resident is placed in other hospitals, where possible, for short periods to gain experience in techniques or the use of equipment not available in the Resident's own department.
- Ensuring that the Resident has sufficient opportunity to prepare for all assessments required as part of the programme.
- Facilitating external assessments of Residents during their training where possible.

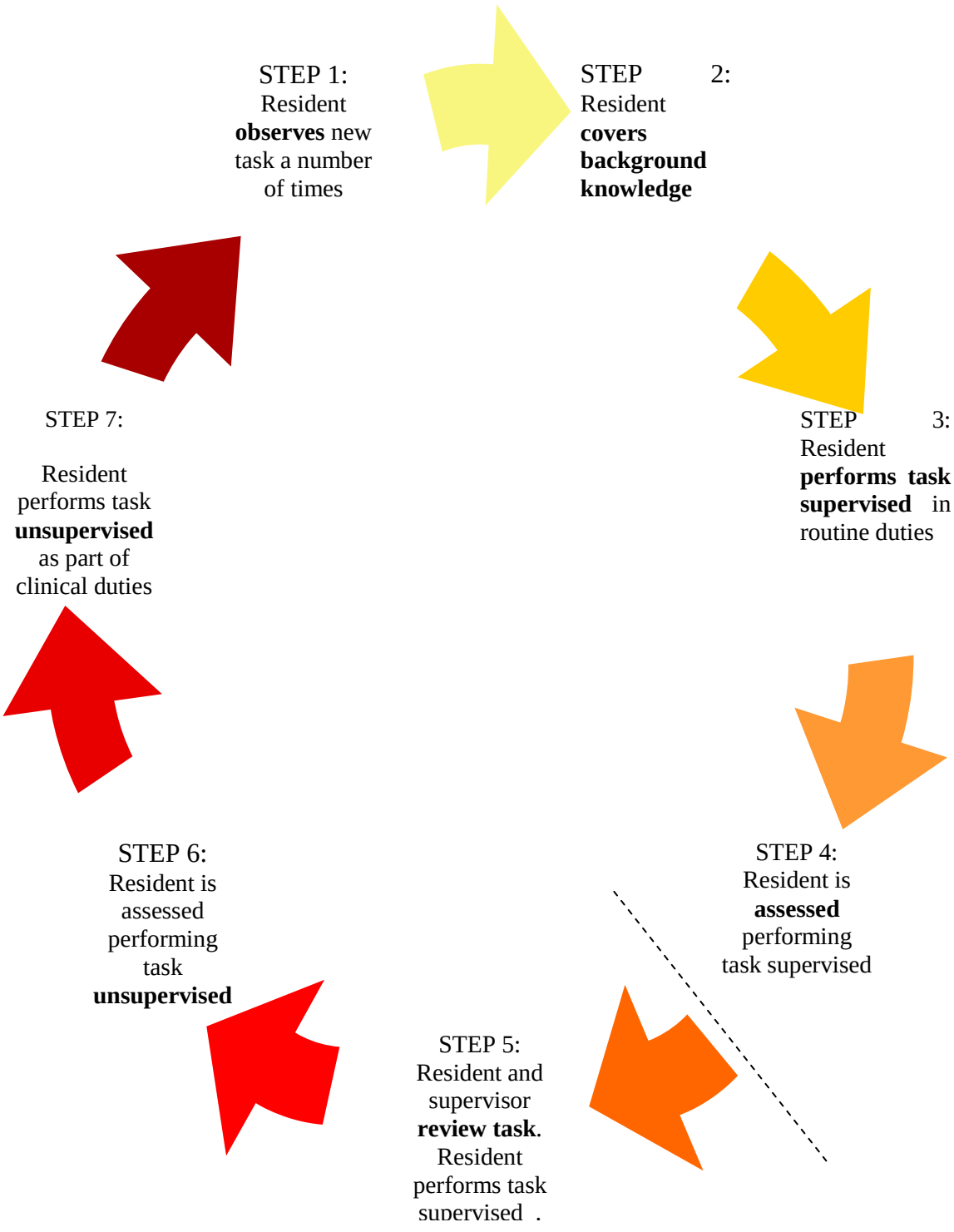

FIG. I.2: Timeline of clinical training and competency assessment. Step 4 to Step 5 may occur after the Resident has had some experience.

I.5. IMPORTANT APPENDICES

In addition to the current appendix there are several other appendices which are of importance to you as a Resident in the programme. These are:

- *The Clinical Training Guide Appendix IV*
- *Competency Assessment Appendix V*
- *The Supplementary Forms and Documents Appendix VI.*

You should keep a hard copy of each of these appendices. You will need to refer to the Clinical Training Guide frequently during you residency and the Competency Assessment appendix will need to be updated as competencies are tested by your Clinical Supervisor or nominee. It may also be inspected by the National Programme Coordinator, the external coordinator or external advisor.

I.6. RESIDENT RECRUITMENT

Residents can only be recruited by departments which have been approved by the National Steering Committee for clinical training of Residents in this programme. The prospective Resident must submit a completed "Application for Entry" form to the National Programme Coordinator (see Appendix VI) and only becomes a Resident when this application has been approved by the National Programme Coordinator and the external coordinator in the case of the IAEA pilot programme.

As a prospective Resident you should have a clear understanding of the expectations and duration of the clinical training programme. Also see Appendix III.4 (Entry requirements for residents).

I.7. NEW RESIDENT ORIENTATION

In addition to the regular hospital and departmental orientation, a new Resident will be given an orientation to the Clinical Training programme in their country.

The first meeting between yourself as a new Resident and your Clinical Supervisor will cover many aspects including the following:

- Explanation of the Clinical Supervisor's role
- Expectations for the Clinical Training Programme
- Responsibilities of the Resident in the Clinical Training Programme,
- The evaluation and assessment schedule (including a regular time for at least monthly meetings).
- Notification of the timing of external assessment including annual reviews
- Direction to resources (e.g. sample assignments, access to basic text books, etc)
- Availability of scholarships and other funding to attend courses and conferences
- Requirement to attend seminars, clinical meetings and level of participation expected
- Role of National Programme Coordinator and other relevant persons outside the department
- General employee duties and responsibilities
- Questions from the Resident

In this meeting you should also discuss with your Clinical Supervisor the following training materials:

- Draft learning agreement including training schedule for the first six months.
- Resources for appropriate documentation requirements

In order to support the clinical training programme as defined by the clinical competencies, it will be necessary to obtain a selection of the knowledge sources found in the guide. There has been an effort to use high quality resources that are downloadable, such as the reports available from the American Association of Medical Physics (AAPM). In addition to this the resident should be aware of the HINARI Access to Research Initiative, http://www.who.int/hinari/en/, which allows residents from some locations to have access to downloadable research articles that are otherwise available only for a fee. In addition the resident is strongly encouraged to purchase a sufficient set of texts that cover most areas of clinical experience for the list of knowledge sources in the modules.

I.8. RESIDENT AGREEMENT WITH SUPERVISOR

Within the first two months a new Resident and his/her Clinical Supervisor should finalise a learning agreement, including learning needs, schedule of training, objectives, resources and strategies. Learning agreements should include a schedule for achievement of specific competencies in the next 6 months as well as an overview of the schedule for completion of the entire training programme (see section I.10 for an explanation of competency as used in this programme).

You need to be aware that the schedule may need to be changed.

Requirements including the scope of competencies and the assessment criteria should be discussed.

The advantages of a learning agreement include:

- Identifying learning needs and resources,
- Providing a forum for discussion of the feasibility of goals relative to the timing and size of workload for the department, Supervisor and Resident,
- Encouraging communication between the Resident and Supervisor,
- Giving you, the Resident, a sense of ownership and commitment to the plan and it is clearly conveyed that you need to take responsibility for your own learning,
- Creating and implementing a strategy which is important due to the volume and scope of work to be completed in the training programme, and
- Prompting evaluation.

Disadvantages include the need for regular updating of the plan as timing of a significant portion of clinical training may be difficult to predict.

As soon as practical, a plan for successful completion of the clinical training programme on schedule should be developed, identifying:

- Short, medium and long term learning outcomes
- Timing of final (national) assessments to permit prioritization of competency completion

- Timing of research and clinical requirements, including courses and conferences
- Timing of clinical rotations, such as radiotherapy and other Diagnostic Radiology Centres
- Possible areas for at least five key portfolio reports of the Resident's best work to be developed over time (see section I.9)
- Level of independence required
- A contingency plan for spare time e.g. assignments or knowledge-based competencies
- Potential issues or situations that may impact on the training experience, such as major changes within the department.
- Opportunities for practice-based learning. For example, attending machine break-downs to observe trouble shooting,

A sample template to assist with the preparation of a learning agreement is provided in the appendix "Supplementary Forms and Documents".

However, the Supervisor and Resident may choose a document that suits their style and is not too time intensive (relative to their needs). An alternate method can be chosen as long as it conveys all the required information and prompts the allocation of resources and staff to support the clinical training.

The learning agreement must be mutually agreed upon as it has to be feasible for both parties and acknowledge the responsibility of both Resident and Supervisor to meeting deadlines. It should take into account departmental and supervisor requirements. Advantages of a learning agreement include:

- Ensuring that the assessment of a significant number of competencies are not left to very late in your programme
- Planning items of training which require access to equipment or cooperation of other staff.

You will need to have or develop good time management skills in order to fulfil your responsibilities of the learning agreement.

The forms ANNUAL CHECKLIST FOR RESIDENTS and COMPLETION CHECKLIST FOR RESIDENTS are two further checklists (Appendix VI) to prompt discussion and completion of requirements.

Note that a Supervisor cannot be held responsible for not completing competency assessment before a deadline if you do not meet milestones or submit a significant amount of work for assessment at the last minute.

It is expected that you may initially need careful guidance to ensure that you achieve milestones and levels of competency as per your learning agreement. However as you progress through the programme, you must become more active and self-directed and accept a greater level of responsibility. It is part of the role of a Clinical Supervisor to guide the Resident through this professional development. One approach to clinical training and competency assessment is shown schematically in Fig. I.2.

I.9. ASSESSMENT

There are several components to the assessment of a Resident in the Clinical Training Programme

- **Competencies** (as per the sub-modules of the Clinical Training Guide)
  Each sub-module defines a unified portion of clinical knowledge or skills. All competencies (or sub-modules) required are listed in the Clinical Training Guide. The sub-modules to be undertaken and the level of competency required to be achieved in each sub-module have been determined by the Responsible National Authority, or its delegate, and are indicated in the Clinical Training Guide.(see Appendix III.3.1.1)

  The Clinical Supervisor can schedule competency assessment at any agreed time. The sub-modules can be undertaken in any order and more than one module can be undertaken at a time. The assessment should comply with the learning agreement and focus on one or a number of the following factors:

  - **Clinical work**, i.e. qualified staff formally observe routine clinical tasks as ongoing assessment of competence,
  - **Module-focussed**, i.e. clinical work is assigned and responsibility given once the competencies within a particular module are covered, e.g. responsibility for supervising radiographer quality control testing can be given once all related performance testing competencies are completed.
  - **Commissioning-focussed**, i.e. scheduling of competencies is related to departmental commissioning projects. This is opportunistic learning and may incorporate several areas of competencies.

  It is expected that many competencies will be assessed on several occasions. For example: a particular competency might be worked on for some time and the Resident assessed as having obtained a level of 3. The Resident might then be rostered to another area and return to work on the first competency (sub-module) at a later time with a second assessment being conducted at the end of this period. Following any assessment of competency the Resident will be provided with supportive and corrective feedback. You should not be upset by this feedback. Note that the assessor is indicating to you how you can improve your performance in the programme.

  The competency assessment criteria are provided in the Clinical Training Guide. As demonstrated by the criteria, competency assessment is not just reviewing technical ability but also attitudes, such as safe practice and communication skills, expected of a qualified medical physicist specializing in diagnostic radiology.

- **Portfolio**
  The portfolio provides you with an opportunity to demonstrate the breadth and depth of your knowledge on certain topics. It is also useful for external competency assessment, evidence of level sign-off, development of scientific writing skills and can be used as proof of competence if appealing an exam result. Each resident should have a folder of evidence that the portfolio reports can be taken from for submission.

  The Clinical Supervisor will examine the folder of evidence at regular (at least 6 monthly) intervals and provide feedback to the Resident. The National Coordinator or

their delegate will review the folder of evidence at the end of each year of the Resident's programme and rate the evidence as satisfactory or unsatisfactory.

The submitted portfolio incorporates the follow documents:

- Curriculum vitae
- Progress reports
- "Summary of Competency Achievement" demonstrating the level of competency achieved in each sub-module.
- Samples of work prepared by the Resident from at least 3 of the 5 core modules of the Clinical Training Guide. The samples of work could be:
    - Departmental reports, e.g. commissioning and clinical implementation of new equipment or treatment technique.
    - Assignments on key competencies.
    - A research paper published in a local or peer-reviewed journal
    - A research presentation in a national or international meeting
    - A presentation delivered covering key aspects of the module

Each portfolio report should ideally be less than 10 pages (10 font, single line spacing, single-sided pages). Lengthy reports are discouraged, therefore tables and graphs of data may be referred to but not included.

- **Assignments**

  Three assignments must be submitted during the training programme. These should be submitted no later than approximately 9, 15 & 21 months after commencement of the training programme. (This schedule for submission may be altered by the National Steering Committee) These assignments will be marked by an appointee of the National Steering Committee and possibly by an external reviewer nominated by the external coordinator and be returned, within one month of submission, to the Resident so as to provide feedback. You should discuss the feedback received with your Clinical Supervisor.

  The assignments will be graded on a 5 to 1 scale with grades of 4 and 5 being unsatisfactory, 3 just satisfactory, 2 good and 1 excellent.

  When a grade of 4 or 5 is awarded you will be required to modify the assignment, taking into consideration the feedback provided, and to resubmit the assignment within 1 month for further assessment.

- **Written exam**

  The written exam is optional, at the discretion of the National Steering Committee or delegate. The content of the written exam is based on the core modules of the Clinical Training Guide but may cover any application of relevant knowledge in the field of Diagnostic Radiology Medical Physics. The written exam tests a deeper understanding than assessed in the MSc.

- **Oral exam**

  This is administered by the National Steering Committee at the end of the training programme. Before taking the oral exam a Resident must satisfactorily complete ALL other aspects of assessment. The content of the oral exam will include a significant

component from the portfolio and the remainder will be drawn from elsewhere in the Clinical Training Guide.

- **Practical exam**
  The practical exam is optional (i.e. at the discretion of the National Steering Committee) and, is ideally, linked to a professional accreditation process. The practical examination is based on scenarios that a medical physicist may encounter at a senior level and incorporates a range of competencies covering the Clinical Training Programme.

- **A Logbook** is recommended but not obligatory and is not included in the assessment process. If used the logbook should be maintained by the Resident and contain a record of training experiences with comments as to difficulties experienced and positive learning outcomes. The logbook can also be utilised by the Supervisor to demonstrate that sufficient work has been covered to sign off a competency if it is difficult for the Supervisor to perform practical assessment of that competency. The logbook can be in hard copy or electronic form.

NOTES:

- The Resident must be assessed as satisfactory in each of the above components to be successful in the total programme.
- The required level of competency in ALL sub-modules must be achieved before the oral exam can be attempted.
- The oral examination, and practical examination if required, are designed to assess whether the candidate has the appropriate approach of a qualified medical physicist i.e. to work unsupervised in a professional, scientific and safe manner. However as limited technical knowledge and competency can be assessed in these examinations, for the assessment of the majority of the medical physicist's roles and responsibilities it is the assessment of competency in actual practice which has a pivotal role in ensuring safe, competent practice.

I.10. EXAMPLES OF COMPETENCY ASSESSMENT TOOLS

There are many possible methods by which your competency in a particular sub-module may be assessed. The assessor may:

- observe, listen and question you during routine clinical experience
- listen to you teaching someone else
- provide you with mock scenarios. Examples:
  - communication with patient or colleague (perhaps also a patient based dilemma)
  - request that you write a commissioning schedule for a new CT scanner
  - commissioning an digital mammography unit
  - commissioning a interventional fluoroscopy unit
- suggest that you attend
  - an internal course on conflict management
  - attend a university course for postgraduate students on oral presentation.
- ask a patient or another professional's feedback of how you communicated with them.

- use oral assessment in a regular Supervisor-Resident meeting Short written report with assessment and constructive feedback
- use practical assessment including oral questioning whilst you perform a routine task (e.g. quality assurance, KAP calibration)
- use objective, structured clinical examinations or series of defined clinical tasks.
- review your logbook.
- set clinical project work
- set patient or equipment trouble-shooting case studies
- ask that you list key steps involved in completing a task
- require an external competency test at another department
- review your portfolio.
- request that you participate in a local tutorial programme
- use self-reflection. Do not be surprised if your supervisor asks “how do you think you went?” after completing a competency assessment.
- suggest that you make a presentation to departmental staff
- require that you write
    - sample letters that are assessed by the supervisor on key points.
    - a report on the role of other professional groups.
    - a report on the pathway of a patient from diagnosis to treatment.
- suggest that you compile decision-making diagrams.
- suggest that you critically appraise a journal article in a departmental “Journal Review Meeting”.

I.11. CLINICAL ROTATIONS

The Resident may be required to obtain training in other hospitals for periods of time to gain experience in techniques or on equipment not available in the Resident’s own hospital. The clinical training guide also requires the Resident to gain knowledge and competencies in Radiation Oncology and Nuclear Medicine.

APPENDIX II: HANDBOOK FOR CLINICAL SUPERVISORS

This appendix has been based on the Handbook for Residents developed in New South Wales (NSW) for use in the Training, Education and Accreditation Programme (TEAP) of the ACPSEM for registrars in radiation oncology medical physics. The input of NSW Health is gratefully acknowledged.

II.1. INTRODUCTION

A necessary component of the training of Residents is the guidance provided by a Clinical Supervisor. This handbook is designed to assist Clinical Supervisors in understanding the roles and responsibilities of the position.

The investment of time and effort in training Residents is repaid as they become more experienced and increase their contribution back to the department. Adequate clinical training resources are essential for the successful implementation of the programme. One of the major resources required within a participating department is the Clinical Supervisor. This appendix outlines the roles and responsibilities of the Clinical Supervisor.

It is important that this appendix is carefully read before commencing Clinical Supervision of a Resident. The Clinical Supervisor should also be familiar with the *Clinical Training Guide* (Appendix IV) and all associated documentation. A list of useful resources (URLs etc) for Clinical Supervisors is provided in section II.16.

II.2. APPOINTMENT OF A CLINICAL SUPERVISOR

A suitably qualified and experienced Clinical Supervisor should be appointed by a department seeking to participate in the pilot of the clinical training programme. It is important that the

Clinical Supervisor has the confidence and willingness to undertake the roles and responsibilities of the position.

The steps in the appointment of a Clinical Supervisor are

- The Chief Physicist, or head of department, normally, initiates the nomination and makes the proposed Clinical Supervisor aware of the expectations of the position.
- The proposed Clinical Supervisor should agree to the nomination which needs to be approved by the National Programme Coordinator.
- An agreement between the Clinical Supervisor and Chief Physicist is made to ensure effective supervision takes place.

The logistics and resources of how training fits into the function of the department also need to be considered. For example the Clinical Supervisor and Chief Physicist or head of department should discuss:

- allocation of time on equipment during normal working hours for training and/or assessment (if possible)
- allocation of overtime funding or flexibility for the Supervisor and other staff involved in the clinical training to take "time-off in-lieu" for training conducted outside normal working hours which may be necessary so that the Resident can gain additional access to equipment
- allowance for clinical supervision workload when distributing roles and responsibilities in the department
- acknowledgement of the importance of the clinical supervision role to the Resident and department.

II.3. ROLES AND RESPONSIBILITIES OF CLINICAL SUPERVISORS

The clinical supervisor's responsibilities include:

- Ensuring that the Resident is trained in all significant aspects of diagnostic radiology medical physics by facilitating a structured training programme in keeping with the guide and with the scope of modules and assessment levels to be completed as determined by the National Steering Committee. Note that this does not mean that all the training is done by the supervisor. It is the responsibility of the supervisor to ensure that suitably qualified specialists undertake the training of the Resident in the various facets of the programme. For further guidance on this please see below in Section II.8 "Models of Supervisory Practice".
- Meeting regularly with the Resident to discuss progress (including reviewing deadlines) and adequate supportive **and** corrective feedback to the Resident such as the level of competency achieved and competency achievements which have fallen behind. (Note: in this document a "meeting' indicates a face-to-face meeting, videoconference or other means as the circumstances allow/require.)
- Providing a six monthly report on the Resident's progress to the National Programme Coordinator.
- Ensuring that the Resident's clinical training and performance is monitored, documented, assessed and reported as required.

- Ensuring that the in-service clinical training is provided to a standard acceptable to the National Steering Committee and providing to the Resident support where required.
- Ensuring that the Resident is placed in other hospitals, where possible, for short periods to gain experience in techniques or the use of equipment not available in the Resident's own department.
- Ensuring that the Resident has sufficient opportunity to prepare for all assessments required as part of the programme.
- Facilitating external assessments of Residents during their training where possible.

Clinical supervisors should be life-long learners themselves. It is also recommended that every Clinical Supervisor attends a "train the trainer" workshop (if possible) to understand the educational framework of the Clinical Training Guide prior to commencement of training.

II.4. NATURE OF A SUPERVISOR

Clinical education (best) occurs in an environment supportive of the development of clinical reasoning, professional socialisation and life long learning, (McAllister 1997). Supervisors should reflect on what helped them learn during their own training and use their own experiences as one guide to providing the best practice in clinical training.

The attributes required of a good supervisor are varied and are listed below:

- **As a manager**
  The supervisor needs to be organised and to provide clear guidance of expectations, clinical work roster, deadlines and assessment criteria to the Resident. In addition the supervisor needs to liaise with other department and external personnel to ensure that the clinical training and day-to-day supervision are not impeded

- **As an instructor**
  Components of instruction for a Clinical Supervisor include:
  - the Supervisor demonstrates to the learner
  - the Resident practises while the Supervisor offers feedback
  - the Supervisor provides support that is gradually reduced as the Resident becomes more proficient
  - the Resident describes his or her problem-solving processes
  - the Resident reflects on the comparison between individual problem-solving processes with those of a peer or more experienced physicist
  - the Resident moves to independent problem-solving

  Other facets of instruction include:

  - providing suitable conditions for self-directed learning
  - directing the Resident's attention towards significant factors of a task (and order of a group of related tasks).
  - imparting the hidden secrets of mastery, rather than just the mechanics of a task
  - ensuring basic knowledge and skills are mastered before more complex tasks are undertaken.

- **As an observer**
  The Clinical Supervisor should take every opportunity to observe the Resident undertaking tasks. This is not only important in the provision of timely supportive and corrective feedback but should be a key element of the assessment process.

- **As a mentor**
  This role may be undertaken by a person other than the Clinical Supervisor. It is important that the "mentor" is someone that the Resident chooses to perform this role.

  Residents are often young adults experiencing considerable social and financial pressures. A mentor may be requested to discuss a Resident's personal issues and should take time to understand the background of the Resident without invading their privacy. If a Clinical Supervisor is willing to act in this role and the Resident agrees, then the Supervisor must only counsel within their own limitations and skill level. If the Resident requires assistance outside a mentor/Clinical Supervisor's skill level, comfort zone or ethical/confidentiality/privacy/assessment role boundaries then they should refer the Resident to the Chief Physicist or Hospital/University Counselling Service. Furthermore, the Clinical Supervisor should encourage or at least make the Resident feel comfortable to seek external help if required.

- **As a giver of feedback**
  Feedback to Residents should consist of supportive as well as corrective feedback. It should also be varied, non-judgemental, specific, focussed on changeable behaviour, descriptive, prompt and private (if professionally appropriate or if the Resident is sensitive to corrective feedback). The Clinical Supervisor should note that questioning often facilitates discussion of corrective feedback (e.g. "how do you think you went?").

- **As an assessor**
  The role of assessor of clinical competency is one of the most important and difficult responsibilities of the Clinical Supervisor. "Transparency" of the assessment is essential and requires that the Resident:

  - is provided with a clear statement of expectations (knowledge and skill level required) to be successful (The *Clinical Training Guide* includes some detail related to assessment of the level of competency achieved)
  - understands the reasons for the level assessed (what was done well, deficiencies in knowledge or skills). It is good practice to explain why the level was chosen and not a level either side, for example if assessing a competency at level 2 then explain why level 1 or 3 was considered to be inappropriate.
  - is provided with supportive feedback following the assessment of any aspect of clinical training (competency, assignment etc).

  The "validity" of the assessment is also important. The logbook, if used, can perform a vital role in assessment by demonstrating the tasks that contributed to completion of competencies.

  The role of the instructor and/or assessor can be delegated by a Clinical Supervisor to other suitably qualified medical physicists (or other professionals) if the Resident is working in an area in which the Clinical Supervisor does not have expertise. For further guidance on this please read Section 10 "Models of Supervisory Practice".

II.5. RESIDENT RECRUITMENT

Before recruiting a Resident you should ensure that

- your department is approved by the National Steering Committee for clinical training of Residents in this programme.
- the prospective Resident has submitted a completed "Application for Entry" form and that this application has been approved by the National Programme Coordinator and the external coordinator in the case of involvement in a pilot programme.
- you have read the Clinical Training Guide and are aware of the scope of modules and assessment levels adopted in your country
- the prospective Resident has a clear understanding of the expectations and duration of the clinical training programme

Also see Appendix III.2 (Entry requirements for residents).

II.6. NEW RESIDENT ORIENTATION

In addition to the regular hospital and departmental orientation, a new Resident should be given an orientation to the Clinical Training programme in their Country. Before this orientation they should read the Clinical Training Guide.

The first meeting between the Clinical Supervisor and new Resident should cover many aspects including the following:.

- Explanation of the Clinical Supervisor's role
- Expectations for the Clinical Training Programme
- Responsibilities of the Resident in the Clinical Training Programme,
- The evaluation and assessment schedule (including a regular time for at least monthly meetings).
- Notification of the timing of external assessment including annual reviews
- Direction to resources (e.g.. sample assignments, access to basic text books, etc)
- Availability of scholarships and other funding to attend courses and conferences
- Requirement to attend seminars, clinical meetings and level of participation expected
- Role of National Programme Coordinator and other relevant persons outside the department
- General employee duties and responsibilities
- Questions from the Resident

In this meeting you should discuss and provide your Resident with the following training materials:

- Draft learning agreement including training schedule for the first six months.
- Resources for appropriate documentation requirements

A checklist is provided in Form 1 CHECKLIST FOR NEW RESIDENTS to ensure all key aspects are covered.

II.7. RESIDENT AGREEMENT WITH SUPERVISOR

II.7.1. Learning agreement and plan

Within the first two months a new Resident and his/her Clinical Supervisor should finalise the learning agreement, including learning needs, schedule of training, objectives, resources and strategies. Learning agreements should include a schedule for achievement of specific competencies in the next 6 months as well as an overview of the schedule for completion of the entire training programme. The Resident should be made aware that the schedule may need to be changed.

Requirements including the scope of competencies and the assessment criteria should be discussed.

The advantages of a learning agreement include:

- Identifying learning needs and resources,
- Providing a forum for discussion of the feasibility of goals relative to the timing and size of workload for the department, Supervisor and Resident,
- Encouraging communication between the Resident and Supervisor,
- Giving the Resident a sense of ownership and commitment to the plan and it is clearly conveyed that they need to take responsibility for their own learning,
- Creating and implementing a strategy which is important due to the volume and scope of work to be completed in the training programme, and
- Prompting evaluation.

Disadvantages include the need for regular updating of the plan as timing of a significant portion of clinical training may be difficult to predict.

As soon as practical, a plan for successful completion of the clinical training programme on schedule should be developed, identifying

- Short, medium and long term learning outcomes
- Timing of final (national) assessments to permit prioritization of competency completion
- Timing of research and clinical requirements, including courses and conferences
- Timing of clinical rotations, such as radiotherapy and nuclear medicine centres
- Possible areas for at least 5 key portfolio reports of the Resident's best work to be developed over time.
- Level of independence required
- A contingency plan for spare time e.g.. assignments or knowledge-based competencies
- Potential issues or situations that may impact on the training experience, such as major changes within the department.
- Opportunities for practice-based learning. For example, attending machine break-downs to observe trouble shooting,

However, the Supervisor and Resident should choose a document that suits their style and is not too time intensive (relative to their needs). An alternate method can be chosen as long as it conveys all the required information and prompts the allocation of resources and staff to support the clinical training.

The learning agreement must be mutually agreed upon as it has to be feasible for both parties and acknowledge the responsibility of both Resident and Supervisor to meeting deadlines. It should take into account departmental and supervisor requirements.

After being accustomed to an academic environment, many Residents struggle with time management when they commence their clinical training programme. A Clinical Supervisor should assist the Resident in developing time management skills.

The forms ANNUAL CHECKLIST FOR RESIDENTS and COMPLETION CHECKLIST FOR RESIDENTS are two further checklists (Appendix VI) to prompt discussion and completion of requirements.

II.7.2. Compliance

At regular and six monthly progress review meetings, the learning agreement should be examined. If there is an identified lack of progress by the Resident, the reasons behind the delay need to be determined. Hence the learning needs, objectives, resources and strategies should be re-examined, including:

- An examination of the clinical learning environment to ensure that the environment is conducive to learning. In some cases delays may be due to a lack of initiative, unwillingness to accept responsibility, inability to manage the competing demands in the workplace, Resident immaturity resulting in unsafe practice.
- Development of a mutually agreed action plan to provide the Resident with specific guidance and support to facilitate progress. The action plan must be documented and should detail the following:
  - Agreement as to the exact area/s where problem/s are identified
  - Specific details of how the problem area/s will be addressed
  - An agreed period of time for further supervised practice
  - An agreed minimum contact time per week that the Supervisor and Resident will practice together.

A record of the meeting should be made.

A Supervisor cannot be held responsible for not completing competency assessment before a deadline if the Resident did not meet milestones or submitted a significant amount of work for assessment at the last minute. It is recommended that a Resident and Clinical Supervisor should not schedule a significant amount of competency assessment within the final months of the training programme so as to minimise the possibility that unexpected events such as an increase in department workload, leave, staff shortages, etc might prevent completion of competencies and assessment prior to final exams.

II.8. MODELS OF SUPERVISORY PRACTICE

When first enrolling, the Residents may be passive and used to being “spoon-fed” at university. They may need guidance on appropriate conduct at work and style of communication with multidisciplinary professionals (internal and external) and with patients. As they progress through the programme, the Residents must become more active and self-directed and accept a greater level of responsibility. It is part of the role of a Clinical Supervisor, with the assistance support through mentorship, to guide the Resident through this professional development. One approach to clinical training and competency assessment is shown schematically in Fig. II.2.

As in the past, a Resident trains "on-the-job" under the direction of experienced staff. However the difference with the previous "ad hoc" approach is that the Resident's clinical training is structured, follows a set of knowledge and competencies and is monitored internally and externally more closely.

There are two main models of Supervision. However one supervisor model is not always appropriate throughout the programme and for all Residents. The two models of supervision are:

(1) "Qualified medical physicists specializing in Diagnostic Radiology per Resident" approach – the majority of training and assessment is performed by the one medical physicist. This is difficult when the Clinical Supervisor is very senior in the department and/or works restricted hours. This approach is more common in small centres.

(2) "Qualified medical physicists specializing in Diagnostic Radiology per module" approach — the Supervisor acting as a local coordinator delegates training and assessment of specific competencies to alternative experienced medical physicist or other appropriate professionals. This approach is more common in larger centres. The local coordinator allocates competencies and reviews progress and assessment, compiles six monthly supervisor reports (in consultation with the other medical physicists involved in training) and communicates with the National Programme Coordinator. In some cases the local coordinator does all the competency assessment which increases the validity of assessment as it is independent of the medical physicist who performed the training. The latter role is difficult when the Clinical Supervisor is a Chief Physicist or works restricted hours. Note: The Clinical Supervisor is not required to do all the training and assessment. However, they are responsible for ensuring appropriate training and assessment is carried out according to the national guidelines.

II.9. ASSESSMENT

See assessment in Appendix I.10.

NOTES:

- The Clinical Supervisor must have an objective and impartial approach and not be biased when assessing a Resident.
- The Resident must be assessed as satisfactory in each of the above components to be successful in the total programme.
- The required level of competency in ALL sub-modules must be achieved before the oral exam can be attempted.
- The oral examination, and practical examination if required, are designed to assess whether the candidate has the appropriate approach of a qualified DRMP i.e. to work unsupervised in a professional, scientific and safe manner. However as limited technical knowledge and competency can be assessed in these examinations, for the assessment of the majority of the DRMP's roles and responsibilities it is the assessment of competency in actual practice which has a pivotal role in ensuring safe, competent practice.
- Where ever possible supervisor should provide assessment criteria and/or sample exam questions before an assessment

II.10. EXAMPLES OF COMPETENCY ASSESSMENT TOOLS

- Observe, listen, question during routine clinical experience
- Listen to Resident teaching someone else
- Mock scenarios
    - communication with patient or colleague (perhaps also a patient based dilemma, e.g. pregnant patient who doesn't speak the local language)
    - write a commissioning schedule for a new interventional unit
    - quality assurance of a film processor
    - commissioning a fluoroscopy unit
- Attend an internal course on conflict management
- Attend a university course for postgraduate students on oral presentation.
- Ask a patient or another professional's feedback of how the Resident communicated with them.
- Oral assessment in a regular Supervisor-Resident meeting (however performance anxiety may reduce the validity of assessment particularly early in the programme).
- Short written report with assessment and constructive feedback
- Practical assessment which includes oral questioning whilst a Resident performs a routine task (e.g.. quality assurance, absolute calibration)
- Objective, structured clinical examinations or series of defined clinical tasks.
- Logbook review demonstrates degree of exposure to certain tasks.
- Clinical project work
- Patient or equipment trouble-shooting case studies
- Resident lists key steps involved in completing a task
- External competency test at another department
- Portfolio reports provide the opportunity for a Resident to show-off the breadth and depth of their knowledge on certain topics
- Problem based learning programme
- Local tutorial programme
- Self-reflection. The supervisor can ask "how do you think you went?" and provide feedback. A supervisor may also provide criteria for a task to allow the Resident to self assess.
- Presentation to departmental staff
- Write sample letters that are assessed by the supervisor on key points.
- Report on the role of other professional groups.
- Report on the pathway of a patient from diagnosis to treatment.
- Compile decision-making diagrams.
- Critical appraisal of journal articles in Journal Review Meetings.

NOTE: Competency assessment demonstrates normal achievement of goals and doesn't always encourage Residents to extend themselves to achieve their full potential. In contrast, the Portfolio gives the Resident the opportunity to demonstrate excellence.

II.11. RESIDENT MOTIVATION

Success of the clinical training programme relies on the Resident undertaking self-directed study including determining and meeting deadlines (i.e. individual accountability). Difficulty completing the programme is expected to be encountered when the Resident has low initiative and/or is slow to accept responsibility. In contrast, pathways for advancing talented and/or experienced Residents before their recommended completion date need to be considered.

It is recommended that Supervisors document all lapsed deadlines and unacceptable behaviour. Serious concerns must be discussed with the Resident. If necessary, co-opt another party e.g. a mentor, Chief Physicist or National Programme Coordinator to participate in these discussions

If a Supervisor has met the requirements of their position but the Resident continues not to achieve the required standard and/or goals, this may be due to a number of reasons. Strategies for addressing some of these issues are indicated in the table below.

Table II.1. Resident Motivation Strategies

	ISSUE	STRATEGY IDEAS
A	A new Resident has difficulty knowing where to start, what to do and how to put it together and therefore may struggle if thrown "in the deep end".	-Start with basics and increase the complexity as the Resident's level of understanding improves (if feasible). -Supervisor organises more one-on-one time to explain their thought processes for troubleshooting.
B	Learning activities are different to the learning style of the Resident.	-Tailor learning activities to the learning style and maturity of the resident if possible (e.g.. visual learners). -Explain expectations of self-directed learning to those Residents used to didactic learning. -Set shorter, more regular, deadlines for achievement of milestones.
C	Assumed prior knowledge or experience doesn't exist.	-Start with more basic activities (if feasible).
D	Personal issues (relationship issues, mental or physical health problems, financial difficulties, remote from family, etc),	-While in some cases a mentor can assist, these issues are often best referred to the hospital/university counsellor or chief physicist. -Review and re-design the learning agreement to give the Resident time to adjust to a new environment.
E	Difficulties communicating expectations between supervisor and Resident	-Write down each others perspectives and try to understand the other point of view. -Ask the Resident to repeat instructions to determine if they have interpreted your instructions correctly. -Resident to work under another medical physicist (internal or external) for a period of time.
F	Resident has difficulties communicating effectively with others in the Diagnostic Radiology Department.	-Mock scenarios to practice appropriate communication styles (for staff and patients). -Encourage participation in social activities which minimise isolation. -Resident to attend "Communication skills" courses including "Communicating with others" or "Conflict resolution" course if relevant.
G	Resident shows lack of initiative.	-Balance the positive and critical feedback carefully. -Review and re-design the learning agreement to include shorter and more regular deadlines to achieve milestones. -Identify activities related to Resident's value system to draw out enthusiasm. -Increase clinical interaction time to draw them away from their desk. -Open/honest discussion of expectations. -Allocate an area of responsibility to the Resident if they feel indifferent as they don't have their own niche. (if appropriate) -Peer-support system with another Resident. -Formative assessment if feasible. Anxiety can be created from a lack of regular assessment or feedback.
H	Not willing to work out of hours	-Discuss conditions of employment and relevant issues (e.g. personal) if progress is behind schedule.

Table 1 (cont.). Resident Motivation Strategies

I	Difficulties managing competing priorities	-Regular meetings with Resident to review the Resident's work/ priorities. -Time management course.
J	Difficulties with scientific thinking and is more suited to a technically-based profession	-Explain expectations. -Start with basic scenarios and increase the complexity as their level of understanding improves (if feasible). -Supervisor organises more one-on-one time to explain their thought processes for troubleshooting. -If unresolved, refer them to their mentor to review career options. -Stop the placement.
K	Difficulties identifying opportunistic learning avenues.	-Supervisor, initially, identifies avenues for opportunistic learning as often such opportunities are one-off and not planned. This should be for a limited period only. -Allow them to work with someone (RT, engineer, medical physicist) for a period of time. -Increase clinical interaction time. -If appropriate, make them responsible for an item of equipment for a period of time.

II.11.1. If a Resident fails to meet required standards

Termination of the clinical training position should be considered if the Resident fails to meet the standards required in the programme following a period of supportive and corrective feed back and opportunity to improve. If this does occur, do not feel as though you have failed the Resident. . Rose and Best (2005) note "you don't fail the Resident….the Resident fails the assessment. In a well-developed assessment system with clear expectations and criteria, adequate feed back for the student and opportunities for improvement, the student should have had every opportunity to achieve the desired standard".

The department is responsible for the continuation of the employment of the Resident. Where progress of a Resident is unsatisfactory then the National Programme Coordinator should communicate with the employing department.

II.12. CLINICAL ROTATIONS

The Resident may require training in other training hospitals for periods of time to gain experience in techniques or on equipment not available in the Resident's own hospital. Examples of this might include dual-energy X ray absorptometry (DXA) equipment, digital/computerized radiographic equipment, cardiac catheterization laboratory and a high field MRI unit. In addition clinical rotations to the radiation therapy and nuclear medicine departments, under the supervision of experienced medical physicists, are also areas that should be planned.

Aspects to consider when rotating Residents to other departments include:

- Time constraints imposed by completion of the clinical training programme, and distances to be traveled by the Resident.
- The pre-requisite knowledge should be completed before any Clinical Rotation is undertaken
- The visiting Resident should work on competencies related to the rotation's focus area but must also be flexible enough to work within the busy schedule of the Host department.

- A Resident can visit another department for varying amounts of time, from a day up to months at a time.
- A clinical rotation can also include a competency test conducted by an experienced person in the Host department.
- The responsibility of coordinating the clinical rotation and delegation of competency assessment during this placement remains with the Clinical Supervisor.

Expectations of both departments and competencies to be addressed, should be documented prior to the commencement of the clinical rotation

II.13. BIBLIOGRAPHY

MCALLISTER, L., (Ed.) Facilitating learning in clinical settings, Stanley Thornes, Cheltenham, UK, (1997).

ROSE, M., BEST, D., (Eds), Transforming practice through clinical education, professional supervision and mentoring, Elsevier, (2005).

II.14. USEFUL RESOURCES FOR CLINICAL SUPERVISORS

European Federation of Medical Physics (EFOMP)

- http://www.efomp.org/docs/CurriculumForMP.pdf
- http://www.medfys.no/misc/EFOMP-Policy1upd_draft4.doc

Mentoring

- http://www.edu.uwo.ca/conted/mentor/index.asp
- "ACPSEM Guide for Mentors". (2004) Mellish and Associates.
- http://www.uscg.mil/leadership/mentoring/mentguid.ppt#1
- http://www.usfirst.org/uploadedFiles/Community/FRC/Team_Resources/Mentoring%20Guide.pdf
- http://www.mentorlinklounge.com/

Clinical Supervision

- "Teaching on the run" is something that doctors, RTs and physicists all have in common when providing clinical training (see Table II.2). http://www.mja.com.au/public/issues/contents.html

Table II.2

Teaching on the run tips: doctors as teachers	MJA 2004; 181 (4): 230-232
Teaching on the run tips 2: educational guides for teaching in a clinical setting	MJA 2004; 180: 527-528
Teaching on the run tips 3: planning a teaching episode	MJA 2004; 180: 643-644
Teaching on the run tips 4: teaching with patients	MJA 2004; 181 (3): 158-159
Teaching on the run tips 5: teaching a skill	MJA 2004; 181 (6): 327-328
Teaching on the run tips 6: determining competence	MJA 2004; 181 (9): 502-503
Teaching on the run tips 7: effective use of questions	MJA 2005; 182 (3):126-127
Teaching on the run tips 8: assessment and appraisal	MJA 2005; 183 (1): 33-34
Teaching on the run tips 9: in-training assessment	MJA 2005; 183 (1): 33-34
Teaching on the run tips 10: giving feedback	MJA 2005; 183 (5): 267-268
Teaching on the run tips 11: the junior doctor in difficulty	MJA 2005; 183 (9): 475-476
Teaching on the run tips 12: planning for learning during clinical attachments	MJA 2006; 184 (5): 238-239
Teaching on the run tips 13: being a good supervisor — preventing problems	MJA 2006; 184 (8): 414-415
Teaching on the run tips 14: teaching in ambulatory care	MJA 2006; 185 (3): 166-167

APPENDIX III: IMPLEMENTATION GUIDE

III.1. ESSENTIAL REQUIREMENTS FOR SUCCESSFUL IMPLEMENTATION OF THE CLINICAL TRAINING PROGRAMME.

III.1.1. Programme management

On the level of an individual resident, the concept of clinical training can be relatively simple. However as a programme begins to involve many individual residences spread over a number of medical facilities, it grows in complexity and importantly it also needs clear assessment standards which need to be established and maintained[8]. This calls for a defined management structure.

This structure would normally be most effective on a national level[9] and usually needs to be placed within an established body or institution (such as a professional body for example). Relatively few countries have developed structures for clinical training currently in place. To assist in cases with limited existing management structures and limited resources, external assistance is advocated.

III.1.1.1. National

The programme should be recognised by a national authority such as the Medical Physics Professional Body, the Ministry of Health, the Ministry of Education or the National Atomic Energy Authority. The national authority is referred to as the ***National Responsible Authority*** (NRA) in this appendix.

[8] See Appendix V Assessment criteria, page 143.
[9] Regional clinical training programmes might also be possible in some circumstances

The National Responsible Authority provides **formal recognition** of the qualification "Diagnostic Radiology Medical Physicist" (or equivalent) and the requirements to become one.

The programme should be managed by a ***National Steering Committee*** comprising of representatives from the relevant Medical Physics Professional Body (where one exists) and other relevant interest groups and stake holders. It is highly recommended that the professional body should form the majority of members in the Committee.

In managing the programme the National Steering Committee must:

- Appoint a ***National Programme Coordinator*** to oversee the implementation of the project (appointment of several Programme Coordinators may be justified in large countries where regional coordination is necessary). The National Programme Coordinator should, ideally, be a person engaged in the practice of diagnostic radiology medical physics.
- Establish a ***Support Group*** of individuals who agree to assist with Resident training. The support group may include radiologists, diagnostic radiology medical physicists and personnel from educational institutions. Ideally, at least one diagnostic radiology medical physicist who is external to the country should be a member of the support group.
- Ensure that guidelines for participation in the clinical training programme are strictly followed by both the clinical departments and the Residents
- Ensure that standards for assessment are set and maintained
- Maintain records of Residents' progress
- Issue certificates that provide an accurate record of a Resident's performance
- Implement an annual survey of departments and Residents of progress of the training programme
- Report to the external coordinator on progress of the programme
- Develop a process for appeals and complaints

In regard to maintaining of assessment standards the NSC should:

- Review all '**competencies addressed**' in the guide (Appendix IV) to determine if each competency is consistent with the required physics practice for diagnostic radiology in the country. This can be done by specifying the appropriate '**level of competency achieved**'.

- Review and authorise the '**recommended items of training'** in the sub-modules to allow items to be added, deleted or altered upon advice.

The National Responsible Authority, having been assured that the National Steering Committee has fulfilled its responsibilities outlined above, should provide formal recognition of the qualification awarded.

III.1.1.2. External

One form of external assistance involved the piloting in selected countries for a trial period of several years. For these pilot programmes an external management structure has been formed

to coordinate external support and to oversee the general conduct of the programme. The external management structure includes an external coordinator and external reviewers.

The external coordinator may assist the programme in the following ways:

- Review the entry qualifications of applicants for the training programme
- Consider Resident numbers in relation to department resources including arrangements for supervision of the Resident(s)
- Review Residents' Progress
- Coordinate the use of external reviewers
- Consider and deal with issues raised by the external reviewers
- Consider difficulties encountered and recommend remedial action to be taken
- Provide advice to the National Programme Coordinator and National Steering Committee
- Coordinate the assessment of the programme and compile statistics on the programme on an annual basis
- Promote the sustainability of the national clinical training programme

The external coordinator will work closely with the National Programme Coordinator and National Steering Committee to ensure the smooth operation and success of the programme.

The role of the external reviewers may include:

- Monitoring of the progress of individual Residents
- Reviewing a Resident's work plan
- Liaising with clinical supervisors.
- Reviewing items of assessment of a Resident
- Giving presentations to medical physicists and Residents

III.1.2. Basic requirements for departments where residents are located

III.1.2.1. Clinical Supervisor

The department must provide any Resident with a supervisor who is clinically competent in diagnostic radiology medical physics. The number of residents in a department should normally not exceed the number of clinically competent medical physicists in that department. More detail concerning the requirements for supervision are provided below (section III.5).

III.1.2.2. Resources

It is important that the Resident is trained in the full range of a medical physicist's duties and hence a department participating in the training programme must have:

- General X ray units
- Fluoroscopy X ray units
- CT unit
- Dosimetry equipment.

The department must also have on-site or be prepared to rotate Residents to other departments with:

- Mammography unit, and
- Dental units.

It would also be advantageous to have access to

- Ultrasound units,
- DXA unit,
- TLD system, and
- MRI unit

III.1.2.3. Clinical service

The Resident must practice in a department that offers a full range of diagnostic radiology services and which employs medical practitioners trained in diagnostic radiology.

III.2. ENTRY REQUIREMENTS FOR RESIDENTS

It is expected that Residents in this programme:

- have a university degree in physics, engineering or an equivalent physical science.
- should have an appropriate academic qualifications in medical physics (or equivalent) at the postgraduate level, or be enrolled in a suitable post graduate programme
- should be employed as a medical physicist and working in a diagnostic radiology clinical environment.

Note: Alternative entry requirements may be approved in consultation with the external coordinator during the pilot process.

III.3. REQUIREMENTS FOR SUPERVISION OF RESIDENTS

A suitably qualified and experienced Clinical Supervisor should be appointed by a department seeking to participate in the pilot of the clinical training programme. The supervisor should be a person working in the same department as the Resident. Participation of the Resident in the training programme and involvement of the department must be approved by the responsible medical specialist (including a guarantee that the Resident will have the necessary access to equipment).

The supervisor should:

- Have a commitment to the programme
- Be available for consultation with the Resident when needed
- Assist the Resident with access to equipment and all aspects of their training programme
- Maintain links with the National Programme Coordinator to access national resources if required.

Although supervision by a person with experience in teaching is desirable, it is recognised that such a person may not always be available on-site. The role of the supervisor is to facilitate the resident's progress rather than necessarily to provide individual advice on all aspects of the training content. It is recommended that the supervisor attend a relevant train-the-trainer programme in clinical supervision. More detail of the roles and responsibilities of the Clinical Supervisor are provided in Appendix II *Handbook for Clinical Supervisors.*

III.4. ELEMENTS OF THE TRAINING PROGRAMME

III.4.1. The Guide

The clinical training guide for medical physics specializing in diagnostic radiology includes ten modules each containing a number of sub-modules. The modules

- Define a unified portion of clinical knowledge or experience and provide detailed content.
- Can be undertaken in any order and with more than one module undertaken at a time.
- Provide recommended items of training.

III.4.2. Items of Assessment

See Appendix 1.10

III.4.3. Supplementary appendices to assist the resident

These include:

- A Resident's Handbook
- A sample Logbook may be obtained from the external coordinator.
  A Logbook is recommended but not obligatory and is not included in the assessment process. If used, the Logbook is maintained by the Resident and contains a record of training experiences with comments as to difficulties experienced and positive learning outcomes. The form of the record is up to the Resident's discretion and could be in electronic or hardcopy form.

III.4.4. A Handbook for clinical supervisors

Designed to assist Clinical Supervisors in understanding and implementing the roles and responsibilities of the position

III.4.5. Implementation manual

This appendix

APPENDIX IV: CLINICAL TRAINING GUIDE

IV. INTRODUCTION

This IAEA Guide to Clinical Training in Diagnostic Radiology Medical Physics is divided into ten modules. Each module defines a unified portion of clinical knowledge or experience required of a Medical Physicist specializing in Diagnostic Radiology.

The ten modules are:

Module 1: Clinical awareness

Module 2: Radiation protection and safety

Module 3: Research, development and teaching

Module 4: Professionalism and communication

Module 5: Performance testing of imaging equipment

Module 6: Technology management

Module 7: Dosimetry, instrumentation and calibration

Module 8: Patient dose audit

Module 9: Image quality assessment

Module 10: Optimization

Modules 2 and 5-10 (highlighted) are considered as core modules.

The modules are further divided into sub-modules which address particular competencies. The sub-modules to be undertaken and the level of competency required to be achieved in **each sub-module** have been determined by the Responsible National Authority, or its delegate. You should refer to Appendix V "*Competency Assessment"* to determine the levels required.

The modules and sub-modules are presented in tabular form. The table for each module includes:

- An objective
- Expected time commitment to the module (note this is a guide only. Particular Resident's may take more or less time to acquire the level of competency expected in particular modules).
- An indication of pre-requisite knowledge required (if any) for the module
- List of sub-modules
- A core reading list

The table for each sub-module includes:

- The objective of the sub-module
- Any prerequisite modules
- The competency or competencies divided into knowledge based and skills based competencies

- Core knowledge summary
- Recommended elements of training.
- Reading list

There are a total of 55 knowledge and 51 skills based competencies included in the sub-modules. The modules and sub-modules can be undertaken in any order and with more than one module undertaken at a time.

Assessment of competencies should be performed using the assessment matrix for each sub-module provide in the appendix cited above.

The guide has been designed to be relevant for all modalities irrespective of the level of equipment complexity in use in the country. This has been done (i) to allow all countries undertaking clinical training to use a uniform national standard determined by their particular equipment types, and (ii) to reduce the effect of obsolescence as equipment technology changes. Where appropriate the national steering committee (NSC) should determine the 'level of competency achieved' for a competency and the type of treatment unit(s) specified within a competency. Further the NSC can authorise changes to the 'recommended items of training' that might be suggested.

	MODULE 1: CLINICAL AWARENESS
Objective	To provide the resident with clinical knowledge and experience related to Diagnostic Radiology.
Expected Duration	3 – 7% of overall time
Sub-Modules	(1) Radiologic Anatomy and Physiology (2) Radiobiology and Epidemiology (3) Patient-Related Experience
Core Reading	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp
	Module 1: Clinical awareness
	Sub-module 1.1: Radiologic anatomy and physiology
Objective	To gain sufficient knowledge of radiological anatomy and physiology to be able to communicate effectively with medical personnel.
Prerequisite	None
Competencies Addressed	• An understanding of radiological anatomy and physiology as seen on medical images.
Core Knowledge	(1) Types of medical images (2) Identify difference in image forming processes needed to produce various medical images (3) Typical anatomy displayed on plain film or digital radiographic images, and CT, MRI, and ultrasound images (4) Typical physiology on nuclear medicine and PET images, or other dynamic imaging modalities, e.g., cardiac catheterization and blood flow in digital images,
Recommended Elements of Training	(1) Discuss various aspects of radiological anatomy and physiology with medical staff including, but not limited to, radiologists, other physicians, and surgeons. (2) Identify anatomy in medical images. (3) Display medical images properly, i.e., correct orientation on the viewbox or display (4) Appreciate physiological function on nuclear medicine, PET images, or other dynamic imaging modalities, e.g., cardiac catheterization and blood flow in digital images,

Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp [2] DORLANDS, Dorlands Illustrated Medical Dictionary. [3] ELAIN, M., Human Anatomy and Physiology, 7th edn. [4] NOVELLINE, R.A., Squire's Fundamentals of Radiology, Harvard University Press (2004).
	Module 1: Clinical awareness
	Sub-module 1.2: Radiation biology and epidemiology
Objective	To understand the basic radiation biology underpinning radiological imaging.
Prerequisite	None
Competencies Addressed	• An understanding of the basic principles of radiation biology and epidemiology.
Core Knowledge	(1) Radiation biology: ° Track structure, LET and absorbed dose ° RBE and Quality Factors ° Equivalent dose and Radiation Weighting Factors ° Effective dose and Tissue Weighting Factors ° Cellular responses, DNA repair and cell survival/death ° Stochastic and deterministic effects ° Acute and late biological responses ° Risk models and quantitative radiation risks ° Doses and risks in diagnostic radiology ° LNT and uncertainties at low doses ° Non-targeted effects (bystander responses & genomic instability) (2) Epidemiology: ° Epidemiologic studies: case control and cohort studies ° Odds ratio, relative risk ratio
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp [2] HALL, E., GIACCIA, A.J., Radiobiology for the Radiologist, 6th edn, Lippincott Wilkins & Williams, Philadelphia, USA (2006). [3] HENNEKENS, C.H., BURING, J.E., MAYRENT, S.L., Epidemiology in Medicine, 1st edn, Lippincott Williams & Wilkins (1987).

	Module 1: Clinical awareness
	Sub-module 1.3: Patient related experience
Objective	To provide the resident with broad patient-related experiences and an understanding of the role of multidisciplinary professionals involved in or receivers of imaging services.
Prerequisite	Sub-module 4.2: Communication
Competencies Addressed	• An understanding of the factors that effect patient care
Core Knowledge	(1) Need for patient care, rapport, privacy, and confidentiality during patient related experiences. (2) Appropriate clinical dress code (3) Need for introducing oneself to the patient. (4) Need to address all professional staff by their appropriate title in patient care areas (5) Appropriate hygiene and infection control procedures (6) Effect of diagnostic and interventional imaging on patient quality of life (7) Patient-staff interactions (8) Interactions, roles and responsibilities of multi-disciplinary professionals involved in patient management.
Recommended Elements of Training	(1) Radiology: ◦ Exposure to the following patient-related clinical experiences: ▪ General radiology including digital or plain film radiography, mammography and fluoroscopy ▪ Interventional and cardiac imaging ▪ Sectional imaging; including CT and MRI ▪ Ultrasound ▪ Dental imaging ◦ During this time, the resident should: ▪ Understand the patient work flow for a range of typical diagnostic procedures including ambulatory and non-ambulatory patients ▪ Attend reporting sessions with different Radiologists over a number of weeks covering all modalities ▪ Attend at least two clinical review meetings covering each of a number of organ systems (case review) ▪ Demonstrate an understanding of the purpose of the typical procedures. ▪ Note the reasons for the patient's admission and their conditions ▪ Understand why only a low percentage of diagnostic and interventional patients need to be admitted to the ward

	▪ Prepare a patient case study for a complex procedure such as a cardiac procedure ▪ Role play a discussion of concerns of a patient regarding the dose they will receive from the procedure and the associated risks in terms that the patient can understand (2) Radiation Oncology: ° Attend all phases of the radiotherapy process from a simulation through to patient treatment. ° Examine the roles of imaging used in this above process (diagnosis, simulation, and treatment) whether the imaging modality is situated within radiation oncology or elsewhere. ° Understand the key differences in the application of identified imaging modalities in therapy compared to radiology (3) Nuclear Medicine: ° Observe a number of nuclear medicine imaging procedures, especially those involving SPECT, SPECT/CT and PET/CT equipment. This should include attendance at reporting sessions. ° Understand the role of CT in nuclear medicine imaging, including optimization measures ° Understand the differences between, and relative advantages of, nuclear medicine and x ray imaging ° Understand the dosimetry and protection differences between nuclear medicine and radiology (patient and staff) ° Understand the QC procedures used in nuclear medicine (4) Ultrasound: ° Observe ultrasound imaging procedures (where ethically possible), including Doppler imaging ° Understand the differences between, and relative advantages of, ultrasound and x ray imaging (5) Other areas: ° Understand and observe the use of x ray imaging at sites outside of the radiology department including operating theatres, and intensive care and emergency areas.
Knowledge Sources	[1] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [2] MUTIC, S., et al., Quality assurance for computed-tomography simulators and the computed-tomography-simulation process: report of the AAPM Radiation Therapy Committee Report No. 83, Medical Physics 30 10 (2003) 2762-92. [3] NOVELLINE, R.A., Squire's Fundamentals of Radiology, Harvard University Press (2004).

	MODULE 2: RADIATION PROTECTION AND SAFETY
Objective	To provide residents with an understanding of all aspects of radiation protection and safety of staff and members of the public. Note 1: Most issues concerning patient protection are dealt with in subsequent modules. Note 2: Some of the tasks defined in this module may be also carried out by a Radiation Protection Officer (RPO). Local circumstances will dictate actual working arrangements.
Expected Duration	10 – 15% of overall time
Sub-Modules	(1) Personnel dosimetry (2) Radiation hazard assessment (3) Radiation protection and safety review (4) Dose reduction – staff and public (5) Unintended and accidental exposures in diagnostic radiology (6) Shielding
Core Reading	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the ICRP. Annals of the ICRP vol 37 (2-4) Rep. 103 (2007). [3] INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, IAEA Safety Standards Series, SF-1, IAEA, Vienna (2006). www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf [4] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996). [5] MARTIN, C.J., SUTTON, D.G., Practical Radiation Protection in Healthcare, Oxford University Press, Oxford (2002). [6] INTERNATIONAL ATOMIC ENERGY AGENCY, Applying Radiation Safety Standards in Diagnostic Radiology and Interventional Procedures Using X Rays, Safety Reports Series No. 39, IAEA, Vienna (2006). http://www-pub.iaea.org/MTCD/publications/PDF/Pub1206_web.pdf. [7] MR SAFETY, www.mrisafety.com.

	Module 2: Radiation Protection and Safety
	Sub-module 2.1: Personnel dosimetry
Objective	To be able to provide a personnel dosimetry service at a local level.
Prerequisite	Sub-module 7.1: Ionising radiation dosimetry and principles of measurement Sub-module 2.2: Radiation hazard assessment
Competencies Addressed	• An understanding of the purpose, principles, and operation of a personnel dosimetry program. • The ability to provide a personnel dosimetry service to one or more radiology departments at a local level.
Core Knowledge	(1) Local legislative requirements for personal dosimetry including those for trainees and women who are or may be pregnant. (2) The theory, principles of operation, and limitations of ° Film based dosimeters ° Electronic personnel dosimeters ° Thermoluminescent dosimeters ° OSL & RPL dosimeters ° Calculation methods. (3) The basic operational quantities and their relationship to effective dose: ° Personal dose equivalent Hp(10), Hp(3) and Hp(07) ° Ambient dose equivalent (4) Principles of whole body monitoring (including calibration) (5) Principles of extremity monitoring (including calibration) (6) How occupational radiation doses differ according to radiological procedures. (7) Requirements for record keeping
Recommended Elements of Training	(1) Methods for measuring personal dose: ° Assess the relative merits of different dose monitors for use in a radiology department. ° Identify the correct type of personal dosimeter to issue to differing staff groups (including pregnant women) and for different imaging modalities ° Ensure that dosemeters are appropriately calibrated in order to guarantee precise, accurate and traceable measure of dose. ° Determine calculation methods to be used for staff dosimetry when measurements are not available or are not applicable. (2) Operational use of personal dosimeters: ° Establish a system for issuing and collecting dose monitors ° Decide on the applicable investigation levels for individual results ° Determine which staff groups and areas need to be monitored

	° Decide on the frequency of monitoring for staff groups and individual members of staff ° Determine the type of monitor (e.g. whole body or extremity) required for a particular situation. ° Explain the need for dose monitoring to staff groups (3) Record keeping and investigation: ° Establish and maintain record keeping procedures for personnel dosimetry results ° Develop and implement procedures for the analysis of doses above the investigation level ° Depending on local circumstances read out dosimeters or obtain dose results from provider, ° Where appropriate calculate doses received using recognised methods. ° Provide results of dose monitoring and assessment, detailing non-compliant or high-risk issues. ° Investigate cases of unusual or unexpected dose readings ° Explain the significance of results to individual staff members and other relevant personnel such as hospital administration
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, L13.2: Occupational exposure - Radioprotection measures, rpop.iaea.org/RPOP/RPoP/Content/Documents/TrainingRadiology/Lectures/RPDIR-L13.2_Occup_radioprot_WEB.ppt. [3] TEMPERTON, D.H., GREEN, S., "Personal Monitoring", Practical Radiation Protection in Healthcare, (MARTIN, C.J.SUTTON, D.G., Eds), Oxford University Press, Oxford, (2002). [4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, ICRP Publication 57. Radiological Protection of the worker in Medicine and Dentistry Annals of the ICRP vol 20(3) (1989). [5] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, ICRP Publication 75. General Principles for the Radiation Protection of Workers. Annals of the ICRP vol 27(1) (1997). [6] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Use of Personal Monitors to Estimate Effective Dose Equivalent and Effective Dose to Workers for External Exposure to Low-LET Radiation., NCRP Rep. 122, Bethesda, MD, USA. (1995). www.ncrppublications.org. [7] INTERNATIONAL ATOMIC ENERGY AGENCY, Occupational Radiation Protection, IAEA Safety Standards Series, No. RS-G-1.1, IAEA, Vienna (1999). www-pub.iaea.org/MTCD/publications/PDF/Pub1081_web.pdf.

	Module 2: Radiation Protection and Safety
	Sub-module 2.2: Radiation hazard assessment
Objective	To acquire the knowledge and skills to be able to perform a hazard assessment of procedures and facilities for staff and members of the public.
Prerequisites	Module 8: Patient dose audit
Competencies Addressed	• An understanding of the principles of hazard assessment and engineering and procedural controls that can be used to reduce hazards to a level that are as low as reasonably achievable and comply with regulatory requirements. • The ability to conduct and act on a hazard assessment.
Core Knowledge	(1) Principles: ° Methodologies for hazard assessment ° Radiation protection principles (Justification, optimization, limitation) ° Dose constraints and reference levels (2) Regulatory requirements and guidelines: ° Requirements for staff and members of the public ° Requirements for medical exposures ° Special requirements for pregnant persons ° Special requirements for trainees ° Special requirements for research involving ionising radiation (3) Hazards and Controls: ° Hazards of ionizing and rf radiation ° Engineering controls (including shielding) for reducing exposure to staff and members of the public ° Procedural controls for reducing exposure to staff and members of the public ° Designation of areas where radiation is used ° Use of Signage ° Use of Personal Protective Equipment (4) Dose assessment (see Module 8): ° Assessment of dose and its impact
Recommended Elements of Training	(1) Carry out hazard assessment of facilities and radiological procedures: ° Identify potential hazards from the work ° Identify all the persons who may be exposed and how they might be exposed ° Evaluate each potential hazard and decide whether the proposed or existing precautions are adequate, taking into account elements such as:

	▪ Type of x ray equipment ▪ Estimates of dose rates to which persons may be exposed ▪ Results of personal dosimetry for similar activities ▪ Engineering and other control measures either planned or in place ▪ Impact of the failure of procedures and engineering controls. ▪ Options for Personal Protective Equipment ▪ Planned or existing Local Rules or Systems of Work (2) Identify measures which need to be put in place to control the potential hazards and ensure compliance with regulation such as: ° The need for shielding and Personal Protective Equipment ° The need for personal and environmental dose monitoring ° Signage ° Local Rules, Systems of Work, and Contingency plans ° Limitation of access to designated (controlled) areas ° Protection of pregnant staff ° Maintenance and testing: ▪ Training (3) Record the assessment (4) Review the assessment at regular intervals.
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Occupational Radiation Protection, IAEA Safety Standards Series, No. RS-G-1.1, IAEA, Vienna (1999). www-pub.iaea.org/MTCD/publications/PDF/Pub1081_web.pdf. [2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the ICRP. Annals of the ICRP vol 37 (2-4) Rep. 103 (2007). [3] INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, IAEA Safety Standards Series, SF-1, IAEA, Vienna (2006). www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf . [4] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996). [5] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiological Protection for Medical Exposure to Ionizing Radiation, IAEA Safety Standards Series, No. RS-G-1.5, IAEA, Vienna (2002). www-pub.iaea.org/MTCD/publications/PDF/Pub1117_scr.pdf . [6] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, ICRP Publication 73. Radiological Protection and Safety in Medicine. Annals of the ICRP 26(2) (1996). [7] MARTIN, C.J., SUTTON, D.G., Practical Radiation Protection in Healthcare, Oxford University Press, Oxford (2002). [8] INTERNATIONAL ATOMIC ENERGY AGENCY, Occupational Radiation Protection, IAEA Safety Standards Series, No. RS-G-1.1, IAEA, Vienna (1999). www-pub.iaea.org/MTCD/publications/PDF/Pub1081_web.pdf .

	Module 2: Radiation Protection and Safety
	Sub-module 2.3: Radiation protection and safety review
Objective	To acquire the knowledge and skills to be able to perform an audit of procedures and facilities in diagnostic radiology.
Prerequisites	None
Competencies Addressed	• An understanding of: (a) The factors underpinning radiation protection and safety review (b) The need to keep doses as low as reasonably achievable and to ensure regulatory compliance. • The ability to carry out a Radiation protection and safety review and implement remedial measures where necessary.
Core Knowledge	(1) Principles: ° Radiation protection principles (Justification, optimization, limitation) ° Dose constraints and reference levels ° Regulatory requirements and guidelines ° Employer's responsibilities ° Requirements for staff and members of the public ° Requirements for medical exposures ° Special requirements for pregnant persons ° Special requirements for trainees (2) Controls: ° Engineering controls for reducing exposure to staff and members of the public ° Procedural controls for reducing exposure to staff and members of the public ° Designation of areas ° Monitoring of the workplace ° Use of Personal Protective Equipment for patients and staff (3) Personal dose monitoring programmes (4) Principles of Equipment Quality Assurance
Recommended Elements of Training	(1) Identify whether: ° Appropriate licences are in place ° Staff and management roles and responsibilities are documented and current, and that all users are aware of their responsibilities for radiation safety and control ° Radiation risk assessments have been performed ° Areas where radiation is used are appropriately designated

	° Local rules, Radiation protection and safety procedures and systems of work are current, and fully compliant with legislative requirements ° Appropriate shielding has been put in place ° Appropriate Personal Protective Equipment has been supplied ° Necessary control features and warning signs (where appropriate) are in place ° All relevant staff training has been completed ° Continuing education programmes are in place ° Personal dosimetry and monitoring systems are in place ° Appropriate arrangements are in place for pregnant staff ° Appropriate arrangements are in place for trainees and young people. (2) Review records of: ° Personal dosimetry and monitoring programme: ° Environmental dose surveys ° Equipment Quality Assurance programmes ° Workload and shielding review ° Checks of personal protective equipment (3) Determine whether any radiation incidents have taken place, the steps taken to minimise their re-occurrence, and whether they were reported to the regulatory authorities. (4) In all cases Identify and implement measures to address shortfalls in compliance and good practice
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the ICRP. Annals of the ICRP vol 37 (2-4) Rep. 103 (2007). [3] INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, IAEA Safety Standards Series, SF-1, IAEA, Vienna (2006). http//www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf [4] INTERNATIONAL ATOMIC ENERGY AGENCY, Applying Radiation Safety Standards in Diagnostic Radiology and Interventional Procedures Using X Rays, Safety Reports Series No. 39, IAEA, Vienna (2006). http://www-pub.iaea.org/MTCD/publications/PDF/Pub1206_web.pdf . [5] INTERNATIONAL ATOMIC ENERGY AGENCY, Occupational Radiation Protection, IAEA Safety Standards Series, No. RS-G-1.1, IAEA, Vienna (1999). http://www-pub.iaea.org/MTCD/publications/PDF/Pub1081_web.pdf [6] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Operational Radiation Safety Program, NCRP Rep. 127, Bethesda, MD, USA. (1998). www.ncrppublications.org.

	[7] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).
	Module 2: Radiation Protection and Safety
	Sub-module 2.4: Dose reduction - staff and public
Objective	To be able to apply dose reduction techniques for radiology staff, other employees and members of the public.
Prerequisites	Sub-module 6.6: Department design
Competencies Addressed	• An understanding of the factors that affect radiation dose to staff and members of the public including the inter-relationship with patient dose. • The ability to advise on practical aspects that will result in lower doses to staff and members of the public.
Core Knowledge	(1) Primary & Secondary Radiation: ° Primary beam ° Scattered radiation ° Leakage radiation (2) Scatter: ° Angular distribution of scatter ° Effect of kV, mA, time and irradiated volume on scatter ° Effect of patient dose on staff dose – scatter ° Scatter vs. primary radiation ° Entrance scatter and exit scatter (3) Time: ° Pulsed operation, e.g. 30 vs. 15 and 7.5 fps ° Last image hold ° Virtual collimation (4) Shielding: ° Ceiling, Table & Intensifier mounted shielding ° Control booth ° Operators consoles and shielding ° Mobile shields ° Room Design ° Personal Protective Equipment: ▪ Lead aprons ▪ Thyroid collars ▪ Protective Gloves ▪ Protective Glasses

	(5) Distance: ° Inverse square law: ▪ Variation of dose in an x ray room – isodose contours (6) Implications of the use of undercouch and overcouch geometry and of lateral and oblique projections on staff dose in fluoroscopy
Recommended Elements of Training	(1) Advise on practical issues to reduce staff dose in a variety of operational scenarios in: ° Plain film radiography ° Fluoroscopic procedures ° Interventional procedures ° Computed Tomography ° Mammography (2) Measure radiation doses around radiological equipment to demonstrate the effect of dose reduction techniques. To include assessment of the efficacy of personal protective equipment. (3) Identify patient dose reduction techniques that do not result in staff dose reduction and vice versa (4) Educate users of x ray equipment in staff dose reduction techniques
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] IAEA , Radiation protection in diagnostic radiology, modules 6,7,12,13,1 & 14, http://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Training/1_TrainingMaterial/Radiology.htm . [3] IAEA , Radiation protection in cardiology: module7 on occupational exposure and module 12 part 2, http://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Training/1_TrainingMaterial/Cardiology.htm .
	Module 2: Radiation Protection and Safety
	Sub-module 2.5: Unintended and accidental exposure in diagnostic radiology
Objective	To understand how to respond to an unintended or accidental exposure occurring in a radiology department affecting staff, patients or members of the public.
Prerequisites	Sub-module 2.4: Dose reduction – staff and public Sub-module 7.1: Ionising radiation dosimetry and principles of measurement Sub-module 10.2: Optimization process
Competencies Addressed	• An understanding of what constitutes an unintended or accidental exposure in a radiology department, the implications and required response.

	• The ability to respond to an unintended or accidental exposure occurring in a radiology department.
Core Knowledge	(1) Procedural and regulatory issues: ° Definitions of unintended or accidental exposure in diagnostic radiology ° Roles and responsibilities for investigation, assessment and reporting of an unintended or accidental exposure. (2) Issues relevant to an investigation into an unintended or accidental exposure: ° Procedural vs. equipment related. unintended or accidental exposures ° Training requirements for equipment ° Normal modes of operation of equipment ° Existing shielding and other engineering controls on radiation ° Knowledge of personal protective equipment available and how it should be used ° Local rules, systems of work, access arrangements and contingency plans ° Collection of appropriate data to enable the best possible post hoc dosimetry to be performed (3) Radiation dose assessment: ° Air kerma, absorbed dose, effective dose and their relationship to other relevant dosimetric quantities ° Techniques for the assessment and estimation of radiation doses to patients, foetuses, staff and members of the public ° Stochastic and deterministic risks arising from radiation exposure in unintended or accidental exposure situations (4) Reporting: ° Regulatory requirements for notification of unintended or accidental exposure ° How to communicate risk ° Methods for implementing measures to change procedures.
Recommended Elements of Training	(1) Procedural and regulatory issues: ° Develop definitions for radiation unintended or accidental exposure in the local workplace taking into account regulatory requirements ° Develop procedures and contingency plans for dealing with unintended or accidental exposures ° Carry out investigation into the circumstances of the unintended or accidental exposure ° Obtain information from individuals involved concerning the circumstances of the unintended or accidental exposure ° Resolve issues in areas where information is lacking or inconsistent ° Identify whether the incident results from an equipment or procedure related error (or both). Identify if a related cause may have been the protocols of procedures used

	° Identify what dosimetry needs to be performed and ensure that the correct data has been obtained (2) Dose assessment: ° When necessary, carry out measurements to assist in the assessment of the magnitude of the dose received by anyone affected by the unintended or accidental exposure ° Perform calculations to determine the dose to anyone affected by the unintended or accidental exposure ° Establish the risk arising from the unintended or accidental exposure (3) Reporting: ° Determine whether the unintended or accidental exposure should be reported to a regulatory body and, if appropriate, do so. ° Prepare a summary report which is understandable to relevant clinicians and if appropriate, the patient (4) Recommendations: ° Make recommendations on action required to comply with regulatory requirements ° Make recommendations on actions required to minimise the possibility of future unintended or accidental exposures occurring: ▪ Recommend appropriate training or retraining to minimise the risk of occurrence of similar unintended or accidental exposure. ▪ Recommend changes to procedures ▪ Recommend equipment replacement ▪ Recommend action by equipment manufacturer
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Avoidance of Radiation Injuries from Medical Interventional Procedures, ICRP Publication 85, Pergamon Press, Oxford and New York (2000). [3] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Report on Methodology for Investigation of Radiation Accidents involving sources of ionising radiation, IAEA, Vienna (2009). [4] INTERNATIONAL ATOMIC ENERGY AGENCY, L13.2: Occupational exposure - Radioprotection measures, rpop.iaea.org/RPOP/RPoP/Content/Documents/TrainingRadiology/Lectures/RPDIR-L13.2_Occup_radioprot_WEB.ppt . [5] KOENIG, T.R., WAGNER, L.K., METTLER, F.A., WOLFF, D., Radiation Injury to the Skin Caused by Fluoroscopic Procedures: Lessons on Radiation Management. The University of Texas Health Science Center at Houston, TX, (2000), http://www.uth.tmc.edu/radiology/exhibits/koenig_wagner/index.html . [6] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

	[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation protection in diagnostic and interventional radiology, http://www.rpop.iaea.org/RPOP/RPoP/Content/Documents/TrainingRadiology/Lectures/RPDIR-L09_Med_Exp_BSS_WEB.ppt .
	Module 2: Radiation Protection and Safety
	Sub-module 2.6: Shielding
Objective	To specify shielding for an x ray facility using diagnostic x ray imaging systems for energies between 15 and 150 kVp. Facilities include hospitals, clinics, mobile systems, and dental installations.
Pre-requisites	None
Competencies Addressed	• An understanding of the principles and requirements of shielding design at diagnostic x ray energies. • The ability to design satisfactory radiation shielding for all types of diagnostic radiology equipment
Core Knowledge	(1) Principles: ° Radiation dose units and metrics applicable to shielding design ▪ Ambient dose equivalent and its relation to effective dose & kerma ▪ Kerma Area Product ▪ Entrance Surface Dose ° Primary Radiation: ▪ Unattenuated ▪ Attenuated ° Secondary Radiation: ▪ Scatter ▪ Leakage ° Transmission of primary and secondary radiation through patients, imaging components and barriers. (2) Regulatory Requirements and Guidelines: ° Local legislation and guidance applying to the design of radiological facilities ° Designation of controlled and uncontrolled areas ° Dose limits for workers and members of the public ° Dose constraints and shielding design goals, e.g. 0.3mSv per year for public areas (3) Shielding concepts: ° Concepts of primary and secondary barriers ° Concepts of workload: ▪ Effect of technique factors ▪ Effect of patient numbers

	▪ Effect of future changes in workload, equipment design, and usage, e.g., change from chest room to general radiographic room or to CT room ° Concepts of occupancy and impact of the occupancy of surrounding areas on shielding design ° Potential impact of scatter from walls and ceilings ° How room layout can affect likely exposure, e.g., patient back toward door in mammography room eliminates need for shielding in the door ° Consideration of all walls plus floor and ceiling ° Location of control booth relative to visibility of patient, direction of x ray beam (never pointed toward control booth) ° Importance of leaving sufficient space behind barriers, e.g.., control booths, including consideration relative to those with disabilities (4) Materials: ° Attenuation properties of materials ° Substitute materials and impact on shielding effectiveness ° Common building materials and techniques (5) Shielding Requirements: ° Determination of radiation dose at barrier from workload data ° Calculation of required transmission. ° Specification of required materials (6) Methods of carrying out shielding calculations for: ° Plain Film Radiography ° Mammography ° Fluoroscopy ° Computed Tomography ° DXA ° Temporary and mobile facilities ° Dental facilities (7) Assessment of shielding: ° Visual monitoring during construction ° X ray measurement ° Use of radionuclides ° Relative importance of breaches in shielding integrity. (8) Documentation of complete assumptions, design, and specifications for future reference, and maintenance of documentation
Recommended Elements of Training	(1) Information Requirements: ° Carry out workload assessment – taking into account both radiographic technique & patient numbers ° Determine occupancy of surroundings ° Assess the effect on shielding options of equipment location and orientation (2) Specify the following protective barriers for a range of x ray equipment*: ° Walls

	° Windows ° Floors & Ceilings ° Doors ° Protective screens & shields (3) Specify the shielding requirements for other penetrations, e.g. HVAC, plumbing, electrical sockets * (4) Specify the location and operation of warning signs (if appropriate)* (5) Assess the effectiveness of shielding and errors in measurements.* (6) Documentation: ° Document shielding calculation and assumptions ° Document effect of changes in workload, equipment usage, or equipment design on shielding requirements ° Document assessment outcomes * To include Plain Film Radiography, Mammography, Fluoroscopy, Computed Tomography, DEXA, dental, angiography and temporary and mobile facilities.
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Structural Shielding Design for Medical X ray Imaging Facilities, NCRP Rep. 147, Bethesda, MD, USA. (2004). www.ncrppublications.org . [3] SUTTON, D.G., WILLIAMS, J.R., Radiation Shielding for Diagnostic X rays, British Institute of Radiology, London (2000). [4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Conversion coefficients for use in radiological protection against external radiation, ICRP publication 74. Ann ICRP 1997 (77) 2, Pergamon Press, Oxford and New York (1997). [5] INTERNATIONAL ATOMIC ENERGY AGENCY, Shielding, http://www.rpop.iaea.org/RPOP/RPoP/Content/Documents/TrainingRadiology/Lectures/L12_Shielding_WEB.ppt .
	Module 2: Radiation Protection and Safety
	Sub-module 2.7: Safety in MRI imaging
Objective	To be able to perform assessments of MRI radiation safety and to investigate accidents and incidents involving MRI.
Pre-requisites	Sub-module 2.2: Radiation hazard assessment Sub-module 2.3: Radiation protection and safety review Sub-module 5.9: Magnetic resonance imaging

Competencies Addressed	• An understanding of the safety issues and requirements in MRI imaging. • The ability to perform the necessary safety assessments and measurements.
Core Knowledge	(1) Relevant national, international standards and guidelines on MR safety (2) The biological effects of static and time varying electromagnetic fields used in MRI (3) The importance of controlling access to MRI facilities (4) Inner and outer controlled areas and Local Rules (5) 0.5mT (5 Gauss) Line (6) Specific Absorption Rate (SAR) (7) Use of devices to measure static, time-varying and radiofrequency magnetic fields (8) The dangers associated with cryogens (9) Implications of a magnet quench (10) Acoustic effects and dB limits. (11) Shielding design and assessment principles (to include iron and RF shielding). (12) Compatibility of equipment associated with MRI (13) Compatibility of medical devices such as implants and pacemakers with MRI (14) Metal detection devices, both hand-held and portal
Recommended Elements of Training	(1) Perform a hazard assessment for an MRI facility (2) Write specimen Local Rules for an MRI facility (3) Partake in safety training for authorised personnel (4) Define inner and outer controlled areas in a facility (5) Measure static, time-varying and radiofrequency magnetic fields around an MRI scanner. (6) Measure the extent of fringe fields (7) Screen patients and staff for ferrous materials. (8) Advise on patient safety issues surrounding medical devices such as implants and pacemakers. (9) Advise on the compatibility of medical equipment in the MRI environment.
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] AMERICAN COLLEGE RADIOLOGY, ACR Guidance Document for Safe MR Practices (2007). http://www.acr.org/SecondaryMainMenuCategories/quality_safety/MRSafety.aspx . [3] INSTITUTE FOR MAGNETIC RESONANCE SAFETY EDUCATION AND RESEARCH, MR Safety, www.mrisafety.com.

[4] INTERNATIONAL COMMISSION ON NON IONISING RADIATION, www.icnirp.de .

[5] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Standard 60601-2-33 Medical electrical equipment - Part 2-33: Particular requirements for the safety of magnetic resonance equipment for medical diagnosis, IEC, Geneva (2007).

[6] MCROBBIE, D.W., MOORE, E.A., GRAVES, M.J., PRINCE, M.R., (Eds), MRI from Picture to Proton, Cambridge University Press, (2003).

[7] MR SAFETY, www.mrisafety.com .

[8] SHELLOCK, F.G., Reference Manual for Magnetic Resonance Safety, Implants and Devices, Biomedical Research Publishing Company, Los Angeles, CA (2009).

	MODULE 3: RESEARCH, DEVELOPMENT AND TEACHING
Objective	To develop key skills in research, development and teaching in Diagnostic radiologic physics.
Expected Duration	10 – 15% of overall time.
Sub-Modules	(1) Research and Development (2) Teaching
Core Reading	[1] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, A guide to the teaching of clinical radiological physics to residents in diagnostic and therapeutic radiology, AAPM Rep. 64, New York (1999). http://www.aapm.org/pubs/reports/rpt_64.PDF . [2] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Quality assurance for clinical trials: A primer for Physicists. 2004 AAPM Rep. 86, New York (2004). www.aapm.org . [3] ICH/CPMP, Good Clinical Practice: Consolidated Guidelines, International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use Rep. E6 (R1) (1996). http://www.ich.org/cache/compo/276-254-1.html .
	Module 3 - Research, development and teaching
	Sub-module 3.1: Research and development
Objective	To develop the ability to perform research in an area of relevance to medical imaging either individually or as a member of a multi-disciplinary research team.
Pre-requisites	None
Competencies Addressed	• An understanding of processes of scientific research including the role of ethics review, statistical analysis, and the publication process. • The ability to carry out research and development in diagnostic medical imaging in cooperation with diagnostic radiologists, other diagnostic medical physicists, and other professionals.
Core Knowledge	(1) Understanding of: ° The role of ethics in research involving human and animal subjects including radiation related subjects ° The application of statistics to experimental design, formulation of hypotheses, and data analysis

	° The format of scientific papers ° The peer-review process of research grant applications and scientific publications (2) Awareness of appropriate international journals in radiology, medical physics, and associated fields of research
Recommended Elements of Training	(1) Design a research project including: ° Identify an area for research, including the specific question which is being asked, in consultation with other professionals such as diagnostic radiologists. ° Formulate hypotheses. ° Review the literature in the area effectively and critically, using appropriate databases e.g., MedLine, PubMed, and Scorpus, and provide this in a written report (including the clinical benefits of the research or development). ° Continually monitor current advances in research and development in the chosen area of research. ° Determine a plan for a research project including milestones, necessary experiments and analysis. ° Consult with statistician as required. ° Evaluate the ethical issues involved against national criteria, including radiation issues, and make the necessary application to an appropriate ethics committee (also know as a human studies committee [HSC] or institutional review board [IRB]) if necessary. ° Evaluate required resources including time, personnel and equipment. ° Manage a budget for a small research project (2) Peer review of results: ° Present and defend results at the departmental level ° Present results at national or international conference ° Publish in a peer-reviewed journal (3) Building on research initiatives: ° Write a simple research grant application in conjunction with a diagnostic radiologist or other experienced staff, including a response to comments from the review process. ° Participate in a multidisciplinary research team by contributing medical physics knowledge and skills, such as providing dosimetry support. ° Provide dose calculations and risk estimates, including comparisons to other risks from ionizing radiation, for use by the ethics committee (HSC or irb) for a proposed project involving radiation exposure to human subjects.
Knowledge Sources	[1] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Quality assurance for clinical trials: A primer for Physicists, AAPM Rep. 86, New York (2005). http://www.aapm.org/pubs/reports/rpt_84.PDF.

	[2] ARPANSA, Code of Practice for the Exposure of Humans to Ionizing Radiation for Research Purposes, Radiation Protection Series Rep. 8, ARPANSA. http://www.arpansa.gov.au/rps8.htm . [3] ICH/CPMP, Good Clinical Practice: Consolidated Guidelines, International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use Rep. E6 (R1) (1996) http://www.ich.org/cache/compo/276-254-1.html [4] ICH/CPMP, Statistical Principles for Clinical Trials, International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use Rep. E9 (1998). http://www.ich.org/cache/compo/276-254-1.html . [5] http://www.nhmrc.gov.au/ethics/human/issues/trials.htm [6] http://www.tga.gov.au/docs/html/ich13595.htm . [7] RAVINDRAN, C., Ethics in Biomedical Research, Calicut Medical Journal 6 2 (2008). [8] WOODWORD, M., Epidemiology: Study Design and Data Analysis, 2nd edn, Chapman & Hall/CRC (2005). [9] WOOLFE, J., How to write a PhD Thesis, http://www.phys.unsw.edu.au/~jw/thesis.html [10] WORLD HEALTH ORGANIZATION, Operational Guidelines for Ethics Committees That Review Biomedical Research, Geneva (2000).
	Module 3 - Research, development and teaching
	Sub-module 3.2: Teaching
Objective	To develop the skills required to be an effective educator and mentor in diagnostic medical physics.
Prerequisites	
Competencies Addressed	• An understanding of the general principles of effective teaching. • The ability to teach principles and methods of medical physics.
Core Knowledge	(1) Understand the general principles of effective teaching including: ° Teaching method and strategies appropriate to the group size, needs, interests, and backgrounds of the audience ° Mechanisms of student feedback and assessment strategy ° Provision of necessary instructional material for the student ° Preparation of teaching material ° Review of teaching processes
Recommended Elements of Training	(1) Attend a general course (often available at national or international radiology and medical physics meetings) on how to teach (2) Teach medical physics, technology, and radiation topics (including radiation safety) to different audiences. Suggested examples include:

	° Teaching to medical physicists, junior physicists, or other technically orientated staff ° Teaching to radiology staff and residents ° Teaching radiation safety to nurses or other paramedical staff (e.g., departmental secretaries) ° Teaching radiographers to carry out quality control of a specific imaging equipment
Knowledge Sources	[1] AAPM ONLINE EDUCATIONAL, Continuing education, http://aapm.org/education/ce/category.asp . [2] SPRAWLS, P., Physical Principles of Medical Imaging., 2nd edn, Aspen. (1993). http://www.sprawls.org/ppmi2/ . [3] Teaching radiology residents resource, http://www.blueskybroadcast.com/Client/AAPM_Annual05/aapm_a74_panel/launch.html . [4] AAPM ONLINE EDUCATIONAL, library, http://aapm.org/meetings/virtual_library/ . [5] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, A guide to the teaching of clinical radiological physics to residents in diagnostic and therapeutic radiology, AAPM Rep. 64, New York (1999). http://www.aapm.org/pubs/reports/rpt_64.PDF .

	MODULE 4: PROFESSIONALISM AND COMMUNICATION
Objective	To provide Residents with knowledge and competencies relating to the professional aspects of their roles and responsibilities and principles in a diagnostic radiology facility.
Expected Duration	10 – 15% of overall time.
Co-requisite modules	Module 5: Performance testing of imaging equipment Module 6: Technology management
Sub-Modules	(1) Professional awareness (2) Communication (3) Information Technology (4) Clinical audit
Core Reading	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL, Communicating with patients: advice for medical practitioners, (2004), http://www.nhmrc.gov.au/publications/_files/e58.pdf. [3] VENABLES, J., Communication Skills for Engineers and Scientists, 3rd edn, Institute of Chemical Engineers (2002).
	Module 4: Professionalism and communication
	Sub-module 4.1: Professional awareness
Objective	To demonstrate an understanding of and participate in (if possible) activities related to professional awareness.
Prerequisites	None
Competencies Addressed	o Demonstrate an understanding of professional issues. o The ability to contribute to professional body activities.
Core Knowledge	
Recommended Elements of Training	(1) Career Planning: ° Demonstrate an understanding of the scope of practice and career structure of diagnostic radiology physicists.

	° Demonstrate an understanding of the opportunities and restrictions in career progression. ° Draw a tree diagram summarising your department's staff structure, including your position. ° Define your own career plan. (2) Professional Organization Activities: ° Demonstrate an awareness of your professional organization including the structure of the organization, identifying key office bearers and administrative staff. ° Attend and actively participate in professional activities. ° Regularly review websites of medical physics professional organizations world-wide ° Demonstrate an awareness of topical issues affecting your profession and your professional organization. ° Demonstrate an awareness of other allied organizations (eg. radiology and radiography) and locate the relevant websites. ° Demonstrate an awareness of international agencies and professional bodies as related to diagnostic radiology physics. ° Demonstrate an awareness of important professional journals in and related to medical physics and radiology, and regularly read relevant papers. (3) Professional Issues: ° Ethics: ▪ Demonstrate an understanding of your professional organization's and hospital's policies and procedures on professional and clinical ethics. ▪ Demonstrate an awareness of the code of conduct and mission statement for your professional organization and hospital. ▪ Understand the local and/or national requirements for ethics clearance for clinical research projects. ▪ Understand the requirements of privacy of staff and patient information. ° Legal Issues: ▪ Outline the objectives, definition and requirements of/for legal issues at your institution/s (eg. hospital and university if relevant) and in your state and country as related to diagnostic radiology medical physicists. This should include the policies on conflict of interest and legislation and regulatory matters. ▪ Outline local and/or national requirements of radiation incident reporting. ▪ Awareness of data protection legislation. ° Intellectual Property: ▪ Understand the types of intellectual property. ▪ Outline the objectives, definition and requirements of/for intellectual property at your institution/s (eg. hospital and university if relevant). ▪ Outline ownership of material produced as a result of your research at your institution.

	▪ Demonstrate an awareness of vendor intellectual property requirements in the workplace, including software licensing and warranties. (4) Continual Professional Development (CPD): ° Demonstrate an awareness of the objective of CPD. ° Demonstrate an awareness of legislation and/or professional organization requirements for CPD.
	Module 4: Professionalism and communication
	Sub-module 4.2: Communication
Objective	To be a good communicator within a multi-disciplinary team, with patients and the general public.
Competencies Addressed	• Demonstrate a high level of oral and written communication and interpretation skills. • The ability to communicate with clinicians and apply physical principles to clinical problems
Pre-requisites	
Core Knowledge	
Recommended Elements of Training	(1) Oral skills: ° Where possible attend a course on: ▪ Oral presentation competencies, ▪ Mentoring competencies, and/or ▪ Conducting professional meetings. ° Actively participate in physics department meetings (chair a meeting if possible). ° Actively participate in Department technical meetings. ° Scientific presentation at meeting of Medical Physicists, multi-disciplinary professionals or an audience containing members of the general public. ° Medical Physics tutoring for other Radiology professionals. Examples include Radiation Safety lectures and tutorials to Radiology Registrars. ° Actively participate in project progress meetings during equipment commissioning. ° Presentation of research results at a national and/or international conference/meeting. ° Provide accurate, clear, clinical medical physics advice regarding optimization of radiological procedures to other Radiology Professionals

	(2) Written skills: ° Demonstrate understanding of professional issues such as legal consequences of information documented and forwarded via email, confidentiality, sensitivity and permission to use data. ° Demonstrate understanding of appropriate format and style of professional written communication, including email, memos and letters. ° Keep a logbook ° Write an example of a professional letter, email and memo that you could send to a key manager in the Radiology Department addressing a medical physics issue. ° Write a brief technical report on an diagnostic procedure optimization. ° Write a business case to management regarding the case for new or a replacement of radiological equipment. ° Write or review a protocol (new or revised) for a quality control process in the Department. ° Write a progress and/or final report for commissioning of new radiological equipment to a Radiology Department. (3) Comprehension Skills: ° Participate in department meetings to review journal papers ° Present a review of an international technical protocol to Physics Department (4) Communication: ° Investigate the roles of other medical and allied health professions in the health system, and especially where those professions involve imaging. ° Talk with work colleagues, to understand their point of view, and to help them understand yours. (5) Consultation and Support: ° Communicate with the clinician in terms they can understand in their specialty ° Listen to a non-radiology problem posed by a clinical colleague ° Use your general physics background to problem-solve ° Think laterally, including outside the radiology context ° Research a problem and postulate a solution, keeping in mind the boundaries of your understanding and ability ° Enlist the help of others with relevant skills
	Module 4: Professionalism and communication
	Sub-module 4.3: Information technology
Objective	To be competent with personal computers (PC), interfacing, networking, data storage, and knowledge of radiology information systems.
Prerequisites	None

Competencies Addressed	• An understanding of basic information technology. • An ability to perform basic skills in information technology.
Core Knowledge	(1) Electronic communication standards (2) Professional IT issues such as privacy, confidentiality, sensitivity and permission to use data. (3) Storage media and principles of data backup (4) Different types of databases and their applications in diagnostic radiology
Recommended Elements of Training	(1) Demonstrate use of storage media. (2) Interface PC s to peripheral devices and to imaging equipment. (3) Perform data reporting, analysis and presentation using available software applications (4) Ability to use tools for backing up radiological data.
Knowledge Sources	
	Module 4: Professionalism and communication
	Sub-module 4.4: Clinical audit
Objective	To demonstrate an understanding of the purpose, conduct and analysis of a clinical audit.
Prerequisite	None
Competencies Addressed	• Understand the physics aspects of a clinical audit. • The ability to participate in the physics aspects of a clinical audit.
Core Knowledge	(1) The purpose of clinical audit in diagnostic radiology. (2) The role of the physicist in clinical audit. (3) Familiarity with local legislative requirements for clinical audits.
Recommended Elements of Training	(1) Acquire an understanding of the purpose of clinical audit and what it involves from the provided knowledge sources. (2) Consult relevant audit documents and other sources to ascertain the acceptable standards for medical physics in a radiology department. (3) Demonstrate ability to assemble departmental information on medical physics activities in a department (e.g. QA, calibration and dosimetry documentation) prior to the commencement of an audit visit. (4) Demonstrate practical aspects of medical physics activities in a department (e.g. in QA, calibration and dosimetry) at the request of an audit team member during an audit visit. (5) Respond to suggestions to change of work practice as a result of an audit visit.

Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Comprehensive Clinical Audits of Diagnostic Radiology Practices: A Tool for Quality Improvement, Human Health Series, 4, IAEA, Vienna (2010). [3] COMMISSION OF THE EUROPEAN COMMUNITIES, European Commission Guideline on Clinical Audit for Medical Radiological Practices (Diagnostic Radiology, Nuclear Medicine and Radiotherapy), European Commission, Luxembourg (2009), http://ec.europa.eu/energy/nuclear/radiation_protection/publications_en.htm.

	MODULE 5: PERFORMANCE TESTING OF IMAGING EQUIPMENT
Objective	To provide residents with the necessary knowledge and skill to undertake performance testing on the full range of radiology imaging and associated equipment.
Expected Duration	25 to 30% of overall time
Sub-Modules	(1) Screen-film systems (2) Film processing and darkroom (3) General radiography (4) Conventional and digital fluoroscopy (5) Computed radiography and digital radiography (6) Automatic exposure control devices (7) Mammography (8) Computed tomography (9) Magnetic resonance imaging (10) Ultrasound (11) Display and printing devices (12) Dental radiography (13) Dual energy X ray absorptometry
Core Reading	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [3] DOWSETT, D.J., KENNY, P.A., JOHNSTON, R.E., The Physics of Diagnostic Imaging, 2nd edn, Oxford University Press (2006). [4] SPRAWLS, P., Physics and Technology of Medical Imaging http://www.sprawls.org/resources/. Also refer to individual sub-modules.
	Module 5: Performance testing of imaging equipment
	Sub-module 5.1: Screen-film systems
Objective	To acquire the knowledge and skills to be able to evaluate screen-film system performance for specification determination, acceptance and routine QC testing.

Prerequisite	Sub-module 7.3: Radiological test equipment, measurement and practice
Competencies Addressed	• An understanding of processes of image formation involving x rays and screen film systems. • The ability to carry out performance testing on X ray film, X ray film cassettes and X ray film display devices:
Core Knowledge	(1) Intensifying screens: ° Uses ° Construction ° Principles of operation ° Conversion and absorption efficiency ° Speed and types ° Speed (absolute and relative) as a function of kVp ° Trade-off between screen speed and resolution ° Resolution ° Spectral output ° Matching spectral emission of screens with spectral sensitivity of film ° Types of phosphor - advantages and disadvantages, e.g., calcium tungstate and rare earth (2) Film: ° Uses ° Construction ° Anti-halation layer ° Overcoat ° Substrate or base ° Dual vs single emulsion films ° Halation and cross-over effects ° Latent image formation by light or x rays ° Reciprocity law failure ° Processing ° Photographic properties ° Optical density, characteristic curve, density, contrast, average gradient, base-plus-fog, latitude ° Speed, differences between types, single- vs dual-emulsion ° Resolution, modulation transfer function (MTF), detail, low contrast resolution ° Contrast-detail curves ° Spectral sensitivity of emulsion ° Matching film sensitivity to spectral output of screens ° Noise including quantum, grain, and screen noise ° Storage conditions (temperature, humidity, radiation exposure, expiration date, pressure sensitivity)

	(3) Cassettes: ° Structure and basic design ° Cleaning, artefacts. ° Mammographic vs conventional (4) Screen-film combinations: ° Screen-film contact for conventional and mammographic imaging ° Inter-relationships between dose and image quality values ° Dual- vs single-screen systems, advantages, disadvantages ° Time required for air to "bleed" from between screen and film and provide optimum contact (5) Viewboxes: ° Viewbox luminance ° Viewing room illuminance ° Impact of masking
Recommended Elements of Training	(1) Measurement and assessment of: ° Film optical density ° Characteristic curves, and associated metrics ° Contrast, base-plus-fog ° Resolution, modulation transfer function (MTF), contrast-detail curves ° View box luminance and room illuminance ° Screen-film contact and recommendation of acceptance or rejection of specific cassettes based on results ° Visual inspection of cassettes, identification of artefacts, light tightness ° Cassette screen-film contact test ° Screen batch-to-batch consistency (acceptance testing) ° Film batch-to-batch emulsion variability ° Compare screen-film performance in terms sharpness, speed, contrast, and latitude. ° Set up an appropriate quality control program.
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [3] DOWSETT, D.J., KENNY, P.A., JOHNSTON, R.E., The Physics of Diagnostic Imaging, 2nd edn, Hodder Arnold (2006). [4] GUNN, C., Radiographic Imaging. A Practical Approach., 3rd edn, Churchill Livingstone. (2002). [5] HAUS, A.G., Measures of Screen-Film Performance, Radiographics 16 (1996) 1165-1181.

	[6] HAUS, A.G., JASKULSKI, S.M., The Basics of Film Processing in Medical Imaging, Medical Physics Publishing, Madison, Wisconsin. (1997). [7] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Medical Imaging - The Assessment of Image Quality, Rep. 54, ICRU, Bethesda, MD (1996). http://www.icru.org/index.php?option=com_content&task=view&id=68 . [8] ISO, Photography - Sensitometry of screen/film systems for medical radiography - Part 1: Determination of sensitometric curve shape, speed and average gradient, Rep. ISO 9236-1:2004 (2004). Cookbooks: [1] BRITISH INSTITUTE OF RADIOLOGY, Assurance of Quality in the Diagnostic Imaging Department. 2nd edition. The Quality Assurance Working Group of the Radiation Protection Committee of the British Institute of Radiology (2001). [2] GRAY, J.E., WINKLER, N.T., STEARS, J., FRANK, E.D., Quality Control in Diagnostic Imaging, Aspen Publishers, Inc., Rockville, Maryland. (1983). [3] LLOYD, P., Quality Assurance Workbook for Radiographers and Radiological Technologists. International Society of Radiographers and Radiological Technologists, World Health Organization, Geneva (2001).
	Module 5: Performance testing of imaging equipment
	Sub-module 5.2: Film processing and darkroom
Objective	To acquire the knowledge and skills to be able to carry out QC tests on photographic processors and associated darkroom equipment.
Prerequisite	Sub-module 7.3: Radiological test equipment, measurement and practice
Competencies Addressed	• An understanding of processes and function of film processing and associated equipment. • The ability to carry out performance tests for X ray film processors and darkrooms.
Core Knowledge	(1) Photographic Processors: ° General Principles ° Types of processors ° Function of developer and fixer solutions ° Function of film washing ° Developer components; developing agent, hardeners, buffers ° Fixer components; hardeners, sodium thiosulfate ° Processing time (speed) and temperature

	° How solution temperatures are maintained ° Wash water temperature control, also used to assist in controlling temperature of other solutions ° Sensitometric properties including speed, contrast, density, base-plus-fog ° Components and function of automatic processors ° Impact of developer temperature and time on film speed, contrast, base-plus-fog level. ° Processor temperature control ° Wash water temperature, need for adequate flow ° Control of drier temperature ° Function and importance of replenishment of developer and fixer solutions ° Determining appropriate replenishment rates ° Replenishment for low volume processors (flood replenishment) ° Effect of processing different types of films ° Residual fixer (sodium thiosulphate) and how to measure it ° Impact of residual fixer on image quality ° Drying ° Artefacts ° Venting of processor dryers ° Contamination of developer with fixer ° Chemical hazards ° Silver recovery ° Disposal of exhausted chemicals ° Extended processing (useful with present emulsions?) ° Cross-over for quality control when changing control emulsion batches (2) Manual Photographic Processing: ° Time-temperature charts ° Aluminium step wedge for processor quality control ° Replenishment frequency, amount ° Agitation ° Proper washing of film ° Hypo retention impact and how to measure it (3) Quality Control of Film Processing: ° Control charts ° Operating levels and control limits ° Detecting trends on control charts ° Corrective action (4) Dark Rooms: ° Safelights- bulb wattage, types of filters, distance from film handling surfaces, age of filters ° Light leakage

	◦ Colour of surfaces, walls ◦ Darkroom cleanliness ◦ Exhaust fans, air circulation, temperature control ◦ Film storage ◦ Chemical storage, replenishment tanks ◦ Design ◦ Fog test, unexposed vs pre-exposed film, light vs. x ray exposed film
Recommended Elements of Training	(1) Measurement and assessment of: ◦ Processor: ▪ Developer temperature ▪ Sensitometry, characteristic curves, contrast, base-plus-fog level ▪ Measurement of chemical replenishment rates ▪ Residual fixer (sodium thiosulphate) ▪ Artefact assessment ▪ Establish and maintain effective processor QC program ▪ Quality control charts, plotting, analysis, control limits ▪ Replenishment rates ◦ Darkroom: ▪ Visual inspection for light leakage and safelight conditions ▪ Assessment of film fog for darkroom light leakage and safelight conditions
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Validating Automatic Film Processor Performance, Rep. 94, AAPM, New York (2006). http://www.aapm.org/pubs/reports/RPT_94.pdf . [3] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [4] GRAY, J.E., WINKLER, N.T., STEARS, J., FRANK, E.D., Quality Control in Diagnostic Imaging, Aspen Publishers, Inc., Rockville, Maryland. (1983). [5] GUNN, C., Radiographic Imaging. A Practical Approach., 3rd edn, Churchill Livingstone. (2002). [6] HAUS, A.G., JASKULSKI, S.M., The Basics of Film Processing in Medical Imaging, Medical Physics Publishing, Madison, Wisconsin. (1997). [7] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Evaluation and routing testing in medical imaging departments - Part 2-1: Constancy tests - Film processors, IEC-61223-2-1, IEC, Geneva (1993).

	[8] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Evaluation and routing testing in medical imaging departments - Part 2-3: Constancy tests - Darkroom safelight conditions, IEC-61223-2-3, IEC, Geneva (1993). [9] MCCLELLAND, I.R., X ray Equipment Maintenance and Repairs Workbook for Radiographers and Radiological Technologists, World Health Organization, Geneva (2004).
	Module 5: Performance testing of imaging equipment
	Sub-module 5.3: General radiography
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on general radiographic equipment.
Prerequisites	
Competencies Addressed	• An understanding of the operation of x ray equipment and the factors that affect the radiographic output. • The ability to carry out performance testing of general radiographic equipment.
Core Knowledge	(1) Production of X ray: ° Continuous Radiation or Bremsstrahlung ° Characteristic Radiation (2) Effect on Radiation Output and Image of: ° kV ° mA ° Exposure time ° Filtration ° Voltage waveform (3) X ray tubes theory of operation: ° Principal types and their construction ° Line focus principle ° Heel effect ° Causes of failure ° Tube ratings (4) Generator Waveforms: ° Single-phase generators ° Three-phase, 6 and12 pulse generators ° Medium and high frequency generators ° Capacitor discharge generators ° Falling load generators

	° Exposure timers (5) Scatter Reduction Techniques: ° Bucky motion ° Grids (types, characteristics, performance) ° Air gaps ° Effect on image quality and patient dose (6) Tomography (optional): ° Linear and other tomography ° Blurring and concept of section thickness.
Recommended Elements of Training	(1) Measurement and assessment of: ° X ray beam alignment: ▪ Accuracy of light beam and collimator alignment ▪ Light beam illuminance ° Basic x ray beam parameters: ▪ Radiation leakage ▪ Tube voltage accuracy ▪ Timer accuracy ▪ Radiation output linearity ▪ Output reproducibility ▪ Beam quality. (Half Value Layer) ° Image quality parameters: ▪ Grid artefacts ▪ Bucky motion ° Tomographic tests: ▪ Tomographic cut height (optional) ▪ Tomographic cut thickness (optional) ▪ Tomographic exposure profile during tomographic exposure (optional)
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007). http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [3] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Quality control in diagnostic radiology Rep. 74, AAPM, New York (2002). http://www.aapm.org/pubs/reports/rpt_74.PDF . [4] BRITISH INSTITUTE OF RADIOLOGY, Assurance of Quality in the Diagnostic Imaging Department. 2nd edition. The Quality Assurance Working Group of the Radiation Protection Committee of the British Institute of Radiology (2001).

	[5] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [6] DOWSETT, D.J., KENNY, P.A., JOHNSTON, R.E., The Physics of Diagnostic Imaging, 2nd edn, Hodder Arnold (2006). [7] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Recommended standards for the routine performance testing of diagnostic X ray imaging systems, Rep. 91, IPEM York (2005).
	Module 5: Performance testing of imaging equipment
	Sub-module 5.4: Conventional and digital fluoroscopy
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on conventional and digital fluoroscopic equipment.
Prerequisite	Sub-module 5.3: General radiography
Competencies Addressed	• An understanding of the theory of operation of fluoroscopy and angiography equipment. • The ability to: (a) Carry out performance testing of simple fluoroscopic equipment. (b) Carry out performance testing of complex fluoroscopic equipment.
Core Knowledge	(1) X ray generation and dose control: ° Design & Operation: ▪ Tube design (specialised) ▪ Collimation (specialised) ▪ Grid characteristics and performance (specialised) (2) Image receptors: ° Design & Operation: ▪ Image intensifier and TV camera (video output) ▪ Image intensifier and TV camera (digital output) ▪ Flat Panel Detectors (digital) ▪ Emerging Detection Systems ° Performance characteristics: ▪ Video camera performance characteristics ▪ Conversion efficiency (II) ▪ Veiling glare (II) ▪ Contrast ratio ▪ Distortion ▪ CNR (digital) ▪ Limiting resolution ▪ MTF

	▪ Noise power spectra ▪ NEQ/DQE (3) Controlling the Fluoroscopic Image: ° Pulsed versus continuous fluoroscopy ° Automatic control modes: control of kV, mA, pulse length, video voltage (4) Viewing the Fluoroscopic Image: ° Image display devices ° Spot film cameras (5) Image Processing Techniques (including but not limited to): ° Digitized image ° logarithmic processing ° image noise ° Mask subtraction ° Pixel shifting ° Temporal filtering ° Edge enhancement and image enhancement (6) Contrast Agents: ° Basic physical properties & safety aspects ° Types of contrast studies: ▪ Iodine ▪ Barium
Recommended Elements of Training	(1) Measurement and assessment of: ° Simple fluoroscopic systems typically not used for angiography or any form of automatic serial imaging with one image receptor size and manual and/or simple automatic exposure control: ▪ Operation of equipment ▪ Fluoroscopic collimation ▪ Fluoroscopic tube voltage accuracy ▪ Beam quality. (Half Value Layer) ▪ Fluoroscopic screening timer ▪ Radiation leakage ▪ Congruency of X ray beam and displayed Image ▪ Image receptor input dose rate ▪ Typical and maximum skin input dose rate and characteristics of automatic brightness control (ABC) ▪ Image Quality: ➢ Limiting resolution ➢ Contrast detail delectability ° Complex fluoroscopic systems typically used for angiography and/or serial imaging including multiple image receptor field sizes, possibly more than one X ray tube and multiple semi automatic or automatic exposure protocols: ▪ Operation of equipment

	▪ Relevant tests from 1 (above) extended to cover relevant conditions ▪ Dose and image quality tests for all relevant clinical exposure protocols ▪ Image quality testing of digital image including testing of noise and contrast noise ratio
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007), http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [3] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [4] DOWSETT, D.J., KENNY, P.A., JOHNSTON, R.E., The Physics of Diagnostic Imaging, 2nd edn, Hodder Arnold (2006).
	Module 5: Performance testing of imaging equipment
	Sub-module 5.5: Computed radiography and digital radiography
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on computed radiography(CR) and digital radiography (DR) systems.
Prerequisite	Sub-module 6.5: Imaging informatics Sub-module 9.1: Assessment of image quality through objective tests Sub-module 9.2: Assessment of image quality with phantoms
Competencies Addressed	• An understanding of the principles of CR and DR radiographic imaging systems. • The ability to carry out performance testing of CR and DR radiographic imaging systems.
Core Knowledge	(1) Principles of the digital image: ° Digitization ° Quantization ° Image matrix and relationship to resolution and contrast ° File size and compression (2) Image detections: principles and devices: ° storage phosphors & photostimulable luminescence ° laser scanning system

	° charge-coupled device(CCD) ° amorphous silicon(a-Si:H) ° amorphous selenium(a-Se) ° input/output relationship (3) Image measurement tools: ° contrast-detail phantom ° QC phantom
Recommended Elements of Training	(4) Measurement and assessment of: ° EI calibration ° EI consistency ° Latent Decay Time (CR only) ° Linearity of dose and DDI ° Erasure thoroughness (CR only) ° Dark noise ° Image uniformity ° Limiting resolution and MTF ° Noise and low contrast ° Scaling errors and spatial accuracy ° Blurring ° Moire effects ° Plate throughput
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems, Rep. 93, AAPM, New York (2006). http://www.aapm.org/pubs/reports/RPT_93.pdf . [3] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Medical Imaging - The Assessment of Image Quality, Rep. 54, ICRU, Bethesda, MD (1996). http://www.icru.org/index.php?option=com_content&task=view&id=68 . [4] SAMEI, E., FLYNN, M.J., (Eds), Syllabus: Categorical Course in Diagnostic Radiology Physics - Advances in Digital Radiography, RSNA, (2003). [5] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, An Exposure Indicator for Digital Radiography, AAPM Rep. 116, New York (2009). http://www.aapm.org/pubs/reports/rpt_116.pdf.

	Module 5: Performance testing of imaging equipment
	Sub-module 5.6: Automatic exposure control devices
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on plain film and digital receptor automatic exposure control devices.
Prerequisite	Sub-module 5.1: Screen-film systems Sub-module 5.3: General radiography Sub-module 5.5: Computed radiography and digital radiography
Competencies Addressed	• An understanding of the theory of operation of Automatic Exposure Control devices, and the differences between the testing requirements for conventional and digital image receptors. • The ability to carry out performance testing of AEC devices for: (a) Conventional radiography (b) Digital radiography
Core Knowledge	(1) Theory of operation of AEC devices: ° Types of radiation detector used ° Number of detectors used ° Physical position in plain film and mammography devices ° Guard and back up timers ° Adjustment of AEC feedback characteristics (2) Use of AEC in clinical radiography: ° Examinations in which AEC is used ° Effect of chamber choice on resulting image ° Effect of selected kV on resulting image (3) Differing requirements for AEC set up for conventional and digital receptors: ° Optical Density techniques in conventional radiography and expected values of optical density ° Dose to plate techniques in digital radiography and expected variation of detector sensitivity with dose
Recommended Elements of Training	(1) Clinical uses of automatic exposure control in radiography: ° Effect of chamber choice on resulting image ° Effect of selected kV on resulting image (2) For conventional radiography, assessment of: ° Film density across kV range for each screen film combination type for different phantom thicknesses ° AEC Repeatability ° AEC Reproducibility

	° Consistency between chambers ° Kerma at image receptor ° Post exposure mAs ° Guard and back up timer (3) For digital radiography, assessment of: ° AEC sensitivity (kerma and EI) across range of kV for each receptor type for different phantom thicknesses. ° AEC Repeatability ° AEC Reproducibility ° Consistency between chambers ° Post exposure mAs ° Guard and back up timer
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Quality control in diagnostic radiology Rep. 74, AAPM, New York (2002). http://www.aapm.org/pubs/reports/rpt_74.PDF . [3] BRITISH INSTITUTE OF RADIOLOGY, Assurance of Quality in the Diagnostic Imaging Department. 2nd edition. The Quality Assurance Working Group of the Radiation Protection Committee of the British Institute of Radiology (2001). [4] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Recommended standards for the routine performance testing of diagnostic X ray imaging systems, Rep. 91, IPEM York (2005).
	Module 5: Performance testing of imaging equipment
	Sub-module 5.7: Mammography
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on mammography systems.
Prerequisite	Sub-module 5.1: Screen-film systems Sub-module 5.2: Film processing and darkroom Sub-module 5.3: General radiography Sub-module 5.5: Computed radiography and digital radiography Sub-module 5.6: Automatic exposure control devices Sub-module 7.1: Ionising radiation dosimetry and principles of measurement Sub-module 9.1: Assessment of image quality through objective tests Sub-module 9.2: Assessment of image quality with phantoms
Competencies Addressed	• An understanding of the theory of image formation and operation of X ray mammography equipment.

	• The ability to carry out performance testing of: (a) Screen-film mammography systems. (b) Digital mammography systems. (c) Biopsy mammography systems
Core Knowledge	(1) Mammography (2) Introduction to Breast Pathology (3) Understand the difference between symptomatic and screening in breast imaging. (4) Basic principles of soft-tissue imaging: ° contrast improvement at low kVp ° image contrast as a function of radiation absorbed dose ° Geometric unsharpness as a limiting factor (5) Basic principles of mammographic system including: ° target/filter combinations including emission spectra ° compression ° magnification technique ° AEC design ° Scatter rejection ° Image receptor design ° Screen – film system and processing ° Digital image receptors (6) Image display (7) Image performance criteria (8) Alternative Imaging Modalities
Recommended Elements of Training	(1) For Screen-film mammography systems: ° Operation of equipment ° Inspection of Screen-film system, processing and all related criteria ° Inspection of viewing conditions ° Reject analysis ° Assessment of collimation ° AEC performance ° Assessment of radiographic parameters ° Assessment of image receptor (uniformity, artefact) ° Assessment of image quality (2) For Digital systems: ° Operation of equipment ° Relevant tests from 1 (above) ° Modified tests from 1 (above) – see relevant protocol (3) For Biopsy systems: ° Operation of equipment ° Relevant tests from 1 (above) ° Modified tests from 1 (above) – see relevant protocol

Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007) (2007), http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [3] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance Programme for Screen–Film Mammography, Human Health Series, 2, IAEA, Vienna (2009). [4] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance Programme for Digital Mammography, IAEA, Vienna (in preparation). [5] NHS Breast Screening Programme Quality Assurance, (last accessed August 2008), http://www.cancerscreening.nhs.uk/breastscreen/quality-assurance.html [6] EUREF, European Guideline for Quality Assurance in Mammography Screening, Rep. V4.0, European Commission, Nijmegen, The Netherlands (2006). http://www.euref.org. [7] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, A Guide to Mammography and other Breast Imaging Procedures, Rep. Report No. 149, NCRP, Bethesda, MD. (2004). [8] RANZCR, Mammographic Quality Control Manual, Royal Australian and New Zealand College of Radiologists (2002).
	Module 5: Performance testing of imaging equipment
	Sub-module 5.8: Computed tomography
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on CT scanners.
Prerequisite	Sub-module 7.1: Ionising radiation dosimetry and principles of measurement
Competencies Addressed	• An understanding of the theory of operation of CT scanning equipment. • The ability to: (a) Carry out performance testing of axial CT systems. (b) Carry out performance testing of helical & MDCT systems (c) Carry out performance testing of CT systems used in radiotherapy (Note: All competencies might be performed on one MDCT unit if necessary)

Core Knowledge	(1) Basic principles of cross sectional imaging (2) Other applications of CT, e.g. treatment planning, PET CT, SPECT CT, Cone Beam CT (dental, ENT). (3) Data acquisition components: ° X ray tube ° Collimation ° Detectors; ° Automatic Exposure Control (4) Scanner Design: ° 1st and 2nd generation ° 3rd generation ° 4th generation ° Single slice scanning ° Helical (spiral) scanning ° MDCT scanning ° Cone beam ° Electron beam and other CT (5) Image matrix, reconstruction and display: ° Voxels and pixels ° CT-numbers ° Basic principles of image reconstruction ; ° Reconstruction techniques. e.g. Helical, multislice (z-interpolation), cardiac (multisector) ° Reconstruction filters (soft, bone, standard) ° Window width and level (6) Image quality descriptors: ° Spatial [high-contrast] resolution ° Low-contrast resolution ° Spatial uniformity ° Z axis resolution ° Noise ° MTF ° Relationship between image quality descriptors and exposure, reconstruction & display parameters (e.g. Noise, mAs, reconstruction filter) ° Influence of phantom design on image quality descriptors (7) Scanner dose parameters: ° C(air) (CTDI(air)) Cw (CTDIw), Cvol (CTDIvol) ° DLP (8) Artefacts: ° Partial volume ° Metal artefacts ° Motion ° Beam hardening (cupping)

	° Ring artefact (detector malfunction) ° Spiral scanning artefacts ° Photon starvation ° Cone beam artefacts (9) CT Fluoroscopy: ° Basic technical considerations ° CT angiography ° CT perfusion ° Cardiac CT
Recommended Elements of Training	(1) For axial CT systems: ° Operation of equipment ° Setting scan parameters and image display parameters ° Visual inspection and programme review ° Measurement and assessment of: ▪ CT alignment lights ▪ Scan projection radiography accuracy ▪ Radiation dose indicators ▪ CT number accuracy, image noise, CT number uniformity & artefacts ▪ Image display and printing ▪ High contrast spatial resolution, MTF ▪ Imaged slice thickness ▪ Radiation slice thickness (2) For helical & MDCT systems: ° Operation of equipment ° Relevant tests from 1 (above) ° Relevant tests from 1 (above modified to determine conditions in helical and/or MDCT mode) including: ▪ Imaged Thickness ▪ Image Noise ▪ Radiation dose indicators ° Measurement and assessment of: ▪ AEC performance ▪ Safe operating conditions for fluoroscopy mode operation (3) For CT systems used in radiotherapy: Operation of equipment ° Measurement and assessment of: ▪ Laser alignment ▪ Table feed accuracy ▪ Isocentre accuracy ▪ Gantry tilt ▪ Electron density calibration

Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007), http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [3] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality assurance programme for computed tomography, IAEA Rep. TBA, Vienna (in preparation). [4] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Specification and Acceptance Testing of Computed Tomography Scanners, Rep. 39, AAPM, New York (1993). http://www.aapm.org/pubs/reports/RPT_39.pdf . [5] EUROPEAN COMMISSION, European Guidelines on Quality Criteria for Computed Tomography, Rep. EUR 16262 EN, European Commission, Luxembourg (1998). http://www.drs.dk/guidelines/ct/quality/mainindex.htm (last accessed August 2008). [6] IMPACT, Information Leaflet No. 1: CT Scanner Acceptance Testing, Version 1.02, 18/05/01, (2001), http://www.impactscan.org/download/acceptancetesting.pdf. [7] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Measurement of the Performance Characteristics of Diagnostic X ray Systems used in Medicine. Report No 32, second edition, Part III: Computed Tomography X ray Scanners IPEM York (2003). [8] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Managing patient dose in Multi-detector computed tomography (MDCT), ICRP Publication 102, Annals of the ICRP, 37 (1) (2007). [9] KALENDER, W.A., Computed Tomography: Fundamentals, System Technology, Image Quality, Applications, 2nd edn, Publicis Corporate, Erlangen (2005). [10] NAGEL, H.D., (Ed.) Radiation Exposure in Computed Tomography: Fundamentals, Influencing Parameters, Dose Assessment, Optimisation, Scanner Data, Terminology, 4th edn., CTB Publications, Hamburg, (2002).
	Module 5: Performance testing of imaging equipment
	Sub-module 5.9: Magnetic resonance imaging
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on Magnetic resonance imaging (MRI) equipment.
Prerequisite	None

Competencies Addressed	• An understanding of: (a) MRI equipment (b) The principles of image formation • The ability to carry out performance testing of clinical MRI systems.
Core Knowledge	(1) MRI Scanner Hardware: ° Whole body magnet ° Gradients ° RF System ° RF Coils ° RF shielding of magnet room ° Magnetic shielding, types, effectiveness, impact on image quality ° Measurement of RF noise (2) Operation of MRI Computing Interface (3) Image Production: ° NMR Signal and free induction decay ° T1-T2 contrast ° Frequency and phase encoding gradients ° RF pulses and slice selection gradients ° Basic MRI sequences (spin and gradient echo) (4) Quality control in MRI: ° Understanding of artefacts in an image ° Effects on images of SNR, signal and gradient uniformity, ghosting, slice thickness and resolution ° Understanding of most important QC parameters ° Understanding of frequency of testing for various parameters (5) Effect on SNR and image of: ° Coil selection ° Imaging parameters such as TR-TE bandwidth, field of view and matrix size.) ° Signal encoding in phase, frequency and slice orientations (6) Effect of different sequences on images
Recommended Elements of Training	(1) Measurement and assessment of: ° 5 Gauss (0.5 mTesla)measurement ° Field homogeneity ° Signal-to-Noise Ratio ° Signal uniformity ° Geometric distortion ° Ghosting ° Suppression techniques ° High contrast resolution ° Low contrast resolution ° Slice thickness

	◦ Slice location ◦ Echo-planar imaging
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] AMERICAN COLLEGE RADIOLOGY, MRI Quality Control Manual (2004). http://www.acr.org/SecondaryMainMenuCategories/ACRStore/FeaturedCategories/QualityandSafety/QualityControlManuals/MRIQualityControlManual2004.aspx [3] AMERICAN COLLEGE RADIOLOGY, ACR Guidance Document for Safe MR Practices (2007). http://www.acr.org/SecondaryMainMenuCategories/quality_safety/MRSafety.aspx . [4] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [5] DOWSETT, D.J., KENNY, P.A., JOHNSTON, R.E., The Physics of Diagnostic Imaging, 2nd edn, Hodder Arnold (2006). [6] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Quality Control in Magnetic Resonance Imaging, Rep. 80, IPEM York (2002). [7] MCROBBIE, D.W., MOORE, E.A., GRAVES, M.J., PRINCE, M.R., (Eds), MRI from Picture to Proton, Cambridge University Press, (2003). [8] SPRAWLS, P., Magnetic Resonance Imaging: Principles, Methods, and Techniques, 2nd edn, Medical Physics Publishing, Madison, Wisconsin (2000).
	Module 5: Performance testing of imaging equipment
	Sub-module 5.10: Ultrasound
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on ultrasound scanners.
Prerequisite	None
Competencies Addressed	• An understanding of: (a) Theory of operation of ultrasound equipment and the various factors affecting image quality (b) Bioeffects and safety aspects of ultrasound

	• The ability to: (a) Undertake routine quality control tests, (b) Identify and investigate causes of artefacts
Core Knowledge	(1) Ultrasound Plane Waves: ° One-dimensional wave equation and harmonic solution ° Wave variables: pressure, particle velocity, displacement ° Intensity; relation to pressure amplitude ° Decibel notation ° Acoustical impedance ° Reflection and transmission at interfaces (2) Propagation of Sound Waves Through Tissue: ° Speed of sound ° Attenuation and absorption ° Scattering ° Nonlinear propagation; definition of B/A (3) Single Element Transducers: ° General design considerations ° Factors that affect frequency and bandwidth ° Continuous wave beam patterns ° Beam patterns for pulsed operation ° Focusing (4) Transducer Arrays: ° Principle of 1-D array types ° Design; element layout, matching and backing material ° Multi-frequency operation ° Transmit beam forming; transmit focusing ° Beam forming during reception; receive focusing ° Apodization and dynamic aperture ° Estimates of axial and lateral resolution ° Slice thickness (5) Pulse Echo Equipment Signal Processing: ° Pulsing characteristics, duty factors ° Transmit power ° Receiver gain; overall gain and TGC (temporal gain correction) ° Compression and demodulation ° Harmonic imaging ° mode, B-mode, M-mode (6) B-Mode Imaging: ° Principal imaging methods ° Image frame rate ° Continuous Wave and Pulsed Doppler

	° Doppler equation ° Nature of the Doppler signal ° Spectral analysis ° Pulsed Doppler ° Aliasing (7) Flow Imaging with Ultrasound: ° Velocity imaging ° Energy imaging ° Information content on color flow images ° Blood pool contrast agents (8) Equipment Performance Testing: ° Axial, lateral and elevational resolution ° Methods for measuring resolution ° System sensitivity and visualization depth (9) Information and Artefacts in Gray Scale Imaging and Doppler (10) Bioeffects and Safety: ° Acoustic output measurements ° Real-time output labels: MI and TI ° Biological effects of ultrasound ° Safe operating levels
Recommended Elements of Training	(1) Operation of equipment (2) Setting scan parameters and image display parameters (3) Quality control tests in gray-scale imaging mode: ° System sensitivity ° Image uniformity ° Depth of penetration ° Vertical and horizontal distance accuracy ° Axial resolution ° Lateral resolution ° Low contrast object detectability ° Ring-down (Dead zone) ° Photography and other hard copy recording ° Electrical and mechanical safety
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [3] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Quality Assurance for Diagnostic Imaging, Rep. Report No. 99, NCRP, Bethesda, MD. (1990).

	[4] TER HAAR, G., DUCK, F.A., The Safe Use of Ultrasound in Medical Diagnosis, British Institute of Radiology, London (2000). [5] ZAGZEBSKI, J.A., Essentials of Ultrasound Physics, Mosby (1996).
	Module 5: Performance testing of imaging equipment
	Sub-module 5.11: Display and printing devices
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on display and printing devices.
Prerequisite	Module 9: Image quality assessment
Competencies Addressed	• An understanding of: (a) The principles of display and printing devices (b) Image performance characteristics of display and printing devices • The ability to carry out performance testing of display and printing devices.
Core Knowledge	(1) Theory and Principles: ° Luminance and illuminance ° Pixel and sub-pixel ° Contrast resolution ° Spatial resolution ° Noise ° Window and level adjustment tools ° Just noticeable difference(JND) (2) Display devices: ° View box ° Cathode ray tube(CRT) ° Liquid crystal display(LCD) (3) Printing devices: ° Laser printing devices ° Thermal printing devices (4) Measurement: ° Clinically relevant technical parameters ° Viewing environment ° Test patterns ° Grayscale standard display function(GSDF) ° Artefacts ° Uniformity ° Geometric distortion (for only CRT)

Recommended Elements of Training	(1) Measure and assess the performance of display devices (2) Measure the luminance and illuminance (3) Calibration and measurement of luminance response (DICOM Part 14) (4) Use of test patterns (SMPTE, TG18) (5) Choose appropriate display device (6) Choose appropriate printing device (7) Participate in specifications of display and printing devices (8) Measure and assess the performance of printing devices (9) Identify and investigate causes of sub-optimal performance (10) Carry out QC tests on display devices (11) Carry out QC tests on printing devices
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Task Group 18, Imaging Informatics Subcommittee, Assessment of display performance for medical imaging systems, AAPM On-line Report 03, AAPM, College Park (2005). http://www.aapm.org/pubs/reports/OR_03.pdf Supplemental files available at http://www.aapm.org/pubs/reports/OR_03_Supplemental/. [3] ROYAL COLLEGE OF RADIOLOGISTS, Picture archiving and communication systems (PACS) and quality assurance Rep. BFCR(08)8 (2008). http://www.rcr.ac.uk/docs/radiology/pdf/IT_guidance_QAApr08.pdf. [4] LEUVENS UNIVERSITAIR CENTRUM VOOR MEDISCHE FYSICA IN DE RADIOLOGIE, MoniQA, Monitor Quality Assurance, http://www.kuleuven.be/radiology/lucmfr/moniqa/. [5] AMERICAN COLLEGE RADIOLOGY, ACR Technical Standard for Electronic Practice of Medical Imaging (2007). http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/med_phys/electronic_practice.aspx (last accessed August 2008). [6] DICOM STANDARD, Digital Imaging and Communications in Medicine (DICOM), http://medical.nema.org. [7] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Evaluation and Routine Testing in Medical Imaging Departments - Part 2-5: Constancy Tests - Image Display Devices, IEC-61223-2-5, IEC, Geneva (1994). [8] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Recommended standards for the routine performance testing of diagnostic X ray imaging systems, IPEM Rep. 91, York (2005).

	Module 5: Performance testing of imaging equipment
	Sub-module 5.12: Dental radiography
Objective	To acquire the knowledge and skills to be able to perform acceptance and QC tests on dental radiographic imaging equipment including direct film imaging, computed and digital radiography, panoramic radiography, cephalometric radiography, and cone-beam CT.
Prerequisite	Sub-module 5.1: Screen-film systems Sub-module 5.2: Film processing and darkroom Sub-module 5.5: Computed radiography and digital radiography
Competencies Addressed	• An understanding of clinical implementation and supervision of a quality control program with routine testing by medical physicist and oversight of periodic testing by dental technician. • The ability to: (a) Review, on an annual basis, the QC program with the responsible dentist and dental technician (b) Use a simple dental x ray test tool (Dental Radiographic Quality Control Device) (c) Carry our performance testing on computed and digital radiography, panoramic radiography, cephalometric radiography, and cone-beam CT
Core Knowledge	(1) Principles of quality assurance and quality control. (2) Use of control charts including operating levels, upper and lower control limits. (3) Generic steps in the clinical implementation and supervision of a quality control program with routine testing by medical physicist and oversight of periodic (weekly, daily) (QC) testing by dental technician.
Recommended Elements of Training	Implement: ° Quality control program including radiography (film imaging with photographic processing and computed-digital radiography), cone-beam CT, cephalometry, and panoramic radiography, including appropriate quality control charts, in at least one facility ° Establishment of operating levels, control limits, and control charts ° Quality control, maintenance, and calibration of equipment used in quality control such as dosimetry systems, kVp measurement equipment and computer systems ° Implement quality control program using a simple radiographic quality control test device ° Routine review of quality control program with responsible dentist and dental technician

	° Carry our performance testing on available complex dental equipment such as: computed and digital radiography, panoramic radiography, cephalometric radiography, and cone-beam CT.
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007), http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [3] AUSTRALIAN RADIATION PROTECTION AND NUCLEAR SAFETY AGENCY, Code of practice & safety guide. Radiation protection in dentistry, Radiation Protection Series, ARPANSA Rep. 10 (2005). http://www.arpansa.gov.au/rps10.htm . [4] LANGLANDS, O.E., LANGLAIS, R.P., Principles of Dental Imaging, Williams & Wilkins, Baltimore (1997). [5] Dental Radiographic Quality Control Test Device, http://www.xrayqc.com/ . [6] ADA-FDA Publication: The Selection of Patients for Dental Radiographic Examinations, (2004), http://www.ada.org/prof/resources/topics/topics_radiography_examinations.pdf . [7] Quality Assurance in Dental Radiography, (2005), http://www.kodakdental.com/documentation/film/N-416.pdf . [8] Exposure and Processing for Dental Film Radiography, (2005), http://www.kodakdental.com/documentation/film/N-413.pdf . [9] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Recommended standards for the routine performance testing of diagnostic X ray imaging systems, IPEM Rep. 91, York (2005). [10] Cone Beam Computed Tomography for Craniofacial Imaging, (2006), http://www.conebeam.com/ .
	Module 5: Performance testing of imaging equipment
	Sub-module 5.13: Dual-energy X ray absorptometry (DXA)
Objective	To acquire the knowledge and skills to be able to carry out acceptance and QC tests on DXA units.
Prerequisite	Sub-module 5.3: General radiography
Competencies Addressed	• An understanding of : (a) theory of DXA and the operation of DXA equipment (b) the importance of QC and calibration in the accurate use of normal ranges

	• The ability to carry out routine QC tests and identify and investigate causes of errors.
Core Knowledge	(1) Dual energy x ray absorptiometry principles. (2) Bone mineral densitometry concepts (3) DXA equipment components (4) Basic introduction to osteoporosis, bone physiology and risk factors (5) Radiation safety – shielding and patient dose. (6) Scan acquisition modes (7) Phantom calibration (8) Normal range, precision and reproducibility (9) Procedures for AP Spine, Femur/Dual Femur, Total Body, Forearm and LVA/Lateral spine.
Recommended Elements of Training	(1) Carry out routine QC on a bone mineral densitometer (2) Calibration of a bone mineral densitometer
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Guidelines for the use of DXA in measuring bone density and soft tissue body composition, Rep. TBA, IAEA, Vienna (2009). [3] Bone Densitometry: What is the Fundamental Basis - Tissue Interaction? , http://www.chrislangton.co.uk/clip/html/Aspects%20of%20Osteoporosis/bone_densitometry.html. [4] BLAKE, G.M., WAHNER, H.W., FOGELMAN, I., The evaluation of osteoporosis: dual energy x ray absorptiometry and ultrasound in clinical practice, 2nd edn, Martin Dunitz, London (1999). [5] BONNICK, S.L., LEWIS, L.A., Bone Densitometry for Technologists 2nd edn, Human Press, NJ, USA (2006).

	MODULE 6: TECHNOLOGY MANAGEMENT
Objective	To provide residents with an understanding of issues surrounding the management of the technological infrastructure of the radiology department.
Expected Duration	10 – 15% of overall time
Sub-Modules	(1) Quality management of systems in radiology (2) Lifecycle of imaging equipment (3) Acceptance and Commissioning of Imaging Equipment (4) Manage the routine QC testing of imaging equipment (5) Imaging Informatics (6) Department design
Core Reading	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Understanding the basics. ISO, http://www.iso.org/iso/iso_catalogue/management_standards/understand_the_basics.htm . [3] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Clinical use of electronic portal imaging AAPM Rep. 74, New York (2001). http://www.aapm.org/pubs/reports/rpt_74.PDF . [4] INTERNATIONAL ATOMIC ENERGY AGENCY, Organizing a QA program in diagnostic radiology, http://rpop.iaea.org/RPOP/RPoP/Content/Documents/TrainingRadiology/Lectures/RPDIR-L23_Organizing_QA_WEB.ppt . [5] NHS PURCHASING AND SUPPLY AGENCY, Clinical and cost effectiveness of technology, http://www.pasa.nhs.uk/PASAWeb/NHSprocurement/CEP/CEPproducts.htm . [6] CLUNIE, D., DICOM, http://www.dclunie.com/. [7] GRAY, J.E., MORIN, R.L., Purchasing medical imaging equipment, Radiology 171 1 (1989) 9-16. [8] GRAY, J.E., STEARS, J.G., "Acceptance testing of diagnostic imaging equipment: considerations and rationale", Specification, Acceptance Testing, and Quality Control of Diagnostic X ray Imaging Equipment, Proceedings of the 1991 AAPM Summer School, University of California, Santa Cruz, CA, (SEIBERT, J.A., BARNES, G.T.GOULD, R.G., Eds), American Institute of Physics, (1991) 1-9. [9] NELSON, R.E., STEARS, J.G., BARNES, G.T., GRAY, J.E., Acceptance testing of radiologic systems: experience in testing 129 imaging systems at two major medical facilities, Radiology 183 2 (1992) 563-7.

	Module 6: Technology management
	Sub-module 6.1: Quality management of systems in radiology
Objective	To develop an understanding of the principal requirements and elements for a quality management system in diagnostic radiology.
Prerequisite	None
Competencies Addressed	• An understanding of the essential elements of a quality management system. • The ability to design the structure of a quality management system.
Core knowledge	(1) Understanding of quality management, quality assurance and quality control and their need and benefits in diagnostic imaging. (2) Document quality control methods and implementation
Recommended Elements of Training	(1) Explain the meaning of relevant terms such as quality, quality process, quality assurance, continuous quality improvement, quality control and quality audit (2) Demonstrate an understanding of the role of quality management in diagnostic radiology (3) Discuss key elements of a quality management system: ° Document control ° Documentation of quality policy ° Documentation of quality procedures (quality manual) (4) Analyze the patient work flow (5) Design the structure of a quality manual and apply it to a representative selection of items (6) Participate in a relevant course (either at the management or at the professional level)
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Understanding the basics. ISO, http://www.iso.org/iso/iso_catalogue/management_standards/understand_the_basics.htm .
	Module 6: Technology management
	Sub-module 6.2: Life cycle of imaging equipment
Objective	To assist in the management of all diagnostic imaging equipment.

Pre-requisites	Module 5: Performance testing of imaging equipment
Competencies Addressed	• An understanding of the life cycle of imaging equipment including the elements of planning, purchase; acceptance and commissioning, maintenance, routine testing and disposal. • The ability to: (a) Form an equipment business plan and draft a tender document (b) Oversee equipment maintenance, including verification of equipment quality after maintenance and disposal
Core Knowledge	(1) Principles of Equipment Planning: ° Creation of the business plan ° Clinical consideration; evidence review ° Technical evaluation ° Power supply and earthing (grounding) ° Maintenance planning ° Equipment limitations ° Workflow and limitations ° Room layout ° Workload and radiation shielding (2) Principles of Equipment Acquisition: ° Conflict of interest, probity and confidentiality ° Specification ° Tender ° Selection of vendors (3) Principles of Equipment Installation, Acceptance Testing and Commissioning: ° The need for detailed planning ° The need for oversight of the installation process ° The role of acceptance testing ° The role of commissioning (4) Principles of Equipment Oversight: ° Quality control programmes ° Equipment service and maintenance (5) Principles of Equipment Disposal: ° Concept of equipment life cycle
Recommended Elements of Training	(1) Equipment business plan and draft of a tender document: ° Equipment Planning: ▪ Development of room layout ▪ Establish workload and radiation shielding requirements ° Equipment Acquisition: ▪ Development of specifications based on needs analysis ▪ Selection of primary vendors

	▪ Selection of final vendor ▪ Negotiation with vendors to optimize equipment and price ° Supervise and mentor technical staff to successfully complete a project on schedule. ° Where possible attend a course on: ▪ Time management ▪ Conflict resolution ▪ Performance management (2) Oversight of equipment maintenance (advanced): ° Supervise the maintenance of radiological equipment units, such as: ▪ Participate in trouble-shooting equipment faults for a period of time. ▪ Assume responsibility for different units for a period of time, including being a contact point for equipment faults and liaising with engineers. ▪ Write a report and/or present to the physics department case studies outlining the equipment fault, its cause and required verification measurements required to ensure suitable image quality and patient dose. ▪ Understand differences between units from different manufacturers. ▪ Perform appropriate testing after maintenance, calibration, and software upgrades to assure image quality, dose optimization, and patient safety ° Principles of Equipment Disposal: ▪ Assist in planning for equipment replacement and disposal ▪ Negotiate for beneficial arrangements for equipment removal ▪ Ensure appropriate disposal considering hazardous materials in the equipment.
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] GRAY, J.E., MORIN, R.L., Purchasing medical imaging equipment, Radiology 171 1 (1989) 9-16. [3] LEITGEB, N., Safety in Electromedical Technology, Interpharm Press, Inc., Illinois,USA (1996). [4] MCCLELLAND, I.R., X ray Equipment Maintenance and Repairs Workbook for Radiographers and Radiological Technologists, World Health Organization, Geneva (2004). [5] CENTRE FOR EVIDENCE-BASED PURCHASING, Evaluation of EIZO RadiForce G33 and G33-N LCD displays: CEP 07003; NHS PASA Aug 2007 [online] (2007). http://www.cep.dh.gov.uk/CEPProducts/Catalogue.aspx . [6] CENTRE FOR EVIDENCE-BASED PURCHASING, Multislice CT scanners. Buyers guide: CEP 08007; NHS PASA March 2009 [online] (2009). http://www.cep.dh.gov.uk/CEPProducts/Catalogue.aspx .

	[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Applying Radiation Safety Standards in Nuclear Medicine, Safety Reports Series No. 40, IAEA, Vienna (2005). [8] NHS, Estates HBN 6 Facilities for Diagnostic Imaging and Interventional Radiology. The Stationery Office, www.tsoshop.co.uk .
	Module 6: Technology management
	Sub-module 6.3: Acceptance and commissioning of imaging equipment
Objective	To be able to accept and commission diagnostic imaging equipment.
Prerequisite	
Competencies Addressed	• An understanding of the concept and principles of acceptance and commissioning of equipment. • The ability to carry out and report on acceptance testing of new equipment and its commissioning.
Core Knowledge	(1) In depth understanding of the imaging modality in question including image quality and typical patient doses (2) The procurement process (3) Roles and responsibilities of the procurement team (4) Knowledge of warranty conditions and their implications on equipment testing. (5) The concept of commissioning (6) Methods for testing radiological equipment (7) Quality assurance programmes (8) Regulatory requirements applying to the imaging modality.
Recommended Elements of Training	(1) Roles and responsibilities (2) Accept equipment supplied by manufacturer: ° Understand manufacturer's specification ° Verify that equipment specified has been supplied ° Verify that all manuals and accessories have been supplied ° Verify that equipment meets the manufacturer's and purchaser's performance specification ° Confirm that the equipment meets all regulatory requirements for diagnostic imaging equipment ° Confirm electrical and mechanical safety ° Write report summarising outcomes and recommending remedial action if required. (3) Commission equipment prior to first use: ° Identify clinical protocols that will be used in routine use.

	° Determine equipment performance in a range of clinical protocols. ° Confirm viability of data transfer via DICOM or other links ° Establish baseline values against which routine performance tests (quality control tests) can be carried out. ° Compare baseline values with expected and other similar results from national / or international sources. ° Use commissioning data to make recommendations for optimization of clinical protocols ° Write report summarising outcomes and recommending remedial action if required.
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Clinical use of electronic portal imaging AAPM Rep. 74, New York (2001). http://www.aapm.org/pubs/reports/rpt_74.PDF . [3] GRAY, J.E., MORIN, R.L., Purchasing medical imaging equipment, Radiology 171 1 (1989) 9-16. [4] GRAY, J.E., STEARS, J.G., "Acceptance testing of diagnostic imaging equipment: considerations and rationale", Specification, Acceptance Testing, and Quality Control of Diagnostic X ray Imaging Equipment, Proceedings of the 1991 AAPM Summer School, University of California, Santa Cruz, CA, (SEIBERT, J.A., BARNES, G.T.GOULD, R.G., Eds), American Institute of Physics, (1991) 1-9. [5] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Recommended standards for the routine performance testing of diagnostic X ray imaging systems, IPEM Rep. 91, York (2005). [6] INTERNATIONAL ATOMIC ENERGY AGENCY, Organizing a QA program in diagnostic radiology, http://rpop.iaea.org/RPOP/RPoP/Content/Documents/TrainingRadiology/Lectures/RPDIR-L23_Organizing_QA_WEB.ppt . [7] NELSON, R.E., STEARS, J.G., BARNES, G.T., GRAY, J.E., Acceptance testing of radiologic systems: experience in testing 129 imaging systems at two major medical facilities, Radiology 183 2 (1992) 563-7.
	Module 6: Technology management
	Sub-module 6.4: Manage the routine QC testing of imaging equipment
Objective	To understand and manage the all aspects of a routine radiological quality control programme.
Prerequisite	Sub-module 4.2: Communication

Competencies Addressed	• An understanding of the methods for the clinical implementation and supervision of a quality control programme. • The ability to manage a QC programme including the appropriate use of instrumentation, test selection and test frequency.
Core Knowledge	(1) Principles of quality control (2) Regulatory requirements (3) Roles and responsibilities of staff involved in the QC programme: ° Which staff groups are required to perform different types of test ° Supervision requirements ° Training needs and delivery ° Reporting (4) Quality Control tests: ° Types of test ° Complexity of differing tests ° Applicability of tests ° Appropriate frequencies for performance of different tests ° Use of control charts including operating levels, upper and lower control limits
Recommended Elements of Training	(1) Participation in the training of staff to: ° Operate equipment used to perform QC tests ° Perform QC tests (2) Establishment of: ° Operating levels ° Control limits ° Control charts (3) Implement QC program to include: ° Radiography (film imaging with photographic processing and digital radiography), ° Fluoroscopy, computed tomography ° Magnetic resonance imaging ° Ultrasound ° Appropriate quality control charts (4) Carry out periodic review of quality control program with supervisory radiographer or technologist: ° Perform medical physicist level quality control tests ° Develop quality control program ° Monitor radiographer's quality control tests
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp.

	[2] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Quality control in diagnostic radiology AAPM Rep. 74, New York (2002). http://www.aapm.org/pubs/reports/rpt_74.PDF . [3] BRITISH INSTITUTE OF RADIOLOGY, Assurance of Quality in the Diagnostic Imaging Department. 2nd edition. The Quality Assurance Working Group of the Radiation Protection Committee of the British Institute of Radiology (2001). [4] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Recommended standards for the routine performance testing of diagnostic X ray imaging systems, IPEM Rep. 91, York (2005). [5] INTERNATIONAL ATOMIC ENERGY AGENCY, Organizing a QA program in diagnostic radiology, http://rpop.iaea.org/RPOP/RPoP/Content/Documents/TrainingRadiology/Lectures/RPDIR-L23_Organizing_QA_WEB.ppt. [6] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality control, http://rpop.iaea.org/RPOP/RPoP/Content/Documents/TrainingRadiology/Lectures/RPDIR-L11_QA_WEB.ppt .
	Module 6: Technology management
	Sub-module 6.5: Imaging informatics
Objective	To acquire the knowledge and skills to practice basic imaging informatics in digital imaging environments.
Prerequisite	Sub-module 4.3: Information technology Sub-module 5.11: Display and printing devices
Competencies Addressed	• An understanding of : (a) Basic digital imaging principles including image archiving, compression storage, communication, standards and display (b) Medical and health information systems including applications and ethical considerations • The ability to perform basic performance testing in the PACS environment including the verification of DICOM conformance statements and the utilization of header information.
Core Knowledge	(1) Image Basics: ° Image digitization ° Image acquisition ° Image transmission ° Image compression ° Image processing and enhancement ° Image storage and archive (2) Communication and networking: ° Architecture and topology

	° Network Infrastructures and Protocols ° Integration ° Connectivity ° Security (3) Standards and Protocols: ° DICOM and DICOM conformance ° Health Level 7 ° Integrating the Healthcare Enterprise (4) Image displays and workstations: ° Display Device Technology ° Luminance ° Performance Assessment ° Calibration (5) HIS RIS & PACS: ° Picture Archiving and Communication System (PACS) ° Radiology Information System (RIS) ° Hospital Information System (HIS) ° Electronic Medical Records (EMR) (6) Applications: ° Teleradiology ° 3-D image applications ° Computer Aided Diagnosis ° Voice recognition (7) Professional and ethical IT issues such as privacy, confidentiality, sensitivity and permission to use data.
Recommended Elements of Training	(1) Image Basics: ° Read and manipulate images from a range of modalities. ° Apply and recognise effects of a range of image processing and enhancement techniques ° Identify image compression artefacts (2) Networking: ° Analyse network configurations (3) Standards and Protocols: ° Set-up two computers to be able to communicate via DICOM using freeware DICOM tools ° Review the DICOM header for a range of imaging modalities ° Review DICOM conformance statements (4) Image displays and workstations (see Sub-module 5.11): ° Perform acceptance and QA on image displays and workstations ° Perform quality control on image display integrity (5) HIS RIS and PACS: ° Participate in acceptance testing and quality control of PACS environment ° Participate in PACS implementation

	° Participate in PACS management ° Review RIS, HIS, and EPR implementation
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] AMERICAN COLLEGE RADIOLOGY, ACR Technical Standard for Electronic Practice of Medical Imaging (2007). http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/med_phys/electronic_practice.aspx (last accessed August 2008). [3] CENTRE FOR EVIDENCE-BASED PURCHASING, A beginner's guide to PACS: MDA 02044; NHS PASA May 2002 [online] (2002). http://www.cep.dh.gov.uk/CEPProducts/Catalogue.aspx. [4] CENTRE FOR EVIDENCE-BASED PURCHASING, A beginner's guide to virtual private networks in a Picture Archiving and Communication System environment: CEP 05094; NHS PASA March 2006 [online] (2006). http://www.cep.dh.gov.uk/CEPProducts/Catalogue.aspx. [5] CLUNIE, D., DICOM, http://www.dclunie.com/ . [6] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Assessment of display performance for medical imaging systems, AAPM On-line Report 03, AAPM, College Park (2005). http://www.aapm.org/pubs/reports/OR_03.pdf Supplemental files available at http://www.aapm.org/pubs/reports/OR_03_Supplemental/ . [7] HUANG, H.K., PACS: Basic Principles and Applications, 2nd edn, John Wiley & sons, inc. (2004). [8] DREYER, K.J., MEHTA, A., THRALL, J.H., PACS: A guide to the digital revolution. Springer, Place, Published.(2002). [9] INTEGRATING THE HEALTHCARE ENTERPRISE, www.IHE.net [10] HEALTH LEVEL 7, www.HL7.org .
	Module 6: Technology management
	Sub-module 6.6: Department design
Objective	To be able to assist radiology department and facility staff, planners and architects, in the appropriate physical layout of the department, examination rooms, and support areas for efficient workflow and radiation protection.
Prerequisite	
Competencies Addressed	• An understanding of the factors important to design of a diagnostic radiology facility. • The ability to design and verify effective and safe rooms for diagnostic radiological examinations.

Core Knowledge	(1) Principles of radiation protection, e.g., time, distance. Shielding (2) Concepts of room and x ray generator workload (3) Use of architectural drawings and the planning process (4) Minimum size requirements for x ray rooms (5) Typical layouts for examination rooms (6) Patient and staff privacy issues (7) Local regulations and building codes
Recommended Elements of Training	(1) Demonstrate an understanding of: ° Patient and staff flow in imaging department ° Differences between inpatient and outpatient movement in the department ° Patient and staff privacy issues ° Difficulties encountered by radiographers in handling patients including moving patients in to the procedure room, onto the examination table, critical patients requiring constant monitoring, and support staff (2) Evaluate present design of examination rooms and department layout (3) Interview staff about issues associated with present design and their ideas relative to improvements in design and patient flow (4) Design department layout for improved workflow, efficiency, and patient privacy (5) Design department layout for optimized radiation protection of patients, staff, and public (6) Design examination rooms as above for some of the following modalities: general radiography, mammography, CT, and special procedures, ultrasound and magnetic resonance imaging (7) Use area monitors to review staff doses and relate this to current shielding design.
Knowledge Sources	[1] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Structural Shielding Design for Medical X ray Imaging Facilities, NCRP Rep. 127, Bethesda, MD, USA. (2004). www.ncrppublications.org . [2] NHS, Estates HBN 6 Facilities for Diagnostic Imaging and Interventional Radiology. The Stationery Office, www.tsoshop.co.uk . [3] SUTTON, D.G., WILLIAMS, J.R., Radiation Shielding for Diagnostic X rays, British Institute of Radiology, London (2000). http://www.bir.org.uk .

	MODULE 7: DOSIMETRY, INSTRUMENTATION AND CALIBRATION
Objective	To provide residents with the: ° Knowledge necessary to understand diagnostic radiology dosimetry for ionizing radiation, including role of dosimetric phantoms ° Knowledge necessary to understand the principles and safety of non-ionising radiation as used in diagnostic radiology ° Skills necessary to correctly operate radiological test equipment ° Principles needed to maintain traceability of equipment calibration and the skills to perform necessary calibrations.
Expected Duration	5 to 10% of total time.
Sub-modules	(1) Ionising radiation dosimetry and principles of measurement (2) Non-ionising radiation quantities and principles of measurement (3) Radiological test equipment, measurement, and practice (4) Dosimetry system calibration
Core Reading	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007), http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [3] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Patient Dosimetry for X Rays Used in Medical Imaging, ICRU Rep. 74, Bethesda, MD (2006). [4] INTERNATIONAL LIGHT INC, The Light Measurement Handbook, (1997), http://www.intl-lighttech.com/services/light-measurement-handbook. [5] KNOLL, G.F., Radiation Detection and Measurement, 3rd edn, John Wiley & Sons, New York (1999). [6] LEITGEB, N., Safety in Electromedical Technology, Interpharm Press, Inc., Illinois,USA (1996).
	Module 7: Dosimetry, Instrumentation and Calibration
	Sub-module 7.1: Ionising radiation dosimetry and principles of measurement
Objective	To provide residents with knowledge necessary to understand diagnostic

	radiology dosimetry for ionizing radiation, including role of dosimetric phantoms.
Prerequisites	None
Competencies Addressed	• An understanding of radiation quantities and units, formalism and uncertainty estimation, and dosimeter types needed for radiation measurement in diagnostic radiology. • The ability to determine through measurement and to record dosimetric quantities: (a) For each of five diagnostic modalities; general radiography, fluoroscopy, mammography, CT and dentistry, with the associated uncertainty estimation (b) For complex situations including those with large components of scattered radiation
Core Knowledge	(1) Dosimetric quantities: ° Basic diagnostic radiology dosimetry quantities: fluence, energy fluence, kerma and kerma rate, energy imparted and absorbed energy. ° Application specific dosimetric quantities: Incident air kerma, entrance surface dose, air kerma product, air kerma length product, quantities for CT dosimetry ° Backscatter estimation: energy and beam area effects ° Quantities related to stochastic and deterministic effects: organ and tissue dose, equivalent dose, effective dose, conversion coefficients for assessment of organ and tissue doses (e.g., mammography) ° Operational dose quantities: ambient dose equivalent, personal dose equivalent. (2) Formalism: ° Traceable and relative dosimetry techniques ° Estimation of uncertainties (3) Dosimeters: ° Ionisation chambers: configuration, standard free air ionisation chamber, measurement of chamber current and charge ° Solid state detectors: diode based detectors, thermoluminescent dosimeters (TLD), optically stimulated luminescence (OSL) detectors ° Energy dependence, other considerations. (4) Dosimetry specific to diagnostic modalities, including required dosimetry phantoms: ° General radiography ° Fluoroscopy ° Mammography ° CT ° Dental radiography
Recommended Elements of	(1) Standard dosimetric measurements: ° Selection and correct use of equipment for dose measurements,

Training	including uncertainties for the following situations: ▪ Direct radiographic exposure (general radiography, fluoroscopy, mammography and intra oral dental modalities) ▪ KAP measurement (general radiography, fluoroscopy and OPG dental modalities) ▪ CT dose indicator measurements (CT and OPG dental) ° Use of ionisation chambers and semiconductor detectors with the use of correction factors (2) Complex dosimetric measurements: ° Selection and correct use of equipment for dose measurements, including uncertainties for the following situations: ▪ Scatter from patient during radiographic exposure ▪ Dose rates, high dose fluoroscopy patient entrance and exit dose rates ▪ Internal doses using solid state detectors and radiological phantoms ▪ Tube leakage and occupational staff measurements (3) Operate a TLD unit including the required quality processes: ° Use of TLD, OSL, and similar solid state detectors ° Documentation of dosimetric records, including doses to patients related to pregnancy and paediatrics, and those used for dose audit and optimization: ▪ Records should be maintained, being clear to the educated lay person, but still with defendable dosimetric detail ▪ Records of dose for particular examinations should involve the use of calibrated instruments and use dosimetry formalisms that are referenced to recognised standards. ▪ The correct use of phantoms, where applicable, should be recorded with the use of photographs.
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] ATTIX, F.H., Introduction to Radiological Physics and Radiation Dosimetry, John Wiley & Sons, New York (1986). [3] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007), http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [4] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Determination of dose equivalents resulting from external radiation sources, ICRU Rep. 39, Bethesda, MD (1985). [5] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Fundamental Quantities and Units for Ionizing Radiation, ICRU Rep. 60, Bethesda, MD (1998). [6] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Patient Dosimetry for X Rays Used in Medical Imaging, ICRU Rep. 74, Bethesda, MD (2006).

	[7] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the ICRP. Annals of the ICRP vol 37 (2-4) Rep. 103 (2007). [8] KNOLL, G.F., Radiation Detection and Measurement, 3rd edn, John Wiley & Sons, New York (1999). [9] MARTIN, C.J., SUTTON, D.G., Practical Radiation Protection in Healthcare, Oxford University Press, Oxford (2002).
	Module 7: Dosimetry, Instrumentation and Calibration
	Sub-module 7.2: Non-ionising radiation quantities and principles of measurement
Objective	To provide residents with the knowledge necessary to understand the principles and safety of non-ionising radiation as used in diagnostic radiology.
Prerequisites	None
Competencies Addressed	• An understanding of the basic principles, measurement, and the safety issues involved in visible light, lasers, ultrasound, radiofrequency radiation, and static magnetic fields. • The ability to perform necessary basic measurements in non ionizing radiation.
Core Knowledge	(1) Visible light: ° Wavelength ° Luminance ° Illuminance ° Color temperature (spectral characteristics of light) ° Radiometric units ° Measurement methods ° Assessment of computer (PACS) displays, viewboxes, and viewing conditions (2) Lasers: ° Laser principles ° Laser safety, eye protection, procedures for safe use ° Lasers used in medicine ° Power, power density, energy, energy density ° Delivery systems ° Laser classification and warning signs ° Laser safety ° Measurement of laser light (3) Ultrasound: ° Ultrasound generation, transducers, beam patterns

	° Continuous, pulsed, and Doppler ultrasound instruments ° Power, power density ° Biological effects, and relevant quantities (spatial and temporal peak and average, thermal index, mechanical index) ° Measurement of ultrasound (4) Radiofrequency (RF) radiation: ° Sources and generation of RF radiation in medicine ° Quantities used (power, specific absorption rate [SAR]) ° Biological effects ° Measurement of RF radiation ° Measurement of static magnetic fields
Recommended Elements of Training	(1) Measurement and assessment of visible light, especially viewboxes and other image displays including computer monitors, and viewing conditions. (2) Assessment of safety of equipment using lasers (3) Assessment of safety of diagnostic ultrasound equipment (4) Assessment of safety of MRI installations (static field and RF field)
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] LASERS, www.research.usf.edu/cs/rad/LASERS.ppt . [3] AMERICAN INSTITUTE OF ULTRASOUND IN MEDICINE, Consensus Statement on Potential Effects of Diagnostic Ultrasound, J Ultrasound Med 27 (2008) 503-515. [4] AMERICAN NATIONAL STANDARD FOR PHOTOGRAPHY, Viewing Conditions for Transilluminated Monochrome Medical Images – Method for Characterizing Rep. ANSI/I3A IT2.45-2006 (2006). [5] IDAHO STATE UNIVERSITY, Radiation Information Network, http://physics.isu.edu/radinf/Source.htm#non . [6] INTERNATIONAL LIGHT INC, The Light Measurement Handbook, (1997), http://www.intl-lighttech.com/services/light-measurement-handbook . [7] LEDTRONICS INC, Common Light Measurement Terms, www.ledtronics.com/pages/downloads/light_measurement_terms.pdf . [8] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Biological Effects of Ultrasound: Mechanisms and Clinical Implications, NCRP Rep. 74, Bethesda, MD, USA. (1983). www.ncrppublications.org . [9] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Exposure Criteria for Medical Diagnostic Ultrasound: I. Criteria Based on Thermal Mechanisms NCRP Rep. 113, Bethesda, MD. (1992).

	[10] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Assessment of display performance for medical imaging systems, AAPM On-line Report 03, AAPM, College Park (2005). http://www.aapm.org/pubs/reports/OR_03.pdf Supplemental files available at http://www.aapm.org/pubs/reports/OR_03_Supplemental .
	Module 7: Dosimetry, Instrumentation and Calibration
	Sub-module 7.3: Radiological test equipment, measurement and practice
Objective	To provide the skills necessary to correctly operate radiological test equipment.
Prerequisites	Sub-module 7.1: Ionising radiation dosimetry and principles of measurement
Competencies Addressed	• An understanding of techniques and instrumentation needed to characterize an x ray beam, focal spot, or film processor. • The ability to use radiological test equipment.
Core Knowledge	(1) X ray kVp and tube current measurement: ° Non-Invasive kVp meters ° Invasive kVp meters and high voltage dividers ° Practical peak voltage ° Current clamps and mAs measurement (2) Focal Spot measurement: ° Pinhole technique ° Star pattern ° Slit camera (3) Sensitometry and densitometry: ° Function and use of sensitometers ° Function and use of optical densitometers ° Calibration and quality control of sensitometers and densitometers
Recommended Elements of Training	(1) X ray kVp and tube current measurement: ° Undertake kVp measurement (20 kVp to 150 kVp) ° Investigate the factors affecting accuracy: beam filtration, instrument orientation with respect to anode-cathode axis, dose rate, measurement windowing, and exposure duration ° Understand how invasive kVp meters are inserted into a circuit and factors affecting performance (actual use of invasive kVp measurement not to be undertaken except with the assistance of a competent x ray equipment service engineer) ° Use of current clamps to measure x ray tube current

	(2) Focal Spot Measurement: ° Use star test pattern to estimate focal spot size ° Investigate effect of magnification ° Use pinhole camera to measure focal spot size ° Investigate measurement with direct film exposure, with a mammography screen-film system, and with a CR plate. ° Define length and width of focal spot ° Compare differences between nominal and measured focal spot sizes (3) Sensitometry and densitometry: ° Use sensitometer, including appropriate selection of spectral setting, to expose different types of films ° Process films taking into account effect of processing direction on sensitometric strip densities ° Measure optical densities using a densitometer taking into account differences in film orientation for single- and dual-emulsion films, e.g., emulsion side up or down ° Establish a calibration and quality control program for the sensitometers and densitometers
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007), http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [3] GRAY, J.E., WINKLER, N.T., STEARS, J., FRANK, E.D., Quality Control in Diagnostic Imaging, Aspen Publishers, Inc., Rockville, Maryland. (1983). [4] GABBAY, E., "X ray Source Assembly Design", Specification, Acceptance Testing and Quality Control of Diagnostic X ray Imaging Equipment, (SEIBERT, J.A., BARNES, G.T.GOULD, R.G., Eds), American Institute of Physics, Woodbury, NY, (1994) 173-204. [5] HAUS, A.G., Advances in Film Processing Systems Technology and Quality Control in Medical Imaging, (2001). [6] INTERNATIONAL ELECTROTECHNICAL COMMISSION, IEC 4274:1995 X ray tube assemblies for medical diagnosis-characteristics of focal spot, IEC, Geneva (1995). [7] KATZ, M.C., NICKOLOFF, E.L., Radiographic Detail and Variation of the Nominal Focal Spot Size: The "Focal Effect", Radiographics 12 (1992) 753-761. [8] KODAK, Sensitometry workbook, http://motion.kodak.com/motion/uploadedFiles/US_plugins_acrobat_en_motion_education_sensitometry_workbook.pdf . [9] KODAK, Characteristics of film, http://www.kodak.com/US/plugins/acrobat/en/motion/newsletters/filmEss/06_Characteristics_of_Film.pdf. [10] HAUS, A.G., (Ed.) The Physics of Medical Imaging: Recording System Measurements and Techniques, (1979).

	Module 7: Dosimetry, Instrumentation and Calibration
	Sub-module 7.4: Dosimetry system calibration
Objective	To provide residents with the principles needed to maintain traceability of equipment calibration and the skills to perform necessary calibrations.
Prerequisites	None
Competencies Addressed	• An understanding of calibration standards, traceability and calibration beam conditions. • The ability to: (a) maintain instrument calibrate traceability records including documentation of cross-checks and field calibrations (b) Perform field calibrations for various dosimeters including TLD and OSL and KAP meters
Core Knowledge	(1) Theory of: ° Calibration, transferring calibrations, and calibration factors ° The role of calibration laboratories ° Use of standard beam qualities (2) Calibrations in the clinical centre: ° Calibration of kerma-Area Product (KAP) meters ° Calibration of CT chambers ° Calibration of TLD and OSL detectors ° Calibration of other detectors, e.g., film and CR plates, (3) Calibration of tube voltage and time measurement devices: ° Non-invasive kVp meters ° Invasive kVp meters and high voltage dividers ° Practical peak voltage ° Current clamps and mAs measurement ° Definitions of exposure time
Recommended Elements of Training	(1) Maintain clear records of traceable calibrations on dosimetric equipment including: ° Calibration traceability and frequency ° Use of cross check documentation (2) Demonstrate the ability to perform the following: ° Determination of beam characteristics through the use of half-value layer measurement (HVL) ° Cross check of working instruments against externally calibrated equipment ° Calibration of a KAP system in clinical environment ° Field check of calibration of CT pencil chambers

	° TLD and OSL calibration ° TLD and OSL use in patient and occupational dose measurement ° Film calibration ° Film use in patient and occupational dose measurement ° CR plate calibration ° CR plate use in dose measurement (3) X ray kVp and tube current measurement: ° Maintain cross calibration of kVp meters ° Maintain cross calibration of current clamps to measure x ray tube current
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007), http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [3] KNOLL, G.F., Radiation Detection and Measurement, 3rd edn, John Wiley & Sons, New York (1999).

	MODULE 8: PATIENT DOSE AUDIT
Objective	To provide residents with the skills necessary to measure and assess radiation dose, and to use this information to estimate patient dose, including adults, children and the foetus.
Expected Duration	8 to 14% of overall time
Sub-modules	(1) Dose audit (2) Paediatric dosimetry (3) Foetal dose
Core Reading	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] WAGNER, L.K., LESTER, R.G., SALDANA, L.R., Exposure of the pregnant patient to diagnostic radiology – A guide to medical management, 2nd edn, Medical Physics Publishing, Madison (1997). [3] THE ALLIANCE FOR RADIATION SAFETY IN PEDIATRIC IMAGING, www.imagegently.org . [4] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Guidance on the Establishment and Use of Diagnostic Reference Levels for Medical X ray Examinations IPEM York (2004). http://www.ipem.ac.uk/ipem_public/default.asp?id=366 . [5] WAGNER, L.K., LESTER, R.G., SALDANA, L.R., Exposure of the pregnant patient to diagnostic radiology – A guide to medical management, 2nd edn, Medical Physics Publishing, Madison (1997). [6] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Guidance on the Establishment and Use of Diagnostic Reference Levels for Medical X ray Examinations IPEM York (2004). http://www.ipem.ac.uk/ipem_public/default.asp?id=366 .
	Module 8: Patient Dose Audit
	Sub-module 8.1: Dose audit
Objective	To be able to assess patient doses from x ray procedures, and to perform patient dose surveys and compare with DRLs and other relevant data.
Prerequisites	Sub-module 7.1: Ionising radiation dosimetry and principles of measurement
Competencies Addressed	• An understanding of the concepts that underpin dose audit including the relevant dosimetric principles, the appropriate selection of the patient

	sample or phantom, and the concept of diagnostic reference levels. • The ability to carry out patient dose surveys, comparing the results with diagnostic reference levels, draw meaningful conclusions and take appropriate action.
Core Knowledge	(1) Units and quantities including: ° Air kerma and absorbed dose, ° Equivalent dose and effective dose and their limitations (2) Dose metrics including: ° Incident air kerma (K_i) and entrance air kerma (K_e) (also known as entrance surface dose) ° Kerma area product (KAP /DAP) ° energy imparted ° CTDI quantities and Kerma length product (P_{KL}) (also known as Dose length product -DLP) ° Mean Glandular Dose (MGD) (3) Theory and use of Radiation detectors including: ° Ionisation chambers ° Free-in-air chambers ° CT chamber ° KAP (DAP) meter ° Solid state devices (diode based) ° Luminescent devices: TLD; OSL ° GAFchromic film (4) Calibration including: ° Primary and secondary standards, traceability ° Field comparisons ° Calibration for CT chambers and KAP meters (5) Dose calculation and estimation including: ° Use of backscatter factors ° Estimation of organ dose and effective dose from physical measurements and patient parameters ° Understanding and use of available dosimetry software (6) Phantoms for dose measurements in radiography, fluoroscopy, CT and mammography (7) Patient selection criteria for dose measurements (8) Diagnostic Reference Levels: ° Derivation ° Application in dose audit
Recommended Elements of Training	(1) For each x ray modality: ° Design dose audit procedure including the dosimetric parameter to be measured, the data collection forms and the method of analysis ° Be able to justify your decision to either conduct the dose audit with a patient sample or with an appropriate phantom.

	° If choosing a patient sample demonstrate an understanding of the selection criteria for suitable patients for measurements and the sample size. ° Ensure calibration traceability of the appropriate radiation detector used to measure patient doses. ° Instruct staff involved in the actual measurements on the appropriate use of dosimeters and completion of survey data form. ° Accurately measure or calculate the different dosimetric quantities. ° Carry out periodic patient dose surveys and compare with diagnostic reference levels or other published data. Take appropriate remedial action where appropriate. ° Determine the uncertainty of the final determination of individual patient doses and/or of the sample dose average. (2) For General Radiography & Fluoroscopy: ° Using measurement or calculation techniques determine Ki or Ke for each patient in the sample or use a phantom as appropriate. Measure or estimate backscatter factors ° Where possible obtain Kerma Area Product data ° Use published tables and software tools to calculate Effective Dose from kerma and KAP data ° Calculation of organ doses (as appropriate) ° Demonstrate an awareness of limitations of the data (such as phantom dimensions, recorded beam size and FSDs) used in calculations and as software parameters ° Determine the uncertainty of the final determined of patient dose and or of the sample dose average. (3) For Mammography: ° Measurement of K_i ° Estimation of Mean/Average Glandular Dose (4) For Computed Tomography: ° Measurement of $C_{100,air}$, C_w ($CTDI_{100,air}$, $CTDI_w$) ° Calculation of C_{VOL} and P_{KL} ($CTDI_{vol}$ and DLP) ° Calculation of effective dose ° Calculation of organ doses (5) For dental radiology: ° Measurement of K_i for intra-oral radiography ° Measurement of P_{KL} (Dose Width Product) for panoramic radiography ° Calculation of effective dose problematic (6) DEXA: ° Measurement of K_i ° Calculation of effective dose and its limitations
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp.

	[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna (2007), http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf. [3] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Patient Dosimetry for X Rays Used in Medical Imaging, Rep. 74, ICRU, Bethesda, MD (2006). [4] IPSM/NRPB/COR, National Protocol for Patient Dose Measurements in Diagnostic Radiology, NRPB, Chilton (1992). [5] WALL, B.F., HARRISON, R.M., SPIERS, F.W., Patient Dosimetry Techniques in Diagnostic Radiology, IPSM Report No. 53, Institute Physical Sciences in Medicine, York (1988). [6] GRAY, J.E., et al., Reference values for diagnostic radiology: application and impact, Radiology 235 2 (2005) 354-8. [7] HART, D., JONES, D.G., WALL, B.F., Estimation of Effective Dose in Diagnostic Radiology from Entrance Surface Dose and Dose-Area Product Measurements, NRPB-R262, National Radiological Protection Board, NRPB (1994). [8] HUFTON, A., "Patient dosimetry", Practical Radiation Protection in Healthcare, (MARTIN, C.J.SUTTON, D.G., Eds), Oxford University Press, Oxford, (2002). [9] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Guidance on the Establishment and Use of Diagnostic Reference Levels for Medical X ray Examinations IPEM Rep. 88, York (2004). http://www.ipem.ac.uk/ipem_public/default.asp?id=366. [10] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Radiological Protection and Safety in Medicine, ICRP Publication 73, Pergamon Press, Oxford and New York (1997).
	Module 8: Patient Dose Audit
	Sub-module 8.2: Paediatric dosimetry
Objective	To acquire the knowledge and skills to determine the dose received and to perform patient dose audits in paediatric radiology.
Prerequisite	Sub-module 7.1: Ionising radiation dosimetry and principles of measurement Sub-module 8.1: Patient Dose Audit
Competencies Addressed	• An understanding of the differences between dosimetry of adult and paediatric patients, including impact of various patient sizes on dosimetry. • The ability to conduct and analyse dose audits of a paediatric population.
Core Knowledge	(1) Dosimetry: ° Determination of organ dose in paediatric patients ° Uses and limitations of effective dose in the context of paediatrics

	° Conversion factors for paediatric patients ° Use of appropriate software (2) Diagnostic Reference Levels (DRLs) and their limitations and applications for paediatrics
Recommended Elements of Training	(1) Recommended elements of training from Module 8.1 with the addition of selection of patient groups based on patient weight and height, body mass index, or other appropriate index of patient size. (The use of patient age as a grouping factor can also be used so long as this is reflected in the uncertainty calculation for the dose estimation.) (2) Carry out paediatric patient dose audits and compare results with diagnostic reference levels, if available, or with published paediatric dose data (3) Determine the uncertainty for the determination of the paediatric sample or phantom dose (4) Initiate reviews when doses are greater than or considerably less than DRLs, or other published dose data (5) Compare the typical patient doses estimated for different paediatric procedures and for different patient samples
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] CHAPPLE, C.L., FAULKNER, K., LEE, R.E., HUNTER, E.W., Radiation doses to paediatric patients undergoing less common radiological procedures involving fluoroscopy, Br J Radiol 66 789 (1993) 823-7. [3] CHAPPLE, C.L., FAULKNER, K., LEE, R.E., HUNTER, E.W., Results of a survey of doses to paediatric patients undergoing common radiological examinations, Br J Radiol 65 771 (1992) 225-31. [4] HART, D., JONES, D.G., WALL, B.F., Coefficients for estimating effective doses from paediatric X ray examinations. NRPB-R279, National Radiological Protection Board, NRPB, Chilton (1996). [5] OGUNDARE, F.O., AJIBOLA, C.L., BALOGUN, F.A., Survey of radiological techniques and doses of children undergoing some common x ray examinations in three hospitals in Nigeria, Med Phys 31 3 (2004) 521-4. [6] STRAUSS, K.J., Pediatric interventional radiography equipment: safety considerations, Pediatr Radiol 36 Suppl 2 (2006) 126-35. [7] STRAUSS, K.J., KASTE, S.C., The ALARA (as low as reasonably achievable) concept in pediatric interventional and fluoroscopic imaging: striving to keep radiation doses as low as possible during fluoroscopy of pediatric patients--a white paper executive summary, Pediatr Radiol 36 Suppl 2 (2006) 110-2. [8] THE ALLIANCE FOR RADIATION SAFETY IN PAEDIATRIC IMAGING, www.imagegently.org. [9] YAKOUMAKIS, E.N., et al., Radiation doses in common X ray examinations carried out in two dedicated paediatric hospitals, Radiat Prot Dosimetry 124 4 (2007) 348-52.

	Module 8: Patient Dose Audit
	Sub-module 8.3: Foetal dose estimation
Objective	To estimate the approximate dose to the conceptus/foetus from a diagnostic x ray examination and determination of consequent risk.
Prerequisites	Sub-module 1.2: Radiation biology & epidemiology Sub-module 7.1: Ionising radiation dosimetry and principles of measurement
Competencies Addressed	• An understanding of the radio sensitivity of the conceptus/foetus and possible effects as a function of gestational age. • The ability to estimate the approximate conceptus/foetal dose from reported radiological examination procedure information and phantom evaluation.
Core Knowledge	Note: The term "foetus" used below applies to any stage of pregnancy. (1) Effects of radiation on the foetus: ° Radio sensitivity of the foetus as a function of gestational age ° Possible effects of radiation as a function of gestational age and foetal dose ° Normal risks of pregnancy ° Location and size of the foetus as a function of gestational age (2) Foetal dosimetry: ° Manual calculation of estimated foetal dose from entrance skin dose using depth dose data ° Effect of foetal size on dose estimation ° Available software, advantages and limitations (3) Foetus protection: ° Methods of minimising foetus dose
Recommended Elements of Training	(1) Estimate foetal dose for case of irradiation of a pregnant patient for the following procedures: general radiography, fluoroscopy, interventional radiology and CT (2) Write a report for each of the above for the radiologist or patient's obstetrician (3) Write one further report using any modality, for the patient (4) Do not issue any reports in this area without clearance from the supervising medical physicist (5) Verify a foetal dose calculation with the use of measurement and a phantom
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp.

[2] OSEI, E.K., FAULKNER, K., Fetal doses from radiological examinations, Br J Radiol 72 860 (1999) 773-80.

[3] OSEI, E.K., FAULKNER, K., Fetal position and size data for dose estimation, Br J Radiol 72 856 (1999) 363-70.

[4] OSEI, E.K., DARKO, J.B., FAULKNER, K., KOTRE, C.J., Software for the estimation of foetal radiation dose to patients and staff in diagnostic radiology, J Radiol Prot 23 2 (2003) 183-94.

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	MODULE 9: IMAGE QUALITY ASSESSMENT
Objective	To understand the theory of image quality assessment and perform appropriate tests.
Expected Duration	10 to 15% of overall time
Sub-modules	(1) Assessment of image quality through objective tests (2) Assessment of image quality with phantoms (3) Assessment of image quality of clinical, patient images
Core Reading	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [3] DOWSETT, D.J., KENNY, P.A., JOHNSTON, R.E., The Physics of Diagnostic Imaging, 2nd edn, Hodder Arnold (2006). [4] HENDEE, W.R., RITENOUR, E.R., Medical imaging physics, John Wiley and Sons Ltd (2002). [5] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Medical Imaging - The Assessment of Image Quality, ICRU Rep. 54, Bethesda, MD (1996). http://www.icru.org/index.php?option=com_content&task=view&id=68 . [6] PETERS, T.M., WILLIAMS, J., (Eds), The Fourier Transform in Biomedical Engineering, Applied and Numerical Harmonic Analysis, (BENEDETTO, J.J. ed.), Birkhauser, Boston, (1998). [7] SPRAWLS, P., Physical Principles of Medical Imaging., 2nd edn, Aspen. (1993). http://www.sprawls.org/ppmi2/ . [8] WEBB, S., (Ed.) The Physics of Medical Imaging, Medical Science Series, (MOULD, R.F. ed.), Adam Hilger, Bristol, Philadelphia, (2003).
	Module 9: Image Quality Assessment
	Sub-module 9.1: Assessment of image quality through objective tests
Objective	To understand and apply the theory of image quality assessment through the use of objective (physical or parametric) tests.
Prerequisites	

Competencies Addressed	• An understanding of physical and mathematical techniques for quantifying and evaluating image quality. • The ability to assess image quality through physical tests for a range of image characteristics and imaging modalities.
Core Knowledge	(1) Fourier Analysis (2) Sampling theory, e.g., Nyquist-Shannon Sampling Theorem (3) Theory of image quality assessment: ° Signal, sensitivity, receptor response curves, dynamic range ° Contrast, contrast detail assessment, contrast-to-noise ratio (CNR) ° Noise, signal to noise ratio, NPS, ° NEQ, detective quantum efficiency ° Spatial resolution: ▪ Point and line spread function. ▪ Modulation transfer function (MTF) ▪ Limiting resolution ° Temporal resolution ° Distortion ° Artefacts
Recommended Elements of Training	(1) For each image quality quantity (see core knowledge image quality assessment): ° Select appropriate equipment, software, and measurement technique for assessing image quality, covering all relevant characteristics for at least one modality ° Determine image quality characteristics. ° For each modality: ° Understand the clinical modality specific requirements for image quality ° Use image quality characteristics to determine the effects of factors such as image processing and data compression on image quality ° Analyse results and compare with reference documents such as previous results or published standards for image quality. ° Make recommendations for image quality improvement (see module on Optimization)
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [3] DOWSETT, D.J., KENNY, P.A., JOHNSTON, R.E., The Physics of Diagnostic Imaging, 2nd edn, Hodder Arnold (2006).

	[4] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Medical Imaging - The Assessment of Image Quality, ICRU Rep. 54, Bethesda, MD (1996). http://www.icru.org/index.php?option=com_content&task=view&id=68 . [5] SPRAWLS, P., Physics and Technology of Medical Imaging http://www.sprawls.org/resources/ . [6] TAPIOVAARA, M., Objective measurement of image quality in fluoroscopic x ray equipment: Fluoroquality, (2003), http://www.stuk.fi/julkaisut/stuk-a/stuk-a196.pdf . [7] WEBB, S., (Ed.) The Physics of Medical Imaging, Medical Science Series, (MOULD, R.F. ed.), Adam Hilger, Bristol, Philadelphia, (2003). [8] TAPIOVAARA, M., Relationships between physical measurements and user evaluation of image quality in medical radiology – a review, STUK • säteilyturvakeskus Strålsäkerhetscentralen: Radiation and nuclear safety authority Rep. STUK-A219, Helsinki (2006). http://www.stuk.fi/julkaisut/stuk-a/stuk-a219.pdf.
	Module 9: Image Quality Assessment
	Sub-module 9.2: Assessment of image quality with phantoms
Objective	To acquire the knowledge and skills to be able to perform image quality evaluation using non-clinical, phantom images.
Prerequisites	Sub-module 9.1: Assessment of image quality through objective tests
Competencies Addressed	• An understanding of image quality phantoms and methodologies useful to assess image quality in various diagnostic radiology modalities. • The ability to use phantoms to assess image quality for various modalities in combination with both objective measures and psychophysical methods as appropriate.
Core Knowledge	(1) See Core Knowledge Sub-module 9.1 (2) Different image quality metrics (3) Various phantoms used to evaluate image quality, including the advantages and disadvantages of each modality (4) Psychophysical methods for comparing image quality, including Receiver operator characteristic (ROC) analysis, and features comparison
Recommended Elements of Training	(1) For each modality: ◦ Select a suitable phantom ◦ Make image quality evaluation of appropriate quantities – for example: ▪ Evaluate resolution and MTF

	▪ Measure, quantitatively, image noise, e.g., images noise as a function of dose for CT ▪ Measure contrast (e.g. CNR) ▪ Measure low contrast characteristics including low contrast resolution patterns, mesh resolution patterns, and contrast detail curves ° Analyse results and compare with reference documents such as previous results or published standards for image quality. For example: ▪ Carry out an ROC analysis or features comparison of images with different characteristics, e.g., CT scans of a phantom at different doses
Knowledge Sources	[1] BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLDT, E.M.J., BOONE, J.M., The Essential Physics of Medical Imaging, 2nd Ed edn, Williams and Wilkins. (2002). [2] DOWSETT, D.J., KENNY, P.A., JOHNSTON, R.E., The Physics of Diagnostic Imaging, 2nd edn, Hodder Arnold (2006). [3] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Medical Imaging - The Assessment of Image Quality, ICRU Rep. 54, Bethesda, MD (1996). http://www.icru.org/index.php?option=com_content&task=view&id=68 . [4] METZ, C., Catalog of available software, (2008), http://xray.bsd.uchicago.edu/cgi-bin/roc_software.cgi. [5] SPRAWLS, P., Physics and Technology of Medical Imaging http://www.sprawls.org/resources/. [6] DAINTY, J.C., SHAW, R., Image Science, principles, analysis and evaluation of photographic-type imaging processes, Academic Press, London (1974). [7] DORFMAN, D.D., BERBAUM, K.S., METZ, C.E., Receiver operating characteristic rating analysis. Generalization to the population of readers and patients with the jackknife method, Invest Radiol 27 9 (1992) 723-31. [8] DORFMAN, D.D., et al., Proper receiver operating characteristic analysis: the bigamma model, Acad Radiol 4 2 (1997) 138-49. [9] HILLIS, S.L., BERBAUM, K.S., Power estimation for the Dorfman-Berbaum-Metz method, Acad Radiol 11 11 (2004) 1260-73. [10] HILLIS, S.L., BERBAUM, K.S., Monte Carlo validation of the Dorfman-Berbaum-Metz method using normalized pseudovalues and less data-based model simplification, Acad Radiol 12 12 (2005) 1534-41. [11] HILLIS, S.L., OBUCHOWSKI, N.A., SCHARTZ, K.M., BERBAUM, K.S., A comparison of the Dorfman-Berbaum-Metz and Obuchowski-Rockette methods for receiver operating characteristic (ROC) data, Stat Med 24 10 (2005) 1579-607. [12] PETERS, T.M., WILLIAMS, J., (Eds), The Fourier Transform in Biomedical Engineering, Applied and Numerical Harmonic Analysis, (BENEDETTO, J.J. ed.), Birkhauser, Boston, (1998).

	[13] SCHUELER, B.A., GRAY, J.E., GISVOLD, J.J., A comparison of mammography screen-film combinations, Radiology 184 3 (1992) 629-34. [14] WEBB, S., (Ed.) The Physics of Medical Imaging, Medical Science Series, (MOULD, R.F. ed.), Adam Hilger, Bristol, Philadelphia, (2003). [15] TAPIOVAARA, M., Relationships between physical measurements and user evaluation of image quality in medical radiology – a review, STUK • säteilyturvakeskus Strålsäkerhetscentralen: Radiation and nuclear safety authority Rep. STUK-A219, Helsinki (2006). http://www.stuk.fi/julkaisut/stuk-a/stuk-a219.pdf.
	Module 9: Image Quality Assessment
	Sub-module 9.3: Assessment of image quality of clinical patient images
Objective	To acquire the knowledge and skills to be able to perform image quality evaluation in the clinical setting.
Prerequisites	Sub-module 9.1: Assessment of image quality through objective tests Sub-module 9.2: Assessment of image quality with phantoms
Competencies addressed	• An understanding of statistical methodologies that can be used to determine image quality from clinical images. • The ability to carry out an evaluation of image quality for a procedure using clinical images and a specified experimental design.
Core Knowledge	(1) See Core Knowledge Sub-modules 9.1 and 9.2 (2) Statistics of experimentation including sample size determination, experimental design, parametric and non-parametric statistical tests for significance (3) The use of a difference design to reduce the degrees of freedom on an image quality evaluation experiment (4) Understanding of medical images and associated terminology (5) Familiarity with standardised quality criteria for different radiological examinations
Recommended Elements of Training	(1) In conjunction with a radiologist design a study to evaluate image quality of a procedure using well defined quality criteria (2) Determine if ethical approval is needed (3) Determine the image sample size and the number of image readers needed for a significance result (4) Record the experimental method including the image reading conditions (5) Analyse results and determine the statistical significance.

Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] EUROPEAN COMMISSION, European Guidelines on Quality Criteria for Computed Tomography, European Commission Rep. EUR 16262 EN, Luxembourg (1998). http://www.drs.dk/guidelines/ct/quality/mainindex.htm (last accessed August 2008). [3] NOVELLINE, R.A., Squire's Fundamentals of Radiology, Harvard University Press (2004). $92.50, used from $60 at www.amazon.com . [4] Dorland's Medical Dictionary, http://www.dorlands.com/wsearch.jsp . [5] BUTLER, P., MITCHELL, A., ELLIS, H., (Eds), Applied Radiological Anatomy for Medical Students, Cambridge University Park Press, Cambridge, UK, (2007). [6] METZ, C., Catalog of available software, (2008), http://xray.bsd.uchicago.edu/cgi-bin/roc_software.cgi . [7] DORFMAN, D.D., BERBAUM, K.S., METZ, C.E., Receiver operating characteristic rating analysis. Generalization to the population of readers and patients with the jackknife method, Invest Radiol 27 9 (1992) 723-31. [8] DORFMAN, D.D., et al., Proper receiver operating characteristic analysis: the bigamma model, Acad Radiol 4 2 (1997) 138-49. [9] HILLIS, S.L., BERBAUM, K.S., Power estimation for the Dorfman-Berbaum-Metz method, Acad Radiol 11 11 (2004) 1260-73. [10] HILLIS, S.L., BERBAUM, K.S., Monte Carlo validation of the Dorfman-Berbaum-Metz method using normalized pseudovalues and less data-based model simplification, Acad Radiol 12 12 (2005) 1534-41. [11] HILLIS, S.L., OBUCHOWSKI, N.A., SCHARTZ, K.M., BERBAUM, K.S., A comparison of the Dorfman-Berbaum-Metz and Obuchowski-Rockette methods for receiver operating characteristic (ROC) data, Stat Med 24 10 (2005) 1579-607. [12] SCHUELER, B.A., GRAY, J.E., GISVOLD, J.J., A comparison of mammography screen-film combinations, Radiology 184 3 (1992) 629-34. [13] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Medical Imaging - The Assessment of Image Quality, ICRU Rep. 54, Bethesda, MD (1996). http://www.icru.org/index.php?option=com_content&task=view&id=68 . [14] TAPIOVAARA, M., Relationships between physical measurements and user evaluation of image quality in medical radiology – a review, STUK • säteilyturvakeskus Strålsäkerhetscentralen: Radiation and nuclear safety authority Rep. STUK-A219, Helsinki (2006). http://www.stuk.fi/julkaisut/stuk-a/stuk-a219.pdf.

	MODULE 10: OPTIMIZATION
Objective	To provide residents with the necessary knowledge and skill to undertake optimization on the full range of radiology imaging procedures.
Expected Duration	10 to 15% of overall time
Sub-Modules	(1) Radiation risk to the patient in diagnostic radiology (2) Optimization Process
Core Reading	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [1] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the ICRP, ICRP Publication 103, Annals of the ICRP Volume 37/2-4, Elsevier (2008). [2] MARTIN, C.J., SUTTON, D.G., Practical Radiation Protection in Healthcare, Oxford University Press, Oxford (2002).
	Module 10: Optimization
	Sub-module 10.1: Radiation risk to the patient in diagnostic radiology
Objective	To be able to assess radiation risk to the patient in diagnostic radiology.
Prerequisites	Sub-module 1.2: Radiation biology and epidemiology Module 7: Dosimetry, instrumentation and calibration Sub-module 8.1: Dose audit
Competencies Addressed	• An understanding of radiation risk and the benefits from diagnostic radiology procedures. • The ability to provide advice on risk to staff and patients and on strategies for radiation risk reduction.
Core Knowledge	(1) The concept of risks versus benefit. (2) Relative and absolute risk (3) The concept of justification (4) Stochastic Risk: ° Concept of effective dose and the link to stochastic risk ° Uncertainties in stochastic risk estimation ° Limited applicability of effective dose to diagnostic exposures ° Determination of effective dose:

	▪ ICRP and Monte Carlo methods ▪ How radiographic projection affects effective dose (e.g. difference between AP and PA chest projection) ° Age related relationship between effective dose and lifetime stochastic risk. ° Typical doses and risks from a range of medical exposures. ° Contribution to population collective dose from medical exposures (5) BEIR risk estimates: ° Concept of Lifetime Attributable Risk (LAR) for solid cancer incidence ° Uncertainties in LAR (6) Risk from Deterministic Effects: ° Deterministic effects observed in radiological exposures ° Threshold for deterministic effects ° Examinations which might result in the production of deterministic effects in patients (7) Special considerations for patients who are or who might be pregnant (8) Special considerations for paediatric patients (9) Special considerations for research exposures
Recommended Elements of Training	(1) Calculate effective dose and associated risk for a range of radiological examinations using a variety of methods. (2) Calculate the risk of cancer induction using BEIR methods (3) Communicate the risk resulting from a range of radiological procedures to other professionals through written reports. (4) Advise to pregnant patients following irradiation of the foetus (5) Advise colleagues on technique and procedures required to reduce the risk of deterministic effects occurring in interventional and cardiovascular procedures. (6) Advise on the suitability of research protocols (7) Develop a method to track patient doses and alert staff to potential high doses which might result in deterministic effects.
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the ICRP, ICRP Publication 103, Annals of the ICRP Volume 37/2-4, Elsevier (2008). [3] MARTIN, C.J., SUTTON, D.G., Practical Radiation Protection in Healthcare, Oxford University Press, Oxford (2002). [4] STUK RADIATION AND NUCLEAR SAFETY AUTHORITY, PCXMC - A PC-based Monte Carlo program for calculating patient doses in medical x ray examinations, http://www.stuk.fi/sateilyn_kaytto/ohjelmat/PCXMC/en_GB/pcxmc/ [5] NATIONAL RESEARCH COUNCIL. Health Risks from Exposure to Low Levels of Ionizing Radiation, - BEIR VII Phase II. Washington: The National Academies Press; 2006 ISBN 978-0-309-09156-5

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	Module 10: Optimization
	Sub-module 10.2: Optimization process
Objective	To balance the required image quality needed for effective diagnosis with detrimental factors; primarily patient dose, but also including in some cases, RF heating, examination time, or other patient related factors.
Prerequisites	Sub-module 1.3: Patient related experience Sub-module 4.2: Communication Module 8: Patient dose audit. Module 9: Image quality assessment
Competencies Addressed	• An understanding of the factors that affect both image quality and patient radiation dose. • The ability to take the lead amongst radiological colleagues in the optimization process of radiological examinations including the giving advise on practical strategies for improving image quality and dose reduction.
Core Knowledge	(1) Controllable factors affecting image quality in plain radiography: ° Radiographic protocol (kVp, mAs, projection etc.) ° Scatter rejection ° Collimation ° Image receptor quantum statistics, receptor speed ° Image resolution ° Optimal display and reading conditions (2) Controllable factors affecting patient dose in plain radiography: ° Radiographic protocol (kVp, mAs, projection etc.) ° Patient size variation usually requires changes in examination protocol ° Added filtration including effect of high z filtration ° Collimation ° Absorption of the beam after the patient, including the grid ° Image receptor sensitivity ° Geometric Factors ° Automatic exposure set up (3) Controllable factors affecting image quality in fluoroscopy: ° Automatic exposure control set up

	° Radiographic protocol (kVp, mA for manual operation, projection, field size or image magnification) ° Collimation, including virtual collimation ° Geometric Factors ° Scatter rejection ° Image receptor quantum statistics, receptor sensitivity ° Image resolution ° Optimal display and reading conditions (4) Controllable factors affecting patient dose in fluoroscopy: ° Beam on, including pulsed fluoroscopy ° Automatic exposure control set up ° Radiographic protocol (kVp, mA for manual operation, projection, field size or image magnification) ° Patient size variation usually requires changes in examination protocol ° Added filtration including effect of high z filtration ° Collimation, including virtual collimation ° Absorption of the beam after the patient, including the grid ° Image receptor sensitivity ° Geometric Factors ° Last image hold (5) Controllable factors affecting image quality in CT: ° Radiographic protocol: ▪ kVp, mAs for manual operation ▪ Pitch ▪ Reconstruction filter ▪ Scan Length and number of scan series ° Automatic exposure control (correct dose modulation techniques) ° Collimation selection including MDCT considerations ° Scan mode (axial, spiral or MDCT) ° Image receptor quantum statistics, image processing algorithms ° Image resolution ° Optimal display and reading conditions (6) Controllable factors affecting patient dose in CT: ° Radiographic protocol: ▪ kVp, mAs for manual operation ▪ Pitch ▪ Reconstruction filter ▪ Scan Length and number of scan series ° Patient size variation usually requires changes in examination protocol ° Automatic exposure control (correct dose modulation techniques) ° Collimation selection including MDCT considerations including overscaning and over beaming ° Scan mode (axial, spiral or MDCT)

Recommended Elements of Training	For each modality: (1) Initial preparation: ° Establish agreement for an optimization process with the radiology department, including a schedule of achievable targets. ° Determine the priority for examinations to be optimised for a particular modality in conjunction with clinicians and radiographers, considering such factors as examination risk and frequency ° Check QA status of equipment used for procedure ° Establish clinically appropriate image quality requirements in collaboration with clinicians (2) Dose & Image Quality Assessment: ° Determine patient doses (preferably from a patient audit or may be phantom based) ° Determine Image Quality. (3) Review of current status of procedure: ° Compare examination dose with appropriate benchmarks if available. ° Compare examination image quality with appropriate benchmarks if available ° In conjunction with the radiologist and radiographer review examination related data including: ▪ Radiographic protocol ▪ Equipment configuration ▪ Image reading conditions ° Investigate the effect on image quality and dose of varying the parameters for the above list. (4) Intervention: ° Recommend changes to the radiographic protocol, equipment configuration and or viewing conditions, based on the review of the procedure (above). (5) Verify effect of optimization process: ° After an agreed period of clinical introduction repeat the dose and image quality analysis to determine the effectiveness of the optimization intervention ° Record the results of the optimization procedure in a way that is accessible to all interested parties, particularly the radiographers and clinicians
Knowledge Sources	[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook on the Physics of Diagnostic Radiology, IAEA, Vienna (in preparation). http://www-naweb.iaea.org/nahu/dmrp/publication.asp. [2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Managing patient dose in digital radiology, ICRP Publication 93, Elsevier Amsterdam (2004). [3] NAGEL, H.D., (Ed.) Radiation Exposure in Computed Tomography: Fundamentals, Influencing Parameters, Dose Assessment, Optimisation, Scanner Data, Terminology, 4th edn., CTB Publications, Hamburg, (2002).

APPENDIX V: COMPETENCY ASSESSMENT

COMPETENCY ASSESSMENT OF

RESIDENTS ENROLLED IN THE

CLINICAL TRAINING PROGRAMME FOR

DIAGNOSTIC RADIOLOGY MEDICAL PHYSICISTS

Resident's name: _____

Clinical Supervisor's name: _____

(Note: Refer to the Appendix IV *Clinical Training Guide* for recommended items of training in each sub-module)

V.1 EXPLANATION OF THE ASSESSMENT PROCESS

The assessment process involves assessment of both knowledge and practical competencies associated with sub modules. Where there is more than one knowledge or one practical competency per sub module, the competency is labelled a, b, etc., so for example sub module 5.10 has two knowledge competencies, a & b, and two practical competencies, a & b.

For assessment of a Resident's knowledge there are two levels to consider. Assessment at level 2 indicates a basic understanding of the core knowledge while level 1 is the level of knowledge expected of a practicing DRMP.

For assessment of practical competencies there are 3 levels to be considered. The levels have descriptive indicators to assist in maintaining a consistent approach to assessment of competency. The descriptive indicator for a level needs to be considered in relation to the indicator for lower levels of competency. For example, when considering assessment at level 1 also ensure that the Resident has demonstrated the levels of competency indicated by levels 3 and 2.

A Resident may progress more than one level at the time of an assessment. Likewise they might in the first assessment of their competency in a particular sub-module be assessed at any level. It is also possible that they might regress from one assessment to the next. i.e. be assessed at level 2 and then at a later date at level 3. A hypothetical assessment of a sub-module is provided below.

As demonstrated by the criteria, competency assessment is not just reviewing technical ability but also professional attributes, such as safe practice and communication skills, expected of a qualified medical physicist specializing in diagnostic radiology medical physics.

IMPORTANT NOTES:

This document should be retained by the Resident for the duration of his/her clinical training programme. It may be reviewed by the National Programme Coordinator or other responsible person at any time. It must also be made available to the National Programme Coordinator just prior to the final oral examination.

It is recommended that a copy is made of this document at regular intervals and that this copy is retained by the Clinical Supervisor. In the event that the Resident loses their copy then the Clinical Supervisor's copy provides a reasonably up to date record of competency assessment.

V.2 ASSESSMENT CRITERIA

The assessment process has two principal objectives:

(1) To determine whether the resident has the knowledge, experience and skills to satisfactorily complete aspects of diagnostic radiology medical physics work that are commonly encountered in clinical practice.

(2) To satisfy the relevant professional body and/or the National Responsible Authority[10] that the resident can work competently and safely as a clinically qualified diagnostic radiology medical physicist.

This requires an assessment of the abilities that the resident exhibits during training as evidenced by the processes described in this document. In this assessment process the criteria used include the following competency indicators:-

- A careful, logical and thorough approach to work undertaken;

[10] Appendix III. ("Implementation Guide", Section 1.1.1 ("Essential Requirements for Successful Implementation of the Clinical Training Guide", "Programme Management", "National").

- Self-confidence together with recognition of the limitations of one's knowledge and expertise;
- A broad understanding of tasks or topics;
- Adequate theoretical knowledge relating to diagnostic radiology medical physics;
- Ability to identify and define a problem then formulate strategies to address the problem;
- Practical skills in carrying out tasks and completing them in a timely manner;
- A clear understanding of the various procedures involved in carrying out tasks undertaken during their training and in their examinations;
- Knowledge of relevant standards and in most cases the type of results to be expected in relation to the tasks undertaken;
- Ability to correctly interpret data, including novel or non-standard data;
- An appreciation of the significance of results obtained in a task and their applicability within a radiology department;
- Ability to critically evaluate processes and outcomes, and make value judgements for particular situations;
- Ability to communicate scientific information clearly, logically and accurately, including explaining work as it is undertaken;
- Taking responsibility for work undertaken.

V.3 AN EXAMPLE OF THE ASSESSMENT MATRIX OF A SUB-MODULE

Sub module 5.1 Screen-film systems

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of processes of image formation involving x rays and screen film systems.	Demonstrates a **basic understanding** of the principles of image formation involving x ray and screen film systems.	Demonstrates a **good understanding** of the principles of image formation involving x ray and screen film systems.
Date Achieved	3 March 2010	6 June 2010
Supervisor's Initials	*MeL*	*MeL*

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out performance testing on x ray film, x ray film cassettes and x ray film display devices:	Is capable of undertaking performance testing of x ray film, x ray film cassettes and x ray film display devices: **Requires significant assistance.**	**Requires only limited assistance** with appropriate performance testing of x ray film, x ray film cassettes and x ray film display devices	Is capable of **independently performance testing** x ray film, x ray film cassettes and x ray film display devices **to an acceptable level.**
Date Achieved	6 June 2010		19 Dec 2010
Supervisor's Initials	*MeL*		*MeL*

Date	**Supervisor's comments**
3 March 2010	Needs to learn more detail of the principles involved.
6 June 2010	Has made good progress in acquiring this competency.
19 Dec 2010	I would be happy to accept this Resident's results of performance testing of x ray film, x ray film cassettes and x ray film display devices

V.4 ASSESSMENT SUMMARY

MODULE 1: CLINICAL AWARENESS

Sub-module	Level of Competency Achieved	
	2	**1**
1.1 Radiologic anatomy and physiology		
1.2 Radiobiology and epidemiology		
1.3 Patient-related experiences in ° Radiology ° RT ° NM ° Other		

MODULE 2: RADIATION PROTECTION AND SAFETY

	Level of Competency Achieved					
	Knowledge			**Practical skills**		
	2	**1**		**3**	**2**	**1**
2.1 Personnel dosimetry						
2.2 Radiation hazard assessment						
2.3 Radiation protection and safety review	a) b)					
2.4 Dose reduction – staff and public						
2.5 Unintended and accidental exposure in diagnostic radiology						
2.6 Shielding						
2.7 Safety in MRI imaging						

MODULE 3: RESEARCH, DEVELOPMENT AND TEACHING

	Level of Competency Achieved					
	Knowledge			**Practical skills**		
	2	**1**		**3**	**2**	**1**
3.1 Research and development						
3.2. Teaching						

MODULE 4: PROFESSIONALISM AND COMMUNICATION

	Level of Competency Achieved				
	Knowledge			Practical skills	
	2	1	3	2	1
4.1 Professional awareness					
4.2 Communication					
4.3 Information technology					
4.4 Clinical audit					

MODULE 5: PERFORMANCE TESTING OF IMAGING EQUIPMENT

	Level of Competency Achieved				
	Knowledge			Practical skills	
	2	1	3	2	1
5.1 Screen-film systems					
5.2 Film processing and darkroom					
5.3 General radiography					
5.4 Conventional and digital fluoroscopy			(a) (b)		
5.5 Computed radiography and digital radiography					
5.6 Automatic exposure control devices			(a) (b)		
5.7 Mammography			(a) b) (c)		
5.8 Computed tomography			(a) (b) (c)		

5.9 Magnetic resonance imaging	(a) (b)					
5.10 Ultrasound	(a) (b)			(a) (b)		
5.11 Display and printing devices	(a) (b)					
5.12 Dental radiography				(a) (b) (c)		
5.13 Dual-energy X ray absorptometry (DXA)	(a) (b)					

MODULE 6: TECHNOLOGY MANAGEMENT

	Level of Competency Achieved					
	Knowledge			**Practical skills**		
	2	**1**		**3**	**2**	**1**
6.1 Quality management systems in radiology						
6.2 Life cycle of imaging equipment						
6.3 Acceptance and commissioning of imaging equipment						
6.4 Management of routine QC testing of imaging equipment						
6.5 Imaging informatics	(a) (b)					
6.6 Department design						

MODULE 7: DOSIMETRY, INSTRUMENTATION AND CALIBRATION

	Level of Competency Achieved				
	Knowledge		Practical skills		
	2	1	3	2	1
7.1 Ionising radiation dosimetry and principles of measurement			(a) (b)		
7.2 Non-ionising radiation quantities and principles of measurement					
7.3 Radiological test equipment, measurement, and practice					
7.4 Dosimetry system calibration			(a) (b)		

MODULE 8: PATIENT DOSE AUDIT

	Level of Competency Achieved				
	Knowledge		Practical skills		
	2	1	3	2	1
8.1 Dose audit					
8.1 Paediatric dosimetry					
8.3 Foetal dose estimation					

MODULE 9: IMAGE QUALITY ASSESSMENT

	Level of Competency Achieved				
	Knowledge			Practical skills	
	2	1	3	2	1
9.1 Assessment of image quality through objective tests					
9.2 Assessment of image quality with phantoms					
9.3 Assessment of image quality of clinical, patient images					

MODULE 10: OPTIMIZATION

	Level of Competency Achieved				
	Knowledge			Practical skills	
	2	1	3	2	1
10.1 Radiation risk to the patient in diagnostic radiology					
10.2 Optimization process					

_____ END OF ASSESMMENT SUMMARY_____

MODULE 1: CLINICAL AWARENESS

1.1. Radiologic Anatomy and Physiology

1.2. Radiobiology and Epidemiology

1.3. Patient-Related Experience

Sub-module 1.1: Radiologic anatomy and physiology

Knowledge	**Level of Competency Achieved**	
	2	**1**
An understanding of radiological anatomy and physiology as seen on medical images	Demonstrates **a basic understanding** of radiological anatomy and physiology as seen on medical images. **Not yet capable of independent input** to a discussion of the important features of these images with radiologists.	Demonstrates **a good understanding** of radiological anatomy and physiology as seen on medical images **and is capable of independently discussing** the important features with **radiologists**.
Date Achieved		
Supervisor Initials		

Date	**Supervisor comments**

Sub-module 1.2: Radiation biology and epidemiology

Knowledge	**Level of Competency Achieved**	
	2	**1**
An understanding of the basic principles of radiation biology and epidemiology	Demonstrates a **basic understanding** of **most aspects** of radiation biology and epidemiology of **relevance to medical imaging.**	Demonstrates a **good understanding** of **aspects** of radiation biology and epidemiology of **relevance to medical imaging.**
Date Achieved		
Supervisor Initials		

Date	**Supervisor comments**

Sub-module 1.3: Patient related experiences

Knowledge	**Level of Competency Achieved**	
	2	**1**
An understanding of the factors that effect patient care in the following departments: radiology, radiation oncology (RT), nuclear medicine (NM) and others.	Demonstrates a **basic understanding** of clinical activities and their relation to patient care. **Not yet capable of independent input** to a discussion of the important features of these clinical activities..	Demonstrates a **good understanding** of clinical activities and their relation to patient care **and is capable of independently discussing** the important features of these clinical activities.
Date Achieved - radiology		
Supervisor Initials		

Date Achieved – RT		
Supervisor Initials		

Date Achieved – NM		
Supervisor Initials		

Date Achieved - other		
Supervisor Initials		

Date	**Supervisor comments**

MODULE 2: RADIATION PROTECTION AND SAFETY

2.1. Personnel dosimetry

2.2. Radiation hazard assessment

2.3. Radiation protection and safety review

2.4. Dose reduction – staff and public

2.5. Unintended and accidental exposure in Diagnostic Radiology

2.6. Shielding

2.7. Safety in MRI imaging

Sub module 2.1: Personnel dosimetry

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the purpose, principles, and operation of a personnel dosimetry program	Demonstrates a **basic understanding** of **local legislative requirements** and the **theory, principles of operation, and limitations of a variety of personnel dosimeters**	Demonstrates a **good understanding** of the local legislative requirements and the theory, principles of operation, and limitations of **most personnel dosimeters of relevance to medical imaging**
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to provide a personnel dosimetry service to one or more radiology departments at a local level.	Is capable of performing **most of the functions required** to provide a **personnel dosimeter service at a local level. Requires supervision.**	Is capable of performing **all** of the functions required to provide a personnel dosimeter service at a local level. **Requires only limited assistance.**	Is capable of **independently** providing a personnel dosimetry service to one or more radiology departments at a local level.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 2.2: Radiation hazard assessment

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the principles of hazard assessment and engineering and procedural controls to reduce hazards to a level that are as low as reasonably achievable and comply with regulatory requirements.	Demonstrates a **basic understanding** of **regulatory requirements** and the **principles of hazard assessment and control mechanisms. Requires assistance** with understanding of the **more difficult aspects.**	Demonstrates a **good understanding** of all aspects of hazard assessment and control mechanisms and is able to instruct others.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to undertake and act on a hazard assessment	Is capable of performing **an assessment of hazards. Requires assistance** to ensure **all aspects are included** and that the **all risks are identified.**	Is capable of performing a hazard assessment, evaluating risks identified and acting to control the hazards. **Requires only limited assistance.**	Is capable of **independently performing** a hazard assessment, evaluating risks identified and acting to control the hazards.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 2.3: Radiation protection and safety review

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
(a) An understanding of factors underpinning radiation protection and safety review	Demonstrates a **basic understanding** of the principles of radiation protection and safety review. **Requires assistance** with more difficult concepts.	Demonstrates a **good understanding** of the principles of radiation protection and safety review.
Date Achieved		
Supervisor's Initials		
(b) An understanding of the need to keep doses as low as reasonably achievable and to ensure regulatory compliance.	Demonstrates a **basic understanding** of the need to keep **doses as low as reasonably achievable** and to **ensure regulatory compliance.**	Demonstrates a **good understanding** of the need to keep doses as low as reasonably achievable and to ensure regulatory compliance.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to perform a radiation protection and safety review and to implement remedial measures where necessary.	Is capable of performing a radiation protection and safety review **under supervision. Needs assistance** to identify and implement remedial measures	Is capable of performing a radiation protection and safety review **with only limited supervision.** Able to identify and implement **most** remedial measures	Is capable of **independently** performing a radiation protection and safety review and is able to **independently** identify and implement remedial measures.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 2.4: Dose reduction – staff and public

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the factors that affect radiation dose to staff and members of the public including the inter-relationship with patient dose.	Demonstrates a **basic understanding** of factors that affect radiation dose to staff and members of the public	Demonstrates a **good understanding** of factors that affect radiation dose to staff and members of the public and **the inter-relationship with patient dose.**
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to advise on practical aspects that will result in lower doses to staff and members of the public	Possesses only a **limited ability** to advise others on correct practical aspects to reduce dose.	Is capable of advising others on practical aspects to reduce dose. Requires **supervision** to ensure that **no incorrect advice** is provided.	Is capable of **independently advising** others on practical aspects to reduce dose. **The advice provided is at all times correct and appropriate.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 2.5: Unintended and accidental exposure in diagnostic radiology

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of what constitutes an unintended or accidental exposure in the radiology department, the implications and required response.	Demonstrates a **basic understanding** of what constitutes an unintended or accidental exposure, the roles and responsibilities of personnel and the implications and required response.	Demonstrates a **good understanding** of what constitutes an unintended or accidental exposure, the roles and responsibilities of personnel and the implications and required response.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to respond to an unintended or accidental exposure occurring in a radiology department	Capable of **assisting with the response** to an unintended or accidental exposure in a radiology department	Requires **only limited assistance** in responding to an unintended or accidental exposure in a radiology department	Capable of **independently responding** to an unintended or accidental exposure in a radiology department
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 2.6: Shielding

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the principles and requirements of shielding design at diagnostic x ray energies.	Demonstrates a **basic understanding** of shielding design at diagnostic x ray energies.	Demonstrates a **good understanding** of shielding design at diagnostic x ray energies.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to design satisfactory radiation shielding for all types of diagnostic radiology equipment	Is capable of designing radiation shielding for **simple types** of diagnostic radiology equipment (e.g. dental). R**equires significant assistance** to ensure the accuracy of the design.	Is capable of designing radiation shielding. for **most types** of diagnostic radiology equipment (e.g. general and fluoroscopy). R**equires only limited assistance** to ensure the accuracy of the design.	Is capable of **independently designing radiation** shielding **for all types** of diagnostic radiology equipment (including CT and angiography) **to an acceptable level.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 2.7: Safety in MRI imaging

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the safety issues and requirements in MRI imaging	Possesses a **basic understanding** of safety issues related to MRI imaging.	Possesses a **good understanding** of safety issues related to MRI imaging. Is capable of **instructing** others on the safety of MRI imaging.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to perform the necessary safety assessments and measurements	Capable of performing safety assessment and measurements for MRI imaging **under supervision.**	Capable of performing safety assessment and measurements for MIR imaging safety. **Work requires checking** to ensure error free results.	Capable of **independently** performing safety assessment and measurements for safety in MRI imaging to an **acceptable standard.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 3: RESEARCH, DEVELOPMENT AND TEACHING

3.1. Research and Development

3.2. Teaching

Sub module 3.1: Research and development

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of processes of scientific research including the role of ethics review, statistical analysis, and the publication process	Demonstrates a **basic understanding** of the various aspects of scientific research.	Demonstrates a **good appreciation** of the various aspects of scientific research.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out research and development in diagnostic medical imaging in cooperation with diagnostic radiologists, other diagnostic medical physicists, and other professionals.	Is capable of **contributing** to a R&D project. **Requires significant guidance**.	Able to contribute to a R&D project **without direct supervision**.	Demonstrates a good level of ability for **independent research.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 3.2: Teaching

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the general principles of effective teaching	Demonstrates a **basic understanding** of the requirements for effective teaching.	Demonstrates a **good understanding** of the requirements for effective teaching.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to teach principles and methods of medical physics.	Demonstrates a **limited ability to prepare and deliver short (1-2 hour) courses. Requires guidance.**	Demonstrates a **good ability to prepare and deliver** appropriate short courses **without significant guidance.**	Demonstrates the ability to **decide on content, prepare and deliver a comprehensive course** on principles and methods of medical physics.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 4: PROFESSIONALISM AND COMMUNICATION

4.1. Professional awareness

4.2. Communication

4.3. Information Technology

4.4. Clinical audit

Sub module 4.1: Professional awareness

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
Demonstrated understanding of professional issues .	Demonstrates only a **limited awareness** of relevant professional issues.	Demonstrates a **good awareness** of **most** relevant professional issues.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Contribution to professional body activities	**Occasionally participates** in professional body activities.	**Frequently participates** in professional body activities.	**Contributes** to professional body activities.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 4.2: Communication

Competency	**Level of Competency Achieved**	
	2	**1**
Demonstrate a high level of oral and written communication and interpretation skills.	Generally demonstrates **clear and concise** expression orally and in written forms.	**Consistently demonstrates clear and concise expression** orally and in written forms. **Capable of presenting a scientific seminar** and **preparing a scientific manuscript**.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to communicate with clinicians and apply physical principles to clinical problems	Able to communicate with clinicians at a **basic level.**	Possesses a **good ability** to communicate with clinicians **and to apply (explain)** physical principles applied to clinical problems**. Occasionally requires assistance with these explanations.**	Is capable of **independently communicating** with clinicians in **relation to the physical principles of clinical problems.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 4.3: Information technology

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of basic information technology	Demonstrates a **basic understanding** of electronic communication standards, professional IT issues, storage media, data backup and data bases	Demonstrates a **good understanding** of electronic communication standards, professional IT issues, storage media, data backup and data bases
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Basic skills in information technology.	Demonstrates a **good capability** with routine use of personal computers. **Has limited ability with more advanced aspects** of IT such as electronic communication standards.	Demonstrates an **advanced level** of capability with personal computers and has a **good ability with more advanced aspects** of IT	Demonstrates a high level of capability in the **more advanced aspects of IT** and is able **to identify many of the professional issues related to electronic media, such as licences, levels of access and confidentiality.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 4.4: Clinical audit

Knowledge Base	Level of Competency Achieved	
	2	**1**
Understand the physics aspects of a clinical audit	Demonstrates a **limited understanding** of the physics aspects of a clinical audit.	Demonstrates a **good understanding** of the physics aspects of a clinical audit.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	**2**	**1**
The ability to participate in the physics aspects of a clinical audit	Is capable of **contributing** to a clinical audit. **Requires significant guidance**.	Able to contribute to a clinical audit **without direct supervision**.	Able to **independently conduct** the physics aspects of a clinical audit to an acceptable level.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

MODULE 5: PERFORMANCE TESTING OF IMAGING EQUIPMENT

5.1. Screen-film Systems

5.2. Film Processing and Darkroom

5.3. General Radiography

5.4. Conventional and Digital Fluoroscopy

5.5. Computed Radiography and Digital Radiography

5.6. Automatic Exposure Control Devices

5.7. Mammography

5.8. Computed Tomography

5.9. Magnetic Resonance Imaging

5.10. Ultrasound

5.11. Display and Printing Devices

5.12. Dental Radiography

5.13. Dual-energy X ray Absorptometry (DXA)

Sub module 5.1: Screen-film systems

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of processes of image formation involving x rays and screen film systems.	Demonstrates a **basic understanding** of the principles of image formation involving x ray and screen film systems.	Demonstrates a **good understanding** of the principles of image formation involving x ray and screen film systems.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out performance testing on x ray film, x ray film cassettes and x ray film display devices:	Is capable of undertaking performance testing of x ray film, x ray film cassettes and x ray film display devices: **Requires significant assistance.**	**Requires only limited assistance** with appropriate performance testing of x ray film, x ray film cassettes and x ray film display devices	Is capable of **independently performance testing** x ray film, x ray film cassettes and x ray film display devices **to an acceptable level.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.2: Film processing and darkroom

Competency	**Level of Competency Achieved**	
	2	**1**
An understanding of processes and function of film processing and associated equipment	Demonstrates a **basic understanding** of the processes and function of film processing and associated equipment	Demonstrates a **good understanding** of the processes and function of film processing and associated equipment
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out performance tests for X ray film processors and darkrooms	Is capable of undertaking performance testing of x ray film processors and dark rooms, **Requires significant assistance.**	**Requires only limited assistance** with appropriate performance testing of x ray film processors and dark rooms,	Is capable of **independently performance testing** x ray film processors and dark rooms **to an acceptable level.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.3: General radiography

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the operation of x ray equipment and the factors that affect the radiographic output	Demonstrates a **basic understanding** of the operation of x ray equipment and the factors that affect the radiographic output	Demonstrates a **good understanding** of the operation of x ray equipment and the factors that affect the radiographic output
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out performance testing of general radiographic equipment.	Is capable of undertaking performance testing of general radiographic equipment. **Requires significant assistance.**	**Requires only limited assistance** with appropriate performance testing of general radiographic equipment.	Is capable of **independently performance testing** general radiographic equipment **to an acceptable level.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.4: Conventional and digital fluoroscopy

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the theory of operation of fluoroscopy and angiography equipment	Demonstrates a **basic understanding** of the theory of operation of fluoroscopy and angiography equipment	Demonstrates a **good understanding** of the theory of operation of fluoroscopy and angiography equipment
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
(a) The ability to carry out performance testing of simple fluoroscopic equipment.	Is capable of undertaking some performance testing of **simple fluoroscopic equipment. Requires assistance**	Is capable of undertaking performance testing of **simple** fluoroscopic equipment. **Requires assistance with the more complex tests.**	Is capable of **independently** undertaking performance testing of **simple** fluoroscopic equipment to an **acceptable level.**
Date Achieved			
Supervisor's Initials			
(b) The ability to carry out performance testing of complex fluoroscopic equipment including angiographic equipment	Is capable of undertaking some performance testing of **complex fluoroscopic equipment. Requires assistance**	Is capable of undertaking performance testing of **complex** fluoroscopic equipment. **Requires assistance with the more complex tests.**	Is capable of **independently** undertaking performance testing of **complex** fluoroscopic equipment to an **acceptable level.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.5: Computed radiography and digital radiography

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the principles of CR and DR radiographic imaging systems	Demonstrates a **basic understanding** of the principles of CR and DR radiographic systems	Demonstrates a **good understanding** of the principles of CR and DR radiographic systems
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out performance testing of CR and DR radiographic imaging systems.	Is capable of undertaking performance testing of CR and DR radiographic imaging systems. **Requires significant assistance.**	**Requires only limited assistance** with appropriate performance testing of CR and DR radiographic imaging systems.	Is capable of **independently performance testing of** CR and DR radiographic imaging systems **to an acceptable level.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.6: Automatic exposure control devices

Competency	**Level of Competency Achieved**	
	2	**1**
An understanding of the theory of operation of Automatic Exposure Control devices, and the differences between the testing requirements for conventional and digital image receptors.	Demonstrates a **basic understanding of** the theory of operation of Automatic Exposure Control devices, **and** the differences between the testing requirements for conventional and digital image receptors.	Demonstrates a **good understanding of** the theory of operation of Automatic Exposure Control devices, and the differences between the testing requirements for conventional and digital image receptors.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
(a) The ability to carry out performance testing of AEC devices for conventional radiography	Is capable of undertaking AEC performance testing for **conventional radiographic equipment. Requires assistance with some aspects**	Is capable of **independently** undertaking AEC performance testing for **conventional radiographic equipment under supervision.**	Is capable of **independently** undertaking AEC performance testing for conventional radiographic equipment
Date Achieved			
Supervisor's Initials			
(b) The ability to carry out performance testing of AEC devices for digital radiography	Is capable of undertaking AEC performance testing for **digital radiographic equipment. Requires assistance with some aspects**	Is capable of **independently** undertaking AEC performance testing for **digital radiographic equipment under supervision.**	Is capable of **independently** undertaking AEC performance testing for digital radiographic equipment
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub module 5.7: Mammography

Knowledge Base	Level of Competency Achieved	
	2	**1**
An understanding of the theory of image formation and operation of X ray mammography equipment	Demonstrates a **basic understanding of** the theory of image formation and operation of X ray mammography equipment	Demonstrates a **good understanding of** the theory of image formation and operation of X ray mammography equipment
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	**2**	**1**
(a) The ability to carry out performance testing of screen-film mammography systems.	Is capable of undertaking performance testing of screen-film mammography systems. **Requires close supervision.**	Is capable of undertaking performance testing of screen-film mammography systems. **Requires only limited supervision.**	Is capable of **independently** undertaking performance testing of screen-film mammography systems **to an acceptable standard.**
Date Achieved			
Supervisor's Initials			
(b) The ability carry out performance testing of digital mammography systems	Is capable of undertaking performance testing of digital mammography systems. **Requires close supervision.**	Is capable of undertaking performance testing of digital mammography systems. **Requires only limited supervision.**	Is capable of **independently** undertaking performance testing of digital mammography systems **to an acceptable standard.**

Date Achieved			
Supervisor's Initials			
(c) The ability to carry out performance testing of biopsy mammography systems	Is capable of undertaking performance testing of biopsy mammography systems. **equires close supervision.**	Is capable of undertaking performance testing of biopsy mammography systems. **Requires only limited supervision.**	Is capable of **independently** undertaking performance testing of biopsy mammography systems **to an acceptable standard.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.8: Computed tomography

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the theory of operation of CT scanning equipment	Demonstrates a **basic understanding of** the theory of operation of CT scanning equipment	Demonstrates a **good understanding of** the theory of operation of CT scanning equipment
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
(a) The ability to carry out performance testing of axial CT systems.	Is capable of undertaking performance testing of axial CT systems. **Requires close supervision.**	Is capable of undertaking performance testing of axial CT systems. **Requires only limited supervision.**	Is capable of **independently** undertaking performance testing of systems axial CT **to an acceptable standard.**
Date Achieved			
Supervisor's Initials			
(b) The ability carry out performance testing of helical & MDCT systems	Is capable of undertaking performance testing of helical & MDCT systems. **Requires close supervision.**	Is capable of undertaking performance testing of helical & MDCT systems. **Requires only limited supervision.**	Is capable of **independently** undertaking performance testing of helical & MDCT systems **to an acceptable standard.**
Date Achieved			
Supervisor's Initials			

(c) The ability to carry out performance testing of CT systems used in radiotherapy	Is capable of undertaking performance testing of CT systems used in radiotherapy. **Requires close supervision.**	Is capable of undertaking performance testing of CT systems used in radiotherapy. **Requires only limited supervision.**	Is capable of **independently** undertaking performance testing of CT systems used in radiotherapy **to an acceptable standard.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.9: Magnetic resonance imaging

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
(a) An understanding of MRI equipment	Demonstrates a **basic understanding of** MRI equipment	Demonstrates a **good understanding of** MRI equipment
Date Achieved		
Supervisor's Initials		
(b) An understanding of the principles of image formation	Demonstrates a **basic understanding of** the principles of image formation	Demonstrates a **good understanding of** the principles of image formation
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to: carry out performance testing of clinical MRI systems	Is capable of undertaking performance testing of MRI systems. **Requires close supervision.**	Is capable of undertaking performance testing of MRI systems. **Requires only limited supervision.**	Is capable of **independently** undertaking performance testing of MRI systems **to an acceptable standard.**
Date Achieved			
Supervisor's Initials			
Date	**Supervisor's comments**		

Sub module 5.10: Ultrasound

Competency	**Level of Competency Achieved**	
	2	**1**
(a) An understanding of the theory of operation of ultrasound equipment and the various factors affecting image quality	Demonstrates a **basic understanding of** theory of operation of ultrasound equipment and the various factors affecting image quality	Demonstrates a **good understanding of** theory of operation of ultrasound equipment and the various factors affecting image quality
Date Achieved		
Supervisor's Initials		
(b) An understanding of bioeffects and safety aspects of ultrasound	Demonstrates a **basic understanding of** bioeffects and safety aspects of ultrasound	Demonstrates a **good understanding of** bioeffects and safety aspects of ultrasound
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
(a) The ability to: undertake routine quality control tests of ultrasound equipment.	Is capable of undertaking routine quality control tests of ultrasound equipment. **Requires close supervision.**	Is capable of undertaking routine quality control tests of ultrasound equipment. **Requires only limited supervision.**	Is capable of **independently** undertaking routine quality control tests of ultrasound equipment. **to an acceptable standard.**
Date Achieved			
Supervisor's Initials			

(b) The ability to: identify and investigate causes of artefacts	Is capable of **identifying common** artefacts on ultrasound images. **Not yet able to identify all possible causes** of artefacts	Is capable of identifying **common** artefacts on ultrasound images and **identifying most causes of these artefacts. Has difficulty identifying less common artefacts and their causes.**	Is capable of identifying **most** artefacts on ultrasound images and their causes.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.11: Display and printing devices

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
(a) An understanding of the principles of display and printing devices	Demonstrates an **understanding** of the principles of display and printing devices	Demonstrates a **good understanding** of the principles of display and printing devices
Date Achieved		
Supervisor's Initials		
(b) An understanding of image performance characteristics of display and printing devices	Demonstrates a **basic understanding of image performance characteristics** of display and printing devices	Demonstrates a **good understanding of image performance characteristics** of display and printing devices
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out performance testing of display and printing devices	Is capable of undertaking performance testing of display and printing devices **Requires close supervision.**	Is capable of undertaking performance testing of display and printing devices **Requires only limited supervision.**	Is capable of **independently** undertaking performance testing of display and printing devices **to an acceptable standard.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.12: Dental radiography

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of clinical implementation and supervision of a quality control program with routine testing by medical physicist and oversight of periodic testing by dental technician.	Demonstrates a **basic understanding** of the elements of a QC program of dental radiography equipment	Demonstrates a **good understanding** of the elements of a QC program of dental radiography equipment
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
(a) The ability to review, on an annual basis, the QC program with the responsible dentist and dental technician	Requires **close supervision** in reviewing the QC program**.**	**Requires only limited supervision** in reviewing the QC program**.**	Is capable of **independently** reviewing the QC program **to an acceptable standard.**
Date Achieved			
Supervisor's Initials			
(b) The ability to use a simple dental x ray test tool (Dental Radiographic Quality Control Device)	Possesses a **basic ability** to use simple dental x ray test tools. **Requires considerable assistance.**	Possesses a **good ability** to use simple dental x ray test tools. **Requires only limited assistance.**	Is capable of **independently using** simple dental x ray test tools.
Date Achieved			
Supervisor's Initials			

(c) The ability to carry our performance testing on computed and digital radiography, panoramic radiography, cephalometric radiography, and cone-beam CT	Is capable of undertaking some performance testing of **complex dental equipment. Requires assistance**	Is capable of undertaking performance testing of **complex** dental equipment. **Requires assistance with the more complex tests.**	Is capable of **independently** undertaking performance testing of **complex** dental equipment to an **acceptable level.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 5.13: Dual-energy X ray Absorptometry (DXA)

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
(a) An understanding of theory of DXA and the operation of DXA equipment.	Demonstrates a **basic understanding** of the theory of DXA and the operation of DXA equipment.	Demonstrates a **good understanding** of the theory of DXA and the operation of DXA equipment.
Date Achieved		
Supervisor's Initials		
(b) An understanding of the importance of QC and calibration in the accurate use of normal ranges in DXA	Demonstrates a **basic understanding** of the importance of QC and calibration in the accurate use of normal ranges in DXA	Demonstrates a **good understanding** of the importance of QC and calibration in the accurate use of normal ranges in DXA
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out routine QC tests and to identify and investigate causes of errors	Requires **close supervision** when performing routine QC tests. Has **not yet developed the ability** to identify and investigate causes of errors	Is capable of performing routine QC tests **under supervision**. Has a **limited ability** to identify and investigate causes of errors.	Is capable of performing routine QC tests **without supervision**. Has a **good ability** to identify and investigate causes of errors.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 6: TECHNOLOGY MANAGEMENT

6.1. Quality management of systems in radiology

6.2. Lifecycle of imaging equipment

6.3. Acceptance and Commissioning of Imaging Equipment

6.4. Manage the routine QC testing of imaging equipment

6.5. Imaging Informatics

6.6. Department design

Sub-module 6.1: Quality management systems in radiology

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the essential elements of a quality management system	Demonstrates a **basic understanding** of the **relevant terms** and **the role** of a quality management system in radiology.	Demonstrates a **good understanding** of the key elements and role of a quality management system in radiology.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to design the structure of a quality management system.	Is **capable of designing the basic structure** of a quality manual. **Requires assistance** to ensure all necessary elements are included.	Is **capable of designing the structure** of a quality manual. **Requires only minimal assistance** to ensure all necessary elements are included.	Is capable of **independently** designing the structure of a quality manual and ensuring all necessary elements are included.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 6.2: Life cycle of imaging equipment

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the life cycle of imaging equipment including the elements of planning, purchase; acceptance and commissioning, maintenance, routine testing and disposal	Demonstrates a **basic understanding** of the generic elements of the life cycle of imaging equipment.	Demonstrates a **good understanding** of the elements of the life cycle of imaging equipment.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to develop an equipment business plan and draft a tender document.	Is **capable of developing an equipment business plan and drafting a tender document**. **Requires assistance** with the concepts involved.	Is capable of developing an equipment business plan and drafting a tender document. **Requires only minimal assistance** to ensure all necessary elements are included. **Any omissions are minor.**	Is capable of **independently developing** an equipment business plan and drafting a tender document **to an acceptable clinical standard**.
Date Achieved			
Supervisor's Initials			

The ability to oversee equipment maintenance, including verification of equipment quality after maintenance and disposal	Is **capable of** overseeing equipment maintenance, including verification of equipment quality after maintenance and disposal **Requires assistance** to ensure all necessary elements are included.	Is **capable of** overseeing equipment maintenance, including verification of equipment quality after maintenance and disposal. **Requires only minimal assistance Any omissions are minor.**	Is capable of **independently overseeing** equipment maintenance, including verification of equipment quality after maintenance and disposal **to an acceptable clinical standard**.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 6.3: Acceptance and commissioning of imaging equipment

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the concept and principles of acceptance and commissioning of equipment	Demonstrates a **limited understanding** of the physical principles of the imaging modality in question **and** the concepts of QA programs.	Demonstrates an **in-depth understanding** of the physical principles of the imaging modality in question **and** the concepts of QA programs.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out and report on acceptance of new equipment and its commissioning	Is **capable of performing acceptance testing and commissioning** of simple new equipment (e.g. dental). **Requires assistance** to ensure that there are no errors in the process.	Is **capable of performing and reporting on acceptance testing and commissioning** of most new equipment (e.g. fluoroscopy). Requires only **minimal assistance** Makes **occasional minor errors**.	Is capable of **independently performing and reporting on acceptance testing and commissioning** of all new equipment (including CT and interventional) to **an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 6.4: Management of routine QC testing of imaging equipment

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the methods for the clinical implementation and supervision of a quality control programme	Demonstrates a **basic understanding** of the generic aspects of a clinical QC programme.	Demonstrates a **good understanding** of the methods of a clinical QC programme.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to manage a QC programme including the appropriate use of instrumentation, test selection and test frequency	Is **capable of performing a QC programme** including **selection and use of appropriate equipment. Requires assistance** to ensure that there are no errors in the process.	Is capable of performing a QC programme. **Requires only minimal supervision.** Makes **occasional minor errors**.	Is capable of **independently performing QC of imaging equipment** to an acceptable clinical standard.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 6.5: Imaging informatics

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
(a) An understanding of basic digital imaging principles including image archiving, compression storage, communication, standards and display.	Demonstrates a **basic understanding** of the various aspects of digital imaging.	Demonstrates a **good understanding** of digital imaging principles.
(b) An understanding of medical and health information systems including applications and ethical considerations	Demonstrates a **basic understanding** of medical and health information systems	Demonstrates a **good understanding** of medical and health information systems
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out basic performance testing in the PACS environment including the verification of DICOM conformance statements and the utilization of header information	Is **capable of undertaking performance testing of most items of imaging informatics. Requires assistance** to ensure that there are no errors in the process.	Is capable of undertaking performance testing of most items of imaging informatics. **Requires only minimal assistance.** Makes **occasional minor errors**.	Is capable of **independently** undertaking performance testing of **all** items of imaging informatics to an acceptable clinical standard.
Date Achieved			
Supervisor's Initials			

Date	Supervisor’s comments

Sub-module 6.6: Department Design

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the factors important to design of a diagnostic radiology facility	Demonstrates a **limited understanding** of the design considerations.	Demonstrates a **good understanding** of all aspects of the design of a diagnostic radiology facility.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to design and verify effective and safe rooms for diagnostic radiological examinations.	Is **capable of designing** safe rooms for diagnostic radiological examinations**. Requires assistance** to ensure that there are no errors in the design.	Is **capable of designing** safe rooms**. Requires only minimal assistance** Makes **occasional minor errors**.	Is capable of **independently designing** safe rooms for diagnostic radiological examinations to an acceptable clinical standard.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 7: DOSIMETRY, INSTRUMENTATION AND CALIBRATION

7.1. Ionising radiation dosimetry and principles of measurement

7.2. Non-ionising radiation quantities and principles of measurement

7.3. Radiological test equipment, measurement, and practice

7.4. Dosimetry system calibration

Sub module 7.1: Ionising radiation dosimetry and principles of measurement

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of radiation quantities and units, formalism and uncertainty estimation, and dosimeter types needed for radiation measurement in diagnostic radiology	Demonstrates a **basic understanding** of the principles of ionising radiation dosimetry and the principles of measurement	Demonstrates a **good understanding** of the principles of ionising radiation dosimetry and the principles of measurement
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
(a) The ability to determine dosimetric quantities and associated uncertainty for each of the five diagnostic modalities; (general radiography, fluoroscopy, mammography, CT and dentistry)	Is capable of **determining dosimetric quantities** for a **number** of the diagnostic modalities in simple situations including for conventional and fluoroscopy exams. **Requires assistance.**	Is capable of determining dosimetric quantities for **most** of the diagnostic modalities including mammography. **R**equires **only limited assistance**	Is capable of **independently** determining dosimetric quantities for **all** of the diagnostic modalities including CT.
Date Achieved			
Supervisor's Initials			

(b) The ability to determine dosimetric quantities in non standard and complex situations including those with **large components of scattered radiation**	Is capable of **determining dosimetric quantities** for a **number** of the non standard situations. **Requires supervision and assistance with more complex situations.**	Is capable of determining dosimetric quantities for **many situations involving scatter radiation**. **R**equires **only limited assistance.**	Is capable of **independently** determining dosimetric quantities in complex situations involving scatter radiation..
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 7.2: Non-ionising radiation quantities and principles of measurement

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the basic principles, measurement, and the safety issues involved in visible light, lasers, ultrasound, radiofrequency radiation, and static magnetic fields	Demonstrates a **basic understanding** of the principles, measurement and safety issues of non-ionising radiation.	Demonstrates a **good understanding** of the principles, measurement and safety issues of non-ionising radiation.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out necessary basic measurements in non ionizing radiation	Is capable of **performing basic dosimetric measurements** for non-ionising radiations. **Requires assistance.**	Is capable of performing basic dosimetric measurements for non-ionising radiations. **R**equires **only limited assistance.**	Is capable of **independently** performing basic dosimetric measurements for non-ionising radiations.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 7.3: Radiological test equipment, measurement and practice

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of techniques and instrumentation needed to characterize an x ray beam, focal spot, and film processor	Demonstrates a **basic understanding** of techniques and instrumentation needed to characterize an x ray beam, focal spot, and film processor	Demonstrates a **good understanding** of techniques and instrumentation needed to characterize an x ray beam, focal spot, and film processor
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to use radiological test equipment	Is capable of using radiological test equipment. Requires **close supervision.**	Is capable of using radiological test equipment. Requires **only limited supervision.**	Is capable of **independently** using radiological test equipment.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 7.4: Dosimetry system calibration

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
(a) An understanding of calibration standards, traceability and calibration beam conditions	Demonstrates a **basic understanding** of calibration standards, calibration beam conditions and the need for traceability of the standards.	Demonstrates a **good understanding** of calibration standards, calibration beam conditions and the need for traceability of the standards.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
(b) The ability to maintain instrument calibration records including documentation of cross-checks and field calibrations	Is capable of maintaining instrument calibration records. **Requires assistance** to ensure the that the records are of an acceptable standard	Is capable of maintaining instrument calibration records. **Requires only limited assistance**	Is capable of **independently** maintaining instrument calibration records.
Date Achieved			
Supervisor's Initials			
Perform field calibrations for various dosimeters including TLD and OSL, and KAP meters	Is capable of calibrating the various dosimeters. Requires **considerable assistance to ensure the accuracy of the calibration.**	**Requires only limited assistance** in calibrating the various dosimeters	Is capable of **independently** calibrating the various dosimeters
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 8: PATIENT DOSE AUDIT

8.1. Dose audit

8.2. Paediatric dosimetry

8.3. Foetal dose estimation

Sub module 8.1: Dose audit

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the concepts that underpin dose audit including the relevant dosimetric principles, the appropriate selection of the patient sample or phantom, and the concept of diagnostic reference levels.	Demonstrates a **basic understanding** of the concepts that underpin dose audit	Demonstrates a **good understanding** of the concepts that underpin dose audit
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out patient dose surveys, compare the results with diagnostic reference levels, draw meaningful conclusions and take appropriate action.	Is capable of performing patient dose surveys and comparing the results with diagnostic reference levels **under supervision. Requires assistance** in drawing meaningful conclusions and recommending appropriate actions	Is capable of performing patient dose surveys and comparing the results with diagnostic reference levels **at an acceptable standard. Requires only limited assistance** in drawing meaningful conclusions and recommending appropriate actions	Is capable of **independently** performing patient dose surveys and comparing the results with diagnostic reference levels**. Is able to draw meaningful conclusions and recommend appropriate actions**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub module 8.2: Paediatric dosimetry

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the differences between dosimetry of adult and paediatric patients, including impact of various patient sizes on dosimetry.	Demonstrates a **basic** understanding of the differences between dosimetry of adult and paediatric patients.	Demonstrates a **good** understanding of the differences between dosimetry of adult and paediatric patients.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The ability to conduct and analyse dose audits of a paediatric population	**Requires close supervision** when performing dose audits of a paediatric population.	**Requires only limited supervision** when performing dose audits of a paediatric population.	Is capable of **independently** performing when performing dose audits of a paediatric population **to an acceptable standard**.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub module 8.3: Foetal dose estimation

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the radio sensitivity of the conceptus/foetus and possible effects as a function of gestational age	Demonstrates a **basic** understanding of the radio sensitivity of the conceptus/foetus	Demonstrates a **good** understanding of the radio sensitivity of the conceptus/foetus
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to estimate the approximate conceptus/foetal dose from reported radiological examination procedure information and phantom evaluation.	**Requires considerable assistance to** estimate the approximate conceptus/foetal dose.	**Requires only limited assistance to** estimate the approximate conceptus/foetal dose.	Is capable of estimating the approximate conceptus/foetal dose **without assistance.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 9: IMAGE QUALITY ASSESSMENT

9.1. Assessment of image quality through objective tests

9.2. Assessment of image quality with phantoms

9.3. Assessment of image quality of clinical, patient images

Sub module 9.1: Assessment of image quality through objective tests

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of physical and mathematical techniques for quantifying and evaluating image quality	Demonstrates a **basic** understanding of physical and mathematical techniques for quantifying and evaluating image quality	Demonstrates a **good** understanding of physical and mathematical techniques for quantifying and evaluating image quality
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to assess image quality through physical tests for a range of image characteristics and imaging modalities	Is capable of assessing image quality for **several** of the imaging modalities. **Requires assistance** with some aspects.	Is capable of assessing image quality for **all** of the imaging modalities. **Requires assistance** with some aspects.	Is capable of independently assessing image quality for **all** of the imaging modalities.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 9.2: Assessment of image quality with phantoms

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of image quality phantoms and methodologies useful to assess image quality in various diagnostic radiology modalities.	Demonstrates a **basic** understanding of image quality phantoms and methodologies useful to assess image quality in **most** diagnostic radiology modalities	Demonstrates a **good** understanding of image quality phantoms and methodologies useful to assess image quality in **all** diagnostic radiology modalities
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to use phantoms to assess image quality for various modalities in combination with both objective measures and psychophysical methods as appropriate.	Is capable of utilising phantoms to assess image quality for **most** modalities. **Requires assistance** to relate outcomes with objective measures and psychophysical methods.	Is capable of utilising phantoms to assess image quality for the **all** modalities. **Requires only limited assistance** to relate outcomes with objective measures and psychophysical methods.	Is capable of **independently** utilising phantoms to assess image quality for the **all** modalities and relating outcomes with objective measures and psychophysical methods.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 9.3: Assessment of image quality of clinical, patient images

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of statistical methodologies that can be used to determine image quality from clinical images	Demonstrates a **basic** understanding of statistical methodologies that can be used to determine image quality from clinical images	Demonstrates a **good** understanding of statistical methodologies that can be used to determine image quality from clinical images
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out an evaluation of image quality for a procedure using clinical images and a specified experimental design	**Requires assistance in** performing an evaluation of image quality or a procedure using clinical images and a specified experimental design.	Is capable of performing, **with only limited supervision**, an evaluation of image quality or a procedure using clinical images and a specified experimental design.	Is capable of **independently** performing an evaluation of image quality or a procedure using clinical images and a specified experimental design.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 10: OPTIMIZATION

10.1. Radiation risk to the patient in diagnostic radiology

10.2. Optimization Process

Sub module 10.1: Radiation risk to the patient in diagnostic radiology

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of radiation risk and the benefits from diagnostic radiology procedures	Demonstrates a **basic** understanding of radiation risk and the benefits from diagnostic radiology procedures	Demonstrates a **good** understanding of radiation risk and the benefits from diagnostic radiology procedures
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to provide advice on risk to staff and patients and on strategies for radiation risk reduction	Capable of providing **basic** advice on risk to staff and patients and on strategies for radiation risk reduction. **Needs assistance** with ensuring the accuracy of the advice.	Capable of providing **correct** advice on risk to staff and patients and on strategies for radiation risk reduction. **Requires only limited assistance.**	Capable of providing correct advice on risk to staff and patients and on strategies for radiation risk reduction.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub module 10.2: Optimization process

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the factors that affect both image quality and patient radiation dose	Demonstrates a **basic** understanding of factors that affect both image quality and patient radiation dose	Demonstrates a **good** understanding of factors that affect both image quality and patient radiation dose
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to take the lead amongst radiological colleagues in the optimization process of radiological examinations including the giving advise on practical strategies for improving image quality and dose reduction.	Capable of **participating** in the optimization process of radiological examinations.	Capable of taking a **major role** in the optimization process of radiological examinations. Needs **limited assistance.**	Capable of **taking a leading role** in the optimization process of radiological examinations.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

APPENDIX VI: SUPPLEMENTARY FORMS AND DOCUMENTS

APPLICATION FOR

ENTRY AS A RESIDENT TO THE

CLINICAL TRAINING PROGRAMME IN

DIAGNOSTIC RADIOLOGY MEDICAL PHYSICS

ADMINISTERED BY

_____

Family Name: .....**Given Names**:.....……..
(In BLOCK letters) (In BLOCK letters.)
Please highlight the name you prefer to be called by.

Please tick appropriate box

☐ **Ms**

☐ **Mr**

Personal Details of Applicant
(Please complete all details In BLOCK letters)

Address: .....……

.....……

.....…….....

Postcode: .....

Telephone Number: ..... Fax: ……

Email: ……..

Previous Academic Record
A copy of the degree(s) and/or transcript(s) of the academic record in the original language (and English translation if not in English) must be attached to this application and forwarded to the National Programme Coordinator.

Undergraduate Education:

Name of Institution: .....….

Address of Institution: …….....

Year commenced: ……. Year Completed: …….

Name of degree obtained: ……
Majoring in: ….…….

Post Graduate Education in Medical Physics:

Name of Institution: .....….

Address of Institution: …….

Year Commenced: ……. Year Completed: …….

Name of Degree Obtained: ……..……
Majoring in:…….

Other Post Graduate Education:

Name of Institution: .....….

Address of Institution: …….

Year Commenced: ……. Year Completed: …….

Name of Degree Obtained: ……..……
Majoring in:…….

Attach additional pages if required.

To be signed by The National Programme Coordinator:

I have sighted the applicant's degree(s) and/or transcript(s) of their academic record in the original language (and English translation if not in English). These qualifications are appropriate for the applicant to enter the Clinical Training Programme for Diagnostic Radiology Medical Physicists in (insert name of member state).

Signed :…….……. Date: ……/……/……..

National Programme Coordinator for (insert name of member state).

Training Program Details

In-Service Clinical Training Position:

Name of Clinical Department: ……....

Address of Clinical Department: …….

…….

…… Postcode: .....

Chief Physicist[11]: ……

Telephone Number: ..... Fax Number: .....

Email: ……..

Clinical Supervisor (if known): ……

Telephone Number: ..... Fax Number: .....

Email: ……..

Employment details of Resident

Date Commenced/Commencing: ……..

Full or Part Time: ……

☐ Permanent ☐ Temporary

if temporary please state duration: ……

To be signed on behalf of the employer[1]:

I certify that the applicant has been accepted for an In-Service Clinical Training Position in this department and that the details of the In-Service Clinical Training Position provided above are correct.

Endorsed by:…. Date: ……/……/……..
(signed on behalf of the employer)

Name in BLOCK letters ……..

Position (example Head of Department)……..

---

[11] This refers to the person who is overall responsible for the medical physics service in which the resident is being trained.

Statement by the Applicant

I hereby apply to undertake the Clinical Training Programme in Diagnostic Radiology Medical Physics.

I agree that the statements made by me in this application are correct to the best of my knowledge.

APPLICANT'S SIGNATURE: …… DATE: …….

Instructions to the Applicant

Please ensure that:

- *a copy of your **degree(s) and/or transcript(s) of your academic record** in the original language (and English translation if not in English) is attached to this application form, and*
- *the Head of Department or other appropriate authority has signed the **"Training Programme Details"** section (confirming that you have been accepted into a clinical training position).*

This application should be sent by either post or email to the National Programme Coordinator. Electronic signatures are acceptable

You will be advised of the outcome of your application.

Contact details for the National Programme Coordinator

Insert contact details for NPC

CHECKLIST FOR NEW RESIDENTS
(0-3 MONTHS OF TRAINING PROGRAMME)

RESIDENT: _____

DATE OF COMMENCEMENT OF RESIDENCY: _____

	date achieved
ALLOCATION OF A CLINICAL SUPERVISOR	
RESIDENT'S APPLICATION FORM SENT TO NATIONAL PROGRAMME COORDINATOR	
LETTER OF ACCEPTANCE INTO TRAINING PROGRAMME RECEIVED FROM NATIONAL PROGRAMME COORDINATOR	
ORIENTATION BY CLINICAL SUPERVISOR	
RESIDENT STARTS A LOGBOOK (if required)	
CLINICAL TRAINING GUIDE PROVIDED TO RESIDENT	
SCHEDULE FOR REGULAR SUPERVISOR-RESIDENT MEETINGS ESTABLISHED (at least monthly)	
INITIAL 6 MONTH TRAINING PLAN AGREED	
TRAINING PLAN FOR PERIOD OF ENROLLMENT DEVELOPED AND AGREED WITH CLINICAL SUPERVISOR	
RESIDENT BEGINS ATTENDANCE AT CLINICAL MEETINGS AND/OR TUTORIALS	

WORK PLAN AGREEMENT

FOR _____(insert name of Resident)

FOR THE SIX MONTH PERIOD from _____/____/_____ to ____/____/____

Month Specify e.g. Jan	**Sub-modules to be worked on**	**Pre-requisite knowledge to be acquired by (date)**	**Competency assessment schedule (date)**	**Resources/strategies (if necessary use notes section below)**
1.				
2.				
3.				

WORK PLAN AGREEMENT (CONT'D)

Month Specify e.g. Jan	Sub-modules to be worked on	Pre-requisite knowledge to be acquired by (date)	Competency assessment schedule (date)	Resources/strategies (if necessary use notes section below)
4.				
5.				
6.				

LEARNING AGREEMENT (CONT'D)

RESOURCES AND STRATEGIES

Notes:_____

_____

_____

_____

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_____

SIGNED:

_____(Resident)

_____(Clinical Supervisor)

SUMMARY OF SCHEDULE FOR COMPLETION OF CLINICAL TRAINING IN DRMP PROGRAMME

Level of competency to be obtained and assessed by end of period specified.

SUB-MODULE/ COMPETENCY	Year of Training Specify e.g. 2010						
	1 _____		2 _____		3 _____		4 _____
	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June
1.1							
1.2							
1.3							
2.1							
2.2							
2.3							
2.4							
2.5							
2.6							
2.7							
3.1							
3.2							
4.1							
4.2							
4.3							
4.4							

SUMMARY OF SCHEDULE FOR COMPLETION OF CLINICAL TRAINING PROGRAMME (cont'd)

Level of competency to be obtained and assessed by end of period specified.

SUB-MODULE/ COMPETENCY	Year of Training Specify e.g. 2010						
	1 _____		2 _____		3 _____		4 _____
	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June
5.1							
5.2							
5.3							
5.4							
5.5							
5.6							
5.7							
5.8							
5.9							
5.10							
5.11							
5.12							
5.13							
6.1							
6.2							
6.3							
6.4							
6.5							
6.6							
7.1							
7.2							
7.3							
7.4							

SUMMARY OF SCHEDULE FOR COMPLETION OF CLINICAL TRAINING PROGRAMME (cont'd)

Level of competency to be obtained and assessed by end of period specified.

SUB-MODULE/ COMPETENCY	Year of Training Specify e.g. 2010						
	1 _____		2 _____		3 _____		4 _____
	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June
8.1							
8.2							
8.3							
9.1							
9.2							
9.3							
10.1							
10.2							

ASSIGNMENT SCHEDULE

	Year of Training **Specify e.g. 2010**					
	1 _____		2 _____		3 _____	
	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June	July-Dec
ASSIGNMENT 1.						
Topic selected						
Assignment submitted						
Assessed as satisfactory						
ASSIGNMENT 2.						
Topic selected						
Assignment submitted						
Assessed as satisfactory						
ASSIGNMENT 3.						
Topic selected						
Assignment submitted						
Assessed as satisfactory						

PORTFOLIO PREPARATION SCHEDULE

	Year of Training Specify e.g. 2010					
	1 _____		2 _____		3 _____	
	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June	July-Dec
Curriculum Vitae prepared and updated (at least annually)						
Progress Reports completed by Resident and Clinical Supervisor						
Samples of Work						
SAMPLE 1						
Area and nature of sample selected						
Sample of work Prepared						
SAMPLE 2						
Area and nature of sample selected						
Sample of work Prepared						
SAMPLE 3						
Area and nature of sample selected						
Sample of work Prepared						
SAMPLE 4						
Area and nature of sample selected						
Sample of work Prepared						
SAMPLE 5						
Area and nature of sample selected						
Sample of work Prepared						

SIX MONTH PROGRESS REPORT FORM (RESIDENT / SUPERVISOR)

Resident: _____ Clinical Supervisor: _____
(insert names in BLOCK LETTERS)
Date of this Report: ____/____/____
Date of Commencement in the Training Programme: ____/____/____

The Report is an opportunity for you and your Clinical Supervisor to assess how your clinical training has progressed over the past six months, to re-formulate your work-plan for the next six months and to revise your schedule for completion (if necessary) and to review all aspects of your Residency. It is expected that your Clinical Supervisor will read and discuss this progress report with you.

It is particularly important that you report any obstacles to progress (lack of access to equipment, illness, etc) and that you're Clinical Supervisor indicates actions taken to address the issues (where appropriate).

SUMMARY OF PROGRESS IN THIS SIX MONTH PERIOD
(to be completed by the Resident)

Sub-modules worked on Competency level achieved (if assessment conducted)													
Sub-modules worked on													
Competency level achieved (if assessment conducted)													
Scheduled assignment submitted (yes/no/not applicable)													
Scheduled sample for portfolio prepared (yes/no/not applicable)													
Other (e.g. seminar presentation, research project)													

DEVELOPMENT OF PROFESSIONAL ATTRIBUTES
(to be completed by the Clinical Supervisor).

Generic Skill	Indicate your assessment of the Resident's capabilities in relation to the following professional attributes. Is there evidence of development or acquisition of this skill in the Resident's Portfolio?
Communication	
Initiative	
Motivation	
Problem Solving	
Safe work practice	
Teamwork	
Technical skills	
Time management	
Up-dates knowledge	

STATEMENT BY CLINICAL SUPERVISOR

I have discussed the attached summary of progress in this reporting period with the Resident and believe that it reflects the progress made in the past six months. The status of this Resident's Clinical Training Programme is considered to be

☐ **Satisfactory** (The Resident is on schedule to complete the training programme by the agreed date)

☐ **Somewhat behind schedule: Progress has been impeded – as a result of**

A ☐ **Issues, beyond the control of the Resident, which have now been resolved,**

or

B ☐ **Issues yet to be resolved**

These issues are described in the comments section of this report which also indicates the remedial actions taken. A revised schedule for completion has been developed and agreed to by the Resident and Clinical Supervisor.

☐ **Unsatisfactory**

Issues, as indicated below, need to be resolved.

A follow-up progress report is required from the Resident in 3 months

Comments by Resident: (Attach additional pages if necessary. Please indicate any concerns/obstacles you may have experienced which have affected progress)

Comments by Clinical Supervisor: (Attach additional pages if necessary. Please comment on remedial actions proposed to address any concerns indicated by the Resident.)

Signatures:
I agree that this report provides an accurate summary of progress in the clinical training programme of the named Resident and that any remedial action necessary to address obstacles to progress have been agreed to by both the Resident and Clinical Supervisor.

Resident_____

Clinical Supervisor: _____

ANNUAL CHECKLIST FOR RESIDENTS

RESIDENT: _____

YEAR: 1 2 3 4 5 (please circle)

YEAR: 20____

	✓ when satisfactory	Comment
REGULAR SUPERVISOR-RESIDENT MEETINGS HELD (at least monthly)		
RESIDENT LOGBOOK UP TO DATE		
COMPETENCY ASSESSMENT UP TO DATE		
SIX MONTHLY SUPERVISOR REPORTS COMPLETED (AND FORWARDED TO NATIONAL PROGRAMME COORDINATOR		
ANNUAL REVIEW & REPORT ON FILE		
ANNUAL TRAINING PLAN UP TO DATE		
TRAINING PLAN FOR PERIOD OF ENROLLMENT UP TO DATE		
RESIDENT REGULARLY ATTENDING CLINICAL MEETINGS AND/OR TUTORIALS		
AT LEAST 5 KEY PORTFOLIO REPORTS TARGETTED FOR ASSESSMENT ARE PLANNED OR UNDER DEVELOPMENT		
ASSIGNMENT FOR THIS YEAR COMPLETED		

COMPLETION CHECKLIST FOR RESIDENTS

RESIDENT: _____

COMPLETION OF REQUIREMENTS CHECKLIST	**Date achieved**
Required level of competency attained in all sub-modules	
Portfolio completed and assessed as satisfactory	
Three assignments completed and graded as 3 or better.	
Oral exam conducted and assessed as satisfactory	
Practical exam conducted and assessed as satisfactory (if required)	

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

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[3] INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS, IOMP Policy Statement No. 2, Basic. Requirements for Education and Training (in press).

[4] NG, K.H., et al., The role, responsibilities and status of the clinical medical physicist in AFOMP, Australas Phys Eng Sci Med **32** 4 (2009) 175-9.

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[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Clinical training of medical physicists specializing in radiation oncology, Training Course Series, 37, IAEA, Vienna (2009). http://www-pub.iaea.org/MTCD/publications/PDF/TCS-37_web.pdf.

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