Radiotherapeutic Physics Syllabus

* Candidates are advised that the Radiotherapeutic Physics syllabus will be reviewed as part of the Curriculum Development Project. Details of changes will be advised in due course.

Aims

The aim of the Radiotherapeutic Physics unit of study is to provide candidates with the knowledge of physics and its clinical application. This knowledge is a fundamental requirement in forming the foundation of competent radiation oncologists

Pre-requisites

Familiarity with the physics of electricity, atomic structure and electromagnetic behaviour is a basic requirement, for full appreciation of many facets of this curriculum. If understanding is poor in these areas, we advise candidates to refresh their memories, prior to commencing this unit of study, through the use of standard HSC or first year university physics texts.

Objectives

On completion of this unit of study, the candidate will be able to:

1. apply physics knowledge to safely use ionising radiation;
2. justify the use of ionising radiation in clinical radiotherapeutic practice; and
3. differentiate between different treatment approaches and optimise solutions to clinical problems, based on physical concepts.

Syllabus Specification

The detailed components involved in achieving these objectives are listed in the syllabus below. The syllabus describes the breadth of the material which must be covered in the pursuit of competence, and which may be included in the assessments of this competence.

1. PHOTON ABSORPTION AND SCATTERING PROCESSES AND ELECTRON INTERACTIONS
   Photoelectric effect, Compton scattering, coherent (elastic) scattering, pair production, annihilation radiation, characteristic radiation, photonuclear reactions. Attenuation, energy transfer and absorption and their coefficients. Electron interactions with matter. Energy loss mechanisms: collisional losses, radiation losses. Ionization, excitation, heat production, delta rays. Polarisation effects. Scattering.

2. PRODUCTION OF X-RAYS FOR CLINICAL USE
   Production of bremsstrahlung and characteristic radiation by electron bombardment. Efficiency of X-ray production and its dependence on electron energy and target atomic number.

3. RADIOACTIVITY
   Natural and artificial radioactivity, decay processes, exponential decay, physical, biological and effective half-lives, mean life, decay constant, principles of radionuclide production.

4. RADIOACTIVE SOURCES FOR BRACHYTHERAPY
   Sources containing caesium-137, iridium-192, gold-198, cobalt-60, iodine-125, strontium-90, yttrium-90, ruthenium-106. Source construction including filtration. Spectra of radiation emitted, half-life, specific activity. Comparative advantages of these radionuclides.

5. UNSEALED SOURCES
   Iodine-131, phosphorus-32, yttrium-90, strontium-89, samarium-153. Spectra of radiation emitted, half-life, physical form. Comparative advantages of these radionuclides.

6. EXTERNAL BEAM RADIATION SOURCES
   Brief description and principles of operation of radiation therapy treatment units: linear accelerator, cobalt-60 teletherapy unit, orthovoltage unit, superficial therapy unit.

7. RADIATION QUANTITIES AND UNITS
   Concept, definition and units of kerma, absorbed dose, dose equivalent, equivalent dose, effective dose, air kerma rate constant, reference air kerma rate, activity, apparent activity, linear energy transfer, stopping power, integral dose.

8. RADIATION MEASURING DEVICES
   (An outline only of principles of the following instruments is necessary). Ionization chambers, semi-conductor detectors, thermoluminescent dosimeters, photographic film, Geiger-Muller counters, scintillation counters, chemical dosimeters, calorimeters.

9. MEASUREMENT OF RADIATION
   Phantoms. Measurement of radiation quality, output and dose distribution for photon and electron beams. IAEA megavoltage dosimetry protocol (brief outline of principles only, details not required). Measurement of activity and dose rates for brachytherapy sources and unsealed radionuclides.

10. COMMISSIONING AND QUALITY ASSURANCE OF RADIOTHERAPY EQUIPMENT
    Acceptance testing of equipment, data acquisition, establishment of baseline values for QA checks, frequency of QA checks and parameters measured.

11. CHARACTERISTICS OF PHOTON BEAMS
    Intensity and its angular distribution, energy spectra, radiation quality (MV, effective energy, half value layer). Variation of these characteristics with maximum electron energy, voltage, current and filtration where applicable.

12. DOSE DISTRIBUTION IN TISSUE PRODUCED BY EXTERNAL BEAM PHOTON RADIATION
    Primary and scattered radiation, percentage depth dose, tissue-air ratio, scatter-air ratio, tissue-phantom ratio, tissue-maximum ratio, scatter-maximum ratio, back scatter factor, peak scatter factor, off-axis ratio. Variation of these beam parameters with depth, field size and shape, source–skin distance, beam quality or energy, type of beam defining device. Beam profiles, isodose curves and charts, flatness and symmetry, penumbra, surface dose (entrance and exit), skin sparing. Output factors. Integral dose. Effects of patient contour, bone, lung, cavities, prostheses on dose distribution, including dose within bone cavities, interface effects and effects of electronic disequilibrium. Dose-volume histograms.

13. IRREGULAR OR OFFSET PHOTON FIELDS

Obtained by beam blocking, multileaf collimators, independent jaws. Effects on dose distribution.

14. DOSE MODIFICATION TECHNIQUES FOR PHOTON BEAMS

Methods of compensation for patient contour variation and/or tissue inhomogeneity. Shielding of dose-limiting tissues. Wedge filters and their use. Dynamic wedging, bolus, build-up material, compensating filters, multileaf collimators.

15. TREATMENT PLANNING FOR PHOTON BEAMS

ICRU 50 & ICRU 62 terminology. Determination of body contour and location of internal structures, target volume and critical tissues. Plain film, fluoroscopy, CT, MRI, ultrasonography, nuclear medicine imaging. Simulation. Calculation of monitor units or treatment time. 3-D planning. Field junctions.

16. TREATMENT TECHNIQUES WITH PHOTON BEAMS

SSD and isocentric techniques. Parallel opposed, multiple fields. Rotation (full or partial) therapy, conformal therapy, intensity modulated radiation therapy. Total body irradiation. Stereotactic radiosurgery and radiotherapy.

17. ACCURACY OF TREATMENT PLANNING AND DOSE DELIVERY

Methods of ensuring reproducibility of patient positioning throughout treatment and planning-simulation, treatment set-up, lasers, immobilisation methods. Light field, cross-wire images, optical distance indicators, front and back pointers, breast bridges. Accuracy of movements and scales of treatment machines and simulators. Port films, electronic portal imaging, in vivo patient dosimetry. Changes in patient contour and in position of normal and tumour tissues during course of treatment. Accuracy of calibration. Stability of beam parameters. Accuracy of isodose calculation. Avoidance and detection of dose delivery errors including record and verify systems, select and confirm procedures, interlocks. Potential errors arising from computer control of set up and treatment machine operation.

18. ELECTRON BEAM THERAPY

Energy spectra. Energy specification. Variation of mean energy with depth. Suitability of measuring instruments for electron beam dosimetry. Characteristics of electron beams. Surface dose, percentage depth dose, beam profiles, isodose curves and charts. Flatness and symmetry. Beam collimation. Variation of percentage depth dose and output with field size and SSD. Photon contamination.

Treatment planning, energy and field size choice, air gaps and obliquity, tissue inhomogeneity:- lung, bone, air filled cavities. Bolus. Field junctions (with either electron or photon beams). Internal shielding. Arc therapy. Total skin electron irradiation.

19. PHYSICAL CHARACTERISTICS AND CLINICAL APPLICABILITY OF PROTON BEAMS

20. BRACHYTHERAPY

Basic principles: surface, interstitial, intracavitary, intravascular and intraluminal techniques. Low medium, high and pulsed dose rate. Remote afterloading machines and manual afterloading. Brachytherapy dosimetry. Dosage systems – Manchester system (outline only), Paris system (working knowledge). Outline of methods of reconstruction and dosage calculation using radiography, CT and MRI. ICRU dose specification system. Stereotactic technique. Beta-particle brachytherapy, including methods of use and dose distribution. Handling, calibration, cleaning, inspection, storage and transport of brachytherapy sources.

21. COMPARISON OF MODALITIES AND TECHNIQUES

Relative advantages of photon and electron beams and brachytherapy including choice of field arrangement (including rotation therapy, conformal therapy, and intensity modulated radiation therapy).

22. UNSEALED SOURCE RADIOTHERAPY

Concepts of uptake, distribution and elimination. Activities used in clinical practice. Estimation of dose to target tissues and critical organs. Procedures for measurement of activity, safe handling and administering radionuclides to patients.

23. COMPUTERS IN RADIOTHERAPY

Basic computer technology. Processor, memory, input and output devices, storage media.

Operating systems, software, networks. Use of computers for planning, input of patient contours and internal structures (including CT and MRI data) and beam parameters. Dose calculation methods for photon and electron beams and brachytherapy. Monte Carlo method (concept only). Plan optimization. Display of dose distribution information. Hard copy output. Storage and retrieval of completed plans. 3-D treatment planning. Patient treatment records. Treatment control and verification. Quality assurance of computer generated information.

24. RADIATION PROTECTION

Principles and data underlying ICRP recommendations. ICRP and national radiation protection standards. Regulatory frameworks in Australia and New Zealand. ICRP dose limits.

Working procedures for use with radiation sources including simulators, teletherapy, brachytherapy and unsealed sources. Spillage and clean up. Minimisation of dose to patients and others. Nursing procedures. Control of areas and radiation sources. Radiation protection surveys. Personal monitoring. Area monitoring. Record keeping. Design of departments. Custody and leakage testing of radioactive sources. Structural shielding design (principles only).

Recommended sources of information relevant to Syllabus

1) Khan FM: "The Physics of Radiation Therapy" 2nd Edition Williams and Wilkins (1994).
2) Williams JR & Thwaites DI (Eds): "Radiotherapy Physics in Practice" OUP (1993).
3) Metcalfe P, Kron T & Hoban P: "The Physics of Radiotherapy X-Rays from Linear Accelerators" (1997)
4) ICRU Reports with sections relevant to the syllabus, in particular:
   - No.24 Determination of Absorbed Doses in a Patient Irradiated by Beams of X or Gamma Rays in Radiotherapy Procedures (1976)
   - No.38 Dose and Volume Specification for Reporting Intracavity Therapy in Gynaecology (1985)
   - No.42 Use of Computers in External Beam Radiotherapy Procedures with High-Energy Photons and Electrons (1987)
   - No.50 Prescribing, Recording and Reporting Photon Beam Therapy (1993)
   - No.51 Quantities and Units in Radiation Protection Dosimetry (1993)
   - No.58 Dose and Volume Specifications for Reporting Interstitial Therapy (1997)
   - No.60 Fundamental Quantities and Units for Ionizing Radiation (1998)
   - No.62 Prescribing, Recording and Reporting Photon Beam Therapy [Supplement to ICRU report 50] (1999)

5) ICRP Publications with sections relevant to the syllabus, in particular:
   - No.60 1990 Recommendation of the International Commission on Radiological Protection (1991)
   - No.73 Radiological Protection and Safety in Medicine (1996)
   - No.86 Prevention of Accidents to Patients Undergoing Radiation Therapy (2001)

6) For Australian candidates: The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) booklets available online at www.arpansa.gov,au
   (a) Radiation Health Series relevant to the syllabus, in particular
      - No.8 Code of Nursing Practice for Staff exposed to Ionizing Radiation (1984)
      - No.18 Code of Practice for the Safe Handling of Corpses Containing Radioactive Materials (1986)
      - No.23 Code of Practice for the Control and Safe Handling of Radioactive Sources Used for Therapeutic Purposes (1988)
      - No.32 Intervention in Emergency Situations Involving Radiation Exposure (1990)

   (b) Radiation Protection Series relevant to the syllabus, in particular:
      - No.1 Recommendation for Limiting Exposure to Ionizing Radiation and National Standard for Limiting Occupational Exposure to Ionizing Radiation (Printed 1995 – Republished 2002)
      - No.4 Discharge of Patients Undergoing Treatment with Radioactive Substances (2002)

7) For New Zealand candidates: National Radiation Laboratory Codes of Safe Practice relevant to the syllabus, in particular:

C3 Code of Safe Practice for the Use of Unsealed Radioactive Materials in Medical Diagnosis, Therapy and Research (1994)
C12 Code of Safe Practice for the Use of Irradiating Apparatus in Medical Therapy (1992)
C13 Code of Safe Practice for the use of ^{90}Sr Opthalmic Applicators (1997)
C14 Code of Safe Practice of the Use of Sealed Radioactive Materials in Brachytherapy (2000)

8) AAPM Reports:
No.17 The Physical Aspects of Total and Half Body Photon Irradiation (1986)
No.54 Stereotactic Radiosurgery (1995)
TG 36 Fetal Dose from Radiotherapy with Photon beams: Report of the AAPM Radiation Therapy Committee Task Group No. 36 *Med.Phys. 22(1) 63-81 Jan 1995*
TG 60 Intravascular brachytherapy physics: Report AAPM Radiation Therapy Committee Task group No. 60 – *Med.Phys. 26(2) 119-152 Feb 1999* [detailed dosimetry not needed]

9) Relevant articles in the current literature including:-
- International Journal of Radiation Oncology Biology and Physics.
- Radiotherapy and Oncology.
- Medical Physics
- Physics in Medicine and Biology

It is expected that candidates will keep abreast of current literature relating to new developments.