Handbook
Master Degree in Medical Physics
Department of Physics
Faculty of Mathematics and Natural Sciences
Universitas Indonesia

Address:

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CONTENTS

1. Introduction

Medical Physics is a branch of Applied Physics, pursued by medical physicists, that uses physics principles, methods and techniques in practice and research for the prevention, diagnosis and treatment of human diseases with a specific goal of improving human health and well-being. Medical physics may further be classified into a number of sub-fields (specialties), such as Radiation Oncology Physics, Medical Imaging Physics, Nuclear Medicine Physics, Medical Health Physics (Radiation Protection in Medicine), Non-ionizing Medical Radiation Physics, and Physiological Measurements. Medical physics is a multidisciplinary science. Besides Physics, it also involves other disciplines such as Medicine, Biology, Chemistry, Mathematics, Pharmacy, and Engineering.

Currently, there are only a few radiotherapy centers particularly at hospitals in big cities that have been provided with relatively good medical physics infrastructures. Even though some medical physicists already have master degrees, they have not undergone clinical trainings matched with international level. Most medical physicists throughout the country still have bachelor degrees. According to the recommendation of international community, it is explicitly mentioned that medical physicists at hospitals should be professionals, preferably those with master and PhD degrees with additional clinical training to be competent and able to work independently in their field. Besides at hospitals, medical physicists also work in academic institutions, research institutions, and other private sectors institutions.

In order to meet the requirement to produce internationally recognized medical physicists, Department of Physics Faculty of Mathematics and Natural Sciences, University of Indonesia operated Bachelor of Physics (Sarjana Fisika) program with majoring in Medical Physics and Biophysics and Master of Medical Physics program since 1998 and 2002, respectively. During one decade of our program, we have prepared leader candidates, either university staff or medical physicists from hospitals and other research institutions to have internships at overseas hospitals. These activities have been supported by International Atomic Energy Agency (IAEA) through our Technical Cooperation Project (2007 – Now) and National Atomic Energy Agency (BATAN).

This master program was initiated in 2002 under Master Program in Physics. After 20 years, we decide to make independent study program to recognize the alumnae in the government level to be candidate of qualified medical physicist. This program is also mandated by International Organization for Medical Physics (IOMP) and International Atomic Energy Agency to harmonize and standardize medical education in the regional and international level.

2. Management of the Program

The program management structure of this collaboration reads as follows:

Advisory Board

Dean of FMIPA UI	: Prof. Dr. Tito Latif Indra, S.Si., M.Si.
Head of Physics Department	: Dr. Adhi Harmoko

Executive Board

Head of the Program	: Dr.sc.hum. Dwi Seno Kuncoro Sihono

3. The List of Teaching Staffs

The list of lecturers on this program are as follows:

1. Prof. Dr. Djarwani Soeharso — Physics Department, FMIPA UI
2. Prof. Supriyanto Ardjo Pawiro, PhD — Physics Department, FMIPA UI
3. Dr.sc.hum. Dwi Seno K. Sihono — Physics Department, FMIPA UI
4. Dr.sc.hum. Deni Hardiansyah — Physics Department, FMIPA UI
5. Dr. Lukmanda E Lubis, M.Si — Physics Department, FMIPA UI
6. Dr. Akbar Azzi, M.Si — Physics Department, FMIPA UI
7. Syahril Siregar, PhD — Physics Department, FMIPA UI
8. Neng Tine, MD, PhD — Faculty of Medicine, UI
9. Yessie Widya Sari, PhD — Physics Department, FMIPA IPB
10. Kristina Tri Wigati, M.Si (PhD cand) — Physics Department, FMIPA UI

4. Teaching Facilities

We organize Medical Physics and Biophysics Laboratory which provide the laboratory for education and service for the public. The management of Laboartory organize 4 Laboratory, are :

a. X-ray and Dosimetry Laboratory at First Floor, Department of Physics Building, Depok Campus
b. Biophysics Laboratory at First Floor, Department of Physics Building, Depok Campus
c. Treatment Planning System Laboratory at 3rd floor, Department of Physics Building, Salemba Campus
d. Radiation Physics Laboratory, 3rd floor Department of Physics Building, Depok Campus

5. Curriculum

Curriculum of Master in Medical Physics, Department of Physics is Course – Research

Subjects for 1st semester	Credit Unit*	Subjects for 2nd semester	Credit Unit*
Patho-Anatomy and Physiology	2	Radiation Safety and Protection	2
Advanced Radiological Physics and Dosimetry	2	Medical and Professional Ethics	2
Computational Medical Physics	2	Integration of Science and Mathematics	3
Applied Radiobiology	2	Radiation Protection Lab	2
Biomedical Physics Medical Imaging Physics	2 3	**Elective Courses (6 credits):**	
Nuclear Medicine Physics	2		
Radiotherapy Physics	3	Advanced Radiotherapy	3

		Techniques	
		Imaging Technology and Radiotherapy Planning	3
		Advanced Medical Imaging Physics	4
		Non-Ionizing Medical Imaging Physics	2
		Nuclear Medicine Imaging	2
		Nuclear Medicine Dosimetry	2
		Production and Safety of Radiopharmaceuticals	2
Total	18	Total	15

Subjects for 3rd semester	**Credit Unit***	**Subjects for 4th semester**	**Credit Unit***
Scientific Dissemination	2	Thesis	16
Research Proposal	3		
Total	5		16

*) 1 credit unit is equivalent with 50 minutes lecture activity during 1 semester (16 weeks)

Appendices

Syllabus of the Courses

CORE MODULES

1. Patho-Anatomy and Physiology

Objectives:
Upon finishing this course, students should master medical terminologies originated from Greek and Latin languages. Students will be able to roughly identify various anatomical structures, define most organ system, describe physiological mechanism for repair, maintenance, and growth. Anatomical structure and physiological functions should be delivered in accordance with image evaluation from various modalities.

Syllabus:
1. Anatomical Nomenclature
2. Bones and Bone Marrow
3. Brain and CNS
4. Thorax
5. Abdomen
6. Respiratory System
7. Digestive System
8. Urinary System
9. Reproductive System
10. Circulatory System

References:

- P.W. Ballinger, E.D. Frank, *Merrill's Atlas of Radiographic Positions and Radiologic Procedures,* 9th ed. (Mosby, St. Louis, MO, 1999).
- W.J. Bo. *Basic Atlas of Sectional Anatomy with Correlated Imaging,* 3rd ed. (W.B. Saunders
- Co., Philadelphia, PA, 1998).
- C.D. Clemente. *Anatomy: A Regional Atlas of the Human Body.* (Urban & Schwartzenberg,
- Baltimore, MD, 1997).
- J.T. Dennerll. *Medical Terminology—A Programmed Text,* 6th ed. (Delmar Publishers, Albany, NY, 1995).
- W. Lothar. *Atlas of Radiological Anatomy,* 3rd ed. (William & Wilkins, Baltimore, MD, 1997).
- M. Mallett. *Handbook of Anatomy and Physiology for Students of Medical Radiation Technology,* 3rd ed. (The Burnell Company/Publishers, Inc., 1990).

2. Advanced Radiological Physics and Dosimetry

Objectives:
Materials in this course is designed to provide knowledge to students about radiology. Starting with measurement units in radiology, the course continues to materials concerning radiation interactions focused on energy transfer and dose deposition. Students are also expected to master exponential attenuation for narrow and broad radiation before they learn about shielding design system for diagnostic and therapy utilization.The application of electronic equilibrium and cavity theory become the fundamental basis on the use of ionization chamber detector. The use of equilibrium system on dose measurement with ionization chamber or solid-state detector is also delivered to the students.

Syllabus:

1. Atomic and Nuclear Structure (Basic definitions of atomic structures, Rutherford model of the atom, Bohr model of the hydrogen atom, Multi-electron atoms, Nuclear structure, including nuclear binding energy, n/p radio, fission, and nuclear bombardment, Radioactivity and modes of decay [Matriculation]
2. Classification of Radiations (Basic physical quantities and units used in radiation physics, Types and sources of directly and indirectly ionizing radiations), Description of ionizing radiation fields) [Matriculation]
3. Indirectly Ionizing Radiations: Photon Beams (X-ray transitions, characteristic radiation, ionization vs. excitation of atoms, Moseley's law, x-ray line spectra, Hartree's theory of multi-electron atoms, Radiation from accelerated charge, production of bremsstrahlung, Larmor relationship, X-ray targets, bremsstrahlung yield, Beam quality and filtering, Energy deposition in tissue by photon beams) [Matriculation]
4. Exponential Attenuation (Simple exponential attenuation, Half-value layer, tenth-value layer, attenuation coefficients, interaction cross sections, Narrow vs. broad beam attenuation, Buildup factor, Spectral effects in attenuation, beam hardening and softening, Reciprocity theorem, Energy transfer coefficient, energy absorption coefficient) [Matriculation]
5. Photon Interactions with Matter (Thomson scattering, Rayleigh scattering, Photoelectric effect, Compton scattering, Pair production, triplet production, Photonuclear reactions, Relative predominance of individual effects as a function of energy and atomic number, Effects following individual photon interactions, fluorescence yield, Auger effect, Contributions of individual effects to the attenuation coefficient, energy transfer), coefficient, and energy absorption coefficient (Neutron types by kinetic energy, Neutron sources, Neutron beam specifications)
6. Indirectly Ionizing Radiations: Neutron Beams (Neutron interactions including scatter, absorption kinematics, and cross sections, Shielding consideration for neutrons, Neutron kerma and absorbed dose calculations, Absorbed dose in a body phantom, Gamma-neutron mixed field dosimetry, Neutron quality factor)
7. Neutron Interactions with Matter (Types of charged particle beams used clinically, Sources of charged particle beams, Energy deposition in tissue by charged particle beams)
8. Directly Ionizing Radiations (Stopping power (collisional and radiative), scattering power, range, straggling, Restricted stopping power, linear energy transfer, Orbital electron interactions, Nuclear interactions, Energy distribution of electrons in matter (charged particle spectrum), Calculation of absorbed dose in charged particle interactions)

9. Interactions of Directly Ionizing Radiations with Matter (Stopping power (collisional and radiative), scattering power, range, straggling, Restricted stopping power, linear energy transfer, Orbital electron interactions, Nuclear interactions, Energy distribution of electrons in matter (charged particle spectrum), Calculation of absorbed dose in charged particle interactions)
10. Radioactive Decay (Total and partial decay constants, Units of activity, Mean-life and half-life, Parent-daughter relationships, Transient and secular equilibrium, Harvesting of daughter products, Radioactivation by nuclear interaction, Exposure rate constant and air-kerma rate constant)[Matriculation]
11. Quantities and Units Used for Describing Radiation Fields (Fluence and fluence rate, Energy fluence and energy fluence rate, Monoenergetic and polyenergetic spectra)
12. Quantities and Units Used for Describing the Interaction of Ionizing Radiation with Matter (Terma, kerma, collisional kerma, radiative kerma, Absorbed dose, Activity, Energy transferred, net energy transferred, energy imparted, Equivalent dose and quality factor, Exposure)
13. Charged Particle and Radiation Equilibrium (Radiation equilibrium, Charged particle equilibrium (CPE), Relationships between absorbed dose, collisional kerma, and exposure under CPE, Conditions that enable CPE or cause its failure, Transient CPE)
14. Radiation Dosimetry (Types and general characteristics of dosimeters, ICRU (International Commission on Radiation Units and Measurements) definitions of dosimetry quantities and units, Absolute vs. relative dosimetry techniques, Interpretation of dosimeter measurements
15. Calorimetric Dosimetry (Basic principles and measurement techniques, Heat defect and thermal equilibrium, Thermocouples and thermistors, Adiabatic, isothermal, and constant temperature techniques)
16. Chemical (Fricke) Dosimetry (Basic principles and measurement techniques, G-value and radiation chemical yield, Absorption spectroscopy)
17. Cavity Theory (Bragg-Gray cavity theory and corollaries (restricted and unrestricted stopping powers), Spencer-Attix and Burlin cavity theories, Fano's theorem, Stopping power averaging, Dose near interfaces
18. Ionization Chamber (Basic configuration of ionization chambers, Standard free air ionization chamber, Cavity (thimble) ionization chamber, Extrapolation chamber, Measurement of chamber current (differential mode) and charge (integral mode) and operation of electrometer, Mean energy required to create an ion pair, Saturation characteristics of ionization chambers: initial and general recombination, diffusion loss (understanding correction factors applied to ion chamber measurement)
19. Calibration of Photon and Electron Beams with Ionization Chamber (Cavity chamber calibration: air-kerma in air and dose in water, Dosimetry protocols: AAPM TG-21; AAPM TG-51; International Atomic Energy, Agency Technical Report Series 398 (IAEA TRS-398), Phantom materials for photon and electron beams)
20. Dosimetry and Phantoms for Special Beams (or Non-TG-51 Compliant Beams) (Effects of partially exposed radiation detectors, Effects of field size and time patterns in radiotherapy delivery, Stereotactic beams, Robotic linac: CyberKnife, Intensity-modulated radiation therapy, Tomotherapy, Phantoms for special beams (or non-TG-51 compliant beams)
21. Relative Dosimetry Techniques (Thermoluminescent dosimetry (TLD), including excitation and de-excitation of crystalline solids, Film dosimetry: radiographic film and radiochromic film (and understanding of issues with using film as an absolute dosimeter), Semiconductor dosimeters: diodes, Optically stimulated luminescence (OSL), MOSFET (metal oxide semiconductors—field effect transistor) dosimeters and diamond detectors, Gel dosimeters
22. Dosimetry by Pulse-Mode Detectors (Geiger-Müller (GM) counters and proportional counters, Scintillation dosimetry, Radiation survey meters, Neutron detectors)

23. Technical Report Series IAEA 457
24. Technical Report Series IAEA 277 and 381
25. Technical Report Series IAEA 398
26. Technical Report Series IAEA 483

References:

- F. H. Attix. Introduction of Radiological Physics and radiation Dosimetry (John Willey and Sons, New York, NY, 1986)
- F. H. Attix, W. C. Roesch, and E. Tochilin. Radiation Dosimetry. 2nd ed. (Academic Press, New York, NY, 1968)
- J. R. Cameron, N. Suntharalingam, and G. N. Kenney. Thermoluminiscencent Dosimetry. (University of Wisconsin Press, Madison, WI, 1968)
- H. E. Johns and J. R. Cunningham. The Physics of Radiology, 4th ed. (Charles C. Thomas, Springfield, IL, 1983)
- E.B. Podgorsak, Radiation Oncology Physics : A handbook for teacher and students, IAEA, Veianna, 2005
- IAEA Technical Report Series 277
- IAEA Technical Report Series 381
- IAEA Technical Report Series 398
- IAEA Technical Report Series 457
- IAEA Technical Report Series 483

3. Computational Methods for Medical Physics

Objectives:

Upon compeletion this course, the students should have good foundation and practicing to write the basic algoritthm. This course will be a good foundation to know the foundation of algorithm whic is used in medical application.

Syllabus:

1. Introduction Programming
2. Numerical Methods for root of function
3. Solving of linear equation and Fitting
4. Interpolation and Numerical Integration
5. Ordinary Equation and Partial differtial equation
6. Eigen value equation
7. Fourier Transform
8. data and Visualization image
9. Image Segmentation
10. Filter Images
11. Introduction Monte Carlo
12. Application Monte Carlo in Medical Physics
13. Introduction Fitting data analysis
14. Introduction of Bio kinetics

References

1. Computational Methods for Biomedical Image Analysis and Interpretation: Master of

Science, Stanford University https://canvas.stanford.edu/courses/98045/
2. Computational Medical Physics : Master of Science, Heidelberg University, https://www.uni-heidelberg.de/md/studium/download/hand-book-bme-2y-16.03.2017.pdf
3. Monte Carlo Radiation Technique : Master, St. Andrew University, http://www-star.st-and.ac.uk/~kw25/teaching/mcrt/mcrt.html

4. Application Radiobiology

Objectives:
By taking this course, students are expected to master the fundamental concepts of radiation biology. It commences with a review on interaction of radiation with matter before going further into radiation injury to DNA, repair of DNA damage, radiation-induced chromosome damage and repair, survival curve theory to concepts of cell deaths. It covers as well the concepts of cellular recovery processes, cell cycle, sensitizers and protectors, RBE, OER and LET, cell kinetics, and radiation injury to tissue. Consequently, the course also discusses about radiation pathology, time-dose fractination, radiation genetics, as well as molecular mechanisms.

Syllabus:
1. Review of Interaction of Radiation with Matter (Types of radiation, Mechanisms of radiation absorption, Ionization density) [Matriculation]
2. Radiation Injury to DNA (Radiation chemistry of water, Structure of DNA and radiation-induced lesions, Double-strand breaks)[Matriculation]
3. Repair of DNA Damage (Excision repair, Repair of double-strand breaks)[Matriculation]
4. Radiation-Induced Chromosome Damage and Repair (Chromosome biology and aberrations, Linear-quadratic model) [Matriculation]
5. Survival Curve Theory (Target theory, Survival curve models, Cellular sensitivity)[Matriculation]
6. Cell Death: Concepts of Cell Death (Apoptosis and Reproductive Cell Death)
7. Cellular Recovery Processes (Types of radiation damage, Potentially lethal and sublethal damage, Fractionation effort, Dose rate effects)
8. Cell Cycle (Cell kinetics and cycle phases, Radiosensitivity and cell cycle position, Radiation effects on cell cycle
9. Modifiers of Radiation Response—Sensitizers and Protectors (Oxygen effect and other radiosensitizers, Radioprotection)
10. RBE, OER, and LET (Linear energy transfer (LET), Relative biological effectiveness (RBE), Oxygen enhancement ratio (OER)
11. Cell Kinetics (The cell cycle and quantitation of its constituent parts, The growth fraction and cell loss from tumors, Autoradiography and flow cytometry, The growth kinetics of human tumors)
12. Radiation Injury to Tissues (Tissue and organ anatomy, Expression and measurement of damage)
13. Radiation Pathology—Acute and Late Effects (Acute and late responding normal tissues, Pathogenesis of acute and late effects, Different kinds of late responses, Residual damage/Radiation syndromes/Clinical TBI (total body irradiation)
14. Time, Dose, and Fractionation (The 4 R's of radiobiology, Volume effects, The basis of fractionation, Dose-response relationships for early and late responding normal tissues, Hyperfractionation and accelerated treatments, Hypofractionation and high doses per fraction, a/b model)

15. Radiation Genetics: Radiation Effects of Fertility and Mutagenesis
16. Molecular Mechanisms

References :

- G. Gordon Steel (Editor). Basic Clinical Radiobiology. (Edward Arnold,London, UK, 1993)
- Eric J. Hall . Radiobiology for the Radiologist. 5th ed. (Lippincott Williams and Wilkins,Philadelphia, PA, 2000).

5. Biomedical Physics

Objectives :

This course addresses the principles governing the interactions between light and biological tissue, their optical properties, and basic concepts of biosensing. Diagnostic and therapeutic applications of light in medicine and biology will also be described. After completion of this course students will be able to:

- describe basic physical principles in optics and lasers
- select appropriate hardware for biomedical experiments using optics
- experiment with laser systems in medical applications

Syllabus :

1. Brief history (History on biomedical optics)
2. Introduction to general optics and light sources (Nature of light, photobiology, photo physics, photochemistry, Laser and light source)
3. Light-tissues interactions (Light-matter interactions, photochemical interaction, biostimulation., Photo-thermal effects, photoablation, photoacoustic effects, Photon transport and Monte Carlo simulation, Tissue optics)
4. Introduction to spectroscopy (Absorption, diffuse reflectance, fluorescence, Raman spectroscopy, and LIBS)
5. Biosensor / Photodetection (Principle and method on optical biosensing and microscopy, Endoscopy, microscopy, diffuse reflectance, laser Doppler perfusion imaging, laser speckle perfusion imaging (2D Bioimaging, Optical coherence tomography, polarimetry, diffuse optical tomography, photo (3D Bioimaging).
6. Application of Laser and Optics in Medicine (Low and mid power laser therapy and biostimulation: techniques and possible mechanisms. Laser acupuncture and wound healing. Laser photodynamic therapy: basic idea and the optical energy transfer scheme. Designs of optical diffusers used for PDT. Port wine strain and tattoo removal by laser irradiation: physical principles, High-power laser applications. Principles of laser surgery, laser angioplasty and laser dentistry. Tissue welding by laser radiation. Laser spark, bubble creation and shock wave dynamics. Advantages and applications of Holmium and Erbium lasers in medicine. Microarray and microfluidic technology for genomics)
7. Medical laser safety (Laser safety classes 1, 2, 3A, 3B and 4 and the corresponding potential hazards. Occupational exposure limits for commonly used lasers. Laser-protective goggles. Laser danger warning labels and their colouring. Laser safety national and international standards.

References

1. Caroline Boudoux, *Experiments for Electronic Principles*, Blurb, 2017.

2. Lihong V. Wang, *Biomedical Optics: Principles and Imaging,* John Wiley & Sons, Inc, 2009
3. Paras N. Prasad, *Introduction to Biophotonics*, John Wiley & Sons, Inc, 2007

6. Medical Imaging Physics

Objectives:
The course covers conventional planar imaging which includes radiography and fluoroscopy. Detailed materials ranges from X-ray production, radiation interaction with patient, film production with intensifying screen, to X-ray film development. It is also given various parameter which effect on the image production, e.g.: grids, contrast media, noise, detail, blurring, etc.

Syllabus:
1. X-Ray Production (The x-ray tube, Electron energy, Bremsstrahlung, Characteristic radiation, Efficiency, Efficacy (Output), Filtration, self-filtration, heel effect
2. Energizing and Controlling the X-Ray Tube (kV production, Voltage waveform and x-ray production, Capacitors, rectifiers, High-frequency power supplies, mA control, Exposure timing, Quality assurance procedures, X-Ray Tube Heating and Cooling, Heat production, Heat capacity, Focal spot area, Anode body, Tube housing, Cooling charts)
3. X-Ray Image Formation and Contrast (Contrast types, Effects of photon energy (kVp), Area contrast)
4. Scattered Radiation and Contrast (Contrast reduction, Collimation, Air gap, Grids, Grid penetration, Grid selection)
5. Radiographic Receptors (Screen functions, Receptor sensitivity, Image blur, Image noise, Artifacts)
6. The Photographic Process and Film Sensitivity (Film functions, Optical density, Film structure, The photographic process, Sensitivity, Processing quality control)
7. Film Contrast Characteristics (Contrast transfer, Film latitude, Film types, Effects of processing, Film fog)
8. Radiographic Density Control (The x-ray generator, Receptor sensitivity, Patient, Distance and area, Automatic exposure control
9. Blur, Resolution, and Visibility of Detail (Visibility of detail, Unsharpness, Resolution, Modulation Transfer Function (MTF)
10. Radiographic Detail (Object location and magnification, Motion blur, Focal spot blur (geometric unsharpness), Receptor blur, Composite blur)
11. Image Noise (Effect on visibility, Quantum noise, Receptor sensitivity, Grain and structure noise, Electronic noise, Effect of noise on contrast, Effect of blur on noise, Image integration, Image subtraction)
12. Fluoroscopic Imaging Systems (Intensifier tubes, Video systems, The optical system and cameras, Receptor sensitivity, DSA)
13. Mamographics System
14. Computerize Tomography System
15. Dose and Dose Reduction Issues
16. Digital Imaging Systems and Image Processing (Digital images, Digital image receptors and conversion, Image processing, Image storage and retrieval, Image display systems and QC, Digital x-ray imaging systems
17. Gamma Camera (Image formation and image reconstruction)
18. Radionuclide Image Quality (Contrast, Blur and visibility of detail, Image noise, Uniformity, Clinical gamma camera applications)

References:

- J. T. Bushberg, J. A. Seibert, E. M. Leidhodt, Jr., J. M. Boone. The Essential Physics of Medical Imaging. 2nd ed., (Williams and Wilkins, Baltimore, MD, 2002).
- P.P Dendy and B. Heaton. Physics of Diagnostic Radiology. (Institute of Physics Publishing, London, UK, 1999).
- P. Sprawl. Physical Principles of Medical Imaging. (Aspen Publishers,. Gaithersburg, Maryland, 1987).
- Adrienne Finch (Editor). Assurance of Quality in the Diagnostic Imaging Department. (The British Institute of Radiology, London, 2001)
- G. ter Haar and F. A. Duck (Editor). The Safe Use of Ultrasound in Medical Diagnostic. (The British Institute of Radiology, London, 2001)
- AAPM Report No. 39. Specification and Acceptance Testing of Computed Tomography Scanners. (American Institute of Physics, New York,1993)
- AAPM Report no. 76. Quality Control in Diagnostic Radiology. (American Institute of Physics, New York, 2002).
- J. T. Bushberg, J. A. Seibert, E. M. Leidhodt, Jr., J. M. Boone. The Essential Physics of Medical Imaging. 2nd ed., (Williams and Wilkins, Baltimore, MD, 2002).
- P.P Dendy and B. Heaton. Physics of Diagnostic Radiology. (Institute of Physics Publishing, London, UK, 1999).
- P. Sprawl. Physical Principles of Medical Imaging. (Aspen Publishers,. Gaithersburg, Maryland, 1987).
- AAPM Report No. 6. "Scintillation Camera Acceptance Testing and Performance Evaluation." (American Institute of Physics, New York, 1980)

7. Nuclear Medicine Physics

Objectives:

After completing this course, students are expected to have a good foundation and also have deeper knowledge of the concepts of Physics in Nuclear Medicine.

Syllabus:

1. Basic concepts of immunology, radiopharmaceuticals, and calibrators
2. Physics in radiopharmaceuticals
3. Radiopharmaceutical production
4. Basic concepts of radiobiology in KN
5. Radiation protection in KN
6. Basic concepts of statistics in KN
7. Gamma cameras
8. SPECT
9. PET
10. Hybrid imaging
11. Evaluation of diagnostic systems
12. Tools for diagnostic evaluation
13. Pharmacokinetics in KN
14. Basic concepts of internal dosimetry
15. Planning of standardized tests in KN
16. Advanced dosimetry topics in KN

References:

- Cherry, Physics in Nuclear Medicine
- IAEA:https://humanhealth.iaea.org/HHW/MedicalPhysics/e-learning/Nuclear_Medicine_Handbook_slides/index.html

8. Radiotherapy Physics

Objectives:

- Radiation Oncology
  - Radiation therapy is the clinical process that uses radiation for the treatment of a variety of cancers. It utilizes a variety of radiation sources with unique characteristics and procedures. Theseare used alone or in combination with other treatment modalities. This section provides an overall view of these modalities and identifies their roles in the management of cancer treatments.
- External Beam Radiation Therapy
  - The material in this section is designed to teach a graduate student the applications of external
  - beams from equipment designed to produce collimated beams. The characterization of these
  - beams, related fundamental dosimetric quantity, and the methods of delivering dose are presented. The resultant dose distributions in tumors and normal tissue in patients are also presented.
- Brachytherapy
  - Brachytherapy is a method of treatment in which radioactive sources are used to deliver radiation at a short distance by interstitial, intracavitary, or surface application. This section discusses the physical characteristics, dose distribution, and clinical methodology of these services.

Syllabus:

1. Introduction Radiotherapy (Radiotherapy procedures and External Beam Radiotherapy, Brachytherapy, Cobalt-60, linear accelerator modalities)
2. Clinical Photon Beams (Field size, source-skin distance, source-axis distance, sourcecollimator, distance)
3. Clinical Photon Beams: Point Dose Calculation (Percentage depth dose (PDD), Peak-scatter factor (PSF), Tissue-air ratio (TAR), Tissue-maximum ratio (TMR), Tissue-phantom ratio (TPR), Scatter function, Scatter-air ratio (SAR), Scatter-maximum ratio (SMR), Collimator factor, Relative dose factor/output factor, Off-axis ratio)
4. Clinical Photon Beams: Basic Clinical Dosimetry (Factors affecting the fundamental dosimetry quantities, Relationships between the fundamental dosimetry quantities, Collimator and phantom scatter corrections, Irregular fields and Clarkson's integration method, Tissue heterogeneities and corrections)
5. Clinical Electron Beams (Electron treatment head, Depth-dose distribution, Energy spectrum, Dose distribution, Determination of monitor units, Effect of air gap on beam dosimetry, Fundamental principles)
6. Brachytherapy (Radionuclides used in brachytherapy, Source types used in brachytherapy, Sealed-source dosimetry (source strength, air kerma rate, absorbed dose calculation), Source calibration, assay, and quality assurance, Source specifications and dosimetry)

References:

- AAPM Report No. 46. Comprehensive QA for Radiation Oncology. (American Institute of Physics, New York, 1994)
- AAPM Report No. 47. AAPM Code of Practice for Radiotherapy Accelerator. (American Institute of Physics, New York, 1994)
- AAPM Report No. 67. Protocol for Clinical Reference Dosimetry of High Energy Photon and Electron Beams. (American Institute of Physics, New York, 1999).
- IAEA Report No. 23. Absorbed Dose Determination in Photon and Electron Beams. An International Code of Practice. (International Atomic Energy Agency, Vienna, Austria, 1987).
- ICRU Report No. 38. Dose and Volume Specifications for Reporting Intracavitary Therapy in Ginecology. (International Commission on Radiation Unit and Measurements, Bethesda, MD, 1985).
- ICRU Report No. 50. Prescribing, Recording and Reporting Photon Beam Therapy. (International Commission on Radiation Unit and Measurements, Bethesda, MD, 1993).
- H. E. Johns and J. R. Cunningham. The Physics of Radiology, 4th ed. (Charles C. Thomas, Springfield, IL, 1983)
- S. C. Klevenhagen, Physics and Dosimetry of Therapy Electron Beams. (medical Physics Publishing, Madison, WI, 1993)
- W. J. Meredith and J. B. Massey. Fundamental Physics of Radiology. 3rd ed. (J. Wright, Bristol, UK, 1977)
- J. Van Dyk (Editor). The Modern Technology of Radiation Oncology (Medical Physics Publishing, Philadephia, PA, 1999)
- J. R. Williams and D. I. Thwaites. Radiotherapy Physics in Practice. (Oxford University Press, New York, 1994)
- Siamak Shahabi (Editor). Blackburn's Introduction to Clinical Radiation Therapy Physics. (Medical Physics Publishing Corporation, Madison, Wisconsin, 1989)
- P. M. K. Leung. The Physical Basis of Radiotherapy. (The Ontario Cancer Institute incorporating The Princess Margaret Hospital, 1990).
- G. C. Bentel, C. E. Nelson, and K.T. Noell. Treatment Planning Dose Calculation in Radiation Oncology. McGraw Hill, New York, NY, 1989)

9. Radiation Protection and Safety

Objectives:

The course is aimed introducing and strenghtening student's knowledge about radiation protection. It introduces the historical perspectives and continues to interaction physics applied to the scope of radiation protection. The sessions also covers operational dosimetry, radiation protection instrumentation, shielding, statistics, radiaiton monitoring personnel, internal exposure, biological effects, regulation, and nonionizing radiation protection.

Syllabus:

1. Introductions and Historical Perspective (Discovery and early application of ionizing radiation, Observed radiation injury, Suggested radiation protection practices, Pre-regulatory initiatives)
2. Operational Dosimetry (Units, Kerma and absorbed dose, Dose equivalent, Recommendations of the ICRU Recent changes in the neutron quality factor)

3. Radiation Detection Instrumentation (Ionometry including proportional and GM counters, Scintillation and TLD devices, Dose equivalent instrumentation)
4. Shielding: Properties and Design (Directly ionizing particles, Indirectly ionizing particles, Build-up parameterization, Stochastic sampling: Monte Carlo, Particle Accelerators, NCRP (National Council on Radiation Protection and Measurements) shielding recommendations and techniques)
5. Statistics (Statistical interpretation of instrument response, Design of experiments, Stochastic and nonstochastic error analysis, Interpreting experimental results)
6. Radiation Monitoring of Personnel (Instrumentation and techniques, lntegral and active devices, Dynamic range and response sensitivities, Film, TLD, Lexan, and CR-39, Pocket ion chambers and GM counters, Pregnant workers and fetal dose limits)
7. Internal Exposure (ICRP 26, ICRP 2A recommendations, Medical internal radiation dose (MIRD) dosimetry, Monitoring and radiation control, Biological assay, Dispersion in a working environment, Allowed limit of intake and derived air (or water) concentrations)
8. Biological Effects (Basic radiation biology, Nonstochastic and stochastic responses, Biological experimental data base of radiation injury, BEIR (Biological Effects of Ionizing Radiation) and UNSCEAR (United Nations, Scientific Committee on the Effects of Atomic Radiation) Reports, Patient and fetal dose issues)
9. Regulations
10. Nonionizing Radiation

References :

- ICRP No. 60. 1990 Recommendations of International Commission on Radiological Protection. (Elsevier Science, 1990)
- Herman CemberIntroduction to Health Physics. 2nd ed., (Pergamon Press Inc. New York, NY. 1983).
- RL. Kathren. Radiation Protection. (Adam Hilger LTD., Bristol, 1985).
- D. A. Gollnick. Basic Radiation Protection Technology. 2nd ed. (Pacific Radiation Corporation, Altadena, CA, 1993)

10. Medical and Professional Ethics

Objectives:

After completing this course, students will have a basic knowledge of medical ethics, ethics and standards of the medical physics profession, research ethics, and scientific ethics.

Syllabus:

1. Etika medik
2. Regulasi profesi fisika medik
3. Etika dan standar pelayanan fisika medik
4. Etika penulisan thesis dan publikasi ilmiah
5. Pemanfaatan teknologi informasi dan komunikasi dalam kegiatan ilmiah
   Latihan aplikasi etika, standar, dan pemanfaatan TI dalam kegiatan ilmiah

References:

- Bulletin of the World Health Organization, 2001, 79 (4), https://www.who.int/bulletin/archives/79(4)373.pdf
- IAEA Training Course Series No 37, Clinical Training of Medical Physicist Specializing in Radiation Oncology, Vienna, 2009

- IAEA Training Course Series No 47, Clinical Training of Medical Physicist specializing in Diagnostic Radiology, Vienna, 2009
- IAEA Training Course Series No 50, Clinical Training of Medical Physicist spwcializing in Nuclear Medicine , Vienna, 2009
- Buku Panduan Diklat Profesi Fisikawan Medik Batch 3, Universitas Indonesia, 2019.
- UU 36 Tenaga Kesehatan
- UU 10 Ketenaganukliran
- Peraturan BAPETEN tentang proteksi radiasi di RT, RDI, dan KN
- Permenkes Standar Pelayanan Fisika Medik
- Permenkes Standar Profesi Fisikawan Medik
- SK Rektor UI 2017 tentang Pedoman Penulisan Tugas Akhir

11. Radiation Protection Laboratory

Objectives:
This course covers the basic requirements, regulations and procedures for radiation protection, radiation source safety, radiation protection design in radiation installation rooms, protection against medical, occupational and public exposure, emergency situations.

Syllabus:
1. Relationship between exposure time and radiation dose
2. Relationship between distance and radiation dose
3. Relationship between radiation shielding materials and radiation dose
4. Half-Value Layer (HVL) measurement
5. Film badge dosimeter
6. TLD dosimeter
7. Direct-reading personal dosimeter
8. Surveymeter
9. Radiation output reproducibility test
10. Effect of kV and mAs changes on X-ray output
11. Diagnostic X-ray leak test
12. Radiation exposure measurement (wall effectiveness test)

References:

1. PODGORSAK, E.B., (Ed.) Review of Radiation Oncology Physics: A Handbook for Teachers and Students, International Atomic Energy Agency, Vienna, (2005).
2. 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).
3. INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 2005 Edition Safety Requirements Details IAEA Safety Standards Series, No. TS-R-1, IAEA, Vienna (2005).
4. INTERNATIONAL ATOMIC ENERGY AGENCY, Applying Radiation Safety Standards in Diagnostic Radiology and Interventional Procedures Using X Rays, IAEA Safety Reports Series No. 39, IAEA, Vienna (2006).
5. INTERNATIONAL ATOMIC ENERGY AGENCY, Setting up a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, IAEA, Vienna (2008)

12. Scientific Dissemination

Objectives: To translate and distribute research findings to specific audiences so they can be understood and put into practice.

13. Research proposal

Objectives: This course is expected to write the project proposal and present the research proposal in panel members

ELECTIVE COURSES

1. Advanced Radiotherapy Techniques

Objectives:

This course provides students with further knowledge and understanding regarding the core of radiotherapy learning which includes radiotherapy acceptance and commissioning tests, quality assurance of teletherapy devices and radiotherapy support, and an introduction to modern advanced radiotherapy techniques.

Syllabus:

1. Teletherapy Device Acceptance and Commissioning Test
2. Brachytherapy Device Acceptance and Commissioning Test,
3. Teletherapy Device Quality Assurance,
4. Brachytherapy Device Quality Assurance,
5. Conventional and CT Simulator Quality Assurance,
6. PET and MR Simulator Quality Assurance,
7. Treatment Planning System Device Quality Assurance,
8. Tomotherapy Systems and Dosimetry,
9. Gamma Knife Systems and Dosimetry,
10. Cyber Knife Systems and Dosimetry,
11. MR-Cobalt and MR-Linac Hybrid Technology Systems and Dosimetry,
12. Proton Therapy Systems and Dosimetry,
13. Carbon Ion Therapy Systems and Dosimetry, Boron Neutron Capture Therapy, Thermal Therapy, and Laser Therapy.

References :

- AAPM Report No. 46. Comprehensive QA for Radiation Oncology. (American Institute of Physics, New York, 1994)
- AAPM Report No. 47. AAPM Code of Practice for Radiotherapy Accelerator. (American Institute of Physics, New York, 1994)
- AAPM Report No. 67. Protocol for Clinical Reference Dosimetry of High Energy Photon and Electron Beams. (American Institute of Physics, New York, 1999).
- IAEA Report No. 23. Absorbed Dose Determination in Photon and Electron Beams. An International Code of Practice. (International Atomic Energy Agency, Vienna, Austria, 1987).

- ICRU Report No. 38. Dose and Volume Specifications for Reporting Intracavitary Therapy in Ginecology. (International Commission on Radiation Unit and Measurements, Bethesda, MD, 1985).
- ICRU Report No. 50. Prescribing, Recording and Reporting Photon Beam Therapy. (International Commission on Radiation Unit and Measurements, Bethesda, MD, 1993).
- H. E. Johns and J. R. Cunningham. The Physics of Radiology, 4th ed. (Charles C. Thomas, Springfield, IL, 1983)
- S. C. Klevenhagen, Physics and Dosimetry of Therapy Electron Beams. (medical Physics Publishing, Madison, WI, 1993)
- W. J. Meredith and J. B. Massey. Fundamental Physics of Radiology. 3rd ed. (J. Wright, Bristol, UK, 1977)
- J. Van Dyk (Editor). The Modern Technology of Radiation Oncology (Medical Physics Publishing, Philadephia, PA, 1999)
- J. R. Williams and D. I. Thwaites. Radiotherapy Physics in Practice. (Oxford University Press, New York, 1994)
- Siamak Shahabi (Editor). Blackburn's Introduction to Clinical Radiation Therapy Physics. (Medical Physics Publishing Corporation, Madison, Wisconsin, 1989)
- P. M. K. Leung. The Physical Basis of Radiotherapy. (The Ontario Cancer Institute incorporating The Princess Margaret Hospital, 1990).
- G. C. Bentel, C. E. Nelson, and K.T. Noell. Treatment Planning Dose Calculation in Radiation Oncology. McGraw Hill, New York, NY, 1989)

2. Imaging Technology and Radiotherapy Planning

Objectives:
As one of fundamental courses for medical physics students, the course serves delivering core materials including target volume definition and dose prescription criteria, photon and electron beams modeling and treatment planning details as well as their clinical implementation, transition of 2D radiotherapy planning to 3D planning, brachytherapy planning, as well as explaining imaging technology in radiotherapy.

Syllabus:
1. Target Volume Definition and Dose Prescription Criteria (Gross tumor volume (GTV), Clinical target volume (CTV), Planning target volume (PTV), Dose prescription point, isodose line, or isodose surface)
2. Photon Beams: Dose Modeling and Treatment Planning (Single-field dose distribution, Parameters influencing isodose curves and isodose surfaces, Combination of fields, Wedged and angled fields, Corrections for SSD (source-to-surface distance), missing tissue, and inhomogeneities, Dose specification and normalization)
3. Photon Beams: Treatment Planning (Acquisition of isodose data, Computer hardware, Common algorithms: Convolution, superposition, pencil beam, Dimensionality (2D, 2.5D, and 3D treatment plans), Non-coplanar plans, Treatment planning with asymmetric collimators, Treatment planning with wedges (hard, dynamic, and virtual), Treatment planning with multileaf collimators (MLCs), Compensator design, 3-D treatment planning, Forward vs. inverse treatment planning, Inverse planning objectives and techniques. Optimization methods, Treatment planning with Monte Carlo techniques, Quality assurance of treatment planning systems, Biological modifiers/optimization)

4. Clinical Photon Beams: Patient Application (Patient data acquisition, Conventional simulator techniques, Accessory devices and techniques, CT-simulator techniques, Special considerations)
5. Clinical Electron Beams: Dose Modeling and Treatment Planning (Effects of patient and beam geometry, Dose algorithms, Treatment planning techniques, Special electron treatment techniques)
6. Transisition Two dimensional radiotherapy planning to Thrre dimensional conformal radiotherapy (3D-CRT)
7. Brachytherapy planning (Brachytherapy techniques: Interstitial, intracavitary; surface applicators, Brachytherapy systems: Direct-loading vs. afterloading; manual vs. remote afterloading, Interstitial therapy: Manchester and Paris systems, Seed implants, Ultrasound-guided prostate seed implants, Gynecological intracavitary therapy, Clinical prescriptions and dose-volume histograms, Remote afterloading machines, Electronic brachytherapy, Radiological models (linear-quadratic model)
8. Conventional Simulator
9. CT Simulator
10. MR Simulator
11. PET/CT Simulator
12. US Simulator
13. PACS
14. Image Registration

References :

- AAPM Report No. 46. Comprehensive QA for Radiation Oncology. (American Institute of Physics, New York, 1994)
- AAPM Report No. 47. AAPM Code of Practice for Radiotherapy Accelerator. (American Institute of Physics, New York, 1994)
- AAPM Report No. 67. Protocol for Clinical Reference Dosimetry of High Energy Photon and Electron Beams. (American Institute of Physics, New York, 1999).
- IAEA Report No. 23. Absorbed Dose Determination in Photon and Electron Beams. An International Code of Practice. (International Atomic Energy Agency, Vienna, Austria, 1987).
- ICRU Report No. 38. Dose and Volume Specifications for Reporting Intracavitary Therapy in Ginecology. (International Commission on Radiation Unit and Measurements, Bethesda, MD, 1985).
- ICRU Report No. 50. Prescribing, Recording and Reporting Photon Beam Therapy. (International Commission on Radiation Unit and Measurements, Bethesda, MD, 1993).
- H. E. Johns and J. R. Cunningham. The Physics of Radiology, 4th ed. (Charles C. Thomas, Springfield, IL, 1983)
- S. C. Klevenhagen, Physics and Dosimetry of Therapy Electron Beams. (medical Physics Publishing, Madison, WI, 1993)
- W. J. Meredith and J. B. Massey. Fundamental Physics of Radiology. 3rd ed. (J. Wright, Bristol, UK, 1977)
- J. Van Dyk (Editor). The Modern Technology of Radiation Oncology (Medical Physics Publishing, Philadephia, PA, 1999)
- J. R. Williams and D. I. Thwaites. Radiotherapy Physics in Practice. (Oxford University Press, New York, 1994)
- Siamak Shahabi (Editor). Blackburn's Introduction to Clinical Radiation Therapy Physics. (Medical Physics Publishing Corporation, Madison, Wisconsin, 1989)

- P. M. K. Leung. The Physical Basis of Radiotherapy. (The Ontario Cancer Institute incorporating The Princess Margaret Hospital, 1990).
- G. C. Bentel, C. E. Nelson, and K.T. Noell. Treatment Planning Dose Calculation in Radiation Oncology. McGraw Hill, New York, NY, 1989)

3. Advanced Medical Imaging Physics

Objectives:
The course covers advanced technology in medical imaging modalities.

Syllabus:
1. Mamographics System
2. Computerize Tomography System
3. Digital Imaging Systems and Image Processing (Digital images, Digital image receptors and conversion, Image processing, Image storage and retrieval, Image display systems and QC, Digital x-ray imaging systems
4. Cone Beam CT : Dental and other application
5. Ultrasound
6. Magnetic Resonance Imaging
7. Hybrid Imaging
8. Image Guidance

References:
- J. T. Bushberg, J. A. Seibert, E. M. Leidhodt, Jr., J. M. Boone. The Essential Physics of Medical Imaging. 2nd ed., (Williams and Wilkins, Baltimore, MD, 2002).
- P.P Dendy and B. Heaton. Physics of Diagnostic Radiology. (Institute of Physics Publishing, London, UK, 1999).
- P. Sprawl. Physical Principles of Medical Imaging. (Aspen Publishers,. Gaithersburg, Maryland, 1987).
- Adrienne Finch (Editor). Assurance of Quality in the Diagnostic Imaging Department. (The British Institute of Radiology, London, 2001)
- G. ter Haar and F. A. Duck (Editor). The Safe Use of Ultrasound in Medical Diagnostic. (The British Institute of Radiology, London, 2001)
- AAPM Report No. 39. Specification and Acceptance Testing of Computed Tomography Scanners. (American Institute of Physics, New York,1993)
- AAPM Report no. 76. Quality Control in Diagnostic Radiology. (American Institute of Physics, New York, 2002).

4. Non-Ionizing Medical Imaging Physics

Objectives:
After completing this course, students will have a basic knowledge base regarding the application of physics concepts in non-ionizing medical imaging modalities.

Syllabus:
1. Introduction to Ultrasonography: Characteristics of Ultrasound Waves and Their Interaction with Biological Tissue
2. Ultrasonic Transduction, Doppler Physics, and the Biological Effects of Ultrasound Waves
3. Principles of Array Ultrasound Detection Systems and B-Mode Instrumentation
4. Advanced Ultrasound Methods: Use of Contrast Agents, Tissue Harmonic Imaging, Coded

Excitation Imaging, 3D and 4D Ultrasound
5. Image Artifacts and Ultrasound Quality Control
6. Nuclear Magnetic Resonance, Relaxation, and Tissue Contrast
7. MR Spectroscopy, Spatial Encoding, and Basic Pulse Sequences
8. MRI Instrumentation, MRI Image Quality Issues
9. MRI Image Acquisition and Reconstruction
10. Image Artifacts and the Biological Effects of MRI
11. Introduction to Electric Capacitance Volume Tomography (ECVT)
12. ECVT Reconstruction Methods and Applications
13. Physical Principles and Applications of Photoacoustic Imaging (PAI)
14. Physical Principles and Applications of Optical Coherence Tomography (OCT)

References:

- J. T. Bushberg, J. A. Seibert, E. M. Leidhodt, Jr., J. M. Boone. The Essential Physics of Medical Imaging. 2nd ed., (Williams and Wilkins, Baltimore, MD, 2002).
- P.P Dendy and B. Heaton. Physics of Diagnostic Radiology. (Institute of Physics Publishing, London, UK, 1999).
- P. Sprawl. Physical Principles of Medical Imaging. (Aspen Publishers,. Gaithersburg, Maryland, 1987).
- Sprawls P. Magnetic Resonance Imaging: Principles, Methods, and Techniques. Medical Physics Publishing; 2000.
- G. ter Haar and F. A. Duck (Editor). The Safe Use of Ultrasound in Medical Diagnostic. (The British Institute of Radiology, London, 2001)

5. Nuclear Medicine Imaging

Objectives:

Advance Imaging Physics course is designed to ensure the students' knowledge on nuclear medicine physics which cover the basic of biochemistry, tracer and radiopharmaceutical, radiactivity, Statistic nuclear counting, Gamma Camera, Spect and PET System.

Syllabus:

1. Immunology and Radiopharmaceuticals
2. Concept of Activity Calculation with Dose Calibrators and Radiation Protection
3. Radiobiology in Nuclear Medicine
4. Imaging Using Gamma Cameras
5. Imaging Using SPECT
6. Imaging Using PET
7. Hybrid PET/CT and SPECT/CT Imaging
8. Concept of Non-Imaging Functional Diagnosis
9. Image Quality in Nuclear Medicine
10. Issues in Radiation Detection
11. Clinical Applications of Functional Diagnosis: Non-Imaging
12. Clinical Applications of Functional Diagnosis: Imaging
13. Tools for QC/QA Evaluation of Functional Imaging Systems
14. QC Mechanisms of Gamma Cameras and PET/CT

References :

- J. T. Bushberg, J. A. Seibert, E. M. Leidhodt, Jr., J. M. Boone. The Essential Physics of Medical Imaging. 2nd ed., (Williams and Wilkins, Baltimore, MD, 2002).
- P.P Dendy and B. Heaton. Physics of Diagnostic Radiology. (Institute of Physics Publishing, London, UK, 1999).
- P. Sprawl. Physical Principles of Medical Imaging. (Aspen Publishers,. Gaithersburg, Maryland, 1987).
- AAPM Report No. 6. “Scintillation Camera Acceptance Testing and Performance Evaluation.” (American Institute of Physics, New York, 1980)
- K. S. Krane. Introductory Nuclear Physics. (John Wiley and Sons, New York, 1987).
- Solomon Silver. Radioactive nuclide in medicine and biology. (Lea & Febriger, Philadelphia, 1968)
- Otto G. Raabe. Internal radiation dosimetry. (Medical Physics Publishing, Madison, 1994)
- Michael Ljungberg. Monte Carlo calculation in nucler medicine: application in diagnostic imaging. (Institute of Physics, Bristo, 1998)
- Positron Emission Tomography: Basic Sciences, Dale L. Bailey (Editor), David W. Townsend (Editor), Peter E. Valk (Editor), Michael N. Maisey (Editor). Springer.
- Fundamentals of Nuclear Medicine Dosimetry by Michael G. Stabin(Feb 20, 2008)
- NM General: Physics of Nuclear Medicine 3rd Edition (Cherry, Sorenson & Phelps – updated version of one that Roger has loaned you which is 2nd Ed)
- Positron Emission Tomography: Basic Science (Bailey, Townsend, Valk & Maisey – Springer); Basics of PET Imaging (GP Saha, Springer).

6. Nuclear Medicine Dosimetry

Objectives:

This course is designed to ensure students have advanced knowledge of MIRD-based dosimetry in nuclear medicine.

Syllabus:

1. Review of basic dosimetry concepts in nuclear medicine
2. Techniques for achieving good accuracy, traceability, and consistency
3. Quantizing two-dimensional planar images
4. Quantizing three-dimensional images and their uncertainty
5. Whole-body dosimetry
6. Input-process and output concepts of curve fitting
7. Curve fitting concepts with objective functions
8. Organ and voxel-level radiation transport
9. CDW concepts
10. CDW case examples
11. Thyroid dosimetry
12. Bone marrow dosimetry
13. Dosimetry concepts using PBPK and NLME
14. SIRT dosimetry

References :

- SIGFRID EFOMP Workshop on Dosimetry in MRT
- Dosimetry for Radiopharmaceutical Therapy. IAEA Book
- Bolch WE, et al. MIRD Pamphlet No. 21: A generalized schema for radiopharmaceutical dosimetry. J Nucl Med. 2009.

- Siegel JA, et al. MIRD Pamphlet No. 16: Techniques for quantitative radiopharmaceutical biodistribution data acquisition and analysis for use in human radiation dose estimates. J Nucl Med. 1999.
- Stabin MG, et al. OLINDA/EXM: the second-generation personal computer software for internal dose assessment. J Nucl Med. 2005.
- ICRU Report 96: Dosimetry-Guided Radiopharmaceutical Therapy. International Commission on Radiation Units and Measurements. 2021.
- Gear JI, et al. EANM practical guidance on uncertainty analysis for molecular radiotherapy absorbed dose calculations. Eur J Nucl Med Mol Imaging. 2018.
- Kletting P, et al. Molecular radiotherapy: the NUKFIT software for calculating the time-integrated activity coefficient. Med Phys. 2013.
- Lassmann M, Eberlein U. Radiation dosimetry aspects of radionuclide therapy. Front Med. 2014.
- Dewaraja YK, et al. MIRD Pamphlet No. 24: Guidelines for quantitative 131I SPECT in dosimetry applications. J Nucl Med. 2013.
- Garkavij M, et al. 177Lu-DOTATATE therapy in patients with disseminated neuroendocrine tumors: analysis of dosimetry with impact on future therapeutic strategy. Cancer. 2010.

7. Production and Safety of Radiopharmaceuticals

Objectives:
This course is designed to ensure students have advanced knowledge of radiopharmaceutical production and safety in nuclear medicine.

Syllabus:
1. Concept of radionuclide production and accelerators
2. Kinematics, production rates, cross-sections, saturation factors, and yields in radionuclide production
3. Targetry concept
4. Concept of planning and design of cyclotron facilities
5. Safety, decommissioning, and cyclotron laboratories
6. Hot cell design, shielding design, workflow, and PPE for cyclotron facilities
7. Outlining the QC area, radiopharmaceutical dispensing, and personnel
8. Types of cyclotron facilities: I-V
9. Quality management system for cyclotron facilities
10. Cyclotron acceptance testing
11. Cyclotron quality control testing
12. FDG synthesis stages
13. Cyclotron facility GMP
14. Cyclotron facility radiation protection

References :

- IAEA Technical reports series 471: Cyclotron produced radionuclide, guideline for setting up a facility
- IAEA Technical reports series 465: Cyclotron produced radionuclide, principle and practice