Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

Expected Implementation in Academic Year	AY2025-2026
Semester/Trimester/Others (specify approx. Start/End date)	Semester 1
Course Author * Faculty proposing/revising the course	Koh Wei Yang, Calvin (Dr), S.Somanesan, Tay Young Soon
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Course Title	Ionising Radiation-Based Imaging
Course Code	PH4610
Academic Units	3
Contact Hours	39
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	PH3301
Co-requisites	Nil
Pre-requisite to	Nil
Mutually exclusive to	Nil
Replacement course to	Nil
Remarks (if any)	

Course Aims

The main objective of the “Ionising radiation-based imaging” course is to give you a bachelor-level introduction to the application of ionizing radiations in biomedical imaging. The course surveys both major forms of ionizing radiation used in imaging: (1) electromagnetic waves used primarily in X ray and CT and (2) particle-based radiation used in nuclear medicine instruments such as gamma cameras, SPECT and PET. The course covers the physical and biological foundations, engineering solution, diagnostic and research applications of various imaging techniques, based on radiation. The course will cover the most common techniques in this field, including X-ray, CT, SPECT and PET, as well as hybrid imaging modalities. The theoretical bases of the study material will be given via lectures, tutorials and e-learning, whereas ample hands-on experience will also be provided for the various modalities.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Distinguish the difference between ionising and non-ionising radiation and calculate the probability of interactions of radiation
ILO 2	Evaluate the quality of medical images and improve contrast in images.
ILO 3	Describe the concept of Image Quality in Medical Imaging and be able to provide solutions to improve image quality.
ILO 4	Explain the principles of statistics and apply statistical methods to describe radiation.
ILO 5	Identify the components of x-ray system and explain the concept of X-ray Imaging.
ILO 6	Provide suggestions for clinical situations through the understanding of the principles and concept of Radiography.
ILO 7	Provide suggestions for clinical situations through the understanding of the principles and concept of Mammography.
ILO 8	Provide suggestions for clinical situations through the understanding of the principles and concept of Fluoroscopy.
ILO 9	Provide clinical input on the CT image quality through the understanding of the principles and concepts in Computed Tomography.
ILO 10	Provide suggestions for clinical situations through the understanding of the limitations of CT imaging and reconstruction techniques.
ILO 11	Explain the concept and the principles of image acquisition, processing and analysis.
ILO 12	Perform imaging dosimetry measurements in clinical situations.
ILO 13	Give an overview of pre-clinical imaging and how to operate a CT machine.
ILO 14	Explain and describe the errors in medical imaging and possess the ability to spot errors in clinical images.
ILO 15	Give an overview of imaging modalities used in medical imaging.
ILO 16	Provide suggestions for clinical situations through understanding the principles and concept of Nuclear Medicine Imaging.

ILO 17	Provide suggestions for clinical situations through understanding the basic concepts in radiochemistry.
ILO 18	Describe the principles and concept of various radiation detectors and suggest the correct detectors for different applications.
ILO 19	Provide suggestions for clinical situations through understanding the principles and concept of Single Photon Emission Computerised Tomography (SPECT).
ILO 20	Provide suggestions for clinical situations through understanding the principles and concept of Positron Emission Tomography (PET).
ILO 21	Explain the basics of radiobiology in Nuclear Medicine and evaluate the radiosensitivity of various organs.
ILO 22	Explain the principles of Internal Dosimetry for Radionuclide Therapy and perform dosimetry calculation.
ILO 23	Describe the principles and concept of Radiation Safety in Nuclear Medicine and able to suggest suitable safety measures.
ILO 24	Describe the principles and concept of Nuclear Medicine Quality Assurance and perform the quality assurance test.

Course Content

This course aims to cover imaging modalities based on ionising radiation from X-ray, CT, SPECT and PET. You will be taught from the fundamentals, such as the mathematical concept of how medical imaging works to the applications used clinically. This course surveys both major forms of ionizing radiation used in imaging: (1) electromagnetic waves used primarily in X-ray and CT and (2) particle-based radiation used in nuclear medicine instruments such as gamma cameras, SPECT and PET. They will also be taught the latest medical imaging techniques and the radiation safety aspects of ionising radiation-based imaging.

Reading and References (if applicable)

- Bushberg, J. T. (2020). *The Essential Physics of Medical Imaging Fourth Edition*. Wolters Kluwer/Lippincott Williams & Wilkins. (ISBN 978-1975167660)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Diagnostic Radiology Physics, Non-serial Publications , IAEA, Vienna (2014)
- David Gilmore (2022). Nuclear Medicine and Molecular Imaging Nineth Edition. ELSEVIER. (ISBN 9780323775502)
- INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Medicine Physics, Non-serial Publications, IAEA, Vienna (2014)
- Simon R. Cherry (2012) Physics in Nuclear Medicine (ISBN 978-1-4160-5198-5)
- Lecture notes

NOTE: The above readings comprise the foundational readings for the course and more up-to-date relevant readings will be provided when they are available.

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	1. Introduction. Structure and scope of the course. Lectures, tutorials, hands-on. Assignments and examinations. Course literature. 2. The history of ionising radiation-based imaging. 3. Physical basis: The physics of ionising radiation.	1	Lecture Notes	In-person	Classroom Lecture
2	4. Introduction to Medical Imaging 5. Medical Imaging Technology and Terminology 6. Image Quality 7. Counting Statistics	2, 3, 4	Lecture Notes	In-person	Classroom Lecture
3	8. ray Production, X-ray tubes and X-ray Generation 9. Diagnostic Radiology 10. Diagnostic Radiology 11. Mammography	5, 6, 7	Lecture Notes	In-person	Classroom Lecture

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
4	12. Fluoroscopy 13. Computed Tomography (CT) Generation 14. CT Hardware	8, 9	Lecture Notes	In-person	Classroom Lecture
5	15. CT Back-Projection Reconstruction – Sinogram 16. CT Back-Projection Reconstruction – Radon Transform	10, 11	Lecture Notes	In-person	Classroom Lecture + Tutorial 1
6	17. CT Back-Projection Reconstruction – Filtered-Back Projection/Convolution Back Projection 18. CT Back-Projection Reconstruction – Algebraic Reconstruction	10, 11	Lecture Notes	In-person	Classroom Lecture
7	19. Imaging Dosimetry 20. CT in Radiotherapy	12, 13	Lecture Notes	In-person	Classroom Lecture
8	Clinical Tutorial	12, 13, 15	IAEA Diagnostic Radiology Physics	In-person	Classroom Lecture + Tutorial 2

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
9	22. Errors in Imaging 23. Pre-clinical imaging: challenges, modalities, instrumentation, workflow, safety, research questions, interpretation 24. Dual Energy CT 25. Photon Counting CT	14, 15	Lecture Notes	In-person	Classroom Lecture
10	26. The history of nuclear tracer techniques and molecular 27. Molecular imaging modalities (ex vivo, imaging in vivo) 28. Radiation sources 29. Radionuclides decay 30. Radiochemistry: Radiotracers, radiopharmacons, radioligands, radiometabolites (including Radiochemistry: Foundations, safety, 11C, 18F and other radionuclides)	15, 16, 17	Lecture Notes	In-person	Classroom Lecture

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
11	31. Radiation Detectors: Gas-filled, semiconductor and scintillation 32. Radiation Detectors: Gas-filled, semiconductor and scintillation 33. Principles of SPECT and Hybrid Imaging – SPECT/CT, PET-CT and PET-MR (including Instrumentation: Gamma cameras, SPECT, PET and imaging method)	18, 19, 20	Lecture Notes	In-person	Classroom Lecture + Tutorial 3
12	34. Radiobiology in Nuclear Medicine: Interaction between radiation and living systems, cellular effects of radiation, special radiobiological considerations in targeted radionuclide therapy 35. Radiotracer distribution, metabolism and elimination 36. Internal Dosimetry for Radionuclide Therapy	21, 22	Lecture Notes	In-person	Classroom Lecture + Midterm

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
13	37. Radiation Safety in Nuclear Medicine 38. Nuclear Medicine Quality Assurance	23, 24	IAEA Diagnostic Radiology Physics	In-person	Clinical Tutorial - Visit to SGH Nuclear Medicine & Molecular Imaging

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures and Clinical Tutorials	The lectures aim at providing the students with basic information about the subject, but more importantly also a strong motivation to look into the detailed literature of the subject and to read the mandatory course literature, but also the relevant scientific literature available in the internet and in form of textbooks and scientific publications. A part of the teaching in this course is based on the laboratory visits and field experiments. The laboratory visit will take place in Singapore General Hospital where the students will get a first- hand experience on the operations of a preclinical and clinical imaging centre. Hands-on practicals: visits to NCCS, Nuclear Medicine SGH
Tutorial	The tutorials aim to assess the students understanding about the subject and determine the students' ability to explain technical knowledge. It also serves as a feedback to the instructors to emphasize on the areas where the students are lacking.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Test/Quiz(Midterm Test)	1-20	Not Applicable	20		Individual	Analytic	Relational
2	Continuous Assessment (CA): Others(Clinical Tutorial)	12-15, 23-24	Not applicable	10		Individual	Analytic	Relational
3	Continuous Assessment (CA): Assignment(Tutorial)	1-7, 8-11, 10-20	Not Applicable	10		Individual	Analytic	Multistructural
4	Summative Assessment (EXAM): Final exam()	All	Not Applicable	60		Individual	Analytic	Extended Abstract

Description of Assessment Components (if applicable)

Students will be given the tutorial questions at least 1 week before the tutorial week and they are required to submit the tutorial on the respective tutorial day (Week 5/8/11). The tutorial solution will be discussed on the tutorial day itself. Students will need to physically attend all clinical tutorial and Midterm test unless he/she are absence due to legitimate reason.

Formative Feedback

You will receive formative feedback through discussion within tutorial lessons.

Feedback is also given after the term test on the common mistakes and level of difficulty of the problems. Past exam questions and content of previous examiner's report will be discussed in lecture.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Communication	Intermediate
Creative Thinking	Intermediate
Curiosity	Advanced
Learning Agility	Advanced
Problem Solving	Advanced

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

You are expected to complete all assigned readings, activities, assignments, attend all classes punctually and complete all scheduled assignments by due dates. You are expected to take responsibility to follow up with assignments and course related announcements. You are expected to participate in all project critiques, class discussions and activities.

Policy (Absenteeism)

Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class (particularly the mid-terms), you must:
1. Send an email to the instructor regarding the absence.
2. Submit the Medical Certificate* or official letter of excuse to to your Home school.

* The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

There will not be any make-up test. In the event where student miss the midterm test with valid reasons, the total course marks would subsequently be rescaled to a base of 100%.

Policy (Others, if applicable)

Diversity and inclusion policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science.

It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences, and that honours your identities; including ethnicity, gender, socioeconomic status, sexual orientation, religion or ability.

To help accomplish this:

If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety disorder or social phobia;
If you feel like your performance in the class is being impacted by your experiences outside of class;
If something was said in class (by anyone, including the instructor) that made you feel uncomfortable;
Please speak to your teaching team, our school pastoral officer or a peer or senior (either in-person or via email) about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: using preferred pronouns and names; being respectful of others opinions and actively making sure all voices are being heard; and refraining from the use of derogatory or demeaning speech or actions.

All members of the class are expected to adhere to the NTU anti-harassment policy. if you witness something that goes against this or have any other concerns, please speak to your instructors or a faculty member.

Point-based marking (not rubric-based)