Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2024/25	**Semester**	1
Course Coordinator	Dinish U. S		
Course Code	PH3301		
Course Title	Introduction to Bioimaging and Biosensing Techniques		
Pre-requisites	Nil		
Mutually Exclusive	PH4607/CM4017 Biomedical Imaging & Sensing		
No of AUs	3 AU		
Contact Hours	Lectures and tutorials: 39 (27 hrs lecture and 12 hrs tutorials)		
Proposal Date	22 March 2024		

Course Aims

This foundational course aims to develop a basic understanding of core physics, engineering, basics of chemistry and related concepts including nanotechnology behind the cutting edge bioimaging and biosensing techniques for clinical diagnostics. Through this course, you will learn the fundamental theoretical background of these techniques. Further, you will be able to apply the basic knowledge of physics and engineering to understand the instrumentation of these biosensing and imaging modalities. As a result, you will understand how these techniques are applied to current common medical problems, which may eventually open up new doors to enormous possibilities in biomedical research and related industries that you may undertake in future. You will also be able to compare the merits and demerits of these techniques and how to select a particular technique for a specific application. You will also learn the latest development and research trends in this domain. This course comprises of 27 hours of lectures and 12 hours of tutorials and terms tests.

Intended Learning Outcomes (ILO)

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

1. Identify and discuss fundamental problems in biomedical imaging and sensing.
2. Describe the basic principles of biomedical imaging and sensing technologies and discuss the fundamental problems in biomedical imaging and sensing.
3. Apply the knowledge of physics and related concepts in engineering and chemistry to the solution of common problems in medical imaging and sensing.
4. Determine the merits and demerits in using a particular technique while tackling a specific biomedical imaging/sensing problem and propose a combination of the complementary techniques for the better outcome.
5. Analyse common healthcare problem from a physical science/engineering perspective and communicate and discuss possible solutions with healthcare stake holders such as patients, doctors, healthcare industry and policy makers.

Course Content

This course will give an overview of the cutting-edge medical imaging and bio-sensing techniques currently being developed, by giving special emphasis on the physics fundamentals for various system designs.

This course will be divided into two parts. First part will cover the concepts behind photonics-based biosensors and its real applications. In the second part, state of the art medical imaging techniques will be covered by introducing its basics followed by instrumentation and its real applications for

disease diagnosis and drug discovery. Finally, a comparative analysis of these techniques will be discussed.

Course Outline

I. Introduction

Introduction to properties of light, light as EM wave, absorption and scattering of light in tissues, basics of biophotonics, basics of biosensors, biomarkers, basics of biology and related terms.

II. Biosensors

- Fluorescence: basic concepts, fluorescence sensing systems, instrumentation, biosensing applications
- Raman scattering (RS) and Surface enhanced Raman scattering (SERS) spectroscopy- Basics of light scattering, origin of SERS, plasmonic materials and designs, SERS substrates, SERS active nanoparticles, SERS biosensors. RS and SERS for preclinical and clinical applications.
- Fiber optic biosensors: Physics of optical fibers, physics of light guidance, optical fiber as biosensor and endoscope, new class of fiber sensors and biosensing applications
- Diffuse optical spectroscopy and near infrared (NIR) spectroscopy-based techniques.

III. Bioimaging

A. Optical Techniques for Bioimaging

- Photoacoustic imaging (PAI): Introduction, physics of PAI, image formation, reconstriction, PAI systems, PA contrast agents, preclinical and clinical applications
- Optical coherence tomography (OCT): Introduction, physics and principle of OCT, instrumentation, system resolution, clinical applications
- Fluorescence based bioimaging, basics of optical microscopic techniques and applications.

B. Other Bioimaging Modalities

- Magnetic Resonance Imaging (MRI), basic physic concepts, nuclei spin in a magnetic field, principles, instrumentation, applications.
- Ultrasound Imaging (USI): Physics of USI, US generation and detection, instrumentation, US scanning schemes, applications
- Positron Emission Tomography (PET), Principles, instrumentation, PET tracers, imaging techniques, applications
- X-ray and Computed Tomography (CT): Principles, instrumentation, production of x-rays, CT basics and applications
- Comparison of various imaging modalities and multimodal imaging concepts
- Regulatory and safety considerations

Teaching Schedule

S/N	Topic	Lecture Hours	Tutorial Hours
1	Introduction	2	1
2	Biosensors	11	5
3	Optical bioimaging	7	3

4	Other common bioimaging modalities	7	3

Assessment (include both continuous and summative assessment)

Component	Course LO Tested	Weighting	Team / Individual	Assessment Rubrics
1. Final Examination	All	60%	Individual	Point-based marking (not rubric-based)
2. Continuous Assessment (CAs): Two mid-term tests	All	40%	Individual	Two mid-term tests (each with 20% weightage). Format similar to the final exam. Point-based marking (not rubric-based
Total		**100%**		

Formative feedback

Here are some ways through which you will receive feedback on your learning in this course:

1. The instructor will regularly seek your feedback about the course and contents and the way to improve it.
2. Based on the performance of students in tutorials and CAs, the instructor will offer suggestions and ways to improve.
3. During tutorials, you will be asked to solve problems/concept-oriented questions, which will help the instructor to gauge your understanding in the subject and hence doubts will be clarified accordingly.
4. At the end of every class, you will be given ~10-15 minutes to clarify your doubts and ask relevant questions related to topic.
5. To clear the doubts, instructor is open to keep a virtual session (via ZOOM) before 2 midterm tests and final examination.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lectures	1. Describe fundamental physical science theories, mathematical formulation in the field of biomedical imaging and sensing 2. Describe the physics/chemistry and engineering principles behind instrumentation of these techniques and schemes 3. Describe and analyze recent developments in research in the field of biomedical imaging and sensing

Tutorials	1. Apply learned scientific knowledge and its fundamentals to practical problems in biomedical imaging and sensing. 2. Design solutions to improve the quality and well beings of human life and promote awareness

Reading and References

1. 'Introduction to Biophotonics' by Paras N. Prasad (ISBN: 978-0-471-28770-4); Wiley (2003).
2. 'Biomedical Optics: Principles and Imaging' by L. V. Wang and H.-I Wu, (ISBN: 978-0-471-74304-0); Wiley (2007).
3. 'Principles of Fluorescence Spectroscopy' by Joseph. R. Lakowicz (ISBN: 978-0-387-31278-1); Springer (2006).
4. 'Frontiers in Biophotonics for Translational Medicine', Edited by Malini Olivo and U. S Dinish, Springer publisher (ISBN: 978-981-287-626-3); Springer (2015).
5. 'Principles of Surface Enhanced Raman Spectroscopy and Related Palsmonic Effects', E. C. Le Ru and P. B. Etchegoin (ISBN: 9780444527790); Elsevier (2008).
6. 'Medical Imaging Technology', Victor I Milka and Victor V Milka (ISBN: 9780124170216); Elsevier (2013).
7. 'Biomedical Imaging: Principles and Applications' Edited by Reiner Salzer (ISBN: 978-0-470-64847-6); Wiley (2012).
8. 'Biophotonics: Concepts to Applications' by Gerd Keiser, Springer Publisher, (ISBN: 978-981-10-0943-3); Springer (2016).
9. Lecture notes.

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

Course Policies and Student Responsibilities

1) General

You are expected to complete all tutorial before each class, attend all classes punctually. You are expected to take responsibility to follow up with course notes, and course related announcements for classes you have missed. You are expected to participate in all class discussions and activities.

2) 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 with medical certificate.
2. Submit the Medical Certificate* or official letter of excuse to your home school.
3. There are no make-up for midterm tests.

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

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.

Course Instructors

Instructors	Office Location	Phone	Email
Dinish U. S			dinish@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
Weekday evening (6.30 pm 9.30 pm)	Lecture and Tutorials	As described above	Lecture and tutorials
Week 1	Introduction	1, 2	Ref. books 1, 2 and 8, 9
Week 2-3	Fluorescence technique, instrumentation and biosensing	2, 3, 4, 5	Ref. books 3, 4, 9
Week 3-5	Raman scattering, SERS technique, instrumentation and biosensing. fiber optic biosensor	2, 3, 4, 5	Ref. books 4, 5, 9
Week 6	Mid-term test 1 Diffuse optical spectroscopy and near infrared (NIR) spectroscopy fiber optic biosensor	2, 3, 4, 5	Ref. books 1, 2, 8, 9
Week 7-10	Optical bioimaging techniques: Photoacoustic imaging, optical Coherence Tomography, Fluorescence and optical microscopy,	2, 3, 4, 5	Ref. books 1, 2, 3, 4, 8, 9

	multimodal imaging concepts		
Week 11	Mid-term test 2 Bioimaging using other (non-optical) modalities: magnetic resonance imaging and instrumentation	2, 3, 4, 5	Ref. books 6, 7, 9
Week 12	ultrasound imaging and positron emission tomography	2, 3, 4, 5	Ref. books 6, 7
Week 13	Xray and CT. Comparison of various imaging modalities and Regulatory and safety considerations	2, 3, 4, 5	Ref. books 4, 6, 7,