Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	AY1819	**Semester**	1
Course Coordinator	Asst. Prof (Adj) Dinish U. S		
Course Code	PH4607/ CM4017		
Course Title	Biomedical Imaging and Sensing		
Pre-requisites	PH2301 Physical Optics (for PHY) OR CM3041 Physical and Biophysical Chemistry 2 (For CHEM)		
No of AUs	3		
Contact Hours	39 (Lecture Hours: 27 hours, Tutorial Hours: 12 hours)		
Proposal Date	10 July 2018		

Course Aims

This course aims to develop a basic understanding of core physics and related concepts behind the cutting edge biosensing and bioimaging techniques. Further, you will be able to apply the basic knowledge of physics to understand the instrumentation of these biosensing and imaging modalities. Through this course, you will learn the fundamental theoretical background of these techniques. 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.

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. **Apply the** *knowledge of physics and* related concepts in engineering and chemistry to the solution of common problems in medical imaging and sensing
3. Determine the merits and demerits in using a particular technique while tackling a particular biomedical imaging/sensing problem and propose a combination of the complementary techniques for the better outcome
4. Analyse common healthcare problem from a physics/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 1: Introduction to biophotonics, properties of light, absorption and scattering of light in tissues, basics of bioimaging and sensing, basics of biology and terms

II. Biosensors

- Fluorescence: Basic physics concepts, fluorescence sensing systems, Instrumentation, Biosensing applications
- Raman scattering (RS) and Surface enhanced Raman scattering (SERS) spectroscopy- Introduction, 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.
- Surface Plasmon Resonance (SPR) sensors: Basics, physics of SPR. instrumentation, biosensing applications and new trends
- 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

III. Bioimaging

A. Optical Techniques for Bioimaging

- Photoacoustic imaging (PAI): Introduction, physics of PAI, image formation, 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 bioimaging: Imaging techniques, Instrumentation, applications
- Raman and SERS imaging: Fundamentals, imaging schemes, applications

B. Other Bioimaging Modalities

- Magnetic Resonance Imaging (MRI), Physics basics, 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

Teaching Schedule

S/N	Topic	Lecture Hours	Tutorial Hours
1	Introduction	3	1
2	Biosensors	10	4
3	Optical Bioimaging	8	4
4	Other Bioimaging modalities	6	3

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/Individual	Assessment Rubrics

1. Final Examination	Points 1, 2 and 3 in ILO	1. Competent, 2. Creative and 3. Communication	60%	Individual	• 2.5 hours closed book examination • Structured questions
2. Continuous Assessment 1 (CA1): Two mid-term tests	Points 1, 2 and 3, 4 in ILO	1. Competent, 2. Creative and 3. 3. Character	40%	Individual	Two mid-term tests similar to the format of the final exam
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, the instructor will offer suggestions and ways to improve.
3. During tutorials, you will be asked to solve problems, 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.

Learning and Teaching approach

Approach	How does this approach support you in achieving the learning outcomes?
Lecture	**1. Describe** *fundamental physics theories, mathematical formulation* in the field of biomedical imaging and sensing 2. Describe the physics and engineering principles behind instrumentation of these techniques and schemes **3. Describe** *recent developments in research* in the field of biomedical imaging and sensing
Tutorials	1. Apply learned scientific knowledge in physics and its fundamentals to practical problems in biomedical imaging and imaging 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.

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

Course Policies and Student Responsibilities

1) General

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

(2) Compulsory Assignments

You are required to submit compulsory assignments on their specified due dates. Assignments are meant to be a reflection of individual/group work (based on the project) and plagiarism is taken very seriously.

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. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email

Asst. Prof (Adj) Dinish U. S	No office in SPMS	Nil	dinish@ntu.edu.sg

Planned Weekly Schedule

Week	**Topic**	**Course LO**	**Readings/ Activities**
Preferably Monday morning (9 am-12 noon)	Lecture and Tutorials	As described above	Lecture and tutorials
Week 1	Introduction	1	Ref. books 1, 2 and 8
Week 2-3	Optical biosensing based fluorescence technique and instrumentation	2, 3, 4	Ref. books 3, 4
Week 4-5	Optical biosensing based Raman scattering, SERS technique and instrumentation	1, 2, 3, 4	Ref. books 4, 5
Week 6	Surface plasmon biosensor and fiber optic biosensor	1, 2, 3, 4	Ref. books 1, 2, 8
Week 7-10	Optical bioimaging techniques: optical Coherence Tomography, Fluorescence, Photoacoustics, Raman and SERS	1, 2, 3, 4	Ref. books 1, 2, 3, 4, 5, 8
Week 11	Bioimaging using other (non-optical) modalities: magnetic resonance imaging and instrumentation	1, 2, 3, 4	Ref. books 6, 7
Week 12	Bioimaging using other (non-optical) modalities: ultrasound imaging and positron emission tomography	1, 2, 3, 4	Ref. books 6, 7
Week 13	Bioimaging using other (non-optical) modalities: Xray and CT. Comparison of various modalities and Revision	1, 2, 3, 4	Ref. books 4, 6, 7,

Appendix 1: Assessment Criteria for Final Exam

By mark range

Marks	Criteria
> 90%	Demonstrates complete understanding of physics fundamentals of biosensing, and imaging, their practical applications and potential future advancements. They should be able to solve all mathematical problems related to the topic. Capable of applying these to potentially new problems in biomedicine
75% to 89%	Demonstrates excellent understanding of physics fundamentals of biosensing and imaging, their practical applications and potential future advancements. They should be able to solve most of the mathematical problems related to the topic.
65% to 74%	Demonstrates reasonable understanding of physics fundamentals of biosensing and imaging, their practical applications. They should be able to solve some of the mathematical problems related to the topic.
50% to 64%	Demonstrates only basic understanding of physics fundamentals of biosensing and imaging. Not very sure about their practical applications covered in the lecture. Experience significant difficult in combining ideas. They struggle to solve the mathematical problems related to the topic.
< 50%	Do not possess sufficient understanding of course content to answer basic questions that they have seen during lectures and tutorials.

Appendix 2: Assessment Criteria for Midterm test

By mark range

Marks	Criteria
> 90%	Demonstrates complete understanding of physics fundamentals of biosensing, and imaging, their practical applications and potential future advancements. They should be able to solve all mathematical problems related to the topic. Capable of applying these to potentially new problems in biomedicine
75% to 89%	Able to solve basic questions that test basic course knowledge. Able to extend these to study an entirely new research problem and deliver the solution to a problem they have not seen before. Exhibits partial success in describing the fully physical consequences of their solution.
65% to 74%	Able to solve most basic questions that test course knowledge. Makes a partial attempt in extending these ideas in an unfamiliar setting. Has trouble describing the physical consequences of their results
50% to 64%	Able to solve only most basic questions that test course knowledge. Has trouble in applying the ideas to unfamiliar settings, or interpreting their physical meaning.
< 50%	Unable to solve most of the basic questions that test course knowledge. Makes little or no attempt to extend these ideas to unfamiliar settings. Unable to interpret the physical meaning of their results.