MEDICAL IMAGING - 2024/5

Module code: PHY3045

Module Overview

The course will follow the historical development of the main medical imaging techniques.

The first part will consider, from a theoretical perspective, the fundamentals of X-ray image formation both in the planar modality and in the Computed Tomography modality. Elements of image processing and image reconstruction will be addressed.

The second will look at the physical principles and methods of Nuclear Medicine.

The third will look at the principles underlying the application of diagnostic ultrasound in medicine.

The fourth will consider Magnetic Resonance Imaging (MRI), one of the most important techniques of medical imaging used in hospitals today.

In parallel to the related theoretical classes, laboratory experiments will be carried out on X-ray imaging and ultrasound.

Module provider

Mathematics & Physics

Module Leader

PANI Silvia (Maths & Phys)

Number of Credits: 15

ECTS Credits: 7.5

Framework: FHEQ Level 6

Module cap (Maximum number of students): 40

Overall student workload

Independent Learning Hours: 79

Lecture Hours: 11

Tutorial Hours: 13

Laboratory Hours: 14

Guided Learning: 11

Captured Content: 22

Module Availability

Semester 2

Prerequisites / Co-requisites

None.

Module content

Indicative content includes:

LECTURES:

Introduction to Medical Imaging: modalities and applications; basic elements of image quality assessment.

Mathematics of Imaging: Fourier transform and convolution.

X-ray Projection Imaging Systems: origins of contrast in X-ray imaging; the effect of source and detector on image quality; Nyquist's sampling theorem; medical X-ray system design and applications

Introduction to X-ray Computed Tomography: the evolution of transmission X-ray CT imaging systems; image reconstruction from projections; Radon Transform; filtering in the frequency domain and in the space domain; applications.

Introduction to Nuclear Medicine: basic principles; production of isotopes for Nuclear Medicine; the gamma camera; emission tomographies: SPECT and PET.

Introduction to Ultrasound: basic principles; interaction of ultrasound with matter; reflection coefficients; practical ultrasound imaging (time gain compensation, beam steering, Doppler imaging); applications.

Introduction to MRI: spin quantisation and magnetic moment; radiofrquency excitation and free induction decay; Fourier transform relationship; complex representation of the magnetisation vector, T1 , T2, T2* the Bloch equations; gradients and the idea of a "positional spectrum"; frequency and phase encoding; MRI sequences; applications.

LABORATORY EXPERIMENTS:

X-ray imaging modelling sessions: Planar versus Computed Tomography imaging; Parameters affecting image quality and detail visibility; Receiver Operating Characteristic curves.

Ultrasound Imaging: Design project involving the following topics, or related ones: design and characterisation of tissue equivalent materials; design and characterisation of a blood-equivalent fluid; design and characterisation of a resolution phantom.

Assessment pattern

Assessment type	Unit of assessment	Weighting
Coursework	X-ray modelling report	15
Oral exam or presentation	Ultrasound presentation	15
Examination	End of Semester Examination (2 hours)	70

Alternative Assessment

Alternative assessment: If a student is unable to attend the ultrasound laboratory sessions an alternative individual experiment will be arranged for them.

Assessment Strategy

The assessment strategy is designed to provide students with the opportunity to demonstrate their understanding of the importance of different parameters on image quality for various modalities, their knowledge of the functioning of the components of the imaging systems for each modality, and their capability for interpreting their result in the context of the underpinning theory and of the limitations of the instrumentation used.

They will be also provided with the opportunity to demonstrate their capability for communicating their results and observations in a scientific report and in a presentation.

Thus, the summative assessment for this module consists of:

- A report, on one experiment on X-ray imaging.
- A presentation, on the ultrasound project.
- A written examination of 2h duration with a section of short compulsory questions, and a section of longer questions with a choice of 2 out of 3.

Formative assessment

Non-marked problems will be provided for discussion during tutorials; mock exam papers will be provided for students to attempt individually and the opportunity to get feedback on such papers will be offered.

Feedback

During laboratory sessions, students will be given verbal feedback on their work.

Module aims

- Provide the student with the theoretical skills necessary to understand the physics and also essential aspects of signal processing underpinning the formation of diagnostic imaging systems; to provide an understanding of the elementary aspects of X-ray planar and CT imaging, Nuclear Medicine, Magnetic Resonance Imaging and Ultrasound.
- Give the students experience of handling imaging instrumentation and of analysing imaging data.

Learning outcomes

		Attributes Developed
1	Illustrate the key concepts of projection imaging, computed tomography and elementary image processing in the two conjugate domains	KC
2	Describe from first principles the way in which image signals are acquired and manipulated and interpret the effect of different parameters on image quality	K
3	Identify the main elements of the imaging systems for the different modalities and the role of the different components	KC
4	Compare the different mechanisms of image contrast in the different modalities and thus recognise the most appropriate applications of the different modalities, as well as their advantages and limitations .	KC
5	Critically apply their theoretical knowledge to the use of lab equipment and to the analysis of imaging data	CPT
6	Appraise the applicability of the different medical imaging techniques	KCT

Attributes Developed

C - Cognitive/analytical

K - Subject knowledge

T - Transferable skills

P - Professional/Practical skills

Methods of Teaching / Learning

The learning and teaching strategy is designed to:

Give the students an understanding of the physical principles and practical constraints for the main clinically established medical imaging applications, with particular emphasis on the factors affecting image quality.

The learning and teaching methods include:

- pre-recorded lectures.
- Weekly lectures and tutorials (typically in two-hour sessions, each including recap of the recording, Q&A and problem solving)
- Computer modelling and laboratory classes

Indicated Lecture Hours (which may also include seminars, tutorials, workshops and other contact time) are approximate and may include in-class tests where one or more of these are an assessment on the module. In-class tests are scheduled/organised separately to taught content and will be published on to student personal timetables, where they apply to taken modules, as soon as they are finalised by central administration. This will usually be after the initial publication of the teaching timetable for the relevant semester.

Reading list

https://readinglists.surrey.ac.uk
Upon accessing the reading list, please search for the module using the module code: PHY3045

Other information

The module is open to FHEQ Level 6 students on all Physics programmes and on the Biomedical Engineering MEng.

The maximum number of students on the module is set to 40, with priority given to Physics students.

This module has a capped number and may not be available to ERASMUS and other international exchange students. Please check with the International Engagement Office email: ieo.incoming@surrey.ac.uk

The School of Mathematics and Physics is committed to developing graduates with strengths in Employability, Digital Capabilities, Global and Cultural Capabilities, Sustainability, and Resourcefulness and Resilience. This module is designed to allow students to develop knowledge, skills, and capabilities in the following areas:

Digital capabilities: The module includes a series of computer modelling sessions, each focussing on a different aspect of X-ray imaging. Students will then use their computing skills to analyse and present their data.

Resourcefulness and Resilience: For their ultrasound projects, the students will use their problem solving, experimental and design skills to address a challenge in ultrasound imaging. The projects are open-ended, and students are expected to contribute their own ideas and research possible solutions independently.

Employability: the module focuses on imaging modalities in use in standard clinical practice, thus giving students an understanding of real-life scenarios that will prepare them well for a career in the healthcare or in industry. The assessments (a report and a presentation) will enhance their transferable skills.

Sustainability: a recurring theme in the module is the practical viability of each imaging modality, in the context of effectiveness, availability of materials (e.g., helium for cooling superconductive magnets) as well as clinical workflow and costs.

Programmes this module appears in

Programme	Semester	Classification	Qualifying conditions
Biomedical Engineering BEng (Hons)	2	Optional	A weighted aggregate mark of 40% is required to pass the module
Biomedical Engineering MEng	2	Optional	A weighted aggregate mark of 40% is required to pass the module
Mathematics and Physics BSc (Hons)	2	Optional	A weighted aggregate mark of 40% is required to pass the module
Mathematics and Physics MMath	2	Optional	A weighted aggregate mark of 40% is required to pass the module
Mathematics and Physics MPhys	2	Optional	A weighted aggregate mark of 40% is required to pass the module
Physics BSc (Hons)	2	Optional	A weighted aggregate mark of 40% is required to pass the module

Programme	Semester	Classification	Qualifying conditions
Physics with Astronomy BSc (Hons)	2	Optional	A weighted aggregate mark of 40% is required to pass the module
Physics with Nuclear Astrophysics BSc (Hons)	2	Optional	A weighted aggregate mark of 40% is required to pass the module
Physics with Quantum Computing BSc (Hons)	2	Optional	A weighted aggregate mark of 40% is required to pass the module