Engineering Specialization Biomedical Imaging and Sensing
FROM 2017 ONWARDS
In 2017, four biomedical engineering subjects will be introduced as electives in the existing curriculum. The package of four units will constitute a **Specialisation in Biomedical Imaging and Sensing.**

**COURSE AIM AND CONTENT**

The Specialization in Biomedical Imaging and Sensing aims at providing the student with a comprehensive understanding and competency in contemporary medical imaging and biomedical sensing technologies from the acquisition to the formation, interpretation and analysis of biomedical signals and images.

The essence of biomedical imaging and sensing lies in the interaction and/or emanation of different forms of energy from the human body which can be acquired in the form of electrical signals. The underlying state of the body, 'diseased' or 'healthy', is reflected in changed patterns of the acquired signals which can be further processed or transformed into images that help the physician to extract relevant clinical information.

Biomedical Imaging and Sensing has transformed medicine in how physicians detect, stage or treat disease and plays a front role in an emerging era of personalized medicine. Biomedical imaging also provides clinical researchers with an important analytic tool to observe and study how diseases emanate and progress.

While this program draws on general physics and engineering principles, it is distinct in its application to living organisms as opposed to the technical world. In addition to a profound understanding of the underlying physics principles, the program also aims at empowering student with a basic understanding of human physiology in order to better understand clinical needs, and to be able to provide adequate engineering solutions in healthcare.

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**LEARNING OUTCOMES**

By the end of the specialization program, it is anticipated that the student should be able to:

- Demonstrate a profound understanding of elementary life science concepts;
- Apply underlying physics, mathematics and engineering principles to contemporary medical imaging and sensing problems;
- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare professionals.
stakeholders (patients and patient organizations, clinicians, government policy makers, healthcare industry);

**PROGRAM IN A GLIMPSE**

**ELEC215**  
BIOMEDICAL ENGINEERING FUNDAMENTALS

With this unit of study, we aim at providing a basic understanding of human physiology with an emphasis on the human body that can be described as an ensemble of interacting systems. After a brief introduction of the major physiological systems, we will discuss the physiological models from an engineering point-of-view. This involves quantitative mechanical analysis, flow dynamics, heat and mass transport and electrical analysis. In addition, an overview of pharmacokinetic models will be discussed. Finally, it will be demonstrated how analytical and/or numerical modelling can help in obtaining a better understanding of disease progression and treatment response.

The unit focuses on the integration of fundamental knowledge of mathematics and physics acquired in the first year of a standard science and engineering discipline into the description of human physiology. Many engineering concepts (such as systems thinking approach, feedback mechanisms, control systems, etc.) are aligned with typical engineering concepts also present in other streams of engineering where they are applied to the material non-living world. Social and ethical implications of healthcare will be touched upon during lectures and will be part of open group discussions during practical sessions.

The unit consists of three major modules:

In a first module, an overview of physiological dynamics will be provided against a background of structural components from biological cells and tissues to organs.

In a second module, major physiological systems will be explained such as the cardiovascular (circulatory) system, the respiratory system, the nervous system, the endocrine and urinary system, the sensory (auditory, visual, olfactory) system, the skeletal and muscular system. The physiological systems will be discussed from an engineering point-of-view with an emphasis on numerical modelling. This involves quantitative mechanical analysis, flow dynamics, heat and mass transport and electrical analysis.

The third module will focus on pharmacokinetic modelling, i.e. how the uptake, distribution and excretion of exogenous substances can be modelled using differential equations. Finally, it will be shown how a multiscale model can be used to model cancer progression.

The theory of physiological systems will be tested in practice through practical sessions which involve fluorescence microscopy and measurements of physiological signals with an eHealth arduino module, Doppler ultrasound scanning, electroencephalogram (EEG) and numerical modelling in Matlab.
Prerequisites for the unit ELEC215 are first year mathematics and physics subjects: MATH133 (or MATH136), PHYS106 (or PHYS140) and the co-requisite MATH235.

**ELEC316**  
**MEDICAL IMAGING SYSTEMS I**

Medical imaging methods will be discussed from the point of view of the physical mechanisms, the instrumentation (hardware and software) and the medical applications. Health and safety aspects of the imaging technologies will also be discussed. The techniques that will be discussed are the main medical imaging technologies such as:

- X-ray radiography, angiography and mammography
- X-ray computed tomography (CT)
- Magnetic Resonance Imaging (MRI)
- Diagnostic Ultrasound
- Nuclear Medicine: Scintigraphy, SPECT and PET
- Other experimental imaging techniques: Electrical Impedance Tomography (EIT), Photo-acoustic imaging, terahertz imaging, infrared imaging, diffuse optical tomography.

Practical sessions involve hands-on experimentation with demonstration tools for X-ray radiography, CT, Ultrasound and MRI in a clinical and laboratory setting. Exercises involve numerical calculations of signal magnitudes and estimates of signal-to-noise ratios.

Prerequisites for the unit ELEC316 are having completed the unit ELEC215 and second year subjects MATH235 and ELEC270 or PHYS201.

**ELEC317**  
**MEDICAL IMAGE AND SIGNAL PROCESSING**

In 'medical image and signal processing', mathematical techniques used for image analysis, image reconstruction, image improvement, information extraction and data storage will be discussed.

The unit consists of four modules:

The focus of the first module is on medical image and signal quality and information metrics. In a second module, image reconstruction methods are discussed such as filtered back projection, iterative image reconstruction, Fast Fourier Transform, inverse transport equations and compressed sensing. The third module focuses on image and signal improvement techniques such as noise reduction and filtering, deblurring, grey level renormalization, artifact compensation techniques and image deformation compensation. In a fourth module, methods for extracting image information will be discussed such as segmentation, registration, statistical analysis,
texture analysis, image based physiological modelling
Finally some advanced methods such as high performance computing and 3D and 4D medical visualization and virtual reality will be discussed as well as concepts of big data analysis and medical image storage and management.

Practical sessions involve the use of image visualization and reconstruction software and writing snippets of image processing software in Matlab.

Prerequisites for the unit ELEC317 are having completed the second year mathematics subject MATH235 and the biomedical unit ELEC215.

The aim of the course is to provide a comprehensive introduction to the physics of MRI. The course will cover the basic physics of nuclear magnetization and nuclear magnetic resonance, image formation, the hardware components of an MRI scanner, safety and health aspects of MRI scanning and advanced research techniques such as diffusion MRI, functional MRI, multi-nuclear MRI and hyperpolarized MRI.

Hands-on imaging experiments will be conducted on an experimental MRI scanner. Practical sessions also involve exercises on MRI pulse sequences and RF coil design. Practical sessions will involve numerical exercises, hands-on experiments, problem solving and some literature study. Ethical implications and social aspects of medical imaging will be addressed and discussed.

ELEC418
MEDICAL IMAGING SYSTEMS II

In the capstone unit ‘Medical Imaging Systems II’ we will focus on Magnetic Resonance Imaging (MRI), one of the technologically most challenging medical imaging technologies. Magnetic Resonance Imaging (MRI) is a powerful medical imaging technique which is nowadays routinely applied in all major hospitals. A well-known advantage of MRI is its superior soft tissue contrast and its harmless character. Since its invention, MRI technology has known an enormous expansion both conceptual as with respect to the hardware. This evolution has enabled quantitative mapping of different microstructural and physiological properties non-invasively. MRI comprises a growing field of multi-disciplinary research that involves physics, chemistry, biology, engineering, computational modelling, image processing and medicine.
This unit is a capstone unit for which the following units need to be completed: ELEC316, ELEC275 (or PHYS201) and PHYS202.

POSTGRADUATE RESEARCH
There are many opportunities for postgraduate research in the field of biomedical imaging and sensing. Please visit our website for more information on our research topics. Google: “Biomedical Imaging and Sensing Group MQ”

COURSE COORDINATOR
Yves De Deene is a professor of Biomedical Engineering who joined Macquarie University in 2014. He started his academic career at the Ghent University in Belgium where he worked as a medical physics researcher at the Ghent University Hospital in the field of radiotherapy and medical imaging. At the Ghent University, he also the group leader of an MRI physics research team with a focus on quantitative MRI. His primary research interest is in safeguarding modern radiotherapy and improving quantitative magnetic resonance imaging (MRI) for the guidance of radiation treatment of cancer patients. He is an Honorary Associate Professor at the University of Sydney and has affiliations with the Ingham Institute – Liverpool Hospital and Macquarie Medical Imaging which is hosted in the Macquarie University Hospital. He collaborates with several medical centers in Sydney.

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Hyperpolarizd MRI gas generator under construction at the Biomedical Engineering lab (Macquarie University).