ELEC418

Advanced Medical Imaging Systems

S1 Day 2019

School of Engineering

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General Information

Unit convenor and teaching staff
Unit Convenor - Lecturer
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Credit points
3

Prerequisites
ELEC316 and (ELEC275 or PHYS201) and PHYS202

Corequisites

Co-badged status

Unit description
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 and in hardware development. 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. 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. Finally, other experimental imaging techniques such as electrical impedance tomography (EIT), photo-acoustic imaging, Terahertz imaging, infrared (IR) imaging and diffuse optical tomography (DOT) will be discussed.

Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://www.mq.edu.au/study/calendar-of-dates

Learning Outcomes

On successful completion of this unit, you will be able to:

Demonstrate a solid understanding of the physical principles behind nuclear magnetic resonance (NMR)

Demonstrating a clear understanding of image formation and analyse an MRI pulse sequence

Ability to construct a basic radio-frequency (RF) MRI coil and associated hardware

Able to perform quality assurance of MRI and recognize image artifacts

Explain differences between contrast weighted images and quantitative images and compare novel medical imaging techniques

General Assessment Information

Notifications

Formal notification of assessment tasks, grading rubrics and due dates will be posted on iLearn. Although all reasonable measures to ensure the information is accurate, the University reserves the right to make changes without notice. Each student is responsible for checking iLearn for changes and updates.

Weekly Plan

A weekly plan of lectures, assignments, tests, laboratory and workshop sessions will be posted on iLearn. Students are expected to be aware of possible minor variations.

Assignment Tasks

Assignment questions will be posted on iLearn. Assignment solutions will be posted within one to five days after the submission date. Submissions will not be accepted once the solution is posted.

All assignments must be submitted electronically through iLearn (in pdf format). Submissions are expected to be typed in a logical layout and sequence. Markers WILL NOT grade poorly organized or illegible scans or drafts. Illegible scans or drafts are assignments that are handwritten or digital photographed with for example a smartphone. The expected workload includes preparation of final copies and clear diagrams. Resubmissions will be permitted up to due date.

All assignments should be prepared individually. It is expected that students consult tutors, lecturers or other students while learning the concepts, but copying assignments from others is not accepted. Students are expected to have read and understood the academic honesty policy.

Absences

Late notices or absences from tests, workshops and laboratories will be considered under extenuating circumstances upon lodgement and approval of a formal notice of disruption of studies.

Grading

To obtain a passing grade (P/CR/D/HD) a total mark of 50% or more is required AND a mark of 50% or more is required for the final examination. The final exam is a hurdle requirement because it is the only reliable assessment of individual performance for this unit. A passing grade of 50% or more in the final examination is a condition of passing this unit. Students who make a serious attempt but fail to meet the hurdle requirement will be given one further opportunity to pass. A serious attempt is defined as achievement of a mark of 40% or greater.

Assessment Tasks

Name	Weighting	Hurdle	Due
NMR laboratory	10%	No	Week 3
MRI acquisition	10%	No	week 6
MRI hardware	10%	No	week 8
Literature study	15%	No	week 10
Exam	55%	Yes	week 14-16

NMR laboratory

Due: **Week 3**
Weighting: **10%**

NMR spectroscopy and relaxometry experiments will be conducted in the laboratory on self-made phantoms and a biological sample.

- Samples will be prepared in the wet lab.

- NMR spectra will be acquired on a 9.4 T NMR spectrometer and T1 and T2 relaxation curves will be acquired on a 0.5 T NMR relaxometer at different temperatures.

- The findings will be explained using the lecture material.

On successful completion you will be able to:

- Demonstrate a solid understanding of the physical principles behind nuclear magnetic resonance (NMR)

MRI acquisition

Due: **week 6**
Weighting: **10%**

Numerical exercises on image formation will be solved which demonstrate the relation between imaging parameters on image properties such as the field-of-view, slice thickness and resolution.

This is a written exercise. Worked out solutions will be submitted as a written report.

On successful completion you will be able to:

- Demonstrate a solid understanding of the physical principles behind nuclear magnetic resonance (NMR)
- Demonstrating a clear understanding of image formation and analyse an MRI pulse sequence
- Able to perform quality assurance of MRI and recognize image artifacts
- Explain differences between contrast weighted images and quantitative images and compare novel medical imaging techniques

MRI hardware

Due: **week 8**
Weighting: **10%**

A high frequency radio-frequency coil will be constructed using the theory provided in the lecture. The RF coil will be provided with a tuning and matching circuit and the coil will be tuned for 1H proton MRI and matched to a 50 Ohm impedance.

The B1-field homogeneity of the RF coil will be acquired using a small loop pick-up coil.

The results will be reported in a short lab report.

On successful completion you will be able to:

- Demonstrate a solid understanding of the physical principles behind nuclear magnetic resonance (NMR)
- Ability to construct a basic radio-frequency (RF) MRI coil and associated hardware

Literature study

Due: **week 10**
Weighting: **15%**

An MRI review research paper will be selected, analyzed and discussed in the form of a short essay and will be discussed in-class.

On successful completion you will be able to:

- Demonstrate a solid understanding of the physical principles behind nuclear magnetic resonance (NMR)
- Demonstrating a clear understanding of image formation and analyse an MRI pulse sequence
- Able to perform quality assurance of MRI and recognize image artifacts
- Explain differences between contrast weighted images and quantitative images and compare novel medical imaging techniques

Exam

Due: **week 14-16**
Weighting: **55%**
This is a hurdle assessment task (see assessment policy for more information on hurdle assessment tasks)

The exam will consist of two parts:

- The first part (1 hour) is with closed book where general knowledge will be assessed
- The second part (2 hours) is with open book where the ability to apply knowledge on real world problems is assessed.

On successful completion you will be able to:

- Demonstrate a solid understanding of the physical principles behind nuclear magnetic resonance (NMR)
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Delivery and Resources

Delivery of this course is through a series of 13 theoretical lectures of 2 hours each and a series of practical sessions / tutorials.

The theoretical lecture series consist of 3 modules:

1. Nuclear magnetization, NMR signal formation and relaxation
2. MRI image formation
3. Advanced MRI applications: Quantitative and functional MRI

The practical sessions involve hands-on experimentation on an NMR spectrometer, an earth filed

MRI system, an NMR relaxometer and a whole body clinical MRI scanner (after hours). MRI hardware components will be build in the MRI research laboratory.

Tutorials are designed around numerical exercises on image formation and image contrast. Students will also have the ability to present and discuss a literature study (one review paper) during the tutorials.

Technology used and required

- Word processing (MS Word, Latex, ...)
- Matlab (can be downloaded from the university depositories)
- Image visualization software (3DSlicer)
- Electronics bench (research and teaching laboratories)
- Powerpoint (or alternative presentation software (e.g. SliTex))
- Library and Internet search engines

Syllabus

De Deene Y, Magnetic Resonance Imaging - From Basic Principles to Advanced Techniques (A Biomedical Engineering Perspective)

Recommended books (optional)

- Haacke E M et al, Magnetic Resonance Imaging - Physical Principles and Sequence Design
- Bernstein M A et al, Handbook of MRI Pulse Sequences
- Tofts P, Quantitative MRI of the Brain - Measuring Changes caused by Disease
- Jin J, Electromagnetic Analysis and Design in Magnetic Resonance Imaging
- Levitt M H, Spin Dynamics - Basics of Nuclear Magnetic Resonance

Unit Schedule

Unit Schedule

Week	Lecture	Practical session / tutorial	Assignments
Module 1	***Nuclear magnetization***		
1	Introduction to quantum mechanics (QM)		
2	Nuclear magnetism: A classical and QM model	Problem solving: written exercises	
3	Nuclear spin interactions	Laboratory: NMR spectroscopy	NMR laboratory

Week	Lecture	Practical session / tutorial	Assignments
4	Relaxation mechanisms	Laboratory: NMR relaxometry	
Module 2	***MRI image formation***		
5	MR imaging principles	Problem solving: written exercises	
6	MRI hardware 1	Visit and exercise on clinical MRI scanner (MQ hospital)	MRI acquisition
7	MRI hardware 2	Laboratory: NMR RF coil fabrication - tuning and matching	
8	MRI safety and potential health effects	Laboratory: Low field MRI designs	MRI hardware
9	MRI sequence design 1	Problem solving: written exercises	
10	MRI sequence design 2	Problem solving: written exercises	Literature study
Module 3	***Advanced MRI applications***		
11	Quantitative MRI	Literature study: in-class critical discussion	
12	Functional MRI	Seminar by MRI researcher(s)	
13	Functional MRI	Tutorial: Questions and Answers	

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central (https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central). Students should be aware of the following policies in particular with regard to Learning and Teaching:

- Academic Appeals Policy
- Academic Integrity Policy
- Academic Progression Policy
- Assessment Policy
- Fitness to Practice Procedure
- Grade Appeal Policy
- Complaint Management Procedure for Students and Members of the Public
- Special Consideration Policy *(**Note:** The Special Consideration Policy is effective from 4 December 2017 and replaces the Disruption to Studies Policy.)*

Undergraduate students seeking more policy resources can visit the Student Policy Gateway (https://students.mq.edu.au/support/study/student-policy-gateway). It is your one-stop-shop for the

key policies you need to know about throughout your undergraduate student journey.

If you would like to see all the policies relevant to Learning and Teaching visit Policy Central (https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central).

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/study/getting-started/student-conduct

Results

Results published on platform other than eStudent, (eg. iLearn, Coursera etc.) or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au or if you are a Global MBA student contact globalmba.support@mq.edu.au

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to improve your marks and take control of your study.

- Workshops
- StudyWise
- Academic Integrity Module for Students
- Ask a Learning Adviser

Student Services and Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

Student Enquiries

For all student enquiries, visit Student Connect at ask.mq.edu.au

If you are a Global MBA student contact globalmba.support@mq.edu.au

IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.

Graduate Capabilities

Creative and Innovative

Our graduates will also be capable of creative thinking and of creating knowledge. They will be imaginative and open to experience and capable of innovation at work and in the community. We want them to be engaged in applying their critical, creative thinking.

This graduate capability is supported by:

Learning outcomes

- Ability to construct a basic radio-frequency (RF) MRI coil and associated hardware
- Explain differences between contrast weighted images and quantitative images and compare novel medical imaging techniques

Assessment tasks

- MRI hardware
- Literature study

Capable of Professional and Personal Judgement and Initiative

We want our graduates to have emotional intelligence and sound interpersonal skills and to demonstrate discernment and common sense in their professional and personal judgement. They will exercise initiative as needed. They will be capable of risk assessment, and be able to handle ambiguity and complexity, enabling them to be adaptable in diverse and changing environments.

This graduate capability is supported by:

Learning outcomes

- Ability to construct a basic radio-frequency (RF) MRI coil and associated hardware
- Able to perform quality assurance of MRI and recognize image artifacts
- Explain differences between contrast weighted images and quantitative images and compare novel medical imaging techniques

Assessment tasks

- NMR laboratory
- MRI hardware
- Literature study

Commitment to Continuous Learning

Our graduates will have enquiring minds and a literate curiosity which will lead them to pursue knowledge for its own sake. They will continue to pursue learning in their careers and as they participate in the world. They will be capable of reflecting on their experiences and relationships

with others and the environment, learning from them, and growing - personally, professionally and socially.

This graduate capability is supported by:

Learning outcomes

- Ability to construct a basic radio-frequency (RF) MRI coil and associated hardware
- Able to perform quality assurance of MRI and recognize image artifacts
- Explain differences between contrast weighted images and quantitative images and compare novel medical imaging techniques

Assessment tasks

- NMR laboratory
- Literature study

Discipline Specific Knowledge and Skills

Our graduates will take with them the intellectual development, depth and breadth of knowledge, scholarly understanding, and specific subject content in their chosen fields to make them competent and confident in their subject or profession. They will be able to demonstrate, where relevant, professional technical competence and meet professional standards. They will be able to articulate the structure of knowledge of their discipline, be able to adapt discipline-specific knowledge to novel situations, and be able to contribute from their discipline to inter-disciplinary solutions to problems.

This graduate capability is supported by:

Learning outcomes

- Demonstrate a solid understanding of the physical principles behind nuclear magnetic resonance (NMR)
- Demonstrating a clear understanding of image formation and analyse an MRI pulse sequence
- Ability to construct a basic radio-frequency (RF) MRI coil and associated hardware
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Assessment tasks

- NMR laboratory
- MRI acquisition
- MRI hardware
- Literature study

- Exam

Critical, Analytical and Integrative Thinking

We want our graduates to be capable of reasoning, questioning and analysing, and to integrate and synthesise learning and knowledge from a range of sources and environments; to be able to critique constraints, assumptions and limitations; to be able to think independently and systemically in relation to scholarly activity, in the workplace, and in the world. We want them to have a level of scientific and information technology literacy.

This graduate capability is supported by:

Learning outcomes

- Demonstrate a solid understanding of the physical principles behind nuclear magnetic resonance (NMR)
- Demonstrating a clear understanding of image formation and analyse an MRI pulse sequence
- Ability to construct a basic radio-frequency (RF) MRI coil and associated hardware
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Assessment tasks

- NMR laboratory
- MRI acquisition
- MRI hardware
- Literature study

Problem Solving and Research Capability

Our graduates should be capable of researching; of analysing, and interpreting and assessing data and information in various forms; of drawing connections across fields of knowledge; and they should be able to relate their knowledge to complex situations at work or in the world, in order to diagnose and solve problems. We want them to have the confidence to take the initiative in doing so, within an awareness of their own limitations.

This graduate capability is supported by:

Learning outcomes

- Demonstrate a solid understanding of the physical principles behind nuclear magnetic resonance (NMR)
- Demonstrating a clear understanding of image formation and analyse an MRI pulse sequence

- Ability to construct a basic radio-frequency (RF) MRI coil and associated hardware
- Able to perform quality assurance of MRI and recognize image artifacts
- Explain differences between contrast weighted images and quantitative images and compare novel medical imaging techniques

Assessment tasks

- NMR laboratory
- MRI acquisition
- MRI hardware
- Literature study
- Exam

Effective Communication

We want to develop in our students the ability to communicate and convey their views in forms effective with different audiences. We want our graduates to take with them the capability to read, listen, question, gather and evaluate information resources in a variety of formats, assess, write clearly, speak effectively, and to use visual communication and communication technologies as appropriate.

This graduate capability is supported by:

Learning outcome

- Explain differences between contrast weighted images and quantitative images and compare novel medical imaging techniques

Assessment task

- Literature study

Engaged and Ethical Local and Global citizens

As local citizens our graduates will be aware of indigenous perspectives and of the nation's historical context. They will be engaged with the challenges of contemporary society and with knowledge and ideas. We want our graduates to have respect for diversity, to be open-minded, sensitive to others and inclusive, and to be open to other cultures and perspectives: they should have a level of cultural literacy. Our graduates should be aware of disadvantage and social justice, and be willing to participate to help create a wiser and better society.

This graduate capability is supported by:

Learning outcome

- Explain differences between contrast weighted images and quantitative images and compare novel medical imaging techniques

Assessment task

- Literature study

Socially and Environmentally Active and Responsible

We want our graduates to be aware of and have respect for self and others; to be able to work with others as a leader and a team player; to have a sense of connectedness with others and country; and to have a sense of mutual obligation. Our graduates should be informed and active participants in moving society towards sustainability.

This graduate capability is supported by:

Assessment task

- Literature study

Changes from Previous Offering

This is the first offering of this course.