ELEC ENG 4BF4
Medical Imaging

Winter 2018
Course Outline

CALENDAR/COURSE DESCRIPTION

Physical principles of medical image acquisition and formation; post-processing for magnetic resonance imaging and spectroscopy; comparisons to other medical imaging modalities.

PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): EE-2FH3 (Electromagnetics-I), EE-3TP4 (Linear Systems and Control); and registration in Biomedical and Electrical Engineering Level IV, or permission of the instructor.

SCHEDULE

Lectures:	Tuesdays 7:00-10:00pm, ETB-228
Labs:	Thursdays 3:00-6:00pm or 7:00-10:00pm (see below for locations)
Tutorial:	Mondays 1:30-2:20pm, ETB-224

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. Michael Noseworthy, PhD, PEng

→ Campus Office: ETB-406
905-525-9140, ext. 23727
→ Hospital Office: SJH-126
Imaging Research Centre (IRC)
905-525-1155 ext. 35218
nosewor@mcmaster.ca

Office Hours: Fridays 12noon-2:30pm, (or by appointment)

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

Paul Polak, MASc
polakpa@mcmaster.ca
Office: ETB-301
905-522-1155 ext. 34102

Office Hours: Mon. 2:30am-4:00pm

Martin Villegas, BEng
villegm@mcmaster.ca
Office: ETB-301

Office Hours: TBA

COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

https://avenue.cllmcmaster.ca/d2l/le/content/176810/Home

COURSE OBJECTIVES

This course is designed to allow students to become familiar with medical imaging technologies- both from a physics and engineering perspective through to a practical perspective. The course will focus primarily on magnetic resonance techniques (e.g. MRI, in vivo NMR, etc.). However, comparative applications with other imaging modalities (e.g. PET, SPECT, ultrasound, mammography, CT, EEG, MEG) will be made where appropriate. Practical applications and clinical usage of the technologies, outlining advantages and disadvantages of techniques, will be thoroughly demonstrated in most lectures. In addition, throughout the course, students will learn the most frequent artefacts and their causes.

ASSUMED KNOWLEDGE

You should have a solid knowledge of linear algebra and vector calculus. Also, a thorough mastering of Matlab is critical. Lastly, working knowledge of anatomy and physiology is assumed.

COURSE MATERIALS

Course Website
All course material will be regularly posted to the Avenue to Learn site. It is the student's responsibility to check regularly for updates.

Text Book
A number of key review papers that fully complement the course material will be suggested to students throughout the term. Highly Recommended: Prince JL, and Links J (2014) Medical Imaging Signals and Systems, 2nd Edition, Prentice Hall. Other excellent books (none are required) include:

1) Bernstein MA, King KF, Zhou XJ. (2004) Handbook of MRI Pulse Sequences. Elsevier Academic Press. ISBN: 0-12-092861-2.
2) de Graaf RA (2007) *In vivo* NMR Spectroscopy, John Wiley & Sons Ltd. ISBN: 978-0470-026700.
3) A. Oppelt (2005) Imaging Systems for Medical Diagnostics, Publicis Corporate Publishing. ISBN: 3-89578-226-2.
4) Bushberg JT, et al. (2011) The Essential Physics of Medical Imaging. Lippincott Williams & Wilkins; 3rd Ed. ISBN: 078-178-0578.

These books are only recommended if you intend to pursue work or study in this area of engineering.

Additional Materials
Lecture Information: All lecture notes will be posted on the course web page the day before lecture.

Tutorial Information: All tutorial notes get posted after the tutorial.
Lab Information: There will be lab lectures, handouts, and data obtained in each lab, all of which will be posted on the lab section of the website.
NOTE: Both Dr. Noseworthy and the TA use the white/black boards extensively. Students will also be responsible for understanding any such materials detailed on the board.

COURSE OVERVIEW

Date/Week	Topic	Readings
1	General concepts and history of medical imaging. Interactions of radiation with matter. Types of images and simple concepts of medical image formation. Image quality, point spread function (PSF), modulation transfer function (MTF).	TBD
2	Molecular imaging and imaging metabolism: In vivo NMR (magnetic resonance spectroscopy) vs. positron emission tomography (PET) vs. single photon emission computed tomography (SPECT).	TBD
3	An introduction to the basic concepts of hyperpolarization. CT/PET reconstruction using Radon transformations, filtered back projection, and iterative reconstruction (e.g. Ordered Subsets Expectation Maximization, OSEM).	TBD
4	Basics of Ultrasound (US) imaging.	TBD
5	Physics and chemistry of contrast agents.	TBD
6	Imaging Flow and Perfusion: MRI vs. PET/SPECT vs. Ultrasound techniques	TBD
7	Basics of nuclear magnetic resonance (NMR). Going from NMR to magnetic resonance imaging (MRI): Application of magnetic field gradients, signal sampling, k-space, 2D and 3D Fourier transformations.	TBD
8	Families of RF pulses for use in MRI; Basic MR imaging pulse sequences	TBD
9	Specialized gradients for imaging flow, diffusion, perfusion. Corrective gradients.	TBD
10	Advanced MRI pulse sequences: diffusion tensor imaging (DTI), fat/water imaging	TBD
11	Functional Imaging: fMRI	TBD
12	Real-time imaging: fluoroscopic vs. real time MRI, and ultrasound	TBD
13	Biomedical engineering of multimodal imaging	TBD

LABORATORY OVERVIEW

The goal of the labs will be 2 fold: 1) Medical imaging equipment will be demonstrated on a wide range of objects; and 2) labs will be used to acquire data for analysis in assignments. Note- labs 1 and 4 will be held in ETB, lab 2 is in MUMC, MRI / Nuclear Medicine area (Blue area, level 1). Labs (3, 5 and 6) will be held at the Imaging Research

Centre, at St. Joseph's Healthcare, Fontbonne Bldg, F-126. You will be responsible for getting to/from these labs. The location and directions may be found here: http://www.ece.mcmaster.ca/~mikenose/web/Lab_Info.html
To accommodate everyone in the small space of the imaging lab, the class will be divided into 4 equally sized groups. Labs will be every other week and you will be assigned either the afternoon (Thursdays 3-6pm) or evening (Thursdays 7-10pm) slot.

LAB #1- January 11th and 18th: X-ray systems. Optical "CT".
Location: ETB-406

LAB #2- January 25th and February 1st: Positron emission tomography (PET) Single Photon Emission Computed Tomography (SPECT) and CT scanning. Evaluation of CT and SPECT system quality.
Location: MUMC Blue area (MRI)

LAB #3- February 8th and 15th: Ultrasound and real time optical tracking. Ultrasound scanning will be demonstrated. Students will be taught how to guide a biopsy using ultrasound.
Location: Imaging Research Centre, SJH F-126

LAB #4- March 1st and 8th: MRI Part1- Earth's field MRI. T1 and T2 measurements
Location: ETB-406

LAB #5- March 15th and 22nd: MRI Part2 - Structural and Functional imaging. Diffusion MRI scanning and fibre tracking will be demonstrated.
Location: Imaging Research Centre, SJH F-126

LAB #6- March 29th and April 5th: MRI Part3 – MRI RF Hardware. Proton and Multinuclear (i.e. non-proton) imaging and spectroscopy.
Location: Imaging Research Centre, SJH F-126

LABORATORY OPERATION

It is important to note that 4 of the labs are held in a clinical area within the hospital. Students must be respectful and mindful of patient confidentiality and exhibit best behaviour. Failure to comply will result in immediate expulsion (via hospital security personnel) from the lab area and result in loss of privileges for all remaining lab activities.

All labs will begin with a brief 'chalk talk' concerning the lab. The talk in lab #5 will be particularly focused on MRI safety. It is essential that all students understand risk of the environments we will be gathering data in. Any person entering the MRI Faraday cage will need to be screened for safety purposes. Screening will be performed in confidence by Dr. Noseworthy who is accredited as special clinical staff in the hospital. If you do not want to enter the MRI room, or you do not want to be screened for safety, this is your choice and you will not lose grades based on such a decision.

ASSESSMENT

Component	Weight
Assignment #1 (due Feb. 6th, 2018 at 11:59pm)	10%
Assignment #2 (due March 6th, 2018 at 11:59pm)	10%
Assignment #3 (due April 3rd, 2018 at 11:59pm)	10%
Midterm (7-10pm) JHE-326H, Wed. Feb. 14th, 2018	25%
Final Exam (2.5hrs, date/time/location TBA)	45%
Total	100%

There will be a combination of exams and assignments over the course of the semester. Students will hand in 3 assignments over the term. These will be based on material learned in lectures and tutorials. Assignments will require programming in Matlab (or Python). If you need access to the student computer lab (ITB-155) please discuss with the TA and/or Professor and you will be provided a login ID and password. Students are encouraged to work on assignments in groups (of up to a maximum of 3 per group). Groups hand in one assignment with all names on the first page. All group members will receive the same grade. However, if anyone feels other group member(s) haven't provided equal input they can also submit group member evaluations (form, with instructions is on the class website).

NOTE: assignments are due digitally (i.e. upload to Avenue) at 11:59pm on the due date. Late assignments will be deducted **0.01389% per minute**.

A midterm exam will be held in the evening of Wednesday February 15th. The final exam will cover all material from the midterm onward (time/place TBA). Both the midterm and final exams will be open book.

Note: Due to the cost of running these labs attendance will be taken. Missing a lab will result in a grade of 0% in the assignment associated with that lab.

ACCREDITATION LEARNING OUTCOMES

Note: The *Learning Outcomes* defined in this section are measured throughout the course and form part of the Department's continuous improvement process. They are a key component of the accreditation process for the program and will not be taken into consideration in determining a student's actual grade in the course. For more information on accreditation, please ask your instructor or visit: http://www.engineerscanada.ca .

Outcomes	Indicators	Measurement Methods(s)
To be able to understand an array of common medical problems, their aetiology and the associated ideal imaging modality for assessment. Shows understanding of how medical problems can be resolved using engineering principles.	1.4	Assignments and exams
To understand how imaging hardware is constructed, including materials, design and operation. Students must know how the device is optimized for ideal function.	2.1	Assignments and exams
Students have an understanding of existing techniques or	2.2	Assignments and exams

are able to formulate new approaches for image reconstruction, quality assurance and image analysis. Students should analyze the benefits of each method and the artifacts or errors generated by the methods.		
Students are fully aware of life cycle analysis of medical imaging equipment, understand sources of raw materials, energy requirements, environmental impact device manufacture and their disposal.	4.2	Assignments and exams
Students are able to take a medical imaging problem and be able to solve it using any of an array of analysis pathways/methods.	4.3	Assignments and exams
Students understand the functioning and use of modern medical imaging systems. They are aware how to acquire data, assess quality and perform quality assurance measures.	5.2	Assignments and exams

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity.

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at http://www.mcmaster.ca/academicintegrity

The following illustrates only three forms of academic dishonesty:

1. Plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
2. Improper collaboration in group work.
3. Copying or using unauthorized aids in tests and examinations.

ACADEMIC ACCOMMODATIONS

Students who require academic accommodation must contact Student accessibility Services (SAS) to make arrangements with a Program Coordinator. Academic accommodations must be arranged for each term of study.

Student Accessibility Services can be contact by phone at 905.525.9140 ext. 28652 or e-mail at sas@mcmaster.ca. For further information, consult McMaster University's Policy for Academic Accommodation of Students with Disabilities.

NOTIFICATION OF STUDENT ABSENCE AND SUBMISSION OF REQUEST FOR RELIEF FOR MISSED ACADEMIC WORK

In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar - "Requests for Relief for Missed Academic Term Work": http://www.mcmaster.ca/msaf/. If any academic work within the term is missed due to these reasons the value of the missed grade will be added to the final exam.

NOTICE REGARDING POSSIBLE COURSE MODIFICATION

The instructor and university reserve the right to modify elements of the course during the term. The university may change the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes.

REFERENCE TO RESEARCH ETHICS

The two principles underlying integrity in research in a university setting are these: a researcher must be honest in proposing, seeking support for, conducting, and reporting research; a researcher must respect the rights of others in these activities. Any departure from these principles will diminish the integrity of the research enterprise. This policy applies to all those conducting research at or under the aegis of McMaster University. It is incumbent upon all members of the university community to practice and to promote ethical behaviour. To see the Policy on Research Ethics at McMaster University, please go to http://www.mcmaster.ca/policy/faculty/Conduct/ResearchEthicsPolicy.pdf.

Electrical and Computer Engineering Lab Safety

Information for Laboratory Safety and Important Contacts

This document is for users of ECE instructional laboratories in the Information Technology Building.

This document provides important information for the healthy and safe operation of ECE instructional laboratories. This document is required reading for all laboratory

supervisors, instructors, researchers, staff, and students working in or managing instructional laboratories in ECE. It is expected that revisions and updates to this document will be done continually. A McMaster University lab manual is also available to read in every laboratory.

General Health and Safety Principles

Good laboratory practice requires that every laboratory worker and supervisor observe the following:

1. Food and beverages are not permitted in the instructional laboratories.
2. A Laboratory Information Sheet on each lab door identifying potential hazards and emergency contact names should be known.
3. Laboratory equipment should only be used for its designed purpose.
4. Proper and safe use of lab equipment should be known before using it.
5. The course TA leading the lab should be informed of any unsafe condition.
6. The location and correct use of all available safety equipment should be known.
7. Potential hazards and appropriate safety precautions should be determined, and sufficiency of existing safety equipment should be confirmed before beginning new operations.
8. Proper waste disposal procedures should be followed.

Location of Safety Equipment

Fire Extinguisher
On walls in halls outside of labs

First Aid Kit
ITB A111, or dial “88” after 4:30 p.m.

Telephone
On the wall of every lab near the door

Fire Alarm Pulls
Near all building exit doors on all floors

Who to Contact

Emergency Medical / Security: On McMaster University campus, call Security at extension **88** or **905-522-4135** from a cell phone.
Non-Emergency Accident or Incident: Immediately inform the TA on duty or Course Instructor.
University Security (Enquiries / Non-Emergency): Dial 24281 on a McMaster phone or dial 905-525-9140 ext. 24281 from a cell phone.
See TA or Instructor: For problems with heat, ventilation, fire extinguishers, or immediate repairs
Environmental & Occupational Health Support Services (EOHSS): For health and safety questions dial 24352 on a McMaster phone or dial 905-525-9140 ext. 24352 from a cell phone.
ECE Specific Instructional Laboratory Concerns: For non-emergency questions specific to the ECE

In Case of a Fire (Dial 88)

When calling to report a fire, give name, exact location, and building.

1. Immediately vacate the building via the nearest Exit Route. Do not use elevators!
2. Everyone is responsible for knowing the location of the nearest fire extinguisher, the fire alarm, and the nearest fire escape.
3. The safety of all people in the vicinity of a fire is of foremost importance. But do not endanger yourself!
4. In the event of a fire in your work area shout "*Fire!*" and pull the nearest fire alarm.
5. Do not attempt to extinguish a fire unless you are confident it can be done in a prompt and safe manner utilizing a hand-held fire extinguisher. Use the appropriate fire extinguisher for the specific type of fire. Most labs are equipped with Class A, B, and C extinguishers. Do not attempt to extinguish Class D fires which involve combustible metals such as magnesium, titanium, sodium, potassium, zirconium, lithium, and any other finely divided metals which are oxidizable. Use a fire sand bucket for Class D fires.
6. Do not attempt to fight a major fire on your own.
7. If possible, make sure the room is evacuated; close but do not lock the door and safely exit the building.

Clothing on Fire

Do not use a fire extinguisher on people

1. Douse with water from safety shower immediately or
2. Roll on floor and scream for help or
3. Wrap with fire blanket to smother flame (a coat or other nonflammable fiber may be used if blanket is unavailable). Do not wrap a standing person; rather, lay the victim down to extinguish the fire. The blanket should be removed once the fire is out to disperse the heat.

Equipment Failure or Hazard

Failure of equipment may be indicative of a safety hazard - You must report all incidents.

Should you observe excessive heat, excessive noise, damage, and/or abnormal behaviour of the lab equipment:

1. Immediately discontinue use of the equipment.
2. In Power Lab, press wall-mounted emergency shut-off button.
3. Inform your TA of the problem.
4. Wait for further instructions from your TA.
5. TA must file an incident report.

Protocol for Safe Laboratory Practice

Leave equipment in a safe state for the next person - if you're not sure, ask!

In general, leave equipment in a safe state when you finish with it. When in doubt,

consult the course TA.

Defined Roles

TA	The first point of contact for lab supervision	
ECE Lab Supervisor	Steve Spencer- ITB 147	steve@mail.ece.mcmaster.ca
ECE Chair	Tim Davidson- ITB A111	davidson@mcmaster.ca
ECE Administrator	Kerri Hastings- ITB A111	hastings@mcmaster.ca
ECE Course Instructor	Please contact your specific course instructor directly	