ELEC ENG 4BF4
Advanced Medical Imaging

COURSE OUTLINE

Please refer to course website for updated information.

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

Pre-requisite(s): ElecEng 2FH3 or 2FH4, ElecEng 3TP4 or 3TP3; and registration in Level IV Electrical and Biomedical Engineering or Level IV and above in the Integrated Biomedical Engineering and Health Sciences (IBEHS) program or permission of the department.

SCHEDULE and MODE OF DELIVERY

All lectures, tutorials and labs will be in person. The Instructor and TAs will not be posting audio or video recordings of any in-class materials. Avenue-to-Learn will be the online management system for the course. Through Avenue, you will be able to:

- Find all course materials (lecture slides, lab materials, linked videos, etc.)
- View course-related announcements
- Submit course work (assignment, project deliverables) for grading
- View your gradebook

NOTE: Regular important announcements will be made on the Avenue course website. It is the student's responsibility to regularly check these notices.

Lectures: Tuesdays 7:00-10:00pm (see A2L for location)
Labs (Every Other Week): Thursdays 2:30-5:30pm or 7:00-10:00pm (see A2L for locations)
Tutorial: Mondays 11:30am-12:20pm, (see A2L for location)

INSTRUCTOR

Dr. Michael Noseworthy
Office: MUMC 3N26-E
Radiology Administration Area
nosewor@mcmaster.ca

Office Hours:
Wednesdays 2:30-3:30pm,
Fridays 1:30-2:30pm
or by appointment

TEACHING ASSISTANTS

Names, contact information and office hours are provided on the course website.

COURSE WEBSITE/S

http://avenue.mcmaster.ca

COURSE OBJECTIVES

By the end of this course students should be able to demonstrate their competency and be knowledgeable with medical imaging technologies- both from a physics and engineering perspective through to a practical perspective. The course will have a large focus 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, DOT, etc.) 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.

CEAB GRADUATE ATTRIBUTES (GAS)

Note: The CEAB Graduate Attributes (GAs) 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

Attributes	Indicators		Measurement Method(s)
	Number	Description	
Investigation	3.1	Selects appropriately from relevant knowledge base to plan appropriate data collection methods and analysis strategies.	Assignments and Exam
Design	4.2	Explores a breadth of potential solutions, considering their benefits and trade-offs as they relate to the project requirements.	Assignments and Exam
Use of Engineering Tools	5.1	Evaluates engineering tools, identifies their limitations, and selects, adapts, or extends them appropriately.	Assignments and Exam
Use of Engineering Tools	5.2	Successfully uses engineering tools	Assignments and Exam
Ethics and Equity	10.2	Applies the principles of equity and universal design to ensure equitable treatment of all stakeholders.	Assignments and Exam

ASSUMED KNOWLEDGE

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

COURSE MATERIALS

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.

Calculator:

Only the McMaster Standard Calculator (Casio fx-991 MS or MS Plus) is permitted in tests and examinations. This is available at the Campus Store.

Additional Materials

Lecture Information: All lecture notes will be posted on the course web page by noon on the lecture day.
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 classroom boards.

COURSE OVERVIEW

Date/Week	Topic
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).
2	X-ray systems. Mammography, tomosynthesis, faxitron, computed tomography (CT)
3	Molecular imaging and imaging metabolism: positron emission tomography (PET) vs. single photon emission computed tomography (SPECT).
4	CT/PET reconstruction using Radon transformations, filtered back projection, and iterative reconstruction (e.g. Ordered Subsets Expectation Maximization, OSEM).
5-6	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.
7	Families of RF pulses for use in MRI; Basic MR imaging pulse sequences, Relaxation theory, T1 and T2 mapping, Bo mapping
8	Specialized gradients for imaging flow, diffusion, perfusion. Corrective gradients.
9	Physics and chemistry of contrast agents. Imaging Flow and Perfusion. Tracers vs. arterial spin labelling (ASL)
10	Imaging in the steady state: SSFP and cardiac imaging
11	Advanced MRI pulse sequences: diffusion tensor imaging (DTI), fat/water imaging, susceptibility mapping
12	Functional Imaging: fMRI
13	An introduction to the basic concepts of hyperpolarization. Lung imaging with MRI, CT and nuclear medicine

A more detailed time line is available on the course website.

At certain points in the course, it may make good sense to modify the schedule. The instructor may modify elements of the course and will notify students accordingly (in class, on the course website).

LABORATORY OVERVIEW

The goal of the labs will be 2 fold: 1) Medical imaging equipment will be demonstrated and/or used on a wide range of objects; and 2) labs will be used to acquire data for analysis in assignments.

Labs are NOT held during the first week of term.

Lab	Topic
1	Planar X-ray systems. Image quality and aspects of patient positioning. Human CT scanner. Dual Energy CT Scanning
2	Positron emission tomography (PET) Single Photon Emission Computed Tomography (SPECT) and CT scanning. Evaluation of CT and SPECT system quality.
3	Human MRI Part1- Introduction to equipment, safety. Basic protocols for imaging
4	Human MRI Part2- Advanced sequences for brain (fMRI, DTI) and knee (T2mapping, IDEAL) imaging.
5	Human MRI Part3 – Elements of RF coils, design/building surface coils.

6	Human MRI Part4 –Proton spectroscopy and multinuclear (i.e. non-proton) imaging and spectroscopy. Imaging/spectroscopy of non-living biological samples (student choice).

LABORATORY OPERATION

- Each student in the course is required to pass the lab safety quiz prior to attempting any of the laboratories. The quiz will be available on Avenue to Learn.
- Each student in the course is required to pass the lab safety quiz prior to attempting any of the laboratories. The video and quiz will be on Avenue to Learn. This is a requirement for anyone who is enrolled in an ECE course.
- It is important to note that many labs are held in clinical areas 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. A safety presentation will be made before the first human MRI lab. It is essential that all students understand all risks 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 Radiology and Nuclear Medicine 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. 16th, 2024 at 11:59pm)	10%
Assignment #2 (due March 16th, 2024 at 11:59pm)	10%
Assignment #3 (due April 5th, 2024 at 11:59pm)	10%
Review paper (due April 10th, 2024 at 11:59pm)[1,2]	30%
Final Exam (2.5hrs, date/time/location TBA)	40%
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, as well as the laboratory work. Assignments will require programming in Matlab (or Python). 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).

[1] Due dates for all term work must be on or before the final day of classes (i.e. April 12th) for courses with a final examination.
[2] Detailed instructions will be posted on Avenue

NOTE1: 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**. No make-up assignments will be granted. The entire weight of missed material will be transferred to the final exam.

NOTE2: 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 component associated with that lab.

The final exam will cover all course materials. The final exam will be open book. Only the McMaster Standard Calculator (Casio fx-991 MS or MS Plus) is permitted in tests and examinations (available at the Campus Store).

Grading and Evaluation Policies

- There are five (3) lab assignments, one (1) term paper and one (1) final exam to be evaluated in this course.
- Use of computers or cell phones are not allowed during exams. Notes, book, etc. are all permitted for the final exam (i.e. open book)

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. It is your responsibility to understand what constitutes academic dishonesty. 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. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at https://secretariat.mcmaster.ca/university-policies-proceduresguidelines/
The following illustrates only three forms of academic dishonesty:
• plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
• improper collaboration in group work.
• copying or using unauthorized aids in tests and examinations.

AUTHENTICITY / PLAGIARISM DETECTION

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.
Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. All submitted work is subject to normal verification that standards of academic integrity have been upheld (e.g., on-

line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

COURSES WITH AN ON-LINE ELEMENT

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

Some courses may use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/software during tests or exams. This software may be required to be installed before the test/exam begins.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, including lectures by University instructors.
The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the Code of Student Rights & Responsibilities (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, whether in person or online. It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated.

Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATIONS

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's Academic Accommodation of Students with Disabilities policy.

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office normally within 10 working days of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations.

Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

REQUESTS FOR RELIEF FOR MISSED ACADEMIC WORK

McMaster Student Absence Form (MSAF): 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".

- All McMaster Student Absence forms (MSAFs) are to be directed to prof1p10@mcmaster.ca. Sending to another email address will delay processing.
- It is the prerogative of the instructor of the course to determine the appropriate relief for missed term work in his/her course. For ElecEng-4BF4 no make-up work will be provided. Instead, the value of the missed grade will be added to the final exam.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.

Electrical and Computer Engineering Lab Safety

Information for Laboratory Safety and Important Contacts

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 and online https://hr.mcmaster.ca/app/uploads/2019/07/2019-McMaster-Lab-Manual.pdf

General Health and Safety Principles

Good laboratory practice requires that every laboratory worker and supervisor observe the following whether conducting lab work at school or at home:

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.
9. Personal ergonomics should be practiced when conducting lab work. https://bit.ly/3fOE71E
10. Current University health and safety issues, and protocol should be known. https://hr.mcmaster.ca/resources/covid19/workplace-health-and-safety-guidance-during-covid-19/

Location of Safety Equipment

Fire Extinguisher	First Aid Kit
On walls in halls outside of labs	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 laboratories, please contact 24103.

In Case of a Fire (On Campus 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 labs, 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

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	Mohamed Bakr- ITB A111	mbakr@mcmaster.ca
ECE Administrator	Shelby Gaudrault- ITB A111	gaudraus@mcmaster.ca
ECE Course Instructor	Please contact your specific course instructor directly	