

IBEHS 4D03
Medical Imaging I

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): IBEHS 3A03 and registration in the Integrated Biomedical Engineering and Health Sciences (IBEHS) program or registration in Level IV Electrical and Biomedical Engineering.

Anti-requisite(s): ElecEng 4BF4

SCHEDULE

Lectures: Tuesdays 7:00-9:00pm, online (Zoom)

Labs: There are 6 labs in the course (every other week). Lab slots are: Mondays, Wednesdays, Thursdays and Fridays, 2:30-5:30pm

INSTRUCTOR

Dr. Michael Noseworthy, PhD PEng

Hospital Office: SJH-130A
Imaging Research Centre (IRC)
905-525-1155 ext. 35218
nosewor@mcmaster.ca

Office Hours:

Mondays: 4:30-5:30pm

TEACHING ASSISTANTS

Leela Pilli (LAB COORDINATOR)

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COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

<http://avenue.mcmaster.ca/>

NOTE #1: Regular important announcements will be made on the Avenue course website. It is the student's responsibility to regularly check these notices.

NOTE #2: During examinations students should be logged in to the class Zoom link, and to the Avenue webmail, at all times in case there is a need to communicate with Dr. Noseworthy or a TA, and also to receive any announcements with regards to the exam. It is a student's responsibility to monitor these during exams. Failure to do so will be inexcusable in terms of [for example] exam errors or any other confusion that can only be broadcast to the class via Avenue email. Also, during the exam students will be able to email and video chat with Dr. Noseworthy and TAs.

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, thorough working knowledge of anatomy and physiology is assumed.

COURSE MATERIALS

All course material will be regularly posted to Avenue. 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.

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: This course (this year) is 100% online. Lectures and lab talks will be presented synchronously, with subsequent lecture videos posted on the class Avenue page, and under Dr. Noseworthy's YouTube channel:

https://www.youtube.com/channel/UCS7Q-0_OhuCPw4GVR1Y0LLw

Both Dr. Noseworthy and the TAs will often use a 'virtual white board' in lectures / lab talks. 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	X-ray systems, mammography, DEXA. Intro to Computed Tomography (CT).	TBD
3	CT image reconstruction using Radon transformation or filtered back projection. Intro to nuclear medicine.	TBD
4	Molecular imaging and imaging metabolism: In vivo NMR (magnetic resonance spectroscopy) vs. positron emission tomography (PET) vs. single photon emission computed tomography (SPECT).	TBD
5	Basics of Ultrasound (US) imaging.	TBD
6	Physics and chemistry of contrast agents. 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	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 are: 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. You are required to attend your lab each week.

LAB #1- Weeks of January 18th & 25th : PSF, LSF, MTF, X-ray systems. CT scanning

LAB #2- Weeks of February 1st and 8th : Optical "SPECT/CT".

LAB #3- Weeks of February 22nd and March 1st : Ultrasound imaging. Ultrasound elastography.

LAB #4- March 8th and 15th : MRI Part1- Earth's field MRI. T1 and T2, FIDs, shimming, RF coil tune/match

LAB #5- March 22nd and 29th : MRI Part2 - MRI RF Hardware. 1H and non-proton imaging and spectroscopy.

LAB #6- April 5th and 12th MRI Part3 – Structural and Functional imaging. Diffusion MRI, fMRI.

LABORATORY OPERATION

All labs will begin with a brief 'chalk talk' concerning the lab. Labs 1 and 2 will be run directly by groups of students by remotely logging in to the 'optical SPECT/CT systems we have in our imaging lab on campus. The TAs will be responsible for being the 'hands' while students remotely access the instruments to do the necessary experiments and acquire the data. Lab 3 (ultrasound) will be done through synchronous demonstrations by the TA, and also some online asynchronous video content. Lab 4 (MRI #1) will be done by groups remotely logging in via Zoom for demonstrations of an earth's field MRI by the TA. Labs 5 and 6 will involve synchronous content presented by the TA in which students remotely login via Zoom. These latter labs also involve asynchronous video content of human MRI scanning done by Dr. Noseworthy. **NOTE: Lab attendance will be taken. Failure to attend your lab will result in a 0% for that lab assignment grade.**

ASSESSMENT

Component	Weight
Lab reports (due 1 week after your assigned lab at 11:59pm)	30% TOTAL
Lab #1 X-ray and CT	5%
Lab #2 SPECT	5%
Lab #3 Ultrasound Imaging	5%
Lab #4 Introduction to MRI	5%
Lab #5 MRI RF coils and in vivo NMR	5%
Lab #6 Human MRI: fMRI and DTI	5%
Quizzes (15min; portal will open at noon for 12hrs)	15% TOTAL
Quiz #1 January 29 th	3%
Quiz #2 February 12 th	3%
Quiz #3 March 5 th	3%
Quiz #4 March 19 th	3%
Quiz #5 April 7 th	3%
Midterm (7-10pm) Wed. Feb. 24 th	20%
Final Exam (2.5hrs, date/time/ TBA)*	35%

Total

100%

There will be a combination of exams, quizzes and group lab reports over the course of the semester. Students will hand in a lab report for each lab. These will be based on data acquired in each lab and also material learned in lectures and tutorials. Lab reports will require programming in Matlab (or Python). Students are encouraged to work in groups (up to a maximum of 3 per group). *Groups hand in only 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, will be available upon request from lab TAs).

NOTE 1: lab reports are due digitally (i.e. upload to Avenue) at 11:59pm on the due date. Late reports will be deducted 20% per day.

NOTE 2: No make-up labs will be granted. A missed lab report will constitute a grade of 0

NOTE 3: Lab reports are to be PDF format and legible (i.e. avoid lossy compression). An illegible lab report due to lossy compression will be given a grade of 0. Verify the PDF quality before uploading.

NOTE 4: Written exam materials also must be submitted as PDF with an avoidance of lossy compression. Illegible submissions will be graded as zero. Check before you upload to Avenue.

If you do not know how to go from writing on paper to PDF format here's a suggestion: use your smartphone to photograph each page (again avoid lossy jpegs). Save to full resolution files and 'print to PDF'. If you don't know how to do this figure it out and verify WAY before the actual exam.

* Due dates for all term work must be on or before the final day of classes for courses with a final examination.

The final exam will be cumulative. Both the midterm and final exams will be open book.

Note: Due to the cost of these labs attendance will be taken. Missing a lab will result in a grade of 0% on the report 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 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.	2.2	Assignments and exams
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

1. The [McMaster Student Absence Form](#) is a self-reporting tool for Undergraduate Students to report absences DUE TO MINOR MEDICAL SITUATIONS that last up to 3 days and provides the ability to request accommodation for any missed academic work. Please note this tool cannot be used during any final examination period.
2. You may submit a maximum of 1 Academic Work Missed request per term. It is YOUR responsibility to follow up with your Instructor immediately (NORMALLY WITHIN TWO WORKING DAYS) regarding the nature of the accommodation. Relief for missed academic work is not guaranteed.
3. If you are absent for reasons other than medical reasons, for more than 3 days, or exceed 1 request per term you MUST visit the Associate Dean's Office (JHE/A214). You may be required to provide supporting documentation.
4. This form must be submitted during the period of absence or the following day, and is only valid for academic work missed during this period of absence.
5. It is the prerogative of the instructor of the course to determine the appropriate relief for missed term work in his/her course.
6. You should expect to have academic commitments Monday through Saturday but not on Sunday or statutory holidays. If you require an accommodation to meet a religious obligation or to celebrate an important religious holiday, you may submit the Academic Accommodation for Religious, Indigenous and Spiritual Observances (RISO) Form to the Associate Dean's Office. You can find all paperwork needed here: <http://www.eng.mcmaster.ca/current/documents.html>

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.

TURNITIN.COM STATEMENT

In this course we will be using a web-based service (Turnitin.com) to reveal plagiarism. Students will be expected to submit their work electronically to Turnitin.com and in hard copy so that it can be checked for academic dishonesty. Students who do not wish to submit their work to Turnitin.com must still submit a copy to the instructor. No penalty will be assigned to a student who does not submit work to Turnitin.com. All submitted work is subject to normal verification that standards of academic integrity have been upheld (e.g., on-line search, etc.). To see the Turnitin.com Policy, please go to <http://www.mcmaster.ca/academicintegrity/>.

ON-LINE STATEMENT FOR COURSES REQUIRING ONLINE ACCESS OR WORK

In this course, we will be using *Avenue to Learn* and its email feature (Avenue email for bulk class announcements, especially during exams/quizzes). Students should be aware that, when they access the electronic components of this course, 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 this course will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure, please discuss this with the course instructor.

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 <https://reo.mcmaster.ca/>.

<https://www.eng.mcmaster.ca/ibiomed/>

Integrated Biomedical Engineering & Health Sciences (IBEHS) Labs/Design Studio Safety

Information for Laboratory Safety and Important Contacts

This document is for users of IBEHS instructional laboratories at the following locations:

- ETB - 533/534 (Medical Imaging & Medical Instrumentation Labs)
- ABB - C104 (Design Studio)
- HSC - 4N72 (Genetic Engineering Lab)

This document provides important information for the healthy and safe operation of IBEHS instructional laboratories. This document is required reading for all laboratory supervisors, instructors, researchers, staff, and students working in or managing instructional laboratories in IBEHS. 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.
9. [Personal ergonomics](#) should be practiced when conducting lab work.
10. [Current University health and safety](#) issues, and protocols should be known.

Location of Safety Equipment

Fire Extinguisher

On walls in halls outside of labs or
ABB C103/A

First Aid Kit

ETB 534/A, ABB C103/A, HSC 4N72 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.

Hospital Emergency Medical / Security:

For McMaster HSC, call Security at extension **5555** or **905-521-2100** 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.

IBEHS Specific Instructional Laboratory Concerns: For non-emergency questions specific to the IBEHS laboratories, please contact appropriate personnel below from a McMaster phone...

- Leela Pilli – 26888
- Parmveer Bola – 23521
- Alexa Huang – 24548

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!

Defined Roles

TA	The first point of contact for lab supervision	
IBEHS Lab Technician	Leela Pilli	pillil@mcmaster.ca
IBEHS Instructional Assistant	Parmveer Bola	bolap1@mcmaster.ca
IBEHS Co-Directors	Dr. Greg Wohl	wohlg@mcmaster.ca
	Dr. Michelle MacDonald	macdonml@mcmaster.ca
IBEHS Administrator	Alexa Behar-Bannelier	huanqa2@mcmaster.ca
IBEHS Course Instructor	Please contact your specific course instructor directly	