

ECE-780 / MedPhys-702 / BME-702
Magnetic Resonance and Ultrasound Medical Imaging

COURSE OUTLINE

Please refer to course website (A2L) for updated information.

CALENDAR DESCRIPTION

This course will compliment Medical Imaging with Ionizing Radiation. In this course imaging methods that rely on non-ionizing radiation will be discussed. The course content focuses on magnetic resonance imaging (MRI), multinuclear spectroscopy (MNS) in vivo nuclear magnetic resonance (NMR) and ultrasound (US) methods. Advanced concepts such as multi-modality imaging approaches, image fusion, and functional medical image processing will be discussed.

SCHEDULE And MODE OF DELIVERY

The material for this course will be delivered through a mixture of in person lectures and visits to clinical research imaging facilities.

Lecture: Fridays, 9:30am-12:30pm. First lecture is Friday September 4th, 2026

Location: Listed on A2L

Format: Synchronous in person

INSTRUCTORS

Dr. Michael Noseworthy PhD PEng
Email: nosewor@mcmaster.ca
Office: To be Discussed
Office Hours: By appointment

Dr. Kevin Diamond, Ph.D., MCCPM
Email: diamonkr@mcmaster.ca
Office: To be Discussed
Office Hours: By appointment

Of Note: This course will only be taught if 6 or more students (total) are registered. Office location depends on the day of e week for each instructor. If you want to meet an instructor the location will need to be determined while making the appointment.

COURSE WEBSITE

All materials will be uploaded to the A2L course website: <http://avenue.mcmaster.ca>

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 on magnetic resonance techniques (e.g. MRI, in vivo NMR, etc.) and ultrasound (US) methods. Occasional comparisons with other imaging modalities (e.g. PET, SPECT, DXA, mammography, CT, EEG, MEG) will be made where appropriate. In addition, throughout the course, students will learn the most frequent artefacts, their causes and potential solutions.

ASSUMED KNOWLEDGE

Students taking this course are expected to already have solid knowledge in image and signal processing, linear algebra, physics of waves/electromagnetics, and medical imaging in general. A working knowledge of anatomy and physiology is also assumed.

COURSE MATERIALS

Textbooks:

- 1). Handbook of MRI Pulse Sequences (2004) Matt A. Bernstein et al. (note: do not buy this as the 2nd edition is coming out in December 2025)
- 2). Magnetic Resonance Imaging: Physical Principles and Sequence Design, 2nd edition. (2014) Robert W. Brown, et al.
- 3). In Vivo NMR Spectroscopy: Principles and Techniques 3rd Edition. (2018). Robin A de Graaf.
- 4). Medical Imaging Signals and Systems 2nd ed. (2014). Jerry L. Prince, Jonathan M. Links.

COURSE OVERVIEW

Week		Topic (Approximately)
1	Sept. 11th	Medical Imaging formats (DICOM, NiFTi), PACS, measurement of image quality, review of image processing. Classical response of a single nucleus to a magnetic field, rotating and lab frames of reference; magnetization, NMR Bloch equations. RF pulses and signal detection. (MDN)
2	Sept. 18 th	Review of Maxwell's equations and their relevance to MRI, introductory signal acquisition methods: free induction decay, spin echoes, inversion recovery. NMR relaxation (T1, T2, T2*, T1rho) (MDN)
3	Sept. 25 th	Solomon-Bloembergen-Morgan equations, Quantum aspects of NMR signal generation, Hamiltonians, Redfield theory of relaxation. (MDN)
4	Oct. 2 nd	Diagnostic transducers, 2-D image formation, 3-D image formation, Doppler/colour flow imaging, performance testing/QA. (KD)
5	Oct. 9 th	Background, acoustical properties of tissues, propagation of sound waves, endogenous contrast, sources. (KD)
6	Oct. 16 th	FALL READING WEEK, no class
7	Oct. 23 rd	One and multidimensional Fourier imaging. Slice excitation and k-space. RF coils (surface coil, T/R switches, birdcage, phased array), B1- and B1+ fields, B1+ mapping. (MDN)

8	Oct. 30 th	Sampling (uniform and non-uniform), image reconstruction, signal, contrast and noise, parallel imaging, optimization and regularization of parallel imaging, compressed sensing, NUFFT vs. regridding. (MDN)
9	Nov. 6 th	Water/fat imaging and chemical selective / suppression methods. Fast imaging in steady state, fast/turbo spin echo, echo planar imaging, spiral and irregularly sampled imaging. (MDN)
10	Nov. 13 th	Magnetic field inhomogeneity effects and T2* dephasing. B0 field mapping. Electromagnetic properties of tissues, magnetic susceptibility, quantitative susceptibility mapping (qSM). (MDN)
11	Nov. 20 th	Motion artifacts, motion sensitizing gradients, measuring spin motion using phase contrast, time-of-flight and diffusion. (MDN)
12	Nov. 27 th	Advanced MRI applications: Functional MRI, diffusion and diffusion tensor imaging (DTI), 2D and 4D flow. Motion encoding with SPAMM. Low field vs. high field. MRI safety (MDN)
13	Dec. 4 th	Proton Spectroscopy. Multinuclear spectroscopy and imaging. Physiologically important non-proton nuclei, hyperpolarization. (MDN)
14	Dec. 11 th	STUDENT PRESENTATIONS. (MDN & KD)
15	Dec. 14-18	FINAL ORAL EXAM (MDN & KD)

A more detailed time line will be provided on the course A2L web site.

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).

At some point in the course there will be MRI scanner demonstrations. Due to limited access of MRI systems the timing of this will be decided upon in class early in the term.

ASSESSMENT

Component	Weight	Due Date
Ultrasound Assignment	15 %	Oct. 16 th 11:59pm
MRI Assignment	25 %	Dec. 20 th 11:59pm
Final Presentation	30 %	Dec. 11 th
Final Oral Exam	30 %	Week of Dec.15 th
Total	100 %	

No make-up presentations will be granted.

The final exam will be an oral examination. The examination will last for 40 minutes and be made up of 4 questions (10minutes each). No calculators, notes, texts, etc. will be permitted. Drs. Noseworthy and Diamond will examine students individually using questions taken directly from the sample CCPM examination booklets:

<https://ccpm.ca/ccpm-english/main/certification/exam-content.html>

The final exam will be in the week of Dec. 14th. Booking of each student's exam time will be determined in class early in the course.

CONDUCT EXPECTATIONS

As a McMaster graduate 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 A2L, MSTeams 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.

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.

ACADEMIC ACCOMMODATIONS OF STUDENTS WITH DISABILITIES

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.

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

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.

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.

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>.