**NOTE: THIS SYLLABUS IS DISTRIBUTED FOR INFORMATION. THE DATES CORRESPOND TO THE 2019-2020 ACADEMIC YEAR AND DO NOT APPLY TO THE 2020-2021 ACADEMIC YEAR.**

# MEDICAL IMAGING
## MDPH607 (3 credits) – Fall 2019

**LOCATION: Room D.S1.5034**
**Cedars Cancer Centre, Royal Victoria Hospital, Glen Site MUHC**
**1001 Decarie Boulevard**
**Métro: Vendôme**

**Monday and Wednesday, 9:00 – 10:30 am**
**First class: Wednesday, September 4th, 2019**

**Instructor:** Prof. Ives Levesque, PhD
Room DS1.9326, Cedars Cancer Centre, Glen Site MUHC
Tel. 514-934-1934, extension 48105
Email. ives.levesque@mcgill.ca

**Office Hours:** By appointment.

**Teaching Assistants:** Zaki Ahmed, zaki.ahmed@mail.mcgill.ca, Room DS1.5037
Véronique Fortier, veronique.fortier@mail.mcgill.ca, Room DS1.5037
Shu (Stella) Xing, shu.xing@mail.mcgill.ca, Room DS1.5037

**Assessment:** There will be 5 assignments (problem sets), a mid-term exam (in class), a final exam (during the exam period), and a project from each student. See page 3 of this document for more details on assessment.

**Texts:**
*Magnetic Resonance Imaging*, D. Nishimura (available from www.lulu.ca)
*Handbook of MRI Pulse Sequences*, Bernstein, King, and Zhou (e-version available via McGill Library)
*The Essential Physics of Medical Imaging,* J.T. Bushberg *et al.*, Lippincott Williams & Wilkins
*Medical Imaging Systems*, A. Macovski, Prentice-Hall
*The Fourier Transform and its Applications*, R. N Bracewell, McGraw Hill

**Handouts:** Class notes and other handouts will be made available.

**Course Description:** This course is concerned with the principles of medical imaging as applied to conventional diagnostic radiography, X-ray computed tomography (CT), and magnetic resonance imaging (MRI). The course emphasizes a linear system approach to the formation, processing, and display of medical images.

Approval of the instructor is required for students not registered in Medical Physics or Biological & Biomedical Engineering at McGill.

*NOTE: Under extreme circumstances, the contents of this document can be modified by the instructor to allow for adjustments in the course.*

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## LEARNING OUTCOMES

By the end of this course, the student should be able to:

1. Apply physics and linear systems theory to the study of medical imaging systems
2. Demonstrate an understanding of approaches to tomographic (CT) medical imaging
3. Understand the principles of NMR physics, MRI, and the basic architecture of an MRI system
4. Discuss applications of human medical imaging along with the underlying physical principles
5. Read and understand scientific papers in medical imaging, especially in MRI

## OUTLINE OF CONTENT

I. **Linear Systems:** Linear systems. Dirac delta function. Multi-dimensional functions and discretization. Sinusoids, impulses, and linear shift-invariant (LSI) systems. Fourier series. The Fourier transform and discrete Fourier transforms. The convolution theorem. Blur and resolution, point-spread function, line spread function, modulation transfer function. The Fast Fourier transform (FFT). Sampling, and aliasing.

II. **Radiographic imaging:** Overview of X-ray production and projection imaging. X-ray absorption. Scatter and grids. Detectors and response. Image quality: contrast, spatial resolution, unsharpness, and noise.

III. **Tomography and Inverse Problems:** Basics of computed tomography (CT). Imaging and inverse problems. Object and data representation. Central section theorem. Image reconstruction. Influence of detector, reconstruction, and display resolution. SNR and dose in CT. Fan-beam, multi-slice, helical, and cone-beam CT. System matrix and the forward model. Iterative solution to the inverse problem. Algebraic reconstruction technique for CT. Maximum Likelihood Expectation Maximisation (ML-EM) reconstruction for CT.

IV. **Nuclear magnetic resonance:** Quantum mechanical and classical NMR theory. Precession. Net magnetization. Relaxation. The Bloch equation. Excitation and induction. Signal detection. Spin echo. Chemical shift. NMR spectroscopy.

V. **Magnetic resonance imaging:** Magnetic field gradients. Signal equation for MRI. Typical system description for proton imaging. Image space and k-space interpretation of MRI. Projection and 2DFT imaging. Sampling, field-of-view and resolution. R.F. and gradient pulse sequences. Selective excitation. MRI noise and noise properties. Gradient and spin echo imaging. Inversion preparation, multi-echo MRI. Image contrast. Fast imaging, spoiling, single-shot imaging. NMR spectroscopy and imaging of other nuclei. Image reconstruction techniques.

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## ASSESSMENT

**Assignments:** Short problems or open-ended questions will be assigned to review material or to explore certain topics in greater detail. These may include programming in MATLAB. The due date will be clearly indicated on each assignment. Expect at least 5 assignments.

**Mid-term exam:** The mid-term exam will be held in class, on October 16th.

**Project:** Students will be expected to submit a project that will consist of a written paper and a short in-class presentation. Details, including dates of project milestones, will be discussed in class.

**Final exam:** The final exam will be held during the exam period, and is tentatively scheduled for. Do not make plans to travel until after the exam period.

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| **Grading:** | Assignments: | 20% |
| | Midterm: | 25% |
| | Project: | 20% |
| | Final Exam: | 35% |

*Barring exceptional circumstances, late submission of assignments or the project will be assessed a penalty of 10% per day (or fraction of a day).*

**McGill Policies:**

**1)** *McGill University values academic integrity. Therefore all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures (see www.mcgill.ca/students/srr/honest/) for more information).*

**2)** *In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded.*

**Health and Wellness Resources at McGill:**

Student well-being is a priority for the University. All of our health and wellness resources have been integrated into a single Student Wellness Hub, your one-stop shop for everything related to your physical and mental health. If you need to access services or get more information, visit the Virtual Hub at mcgill.ca/wellness-hub or drop by the Brown Student Services Building (downtown) or Centennial Centre (Macdonald Campus). Within your faculty, you can also connect with your Local Wellness Advisor (to make an appointment, visit mcgill.ca/lwa).

**Note:**

In the likely scenario that a Federal election will held on Monday, October 21st (or sooner), class will be held as usual.

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## Outline of classes

| Date | # | TOPIC | READING | NOTE |
|---|---|---|---|---|
| 4-Sep-19 | 1 | Introduction and overview | | |
| 9-Sep-19 | 2 | Linear systems: basics | Part 1: 1-13 | |
| 11-Sep-19 | 3 | Fourier analysis | Part 1: 14-38 | |
| 16-Sep-19 | 4 | Sampling | Part 1: 39-59 | |
| 18-Sep-19 | 5 | Linear systems: wrap-up | Part 1: 60-68 | Due: Assignment 1 |
| 23-Sep-19 | 6 | Radiography: basics | Part 2: 1-16 | |
| 25-Sep-19 | 7 | Radiography: image quality | Part 2: 17-37 | Due: Assignment 2 |
| 30-Sep-19 | 8 | Computed tomography | Part 3: 1-11 | |
| 2-Oct-19 | 9 | Tomographic reconstruction | Part 3: 12-30 | |
| 7-Oct-19 | 9 | Iterative tomographic reconstruction | Part 3: 31-50 | |
| 9-Oct-19 | 10 | Advanced CT and image quality in CT | Part 3: 51-62 | Due: Assignment 3 |
| 14-Oct-19 | 10 | NO CLASS – Thanksgiving | | |
| 16-Oct-19 | 11 | **MID-TERM EXAM** (DS1.5034 and DS1.7001) | | |
| 21-Oct-19 | 12 | Spin physics | Part 4: 1-14 | |
| 23-Oct-19 | 13 | Relaxation and pulsed MR | Part 4: 15-28 | Due: Project topic |
| 28-Oct-19 | 14 | Excitation, pulsed MR, and signal detection | Part 4: 29-49 | |
| 30-Oct-19 | 15 | Spin echo, MRS, basic pulse sequences | Part 4: 50-66 | Due: Assignment 4 |
| 4-Nov-19 | 16 | Gradients, signal equation | Part 5: 1-20 | |
| 6-Nov-19 | 17 | Phase encoding | Part 5: 21-31 | Due: Project Outline |
| 11-Nov-19 | 18 | Selective excitation | Part 5: 32-49 | |
| 13-Nov-19 | 19 | Imaging pulse sequences | Part 5: 50-74 | |
| 18-Nov-19 | 20 | Sampling, resolution, and imaging time | Part 5: 75-88 | |
| 20-Nov-19 | 21 | Noise & SNR | Part 5: 89-101 | Due: Assignment 5 & Project Draft |
| 25-Nov-19 | 22 | MRI systems and safety | *notes* | Due: Peer Feedback |
| 27-Nov-19 | 23 | Advanced MRI reconstruction | *notes* | |
| 2-Dec-19 | 24 | **Project presentations** | - | |
| 4-Dec-19 | 25 | **Project presentations** | - | |
| 10-Dec-19 | 26 | **FINAL EXAM** (Room D-02.1312, 2pm-6pm) | | **Due: Final project** |

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