MPHY5178: *Physical Principles of Magnetic Resonance Imaging*
University of Minnesota, Twin Cities
Spring 2018

Days and Times	10-11:15 am, Tuesday and Thursday, Spring Semester 2018
Location	Seminar room, Center for Magnetic Resonance Research (CMRR)
Credits	3 Cr. (two 75-minute lectures per week)
Instructor	Patrick Bolan 2-138 CMRR Office Hours – by appt bola0035@umn.edu
Teaching Asst.	TBD
Prerequisites	Undergraduate level calculus and calculus-based physics; familiarity with linear algebra; basic familiarity with Matlab programming
Text	*Magnetic Resonance Imaging: Physical Principles and Sequence Design* (2nd Edition) by RW Brown, Y-C N Cheng, EM Haacke, MR Thompson, R Venkatesan, Wiley Blackwell Available at UMN Bookstore and online retailers
Course Website	TBD

Course Description:
Physical Principles of MRI is a graduate/undergraduate senior level course that teaches the principles of nuclear magnetic resonance imaging (MRI) as used in biomedical research and clinical radiology. Students will learn about nuclear spin, radiofrequency pulses, spatial encoding, digital signal acquisition and processing, image reconstruction, image contrast, and advanced pulse sequences. Several advanced topics in MR imaging research will also be covered (e.g., fMRI, diffusion imaging, MR spectroscopy). Several laboratory experiences will introduce the students to the operation of an MRI scanner and familiarize them with the system components. *Matlab* will be used throughout the course for simulating MR physics, reconstructing image data, and simulation of MRI system control.

Learning Objectives
After successfully completing this course, students should be able to:

- Explain the classical physics of NMR
- Identify the components of an MR system and describe their use
- Identify the components of an MRI pulse sequence, and be able to calculate their amplitudes & durations
- Use the Bloch equations to analytically describe the evolution of magnetization in an MR pulse sequence
- Perform basic reconstruction of MR images using Matlab

Tentative Course Schedule

15 weeks of instruction, 2 classes per week

Class#	Date	Description	Reading *
1	1/16	Overview	1
2	1/18	Math Review	
3	1/23	Physics: Electromagnetism	Appendix A, 25.1-25.3, 27.1-27.2
4	1/25	NMR Physics	2
5	1/30	Lab 1: MR Systems	
6	2/1	Rotating Frames and Resonance	3
7	2/6	Magnetization, Relaxation, and the Bloch Eqns	4
8	2/8	The QM perspective	5, 6
9	2/13	Signal Detection	7, 27.4
10	2/15	**Midterm #1**	
11	2/20	Basic NMR Experiments (FID, SE, IR, CP)	8
12	2/22	Spatial Encoding: Gradients & frequency encoding	9, 27.3
13	2/27	Spatial Encoding: phase encoding	10
14	3/1	Reconstruction: Fourier Transforms	11
15	3/6	Lab 2: MR Scanner Operation	
16	3/8	Reconstruction: Sampling and Aliasing	12, 13
	3/13-15	Spring Break	
17	3/20	Signal, Contrast, Noise	15
18	3/22	Selective RF Pulses	16
19	3/27	Image Contrast and quantification	22
20	3/29	Pulse Sequence Design	26
21	4/3	**Midterm #2**	
22	4/5	Lab 3: Image SNR and Contrast	
23	4/10	Parallel Imaging	28
24	4/12	Fast Imaging: EPI and Spiral	19
25	4/17	Fast Imaging: Steady State	18
26	4/19	Functional MRI	25.5, 25.6
27	4/24	Diffusion MRI	21
28	4/26	MR Spectroscopy	
29	5/1	Clinical MRI	
30	5/3	MR Systems	27
	5/11	**Final Exam (1:30-3:30p)**	

* From Brown et al.

Grading
Scale:

Grade	Range
A	100-93%
A-	<93-90%
B+	<90-87%
B	<87-83%
B-	<83-80%
C+	<80-77%
C	<77-73%
C-	<73-70%
D+	<70-67%
D-	<67-60%
F	<60-0%

Assessments: weekly homework assignments (25%)
2 mid-term exams (25% each)
1 final exam (25%)

Late Work: All assignments must be submitted by 5 p.m. on the stated due date. Late submissions will be accepted up to 6 days after the deadline, with a penalty of 10% for each day it is late. Submissions >6 days after the deadline will be scored 0%.

Make Up Work: Accommodation for missed exams or assignments will be made for legitimate, documented excuses.

Expected workload
Students are expected to spend 2 hours in out-of-class work for each in-class hour.

Technology Requirements
Students will need access to ***Matlab*** to complete the homework assignments. If you do not have it available through your own lab you can access it through the CSE Labs: https://wwws.cs.umn.edu/download_software/matlab.

Scholastic Conduct
Academic integrity is essential to a positive teaching and learning environment. All students enrolled in University courses are expected to complete coursework responsibilities with fairness and honesty. Failure to do so by seeking unfair advantage over others or misrepresenting someone else's work as your own, can result in disciplinary action.

Communication
We will be using *Canvas* for distributing course materials, submitting homework, and for class discussion. The class URL is pending,

Disability Accommodations
The University of Minnesota views disability as an important aspect of diversity, and is committed to providing equitable access to learning opportunities for all students. The Disability Resource Center (DRC) is the campus office that collaborates with students who have disabilities to provide and/or arrange reasonable accommodations.

- If you have, or think you have, a disability in any area such as, mental health, attention, learning, chronic health, sensory, or physical, please contact the DRC office on your campus (UM Twin Cities - 612.626.1333) to arrange a confidential discussion regarding equitable access and reasonable accommodations.
- Students with short-term disabilities, such as a broken arm, can often work with instructors to minimize classroom barriers. In situations where additional assistance is needed, students should contact the DRC as noted above.
- If you are registered with the DRC and have a disability accommodation letter dated for this semester or this year, please contact your instructor early in the semester to review how the accommodations will be applied in the course.
- If you are registered with the DRC and have questions or concerns about your accommodations please contact your (access consultant/disability specialist).

Student Conduct

Instructors are responsible for maintaining order and a positive learning environment in the classroom. Students whose behavior is disruptive either to the instructor or to other students will be asked to leave. Students whose behavior suggests the need for counseling or other assistance may be referred to their college office or University Counseling Services. Students whose behavior may violate the University Student Conduct Code may be referred to the UMC Student Conduct Committee.

Sexual Harassment

Please note that sexual harassment by any member of the University community, student, faculty, staff, administration, is prohibited. To review the complete policy on this issue, view the following webpage http://www1.umn.edu/regents/policies/humanresources/SexHarassment.pdf.