Spring 2014: MPHY8147 Advanced Physics of MRI

Text: Principles of Magnetic Resonance Imaging
by Dwight G. Nishimura, printed by www.lulu.com

Days and Times: 2 – 3:15 pm, Monday and Thursday, Spring Semester 2014

Location: Seminar room, Center for Magnetic Resonance Research (CMRR)

Credits: 3 Cr. (two 75-minute lectures per week)

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Recommended References: Principles of Nuclear Magnetic Resonance Microscopy, by Paul T. Callaghan, Oxford University Press

Prerequisites: Undergraduate level calculus and calculus-based physics; familiarity with linear algebra

Evaluation Scheme: graded homework assignments, 1 required classroom presentation, 2 mid-term exams, 1 final exam

Advanced Physics 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. Magnetic resonance spectroscopy (MRS), as used to measure metabolism in living systems, will also be covered. The course will include several guest lectures covering many of the specialized uses of MRI and MRS in biomedicine, including fMRI, diffusion, flow, and quantifying metabolite concentrations and fluxes. Near the end of the course, students will have a hands-on opportunity to acquire MR images using one of the human MRI scanners at the CMRR.

Course Schedule:

Date	Topic	Lecturer
Th 1/23	Review of the necessary mathematics	Garwood
M 1/27	Nuclear spin, Boltzman	"
Th 1/30	Semi-classical description of NMR – The Bloch equations	"
M 2/3	Relaxation and Chemical shift	"
Th 2/6	Pulse sequence elements a) RF pulses b) Gradient pulses c) Selective excitation	"
M 2/10	d) Signal acquisition	"
Th 2/13	e) Frequency encoding f) Phase encoding	"
M 2/17	MRI sequences, data acquisition and optimization	"

Date	Topic	Lecturer
	a) Gradient echo b) Hahn and Carr-Purcell Spin Echoes c) Stimulated echo	
Th 2/20	Ernst equation, Signal-to-noise (SNR), spatial resolution	“
M 2/24	1st mid-term exam	“
Th 2/27	Digital signal processing and image reconstruction a) Signal equation b) Digital sampling requirements (Nyquist)	“
M 3/3	c) k-space d) Basic FT reconstruction e) Post-processing and image artifacts	“
Th 3/6	Scanner hardware and RF coils	Adriany
M 3/10	B0 and B1 inhomogeneity mapping	Van de Moortele
Th 3/13	Image contrast and relaxation time weighting and mapping a) T1 b) T2 c) T2* d) contrast agents	Garwood
M 3/20 Th 3/23	SPRING BREAK	
M 3/24	Alternative (non-Fourier) image reconstruction	Moeller
Th 3/27	Parallel imaging	Moeller
M 3/31	Magnetic Resonance Spectroscopy (MRS) a) shimming b) single voxel MRS	Tkac
Th 4/3	c) CSI	Metzger
M 4/7	d) metabolite quantification	Bolan
Th 4/10	2nd mid-term exam	
M 4/14	Dynamic Nuclear Polarization (DNP)	Marjanska
Th 4/17	Mapping relaxation times; rotating frame relaxation ($T1\rho$)	Michaeli
M 4/21	Specialized sequences and applications a) EPI; fMRI	Ugurbil
Th 4/24	b) Radial MRI	Garwood
M 4/28	c) Perfusion	Ugurbil
Th 5/31	d) Diffusion	Lenglet
M 5/5	MRI Safety	Vaughan
Th 5/8	Review	Garwood
M 5/12	Final Exam	