ROCHESTER INSTITUTE OF TECHNOLOGY
COURSE OUTLINE FORM

COLLEGE OF SCIENCE

Chester F. Carlson Center for Imaging Science

NEW COURSE: COS-IMGS-730 Magnetic Resonance Imaging

1.0 Course Designations and Approvals

Required course approvals:	**Approval request date:**	**Approval granted date:**
Academic Unit Curriculum Committee	2/14/2011	3/7/2011
College Curriculum Committee	3/9/2011	4/6/2011

Optional designations:	**Is designation desired?**		***Approval request date:**	****Approval granted date:**
General Education:		No		
Writing Intensive:		**No**		
Honors		**No**		

2.0 Course Information:

Course title:	Magnetic Resonance Imaging
Credit hours:	3
Prerequisite(s):	Graduate standing, or COS-CHMA-221, COS-MATH-219 and one year of College Physics or equivalent
Co-requisite(s):	None
Course proposed by:	Joseph Hornak
Effective date:	Fall 2013

	Contact hours	**Maximum students/section**
Classroom	3	24
Lab		
Studio		
Other (specify)		

2.a Course Conversion Designation ***(Please check which applies to this course)

***For more information on Course Conversion Designation please see page four.**

X	Semester Equivalent (SE) Please indicate which quarter course it is equivalent to: 1014-730 MRI
	Semester Replacement (SR) Please indicate the quarter course(s) this course is replacing:

	New

2.b Semester(s) offered (check)

Fall	Spring X	Summer	Other

All courses must be offered at least once every 2 years. If course will be offered on a bi-annual basis, please indicate here:

2.c Student Requirements

Students required to take this course: (by program and year, as appropriate)
Imaging Science – Medical Imaging Track

Students who might elect to take the course:
Chemistry Undergraduate and Graduate, Physics, Imaging Science – Undergraduate and Graduate

3.0 Goals of the course (including rationale for the course, when appropriate):

3.1 To learn the history of magnetic resonance.
3.2 To understand resonance phenomenon and spin physics in the context of magnetic resonance.
3.3 To understand Fourier transforms from the quadrature sampling perspective.
3.4 To understand the various pulse sequences used in MRI and the relationship between acquisition parameters and spin relaxation times.
3.5 To understand the function of the various components in an MRI system.
3.6 To understand MRI data and image processing.

4.0 Course description (as it will appear in the RIT Catalog, including pre- and co-requisites, and quarters offered). Please use the following format:

COS-IMGS-730 **Magnetic Resonance Imaging**
This course is designed to teach the principles of the imaging technique called magnetic resonance imaging (MRI). The course covers spin physics, Fourier transforms, basic imaging principles, Fourier imaging, imaging hardware, imaging techniques, image processing, image artifacts, safety, and advanced imaging techniques. (Graduate standing or COS-CHMA-221, COS-MATH-219 and one year of College Physics or equivalent)
Class 3, Credit 3 (F)

5.0 Possible resources (texts, references, computer packages, etc.)

5.1 J.P. Hornak, *The Basics of MRI*, Interactive Learning Software
5.2 Z.-P. Lang and P.C. Lauterbur, *Principles of Magnetic Resonance Imaging : A Signal Processing Perspective.* Wiley-IEEE, Hoboken, NJ.
5.3 E.M. Haacke, R.W. Brown, M.R. Thompson, and R. Venkatesan; *Magnetic Resonance Imaging: Physical Principles and Sequence Design*, John Wiley & Sons, Hoboken, NJ.
5.4 D.D. Stark and W.G. Bradley, *Magnetic Resonance Imaging.* San Diego, CA.
5.5 M.A. Bernstein, K.F. King, X.J. Zhou, Handbook of MRI Pulse Sequences. Elsevier, New York, NY

6.0 Topics (outline):

- 6.1. Introduction
  - 6.1.1. NMRI or MRI ?
  - 6.1.2. Opportunities in MRI
  - 6.1.3. Tomographic Imaging
  - 6.1.4. Microscopic property responsible for MRI
- 6.2. The Mathematics of NMR (review)
  - 6.2.1. Exponential Functions
  - 6.2.2. Trigonometric Functions
  - 6.2.3. Differentials and Integrals
  - 6.2.4. Vectors
  - 6.2.5. Matrices
  - 6.2.6. Coordinate Transformations
  - 6.2.7. Convolutions
  - 6.2.8. Imaginary Numbers
  - 6.2.9. The Fourier Transform
- 6.3. Spin Physics
  - 6.3.1. Spin
  - 6.3.2. Properties of Spin
  - 6.3.3. Nuclei with Spin
  - 6.3.4. Energy Levels
  - 6.3.5. NMR Transitions
  - 6.3.6. Energy Level Diagrams
  - 6.3.7. Continuous Wave NMR Experiment
  - 6.3.8. Boltzmann Statistics
  - 6.3.9. Spin Packets
  - 6.3.10. T_1 Processes
  - 6.3.11. Precession
  - 6.3.12. T_2 Processes
  - 6.3.13. Rotating Frame of Reference
  - 6.3.14. Pulsed Magnetic Fields
  - 6.3.15. Spin Relaxation
  - 6.3.16. Bloch Equations
- 6.4. NMR Spectroscopy
  - 6.4.1. Time Domain NMR Signal
  - 6.4.2. +/- Frequency Convention
  - 6.4.3. 90- FID
  - 6.4.4. Spin-Echo
  - 6.4.5. Inversion Recovery
  - 6.4.6. Chemical Shift
- 6.5. Fourier Transforms
  - 6.5.1. Introduction
  - 6.5.2. The + and - Frequency Problem
    - 6.5.2.1. Linear Sampling
    - 6.5.2.2. Quadrature Sampling

6.11.2. RF Quadrature
6.11.3. B_o Inhomogeneity
6.11.4. Gradient
6.11.5. RF Inhomogeneity
6.11.6. Motion
6.11.7. Flow
6.11.8. Chemical Shift
6.11.9. Partial Volume
6.11.10. Wrap Around
6.11.11. Gibbs Ringing

6.12. Advanced Imaging Techniques
6.12.1. Introduction
6.12.2. Volume Imaging (3-D Imaging)
6.12.3. MRI Angiography (MRA)
6.12.3.1. Fractional Nyquist imaging
6.12.4. Diffusion Tensor Imaging
6.12.5. Fractional Nex & Echo Imaging
6.12.6. Fast Spin-Echo Imaging
6.12.7. Chemical Shift Imaging (Fat Suppression)
6.12.8. Functional MRI (fMRI)
6.12.8.1. Echo Planar Imaging
6.12.9. Spatially Localized Spectroscopy
6.12.10. Chemical Contrast Agents
6.12.11. Magnetization Transfer Contrast
6.12.12. Variable Bandwidth Imaging
6.12.13. T_1, T_2, & Spin Density Images
6.12.14. Tissue Classification
6.12.15. Hyperpolarized Noble Gas Imaging
6.12.16. Parallel Imaging
6.12.17. Magnetic Resonance Elastography
6.12.18. Electron Spin Resonance

7.0 Intended course learning outcomes and associated assessment methods of those outcomes

Course Learning Outcome	Homework	Exams
7.1 Describe the evolution of a magnetization vector and a net magnetization when it is perturbed from equilibrium.	X	X
7.2 Solve the Bloch equations.	X	X
7.3 Define common Fourier pairs and solve for new ones using the convolution theorem.	X	X
7.3 Describe simple magnetic	X	X

resonance imaging principles such as slice selection, phase encoding, and frequency encoding.		
7.4 Describe common Imaging Pulse Sequences	X	X
7.5 Explain the importance of MRI safety and the health consequences of being unsafe.	X	X
7.6 Describe the function and operating principles of MRI technology.	X	X
7.7 Describe the process of converting the raw data into a magnetic resonance image.	X	X
7.8 Relate an image artifact to the problem with the imaging system.	X	X
7.9 Describe how advanced MRI techniques work based on an understanding of the fundamental MRI procedures.	X	X

8.0 Program outcomes and/or goals supported by this course

8.1 Solving problems
- 8.1.1 Setting up the problem
- 8.1.2 Stating assumptions
- 8.1.3 Defining symbols
- 8.1.4 Showing work
- 8.1.5 Solving the problem
- 8.1.6 Reporting unit

9.0

	General Education Learning Outcome Supported by the Course	Assessment Method
Communication		
	Express themselves effectively in common college-level written forms using standard American English	
	Revise and improve written and visual content	
	Express themselves effectively in presentations, either in spoken standard American English or sign language (American Sign Language or English-based Signing)	
	Comprehend information accessed through reading and discussion	
Intellectual Inquiry		
	Review, assess, and draw conclusions about hypotheses and theories	
	Analyze arguments, in relation to their premises, assumptions, contexts, and conclusions	
	Construct logical and reasonable arguments that include anticipation of counterarguments	
	Use relevant evidence gathered through accepted scholarly methods and properly acknowledge sources of information	
Ethical, Social and Global Awareness		
	Analyze similarities and differences in human experiences and consequent perspectives	
	Examine connections among the world's populations	
	Identify contemporary ethical questions and relevant stakeholder positions	
Scientific, Mathematical and Technological Literacy		
	Explain basic principles and concepts of one of the natural sciences	
	Apply methods of scientific inquiry and problem solving to contemporary issues	
	Comprehend and evaluate mathematical and statistical information	
	Perform college-level mathematical operations on quantitative data	
	Describe the potential and the limitations of technology	
	Use appropriate technology to achieve desired outcomes	
Creativity, Innovation and Artistic Literacy		
	Demonstrate creative/innovative approaches to course-based assignments or projects	
	Interpret and evaluate artistic expression considering the cultural context in which it was created	

10.0 Other relevant information (such as special classroom, studio, or lab needs, special scheduling, media requirements, etc.)

Smart Classroom