Course Plan: MRI Physics (2 Credits)

Course Information

Course Title: MRI Physics
Level: M.Sc. In Medical Physics
Credits: 2 Credit Hours
Format: 2 Hours Lecture per Week

Course Description

This course provides a comprehensive introduction to the physical principles and clinical applications of Magnetic Resonance Imaging (MRI), following the clear and accessible approach of Hashemi's foundational textbook. The curriculum covers basic principles, pulse sequences, image construction, k-space, scan parameters, artifacts, and advanced techniques, with emphasis on understanding the physics underlying safe and high-quality MRI practice .

Overall Learning Objectives

Upon successful completion of this course, students will be able to:

1. **Explain** the fundamental physical principles of MRI, including nuclear spin, magnetization, precession, and resonance .
2. **Describe** the function of key MRI hardware components: magnets, gradient coils, and RF coils .
3. **Differentiate** the basic pulse sequences (Spin Echo, Gradient Echo, Inversion Recovery) and their clinical applications .
4. **Analyze** the process of image formation, including slice selection, frequency/phase encoding, and k-space data acquisition .

5. **Calculate** the effects of changing scan parameters (TR, TE, FOV, matrix) on image quality, SNR, and CNR .
6. **Identify** common MRI artifacts and apply appropriate corrections .
7. **Explain** flow phenomena, MR Angiography (MRA) principles, and advanced techniques (diffusion, fMRI, MRS) .
8. **Apply** MRI physics principles to clinical imaging protocols and safety practices.

Expectations (What You Will Be Able to Do After This course)

Area	Specific Outcomes
Clinical Readiness	Communicate effectively with radiologists and technologists about sequence selection and parameter optimization
Problem-Solving	Manually calculate SNR and contrast trade-offs for different scan protocols
Equipment Knowledge	Identify components of an MRI system and explain their role in image quality
Image Interpretation	Recognize common artifacts and suggest strategies to minimize or eliminate them
Protocol Optimization	Select appropriate pulse sequences and parameters for different clinical indications
Safety Competency	Understand MR safety zones, contraindications, and the biological effects of RF and gradient fields
Research Readiness	Read and interpret MRI physics literature and understand advanced technique concepts

Weekly Course Schedule (15 Weeks + Exams)

Week	Topic	Key Content
1	Introduction & Basic Principles	Course overview, nuclear spin, magnetic moment, precession, resonance, net magnetization vector (NMV)
2	RF Pulse & Relaxation	RF excitation, flip angle, T1 recovery, T2 decay, T2* relaxation, free induction decay (FID)
3	Tissue Contrast & Clinical Applications	TR, TE and their effect on contrast, clinical examples of T1-weighted, T2-weighted, and PD-weighted imaging
4	Pulse Sequences (Part I)	Saturation recovery, partial saturation, inversion recovery (STIR, FLAIR)
5	Pulse Sequences (Part II)	Spin Echo sequences, multi-echo, fast spin echo (FSE) basics
6	Fourier Transform & Math Review	Fourier transform fundamentals, convolution, sampling, Nyquist criterion
7	Image Construction (Part I)	Slice selection, transmit bandwidth, gradient magnetic fields
8	**Midterm Exam**	
9	Image Construction (Part II)	Frequency encoding, phase encoding, spatial localization

Week	Topic	Key Content
10	Signal Processing & Data Space	Signal detection, demodulation, raw data, data space, pulse sequence diagrams
11	FOV, k-Space & Image Optimization	Field of view, k-space properties, scan parameters and image quality trade-offs (SNR, CNR, spatial resolution, scan time)
12	Artifacts in MRI	Aliasing/wraparound, chemical shift, motion, truncation, susceptibility, cross-excitation artifacts and correction strategies
13	Fast & Advanced Sequences	Fast Spin Echo (FSE), Gradient Echo (GRE), Echo Planar Imaging (EPI), parallel imaging (SENSE, GRAPPA)
14	Flow, MRA & Spectroscopy	Flow phenomena, Time-of-Flight (TOF) MRA, Phase-Contrast (PC) MRA, MR Spectroscopy (MRS) basics
15	Advanced & Clinical Applications	Diffusion/Perfusion imaging, functional MRI (fMRI), clinical protocols (brain, spine, abdomen, joints), safety review
16	**Final Exam**	Comprehensive coverage of all topics

Assessment (Proposed)

Component	Weight
Homework / Problem Sets	10%

Component	Weight
Quizzes	10%
Midterm Exam	30%
Final Exam	40%
Participation / In-class Activities	10%
Total	**100%**

Primary Textbook

Hashemi, R. H., Bradley, W. G., & Lisanti, C. J. *MRI: The Basics*. 3rd edition. Lippincott Williams & Wilkins, 2010 .

Note: This textbook presents complicated topics in a readable, understandable fashion with a minimum of mathematics, covering basic principles to up-to-the-minute techniques .

Recommended Prerequisites

- Basic physics (mechanics, electricity, magnetism)
- Elementary calculus and algebra
- Basic anatomy (helpful but not mandatory)

Teaching Methods

- **Lectures** with slide presentations and board work, following the textbook structure

- **Problem-solving sessions** (SNR calculations, parameter optimization, artifact identification)
- **Case-based discussions** linking physics to clinical scenarios
- **Group activities** and paper discussions (optional for graduate-level depth)
- **Online resources**: e-MRI (IMAIOS), MR-TIP, revisemri.com

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Final Takeaway

By the end of this course, you will master the physical and mathematical foundations of MRI, enabling you to think critically about image quality, protocol selection, and emerging techniques. You will speak the language of MRI physics fluently and be prepared for advanced study or clinical practice in radiology and medical physics.