Module 10 - How Can We Do MR Imaging?
Instructor's Manual

Suggested Prior Modules
Modules 3, 6, and 7

Particular prior knowledge from Module 3 that students are expected to have already learned:

- Quantum spins precess in the presence of a magnetic field (B_0) at the Larmor frequency, $f = \gamma B_0$.

If you do not have time to do the entirety of Module 3, then a good summary of the relevant information is given in the Background Information section of Module 4. This could be assigned as a pre-reading assignment in preparation for this module.

Particular prior knowledge from Module 6 that students are expected to have already learned:

- Basic understanding of T_1 and T_2 relaxation times.

This is only required if students are completing the final section of Module 10, What Provides Contrast in MRI Images? *The entirety of Module 6 could be done as a longer, interactive pre-reading assignment for Module 10. It is estimated to take about 2 hours for students to complete asynchronously.*

Particular prior knowledge from Module 7 that students are expected to have already learned:

- Use of the Hahn echo or CPMG pulse sequence to measure T_2 relaxation times.

This is only required if students are completing the final section of Module 10, What Provides Contrast in MRI Images? *If you do not have time to do the entirety of Module 7, the Hahn Echo Theory and Can We Find T_2 Using a Single Experiment and More Pulses? sections should suffice as preparation for this module and could be done as a pre-reading assignment.*

Suggested Use:
The instructions below are suggestions to help students engage with the material in class and were implementations of the materials that the developers used in their classes. However, all sections and questions in this module can successfully be done asynchronously online to serve as a pre-reading assignment in preparation for a lab or a homework assignment that brings together multiple aspects of MR covered in earlier modules to understand a significant application, MRI.

This material is based upon work supported by the National Science Foundation under award DUE-2120545. Making Nuclear Magnetic Resonance Resonate With Students: Integrating NMR Into the Undergraduate Science Curriculum,

Expected Learning Outcomes

At the end of this module, students should be able to...

1. *explain the importance of magnetic field gradients for encoding spatial information in MR signals*
2. *identify key differences between MRI and other imaging modalities*
3. *utilize prior knowledge about MR signals to determine different ways to provide contrast to an MR image*

Background Information

(5 minutes)

Suggested activity: Have students take turns reading aloud the text, along with the information in the margin. You can have the class do an open brainstorming session on the discussion questions. These open-ended questions serve as a good icebreaker to get students ready to engage with the rest of the material.

Thought Experiments: How Can We Encode Spatial Information into MR Signal?

(10 minutes)

Suggested activity: This section is best done as a classwide think-pair-share. If you have whiteboards, you can have each small group draw what they expect the MR frequency spectrum to look like for each thought experiment.

A New Form of Imaging

(15 minutes)

Suggested activity: Have students take turns reading aloud the text, along with the information in the margin. You can have the class do think-pair-share to answer the guided inquiry questions.

How Do We Use Gradients to Create Images?

(45 minutes)

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Suggested activity: The short text can be read as a class. After verifying that everyone understands the figure demonstrating magnetic field gradients applied in different directions, students can pair up with one person running the PhET simulation and one recording their answers to the guided inquiry questions. (The instructor can clarify that it is fine if students have the same answers for these questions, but also encourage students to write down who they were working with to give proper attribution that it was a shared effort.) The students should alternate roles every couple of questions so that each student has plenty of opportunity to be the 'driver' and the later questions provide a good opportunity for the students to brainstorm possible strategies of what to try with the simulation.

Modern-Day Imaging

(10 minutes)

Suggested activity: Students can read and answer these questions individually. This is a nice activity to have students complete if they finish the previous activity early, and can be easily skipped or saved as a quick homework activity if you have limited class time.

What Provides Contrast in MRI Images?

(20 minutes)

Suggested activity: Have students take turns reading aloud the text. You can have the class do think-pair-share to answer the guided inquiry questions.

Reflection Questions

(Any Remaining Time)

Suggested activity: In any remaining time, you can choose some or all of the questions as a small group or individual reflection activity. Ofte,n these are good open questions that provide an opportunity for students to reflect on everything they have learned in this module. These questions can be completed outside of class as homework and used to assess students' comprehension of the material.

In the last 5 minutes of class: Give the students some time in class to assess themselves on the learning objectives using the provided rubric in the student worksheet that is found on the next page.

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Follow this rubric to assess your work for this module:

Scientific Ability	Adequate	Needs improvement	Inadequate	Missing
Is able to explain the importance of magnetic field gradients for encoding spatial information in MR signals	Correctly explains the importance of magnetic field gradients for encoding spatial information in a comprehensible way.	Some minor errors or unclear portions of the explanation.	A large portion of the explanation contains errors or is incorrect.	No attempt is made to explain the importance of magnetic field gradients for encoding spatial information in MR signals.
Is able to identify key differences between MRI and other imaging modalities	Identifies at least three correct key differences between MRI and other imaging modalities.	Identifies at least two correct key differences between MRI and other imaging modalities.	Only identifies one correct key difference between MRI and other imaging modalities.	No attempt is made to identify key differences between MRI and other imaging modalities.
Is able to utilize prior knowledge about MR signals to determine different ways to provide contrast to an MR image	Successfully utilizes correct and relevant prior knowledge to determine different ways to provide contrast to an MR image.	An attempt is made to utilize prior knowledge, but some small errors are made.	An attempt is made to utilize prior knowledge, but it uses incorrect information or information not relevant to providing contrast to an MR image.	No attempt is made to use prior knowledge to determine ways to provide contrast to an MR image.

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