Module 1 - Why Magnetic Resonance?
Instructor's Manual

Suggested Prior Modules

There are no suggested prior modules, nor required prior knowledge. This optional introductory module provides students with some context and motivation for learning about magnetic resonance. We highly suggest using the optional introductory activity if students have not yet seen the Bohr model of the hydrogen atom or the electromagnetic spectrum.

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 serve as a pre-reading assignment in preparation for class or lab.

Expected Learning Outcomes

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

1. provide different examples of modern-day technologies that use magnetic resonance techniques

2. identify the key elements of a magnetic resonance apparatus

3. specify how magnetic resonance differs from other spectroscopy and imaging modalities

(Optional) Introductory Activity

(20 minutes)

Suggested activity: Energy-Level Transitions and Spectroscopy

We highly suggest this fun activity to warm students up physically and to get them to start thinking about how light interacts with matter and can provide helpful information about the quantum realm. This activity does require some prior setup of the space that might need to be done ahead of time.

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,

Background Information

(5 minutes)

Suggested activity: Have students take turns reading aloud this section. Feel free to pause to explain further the different boldfaced words that may require more clarification.

Small Group Discussion
(10 minutes)

Suggested activity: Have the class discuss in small groups the *Small Group Discussion* questions, and then regroup and have groups share their responses to the questions. It is interesting to see how many examples students can think of for the first question. The main goal is to garner an appreciation for understanding how light interacts with matter and how magnetic resonance techniques offer some interesting information about the sample environment at both the molecular and atomic levels.

Brief History of Magnetic Resonance

(10 minutes)

Suggested activity: Have students work in small groups answering the guided inquiry questions using the provided information for about 5 minutes. Briefly have students share their responses with the rest of the class (5 minutes).

In order to provide a more in-depth history, I have my students each be responsible for presenting a scientist related to MR and spectroscopy each week so we can learn more about their biographies, their contributions to science, and any challenges they faced along the way. The guided inquiry questions for this section provide a nice motivation for this project and provide the opportunity for the instructor to mention how we'll be learning more about these scientists and others in the upcoming modules.

Different MR Technologies

(15 minutes)

Suggested activity: Have students work in small groups answering the guided inquiry questions using the provided information for about 10 minutes. Briefly have students share their responses with the rest of the class (5 minutes). The main goal is for

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,

students to appreciate the diversity of magnetic resonance techniques utilized in various modern-day and future technologies.

How does MR Compare with Related Technologies?

(20 minutes)

Suggested activity: Have students work in small groups answering the guided inquiry questions using the provided information for about 15 minutes. Briefly have students share their responses with the rest of the class (5 minutes).

Optional Hands-On Activity for Spectroscopy: Since the spectroscopy table can be rather dense, you can print out enough copies of the table so there is one set for each group (see the next page for a printout of the tables you can use). Then cut up the table into pieces along the red lines. You can display the related figure so students can use what they learned from the figure to determine how the table pieces go together.

Optional Hands-On Activity for Imaging: For the imaging table and figure, one of our undergraduate researchers developed an activity where students can place various statements into a Venn diagram of the different imaging modalities, using the information provided in the table.

There is an online version making use of Google slides, so students can make a copy and drag the statements to the appropriate location in the Venn Diagram.

- (Instructor's copy) Venn diagram activity (online version)
- Venn diagram activity (online version)

There are also printable PDF versions, which can be printed out and students can do the activity in small groups in class.

- (Instructor's copy) Venn diagram activity (print out version).pdf
- Venn diagram activity (print out version).pdf

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,

Spectroscopy	EM Frequencies	Signal Generated By	Application
Nuclear Magnetic Resonance (NMR)	Radio frequencies (RF) from 1E8 to 8E8 Hz (100 - 800 MHz)	RF radiation absorbed by nuclei in the presence of a magnetic field causing the nuclei to undergo transitions from lower energy to higher energy spin states.	Chemical structure, dynamics, reaction state and chemical environments of primarily liquid sample in fields as diverse as food quality control and research, identifying human disorders, cancer diagnosis, environmental monitoring, and drug discovery and development.
Raman	Broad spectrum of frequencies, measuring photon frequency shifts between 1.2E13 Hz to 1.2E14 Hz (12 - 120 THz)	Monochromatic light is used to illuminate samples causing molecular vibrations or other excitations in the system which shifts the energy of the scattered photons either up or down.	Chemical analysis in fields as diverse as pharmaceuticals, cosmetics, geology and mineralogy, DNA/RNA analysis
Infrared (IR)	IR frequencies from 1.9E13 to 1.2E14 Hz (19 - 120 THz)	IR radiation absorbed by the molecules causing molecular vibrations	Chemical structure, functional group identification, and detection of impurities in solid, liquid, or gas samples.
Ultraviolet (UV)	Ultraviolet frequencies between 7.5E14 to 1.5E15 Hz (750 - 1500 THz)	UV radiation absorbed by electrons causing atomic electron transitions from ground states to higher energy states.	Bacterial culturing, drug identification and nucleic acid purity checks and quantitation, to quality control in the beverage industry and chemical research.
X-ray	X-ray frequencies from about 1E16 to 1E20 Hz (10 - 100,000 pHz)	X-ray radiation absorbed by electrons causing atomic electron transitions from ground states to higher energy states.	Chemical analysis in fields as diverse as mining, medical research, polymer manufacturing, geology, and consumer product quality control.

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,

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. These are often good questions that can be completed outside of class as homework.

These questions do not necessarily have correct answers but provide an opportunity for students to reflect on everything they have learned in this module.

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 and copied below.

Learning Outcome	Adequate	Needs improvement	Inadequate	Missing
Is able to provide different examples of modern-day technologies that use magnetic resonance techniques	Can provide at least 3 examples of modern-day technologies that use magnetic resonance techniques.	Can provide 2 examples of modern-day technologies that use magnetic resonance techniques.	Can provide 1 examples of modern-day technologies that use magnetic resonance techniques.	Cannot provide any examples of modern-day technologies that use magnetic resonance techniques.
Is able to identify the key elements of a magnetic resonance apparatus	Can identify at least 3 key elements of a magnetic resonance apparatus.	Can identify at least 2 key elements of a magnetic resonance apparatus.	Can identify at least 1 key elements of a magnetic resonance apparatus.	Cannot identify any key elements of a magnetic resonance apparatus.
Is able to specify how magnetic resonance differs from other spectroscopy and imaging modalities	Can accurately describe at least 2 differences between magnetic resonance techniques and other spectroscopy and/or imaging modalities.	Can accurately describe at least 1 difference between magnetic resonance techniques and other spectroscopy and/or imaging modalities.	Can roughly describe at least 1 difference between magnetic resonance techniques and other spectroscopy and/or imaging modalities.	Cannot accurately describe any differences between magnetic resonance techniques and other spectroscopy and/or imaging modalities.

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, CC 4.0 BY NC SA © 2025 M. Frey, C. Abernethy, D. Gosser https://sites.google.com/view/makingnmr/