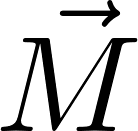
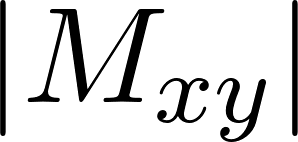
## Module 5 Student Questions

## Faraday’s Law - Guided Inquiry Questions

1. Sketch an example of what the voltage versus time data might look like for the experiment performed in the video when the magnet is being rotated on the central platform. (A rough sketch will do!) If the quantum spins are precessing at the Larmor frequency, what might be a reasonable guess for the frequency of the fluctuating voltage we will be detecting?
2. We need spins to be precessing in order to induce any voltage and measure NMR signal. Draw a picture in the Bloch representation of possible quantum states to put the spins in. Explain your choice.
3. Look closely at the video of the wire loop and the rotating bar magnet in the video above. Everything in the experimental setup was oriented to maximize the signal being measured according to Faraday's law of induction. Using this video as a guide, draw a possible orientation of the loop of wire we could use to detect the NMR signal next to your Bloch sphere.

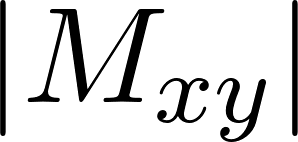
## 

## NMR Signal - Guided Inquiry Questions

1. Open the Bloch simulator and, without clicking on anything, draw a sketch of the motion of the net nuclear magnetization vector, [](https://www.codecogs.com/eqnedit.php?latex=%5Cvec%7BM%7D#0), and copy down the plot of [](https://www.codecogs.com/eqnedit.php?latex=%7CM_%7Bxy%7D%7C#0) and [](https://www.codecogs.com/eqnedit.php?latex=M_x#0) in the upper-right corner. Does this match with our description of the NMR signal described in the previous paragraph? How so?
2. In your sketch, draw the orientation of the wire loop that is collecting the red ([](https://www.codecogs.com/eqnedit.php?latex=M_x#0)) NMR signal. *Hint: It may be helpful to add some x- and y-axes to your sketch!*
3. Draw a sketch of how the net nuclear magnetization vector should be oriented in order to maximize the red ([](https://www.codecogs.com/eqnedit.php?latex=M_x#0)) NMR signal.

## 

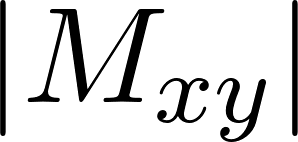
## More Realistic NMR Signal - Guided Inquiry Questions

1. Open the Bloch simulator, select “Inhomogeneity” instead of “Equilibrium” in the drop-down menu, and then click on “[](https://www.codecogs.com/eqnedit.php?latex=90%5E%5Ccirc_x#0) hard”. Describe what you are seeing.
2. Copy down the plot of [](https://www.codecogs.com/eqnedit.php?latex=%7CM_%7Bxy%7D%7C#0) and [](https://www.codecogs.com/eqnedit.php?latex=M_x#0) and explain why it looks that way. Try to make use of *inhomogeneities* and *dephasing* in your explanation.

*Hint: think of what the net nuclear magnetization vector would be doing in this experiment.*

## 

## Different Components of NMR Spectrometer - Guided Inquiry Questions

The videos below show NMR signal from the TeachSpin benchtop NMR spectrometer as shown on an oscilloscope. The yellow trace corresponds to [](https://www.codecogs.com/eqnedit.php?latex=%7CM_%7Bxy%7D%7C#0) and the blue trace corresponds to [](https://www.codecogs.com/eqnedit.php?latex=M_x#0) after subtracting out the input frequency of ~21 MHz.

1. Check out this YouTube video (<https://www.youtube.com/watch?v=SayyvFx6L1I>). Which of the three primary spectrometer settings is being changed during the course of this video? Explain how you arrive at your conclusion.
2. Check out this YouTube video (<https://www.youtube.com/watch?v=5VK8XQ2z_qM>). Which of the three primary spectrometer settings is being changed during the course of this video? Explain how you arrive at your conclusion.
3. Check out this YouTube video (<https://www.youtube.com/watch?v=L7wS_iK9yqE>). Which of the three primary spectrometer settings is being changed during the course of this video? Explain how you arrive at your conclusion.

## 

## Reflection Questions

1. Explain how the free induction decay experiment is designed to maximize NMR signal. *Hint: Consider why a 90-degree pulse is used and why this generates the most signal given what you have learned about Faraday's law and ways to orient the receiver coil relative to the rotating bar magnet in order to maximize the voltage induced.*
2. All three primary spectrometer settings can affect the size of the NMR signal (the overall maximum voltage of the signal as observed on the oscilloscope). If you observe the amplitude changing in the signal, how can you differentiate whether it is the frequency being changed as opposed to either the pulse length or the repetition time?
3. You are unsure if the signal you are seeing is coming from the sample or from leakage coming from the transmitted pulse. (This can occur since we acquire signal right after the pulse and are using the same coil for both transmitting and receiving!) What are some things you can try to do to verify if the signal is indeed coming from the sample?

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## Follow this rubric to assess your work for this module:

| **Scientific Ability** | **Adequate** | **Needs improvement** | **Inadequate** | **Missing** |
| --- | --- | --- | --- | --- |
| **Is able to identify what physical quantities are being measured and describe how to acquire magnetic resonance (MR) signal using an NMR spectrometer** | All measured quantities are correctly identified and the description of how MR signal is acquired is accurate and clear. | All measured quantities are correctly identified but the description of how MR signal is acquired is vague or incomplete. | Not all measured quantities are correctly identified OR no description of how MR signal is acquired is provided. | Measured quantities are incorrect and no description of how MR signal is acquired is provided. |
| **Is able to extract information and interpret MR signal from oscilloscope correctly** | All necessary information has  been extracted correctly, and  written in a comprehensible way. | Some of the information is extracted correctly, but not all of the  information (e.g. missing units). | Information that is extracted is incorrect or  contains errors such as labeling  quantities incorrectly. | No visible attempt is made to extract  information. |
| **Is able to identify which experimental parameters can cause observed changes in MR signal** | All experimental parameters and the resulting changes they make to the MR signal are correctly identified. | Most of the experimental parameters and the resulting changes they make to the MR signal are correctly identified. | An attempt is made, but most of the experimental parameters and the resulting changes they make to the MR signal are incorrectly identified. | No attempt is made to identify the experimental parameters that can cause the observed changes in MR signal. |