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MRI activity.

Open the simulator in https://phet.colorado.edu/en/simulations/mri

1. NMR

   Place yourself in the tab *Simplified NMR*. Remember that the Larmour relationship relates the magnetic field to the resonant frequency:

$$v_L = \frac{\gamma}{2\pi} B_0$$

where v_L is the resonant frequency, $\frac{\gamma}{2\pi}$ is the gyromagnetic ratio and B_0 is the magnetic field.

Table1. Gyromagnetic ratios for different nuclei.

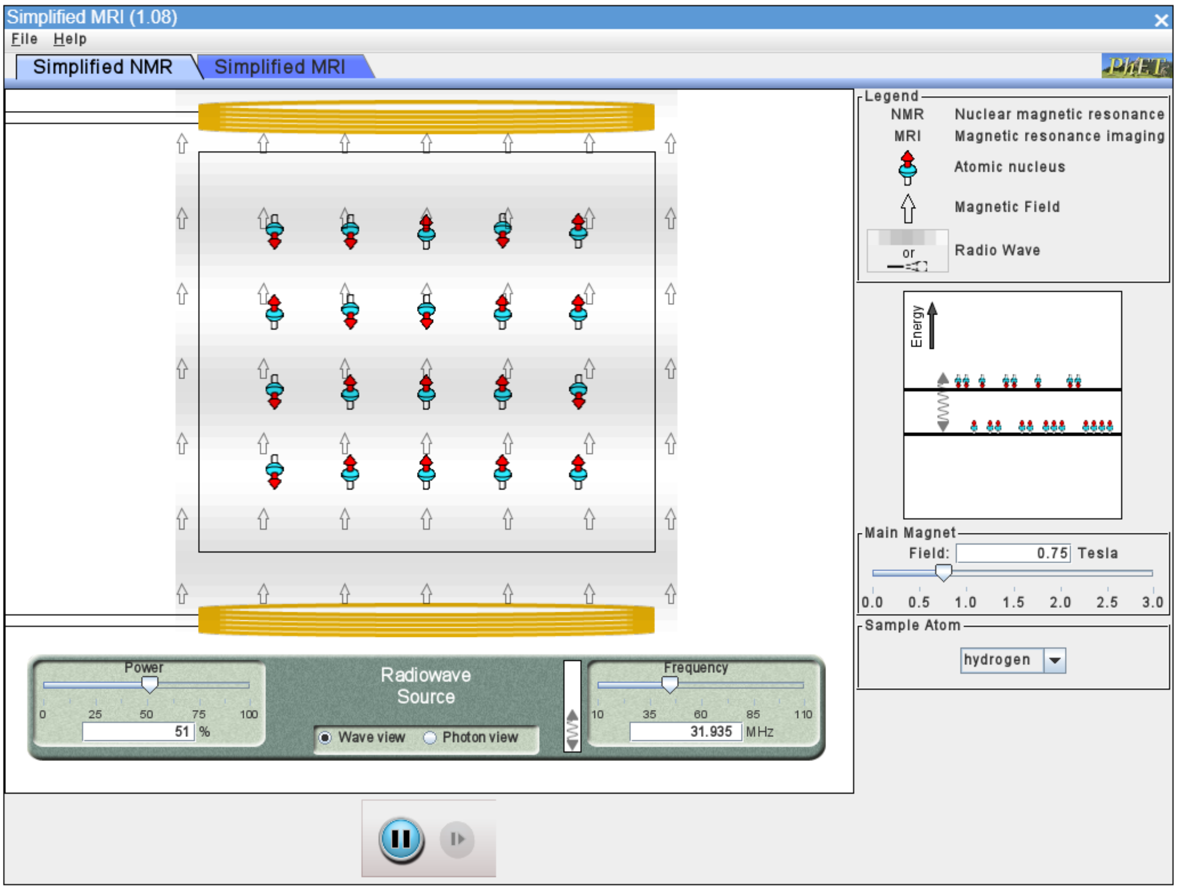
Nuclei	Gyromagnetic ratio	Nuclei	Gyromagnetic ratio
1H	42,58	65Cu	12,09
7Li	16,55	75As	7,291
9Be	5,984	77Se	8,118
11B	13,66	81Br	11,50
13C	10,71	87Rb	13,93
15N	4,314	93Nb	10,41

17O	5,772	117Sn	15,17
19F	40.05	121Sb	10,19
23Na	11,42	127I	8,518
27Al	11,09	133Cs	5,584
29Si	8,458	195Pt	9,153
31P	17,24	199Hg	7,590
35Cl	4,172	203Tl	24,33
51V	11,19	207Pb	8,907
55Mn	10,50	209Bi	6,841
59Co	10,05		

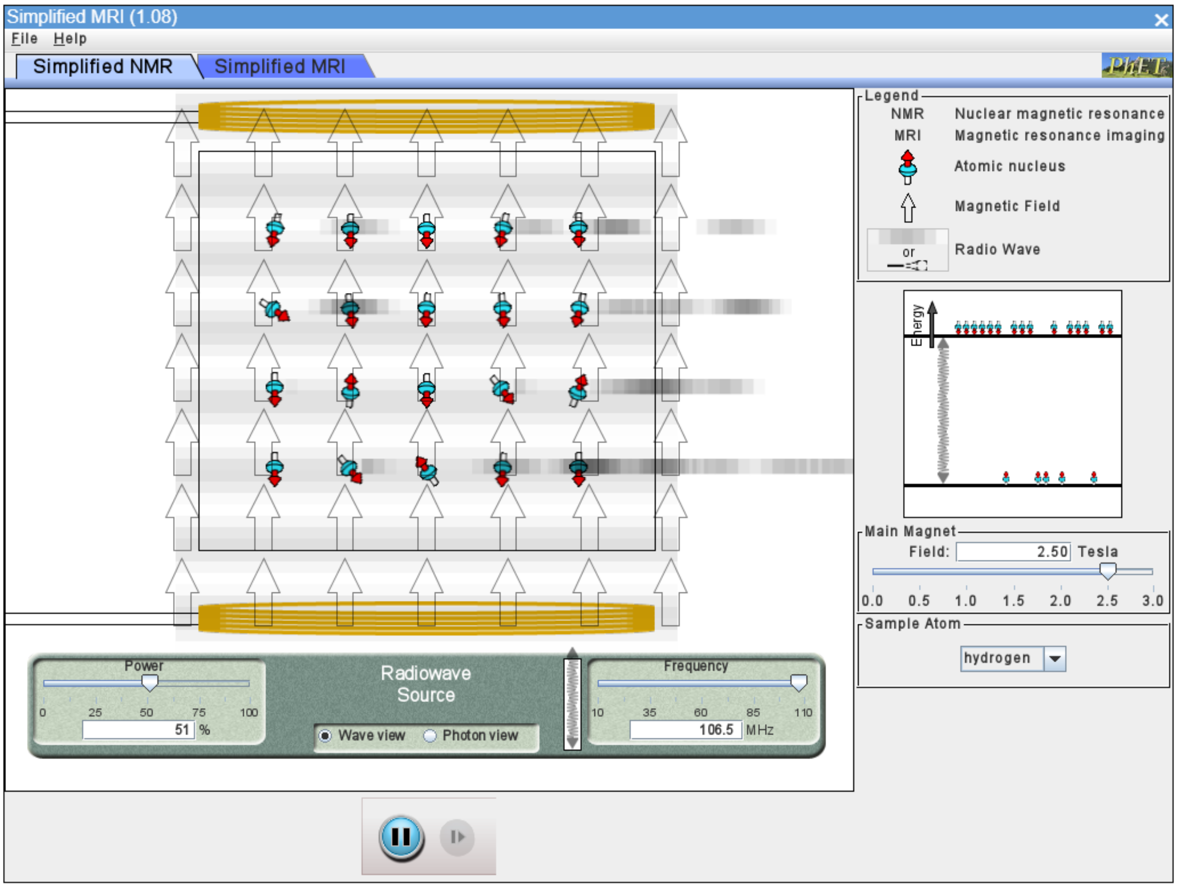
Use the Larmour relationship and the gyromagnetic ratios of various nuclei shown in table 1 to complete table 2. Check your results in the simulation by setting the appropriate frequencies and main magnet field, take a screenshot of the nuclei emitting energy to include in the report. Try to find the last nuclei (????) by playing with the simulation and register the frequency at two different magnetic fields.

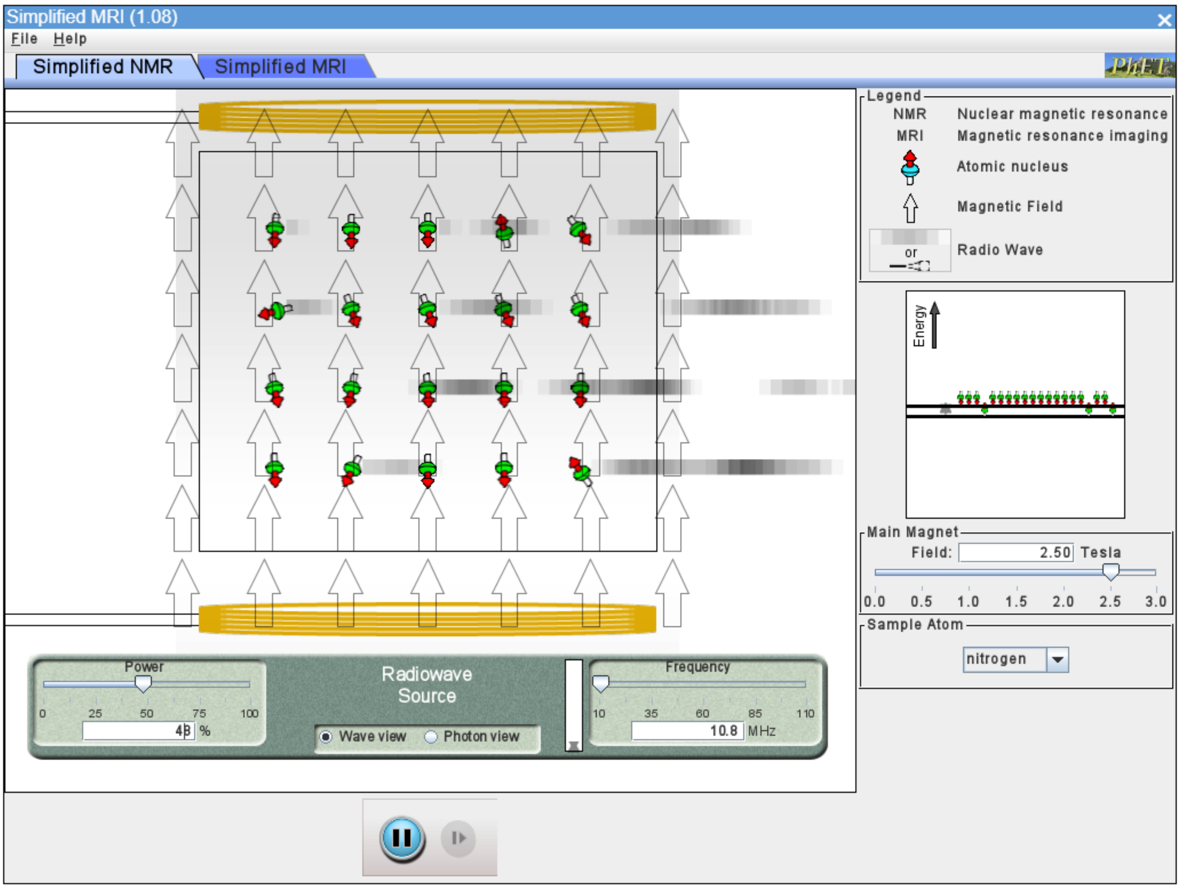
Table 2. Different settings to achieve energy emission.

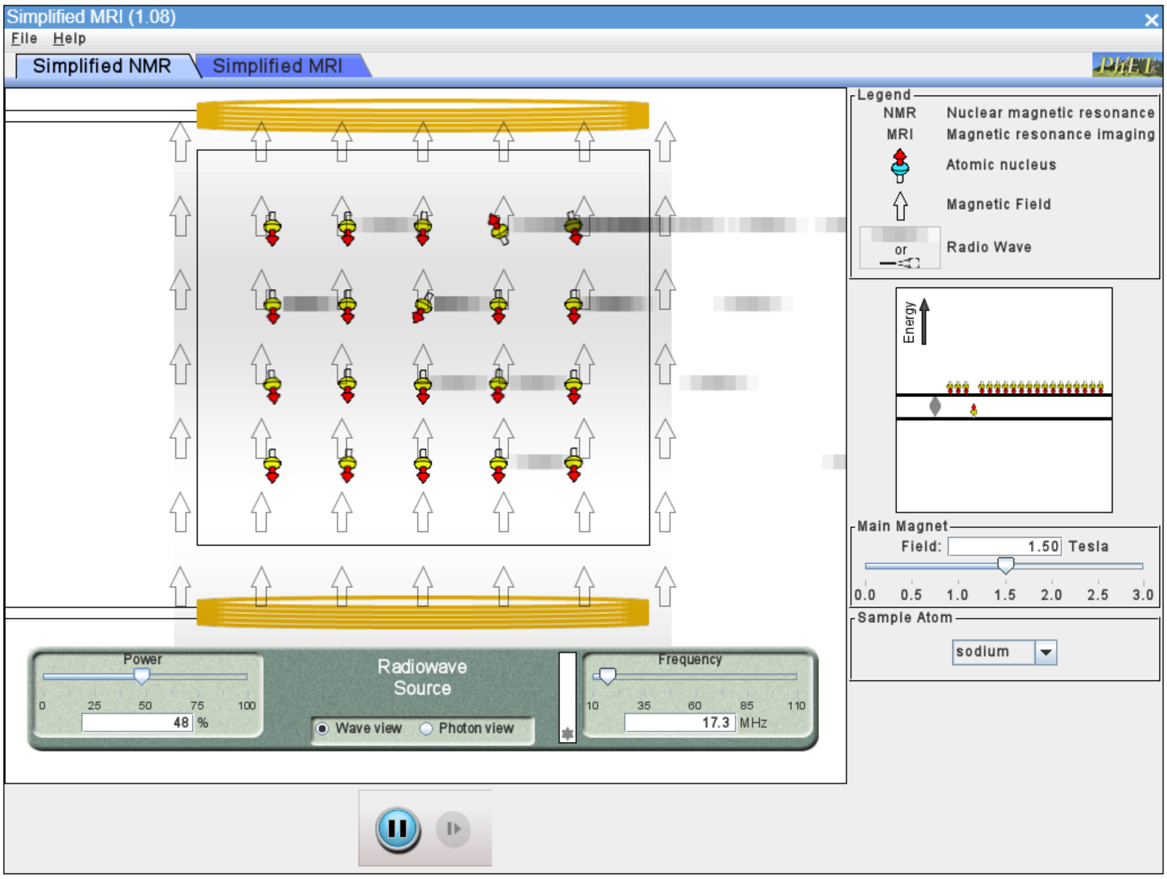
Nuclei	Magnetic Field	Resonant Frequency	Magnetic Field	Resonant Frequency
Hydrogen	0.75	31.935	2.5	106.45
Nitrogen	2.5	10.785	-	-
Sodium	1.515	17.3	2.75	31.405
Carbon-13	1.75	18.7425	2.5	26.775
Oxygen	1.999	11.54	3.0	14.316
Sulfur	3.0	~10	-	-
Copper (65Cu)	3.0	36.3		



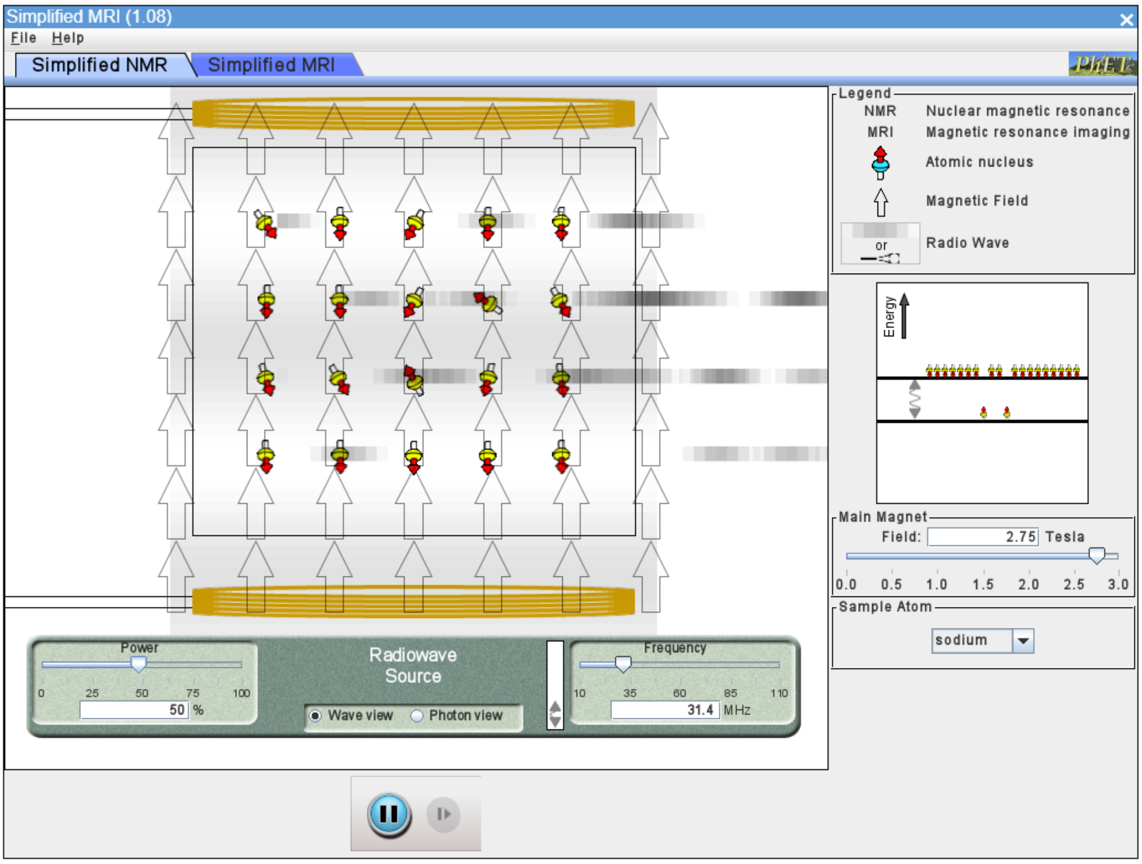
Simplified MRI (1.08)
File
Help
Simplified NMR
Simplified MRI
Legend
NMR
Nuclear magnetic resonance
MRI
Magnetic resonance imaging
Atomic nucleus
Magnetic Field
or
Radio Wave
Energy
Main Magnet
Field: 0.75 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
hydrogen
Power
0 25 50 75 100
51 %
Radiowave Source
Wave view
Photon view
Frequency
10 35 60 85 110
31.935 MHz

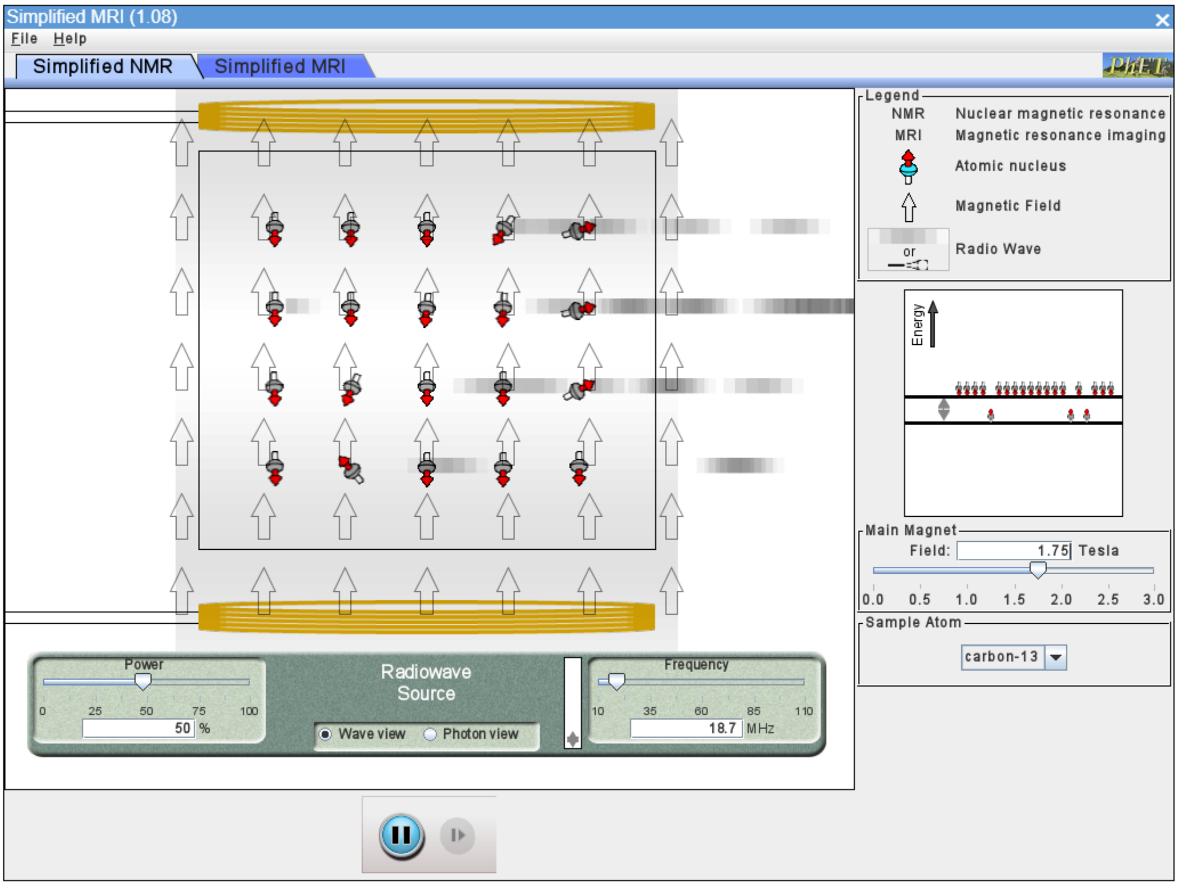

Simplified MRI (1.08)
File Help
Simplified NMR
Simplified MRI
PhET
Legend
NMR Nuclear magnetic resonance
MRI Magnetic resonance imaging
Atomic nucleus
Magnetic Field
Radio Wave
or
Energy
Main Magnet
Field: 2.50 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
hydrogen
Power
0 25 50 75 100
51 %
Radiowave Source
Wave view
Photon view
Frequency
10 35 60 85 110
106.5 MHz

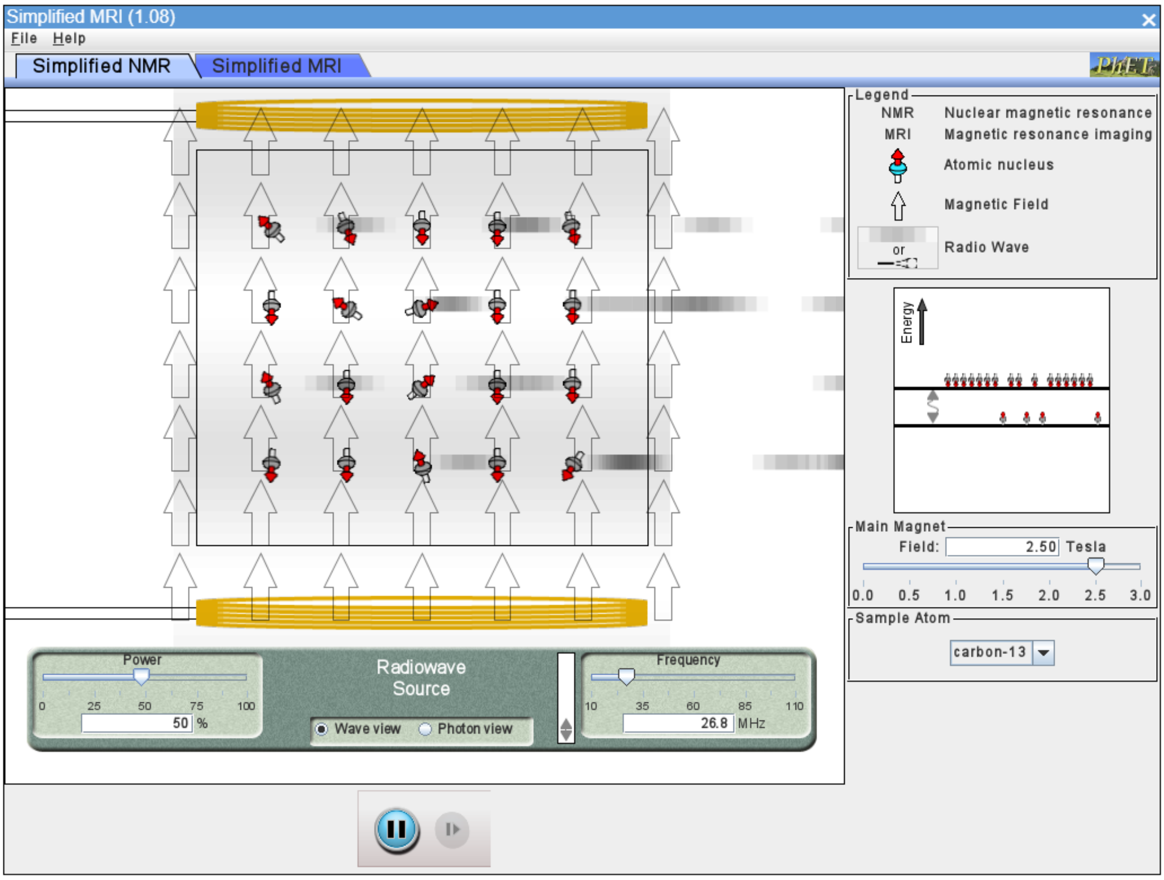

Simplified MRI (1.08)
File Help
Simplified NMR
Simplified MRI
Legend
NMR Nuclear magnetic resonance
MRI Magnetic resonance imaging
Atomic nucleus
Magnetic Field
or
Radio Wave
Energy
Main Magnet
Field: 2.50 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
nitrogen
Power
0 25 50 75 100
48 %
Radiowave Source
Wave view Photon view
Frequency
10 35 60 85 110
10.8 MHz



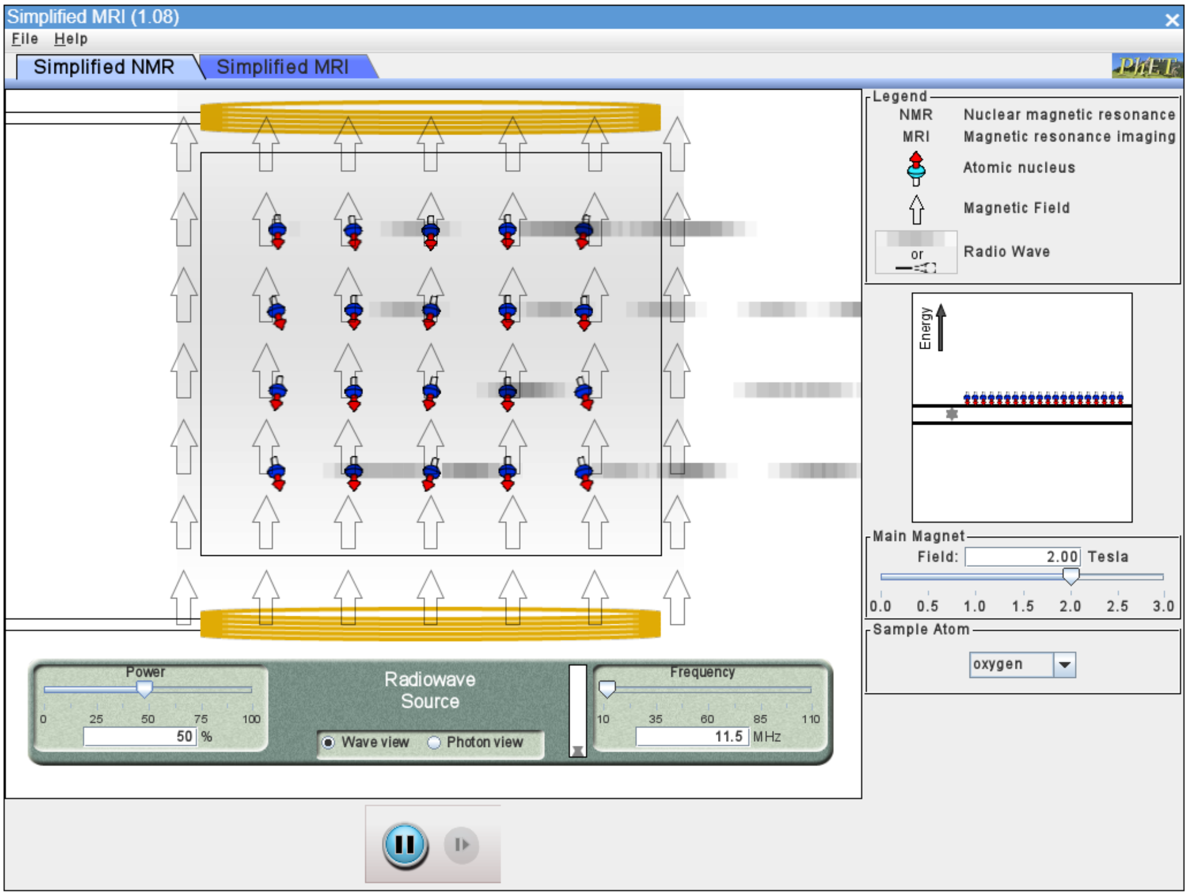
Simplified MRI (1.08)
File Help
Simplified NMR
Simplified MRI
Legend
NMR Nuclear magnetic resonance
MRI Magnetic resonance imaging
Atomic nucleus
Magnetic Field
or
Radio Wave
Energy
Main Magnet
Field: 1.50 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
sodium
Power
0 25 50 75 100
48 %
Radiowave Source
Wave view Photon view
Frequency
10 35 60 85 110
17.3 MHz

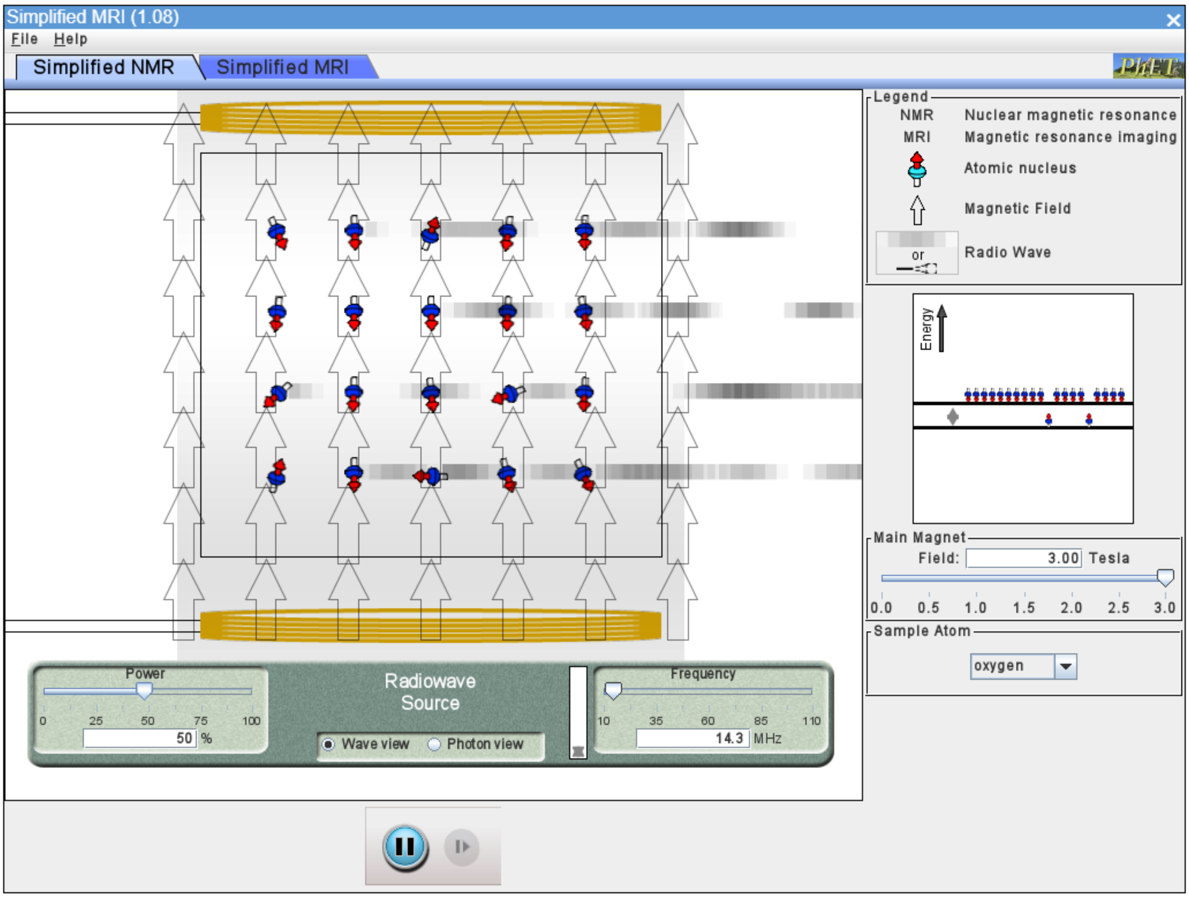

Simplified MRI (1.08)
File Help
Simplified NMR
Simplified MRI
Legend
NMR Nuclear magnetic resonance
MRI Magnetic resonance imaging
Atomic nucleus
Magnetic Field
or
Radio Wave
Energy
Main Magnet
Field: 2.75 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
sodium
Power
0 25 50 75 100
50 %
Radiowave Source
Wave view
Photon view
Frequency
10 35 60 85 110
31.4 MHz

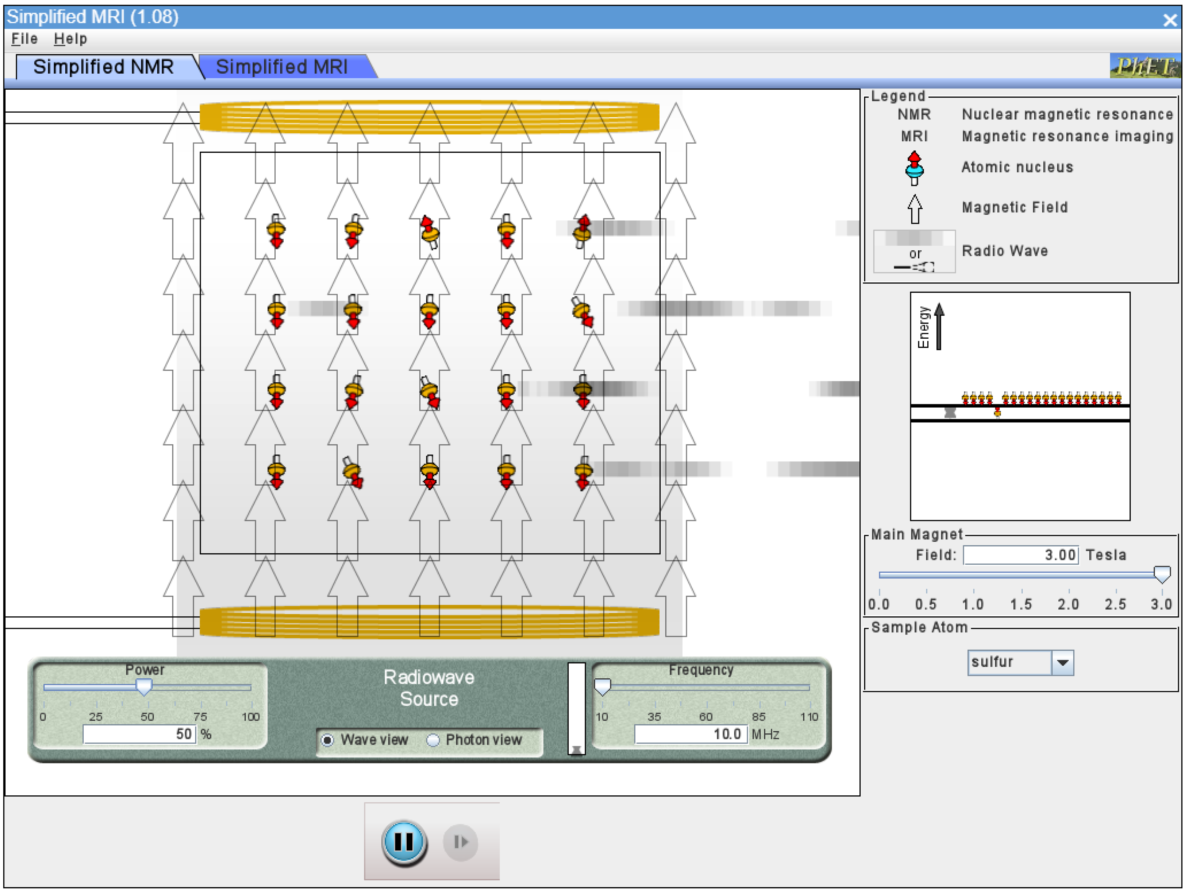

Simplified MRI (1.08)
File Help
Simplified NMR
Simplified MRI
Legend
NMR Nuclear magnetic resonance
MRI Magnetic resonance imaging
Atomic nucleus
Magnetic Field
or
Radio Wave
Energy
Main Magnet
Field: 1.75 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
carbon-13
Power
0 25 50 75 100
50 %
Radiowave Source
Wave view
Photon view
Frequency
10 35 60 85 110
18.7 MHz

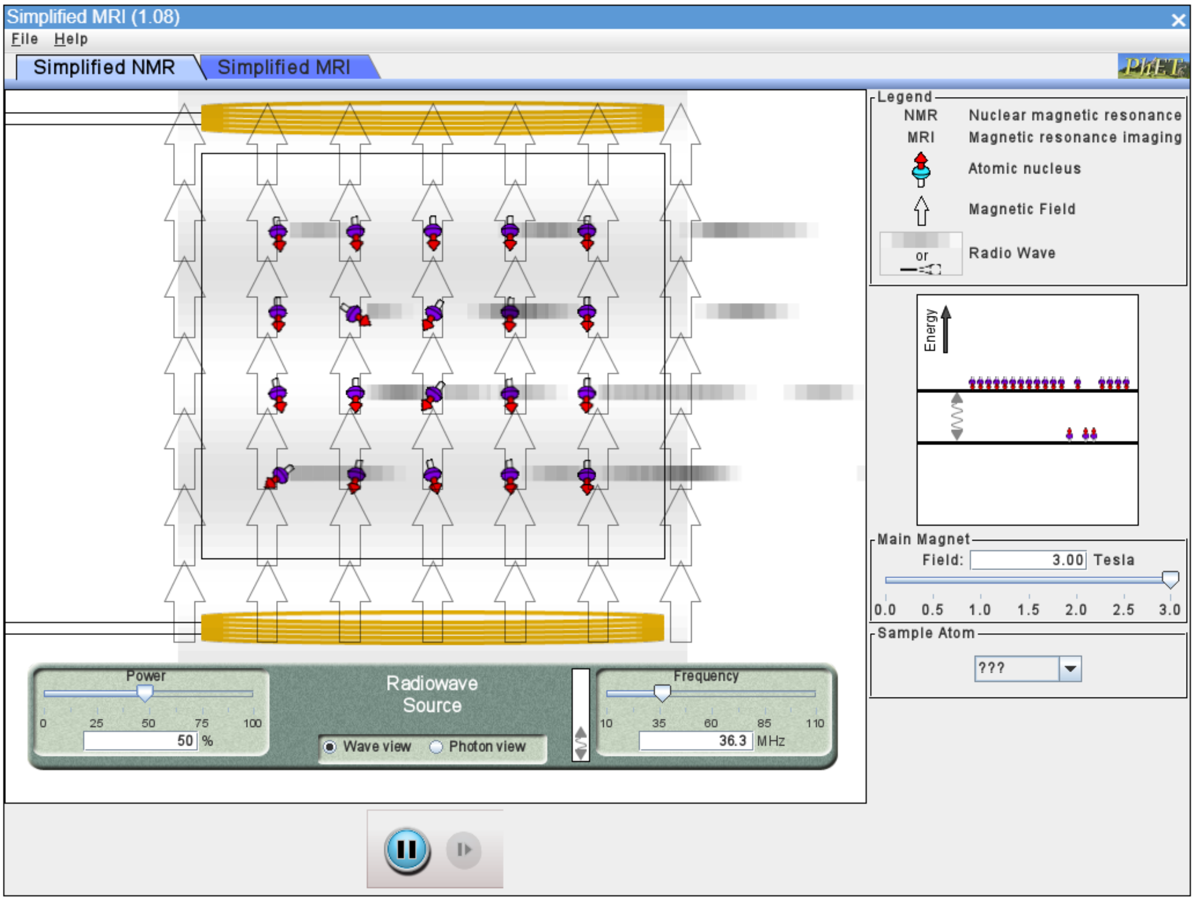


Simplified MRI (1.08)
File Help
Simplified NMR
Simplified MRI
PhET
Legend
NMR Nuclear magnetic resonance
MRI Magnetic resonance imaging
Atomic nucleus
Magnetic Field
or
Radio Wave
Energy
Main Magnet
Field: 2.50 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
carbon-13
Power
0 25 50 75 100
50 %
Radiowave Source
Wave view
Photon view
Frequency
10 35 60 85 110
26.8 MHz


Simplified MRI (1.08)
File Help
Simplified NMR
Simplified MRI
Legend
NMR Nuclear magnetic resonance
MRI Magnetic resonance imaging
Atomic nucleus
Magnetic Field
or
Radio Wave
Energy
Main Magnet
Field: 2.00 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
oxygen
Power
0 25 50 75 100
50 %
Radiowave Source
Wave view
Photon view
Frequency
10 35 60 85 110
11.5 MHz


Simplified MRI (1.08)
File Help
Simplified NMR
Simplified MRI
Legend
NMR Nuclear magnetic resonance
MRI Magnetic resonance imaging
Atomic nucleus
Magnetic Field
or
Radio Wave
Energy
Main Magnet
Field: 3.00 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
oxygen
Power
0 25 50 75 100
50 %
Radiowave
Source
Wave view
Photon view
Frequency
10 35 60 85 110
14.3 MHz

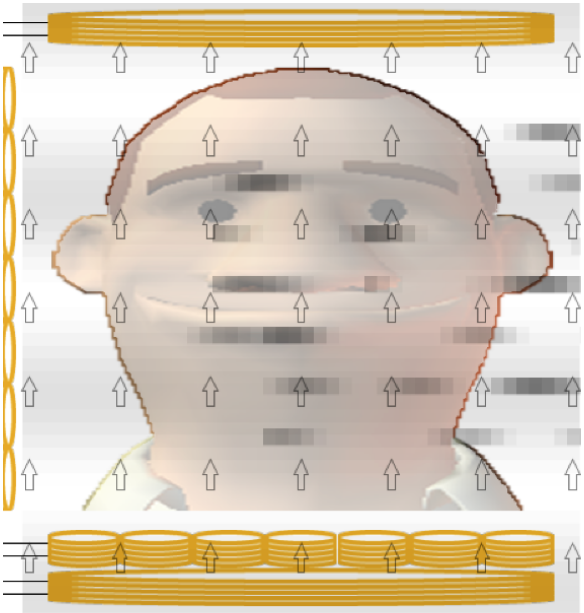

Simplified MRI (1.08)
File Help
Simplified NMR
Simplified MRI
Legend
NMR Nuclear magnetic resonance
MRI Magnetic resonance imaging
Atomic nucleus
Magnetic Field
or
Radio Wave
Energy
Main Magnet
Field: 3.00 Tesla
0.0 0.5 1.0 1.5 2.0 2.5 3.0
Sample Atom
sulfur
Power
0 25 50 75 100
50 %
Radiowave
Source
Wave view
Photon view
Frequency
10 35 60 85 110
10.0 MHz

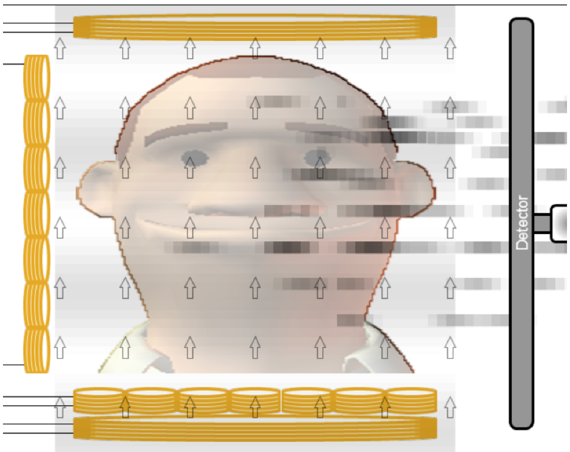


2. MRI

Move to the *Simplified MRI* tab

1. Set the *main magnet field* to 1.0 Tesla, leave the *gradient magnets* in zeros, activate only *show head*, and *show magnetic field* (be sure that *show atomic nuclei* is deactivated), set the frequency in 43 MHz. Finally set the *power* to 50% and observe the flow and distribution of the emissions. After a while observing the emissions, click on *add tumor*, wait for around 7 seconds so the flow distribution stabilizes, look at how the emission changed and try to guess where the tumor is located.





Explain how the emission allowed you to find the correct location: We can identify the tumor by looking at the dark lines (signals) going left to right, the tumor is located where there is a higher concentration of these signals. In the second image we can say that the tumor is located in the middle left side of the patient's head.

2. Play with the main magnet field, frequency, and gradient magnets (both, horizontal and vertical) to try to obtain an emission focused mainly in the zone of the tumor (register your best guess, it doesn't need to be perfect). Answer the following questions.

Best guess: main magnet: 1 Tesla horizontal gradient: 0.05 Tesla vertical gradient: 0.075 frequency: 38MHz

What happens when the horizontal gradient increases its magnitude? How does it affect the emissions? The magnetic field is altered, causing it to increase as it approaches the detector. This change in the magnetic field, that was originally uniform, needs a change in the frequency to spin the atomic nuclei and facilitate the emission focus on the tumor we are looking for.

What about vertical gradients? Just as the horizontal gradient provoque alterations on the magnetic field, also the vertical gradient eliminates the uniformity adding external sources that increase the magnetic field from the top to the bottom. These changes allow us to focalize zones and acquire better emissions. If we apply these alterations it is necessary to find the adequate frequency that matches the zone we are looking for.