# Nuclear Magnetic Resonance

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## 1 Objective

In this experiment, we seek to determine the line width of the fluorine resonance, the g-factor of protons and fluorine as well as demonstrate the nuclear magnetic resonance on protons and fluorine in liquid and solid sample. Nuclear magnetic resonance for the various sample (Glycerine, polystyrene, polytetrafluorethylene, flourine, hand cream, water and apple sample) inserted into the measuring chamber was achieved by varying the current through the 10A coils, optimizing the NMR signal obtained by the analog/digital oscilloscope HM-507 by changing the HF amplitude and adjusting the phase of the signal until the up and down sweep coincide.

Line width of the flourine resonance was obtained by measuring the Full Width at Half Maximum of the NMR signal obtained. The FWHM was approximated to be (0.067000 ± 0.000116) Mhz.

G-factor of the glycerine and polytetrafluorethylene sample was obtained by varying the current through the 10A coils and measuring the frequency as well as the magnetic flux density using the tesla probe. We obtained a g-factor for glycerene and PTFE to be (5.3565E−09 ± 1.8E−12) and (5.6606E−09 ± 1.6E−12) respectively. The theoretical values were 5.3129E−09 and 5.5096E−09. The percentage discrepancy are 0.82% and 2.74%.

## 2 Introduction

Nuclear magnetic resonance is possible due to the magnetic properties of the nucleus. Atoms with a nucleus which possesses a nuclear spin, $I$, have a magnetic moment $\nu_n$, and are based on the relationship:

$$\nu = -g \cdot \nu_n \cdot I \tag{1}$$

, where $\nu_n$ is the nuclear magneton and g is known as the g-factor.

Nuclear magnetic resonance is achieved when the frequency of the magnetic field matches exactly to the energy spacing of the energy levels, as accordingly to the equation:

$$h \cdot v = E_{k+1} - E_k = -g \cdot \nu_n \cdot B_0 \tag{2}$$

, where h is the Planck's constant. When a sample is placed in a static magnetic field, $B_0$, their nuclear spins are distributed over the energy levels as dictated by Boltzmann's equation. Boltzmann's equation is defined as:

$$\frac{N_k}{N_{k+1}} = exp(-\frac{E_{k+1} - E_k}{k_b T}) \tag{3}$$

, where $k_B$ is the Boltzmann constant and $N_k$ is the number of spins in the k level.

The spins may be excited to jump between adjacent energy levels $E_k$ when the energy levels are exposed to a magnetic field $B_1$ of high frequency $v$ which is perpendicular to the static magnetic field $B_0$.

Lastly, the g-factor can be determined using:

$$g = \frac{h}{\mu_n} \cdot \frac{v}{B_0} \tag{4}$$

, where h = 6.626 E-34 Js and $\mu_n$ = 5.051E-27 J/T.

## 3 Experimental Results

The following picture is the resonance frequency we got for glycerene sample. The rest of the signals for the other materials can be found in the Appendix.

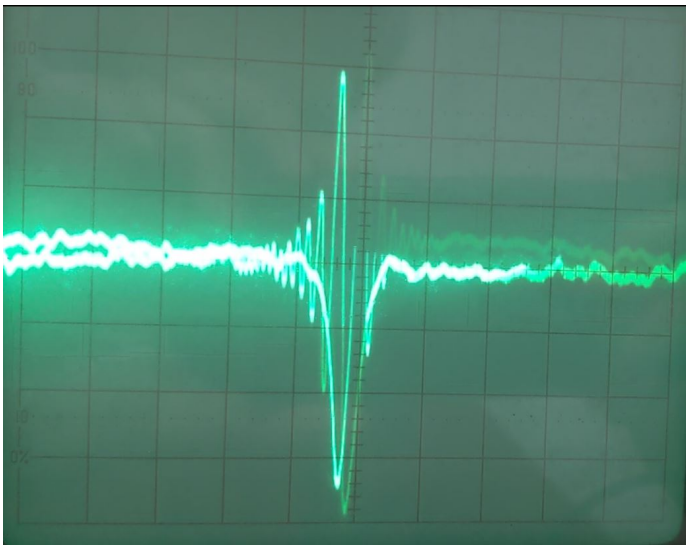

Figure 1: Resonance signal obtained for glycerene sample.

We also tabulated the various frequencies used to obtain resonance signal for various materials.

| Substance | Frequency (±0.000058 MHz) | Voltage (±0.0058V) | Current (±0.00058A) |
|---|---|---|---|
| Glycerine | 18.420400 | 18.2500 | 3.30600 |
| Water | 18.420300 | | |
| Polysterene | 18.419600 | | |
| PTFE | 17.333700 | | |
| Hand Cream | 18.419000 | | |
| Apple | 18.419500 | | |

Figure 2: Table of frequencies used to obtain resonance signal.

Additionally, the FWHM was obtained by obtaining the resonance signal at 2 certain frequency and tabulating the difference in their frequencies and corresponding it to a major tick on the x-axis.

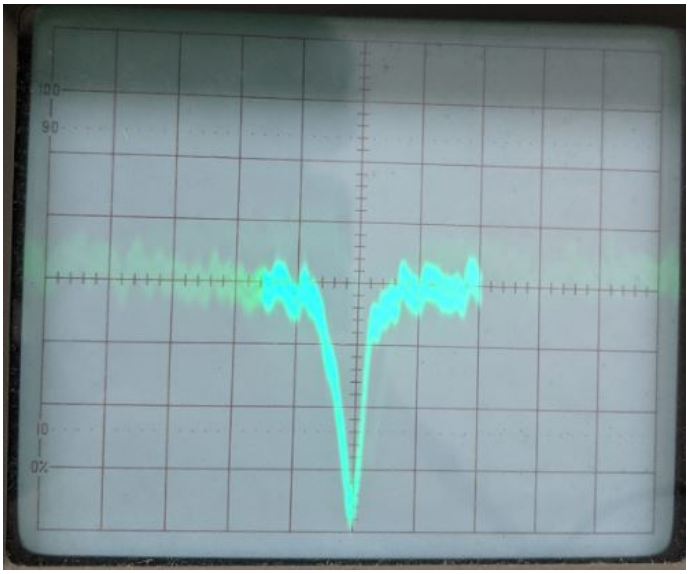

Figure 3: Enhanced resonance signal for PTFE.

The frequencies used were (17.333700 ± 0.000058) MHz and (17.266700 ± 0.000058) MHz. This gives us (0.06700 ± 0.00012) Mhz per major tick on the x-axis. Therefore, the FWHM can be approximated to be (0.06700 ± 0.00012) Mhz. This gives us a resting period of (14.930 ± 0.026)s.

Lastly, we graphed the relationship between the magnetic flux and resonance frequency for glycerene and PTFE. From their gradient, we can get the g-factor for the respective materials using Eqn. (4). Doing so gives us a g-factor of ($5.3565E-09 \pm 1.8E{-}12$) and ($5.6606E{-}09 \pm 1.6E{-}12$) respectively for glycerene and PTFE.

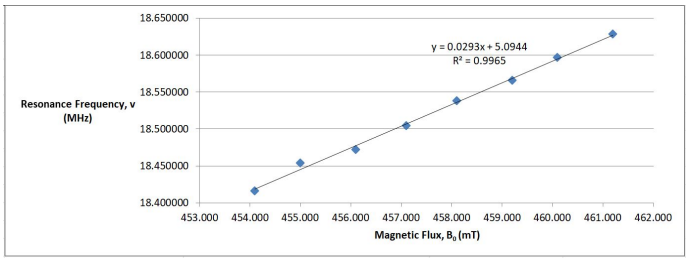


Figure 4: Relationship between magnetic flux and resonance frequency for glycerene sample. The uncertainty is ± 0.000058 MHz.

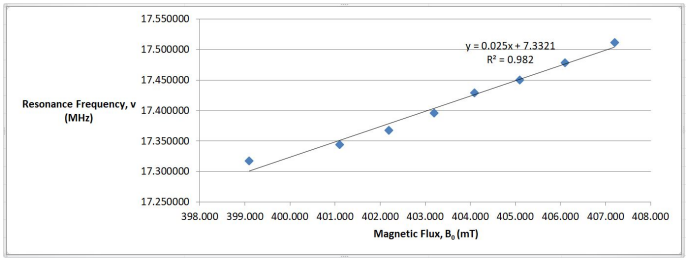


Figure 5: Relationship between magnetic flux and resonance frequency for PTFE sample. The uncertainty is ±0.000058 MHz.

# 4 Conclusion

In conclusion, we were able to get the various resonance signals for glycerine, PTFE, polsyterene, water, hand cream as well as apple at their characteristic frequencies. We also determined the g-factor for glycerine and PTFE - ($5.3565E{-}09 \pm 1.8E{-}12$) and ($5.6606E{-}09 \pm 1.6E-12$) respectively - and FWHM of PTFE.

The percentage discrepancies for the g-factors - 0.82% and 2.74% - are below 5% and are therefore within experimental errors. This shows that our experimental results agree wit the theoretical results of the g-factors. The theoretical g-factors are 5.3129E−09 and 5.5096E−09.

Lastly, the high $R^2$ values demonstrates a close linear relationship between resonance frequency and magnetic flux.

The FWHM was approximated to be (0.067000 ± 0.000116) Mhz.

# 5 Appendix

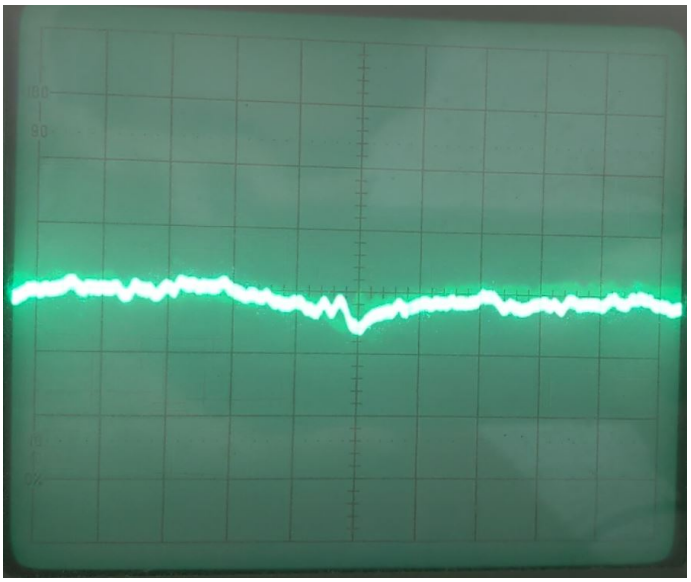

Figure 7: Resonance signal obtained for polysterene sample.

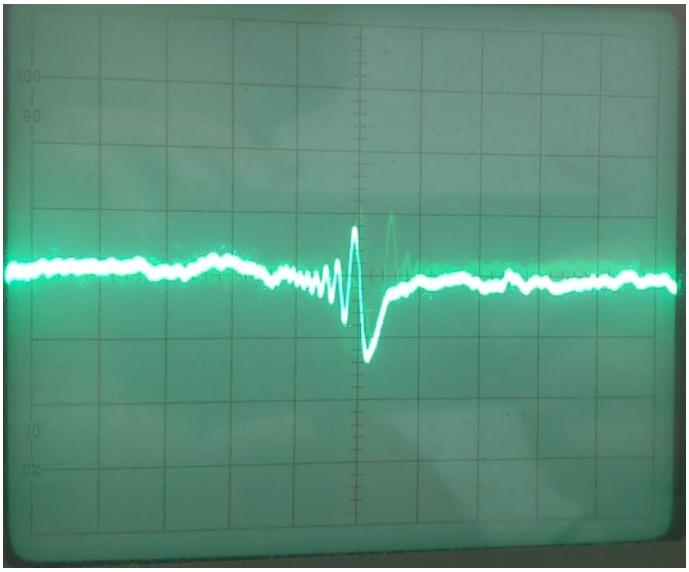

Figure 6: Resonance signal obtained for water sample.

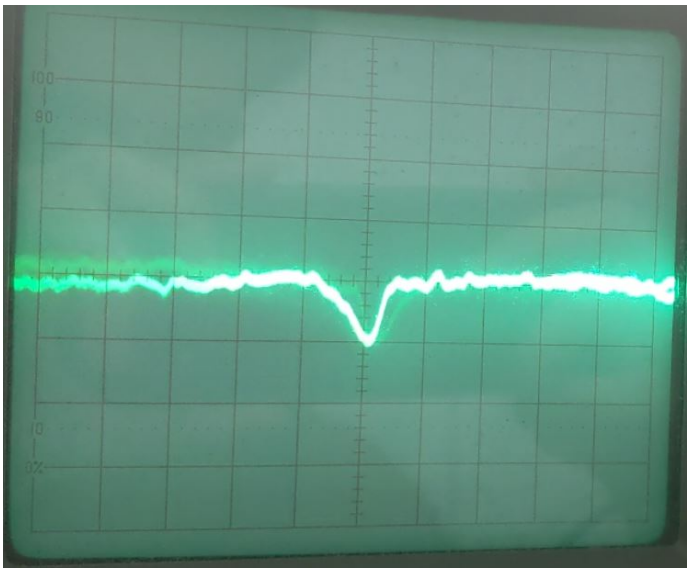

Figure 8: Resonance signal obtained for PTFE sample.