PHY 4210-01 Senior Lab
Lab P2: Electron Spin Resonance

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March 28, 2019

Abstract

The Lande factor, g_s, (or the gyromagnetic ratio of spin) for the electron was determined through the use of electron spin resonance and Helmholtz coils. The g-factor of a diphenyl-picryl-hydrazyl (DPPH) sample was obtained following the measurement of the frequency dependence of the resonance field. The line width of the resonance signal was then calculated.

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1 Data Analysis

1.1 Frequency Dependence of Resonance Field

Voltage was compared to frequency to obtain a graphical relationship of the frequency dependence of the resonance field. The amplitude voltage was obtained by measuring the peak-to-peak voltage from the oscilloscope and dividing it in half. The peak of 1 is the specific resonance frequency for the field.

Figure 1: Graphic representation of the frequency dependence of the resonance field.

1.2 Propagation of Uncertainty in the Frequency Dependence of the Resonance Field

1.3 Experimental Value of Gyromagnetic Ratio

The gyromagnetic ratio is calculated using the following equation, where ν is the frequency, h is Planck's constant, μ_B is the Bohr magneton, and B_0 is the magnetic field strength.

$$g_s = \frac{h \times \nu}{\mu_B \times B_0} \tag{1}$$

The magnetic field used in calculating equation 1 must be calculated as well. It is determined from the measured current using equation 2, where $\mu_0 = 4\pi \times 10^{-7} \frac{Vs}{Am}$, the number of turns is $n = 320$, and the radius of the coils is $r = 6.8cm$.

$$B_0 = \mu_0 \left(\frac{4}{5}\right)^{3/2} \times \frac{n}{r} \times I \tag{2}$$

Rather than measuring the current directly, the current is calculated by measuring the voltage drop across a resistor, of which the resistance is also measured. This calculation is shown below in equation.

$$I = \frac{V}{R} \tag{3}$$

By substituting equation 3 into 2, and then substituting equation 2 into equation 1, we arrive at an expression for the gyromagnetic ratio in terms of known constants and measured quantities. This final expression is shown in equation 4.

$$g_s = \frac{h \times \nu}{\mu_B \times \left(\mu_0 \left(\frac{4}{5}\right)^{3/2} \times \frac{n}{r} \times \frac{V}{R}\right)} \tag{4}$$

1.4 Propagating Uncertainty in Gyromagnetic Ratio

The error in the experimental value of the gyromagnetic ratio is determined by propagating uncertainty in equation 4. There are no uncertainties associated with fundamental constants such as h, μ_B, and μ_0. It is assumed that the number of coil turns, n, also has no associated uncertainty because it was reported in the manual as such. The uncertainty in the radius is constant for all measurements, ,but the frequency, voltage, and resistance will differ for each measurement. Equation 5 shows this error propagation.

$$\delta g_s = g_s \times \sqrt{\left(\frac{\delta\nu}{\nu}\right)^2 + \left(\frac{\delta r}{r}\right)^2 + \left(\frac{\delta V}{V}\right)^2 + \left(\frac{\delta R}{R}\right)^2} \tag{5}$$

An example calculation for the value of g_s and its propagated uncertainty is shown below for a measurement taken with the large coil:

$$\begin{aligned} g_s &= \\ &= 1.93 \end{aligned}$$

$$\begin{aligned} \delta g_s &= g_s \times \sqrt{\left(\frac{1.00 \times 10^4 \mathrm{Hz}}{3.00 \times 10^4 7\mathrm{Hz}}\right)^2 + \left(\frac{0.5\mathrm{cm}}{6.7\mathrm{cm}}\right)^2 + \left(\frac{0.1\mathrm{V}}{2\mathrm{V}}\right)^2 + \left(\frac{0.1\Omega}{1.7\Omega}\right)^2} \\ &= g_s \times \sqrt{(num)^2 + (0.006)^2 + (num)^2 + (num)^2} \end{aligned}$$

1.5 Determining Line Width of Resonance Signal

2 Results

2.1 Discrepancy in Gyromagnetic Ratio

2.2 Discrepancy in Line Width

3 Conclusion

4 Appendices

4.1 Appendix A: Data

4.2 Appendix B: Source Code