Electron Spin Resonance

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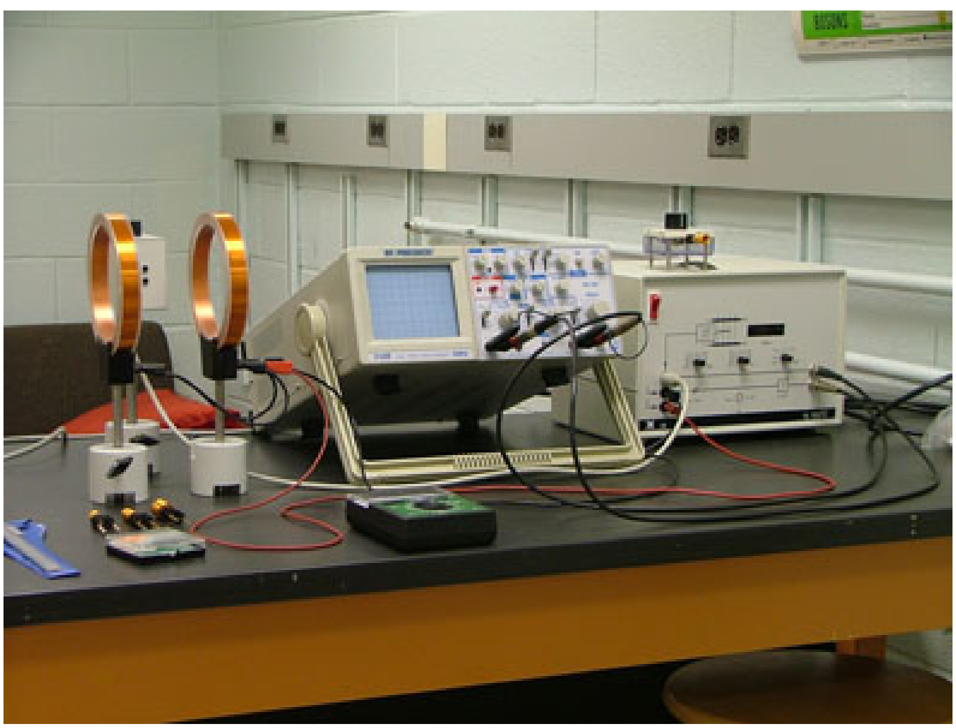
1 Introduction

An oscillating magnetic field is used to induce transitions between energy levels taken on by electrons in this field.

1.1 Apparatus

Helmholtz coils wired in parallel, a multimeter to measure the current in the coils, a power source provides a DC voltage with a possible modulation voltage, and an oscilloscope are used.



2 Theory

Spin angular momentum:

$$\vec{S} = sqrts(s+1)\frac{h}{2\pi},$$

where$s = \frac{1}{2}$ is the spin quantum number. This makes sense considering the half integer multiples of Planck's constant.

The spin angular momentum is related to the magnetic moment:

$$\vec{\mu} = -(g_s \mu_B \vec{S})/\frac{h}{2\pi}$$

Meaning magnetic moments also come in the same multiples as the spin angular momentum. g_s is the g-factor and its value depends on the particle being described. $g_{proton} = 5.586$, $g_{electron} = 2.0023$, and $g_{neutron} = -3.826$.

In a magnetic field that points in one direction, apparently the spin angular momentum can only have projections onto the respective axis, resulting in two values for the spin magnetic moment:

$$S_z = \hbar m_s,$$

where $m_s = \pm\frac{1}{2}$ are the possible values for the magnetic spin quantum number. So the spin magnetic moment also takes on two different values in one dimensional magnetic fields:

$$\mu_z = -(g_s \mu_B S_z)/\hbar = \pm\frac{1}{2} g_s \mu_B.$$

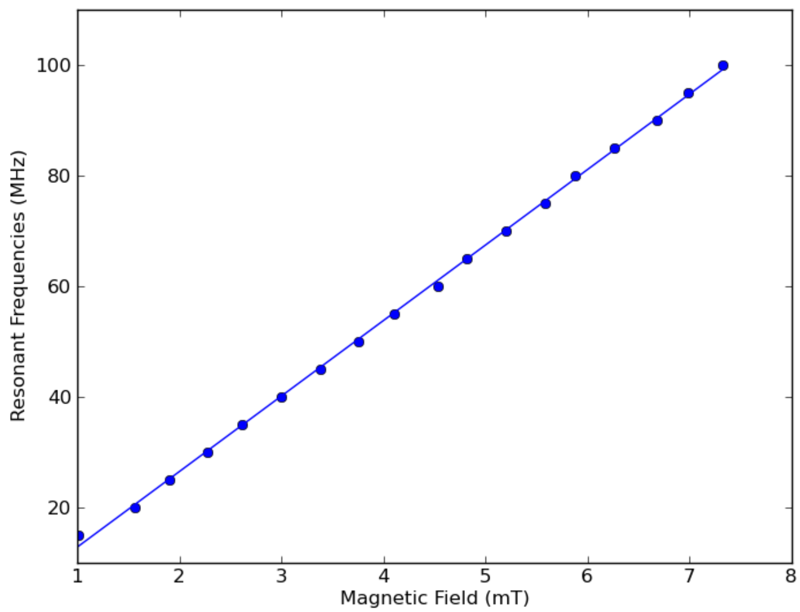
Two possible energy levels are defined by this too:

$$U = -\vec{\mu} \cdot \vec{B} = \pm\frac{1}{2} g_s \mu_B B,$$

$$\Delta E = h\nu = g_s \mu_B B.$$

Where ν is the minimum frequency of radiation that would induce or be emitted during a change of state for a particle in one dimension, derived from the Einstein relation.

3 Data



4 Calculations

Measuring g:

$$\nu =$$

g $\mu_{B\frac{}{h}}$ B

$$\frac{g\mu_B}{h}(10^9) = 13.66\frac{MHz}{mT} = 1.366x10^{10}\frac{Hz}{T}$$

$$g = (1.366x10^{10})\frac{h}{\mu_B} = .975$$

Measuring δB:

$$\delta W = 1.2cm$$

$$I_{mod,rms} = .33A$$

$$I_{mod,p-p} = 2\sqrt{2}I_{mod,rms} = .93A$$

$$\delta(2I_0) = I_{mod,p-p}\frac{\delta W}{10} = .011A$$

$$\delta B = 2.115\delta(2I_0) = .0237mT$$

5 Error Analysis

The value of $\delta Biswithinthedesignatedrangeoflinewidthsquotedintheliterature.Iwon'tcheckit'spercenterrorb$
.05 MHz, as indicated by the decimal accuracy of the machine's readings. The uncertainty in the current readings is ± .005 A, as indicated by the decimal accuracy of the multimeter. Uncertainty propogated linearly through calculating values of the magnetic field between the coils from current:

$$B_{max} = 2.115(2(I_0 + .005A)) = B + .02115mT$$

$$B_{min} = 2.115(2(I_0 - .005A)) = B - .02115mT$$

$$\delta B = \pm.02115mT$$

Percent Error on g:

$$\frac{|2.0023 - .975|}{2.0023} = 51.3\%$$

6 Conclusion

The numbers I obtained for both g and δB seem reasonable and consistent with the accepted value. I did see what I expected to see in terms of the resonance curves.

7 Questions

1. The manufacturer designed this experiment with the coils connected in parallel. A series connection would be better. Why?

If the inductances of two coils located in each others magnetic field are not equal, this can cause short circuiting.

2. The p-p modulation current $\delta(2\mathrm{I}_0) for the half-width \delta$B is obtained from:

$$\delta(2I_0) = I_{mod,p-p}\frac{\delta W}{10}$$

Where does the divisor 10 come from?

It changes the value of δW so that it represents meters.

3. In the method given for measuring δB, the scope controls are not used in a calibrated mode. Why is this OK?

We account for it by dividing δW by 10.

4. Why is the multimeter set for DC amperes for measring g and for AC amperes for measuring the line width?

Not sure. Maybe because AC amperes are required for generating p-p values.

5. Is there an RF electric field associated with the RF coil? If so, make a sketch of what the fields look like.

I think there is an RF electric field but I don't know what it looks like.