Day 1

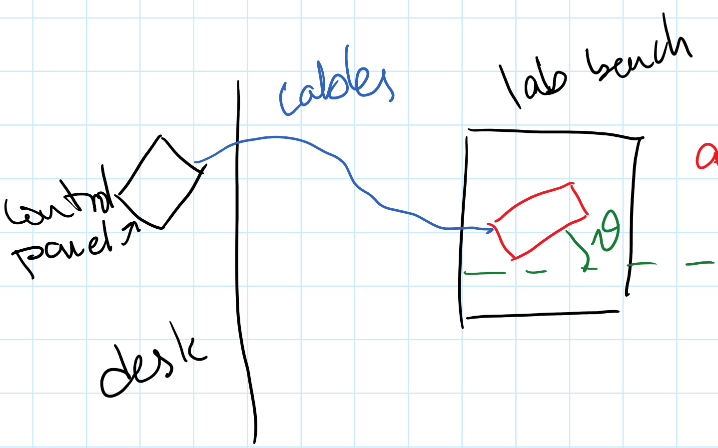
Tuesday, 25 January, 2022 2:04 PM

Horiz. offset zero ~ 3.95 ?

After playing around w/ it (and asking TA for guidance) we're getting the sharpest peak we can at

horiz. range: 5.32
horiz. offset: 0.00
vert. field: 2.93

Apparatus angle:



$\vartheta \approx 10^\circ \pm 5^\circ$

Somewhat concerning is that the depumping event happens at horizontal voltage of 13.0V while the max output field voltage is 14.0 V, which is a bit close for my liking.

Let's estimate the magnitude of the magnetic field we're applying to cancel out the ambient:

according to the wikipedia link listed, the field at the center of the Helmholtz coils is

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

where n is the number of turns in each coil. Ohm's law: $I = \frac{V}{R}$

For horizontal sweep coil *

* assuming both the sweep range and the offset we've been adjusting are for the "sweep" coils:

$V = 13.0V$

$n = 11$ turns

$r = 6.46'' \pm 0.01'' = 16.408 \pm 0.025$ cm

$R = 1.1 \pm 0.1\Omega$ as measured w/ the multimeter

$$\Rightarrow B = \sqrt{\frac{64}{125}} \cdot (1.257 \cdot 10^{-6}) \cdot \frac{nV}{rR}$$

$$= 0.00159 \quad \underbrace{[NA^{-2}(A)(m^{-1})]}_{T}$$

$= 1.6$ mT $= 1{,}600\ \mu T$ off by a factor of 10^2?

$\Rightarrow$ used 25 instead of 125 in calculation. corrected:

$B = 0.000713\,T = 713\,\mu T$

Still not great...

Note: Thus far the RED lead for the horiz. sweep has been plugged into the BLACK terminal!

Vertical field coil:

$I = 0.290$ A (from multimeter)

$n = 20$

$r = 4.61'' \pm 0.01'' = .1171$ m

$$\Rightarrow B = \sqrt{\frac{64}{125}}\,(1.257 \cdot 10^{-6})\,\frac{In}{r}$$

$= 0.0000445\,T$

$= 45\,\mu T \Rightarrow$ consistent with wikipedia for Earth's magnetic field

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To try to figure out why our field readings are so weird, we used an ammeter & dc power supply to measure resistance:

1.645 V   0.99 A $\Rightarrow$ doesn't explain it.

Also, manufacturer estimates vert. coils @ 150 $\mu T/A$ (consistent w/ our findings) and horiz. sweep @ ~60 $\mu T/A$ (also consistent with our 13V / 1.1 Ω ⇒ 700 μT)

Manufacturer lists the horiz. sweep coils at resistance of ~1.3 Ω, consistent w/ our results.

Also, when putting a 5 V_{pp} sine wave into the scope we read 5.12 V_{pp}, which suggests the scope's not off by a factor of 10 on the voltage.

Day 2

Tuesday, 1 February, 2022 2:41 PM

H range: 5.49
H start: 0.57
Vert: 2.94

Recorder offset is all the way clockwise, same as conclusion of day 1

Temp going between ~49.0 and ~50.5°C

Voltage calibration

scope voltage	DMM voltage
−14.2V	0.00V
−13.6V	0.12V
−10.6V	0.24V
−4.8V	0.478V
1.0V	0.715V
7.0V	0.955V
13.0V	1.2V

Main data:

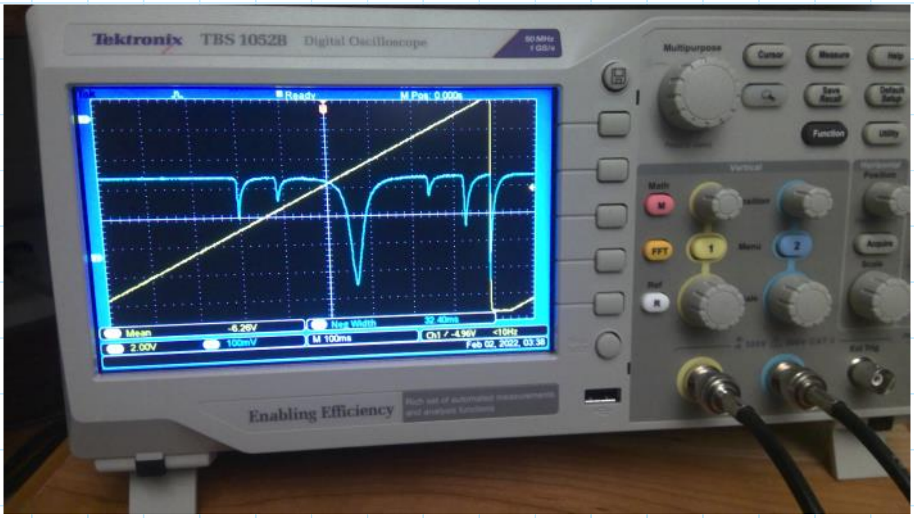
$f_{depumping}$	(Smaller) ΔV^1_{scope} (V)	(bigger) ΔV^2_{scope} (V)
40 kHz	2.84 ± 0.08	4.20 ± 0.08
30	2.12 ± 0.08	3.16 ± 0.08
20	1.48 ± 0.08	2.12 ± 0.08
10	0.68 ± 0.08	1.08 ± 0.08
50	3.48 ± 0.08	5.24 ± 0.08

10	0.68 ± 0.08	1.08 ± 0.08
50	3.48 ± 0.08	5.24 ± 0.08
60	4.20 ± 0.08	6.24 ± 0.08
70	4.84 "	7.32 "
80	5.56	8.32
100	6.96	10.4
120	8.50	12.5
130	9.20	13.8
90	6.20	9.40
110	7.60	11.5

Also: measure the zero-crossing at -3.50 ± 0.08 V in all cases.

These are the voltages output by RECORDER OUTPUT.

Representative scope reading:



Goal is to measure/verify the Landé g-factor g_f for 2 isotopes of Rb:

$$g_f = g_j \frac{F(F+1) + j(j+1) - i(i+1)}{2F(F+1)}$$

with $$g_j = 1 + \frac{j(j+1) + s(s+1) - l(l+1)}{2j(j+1)}$$

For ${}^2S_{1/2}$, we have $j = \frac{1}{2}$, $s = \frac{1}{2}$, $l = 0$

$\Rightarrow g_j =$

Then $F = 2$, $i = \frac{5}{2}$ $\Rightarrow g_f^{Rb85} = \frac{1}{3}$

$F = 2$, $i = \frac{3}{2}$ $\Rightarrow g_f^{87} = \frac{1}{2}$

Agaist the empirically determined

$$g_f = \frac{\Delta E}{\Delta m_f \, \mu_B B} = \frac{hf}{\mu_B \; B}$$

$$= \frac{\hbar f}{\mu_B B}$$

where B is determined by

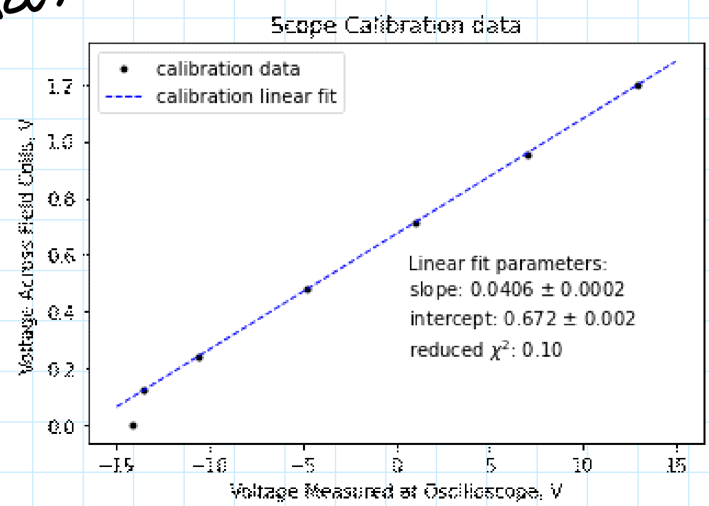
$$B = \left(\frac{4}{5}\right)^{3/2} \frac{\mu_0 \, n \, \Delta I}{r}$$

with $\Delta I = \frac{\Delta V_{coil}}{R_{coil}}$ as the difference between the current that creates a net $B=0$ and the current that creates a B that causes depumping.

ΔV coil is determined by

$$\Delta V_{coil} = M \, \Delta V_{scope}$$

where M is a calibration slope, determined by linear regression on a set of calibration data:



We use a linear regression to determine the ratio $\left(\frac{\Delta V_{scope}}{f}\right)$, so we find

$$g_f = \left(\frac{h}{\mu_B}\right)\left(\left(\frac{4}{5}\right)^{3/2} \frac{\mu_0 \, n \, M}{r R}\right)^{-1}\left(\frac{\Delta V_{scope}}{f}\right)^{-1}$$

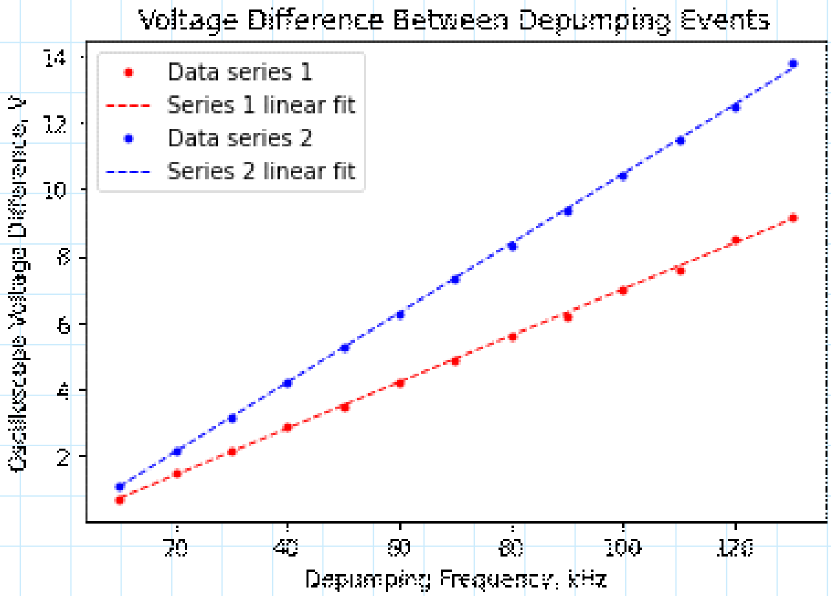
We are given $\mu_B = 5.7883\text{e-}9 \text{ eV/G}$, which is

$\mu_B = 9.27e{-24}\ J/T$

so we find

$$g_f = 0.032 \cdot \left(\frac{\Delta V_{scope}}{f}\right)^{-1}$$

where $\frac{\Delta V_{scope}}{f}$ is measured in V/Hz



The linear fits converge to

$\Delta V_{scope}(f) = af + b$ with

$a_1 = 0.0700 \pm 0.0006$ $\quad b_1 = (7.69e{-4}) \pm (4.7e{-2})$

$a_2 = 0.105 \pm 0.0006$ $\quad b_2 = (-7.69e{-4}) \pm (4.7e{-2})$

With (a) representing $\left(\frac{\Delta V_{scope}}{f}\right)$

Our uncertainty is dominated by δR (the resistance of the horizontal coil) and $\delta\left(\frac{\Delta V_s}{f}\right)$, so

Our full error is given by

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$$\frac{\delta g}{g} = \left[\left(\frac{\delta R}{R}\right)^2 + \left(\frac{\delta\left(\frac{\Delta V_s}{f}\right)}{\left(\frac{\Delta V_s}{f}\right)}\right)^2 \right]^{1/2}$$

So we find

$$g_1 = 0.459 \pm 0.042$$
$$g_2 = 0.307 \pm 0.028$$

With g_1 corresponding to the pair of peaks closer to the zero-crossing and g_2 to the outer pair of peaks.

We can then conclude that

$g_1 = g_f^{87}$ with $t = 0.97$

and

$g_2 = g_f^{85}$ with $t = 0.95$

So we find good agreement with the literature.

Secondary goal: estimate ambient magnetic field:

We again use $B = \left(\frac{4}{5}\right)^{3/2} \frac{\mu_0 n I}{r}$

vertical field:

$n = 20$ turns

$I = 0.290\,A$ (as measured with DMM)

$r = .1171$ m (per mftr specs)

$\Rightarrow B = 45\,\mu T$

horizontal field:

$n = 11$ turns
$r = 16.41$ cm $= .1641$ m (per mftr specs)

$I = \frac{V_{zero}}{R_{coil}}$

$R_{coil} = 1.1\,\Omega$ — which is somewhat suspect, as we simply measured with a DMM. The inductance of the coil may have affected this measurement, but for order-of-magnitude estimates, this should be fine.

V_{zero} is determined by our calibration

data above: we observe the zero-crossing at $V_{scope} = -3.50$ V, so

$$V_{zero} = 0.0406 \cdot (-3.50) + 0.672$$

$$= 0.53 V$$

We then calculate

$$B_{horiz} = 29\,\mu T$$

The lowest point in our calibration

data clearly doesn't fit the linear pattern, which suggests that the calibration may not hold for absolute data. However, this result <u>is</u> within a factor of 2 of the expected result of 40-65 μT, so it's also entirely possible that the horizontal magnetic field in the lab is a bit lower than the Earth's magnetic field.