☐PHYS115 ☐PHYS121 ☐PHYS123
☐PHYS116 ✓PHYS122 ☐PHYS124
Lab Cover Letter

Author (*You*) Trevor N. Signature: Trevor N.

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Lab Partner(s) John Paul

Date Performed 2024-10-03 Date Submitted 2024-10-10

Lab (*such as #1: UNC*) 3-EOM/DSO

TA: Eli

GRADE (*to be filled in by your TA*) See your TA for detailed feedback.
An '*x*' next to a subcategory means you need to improve this aspect of your work.

***Paper Subtotals* (points)**

( ) ***General* (6)**
_____ Sig. figs.
_____ Units
_____ Clarity of Presentation
_____ Format

( ) ***Abstract* (4)**
_____ Quantity or principle
_____ How measurement was made
_____ Numerical Results
_____ Conclusion

( ) ***Intro & Theory* (9)**
_____ Basic principle
_____ Main equations to be used
_____ Apparatus
_____ What will be plotted
_____ Fitting parameters related

( ) ***Exp. Procedures* (15)**
_____ Description
_____ Stating and justifying uncertainties
_____ Data Record
_____ Quality of Lab Work

( ) ***Analysis & Error Analysis* (20)**
_____ Discussion
_____ Equations & Calculations
_____ Presentation inc. Graphs, Tables
_____ Results Reported & Reasonable
_____ Underlined items addressed

( ) ***Discussion & Conclusions* (6)**
_____ Numerical comparison of results
_____ Logical conclusions
_____ Discussion of pos. errors
_____ Suggestions to reduce errors

( ) **Paper Total (60 points)**
(30 points for CME or EPF)

( ) **Notebook (10 points)**
_____ Format (*proper style, following directions*)
_____ Apparatus (*brief description of equipment, including sketches*)
_____ Data (*including computer file names and manually recorded data*)
_____ Experimental Technique (*describing your procedures; stating & justifying uncerts.*)
_____ Analysis (*results and errors*)

( ) **Worksheet(s)/Fill-in-the-Blank-Report (30 points)** *if applicable*

( ) **Adjustments** – late submissions, improper procedures, etc. – or bonus points for exceptional work.

( ) Total Grade

Graded by __________ *(TA's initial)*

3 - DSO

PHYS 122-119B Lab 3a: DSO


```
Trevor Nichols, John Paul Magbitang
PHYS 122-119B
Station 32
Lab 3a: DSO (Digital Storage Oscilloscope)
2024-10-03T17:15:58-04:00

Department of Physics,
Case Western Reserve University,
Cleveland, Ohio,
44106-7079
```


1

What is your estimate of the accuracy to which you can make measurements with your scope, in terms of cm, mm or DIV?

Answer

In both the vertical and horizontal axes:

$\frac{1}{5}$ DIV

2

What is your measured period and frequency (from counting divisions), with uncertainties, of the 1 kHz square wave calibration signal?

Answer

$\text{DIV} = 250\ \mu s$
Period: $\frac{16}{4}\ \text{DIV} = 1000 \pm 10\ \mu s$
Frequency: $\frac{1}{t} \pm \frac{\delta_t}{t} f = 1.00 \pm 0.01\text{kHz}$

3

What is your measurement (by counting divisions) of the peak-to-peak voltage of the calibration signal?

Answer

$\text{DIV} = 500\ mV$

Peak-to-peak: $6\ \text{DIV} = 3.0 \pm 0.1\ V$

4

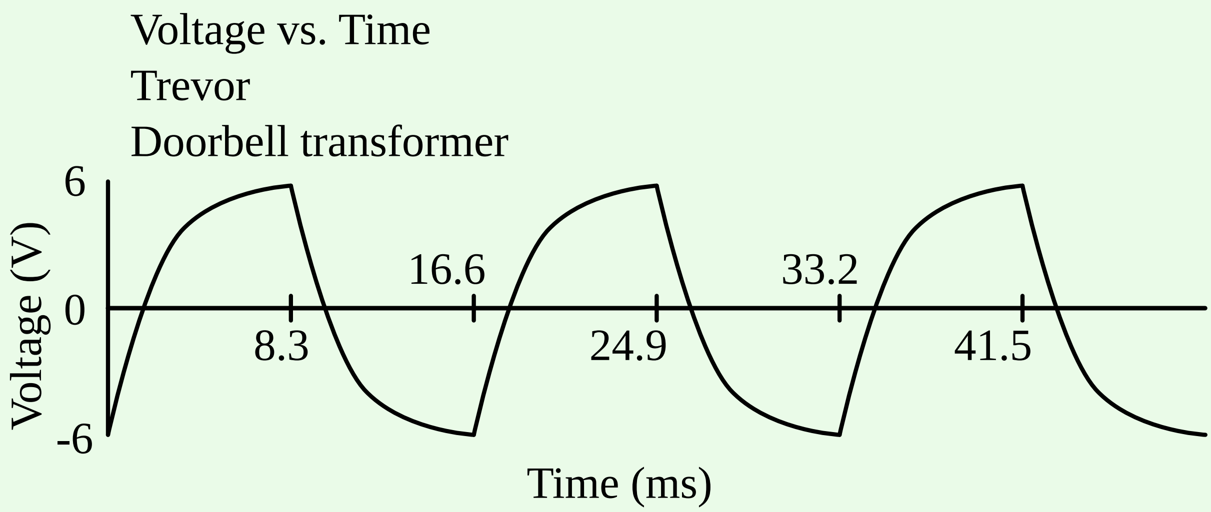
Provide a sketch of the waveform obtained from the doorbell transformer, with appropriate scales on the horizontal and vertical axes. Also provide the period, frequency and peak-to-peak voltage of the signal obtained from your measurements.

Answer

$\text{DIV} = 2\ V, 5\ ms$

$V_{pp} = 6\ \text{DIV} = 12.0 \pm 0.4\ V$

$p = \frac{16.6}{5}\ \text{DIV} = 16.6 \pm 0.2\ ms$



5

What voltage did you measure for the doorbell transformer with your DMM? Is this consistent with the scope measurement? (Explain!)

Answer

DMM: $4.27\ V \pm 1\%$

If we know that:

$V_{pp} = 2\sqrt{2}V_{rms}$

We can calculate our expected V_{pp} from our DMM reading to compare with our DSO reading.

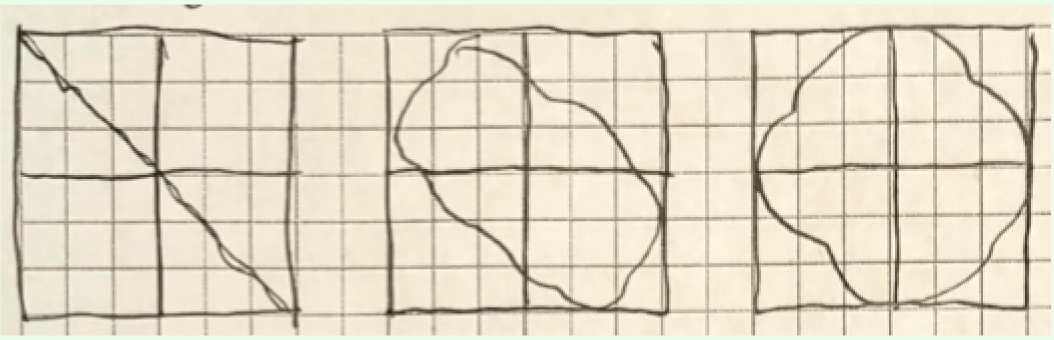
$V_{pp} = 12.1\ V \pm 1\%$

This value lines up closely with the V_{pp} obtained from the DSO.

6

Sketch your Lissajous pattern(s) at 60 Hz. (You should make more than 1 plot to show how this pattern changes during your observation.)

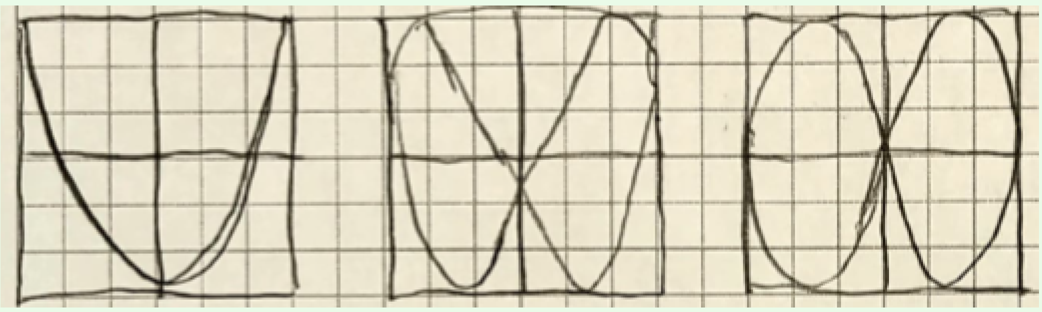
✓ **Answer**



7

Sketch the pattern at 120 Hz.

✓ **Answer**



8

What frequency between 60-120 Hz gives another clear Lissajous pattern?

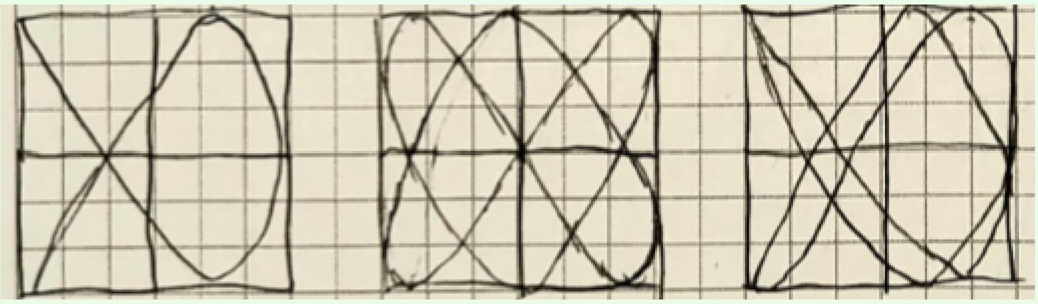
✓ **Answer**

$90.0 \pm 0.1 \; Hz$

9

Sketch the pattern at this intermediate frequency.

✓ **Answer**



10

What conditions are necessary to observe Lissajous patterns?

✓ **Answer**

The ratios of the two waves must be simple or small integers.

11

What is the tuning fork frequency you measured from your scope?

✓ **Answer**

$p = \frac{314 \pm 5}{30} \; ns = 10.5 \pm 0.2 \; ns$
$f = \frac{1}{p} \pm \frac{\delta_p}{p} f = 95 \pm 2 \; MHz$

I doubt this is the actual frequency of the tuning fork, as I would likely be unable to hear it.

3 - EOM

PHYS 122-119B Lab 3b: EOM


```
Trevor Nichols, John Paul Magbitang
PHYS 122-119B
Station 32, Rockefeller 403
Lab 3a: EOM (Charge to Mass Ratio of the Electron)
2024-10-03T17:15:58-04:00

Department of Physics,
Case Western Reserve University,
Cleveland, Ohio,
44106-7079
```


1 Abstract

The purpose of this lab is to confirm the established value for $\frac{e}{m}$ in electrons through the usage of Heimholz coils and their expected field effect on electrons.

$\frac{e}{m}$ **Source**	**Value**
Expected	$1.75882017 \pm 0.00000007 \times 10^{11} \ \frac{C}{kg}$
Current	$(4 \pm 1) \times 10^{9} \ \frac{C}{kg}$
Voltage	$(1.2 \pm 0.3) \times 10^{11} \ \frac{C}{kg}$

2 Theory

2.1 Constants

$$\frac{e}{m} = 1.75882017 \pm 0.00000007 \times 10^{11} \ \frac{C}{kg} \qquad \text{Expected value of e/m}$$

$$\mu_0 = 4\pi \times 10^{-7} \ \frac{Tm}{A} \qquad \text{Heimholz constant}$$

m	Mass of an electron
v	Speed of an electron
$\vec{v}$	Velocity
$\vec{B}$	Magnetic Field
$\vec{B}$	Magnitude of the Magnetic Field
$\vec{e}$	Magnitude of the charge of an electron
$\vec{I}_C$	Current
$\vec{R}$	Radius of beam
$\vec{V}$	Heimholz coil input voltage
r	Radius of Heimholz coil
N	Number of turns in Heimholz coil

2.2 Formulae

Given the relation between potential difference and kinetic energy of an electron, along with the lorenz force of the Heimholz coils, we are able to find a value for $\frac{e}{m}$ given V, B, and R.

Then, we are able to use the known magnetic force of a Heimholz coil in order to find the value of $\frac{e}{m}$ in terms of μ_0, N, I_C, r, V, R

$$\frac{1}{2}mv^2 = eV \quad \text{Definition of Kinetic Energy} \tag{2.2.1}$$

$$\vec{F} = -e(\vec{v} \times \vec{B}) \quad \text{Lorenz force of magnetic field} \tag{2.2.2}$$

$$evB = \frac{mv^2}{R} \quad \text{Centripetal Equation} \tag{2.2.3}$$

$$\frac{eBR}{m} = v \quad \text{Solve for v} \tag{2.2.4}$$

$$v = \sqrt{\frac{2eV}{m}} \quad \text{From 2.2.1} \tag{2.2.5}$$

$$\frac{eBR}{m} = \sqrt{\frac{2eV}{m}} \quad \text{From 2.2.4} \tag{2.2.6}$$

$$\frac{e(BR)^2}{m} = 2V \quad \text{Solving for e/m} \tag{2.2.7}$$

$$\frac{e}{m} = \frac{2V}{(BR)^2} \quad \text{Solve for e/m} \tag{2.2.8}$$

$$B = \frac{8\mu_0 N I_C}{5r\sqrt{5}} \quad \text{Heimholz Equation} \tag{2.2.9}$$

$$\frac{e}{m} = \left(\frac{r}{\mu_0 R N I_C}\right)^2 \frac{5^3 V}{2^5} \quad \text{From 2.2.8} \tag{2.2.10}$$

2.2.1 Formula for relation between current and radius

$$\frac{e}{m} = \left(\frac{r}{\mu_0 R N I_C}\right)^2 \frac{5^3 V}{2^5} \quad \text{From 2.2.10} \tag{2.2.1.1}$$

$$\frac{1}{R} = \frac{\mu_0 N}{r}\sqrt{\frac{2^5 \frac{e}{m}}{5^3 V}} I_C \quad \text{Relate R and I} \tag{2.2.1.2}$$

$$y = ax \quad \text{Linear relationship} \tag{2.2.1.3}$$

$$y = \frac{1}{R}; a = \frac{\mu_0 N}{r}\sqrt{\frac{2^5 \frac{e}{m}}{5^3 V}}; x = I_C \quad \text{With constants} \tag{2.2.1.4}$$

$$\frac{e}{m} = \left(\frac{ar}{\mu_0 N}\right)^2 \frac{5^3 V}{2^5} \quad \text{Solve for e/m} \tag{2.2.1.5}$$

We can then calculate our errors in $x, y, \frac{e}{m}$

$$\delta_y = \frac{1}{R^2}\delta_R \tag{2.2.1.6}$$

$$\delta_x = \delta_{I_C} \tag{2.2.1.7}$$

$$\delta_{\frac{e}{m}} = 2\sqrt{\left(\frac{\delta_N}{N}\right)^2 + \left(\frac{\delta_a}{a}\right)^2 + \left(\frac{\delta_r}{r}\right)^2 + \left(\frac{\delta_V}{2V}\right)^2}\frac{e}{m} \tag{2.2.1.8}$$

2.2.2 Formula for relation between voltage and radius

$$\frac{e}{m} = \left(\frac{r}{\mu_0 R N I_C}\right)^2 \frac{5^3 V}{2^5} \quad \text{From 2.2.10} \tag{2.2.2.1}$$

$$R = \left(\frac{r}{\mu_0 N I_C}\right)\sqrt{\frac{5^3}{2^5 \frac{e}{m}}}\sqrt{V} \quad \text{Relate R and V} \tag{2.2.2.2}$$

$$y = ax \quad \text{Linear relationship} \tag{2.2.2.3}$$

$$y = R; a = \left(\frac{r}{\mu_0 N I_C}\right)\sqrt{\frac{5^3}{2^5 \frac{e}{m}}}; x = \sqrt{V} \quad \text{With constants} \tag{2.2.2.4}$$

$$\frac{e}{m} = \left(\frac{r}{a\mu_0 N I_C}\right)^2 \frac{5^3}{2^5} \quad \text{Solve for e/m} \tag{2.2.2.5}$$

We can then calculate our errors in $x, y, \frac{e}{m}$

$$\delta_y = \delta_R \tag{2.2.2.6}$$

$$\delta_x = \frac{1}{2\sqrt{I_C}}\delta_{I_C} \tag{2.2.2.7}$$

$$\delta_{\frac{e}{m}} = 2\sqrt{\left(\frac{\delta_N}{N}\right)^2 + \left(\frac{\delta_a}{a}\right)^2 + \left(\frac{\delta_r}{r}\right)^2 + \left(\frac{\delta_{I_C}}{I_C}\right)^2}\frac{e}{m} \tag{2.2.2.8}$$

3 Procedure

3.1 Materials

1. Heimholz coil, with:
   I. Power supply
   II. Ammeter
2. Electron gun, with:

    I. Power supply
    II. Volt meter

3.2 General Setup

1. Position the electron gun
    I. Within the Heimholz coil
    II. Pointed tangentially to the coils
    III. Around 5cm offset into the coil
2. Turn on the Heimholz coil to 1A
3. Turn on the electron gun to 150V
4. Turn off the lights and observe the electron beam
5. Rotate the Heimholz coils until the electron beam is circular and not helical
6. Take a baseline measurement of the radius of the beam
7. Vary the amperage within safe bounds
    I. Note down the change in the radius of the beam
8. Set the amperage to the lowest while the beam is still visible
9. Vary the voltage within safe bounds
    I. Note down the change in the radius of the beam

3.3 General Data manipulation

1. Calculate x, y from equations $2.2.1.4$ and $2.2.2.4$
    I. Calculate its error with equations $2.2.1.6$, $2.2.1.7$, $2.2.2.6$, and $2.2.2.7$
2. Since we know x, y should relate linearly due to equations $2.2.1.2$ and $2.2.2.2$
3. Linearly relate x, y for the two variances in order to regress for its slope
4. Calculate $\frac{e}{m}$ given the slope (a) using equations $2.2.1.5$ and $2.2.2.5$
    I. Calculate its error with equations $2.2.1.8$ and $2.2.2.8$
5. Compare our values of $\frac{e}{m}$ with the current widely accepted value and decide if we disprove or fail to disprove the current standard

4 Analysis

4.1 Current vs. Radius

With the following constants:

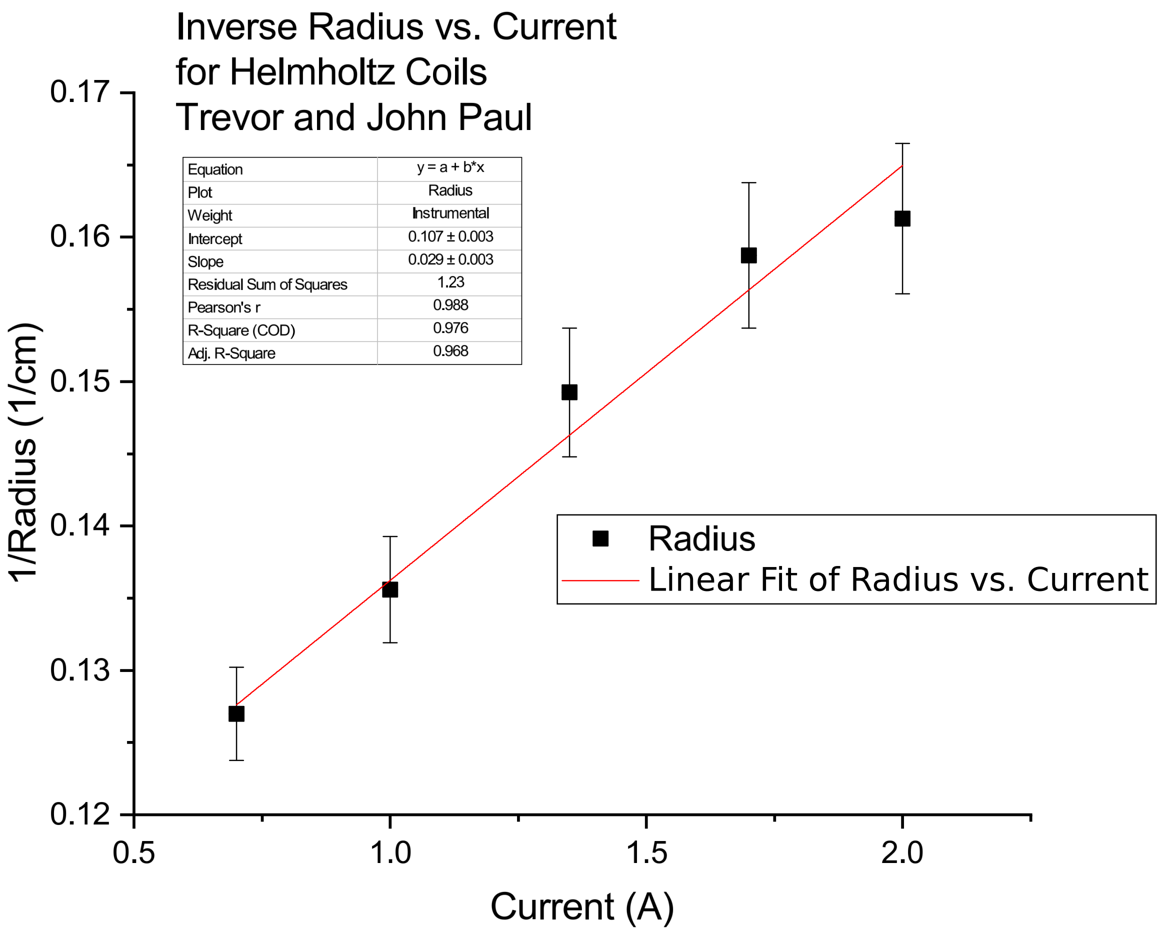
Constant	Value
r	$0.158 \pm 0.005\ m$

Constant	Value
N	130
V	$150 \pm 2\ V$

When varying radius, we obtained the following transformed data:

Current	Radius
A	cm^{-1}
0.7 ± 0.01	0.127 ± 0.003
1 ± 0.01	0.136 ± 0.004
1.35 ± 0.01	0.149 ± 0.004
1.7 ± 0.01	0.159 ± 0.005
2 ± 0.01	0.161 ± 0.005

Graphing this data, we obtain the following graph:



Property	Value
Equation	$y = ax + b$
a	$0.029 \pm 0.003\ \frac{1}{cmA}$

Property	Value
b	$0.107 \pm 0.003\ \frac{1}{cm}$
r^2	0.976

This leaves us with $a = 0.029 \pm 0.003$ to calculate $\frac{e}{m}$ from.

$\frac{e}{m} = (4 \pm 1) \times 10^9\ \frac{C}{kg}$

We find this value to be significantly different from the commonly accepted value.

Our Intercept (b) was relatively high as well. Its expected value is meant to be close to 0 as we expect close to no extraneous magnetic fields to be impacting our results. Our value was unexpectedly high.

4.2 Voltage vs. Radius

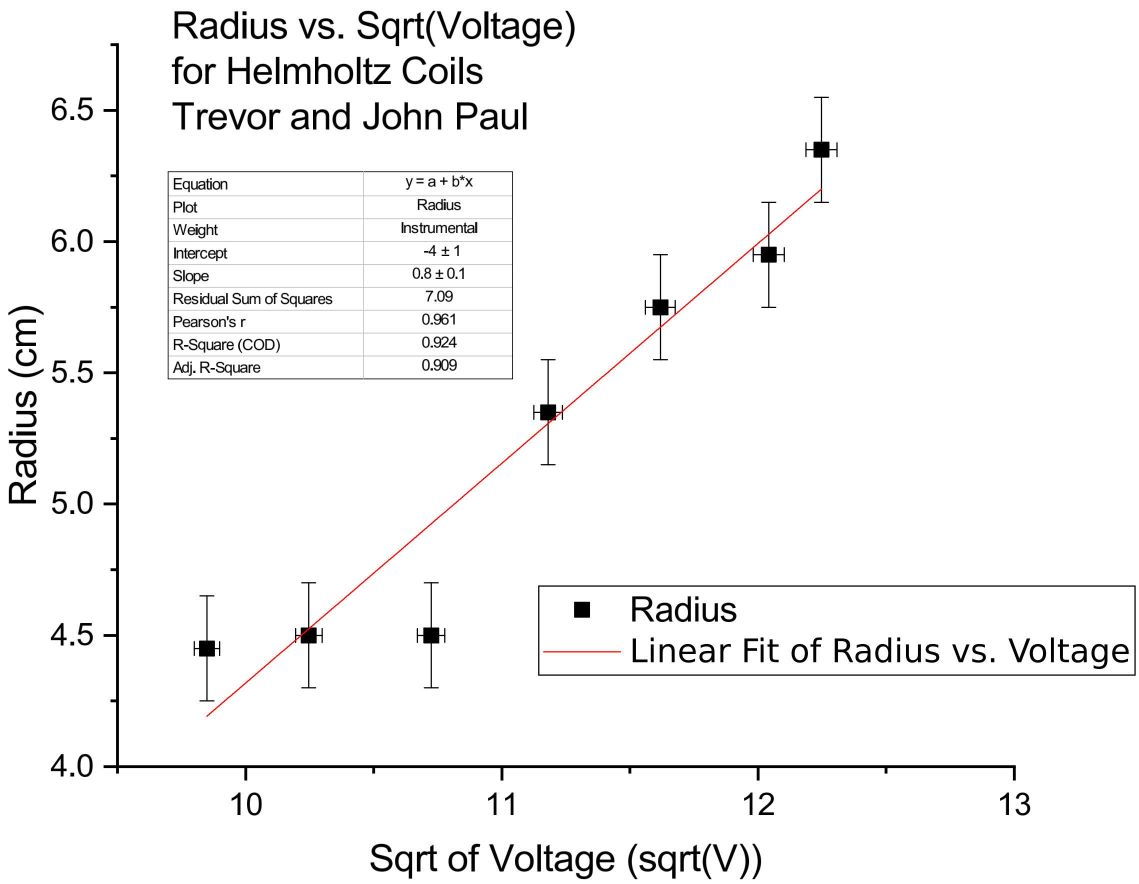
With the following constants:

Constant	Value
r	$0.158 \pm 0.005\ m$
N	130
I_C	$0.70 \pm 0.01\ A$

When varying radius, we obtained the following transformed data:

Voltage	Radius
$\sqrt{V}$	cm
9.85 ± 0.05	4.5 ± 0.2
10.25 ± 0.05	4.5 ± 0.2
10.72 ± 0.05	4.5 ± 0.2
11.18 ± 0.06	5.4 ± 0.2
11.62 ± 0.06	5.8 ± 0.2
12.04 ± 0.06	6 ± 0.2
12.25 ± 0.06	6.4 ± 0.2

Graphing this data, we obtain the following graph:



Property	Value
Equation	$y = ax + b$
a	$0.8 \pm 0.1 \ \frac{cm}{\sqrt{V}}$
b	$-4 \pm 1 \ cm$
r^2	0.924

This leaves us with $a = 0.8 \pm 0.1$ to calculate $\frac{e}{m}$ from.

$\frac{e}{m} = (1.2 \pm 0.3) \times 10^{11} \ \frac{C}{kg}$

We find this value to be pretty close to the accepted value, with only a difference of about 1.5 STD.

Our intercept (b) was also relatively high, but with our uncertainty, this is close enough to 0 for it to likely be a random error instead of a systematic issue. We find this to be consistent with theory as there may be little extraneous magnetic fields in the lab.

5 Conclusion

The purpose of this lab is to confirm the established value for $\frac{e}{m}$ in electrons through the usage of Heimholz coils and their expected field effect on electrons.

We have obtained two different values for $\frac{e}{m}$ by varying Voltage and Current in our Heimholz setup.

$\frac{e}{m}$ **Source**	**Value**
Expected	$1.75882017 \pm 0.00000007 \times 10^{11}\ \frac{C}{kg}$
Current	$(4 \pm 1) \times 10^{9}\ \frac{C}{kg}$
Voltage	$(1.2 \pm 0.3) \times 10^{11}\ \frac{C}{kg}$

For the value we got for our varying current, we got an incredibly imprecise and inaccurate answer, to within two orders of magnitude from our expected result. Our intercept value was also significantly different from what we expected. Due to extremely low accuracy, we fail to accept nor reject current theoretical understanding.

For the value we got for our varying voltage, we got a result that is remarkably close to the expected solution, to within $1.5\ SD$ of the expected result. Additionally, our intercept value was within the bounds random error, so we fail to disprove theory with the intercept. We fail to reject current theoretical knowledge through these results.

I believe a large source of error for our current variance would be due to a low number of sample points and possibly interference from the glass bowl on our last data point, that we did not believe was being interfered with until we saw the plot.

As for the varying voltage, I think a low certainty in our radius measurement could be a large source of error, even if we got a fairly close result to the expected cknowledgements and Info

- Lab 3 - EOM
- 2024-10-03
- Station 32 Rockefeller 403
- PHYS 122-119B

Lab Partner: John Paul Magbitang
Lab Manual: Lab 3 EOM PHYS 122

6.1 References

Driscoll, D., *General Physics 2: Electricity and Magnetism Lab Manual*, "Charge to Mass Ratio of the Electron".

Truur, John Paul

Lab #13b

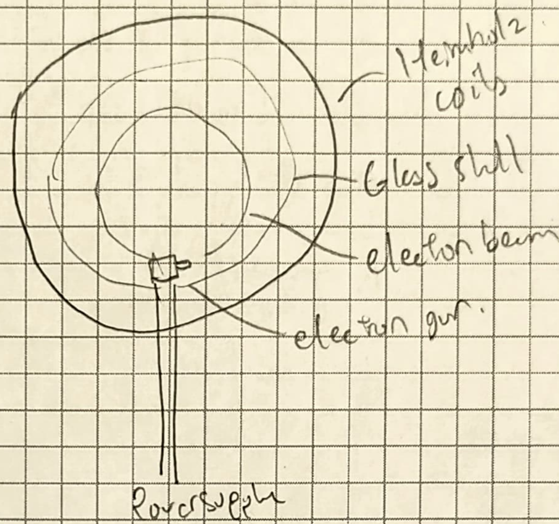
TA: Eli

PHYS 122: 119B Station 32

1) Turn on power supply to 150V
2) Adjust heat so electron path is circular & not helical
3) Measure left & right side of beam, calculate center & radius.

The purpose of this lab is to confirm the established value of e/m for electrons through examination with Helmholz coils.

D1



Measurements

4.5±0.5 − 15.5±0.5 cm

~~10.0~~ cm = 10.0 ± 0.5 cm

r = 5.5 ± 0.5 cm

D2

1) Max A: 2.0 A

Min A: 0.7 A

1) Increase & decrease voltage, repeat measuring the beam across 5 points including min & max

Amperage (A) ±0.01	left (cm) ±0.2	right (cm) ±0.2	diameter (cm) ±0.2
0.7	3.25	15.75	12.5
1.0	5.25	14.75	9
1.35	5.75	13.4	7.65
1.7	6.4	12.6	6.2
2.0	6.8	12.4	5.6

D3

0.7A

Voltage (V) ±1%	left (cm) ±0.2	right (cm) ±0.2	diameter (cm) ±0.2
97	4.7	13.6	8.9
105	4.4	14.3	9.9
115	4.0	14.7	10.7
125	3.6	15.1	11.5
135	3.4	15.3	11.9
145	3.1	15.8	12.7
150	2.9	15.7	13.0

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$\frac{1}{2} m v^2 = eV$

$\vec{F} = -e(\vec{v} \times \vec{B})$

$evB = mv^2/R$

$\frac{e}{m} = \frac{2V}{(BR)^2}$

$B = \frac{8\mu_0 N I_c}{5r\sqrt{5}}$

$\Downarrow$

$\frac{e}{m} = \frac{2V}{(8\mu_0 N I_c / 5r\sqrt{5})^2 R^2}$

m = mass of electron

v = speed of electron

$\vec{v}$ = velocity

$\vec{B}$ = magnetic field

e = magnitude of charge of electron

$\frac{e}{m} \approx 1.75882017 \pm 0.00000007 \times 10^{11} \frac{C}{kg}$

$\mu_0 = 4\pi \times 10^{-7}$ T·m/A

I_c = current

N = turns in coil = 130

$r = 0.158 \pm 0.005$ m

R = radius of beam

B = mag field

V = in. voltage

1) derive the relations between R, I_c, V, e/c to ultimately calculate e/c

Varying current:

$\frac{1}{R} = \frac{8\mu_0 N}{5r}\sqrt{\frac{e/m}{10V}}\, I_c + C$ — extraneous fields

Varying voltage:

$R = \frac{5r}{8\mu_0 N I_c}\sqrt{\frac{10}{e/m}}\, \sqrt{V} + C$

$\delta_{\frac{1}{R}} = \frac{1}{R^2}\delta_R$

$\delta_{\sqrt{V}} = \frac{1}{2\sqrt{V}}\delta_V$

Tracer, John Paul TA: Eli

Lab #13a PHYS 122:119B Section 23

1) Connect calibration to CH1 of the DSO
2) measure Volts/DIV, time/DIV
3) estimate error in DSO
4) Measure period & peak to peak of the calibration wave.

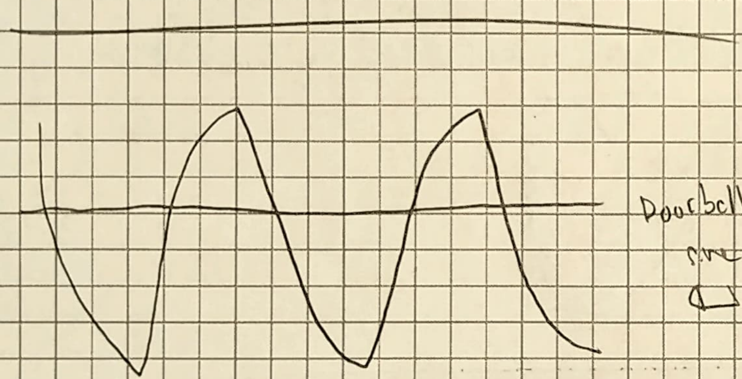
The purpose of this lab is to familiarize myself w/ the wave generator and the DSO, and also to explore how beating works.

V/Div = ~~[illegible]~~ 500mV μs/DIV = 250

error = $\frac{1}{5}$ DIV

period = $\frac{16.}{4.}$ DIV = 1000 μs ± 10 μs

peak to peak = 6 DIV = 3V ± 100mV



Doorbell transformer.
sine wave

$\frac{V}{DIV}$ = 2.00V

$\frac{ms}{DIV}$ = 5.00ms

peak to peak = 6 DIV = 12.0 ± 0.4 V

period = $\frac{16.6 DIV}{5}$ = ~~[illegible]~~

16.6 ± 0.2 ms

DMM measures 4.27 ± 1%

$V_{pp} = 2\sqrt{2}\, V_{rms}$

V_{pp} = 12.077, this is consistent with our oscilloscope reading.

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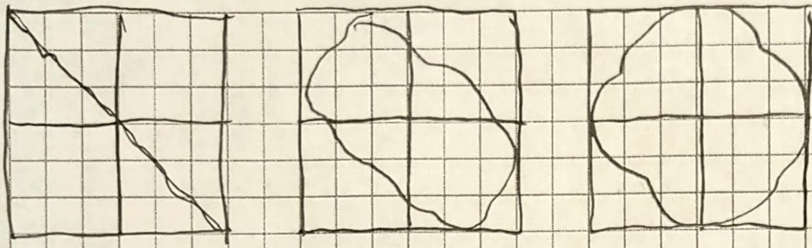
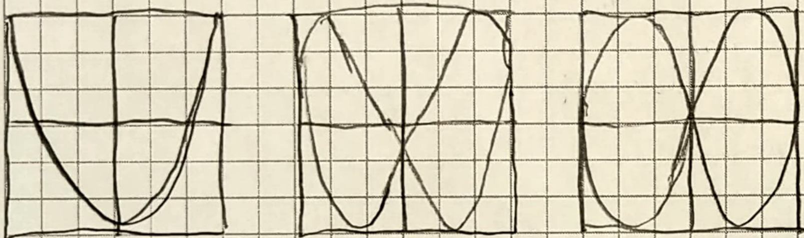
60 Hz:



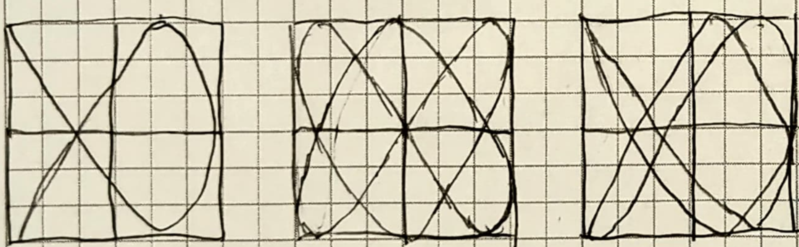
1) add wave generator to CH2 input, these patterns are XY plots of transformer vs. wave generator.

120 Hz:

V = 120.043 V



90 Hz: The ratios of the frequencies need to be a simple ratio.



$$\frac{314\,\text{ns} \pm 5}{30} = 10.47 \pm 0.2$$

10.5 ± 0.2 ns

1) measure waveform of sound, calculate frequency of it.