Classical Physics Laboratory

Professor Jeff Filippini

Physics 401

Spring 2020

ILLINOIS

XCKD #683

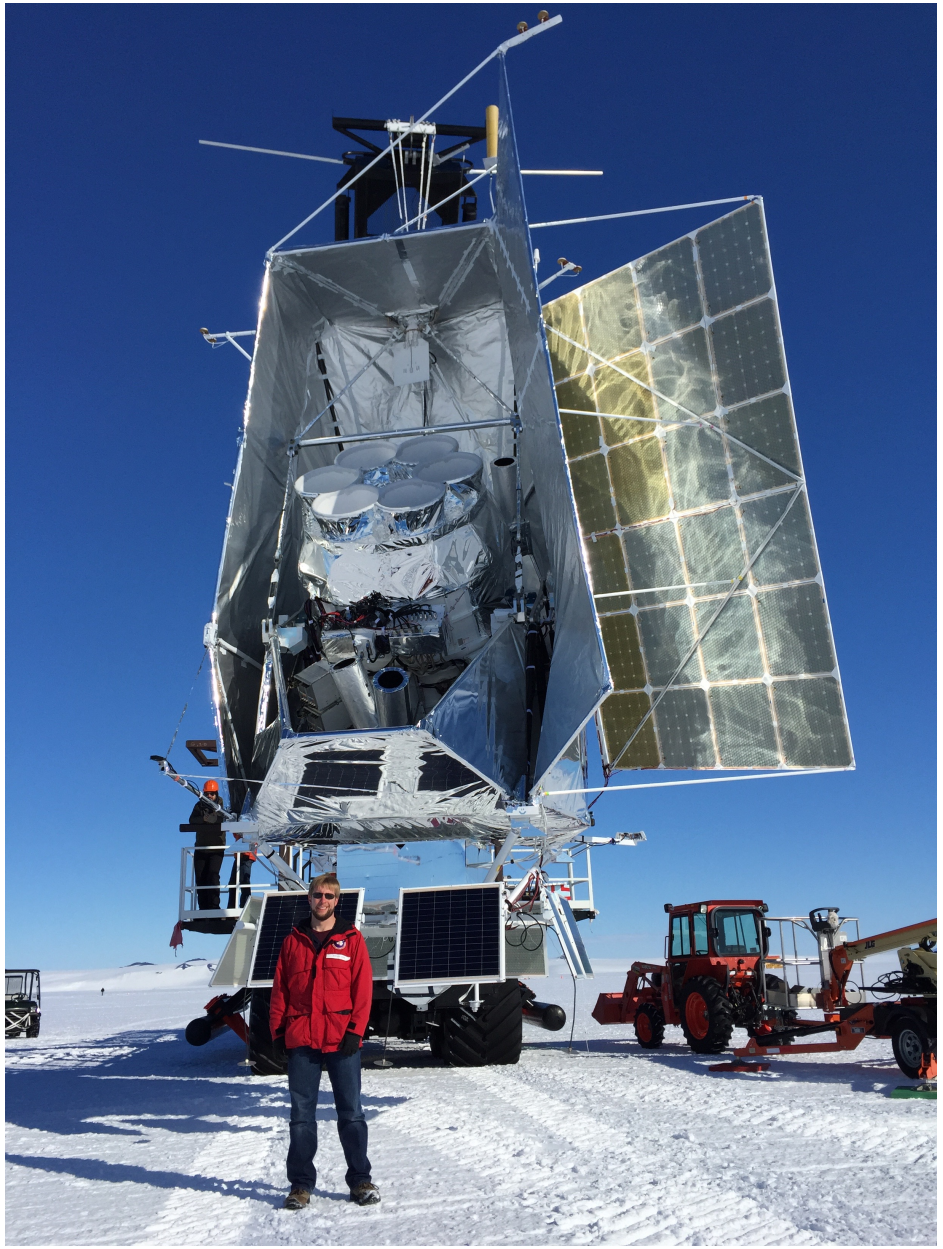
Physics 401 – Spring 2020

- Course Objectives — *Why*
- Organization — *Who, Where*
- How Labs Work — *What*
- Semester Schedule — *When*
- Grading

- **Lab 1**: Transients and Oscillations in RLC Circuits

Who am I?

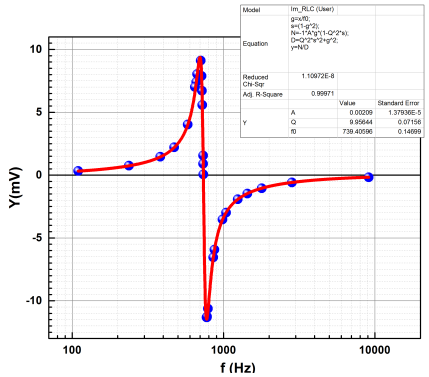
- Prof. Jeff Filippini
- Experimental Cosmology
  - Cosmic Microwave Background
  - Dark Matter
  - Sub-Kelvin detectors and superconducting electronics
  - Antarctic ballooning
- Office: 405 Loomis Lab
  - OH: Monday 10am, or by appt
- E-mail: jpf@Illinois.edu



Main Course Goals

- **Modern** experimental techniques in the context of **classical** physics (mechanics, electromagnetism)

- **Acquire data using modern lab techniques**
  - Tools: scope, DMM, signal generator, lock-in, …
  - Techniques: synchronous detection, …
- **Data analysis**
  - Fitting models and managing uncertainty
- **Presenting results**
  - Scientific writing!



Experiment 2: Transients and Oscillations in RLC Circuits

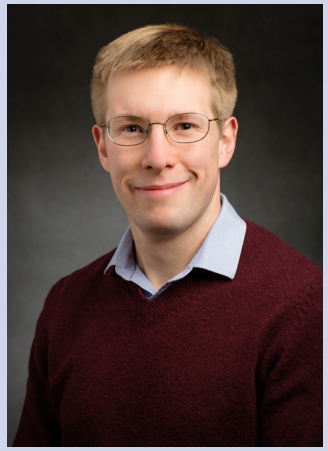
Student #1
Partner: Student#2
TA:
See laboratory book #1 pages 5-7, data taken September 1, 2009

September 7, 2009

Abstract

Transient responses of RLC circuits are examined when subjected to both long time scale (relative to the decay time) square wave voltages and sinusoidally varying voltages over a range of frequencies about the resonant frequency. In general, a good correspondence is found between theory - describing the charge in the sys-

Course Meetings and Staff

					
Instructor	Jeff Filippini	Eric Petersen	Albert Lam	Zidong Ma	Jack Boparai
E-mail	jpf	eapeter2	aclam2	zidongm2	jboparai
Section	A	L1	L3	L4	Lab Technician
Time	M 3:30-4:20	T 1:00-4:50	W 1:00-4:50	R 8:00-11:50	
Location	276 Loomis	6103 ESB	6103 ESB	6103 ESB	6101 ESB

Course Components

- Lecture
  - 1 hour/week: physics background, guide to doing the experiment
- Laboratory
  - 4 hours/week: conduct the experiment, do preliminary data analysis (*quality check!*)
  - 9 labs: 1 intro, 4x 1-week, 3x2-week, 1x3-week *(final project)*
- Reports
  - 10-15 pages/lab: background, procedure, results, interpretation

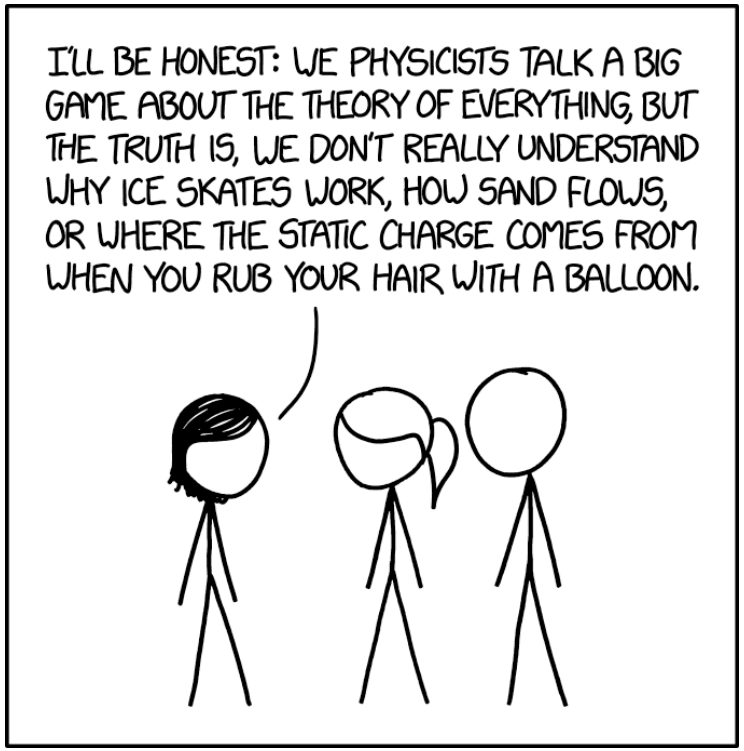
- *No textbook, no exams*

Course website

Course Components: Lecture

- Mondays 3:30-4:20, 276 Loomis
- *Not optional*: +5 points/lecture

- Typical lecture plan
  - Brief outline of the underlying physics
  - Experimental setup and equipment
  - Experiment procedure, common pitfalls
  - Data analysis and presentation *(including error analysis!)*
  - Questions, discussions



XCKD #1867

Course Components: Laboratory Section

- Read the write up **before** lab
- Work in **teams of 2**
- Assemble the apparatus *(draw diagram if needed)*
- Perform experiment and acquire data
  - Record data using DAQ and/or manually in notebook
  - If recorded automatically, you must record file name in notebook!
- Briefly summarize **experimental procedures** and record **observations and results** in your laboratory notebook
- Carry out **preliminary data analysis** and fix experimental settings as needed
- Attendance is **mandatory**! Contact TA/prof ASAP with issues
  - At most *one* excused assignment (with documentation!),
  - You *cannot* be excused from the final project, or pass without it!

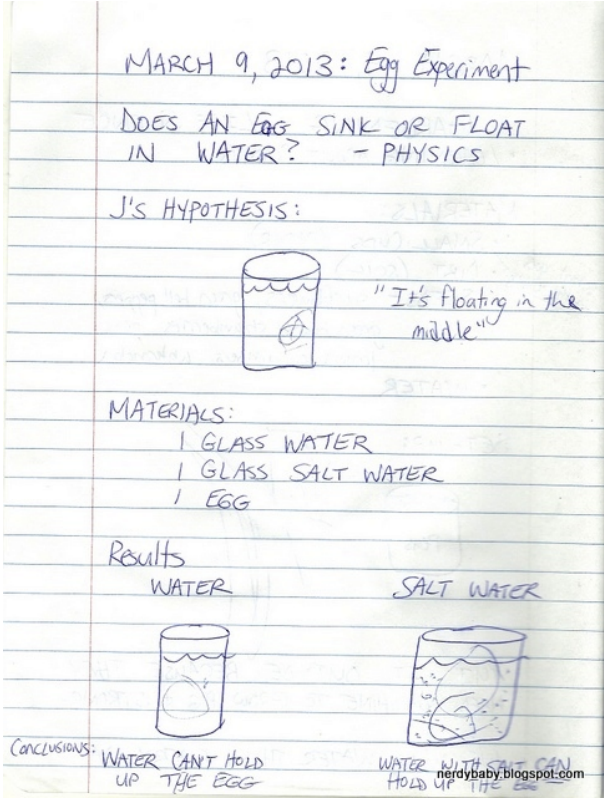
Laboratory Notebook

You need <u>two</u> identical notebooks to alternate between

One submitted with report, other kept for next experiment

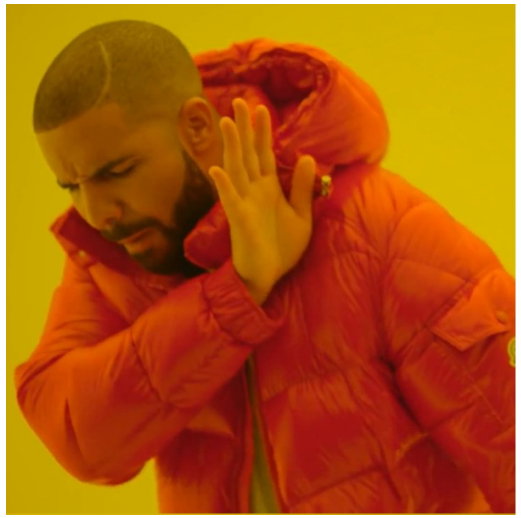
The scientific record of your experiment. It needs to contain in brief *all* information required to solidly connect the experimental data with physics observables in analysis:

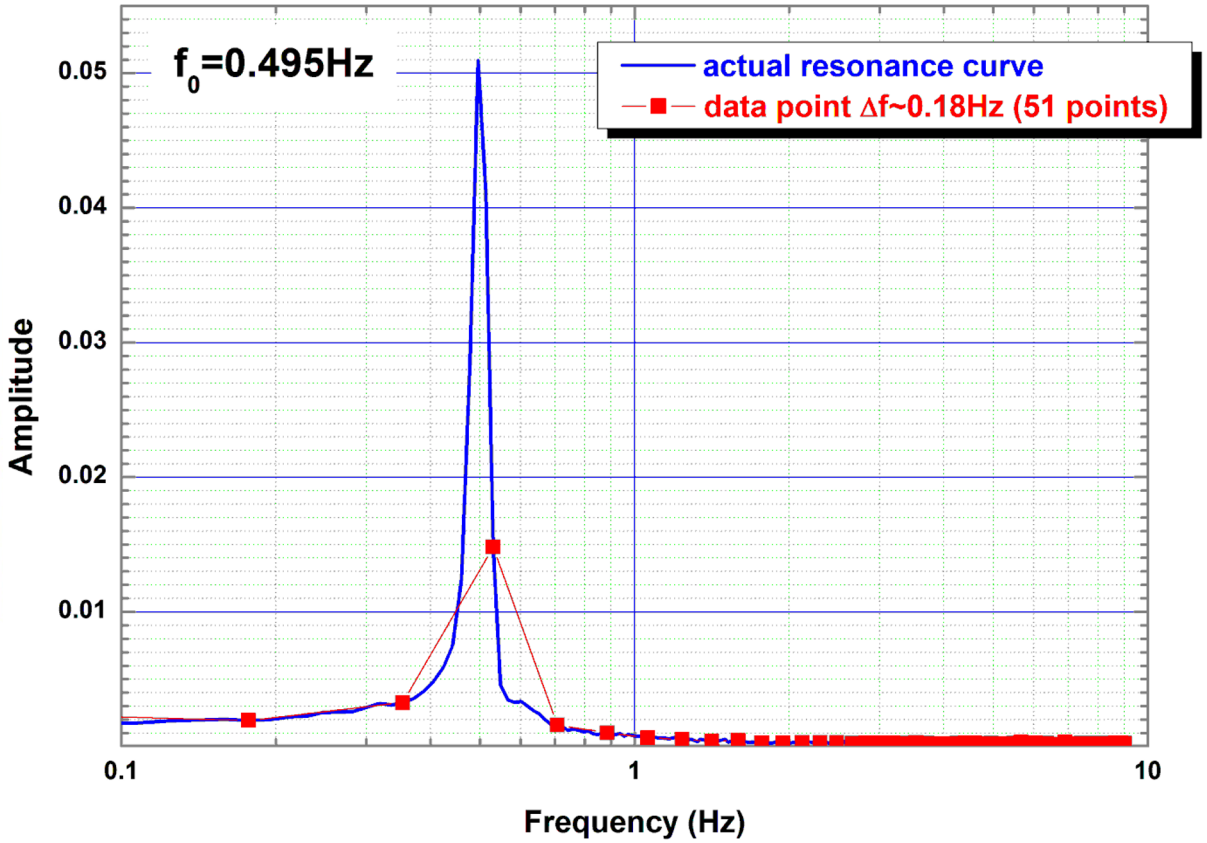
- drawing of the setup
- environment conditions (*as needed*)
- dimensions or other characteristics of experimental equipment relevant to later analysis
- results from calibration procedures
- data and error estimate
- some preliminary results and graphs



Preliminary Analysis? C'mon, who needs that…

Is your data suitable to draw conclusions from?
Don't wait until you're writing your report to find out!





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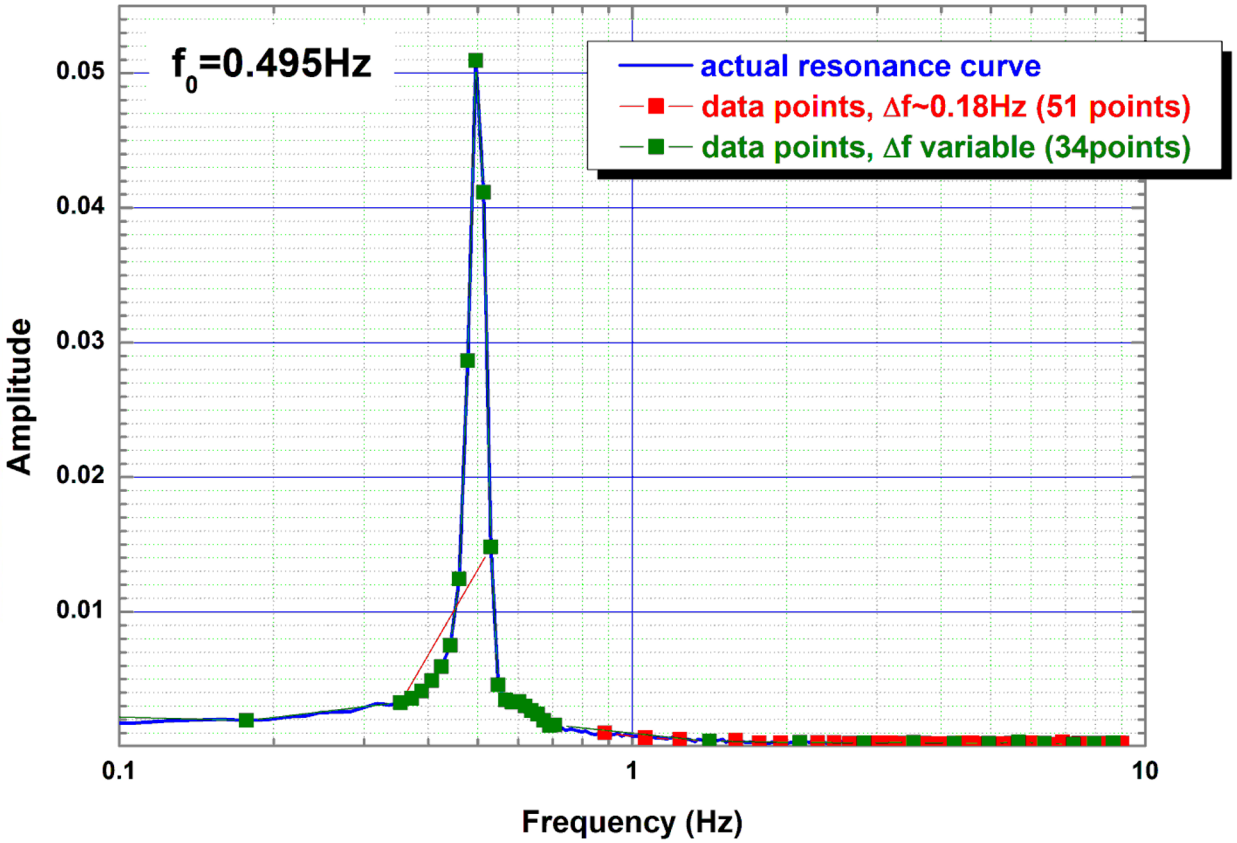
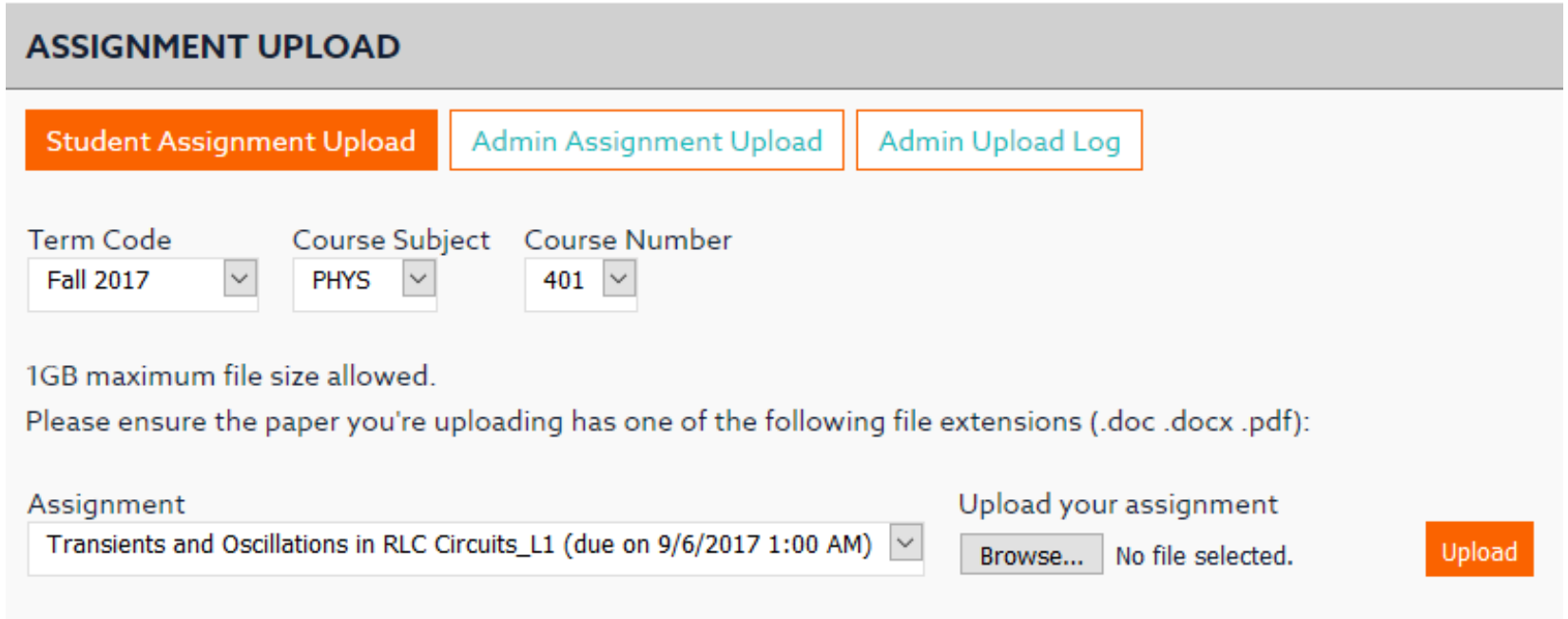


Course Components: Lab Report

- **Goal:** show the experiment's main results and findings *and* how they were obtained
- Lab work is in pairs, but **everyone writes their own report**
- Due not later than **1 week** after lab was completed
  - **Submit** report electronically, then hand in **notebook** to TA



Lab Report #1: Opening

Title → Measurement of the Electronic Charge by the Oil Drop Method

Excellent Student ← Name

Affiliation, date, etc. →

TA: TA's name
Department of Physics, University of Illinois Urbana-Champaign
September 27 and October 4, 2012
Lab Notebook #1 Pages 10-12

Abstract ←

Abstract

The Millikan oil drop method is used to determine the electron charge. Using a special scope aligned with a capacitor, the response of charged oil drops introduced into the capacitor through an atomizer is studied for each drop's rise in the presence of an electric field and fall without the field. The rise and fall times, when applied to several equations along with various environmental constants, give the total charge on the drop. These charge values are then studied using a histogram, and by analyzing fit peaks, mean charge values for the distribution are obtained. These mean values, compared to the previously obtained total charges, allow the estimated charge of the electron to be found. This process is completed for both an individual set of data and data collected by the whole section, the accuracy of the final results is then compared with each other and the theoretical charge on the electron.

Lab Report #2: … What's an Abstract?

Celia Elliot's Foolproof Abstract Recipe™

Answer the following, in this order, 1-2 sentences each

1. What **problem** did you study, and why is it **important**?
2. What **methods** did you use?
3. What were your principal **results**?
4. What did you **learn**? What have you **contributed**?

Lab Report #3: Introduction

Theory and motivation

1. What physics did you touch?
2. Historical background
   Brief, only if necessary
3. From physics to measurable parameters

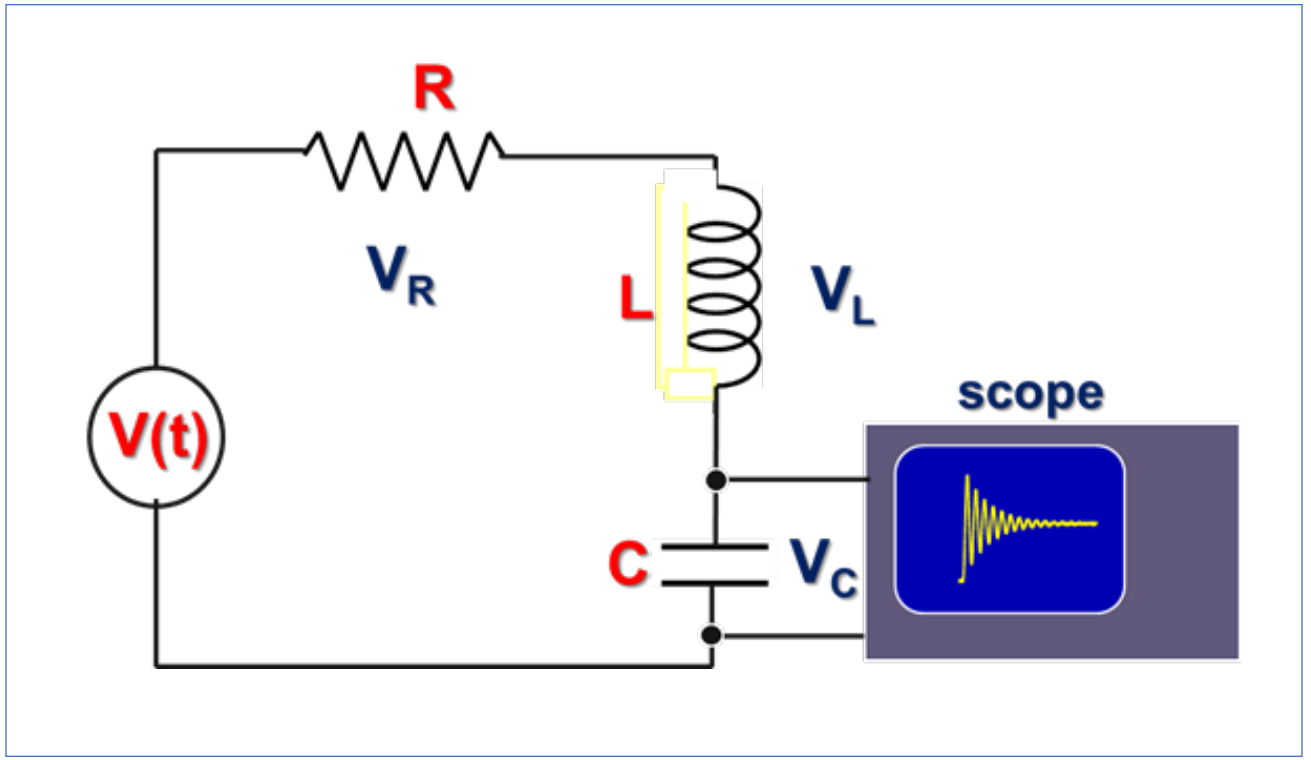
Introduction

Electromagnetism comprises one of the four fundamental forces of nature, and although the applications of electricity are more apparent in the layman's everyday life, the effects of magnetic fields, although more subtle, are no less profound nor less important. Pioneering 19th Century work conducted by experimentalists such as Michael Faraday and theoreticians including James Clerk Maxwell underpin the classical electromagnetic theory still widely used in several applications today, ranging from the spinning turbines in every electrical power station to the MRI scanners in all major hospitals. As such they remain an integral cornerstone of modern physical theory, hence the motivation for conducting this experiment.

Lab Report #4: Procedure

Setup, measurement technique, object of study

1. Measurement concept
2. Experimental setup *with diagram!*
3. Equipment used *model numbers!*
4. DAQ software used



Lab Report #5: Results

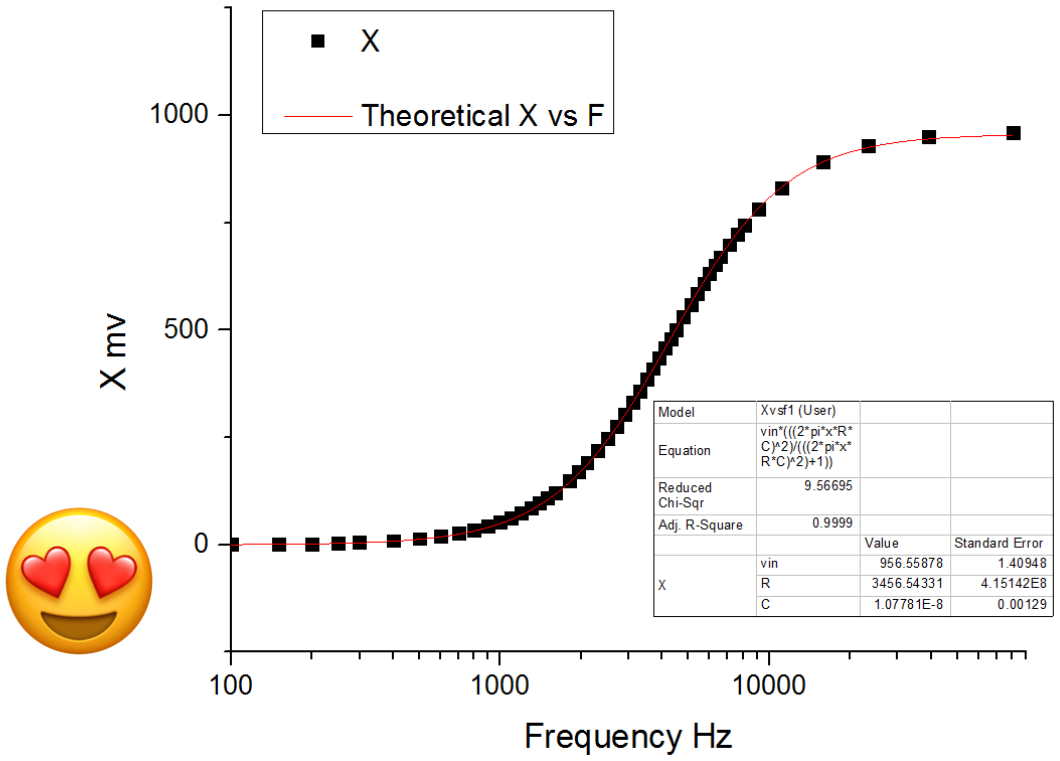
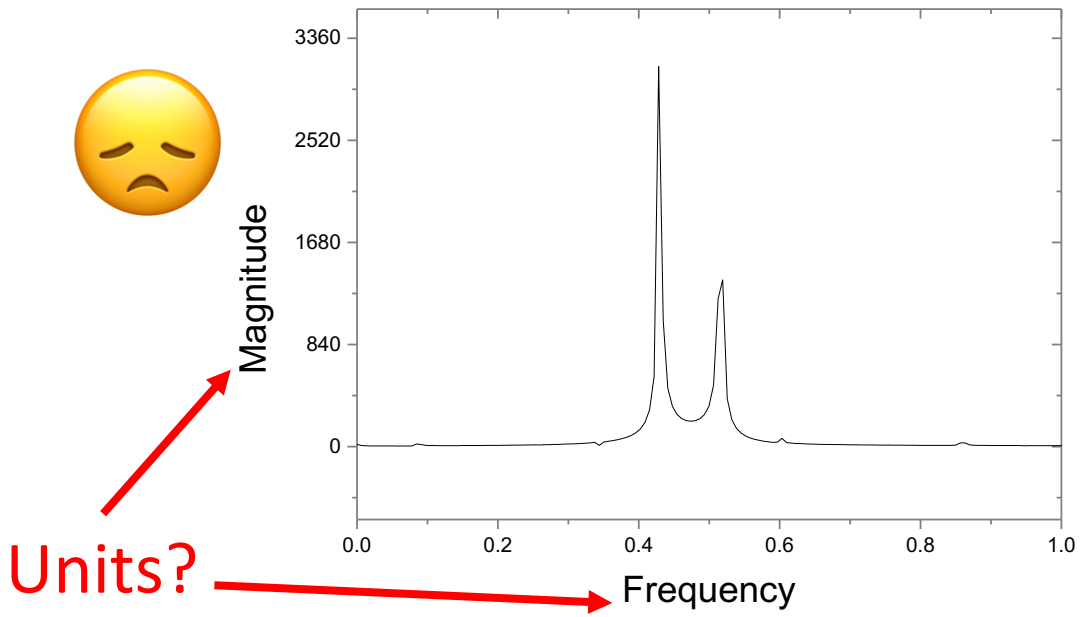


Figure 4. Graph of X vs Frequency over a wide range of frequencies in circuit A

Main findings, analysis, errors

1. Raw results, if appropriate
2. Getting from raw data to physical parameters
3. Errors, uncertainties, problems



Units?

Caption??

Lab Report #6: Conclusions

1. Main findings obtained in the experiment and after data analysis

2. Compare the results obtained to published/known results

In conclusion, a number of results were confirmed by oscillating a copper disk with different damping forces as well as different driving forces. The K value for static measurements produced a sheer modulus value within 3% of the handbook value. Using dynamic measurements the same k was calculated but there was a 17% error between the two, which was most likely due to human error in the static measurements experiment because there was so much hands on activity. No linear correlation for amplitude vs. log decrement for turbulent damping was found, which is due to the fact that the starting position of the disk was not far back enough. Using driven oscillation beats were observed. The amplitude and phase of damped, driven oscillator vs. frequency were also graphed.

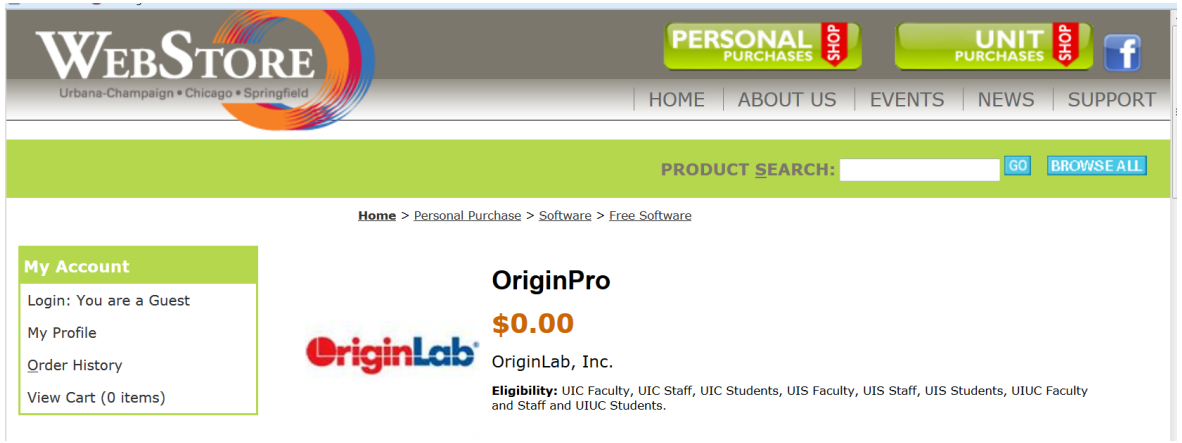
Preparing a Good Lab Report

1. Proofread and check spelling
2. Prepare “polished” graphs
3. Captions for all tables, graphs, and pictures
4. All equations should be numbered
5. Use a reasonable numbers of significant digits on all numerical values
6. All results (physical parameters) should be presented with estimated errors

Helpful references:

Example 401 lab and lab report writing guide

Lab Report: Graphs



OriginPro: Windows software for data analysis and presentation

Installed on all lab PCs

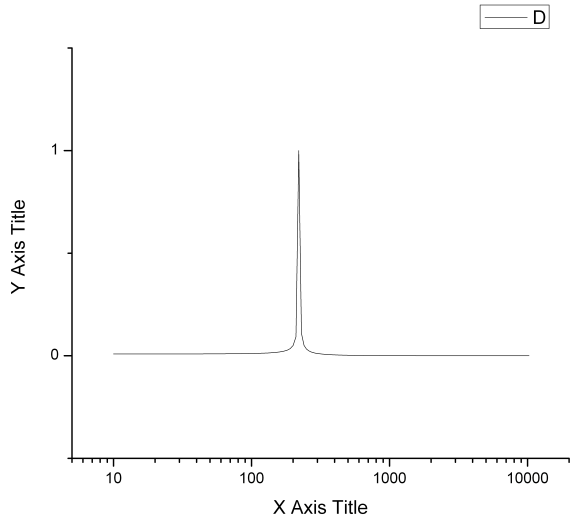
Available for free from WebStore and via Citrix virtual platform

OriginLab has put together a handy multi-page booklet highlighting key features of Origin and OriginPro.

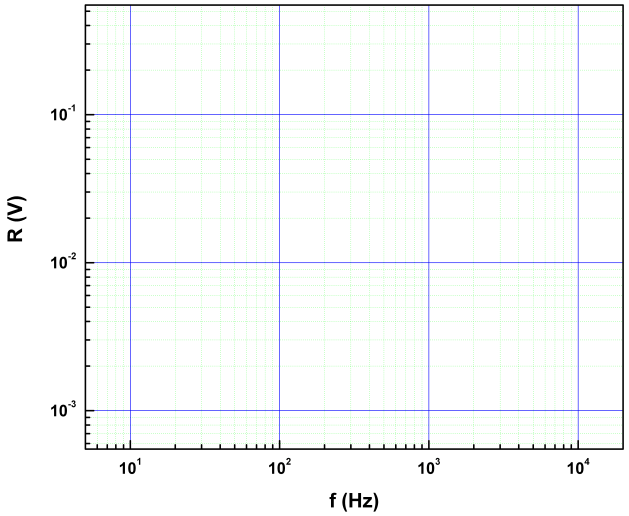
An online version of this booklet is available here.

Lab Report: Graphs

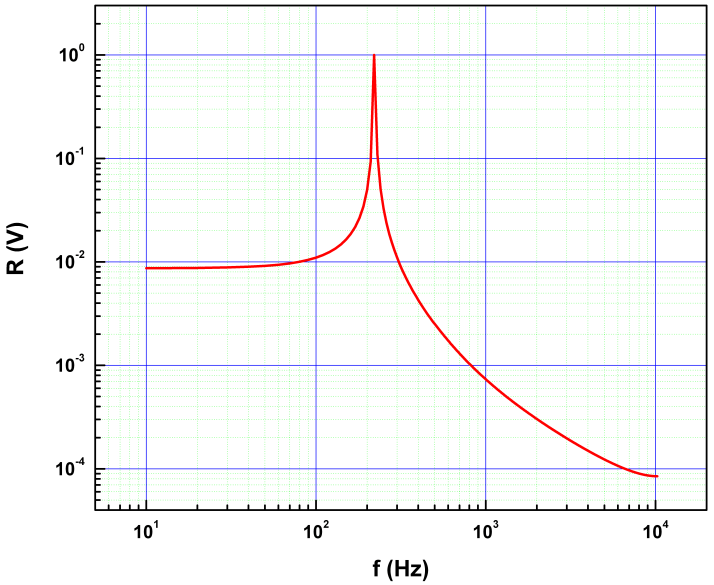
Working with Origin, you can use the course templates

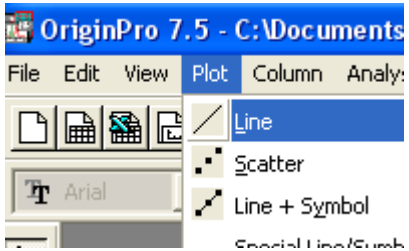


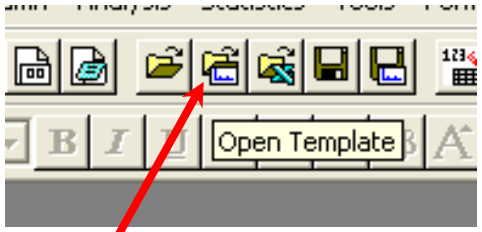
Simple plot of the data



Open the template







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Lab Report: Submission

- Deadline is the day (up to midnight) one week after lab
  - https://my.physics.illinois.edu/courses/upload/
  - If you have upload problems, e-mail to your TA *and* Prof. Filippini
- Late reports are penalized
  - Up to 1 week late: 5% off total score
  - Up to 2 weeks late: 10% off total score
  - After that, it's too late! May 10th is final due date for everything
- Two vouchers to avoid the 1-week penalty
  - Can't use both on same report, or more than one week late
  - Must inform TA that you're using voucher (preferably before!)
  - Can't use on final report. +5 points on final for each unused voucher

Lab Report: Re-Submission

You can resubmit one report for regrade during the semester

1. Original report must be on time or with voucher
2. Original submission must be a real report (not e.g. just title page!)
3. The final report cannot be resubmitted
4. The deadline for resubmission is the same as for the final report – May 10, 2020

Course Grading

- Lab reports (8) 1000 points
- Lecture attendance (12) 60 points

- TOTAL: 1060 points!

- Letter grades typically 90-100% A range, 80-89% B range, …

Course Schedule

Course website

Week of	# Weeks	Lab Title
January 20	1	Introduction to oscilloscope, function generator, digital multi-meter (DMM), and curve fitting.
January 27	1	Transients in RLC circuits
February 3	1	Frequency domain analysis of linear circuits using synchronous detection
February 10	1	Pulses in transmission lines
February 17	1 of 2	Millikan Oil Drop Experiment / Week 1
February 24	2 of 2	Millikan Oil Drop Experiment / Week 2
March 2	1 of 2	Torsion Oscillator / Week 1
March 9	2 of 2	Torsion Oscillator / Week 2
March 16		**SPRING BREAK**
March 23	1	Hall Probe Measurement of Magnetic Fields
March 30	1 of 2	Qualitative Studies with Microwaves / Week 1
April 6	2 of 2	Microwave Cavities / Week 2
April 13	1 of 3	Final Project - AC Measurement of Magnetic Susceptibility / Week 1
April 20	2 of 3	Final Project - AC Measurement of Magnetic Susceptibility / Week 2
April 27	3 of 3	Final Project - AC Measurement of Magnetic Susceptibility / Week 3.
May 10		Final week: Final Project Reports due (uploaded) by May 10th at 11:59 PM.