Intermediate Physics Laboratory (PHY 3802L-0001)

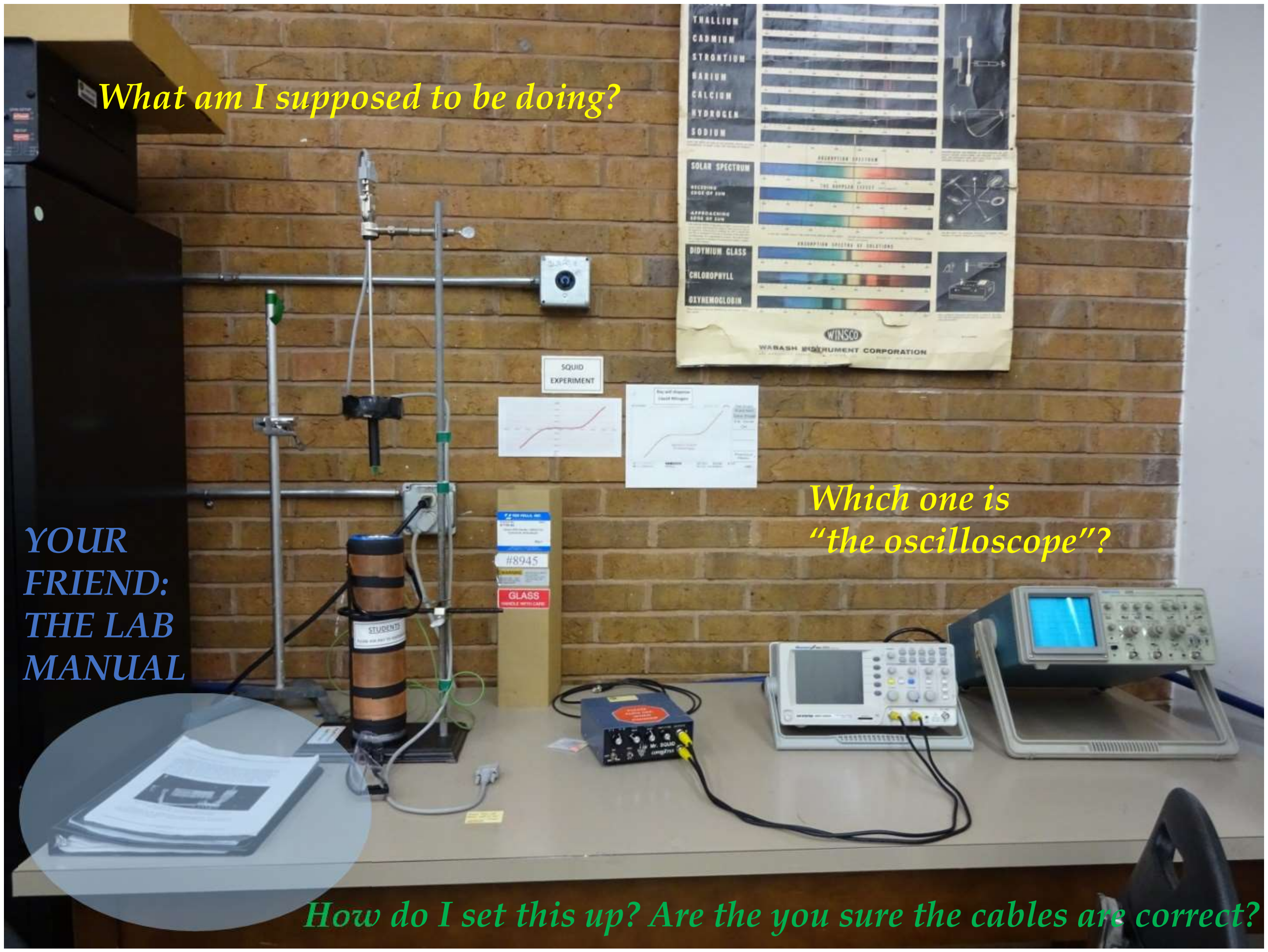
Class held in MSB 333A, Tuesday and Thursday 12:00-2:50 PM

Instructor: Dr. Chris J. Bennett

Office: PSB308

Email: Christopher.Bennett@ucf.edu

Lecture 1 – Introduction to the Course



What am I supposed to be doing?
Which one is
"the oscilloscope"?
YOUR
FRIEND:
THE LAB
MANUAL
How do I set this up? Are the you sure the cables are correct?
SQUID
EXPERIMENT
GLASS

The Objectives of this Course

To utilize historically important experiments relevant to physics to highlight their importance and deepen understanding of key concepts and the underlying principles

Allow you to become more proficient and confident using modern experimental methods and instrumentation

To practice and develop your confidence communicating scientific concepts through written (lab reports → journal articles) and oral (final presentation → conferences) approaches

To increase proficiency in experimental procedures, recording data, data analysis, statistical analysis and presentation of data

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Prerequisites / Course Materials

Prerequisites: PHY 3101 or C.I. Laboratory work in basic measurements of physical constants; experiments in electronics, modern physics, nuclear physics, optics, and solid state physics.

Course Materials: No textbook required, the following Reference books will be reserved in Library…

- The Art of Experimental Physics, D.W. Preston, E.R. Dietz, Wiley & Sons, Inc.
- Experimental Physics, Modern Methods, R.A. Dunlap, Oxford Univ. Press
- Experiments in Modern Physics, A.C. Melissinos, Academic Press
- Statistical Treatment of Experimental Data, H.D. Young, McGraw-Hill Book Co.

Please refer online to the Webcourse or Dr. Bennett's homepage for:

- Quiz #1 on the syllabus (*fulfills active participation requirement*) – deadline is ***Friday 24th Aug***
- Instrument Manuals (where available/applicable)
- Background and Further Reading material on the experiments
- Additional Laboratory Guides

Grading Criteria

Grading:

Introductory quizzes/homework	15%
Laboratory interviews	10%
Laboratory notebook and execution of experiments	10%
Laboratory write-ups	50%
Final oral presentation	15%

Grading Scale:

Your final letter grade will be determined by your total score according to the following scale:

100% ≥ **A** ≥ 90%   90% > **A-** ≥ 85%

85% > **B+** ≥ 80%   80% > **B** ≥ 75%   75% > **B-** ≥ 70%

70% > **C+** ≥ 65%   65% > **C** ≥ 60%   60% > **C-** ≥ 55%

55% > **D** 40 % > **F**

Quizzes / Homework (15%)

(10%) Quiz #1 – Syllabus on Webcourse ***(Due Friday 24th August!)***

(20%) Quiz #2 – Lab Safety *(warning: instant quiz!)*

(35%) Homework #1 - Data Analysis & Error Propagation (Due Thu 13th Sept)

(35%) Homework #2 – Understanding of Course Material (Due Tue 20st Nov)

May also be an internal UCF assessment of your understanding of statistics and experimental approaches done during the last few weeks…

The Experiments (done in pairs)

1. Frank-Hertz Experiment
2. Photoelectric Effect
3. Charge-to-Mass Ratio of Electrons
4. Temperature Dependence of Resistivity
5. Electron Spin Resonance
6. Superconducting Quantum Interference Device
7. Optical Experiment: Spectroscopy & Rydberg Constant
8. Optical Experiment: Diffraction
9. AC Electronics (RC filters, RLC resonant circuits)
10. Nuclear Spectroscopy (Gamma ray spectroscopy, nuclear activation of In, lifetime)

The Lab Report

Additional Details will be Given Next Week on How to Write a Scientific Manuscript

Lab reports for this course should consist of the following sections:

1) Title & Abstract. Include Authors, as well as the week the experiment is performed and the experiment number.
2) Introduction & Background.
3) Methods. A description of the apparatus used (usually including a schematic or photograph of the instrument)
4) Results. Tabulated and/or graphed data of results.
5) Analysis (can be combined with presentation of results)
6) Summary, Applications & Discussion
7) References
8) Supplemental Information (photographs of your lab book)

Changes This Semester

Only Have to Hand in 5 Lab Reports as Primary Author, and 5 as Secondary Author

- **Primary authors are graded on:**

- Everything (50 points lab report & 10 points Notebook/Execution)
- **Secondary authors will still be graded on:**

- Laboratory Notebook & Execution (10 pts total)
- Results & Analysis (15 pts)

Note: This amounts to totals of 75 points out of 325 points (23%) of the total laboratory write-up grade, and ~11.5% of the total grade for the course.

Criteria for Lab Report

Grading (50% of total grade)

Lab report are always due before midnight of the following Thursday. For example, if an experiment is conducted during the week of Sept 4th-6th, then its report is due by webcourses to the instructor ***by*** Sept 13th, the next Thursday night (12 am). Late submission of a lab report will suffer a **2pt penalty for every 24 hrs** behind the due date, or **10pts** per week past the due date. *This rule applies to the homeworks as well.*

- **5 pts (10%): professional presentation** of the word document (not sure what this means? Go to www.aps.org, find any paper to take a look). Write data in tables where appropriate. Use equation editor in word and number your equations for reference throughout the report, and preferably use a graphing program such as Excel (Origin, Python, R, Matlab, IDL, etc. also acceptable). Tables and Figures should be numbered and labeled. References well formated and cited throughout. Correct title, authors, etc.

- **10 pts (20%):** Introduction covers **sufficient background**, including a concise literature review and sufficient theory required to understand how the experiment works, and underlying physics principles. Typically includes a demonstrated understanding of the phyiscs behind how the apparatus and/or experiment works.

- **10 pts (10%):** Description of the apparatus (usually with annotated photograph and/or schematics). Model number, manufacturer, chemical suppliers, etc.

- **15 pts (30%):** clear presentation and derivation of your results and analysis of the data (see No. 5 *Analysis* in format specification above). **The error/uncertainty analysis typically constitutes a significant fraction of the grading criteria for this section (up to 50%).**

- **10 pts (20%):** discussion of the results, as well as relevant example/application/phenomena based on this experiment. I am expecting different contents from each member in the same group, which means you need to complete this part independently.

- **1-2 Bonus points may be awarded for exceptional work in any one of these areas... Awarded one-time only.**

Laboratory Notebook & Execution (10%)

Each week, you will also be graded on how well you perform the tasks and set about solving problems (asking the instructor for help at ***every stage*** of the experiment, for example, doesn't show a lot of initiative in this area, but you are encouraged to ask for help when needed)

This grade will be provided each week in addition to the Laboratory Grade on your returned Lab report.

- **5 pts:** Evidence of well-executed experiment, or documentation of sufficient attempts to recover the experiment if something went wrong.

- **5 pts:** Clear presentation of the original data (photo image of the hand-written data page from your note book, must be your own version, even if several students conduct an experiment together, each must have his/her own copy of the original data).

Laboratory Interviews (10%)

Have been too lenient on this in previous years… since there are 9 sets of experiments being performed each week, you need to be prepared!

Students in each group will be quizzed on the experiments being performed that week as well as the previous week for ~5-15 minutes to assess their understanding of how to perform the current experiment, as well as the underlying principles.

In addition, they will be quizzed on the previous weeks experiment (except in the first week), which be a more in-depth set of questioning to determine how well the experiment was understood after completing the write-up.

Grades will be communicated back to the students along with the lab book report.

Required: Reading lab instructions and manuals beforehand. Write down your answers to the interview questions.

Final Presentation (15%)

A 15-minute oral presentation will be given by each student during the final exam period with a 5 minutes to answer questions from the audience. Audience participation (i.e. asking questions) is a graded criteria.

The presentation style should be similar to a presentation that is given at a scientific conference.

The topic of the presentation should be any experiment in physics history (that is different from what we do in this course) that led to the confirmation of a theory or discovery of a new physics law (or a Nobel Prize winning experiment).

You must propose and finalize your selected topic during the 13th week either in e-mail or in person, but the topic must be given instructor approval prior to Thu 15th Nov.

Schedule

Wk 1	08/21	Introduction to Syllabus & Experiments *(Lecture)*	What is Due this Week…
	08/23	Scientific Writing *(Lecture)*	Quiz #1 due on 08/24
Wk 2	08/28*	Lab safety *(Lecture by EHS)*	Quiz #2 taken on 08/23
	08/30*	Data Analysis *(Lecture)*	HW #1 released
Wk 3	09/04, 09/06	1st Experiment, A leads	
Wk 4	09/11, 09/13	2nd Experiment. B leads	1st Lab report due 9/13
Wk 5	09/18, 09/20	3rd Experiment, A leads	HW #1 & 2nd Lab report due 9/20
Wk 6	09/25, 09/27	4th Experiment, B leads	3rd Lab report due 9/27
Wk 7	10/02, 10/04	5th Experiment, A leads	4th Lab report due 10/04
Wk 8	10/09, 10/11	6th Experiment, B leads	5th Lab report due 10/11
Wk 9	10/16, 10/18	7th Experiment, A leads	6th Lab report due 10/18
Wk 10	10/23*, 10/25*	8th Experiment, B leads	7th Lab report due 10/25
Wk 11	10/30, 11/01	9th Experiment, A leads	8th Lab report due 11/01
Wk 12	11/06, 11/08	10th Experiment, B leads	HW #2 released 11/06 9th Lab report due 11/08
Wk 13	11/13, 11/15	Make-up week	10th Lab report due 11/15 Presentation topic decided
Wk 14	11/20	Prepare for presentations	HW #2 & last date for make-up lab reports.
Wk 15	11/27, 11/29	Final Student Presentations	

** May have a substitute instructor during this session as Dr Bennett is traveling. Class attendance will be taken.*

Group Rotations Determine Which Experiment Will be Carried Out Each Week

Group	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10	Wk11	Wk12	Wk13
A	1	2	3	4	5	6	7	8	9	10	-
B	2	3	4	5	6	7	8	9	10	1	-
C	3	4	5	6	7	8	9	10	1	2	-
D	4	5	6	7	8	9	10	1	2	3	-
E	5	6	7	8	9	10	1	2	3	4	-
F	6	7	8	9	10	1	2	3	4	5	-
G	7	8	9	10	1	2	3	4	5	6	-
H	8	9	10	1	2	3	4	5	6	7	-
I	9	10	1	2	3	4	5	6	7	8	-

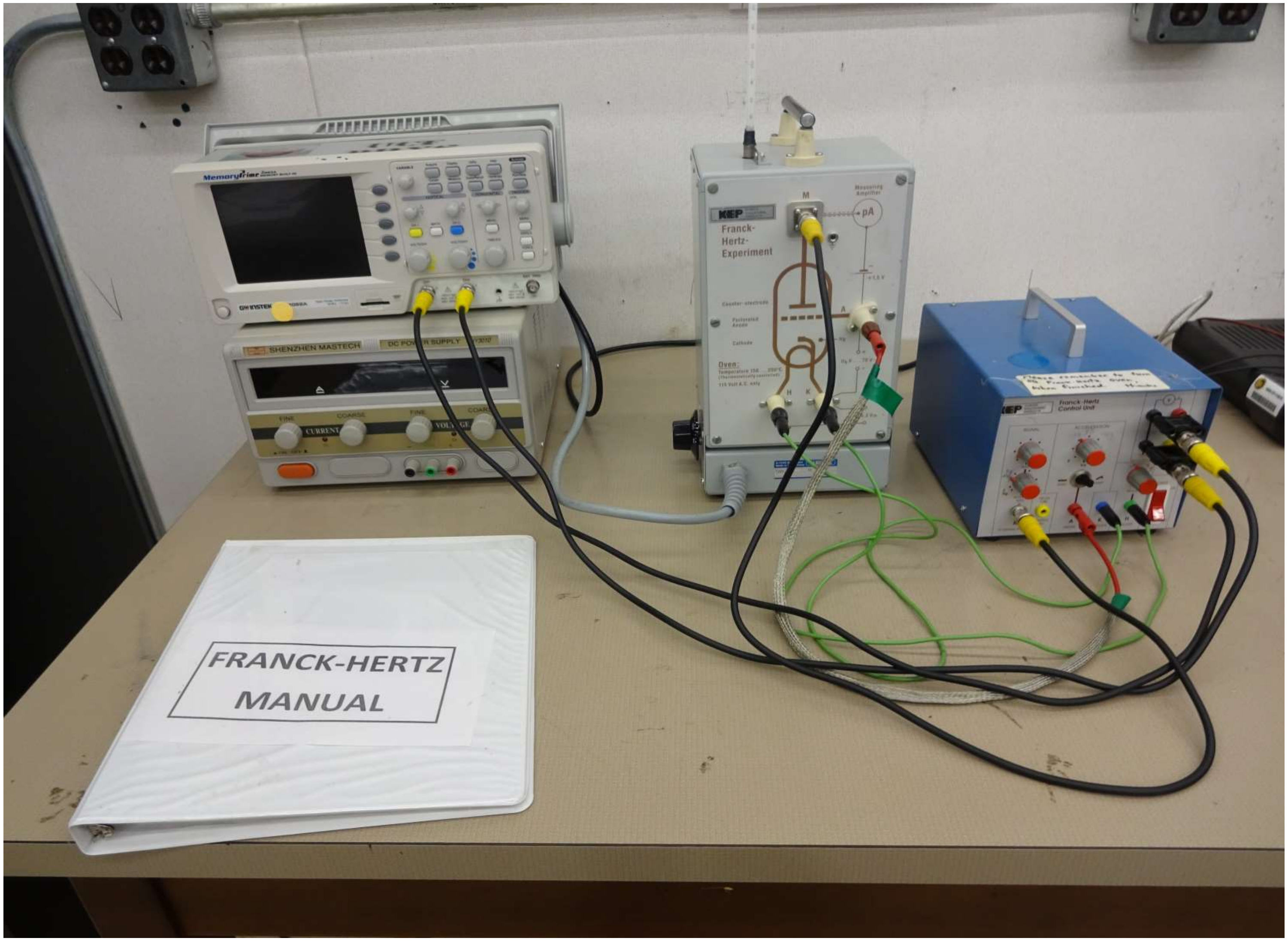
The Experiments

***highly* recommended reading preparation material beforehand**

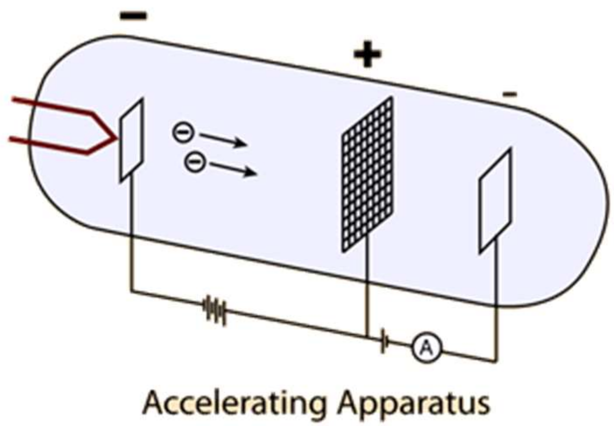
Webcourses → Files → Laboratory Manuals and Further Reading (up within first 2 weeks)

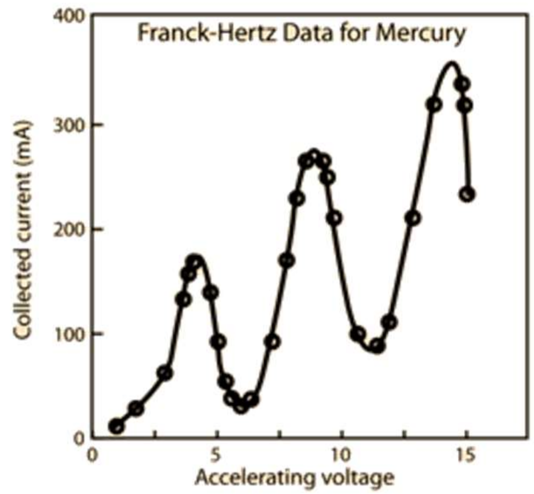
1. Frank-Hertz Experiment
2. Photoelectric Effect
3. Charge-to-Mass Ratio of Electrons
4. Temperature Dependence of Resistivity
5. Electron Spin Resonance
6. Superconducting Quantum Interference Device (or Muon)
7. Optical Experiment: Spectroscopy
8. Optical Experiment: Diffraction
9. AC Electronics (RLC circuits)
10. Nuclear Spectroscopy (Gamma ray spectroscopy)

Expt #1 – The Frank-Hertz Experiment (MSB 333)



Expt #1 – The Frank-Hertz Experiment (MSB 333)





Electrons are emitted by a heated filament (cathode), and accelerated by an applied, variable voltage through a low-pressure Mercury vapor held within a (thyratron) vacuum tube.

With sufficient energy, electrons are promoted from their ground state (6^1P_0) to the electronically excited state (6^3P_1)

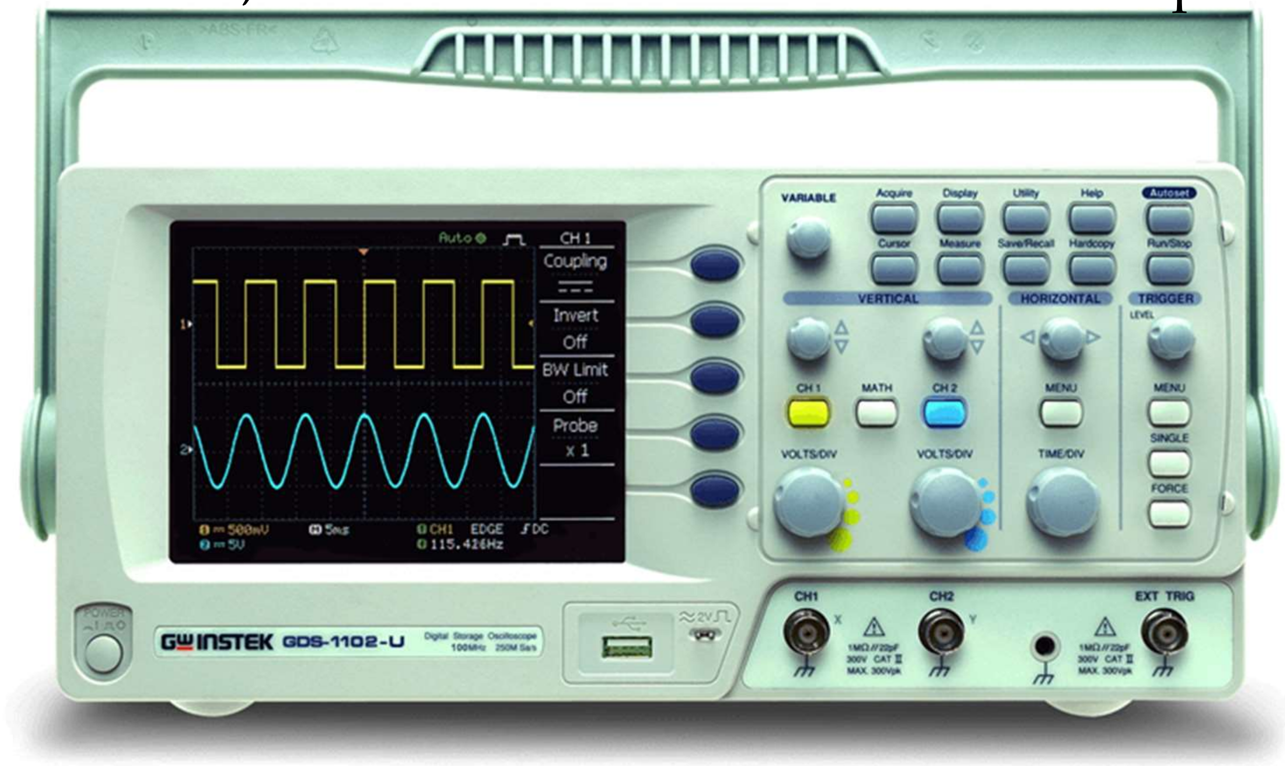
The current of electrons reaching the collecting plate is measured as a function of voltage using an oscilloscope (set in XY mode).

Determine the kinetic energy that corresponds to this transition, and compare with literature value.

Determine for 4 different temperatures (140-190 °C). How does the number of absorptions change depending on temperature, and how does this change your statistical interpretation of the data?

The Oscilloscope (Expts #1, #5 & #6)

- A device for viewing oscillations, as of electrical voltage or current, by a display on the screen of a cathode ray tube.
- Multiple channels (this one has two), quantitative measurements.
- Signal over time, X-Y mode. 'Auto' button can be helpful



Expt #1 – The Frank-Hertz experiment (MSB 333)

Resources to help.

- Lab Manual: (in the lab and on Webcourse)
- Additional Lab Instructions (coming soon to Webcourse)

Warnings and Advice

- DO NOT HEAT ABOVE 200 °C
- Use USB attachment to save data so can use it in write up.
- Turn off and UNPLUG the cables after the experiment is finished.

- Things for write-up…
  - Measure the position of each dip for four temperatures between 140 and 190 °C.
  - Make sure to save your data on the USB drive – can you analyze the data another way to be more precise?
  - What are your errors i) for each temperature, ii) overall
  - How do your values compare to the literature value?

- Further thinking:

If the electrons are being excited into an electronic state, what wavelength of light should the emitted light be? What are the errors reported for your experiment and how do they compare to literature values? Do you observe this light? Explain why, or why not. Could the proposed apparatus be utilized to determine the ionization energy of Mercury? Does the first peak appear at ~4.8 eV? If not, why not?

- Preparation key words:

Bohrs model of the atom, energy levels of electrons in an atom, occupied and unoccupied states, kinetic and potential energy, vapor pressure, mean free path, thermionic emission, elastic vs. inelastic collisions.

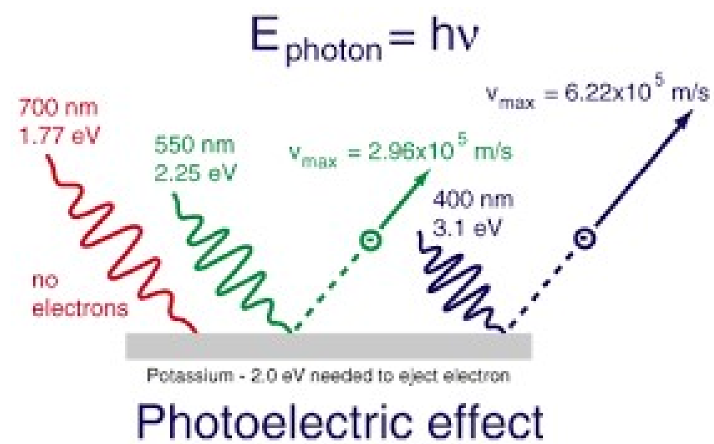
Expt #2 - Photoelectric Effect (MSB 333)

Expt #2 - Photoelectric Effect (MSB 333)

The lab manual is ***very*** thorough on the experimental procedure and requirements for this lab

Determine Plank's constant and measure work function response of material as a function of wavelength

Make sure to investigate the reported current as a function of both aperture size and wavelength

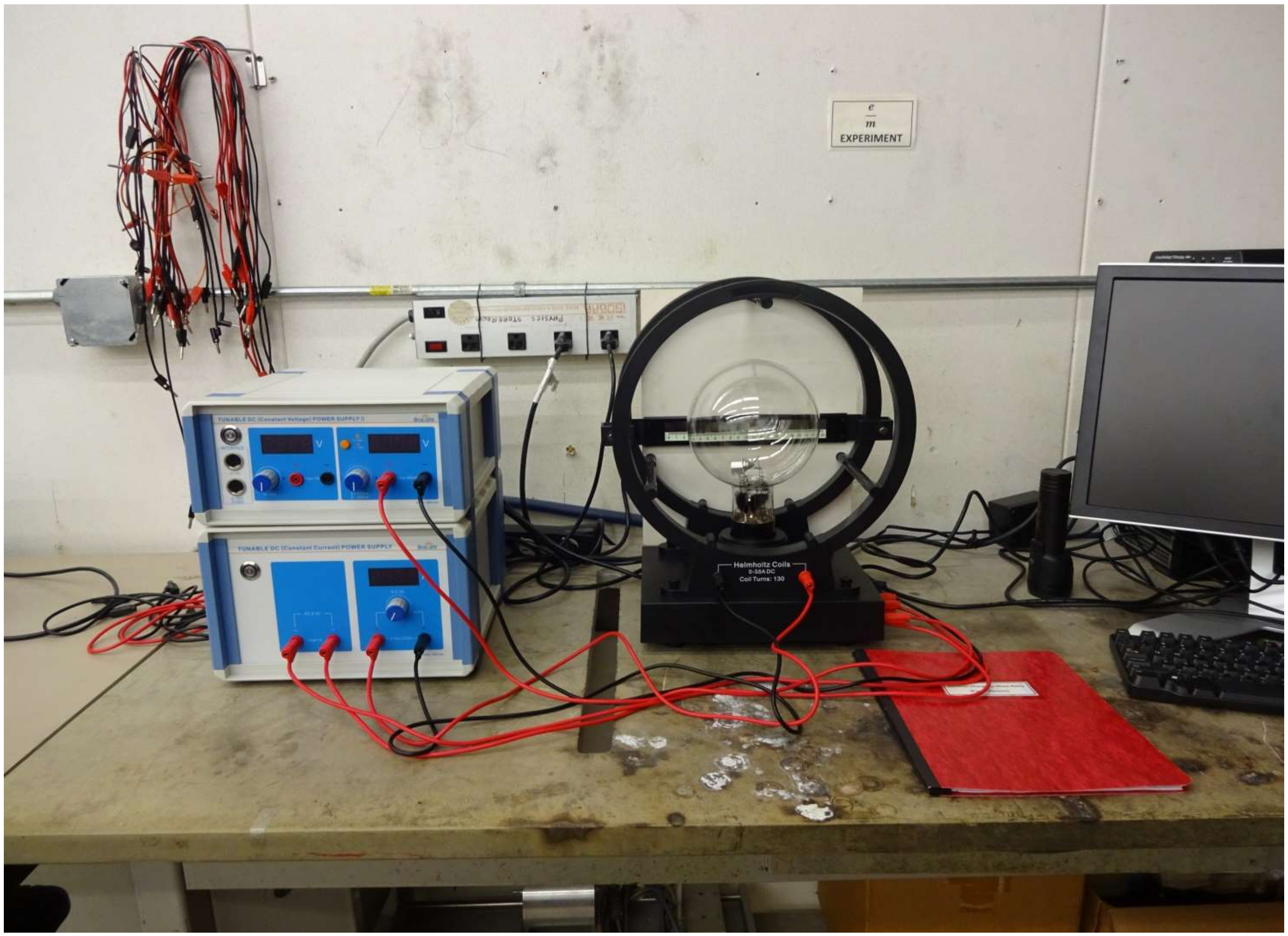


Warnings and Advice:

NEVER REMOVE THE FILTER FROM THE DETECTOR WHILE THE Hg LAMP IS ON AND UNCOVERED - IT WILL BREAK THE DIODE

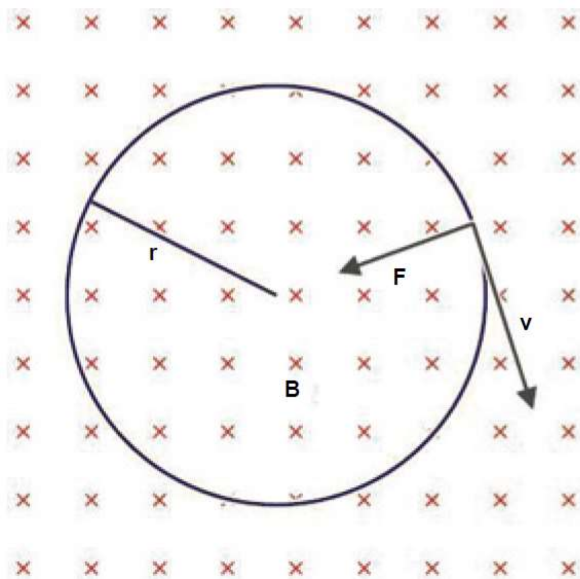
Cover the Hg lamp while exchanging the filters/apertures

Expt #3 - Charge-to-Mass Ratio of Electrons (MSB 333)

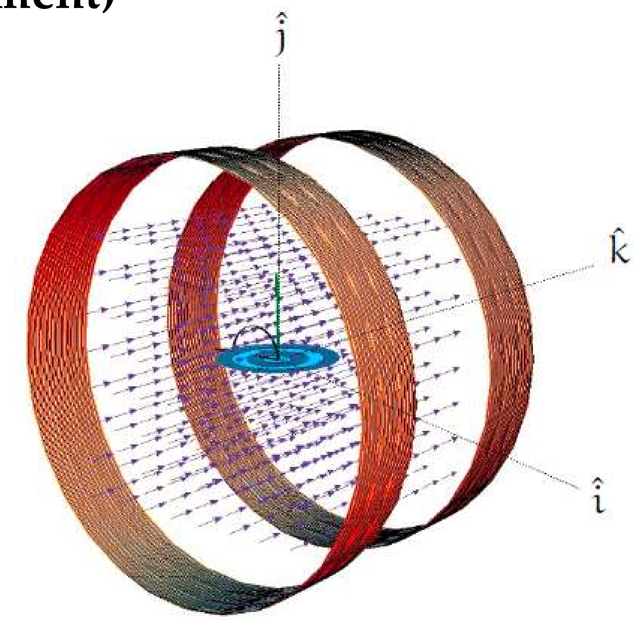


Expt #3 - Electron Charge-to-Mass Ratio (MSB 333A)

Helmholtz coils (also used for ESR experiment)



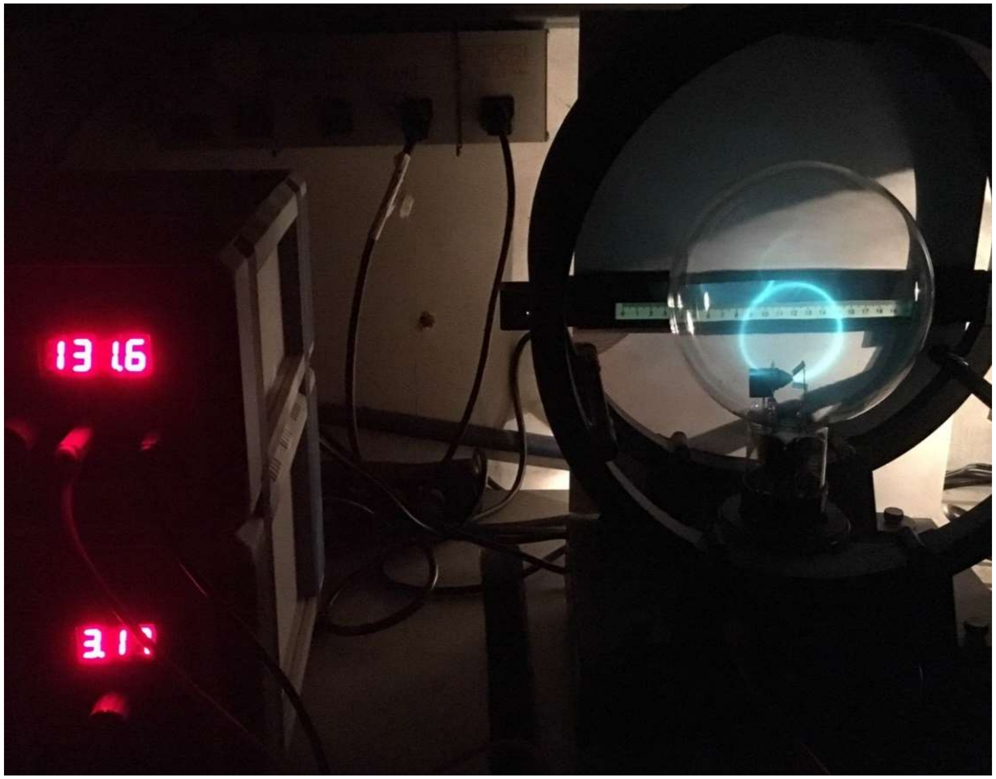
$$\frac{e}{m} = \frac{2U}{B^2 r^2}$$

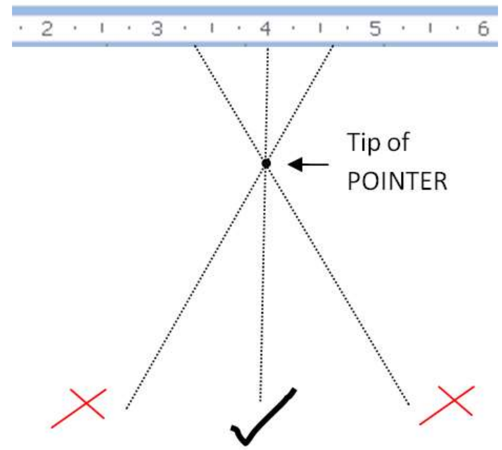


Calculate the magnetic field

$$B = \frac{\left(\frac{4}{5}\right)^{\frac{3}{2}} \mu_0 N I_H}{R}$$

Expt #3 - Charge-to-Mass Ratio of Electrons (MSB 333)



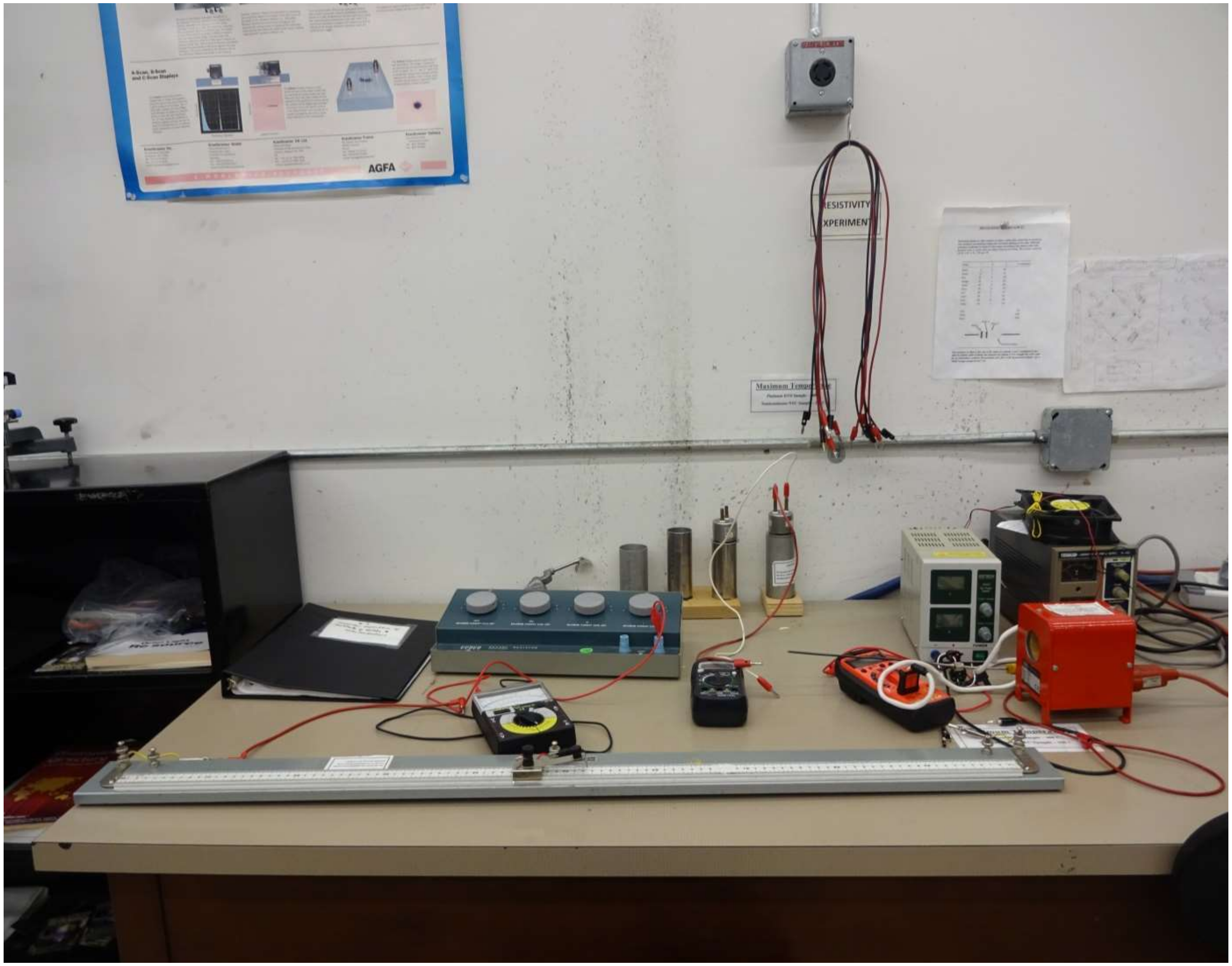


The Laboratory Manual is again ***very*** thorough on what measurements to perform and what to write-up.

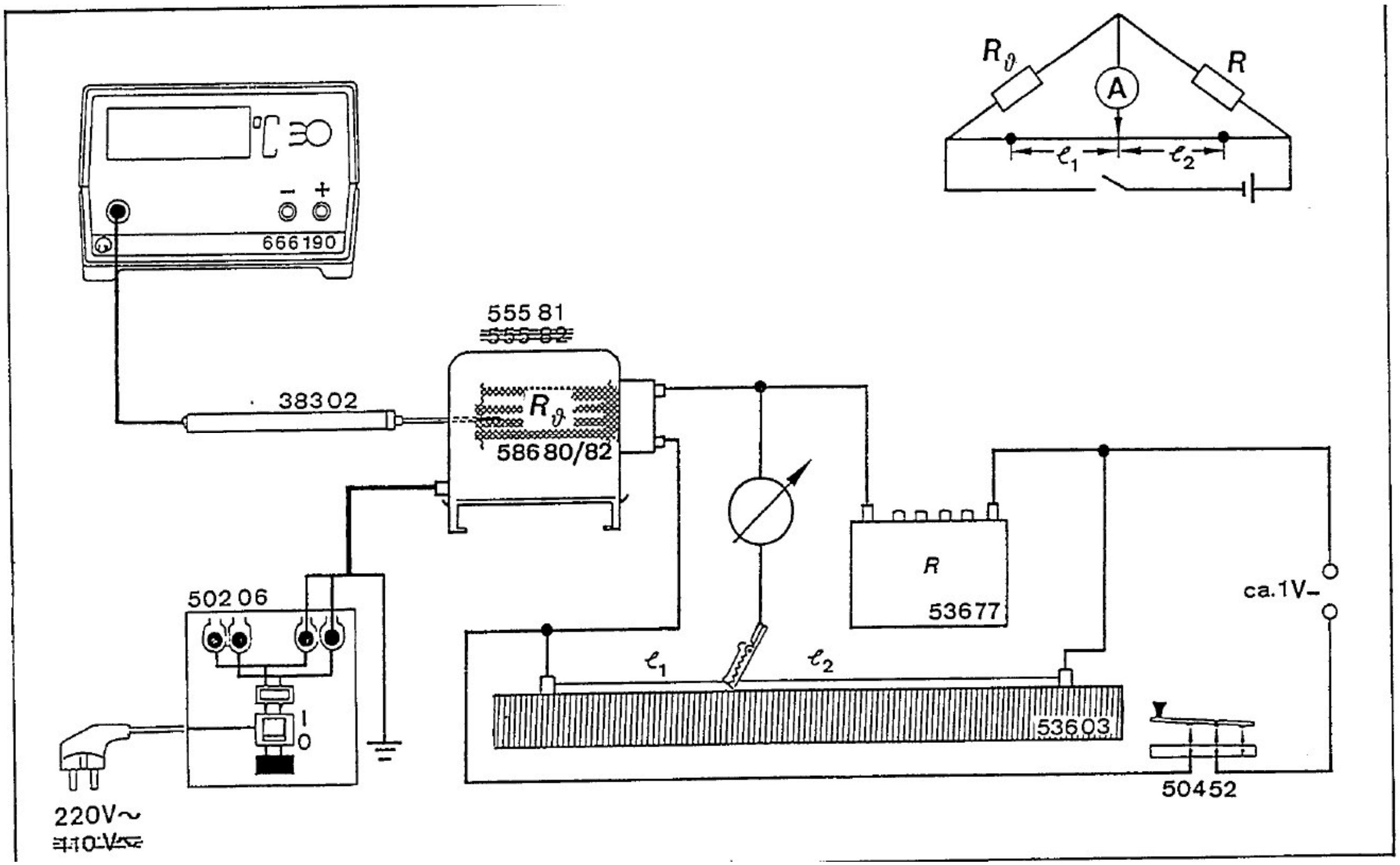
Make sure to use the parallax method (above; use mirror) to avoid reading errors

Caution: Be sure to check if you think this instrument is wired up correctly – are the currents going in the directions as indicated?

Expt #4 - Temperature Dependence of Resistivity (MSB 333)

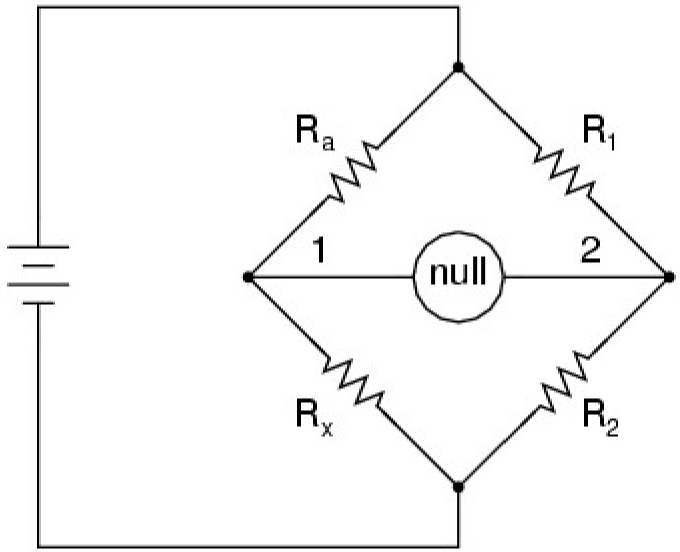


Expt #4 - Temperature Dependence of Resistivity (MSB 333)



Expt #4 - Temperature Dependence of Resistivity (MSB 333)

A Wheatstone bridge circuit can very accurately determine unknown resistance



$$\frac{R_a}{R_x} = \frac{R_1}{R_2}$$

Advice: These experiments are quite simple, but long. If you are having trouble setting up the wheatstone bridge, ask for help so that the experiments can be completed.

Expt #4 - Temperature Dependence of Resistivity (MSB 333A)

Noble Metal Resistor **(< 400 ^{o}C)**

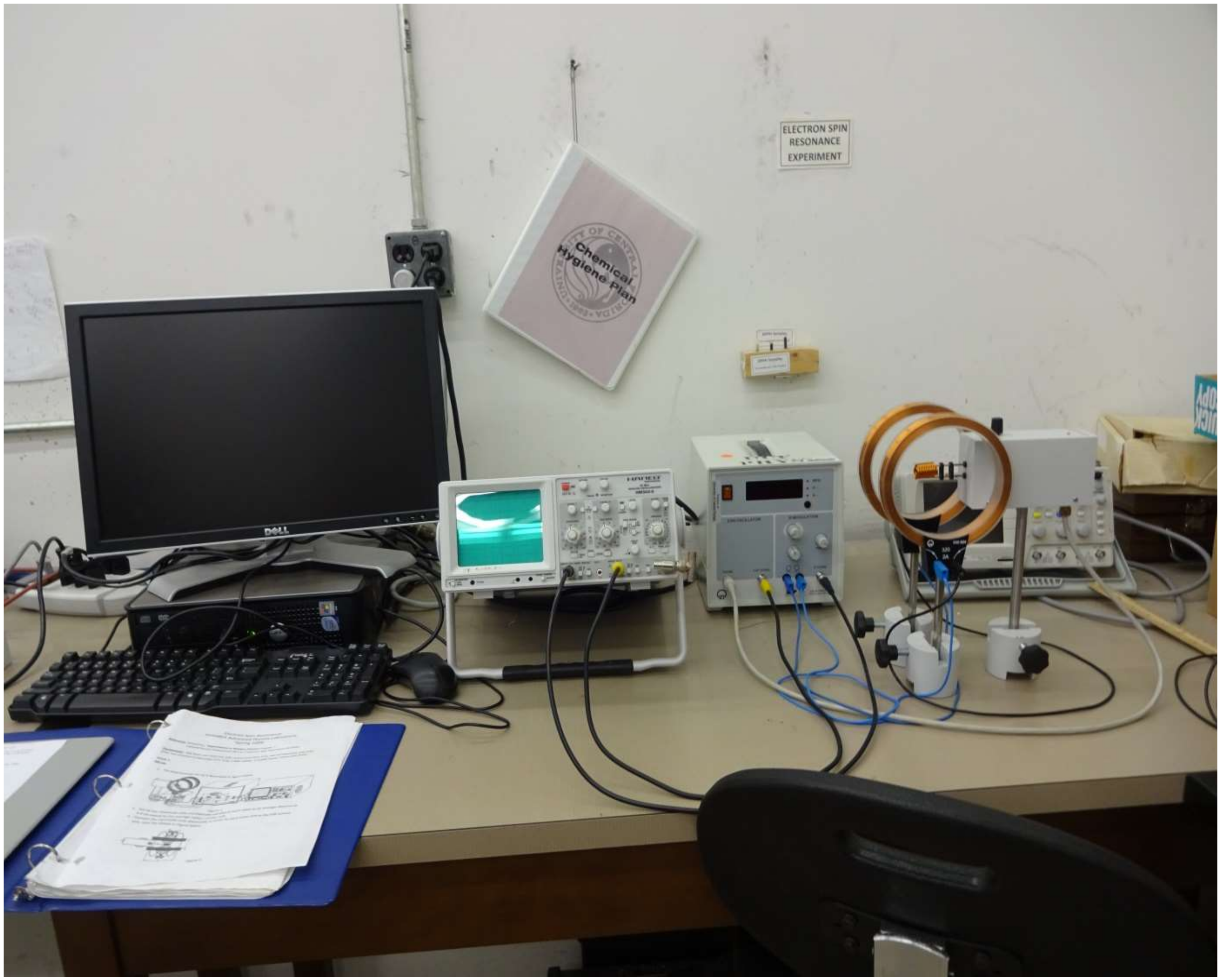
Heat up and then switch off the oven heater at 350 ^{o}C. Measure when it cools down.

Semiconductor Resistor **(< 200 ^{o}C)**

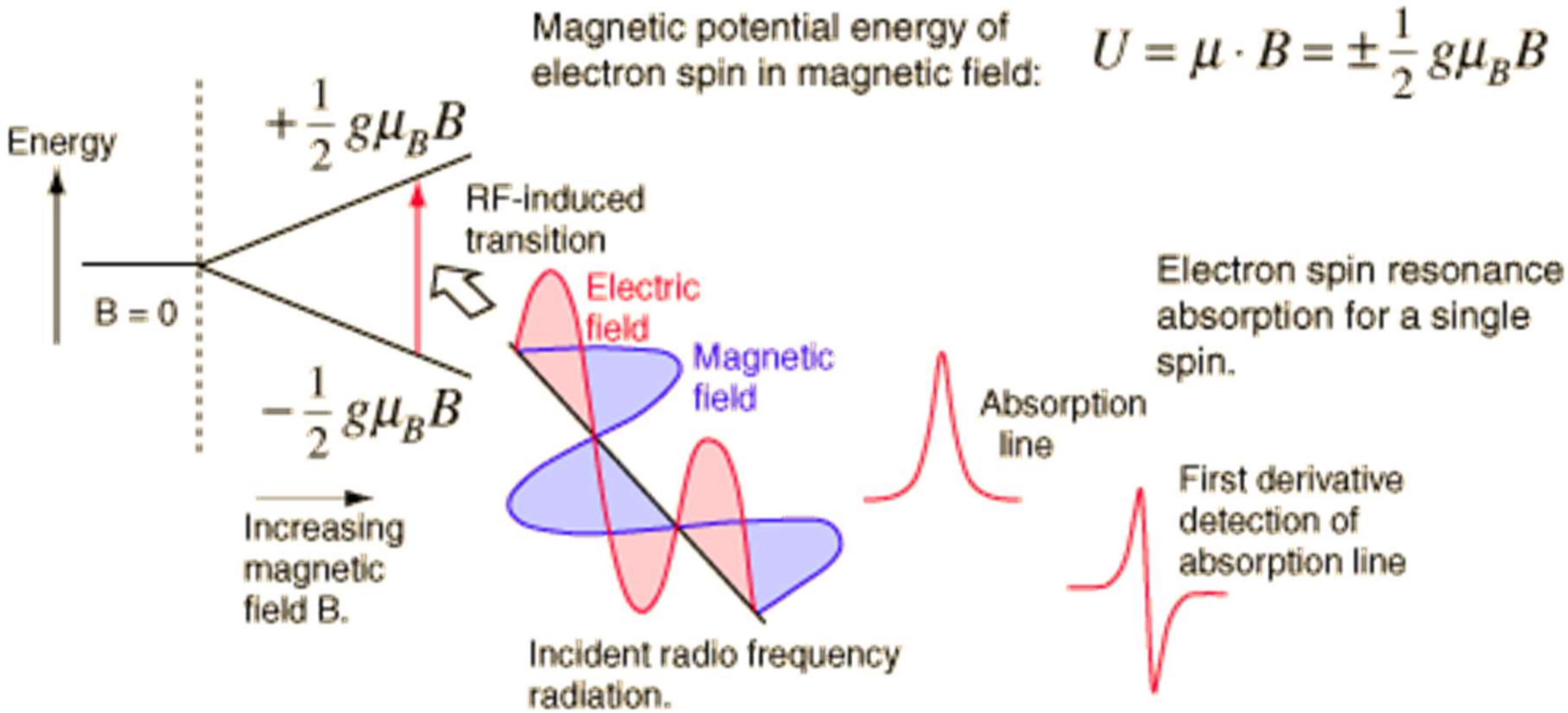
Switch off the oven at 170 ^{o}C.

- How does the resistance change with temperature?
- Can you explain the different behaviors between the metal and semiconductor resistors?
- **Push the thermocouple wire slowly and carefully; make sure not to break the glass seal of the sample.**

Expt #5 - Electron Spin Resonance (MSB 333)



Expt #5 - Electron Spin Resonance (MSB 333A)



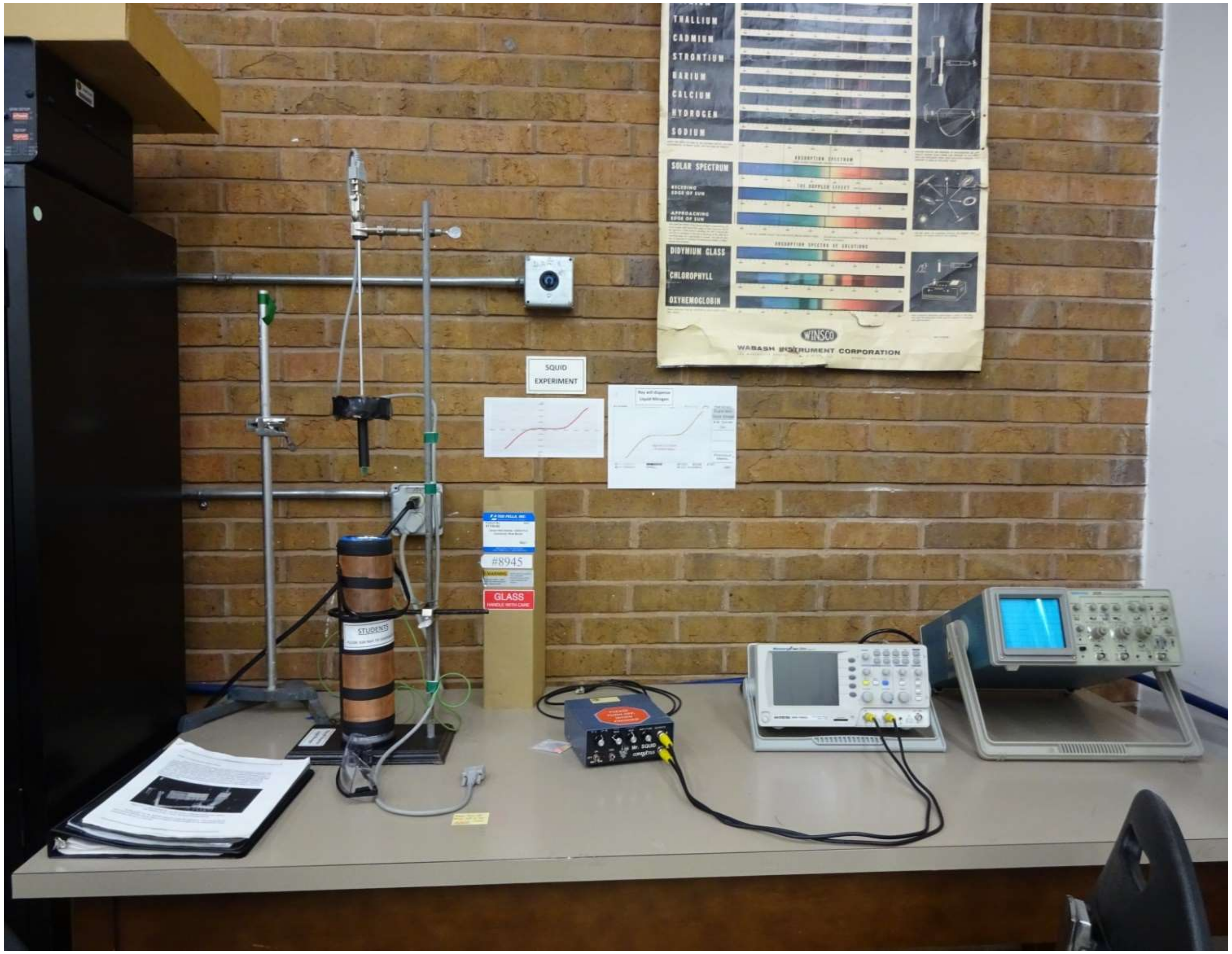
Zeeman effect: $\Delta E = g\mu_B B_0$

Electromagnetic radiation energy $\varepsilon = h\nu$ (microwave range)

Electron Spin Resonance by absorption: $h\nu = g\mu_B B_0$

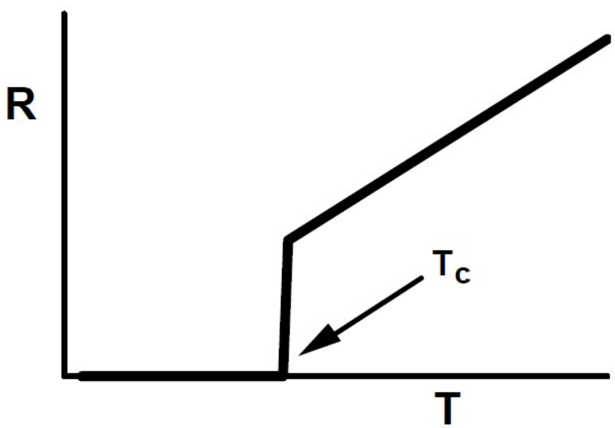
Procedure is written in the manual. *Be careful* with peak alignment

Expt #6 - Superconducting Quantum Interference Device (SQUID; MSB 333)

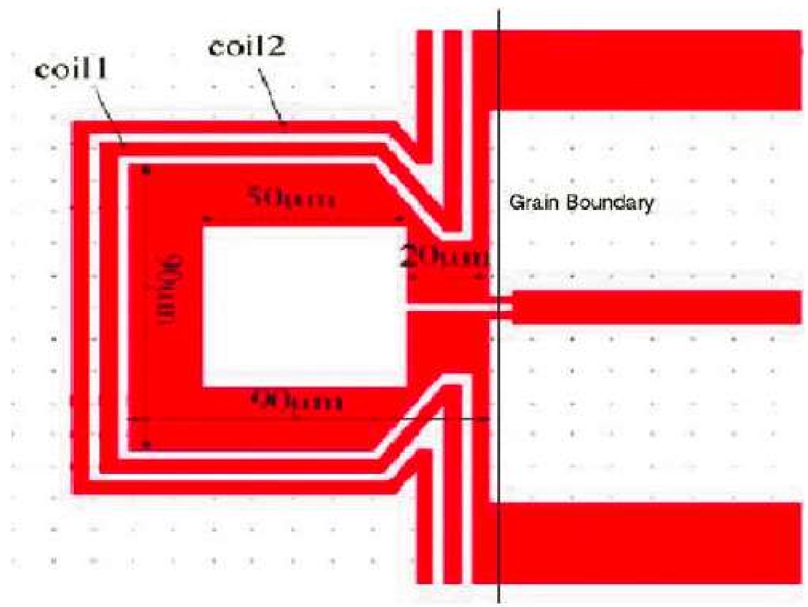


Expt #6 - Superconducting Quantum Interference Device (MSB 333)

Superconductor:
Meissner effect

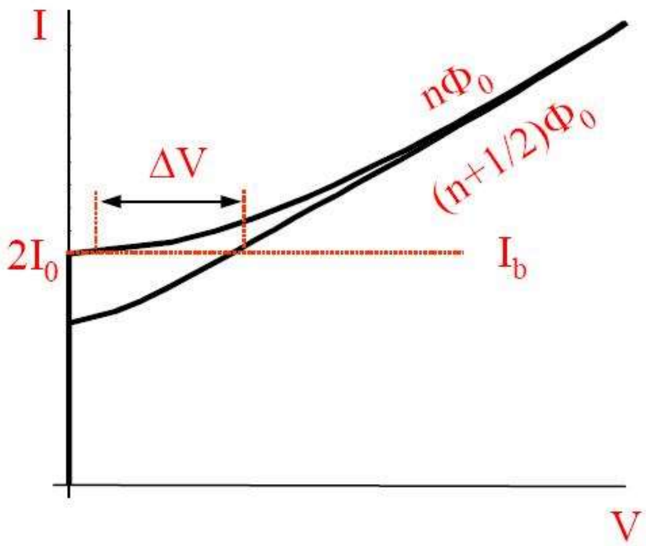


The Mr. SQUID chip contains a dc SQUID made with thin film YBCO superconductor.

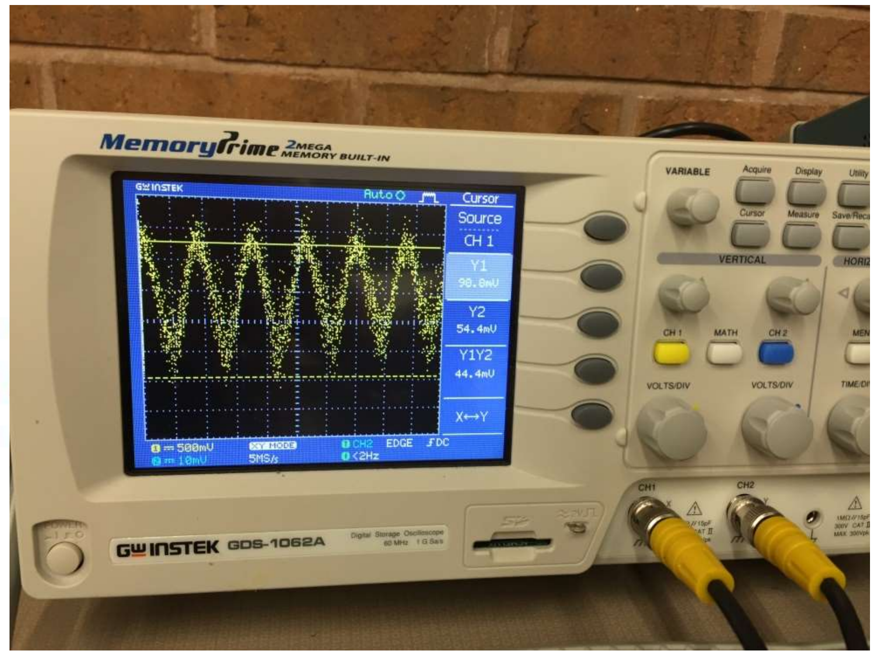


Josephson junction consists of two regions of superconductor that are weakly coupled together. The meaning of this statement is that the junction behaves like a superconductor but can only carry a small amount of resistanceless current before it becomes resistive. (Highly recommended reading the manual)

Expt #6 - Superconducting Quantum Interference Device (MSB 333A)



I-V curve for a SQUID



Periodic voltage response due to flux through a SQUID.

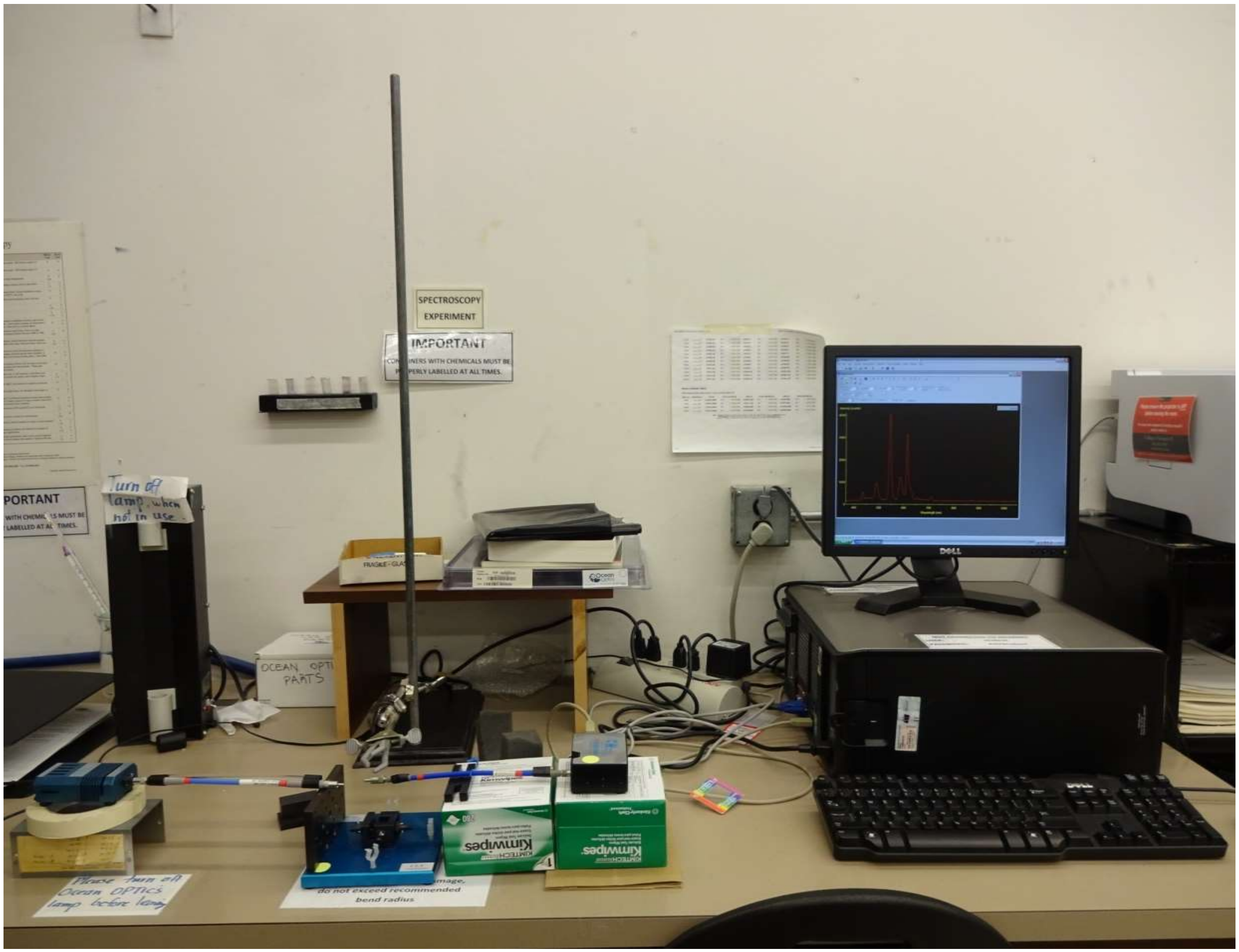
Determine the properties of the SQUID by following the procedure in the Manual for plotting both the I-V and V-φ curves.

Expt #6 - Superconducting Quantum Interference Device (MSB 333A)

Warnings and advice:

- Has a 100+ page manual, need to skim through this to find the relevant sections **BEFORE** coming to class.
- Liquid nitrogen will be filled by Ray.
- Be careful when you work with liquid nitrogen.
- Ask Ray to remove the Dewar after finishing your job.
- Make sure the tip is immersed in liquid nitrogen (it may need to be refilled)
- Try to seal the cap and stabilize the temperature to minimize noise.
- Loose cables contribute to noise signal, which can make measuring the V-ϕ curve difficult.
- A ground cable *may* help reduce noise.

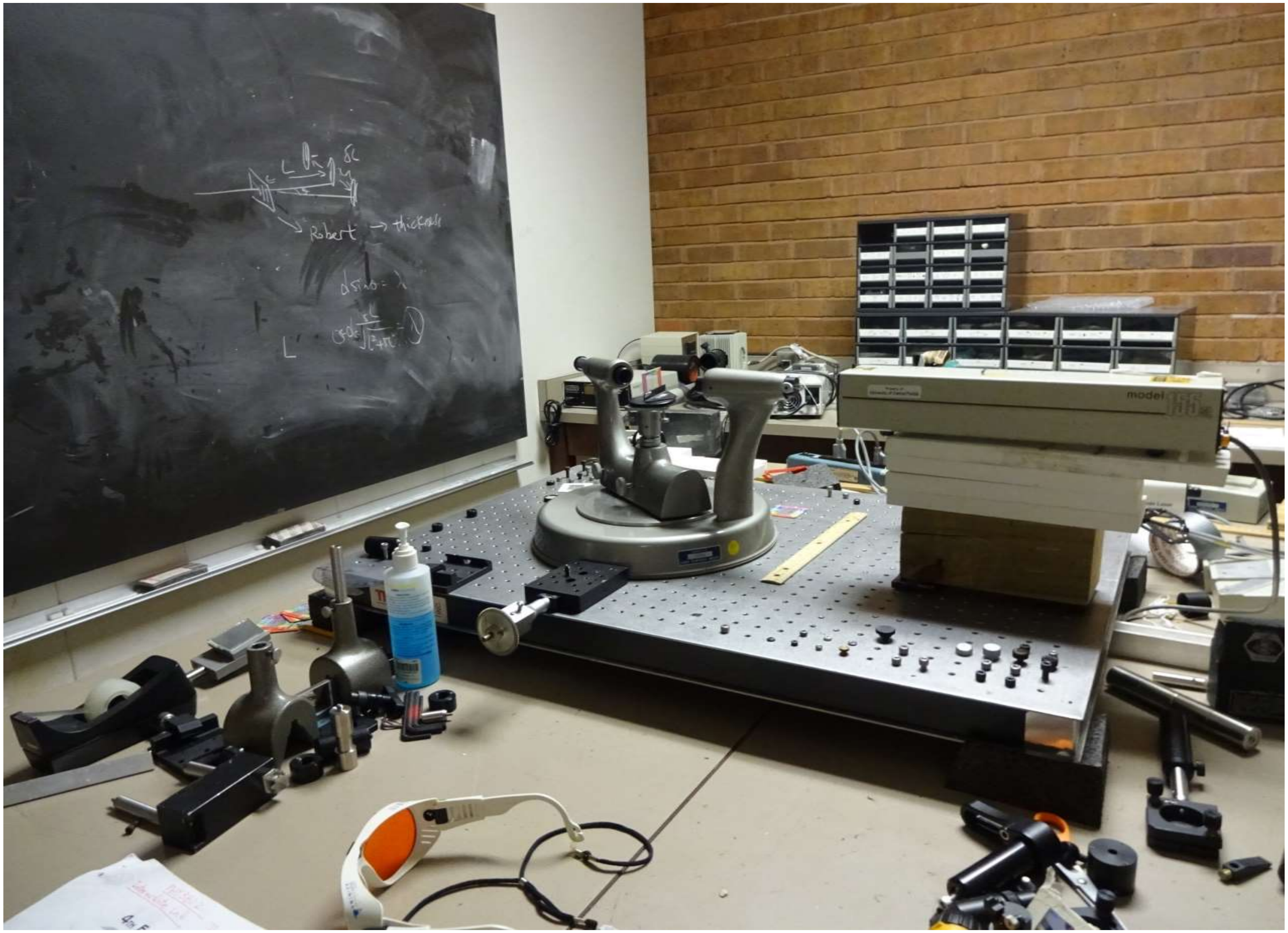
Expt #7 - Optical Experiment: Spectroscopy (MSB 333)



Expt #7 - Optical Experiment: Spectroscopy (MSB 333A)

- Make sure to understand the effects of different settings on the instrument (e.g., collection time)
- Measure the characteristic maxima of the room lights. (this will be a background)
- Measure the emission spectra of different lamps that are available (Helium, Hydrogen, Mercury, etc.)
- Determine the Rydberg constant from the Hydrogen spectrum.
- Measure the absorption from the two different metal complex solutions at various concentrations (you will need a blank reference to measure absorbance).
- Demonstrate each solutions adherence to Beer's Law
- Determine the concentration of an unknown mixture
- **Warning:** <u>read the manual, make sure you don't saturate the spectrometer; if you observe saturation, must know how to deal with it. You may need to re-take backgrounds with the same settings!</u>

Expt #8 - Optical Experiment: Diffraction (MSB 342 – inside MSB 339)



Expt #8 - Optical Experiment: Diffraction (MSB 342 – inside MSB 339)

Definition 3.3. Let source S_1 be a distance r_1 from point P and let source S_2 be a distance r_2 from point P.

- **Constructive interference** $\longrightarrow r_2 - r_1 = m\lambda$
- **Constructive interference** $\longrightarrow r_2 - r_1 = (m + 1/2)\lambda$

where $m = 0, \pm 1, \pm 2, \ldots$.

Diffraction Gratings:

$$\boxed{d(\sin\alpha - \sin\theta) = m\lambda \quad m = 0, \pm 1, \pm 2, \ldots}$$

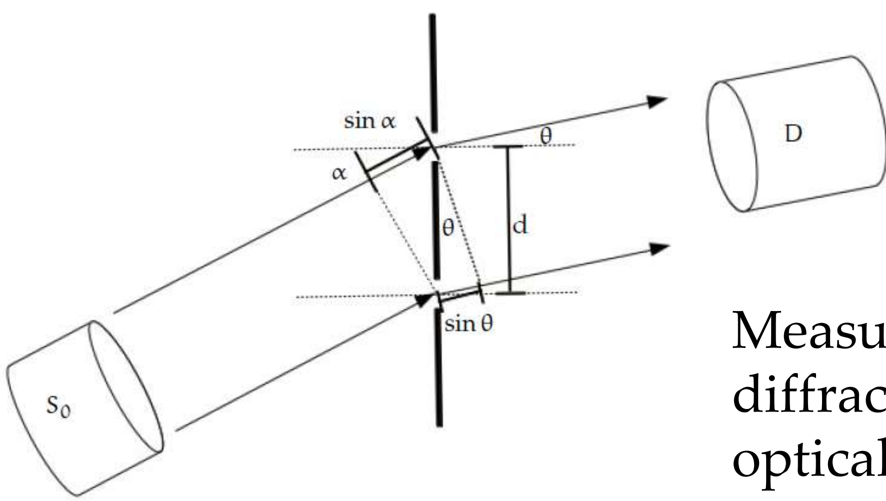


Figure 13: Diffraction grating

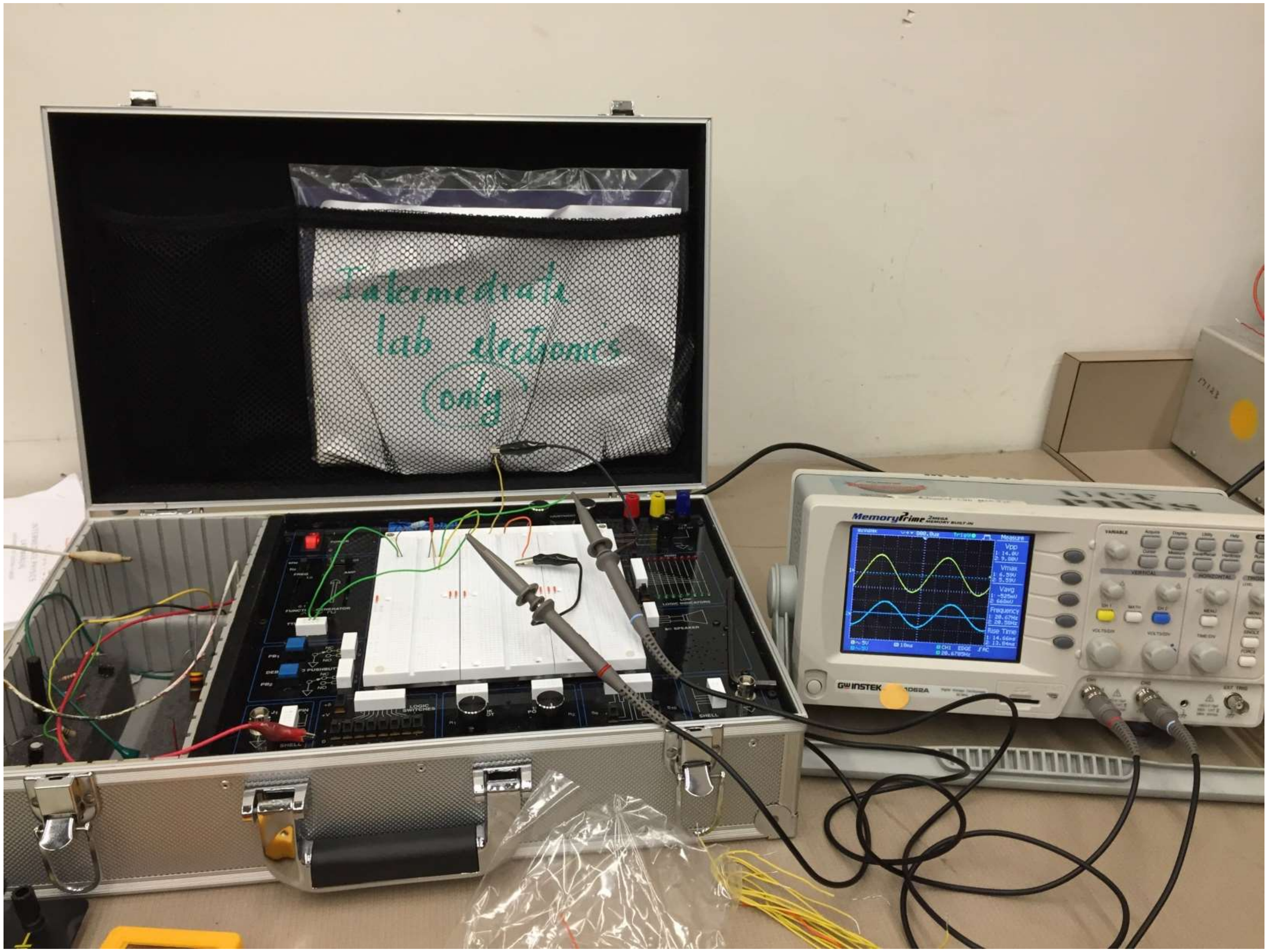
Measure the scattering angles of diffraction pattern for different optical gratings, and with different lasers.

Expt #8 - Optical Experiment: Diffraction (MSB 342 – inside MSB 339)

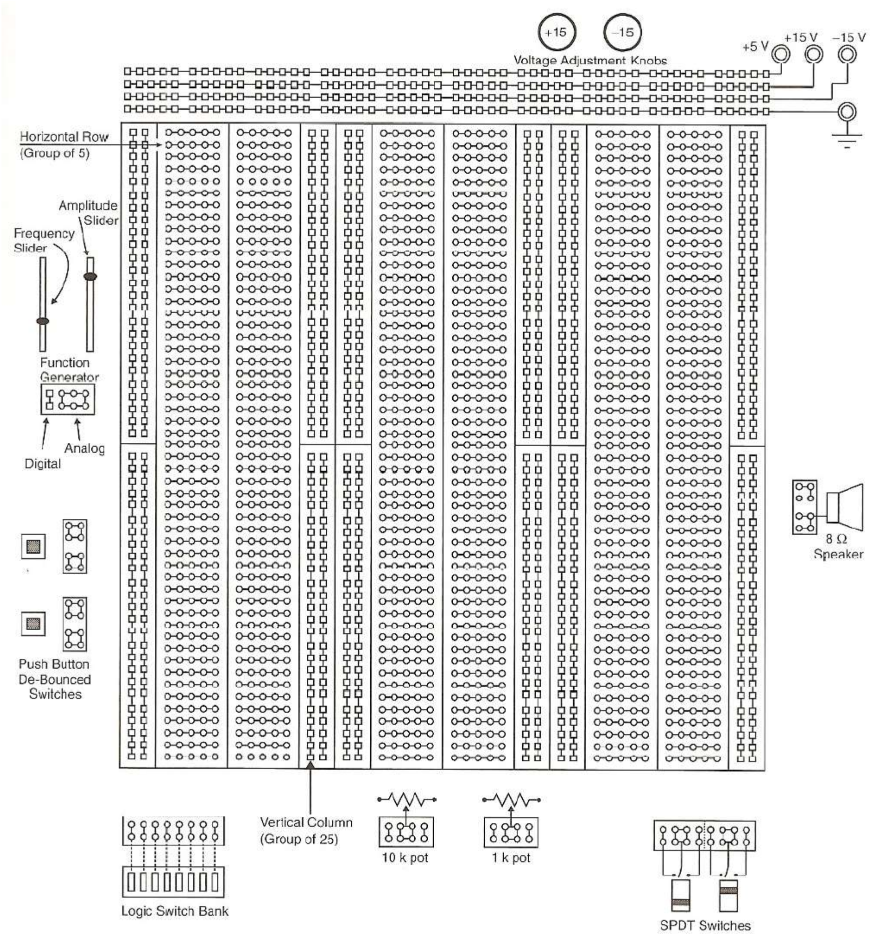
Warnings and Advice:

- Be careful working with the lasers. **Do not look into scope when using lasers.**
- When using lasers, use trigonometry to determine angles.
- Measure diffraction patterns from 632.8, 532, and 405 nm lasers with 300 grooves/mm
- Test one wavelength with 100, 500, 600, 1000 and grooves/mm and 7500 grooves/inch.
- Test Hg lamp to determine wavelength of strongest bands (in this case, do need to look through the scope)
- (if available, determine the groove spacing of an unknown. E.g, a CD, a feather, or the grating labeled 13,500 grooves/inch)

Expt #9 - AC Electronics (MSB 335)



Expt #9 - AC Electronics (MSB 335)



- A **breadboard** with internal connections shown for clarity.
- Each vertical column is broken into halves with no built in connection between the top and the bottom.
- Voltage supplies with different ranges (5 V, 15 V).
- Estimate your maximum current and **don't blow up the ammeter!**
- **If you are unsure…**
  - **Always measure using highest setting first.**
  - **Then disconnect it**
  - **Then lower the setting**

Expt #9 - AC Electronics (MSB 335)

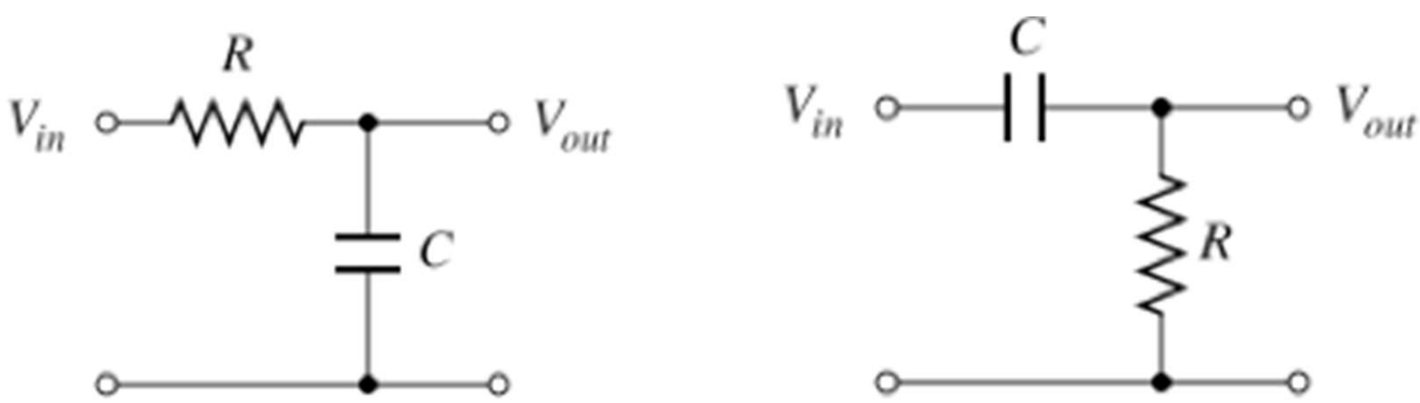


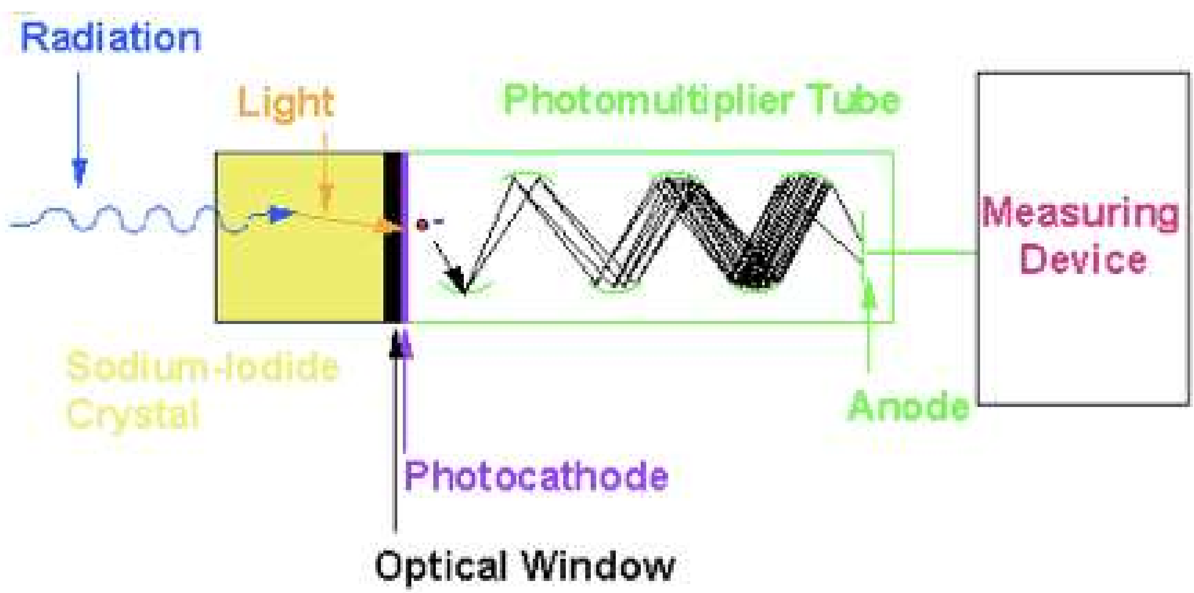
Diagram of a Low Pass Filter (left) and high pass filter (right).

- There is (or will be) a manual on Webcourse how to build and measure these circuits.
- Measure the characteristics I(V) of a diode.
- Build a low-pass, high-pass, and band-pass filter and measure V(out)/V(in) as function of frequency.
- Make a RLC circuit in series and in parallel such that its resonance frequency is around 2000 Hz.

Expt #10 - Nuclear Spectroscopy (MSB 335B)

Expt #10 - Nuclear Spectroscopy (MSB 335B)

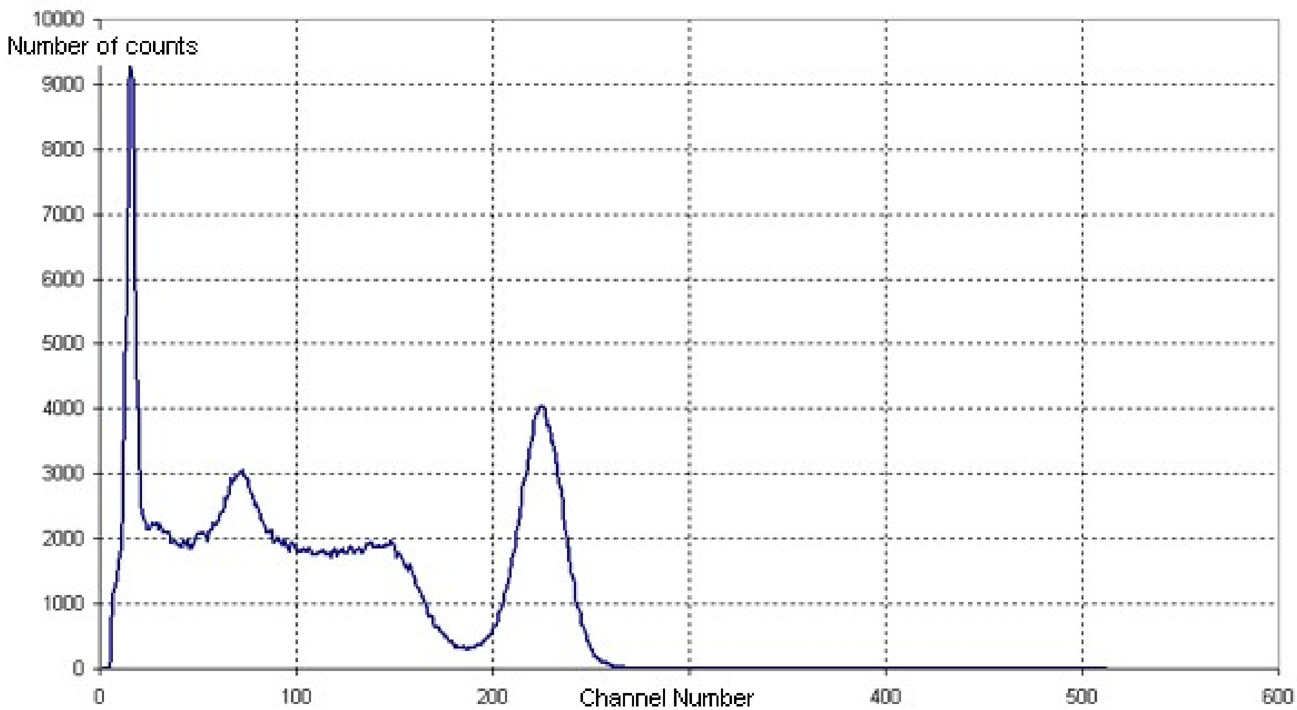
γ radiation detected via a sodium iodide (NaI) scintillation detector.
Should do some background reading to make sure you understand it.



Remember cautions from Safety Radiation Course
Limit exposure, keep distance

What are these features in the Spectrum, for each sample?

How do the values reported compare to literature values?



Expt #10 - Nuclear Spectroscopy (MSB 335B)

1. Make yourself familiar with the software to acquire spectra. If you wish, you can compare the two different acquisition boards and see how gain settings vary the spectra.

***** warning *** when changing settings previous calibration settings need to be discarded**

2. Measure the background signal without any radioactive source.
3. Measure the spectra of the radioactive sources (6), determine the counts per second, their statistical distribution, and determine the FWHM of a peak, use the known spectrum features of Na and Co to calibrate the spectrometer.
4. Use the USB drive to save the data so you can plot it later
5. Measure how the counts change when different filters (Polyethylene, aluminum, and lead) are used.
5. Ask Ray for the neutron-activated In sample.
6. Measure the In sample spectrum and determine its half-life (compare to literature)

The Experiments

Experiment	Difficulty of Performing the Experiments	Difficulty of Physics Concepts	Difficulty/Depth of Analysis
1. Frank-Hertz	★★	★★	★★
2. Photoelectric Effect	★	★★	★
3. Charge-to-mass ratio of an electron	★	★	★
4. Temperature dependence of resistivity	★★★	★	★★
5. ESR	★★★	★★★★	★★★★
6. SQUID	★★★★	★★★★	★★★★
7. Spectroscopy - Absorbance	★★★	★★★	★★★
8. Spectroscopy – Diffraction	★★	★★★	★★★
9. AC Circuits	★★★★	★★★	★★★★
10. Nuclear Spectroscopy	★★★	★★★	★★★★
Odd # total	*2+1+3+3+4 = 13*	*2+1+4+3+3 = 13*	*2+1+4+3+4 = 14*
Even # total	*1+3+4+2+3 = 13*	*2+1+4+3+3 = 13*	*1+2+4+3+4 = 14*

BEFORE YOU LEAVE…

Sign-up in pairs so that you are assigned a partner and experiments for the course…

Note: As of Fall 2016, UCF is required to document students' academic activity at the beginning of each course. In order to document that you began this course, **please complete the syllabus quiz on Webcourses by the end of the first week of classes (Friday August 24th).**

Failure to do so will result in a delay in the disbursement of your financial aid.

Before coming to next class, make sure that you have figured out a lab partner to work with otherwise you will be randomly assigned!