Lab Experiments

Advanced Physics Lab, PHYS 3600
Don Heiman, Northeastern University, 2021

This Week

1a-INTRO-a & 1b-INTRO-b: Introduction to the Course
motivation, boiler plate (syllabus/labs)
Fermi questions, exercises

2-ERRORS: Errors and Uncertainties
accuracy, precision, round off, propagation of errors

3-OPTICS: Optical Properties
EM spectrum, photo detectors, light emitters

4-SEMICOND: Semiconductors
band gap, Fermi energy, resistivity, Hall effect

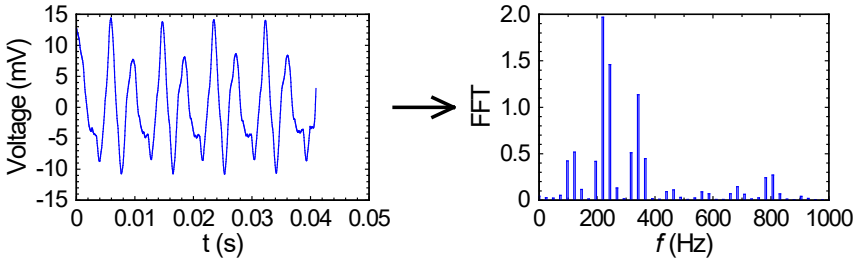
5-ACOUSTICS:
sound, beats, Fourier transform, music

6-EXPERIMENTS: Intro to Lab Experiments
Virtual tour my research lab

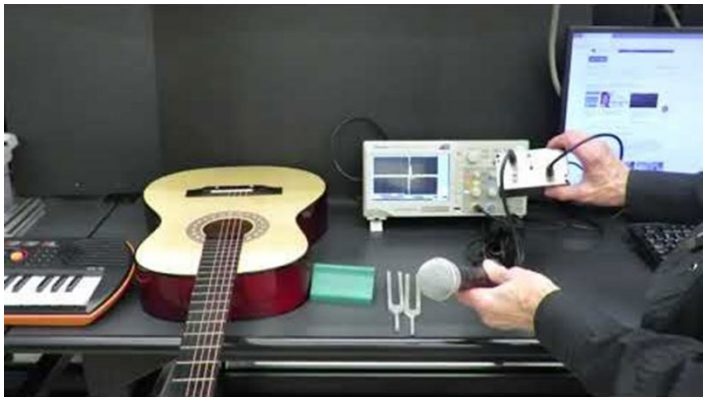
Lab Experiments

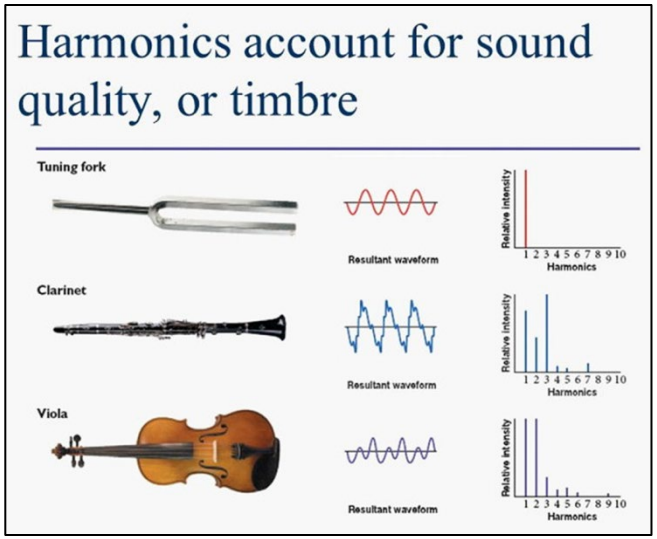
AFT - Acoustics and Fourier Transform

Time is fundamental in our everyday life in the 4-dimensional world. We see things move as a function of time. On the other hand, although sound waves are composed of moving atoms, their movement is too small and the frequency of their vibration is too fast for us to view directly. It is thus easier to describe sounds in *frequency* space rather than *time* space. We can transform sound, or many other things in physics for that matter, from *time* space to *frequency* space by the technique of Fourier transform. **FFT software is required.**



← *The plots show a time-varying voltage on left that is transformed into frequency space on right.*





Lab Experiments

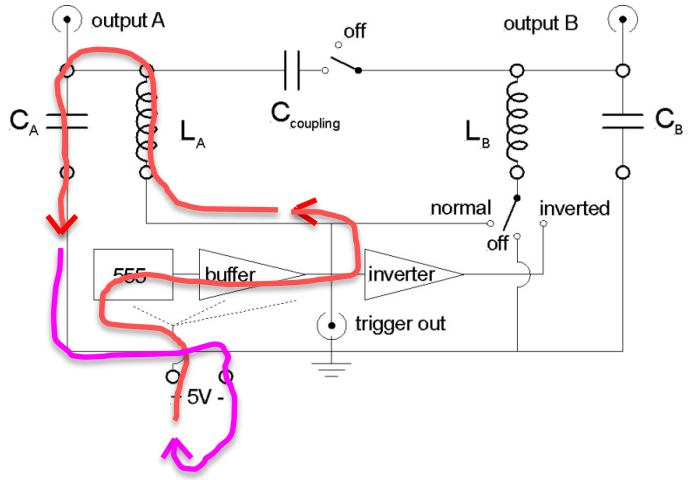
CEO - Coupled Electrical Oscillators

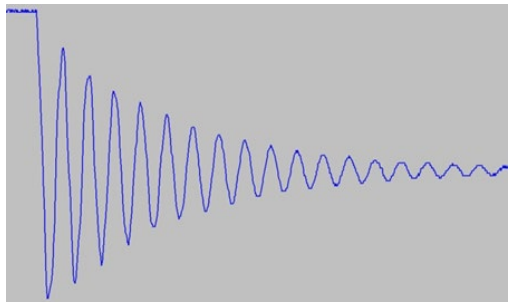
The objectives of this experiment are:

- explore the properties of a single LRC electrical oscillator circuit, including damping;
- study what happens when two oscillators are coupled and allowed to exchange energy.

The electrical circuit shown below contains two LRC electrical oscillator circuits, the A-circuit on the left and the B-circuit on the right. The 555 chip supplies a voltage pulse to the A-circuit, which causes it to oscillate and eventually die out, as shown by the waveform on the right. The energy put in the circuit by the pulse is similar to the energy put into a bell by striking it, where the ringing of the bell eventually dies out.

You will then investigate what happens when the B-circuit is connected to the A-circuit by the coupling capacitor and the circuits exchange energy.





This lab requires you to curve fit the waveform using software (Python, MatLab, SigmaPlot, EasyPlot, etc.)

Lab Experiments

FUEL - Solar Cell, Electrolyzer, Fuel Cell

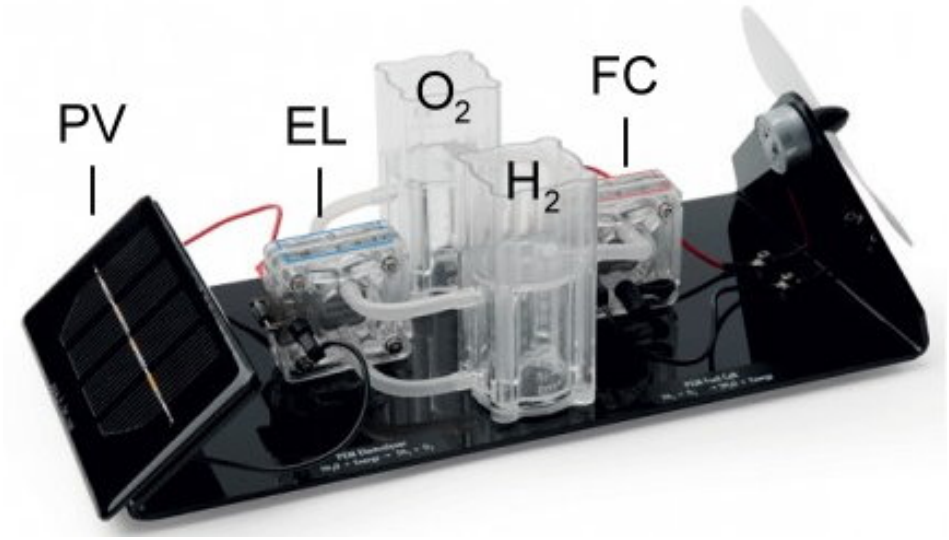
The objective of this experiment is to study the properties of a **solar cell**, **electrolyzer** and **fuel cell**. You will

(1) study the electrical properties of each component, and

(2) measure the conversion efficiency of energy between light, chemical and electrical forms.

The apparatus from H-Tec Educational is used to convert energy:

- from light to electrical energy using a photovoltaic (PV) solar cell;
- from electrical to chemical energy using an electrolyzer (EL), by splitting water into hydrogen and oxygen;
- from chemical to electrical energy using a hydrogen Fuel Cell (FC).



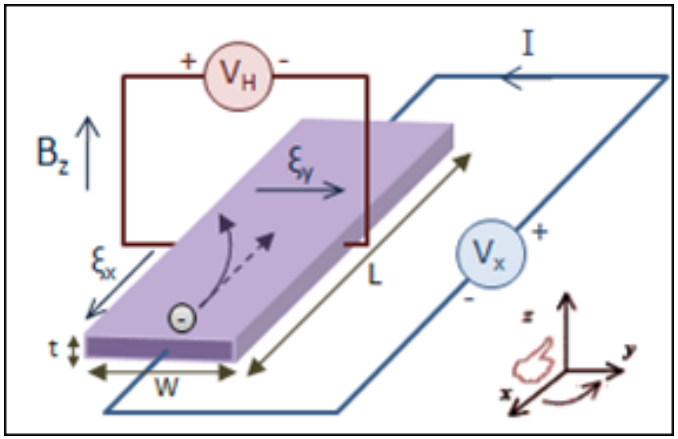
Lab Experiments

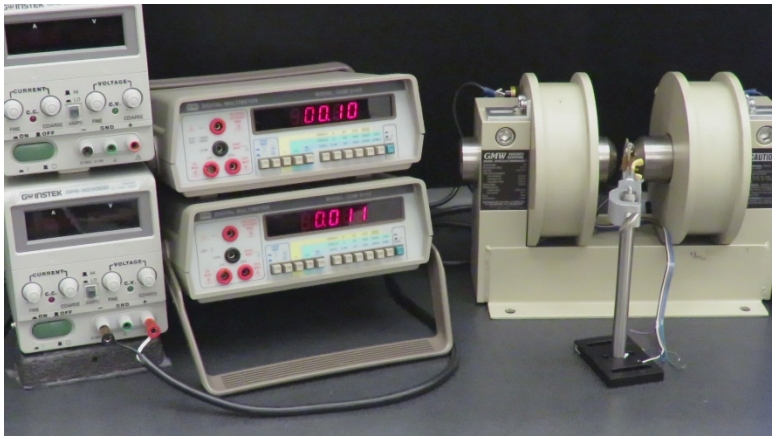
HALL - Hall Effect

Semiconductors are ubiquitous in our modern world. Your phone has nearly 10 billion transistors. The centaury old Edison light bulb is finally being replaced by semiconductor LEDs. For all of these semiconductor devices, one of the most important adjustable properties is the carrier concentration (*n*/*p* for electrons/holes), in addition to the value of the resistivity (ρ) and carrier mobility (μ).

This Lab has several objectives using a doped silicon wafer:

- measure the I-V (current-voltage) properties
- measure the resistivity using a Hall-bar and van der Pauw configurations
- determine the carrier type (*n* or *p)* from the thermoelectric effect
- demonstrate the Hall effect
- use the Hall effect to measure carrier concentration, and carrier type (*n* or *p*)





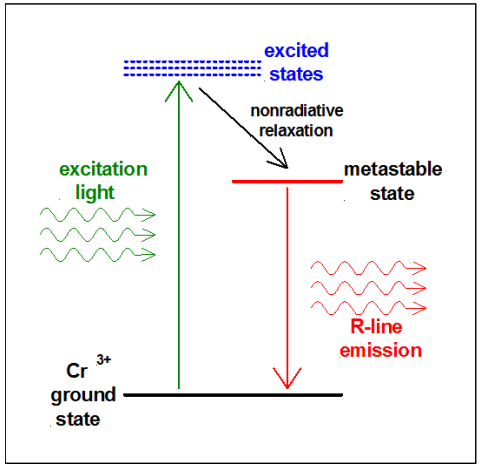
Lab Experiments

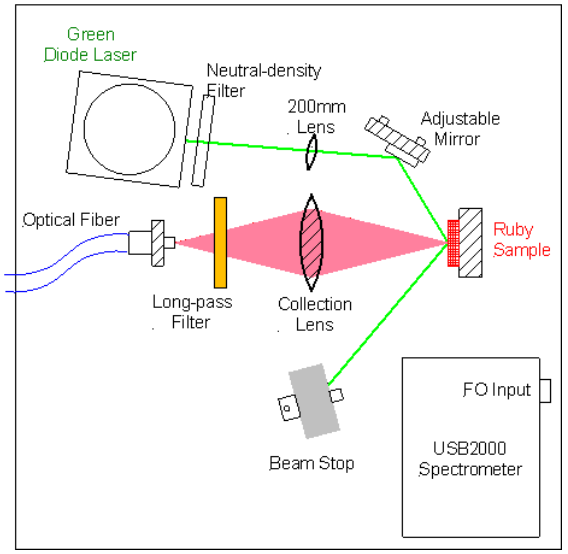
RUBY - Ruby Spectroscopy

The first laser was made using a synthetic ruby crystal (sapphire Al_2O_3 doped with Cr) and a photographer's flashlamp. The lamp when flashed excited the Cr^{3+} ions into excited states, where they quickly relaxed down to a long-lived metastable state shown in the left diagram. This produced a large population of Cr ions in their metastable state, waiting to be de-excited all at once in stimulated emission, leading to a collimated beam of red light.

This lab experiment does not produce lasing in ruby, but it investigates the excited states of Cr via spectroscopy using a spectrometer and green laser pulses.

- The absorption spectrum is measured using a white light source (not shown).
- The R-line wavelength is measured (shown on the right).
- The lifetime of the Cr metastable states measured.



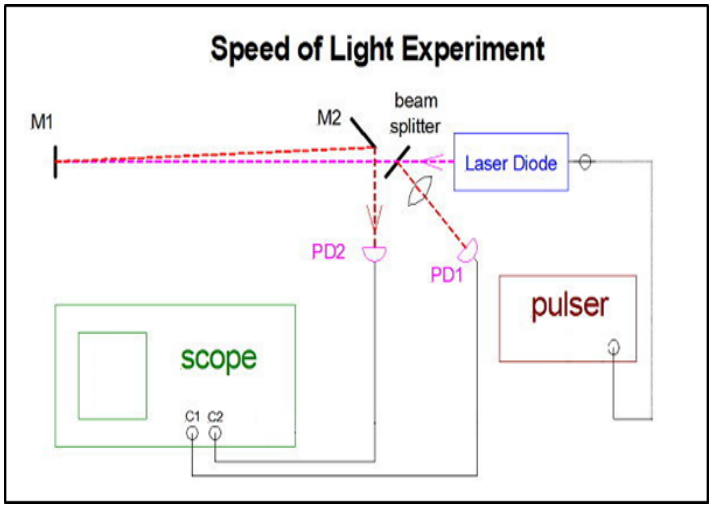


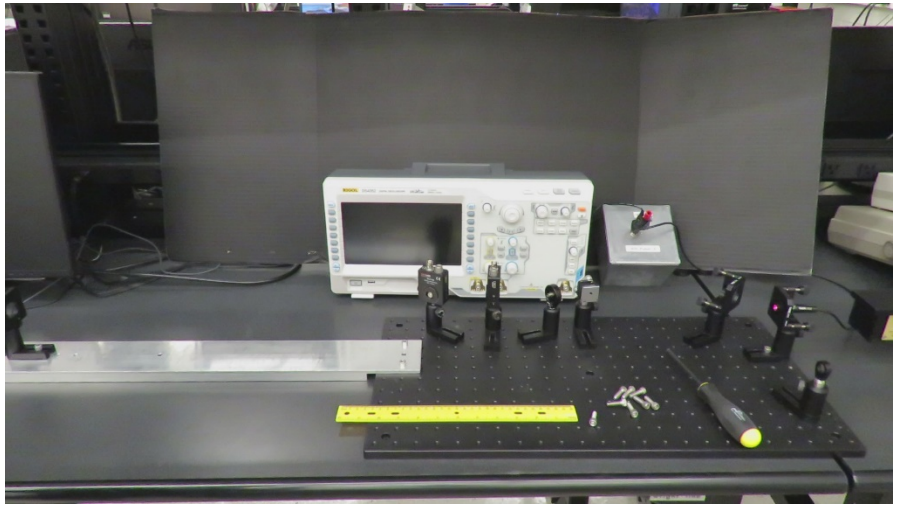
Lab Experiments

SOL - Speed of Light

This experiment allows you to measure the speed of light in various media by measuring the delay time of high-speed laser pulses. The apparatus introduces you to high-speed laser diodes and detectors, which are key elements in optical communications. Here, short light pulses of a few nanosecond duration (few feet long) are sent through various media (air, glass, water,) in order to determine the speed of light (v) and index of refraction ($n=c/v$) in each medium. The speed of light in a vacuum (~air) is c.

The optical set up is shown below. The pulser generates nanosecond electrical pulses to a red diode laser. The nanosecond laser pulses are spit into two separate beams by the beam splitter, to travel two different path lengths to two high-speed photodiode detectors. Time delays are determined by sending the photodiode pulsed to a high-speed oscilloscope





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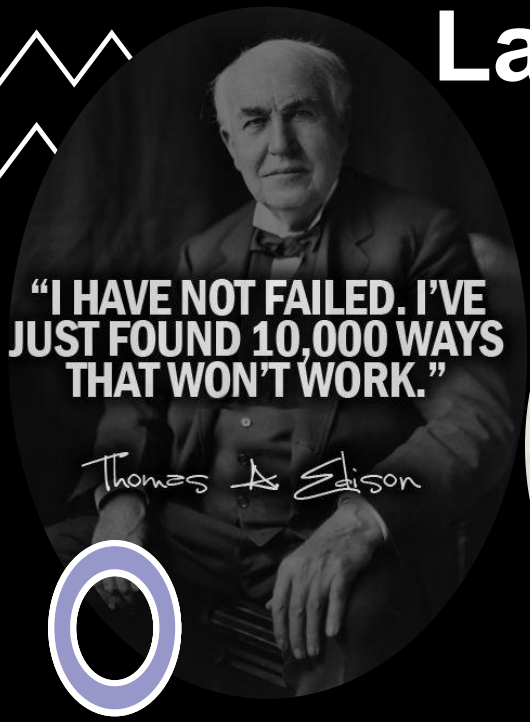

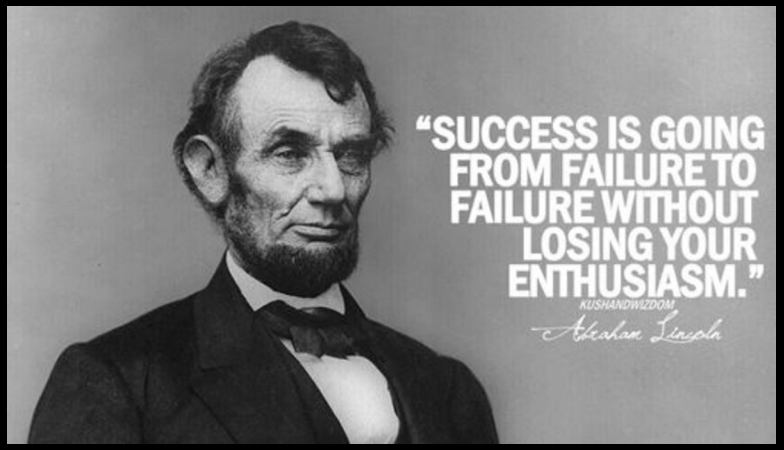

Success thru Failure

- **Friedrich Nietzsche** believed that embracing difficulty is essential for a fulfilling life, considered the journey of self-discovery one of the greatest and most fertile existential difficulties.
- More than a century before our present celebration of "the gift of failure" and our fetishism of failure as a conduit to fearlessness,
- Creativity, the Gift of Failure, and the Crucial Difference Between Success and Mastery - Brain Pickings
- *"You gotta be willing to fail… if you're afraid of failing, you won't get very far,"* Steve Jobs cautioned.
- *"Remember to have fun with what you are doing - ENJOY solving the problems," Don Heiman*

Lab Experiments

Next Week

Begin Lab Experiments on
Monday, May 17

You will receive your Lab assignment on Friday via the course Calendar website.

Homework is due on FRIDAYS
Lab Reports are due on MONDAYS

These are to be turned in to Canvas
by 9:50 am

END