To print higher-resolution math symbols, click the
Hi-Res Fonts for Printing button on the jsMath control panel.

PHY124 Lab 1 - The Oscilloscope

(Spring 2013: revised 1/22/13)

Important! You need to print out the 2 page worksheet you find by clicking on this link and bring it with you to your lab session. [http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/124oscilloscopeworksheet.pdf]

If you need the .pdf version of these instructions you can get them here
[http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/Phy124S13oscilloscope.pdf].

Goals

1. Get a working knowledge of how to use an oscilloscope
2. Measuring a DC voltage (constant in time) and an AC voltage(varying in time as a sine wave)

Video (the Lab number in the video is incorrect: this is Lab 1)

Equipment

- Oscilloscope
- Voltage vs. time generator (usually called a "function generator")
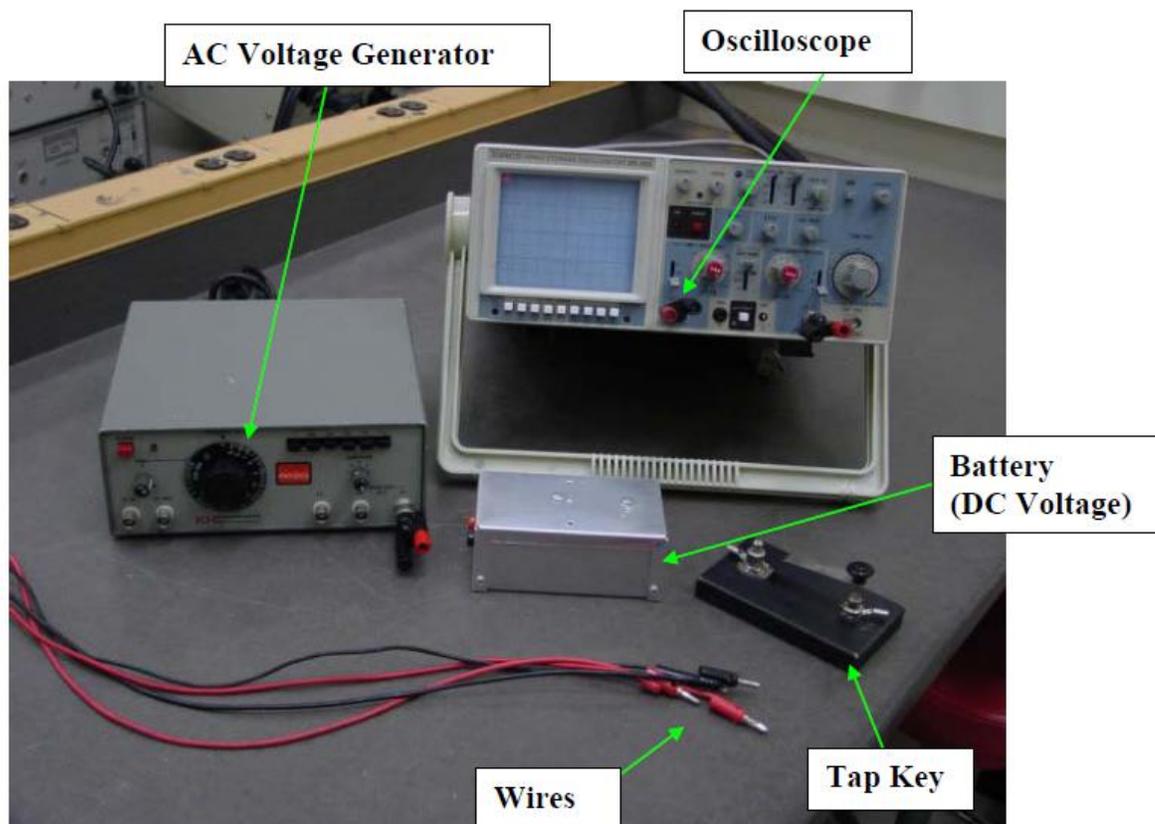- Battery
- Tap Key
- 4 test leads with banana-plug ends

Figure 1 is just above here.

Introduction

The oscilloscope is a very widely used laboratory instrument frequently used to give a visual display of time-varying voltages. While some oscilloscopes now use liquid-crystal displays (LCDs), many (including the ones you will use) still use a cathode-ray tube (CRT). Cathode-ray tubes were invented more than a century ago, and you will be most familiar with them from older televisions and computer monitors.

A brief discussion of how CRT works follows below. *The textbook, Knight, Jones, and Field,* College Physics: A Strategic Approach, 2nd ed. *(KJF2), has some more details worked out in Integrated Example 20.12 on pp. 695-696.* (If you don't have/have access to one, a copy of KJF2 is bolted to a table in the Help Room, A-131 physics building.) Within an evacuated tube (see Fig. 2), a heated filament (much like the filament of an electric lightbulb) and a series of accelerating and focusing electrodes serve as the source of a well-collimated beam of electrons; this assembly is called an electron gun. These electrons are "shot" towards the phosphor-coated, inside front surface (i.e., the "viewing screen") of the tube, causing a visible spot to appear where the electrons strike the surface. Also within the CRT are pairs of metal plates which, when an electric field is established between one or the other pair, can deflect the electron beam horizontally or vertically. This moves the visible spot to any desired point on the screen. In Fig. 2 note that "vertical" and "horizontal" refer, respectively, to the direction of the electric field between the plates and, therefore, in which plane the

electrons are being deflected. The actual plates are, of course, perpendicular to the direction of the deflecting electric field.
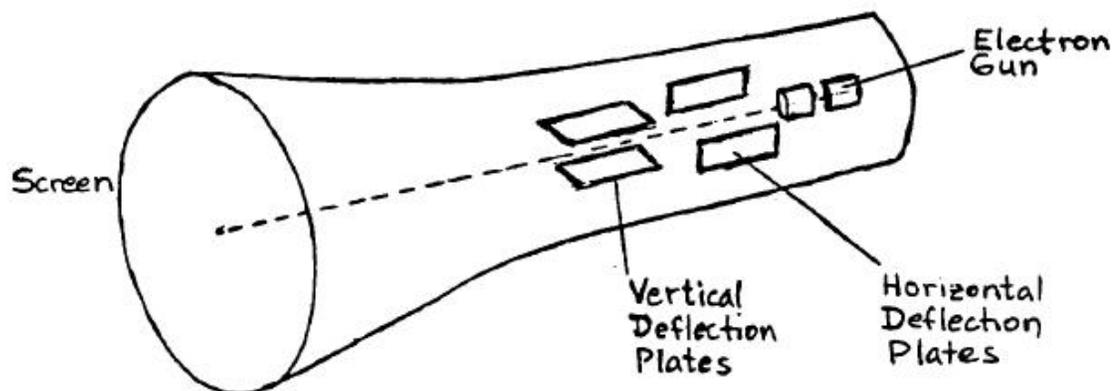

Figure 2 is just above here.

The oscilloscope can be thought of as a voltmeter that plots voltage (vertical axis) vs. time (horizontal axis).

Reading the Oscilloscope

The information given by the oscilloscope is read from the front screen much as you would read information from a graph. Here, the x-axis (horizontal) plots time and the y-axis (vertical) plots voltage. There are, however, important details to know about how to read out information that you will need not only in this lab but for labs throughout the rest of the semester.

Horizontal and vertical scales

Notice that the oscilloscope screen has evenly spaced horizontal and vertical lines that form a grid over which the signal will be displayed. The scale of each axis is important for telling you the voltage and time duration of your signal. The TIME/DIV knob and the VOLT/DIV knob on the control panel set, respectively, the horizontal and vertical scales, and you can (and will!) be adjusting them to observe different "signals" (voltage vs. time variations) well. The setting for each of these knobs tells you how much time or voltage each **large** division represents.

For example, if the TIME/DIV knob is set to 1 μs , then the horizontal side of a box represents 1 μs. Since there are five tick marks in each box, each tick mark on the horizontal axis represents 1/5 as much, viz., 0.2 μs. The same principle applies to voltage. If VOLT/DIV is set at 10 V, each vertical side of a box represents 10 V, and each small tick mark represents 1/5 as much, viz., 2 V.

WARNING: The TIME/DIV and VOLT/DIV knobs tell you the value of an entire box, not the small tick marks inside the box!

Picking an Origin

When reading the oscilloscope you need to think about how to define where the origin (0,0) lies on the screen. On the graphs you've drawn previously the origin has obviously been where your two axes intersect, but with the oscilloscope the position of a trace on the screen can be adjusted and the "zero point" of a particular variable needs to be defined.

You can define the origin (0,0) to be at any intersection on the screen and read the signal with respect to that origin. For some experiments in this course you will want to consider the origin as the lower left corner of the screen. For others you may want to choose the center of the screen. For this lab is it most convenient to consider the time (horizontal) zero point to be at the first horizontal mark on the left side of the screen and

the voltage (vertical) zero point to be at the central line going across the screen. The double arrow in Fig. 3 points to the location of this choice of origin.

On your sketches of measured signals it is important to show where your origin is and what is the scale of each box so that you can correctly interpret your measurements.

Figure 3 is just below here.
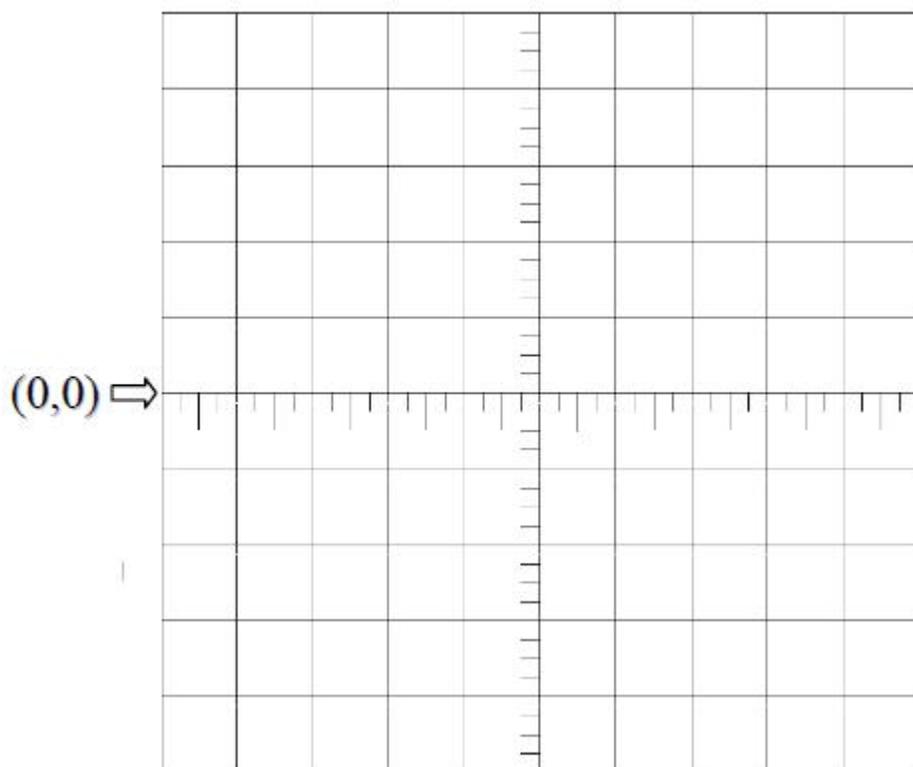
Procedure

The following instructions apply to the particular storage oscilloscope you are using, the Elanco Model DS-203. You will not learn the functions of all the controls but, instead, focus mostly on three three 3 controls labeled in Fig. 4. With the oscilloscope directly in front of you, set the controls as follows:

The white buttons below the display screen on the left should all be in the "out" position. The controls to the right of the screen should be adjusted as given below (*cw* means clockwise):

- INTENSITY: mid-range (line pointing up)
- FOCUS: mid-range
- TRIGGER LEVEL: mid-range
- COUPLING: AC position
- SOURCE: CH 1 position
- HOLDOFF: MIN (ccw) position, knob pushed in
- XY: button in "out" position
- <POS>: mid-range
- POWER: button in "out" position
- POS ^ (Ch 1): mid-range, knob pushed in
- POS ^ (Ch 2): mid-range, knob pushed in
- VAR SWEEP: calibrated (cw) position

- AC AND DC (Ch 1) switch to DC position
- CH 1 knob: set to 1 V(olt), V AR knob in "CAL'D" (cw) position
- VERT MODE: CH 1 position
- CH 2 knob: set to 1 V(olt), V AR knob in "CAL'D" (cw) position
- AC GND DC (Ch 2): set to DC position
- TIME/DIV knob: set to 0.1 (s) position
- STORAGE/ ANALOG: button in "out" (ANALOG) position

Disconnect any wires that may be plugged into the front of the oscilloscope, and make sure the power cord on the back is plugged into an 117 V AC outlet.

You are now ready to turn on the oscilloscope. Push the red "POWER" button to the "in" position. After a few seconds, you should see a bright spot sweeping horizontally across the screen about once per second. IF YOU DO NOT SEE THE SWEEP, ASK YOUR TA FOR ASSISTANCE; DO NOT CHANGE ANY SETTINGS.

Once you have established the sweep, adjust the "INTENSITY" and "FOCUS " controls to give you a sharp, bright spot (but not too bright; avoid a "halo") for clear viewing. Set TIME/DIV to 1 ms – you should see a line across the screen now – and use the "POS" controls to center the sweep on the screen horizontally and vertically. Once adjusted, set TIME/DIV back to 0.1 s.

Push the "XY" button to the "in" position. When you do this, the internal horizontal sweep is disabled, and you should see a stationary spot on the screen. Return the "XY" button to the "out" position to re-establish the horizontal sweep. Try different settings of the "TIME/DIV" knob, and see what effect this has on the sweep rate.

Now connect the battery in series with the tap key to the CH 1 input plug as shown.

Figure 4 is just below here.
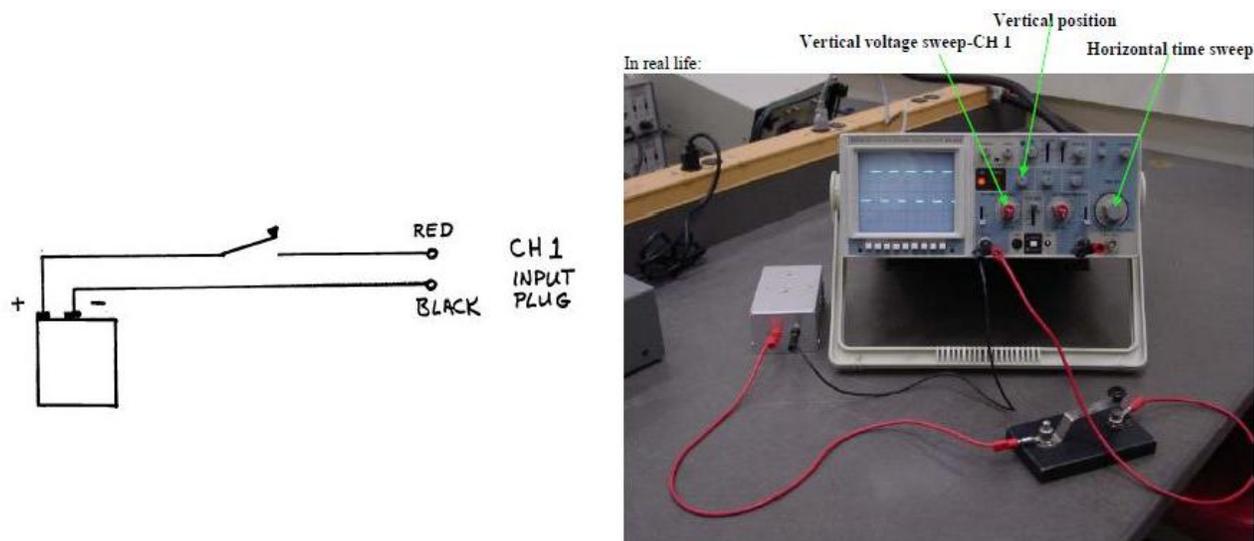
With the CH 1 VOLTS/DIV set to 1 V and the TIME/DIV set to 0.1 s, try tapping the key. Try several different settings of the VOLTS/DIV knob. What is the relationship between the VOLTS/DIV setting and the vertical deflection of the spot?

Instructions for Measurement #1 : Measurement of the Battery Voltage

A battery voltage is reasonably constant in time and is called a "DC (direct current) voltage". Measure the battery voltage with a voltmeter (supplied by the instructor) and record it on your worksheet.

Now press the white STORAGE/ANALOG button to the "in" (STORAGE) position. Set the VOLTS/DIV set at 0.5 V and the TIME/DIV set at 0.5 s and record these settings ion your worksheet, When the light starts to sweep

on the screen, push the tap key down ~5 times in succession, at about once per second. You have generated a "square wave" voltage. Once the "square wave" has been generated on your screen, quickly push the white button "SAVE ALL" under the screen. This is because you need to sketch the trace on your worksheet, and you don't want the next oscilloscope sweep to overwrite your stored picture. Release the "SAVE ALL" button when done with the sketch.

Your sketch should have a clearly defined origin, numbers indicating the horizontal and vertical scales (how much voltage and time does each box represent?), and a sketch of the square wave. You should also label the parts of the trace that are valid for the switch opened and closed on your drawing.

You will need to estimate the uncertainty (see *Uncertainty, Error and Graphs*) in your readings off the screen. You could, for example, estimate the reading uncertainty to be the thickness of the trace on the screen, but you can also consider things like the spacing of the subdivision markings on the screen. Record your estimate of the reading uncertainty for both voltage and time on your worksheet.

Enter the lowest and highest voltage readings from the square wave into the table on your worksheet. Estimate your reading accuracy in the lower voltage reading (V_1) in volts and repeat the same for the upper voltage reading (V_2) and enter the values into the same table. The uncertainties are presumably the same for both voltages.

Your value for the battery voltage measured with the oscilloscope is the difference between the two voltage readings, $V = V_2 - V_1$. Propagate the uncertainties of the high and low voltages into the uncertainty for the difference according to Eq. (E.6) in *Uncertainty, Error and Graphs*.

Instructions for Measurement #2: Measurement of a Sinusoidal Voltage

The voltage put out by the voltage generator changes with time and is called an AC (alternating current) voltage.

Now set the STORAGE/ANALOG button to the out (ANALOG) position and set up the voltage generator with the following settings

- FREQUENCY HZ: 1
- MULT: (multiplier) 10k (=10,000) pushed in
- Button with the sine-wave label: pushed in
- AMPLITUDE: ~ middle position

Connect the output "MAIN OUT HI" to Ch 1 of the oscilloscope and set VOLTS/DIV to 1 Volts, TIME/DIV to 50 μs. You should see ~ 4-5 sine waves. Record TIME/DIV, VOLTS/DIV and the expected frequency from these settings on your worksheet.

Be careful when noting the expected frequency! You must take the FREQUENCY HZ that you set and multiply it by the MULT value to get the frequency that the generator is putting out.

Record the trace on your worksheet. Make sure you have an origin and numbers showing the scales of both axes.

As before, you will need to estimate the uncertainty in your readings off the screen. Record your estimate of the reading uncertainty for both voltage and time on your worksheet.

Observe the time it takes for the signal to complete ~ 4-5 wavelengths. Do this by taking time values for the beginning and end of the wavelengths in your sketch (call them T_1 and T_2). The time difference, or the time it takes to complete these wavelengths is the Time Difference = T_2-T_1. As before, you should estimate the reading uncertainty taking into account the thickness of the trace on the screen and the spacing between subdivisions on the screen.

Since the Time Difference is the period of 4 or 5 waves, simply find the period of one wave, T, by dividing the Time Difference by the number of waves you counted. Since T is your Time Difference divided by ~(4 to 5) you have to calculate the uncertainty of one period according to Eq. (E.1) in *Uncertainty, Error and Graphs*.

From the period T calculate the frequency, f = 1/T, with uncertainty, and compare to the expected frequency. You get the relative uncertainty for 1/T from the relative uncertainty of T using Eq. (E.8) in *Uncertainty, Error and Graphs* with n = -1.

Points to discuss with your TA

You should make sure that you understand how to make accurate measurements with the oscilloscope, and especially how to choose an appropriate scale and then how to read it. You should discuss with your TA the agreement between your measured values and the values you expect based on the voltmeter measurement of the battery voltage and the frequency you dialed in on the signal generator. You should also discuss how you can make reasonbale estimates of your measurement error and ways you could reduce this.