Experiment 0: Review

I. References

The 174 and 275 Lab Manuals
Any standard text on error analysis (for example, *Introduction to Error Analysis*, J. Taylor, University Science Books, 1997)
The manual for your oscilloscope, available on your desk top, by clicking the icon labeled "shortcut to p276"

II. Equipment

Tektronix digital oscilloscope, BK Precision Function Generator, coaxial cables, breadboard, the crystal earpiece from your AM radio kit.

III. Introduction

During this semester, you will be expected to remember what you learned in previous semesters on error estimation, error analysis and on use of the oscilloscope. This lab is a brief refresher on those materials. We will also begin to explore some of the basic materials and principles we will be using in our study of AM radio technology such as a breadboard and the function generator. This lab also introduces a useful tool for collecting data with the oscilloscope, called OpenChoice.

IV. Review of Error Analysis

With your instructor's help, complete the following exercises. Do your work in a spreadsheet and upload it for grading at the end of class. Feel free to ask your instructor or TA to look at your answer before you upload, to guarantee you get a perfect grade.

Error propagation

If you do a calculation that involves measured numbers, the result of that calculation will have an uncertainty that comes from the uncertainties in the measured numbers. The basic formula for propagating the error in the measured numbers to the error in the result of the calculation is:

$$y = f(x_1, x_2, ..., x_n)$$
$$\sigma_y = \sqrt{\sum_{i=1}^{n} \left(\frac{\partial y}{\partial x_i}\sigma_{x_i}\right)^2}$$

Practice: in your spreadsheet: You drop a ball (initially at rest) and it falls 3 m ± 0.01 m in 0.785± 0.002 s. What is the acceleration due to gravity *g* (and, of course, its error)?

Estimating Chi-squared by eye

χ^2 (chi-squared), defined by

$$\chi^2 = \sum_{data} \frac{(data - theory)^2}{error^2}$$

is a useful quantity for comparing the results of a measurement to the prediction from a theory. For quantities with Gaussian-random errors, the distribution of χ^2 values obtained from many independent experiments is given by the function

$$f(z,n) = \frac{1}{2^{n/2}\Gamma(n/2)} z^{n/2-1} e^{-z/2}$$

where z are the values for χ^2, Γ is the gamma function, and n is the "number of degrees of freedom", which is the number of data points minus the number of parameters in the theory that were derived from the data instead of being predicted absolutely. If the theory has free parameters that need to be determined using the data, it is obviously easier to obtain a smaller χ^2, and this affects the distribution for χ^2s. This distribution can be integrated to obtain the probability of obtaining a χ^2 of that size of greater due to random fluctuations due to the errors alone, and there is an EXCEL function available that provides this number.

Practice in your spreadsheet: Estimate by eye the χ^2 for data in the graph shown in Figure 0-1. Assume the theory curve was an absolute prediction and contained no parameters that needed to be estimated from the data. Then, use the appropriate EXCEL function to get the probability of having a χ^2 this big or bigger due to random fluctuations alone.

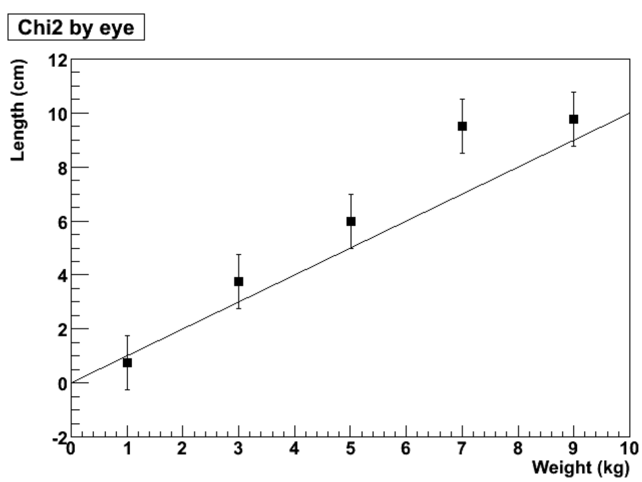


Figure 0-1: Estimating Chi-square by eye

Doing Linear Fits

Sometimes, a theory predicts that the data should follow a certain functional form which has parameters that are determined from initial conditions, and therefore are not predicted absolutely.

In this case, the numerical values of these parameters must be obtained from the data themselves. One way to do this is to find the set of parameters that minimizes the chi-squared between the data and the function.

Using the data in Table 0-1, and the spreadsheet, located via the icon labeled “p276 on (P)” on your desktop, called “linear_fitter_276.xls”, find the slope and intercept that gives the minimum chi-squared, and their errors.

Time (s)	Position (cm)
1 ± 0.1	2 ± 2
2 ± 0.1	11 ± 2
3 ± 0.1	13 ± 2
4 ± 0.1	20 ± 2
5 ± 0.1	28 ± 2
6 ± 0.1	31 ± 2

Table 0-1: Data for Linear Fit

V. Review of the Oscilloscope

Setting Up the Digital Oscilloscope

1. Switch on the power to the oscilloscope using the button on the left on the top of the instrument.
2. Plug one end of a coaxial cable into the scope's Channel 1 input connector. Plug the other end of the coaxial cable into the signal plug on the small black box that is bolted to your work-bench next to the scope. This black box is connected to a signal generator, so that the same signal can be sent to everybody in the class room.
3. Find and Press the AUTOSET button on the oscilloscope.
4. Push the CH1 menu button. Then, set the coupling to AC coupling.

Displaying the Signal

There is a sine wave with a frequency of 2.5 kHz and an amplitude of about 4 Volts on the black distribution box.

(1) What is the period for this signal? Note the answer on your spreadsheet. Carefully label your answer so your TA can easily find it. If the TA can not easily find it, they will mark it as incorrect.

(2) Adjust the time/division for the x-axis to a value appropriate for displaying a few periods of this wave.

(3) Adjust the volts/division for the y-axis to a value appropriate for displaying the signal.

(4) When you have completed the steps shown above, show your instructor or TA, who will write something in your spreadsheet.

Using the CURSORS

Measuring the time between two features of the signal:

(5) Push the CURSOR button in the Control Button Panel. The CURSORS allow you to make time and voltage measurements of the displayed signal.

(6) Set the TYPE selection to Time. Set SOURCE to "CH1."

(7) Note the knob next to the "autorange button". Twist it and you will see one of the cursors move. Look at the two bottom panels on the right-hand side of the display. One of them should be high-lighted and have a label of either "Cursor 1" or "Cursor 2". The other should not be high-lighted. Push the button on the one that is not highlighted and try twisting the knob again. The other cursor should move.

(8) Move your cursors so that one aligns with one peak of the sine wave, the other with the next peak.

(9) On your spreadsheet, record the Cursor times. [The trigger time is set to be zero for this time coordinate system.]. Again, make sure the boxes with these times are carefully labeled.

(10) In the Delta window of the screen (right-hand side, middle panel) note the values of Δt and $f(= 1./ \Delta t)$. Record the values on your spreadsheet.

Measuring the Voltage:

(11) Set the TYPE selection to Amplitude.

(12) Move the cursors so that one is aligned with the peak, the other with the minimum.

(13) On your spreadsheet, record the Cursor voltages. [The GROUND potential is set to be zero for this voltage coordinate system.].

(14) In the Delta window of the screen note the value of ΔV. Record the value on your spreadsheet.

Using MEASURE

(1) Push the MEASURE button in the Control Button Panel. This function allows you to make a variety of automatic measurements on the displayed signal waveform.

(2) Push the buttons on the right-hand side of the screen to set which channel they read and what they display. (press the "back" button on the bottom of the column of buttons to see the reading after doing the set). Set the panels so that all read channel one, and the displays are: Mean, Pk-Pk, Period and Freq.

(3) Adjust the Horizontal Controls "position" and "SEC/DIV" so that one or more periods of the waveform is displayed (some of the MEASURE functions don't work if you have less than a period displayed).

(4) Record the values you get in your spreadsheet (carefully labeling each).

(5) On your spreadsheet, compare qualitatively to the values you got for the various parameters when using CURSOR and MEASURE. (again, as always, make sure your spreadsheet is carefully labeled so your TA can easily find the information, or it will be marked as wrong).

Triggering Off an Unknown AC Signal

Most of the time, you will be using your scope to measure a signal, and you will not necessarily know in advance what your signal is going to look like. You must give your scope a "trigger condition". This is a set of conditions under which the scope will display a signal, for example, if the voltage exceeds a preset threshold.
In this part, you will practice setting the "trigger conditions" for your scope.

Try obtaining a stable trace for each of the following trigger choices: Hit the trigger menu button and adjust the settings so that

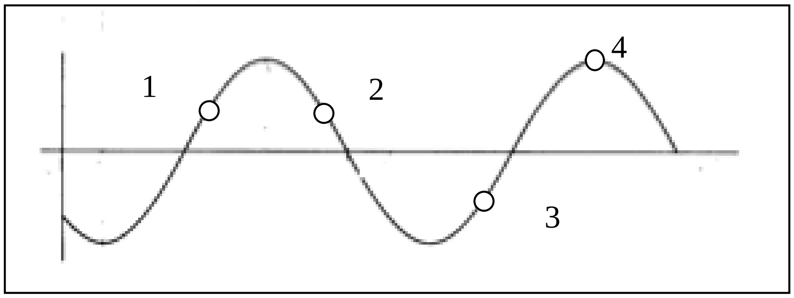
(1) Trigger on the rising slope where signal is $3/4V_{Pk\text{-}Pk}$ (see sketch below for trigger point 1).

(2) Trigger on the falling slope where signal is $3/4V_{Pk\text{-}Pk}$ (see trigger point 2 in sketch below)

(3) Trigger on the rising slope where signal is $1/4V_{Pk\text{-}Pk}$ (see sketch below for trigger point 3).

(4) Trigger on the top of the wave (see sketch below for trigger point 4).

(5) What happens if you use a higher trigger threshold than that used for point 4? Why does this happen (answer in your spreadsheet)



- Once you have done this, show your instructor or TA, who will write something in your spreadsheet.

Hints on Triggering the Scope

The small arrow on the right side of the scope's screen indicates the "trigger level" (the voltage at which the scope triggers).

The number at the bottom right hand corner of the screen gives the voltage that the trigger level is set to.

The small arrow at the top of the screen indicates the time when the scope triggers (the "starting time" or t=0).

Practice Automatic Data Collection Using OpenChoice, and practice using the Function Generator

(1) Using a BNC cable, plug the output from the signal generator into channel 1 of the oscilloscope.

(2) Turn on the function generator and set it so that it is generating a sine wave at a frequency of approximately 2 kHz.

(3) Initialize the scope by using the AUTOSET function.

(4) Adjust the oscilloscope SEC/DIV knob to about 100 μs/div and the VOLTS/DIV knob to about 0.5 V/div until you get a nice stable trace.

(5) Turn the amplitude control knob of the function generator and set it so that it is generating a

sine wave with 3 V peak-to-peak voltage difference.

(6) Show your wave to your instructor or TA. They will write something in your spreadsheet.

(7) Pull the knob used to adjust the amplitude in and out. What happens?

(8) Use the CURSOR to measure the time interval, ΔT_C, between two peaks of the sine. Record your result on your spreadsheet.

(9) Calculate the frequency of the wave. Record your result on your spreadsheet.

(10) Now use the amplitude cursors to measure the difference in voltage between the top of the sine wave and the bottom of the sine wave. Record your result on your spreadsheet.

(11) Press MEASURE and use the menu keys to set up windows to report the frequency, f_M, period, T_M, and peak-to-peak voltage, ΔV_M. Record values in your spreadsheet.

Uncertainties when using MEASURE

The MEASURE function is very handy, but you will probably see that the values reported by MEASURE fluctuate with time. This happens because the function generator does not have a completely stable output signal and there is some noise in the scope and generator The lack of stability causes the scope's estimate for the peak-to-peak voltage, the frequency, and the period to change. When you read the values reported by MEASURE, you should watch the displayed values fluctuate and then estimate an average value and the error uncertainty in that average value based on how much variation you see.

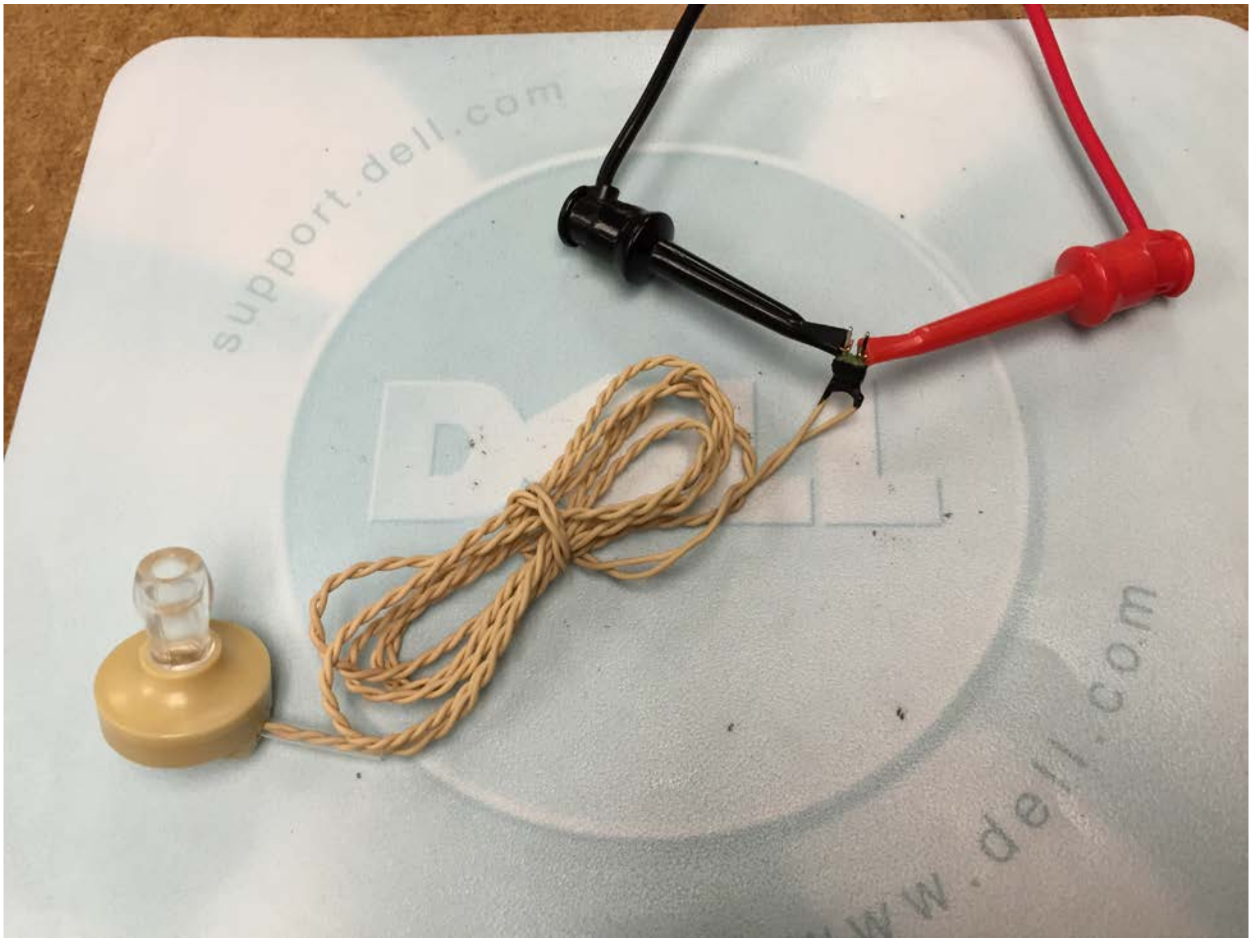
(12) Now click on the Start menu on your computer and click on the program called **OpenChoice**. This is a data collection program that automatically downloads data from the Tektronix Oscilloscope. After OpenChoice starts up, click on INSTRUMENT and choose the instrument that starts “USB0::…”. Then go to the “Waveform Data Capture tab” and hit “Get Data”. It takes a few seconds to download the data from the scope, and Wavestar then makes a plot of the data, just like what is displayed on the scope screen.

(13) Next click “Copy to Clipboard”. Go into Excel and do “Paste”. Your data should be there. Use Excel to make a plot of the data.

VI. Introduction to Audio: test your hearing

We will be studying electricity and magnetism in the course by building an AM radio. The **carrier** frequencies assigned to the AM band span from 540 kHz to 1600 kHz. The content carried by AM radio waves are audible (music and talk). This signal has a very different frequency range from the carrier wave, and is encoded by superimposing the signal on the carrier wave, modulating the amplitude of the carrier wave. The radios we build will then subtract the carrier wave, leaving only the audible sound wave. We will discuss this in more detail later in the semester. For now, you will map out which frequencies the human ear is capable of hearing. This will comprise the range of frequencies in the signal.

1) Retrieve your crystal earpiece out of your AM radio kit.
2) Connect your earpiece to the function generator using the special BNC cables on the front side wall as shown in the picture below.



3) Set your function generator to produce a sine wave at around 1 kHz and to the lowest volume, and gradually increase the volume until you can hear it. (Hint, you can attenuate the amplitude on your function generator by pulling the amplitude control knob out until it clicks.)
4) Turn the frequency up and down with the knob to determine which frequencies you can hear. There are some buttons at the top of the function generator that will switch the range of frequencies. Record the results in your spreadsheet (as always, carefully labeled)