Course Notes: Recording Measurements

Recording Measurements

An understanding of the equipment capabilities and the ability to keep proper records form the foundation of laboratory experiments. In today's experiment you will learn the importance of equipment precision, significant figures, and units of measurement. These are concepts that you will carry with you for the rest of your engineering career.

Instrument Precision and Significant Digits

The instruments used in the ECE 110 Lab have a great deal of **precision**. This means that they have the *potential* to measure data to many **significant digits**. It is important to recognize that the number of digits available in the instrument's precision is not necessarily equal to the number of significant digits gained by a measurement. Measured data should have no more significant digits than the instrument's precision allows. In fact, the recorded data will typically have fewer digits than shown on the instrument display. Most measurements we make in the lab are noisy so that not all the digits displayed on an instrument will "hold still". When one or more of the instrument's digits fluctuates, you should record *all* the non-fluctuating digits and the *average value* of the *first fluctuating digit* you encounter. For example, a 4-digit measurement that fluctuates between 1.314 and 1.351 volts might be recorded as 1.33 V (three significant digits). The last digits of these numbers have no meaningful value in this case and so they are ignored.

Question 1: What kinds of problems might be caused by recording *less* precision than shown by your instruments? For example, the instrument reads "0.803V" but "1V" is recorded.

> You might miss important details in your data analysis. If this goes further down the line, you might end up making incorrect conclusions or expecting incorrect behaviors from a device. This is mostly intended to get the students thinking about possible repercussions.

Question 2: What kinds of problems might be caused by recording *more* significant digits than shown by your instrument? For example, your instrument varies randomly between "1.3xx V" and "1.4xxV" so the snapshot value

Notes:

"1.3512 V" is recorded.

Too much confidence might be placed in a recording that is not as stable as it might appear. Again, possibly wrong conclusions might be drawn. This is mostly intended to get the students thinking about possible repercussions.

Question 3: Why is it fair to "average" the first fluctuating digit instead of just discarding it?

The instrument has already averaged to obtain the result it shows. Sometimes the amount of averaging (often called the "time constant") can be increased through the instrument's control panel. In absence of making this adjustment, averaging might be done by the experimenter.

Units

In science and engineering, numbers are used to represent physical quantities. The physical quantity being represented is made unambiguous by its units. Therefore, when recording a measurement, you must always include the corresponding units. You cannot just assume that you will remember later or that the person reading your report will "just know what you meant". In addition, the units used must be clear – this is why we use standardized units of measurement like volts (V), millivolts (mV), seconds (s), and amps (A).

Question 4: What can go wrong if you don't record the *units* of your measurements? Feel free to discuss the possibilities with your neighbors. When you have time, read this article at http://en.wikipedia.org/wiki/Mars_Climate_Orbiter.

The scale of the measurements may be unclear: mV vs V
The measurement might be totally unknown: cm vs inches
It might be impossible to tell if the measurement was even taken correctly: Volts vs Ohms

Notes:

Question 5: Suppose that a student measured the voltage across a resistor but neglected to write down the units (e.g. "0.920" is written without units). Is it possible to definitively determine the voltage based only on this number?

NO! It might be in mV, V, kV, MV or some other unit of voltage that is not commonly used.

Tables of Data

In the field of engineering, you will often need to characterize the behavior of various devices utilized in larger systems. This is often done by varying a parameter of the circuit (e.g. voltage supplied to a device) and measuring some other parameter (e.g. current flowing through that device). This process typically requires filling tables with measurements, performing calculations and generating graphs with the collected data. Throughout this process, you will need to provide proper units and significant figures for each measurement in a table. To avoid confusion, it is useful to write all your measurements in the same units and make note of the units in the column header.

In addition to keeping track of the details of your measurements, it is equally important to make detailed notes. In this course, the tables provided in your procedures will have a column for comments. The notes you make while recording measurements can describe the behavior of the device you're testing (eg. The wheel just started turning!), events in the surrounding environment (eg. Something smells burnt.), or actions taken by the experimenter that might have had an effect on the measurement (eg. I knocked my motor off the table, but it still seems to work.).

Votage (V)	Current (A)	Comments:
0.00	0.000	Power supply is off
0.11	0.001	I knocked my motor off the table, but it still seems to work
0.20	0.011	
0.31	0.021	The wheel just started turning!
0.40	0.034	Something smells burnt!
0.50	0.001	Motor seems to have died.

***Table 1**: Example of table with comments. Sadly, this experiment seems to have gone wrong…*

Notes:

Question 6: What problems may result if the table shown didn't have any notes in the "Comments" column?

Incorrect conclusions might be drawn about motor behavior. We might not be able to tell when/if the motor starting turning. The motor may have died due to mechanical failure from the fall.

Graphical Representation of Data

How can we depict our measurements in a manner that is easy to read, understand, and draw conclusions from? We can use **graphs**! But we must take care when creating a graph in order to avoid ambiguity. Well-measured data, when poorly plotted, can lead to erroneous conclusions and be very confusing to someone reading your report. Even your future self will likely have difficulty interpreting your own report.

Graphs (and charts) are very concise and useful methods of depicting a large amount of data. This portion of the lab outlines the necessary components for an informative graph. You will be required to draw a few graphs by had, but most will be produced using a powerful computing platform – MATLAB. So, in addition to an introduction to "good plotting habits", you will get a quick introduction to plotting graphs using MATLAB. **MATLAB** is *a high-level programming language and computing environment* that has become a very common tool among engineers. It is important that you get comfortable with it early in your academic career.

Plotting Graphs

Below are the details that are necessary when plotting a graph. Without these details, a person reading your lab report might not understand what your graph means and you will not receive full credit.

Title/Caption

The title of your graph should give the reader an idea of *what* is plotted and *why* it matters. In a lab course like ECE110, it should be made clear which step (or question) in the procedure is being addressed by the graph.

Notes:

Example caption:

Figure 6: The IV characteristic of a DC motor with a linear curve fit to the region after turn-on.

Axes labels and Units

The labels for your axes should tell the reader what physical quantity is being plotted. Calling your axes x and y is uninformative and is considered inadequate in a quantitative experimental setting. Common labels in ECE110 include *time (in seconds)* as the horizontal axis and *voltage (in Volts)* as the vertical axis or *voltage (V)* as the horizontal axis and *current (mA)* as the vertical axis. Always, where appropriate, include the units in the axis label.

Axes scales

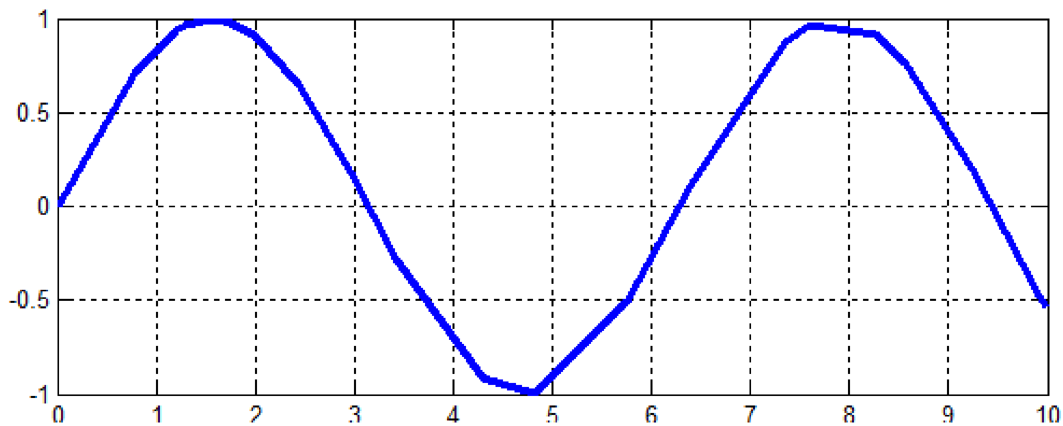
The scale of your axes is usually depicted by *labeling three or more divisions* with a numerical value. Sometimes your scale will be integer-valued and in other cases it might not be. Keep in mind that the scale of your graph should be chosen to show critical detail. If you choose a scale too large, the plot will be too small and the reader will have a hard time seeing important aspects of the curve.

Legend/plot labels

Legends are necessary when you have multiple curves on one graph. Each plot should be clearly labeled so that is clear what data are represented by each curve on your graph.

Notes:

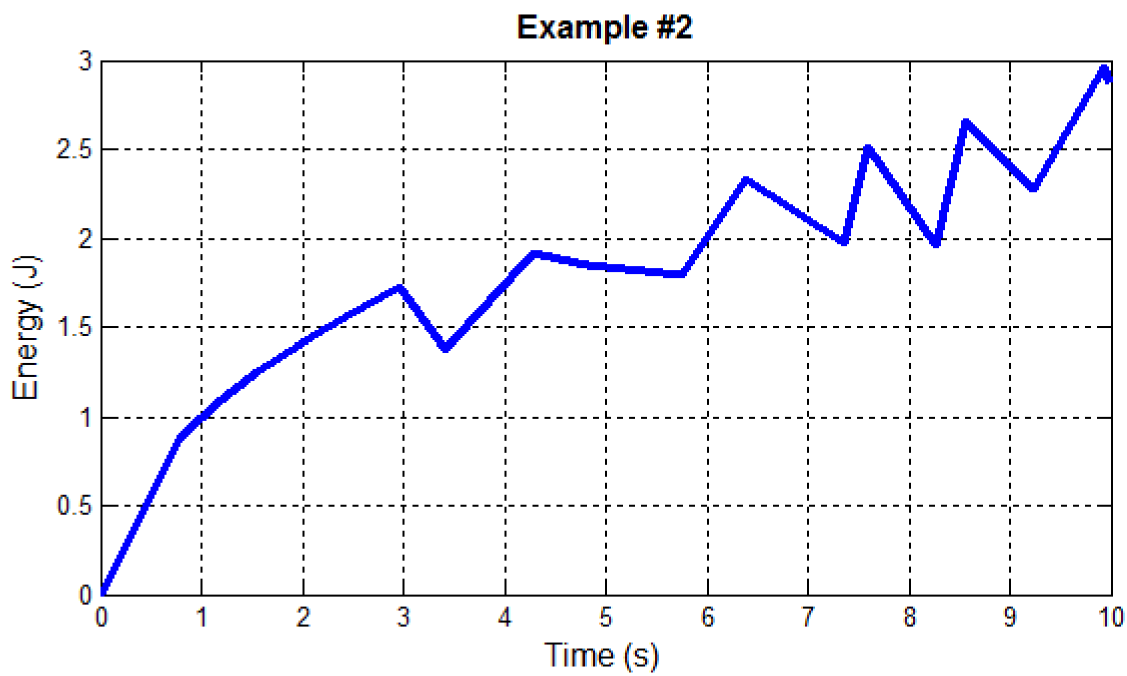
Below are some examples of graphs generated with various data sets. Identify whether each graph is acceptable or not. If you feel a graph is inadequate, clearly state why. This is a good time to discuss your thoughts with your classmates.



Question 7: What is wrong with the graph above? Consider the key features of a good graph described earlier.

No title, no axes labels, no units

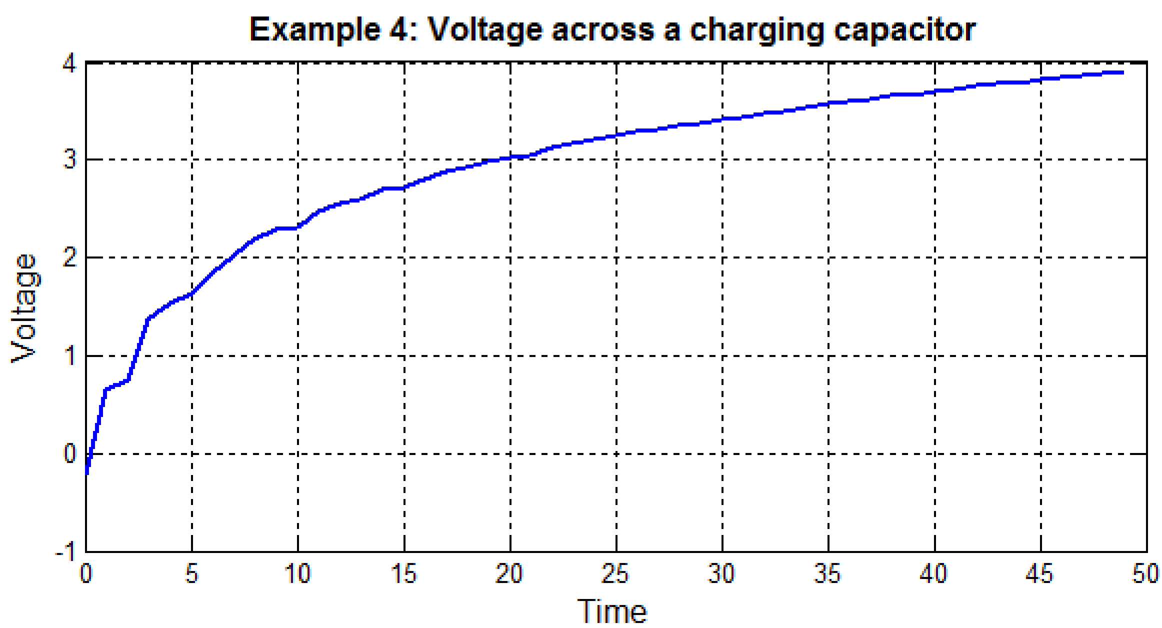
Notes:



Question 8: What is wrong with the graph above?

Title does not tell us anything about the data

Notes:



Question 9: What is wrong with the graph above?

No units