Measurements and Uncertainties
In Science and Engineering

PS253 – Physics Lab for Engineers
Embry-Riddle Department of Physical Sciences
Updated: 29 August 2016

The experiment is designed for you to take simple measurements of various physical properties and explore how experimental uncertainties affect your results. You will learn how to use common measuring devices such as triple-beam balances, thermometers, rulers, and Vernier calipers. The differences between analogue and digital collection will also be investigated. Uncertainties will be propagated through the calculation of the density of a solid, and the standard deviation in measurements of the period of a pendulum will be determined.

Data, calculations, and questions should be answered on the in-lab worksheet.

Temperature Measurements around the Lab

1. Carefully inspect the alcohol thermometer at your table. This is a purely analogue measuring device. What is the resolution of the thermometer?
2. As a group decide on a working value for the precision, or measurement uncertainty, in your temperature readings from this thermometer.
3. How do you think you should hold the thermometer? Does holding it from various places along the tube affect the reading at all?
4. Each group will initialize some kind of time recording device at the exact same instant to begin recording temperature readings on similar relative time scales.
5. Once time is being recorded, every two minutes someone from each lab group will observe their thermometer and record the temperature of the room at their table and the time of their recording. Continue until 20 minutes have elapsed.
6. After each temperature reading report your results to the instructor; these will be added to a master file for the whole class to see and compare results.
7. As a class we will review what the data looks like and see if there are any interesting anomalies. Hopefully we will notice some important characteristics of data collection that normally appear when you start grouping results together from multiple sources using different instruments.

While you are still taking measurements of room temperature with the alcohol thermometer, you will also take some measurements using a Pasco stainless steel temperature probe (CI-6605A).

The temperature probe you are using utilizes a thermistor as the sensing element to determine temperature. A thermistor (thermal resistor) is a device whose electrical resistance changes with changing temperature following a well-defined, continuous function. The probe is used in conjunction with an interface box and software to allow for rapid computer based data collection. The system reads a voltage from the probe, which is converted into a resistance, and finally using an established equation it computes a temperature from this resistance (originally a measured voltage).

The physical process enabling us to record temperature is the changing resistance of our sensor to changes in temperature. This is of course a continuous, analogue, process. However, in order for the computer to store these readings it must convert that analogue process into discrete, digital data. This is called analogue-to-digital conversion.

Numbers are stored by the computer in combinations of bits, where a bit is either 0 or 1. 2-bit data could store four, 2^2, different number states as either 00, 01, 10, 11. Most data storage systems will have something like 8-bit (2^8), 2^{12}, 2^{16}, 2^{32} capability. The total amount of storage states, or counts/numbers, we can record is given the term analogue-digital units or ADUs, these then can be arbitrarily assigned to whatever real numbers we like.

For example, if you have a sensor that has 8-bit capability you can "sense and store" 2^8=256 discrete values. This could give you all the whole numbers between and including 0-255. If you wanted to increase precision to one decimal point you would end up with a much smaller range, only 0.0-25.5, but still have a total of 256 discrete numbers.

1. Make sure the Pasco interface box is turned on. Then use the Windows Search bar to locate and open the *Capstone* software. Seek help from your instructor to initialize the software setup. You will choose either the "stainless steel temperature probe" or the "temperature probe" which appears black.
2. Adjust the sensor sampling frequency to 10-30Hz so we can get a lot of data in a short amount of time. In the *Capstone* window choose to display a "Table" and "Graph" view of the temperature readings (this will populate once you start collecting).
3. Collect some room temperature data for about 3-6 seconds and stop collecting.
4. Increase the displayed precision of the temperature data table to at least 6 significant figures. If the room and probe are both at a steady state temperature and in equilibrium you should notice a lot of very similar data- nearly constant.
5. Scroll through the data to find the minimum measurable digital step change (resolution), in temperature. Record this information on the in-lab worksheet, and complete the remaining parts of the worksheet for this section.

Remember that the sensor and interface system is converting an analogue physical sampling process into digital numbers to be displayed and stored. As you should have realized above, this inevitably always results in some decrease or loss in resolution and precision since not every possible value can be represented and stored. Each stored value, ADU, must cover a finite range of analogue, real world states. In practice, if you must keep the same computing hardware a tradeoff must be made between resolution (range covered by a bit) and sample space (absolute range you can measure across).

Density of a Solid

1. Inspect the solid object provided for this experiment.
2. At your table you have a ruler, Vernier caliper, and triple-beam balance. Determine the resolution of each device. Also find a good working value for the precision, or uncertainty, of each device. Record these on the worksheet.
3. Measure the object height and diameter with the caliper and record them.
4. Record your estimate of the uncertainty in the dimension measurements. Units must be included in all data records.
5. Based on your diameter measurement and uncertainty, determine the object's radius and the uncertainty in the radius. Keep in mind this technically involves propagation of uncertainties (very easy this time).
6. Adjust your triple-beam balance so that it reads zero when it is empty. What type of error does this eliminate?
7. Measure the mass of the solid object on the triple-beam balance. Estimate and record the uncertainty along with the units of this measurement.
8. Complete the remaining parts of the in-lab worksheet for this section.

Period of a Pendulum

1. Record 10 measurements of the time it takes for a pendulum to swing away from its highest point and then to return to that point (one period) using a stopwatch. Try to keep the same swing arc and of course the same pendulum string length for each measurement.
2. Using a meter stick, measure and record the pendulum length from the point where it is fastened at the top down to the best estimate of the pendulum bob's center of mass. Don't forget to include units and your estimate on the measurement uncertainty.
3. Complete the remaining parts of the in-lab worksheet for this section.

Make sure you complete the in-lab worksheet and turn it in to the instructor before leaving lab. Also, do not forget to look on Canvas for the post-lab worksheet and complete it before next week's lab.