Experiment 1: Introductory Experiments

Density of Matter

The density of a material is an intrinsic quantity given by $\rho = M/V$, where M is the mass of the material and V is the volume of the material. In this exercise you will use vernier calipers and the balances to measure the density of various sets of materials. Each material set includes four pieces of various sizes. Start with one of the aluminum cylinders and measure (using the vernier caliper and balance) the dimensions and the mass of the cylinder. Note, that each of the measurements must be repeated at least 3 times and by each of the students in your group. Repeat this whole procedure for all of the aluminum cylinders. Choose one other set of materials and repeat this experiment. The materials in the set include the following: maple, polypropylene, nylon, acrylic, polyurethane, phenolic, pvc, teflon, and aluminum.

Obtain an average density for aluminum from your data (remember to properly take into account errors) and create a graph of mass vs. volume. Find the tabulated value for the density of aluminum and compare to your results. Explain any difference. Repeat this for the other materials you measured. Write a brief description of the material you used. For example, describe its color, translucence, opacity, and texture.

Hooke's Law

This experiment is intentionally very basic in order to allow the student time to become acquainted with using a computer to write a laboratory report and to familiarize them with the PASCO Capstone software. Pretend you are living in the 1600's. Robert Hooke has just proposed his empirical relation for springs known as Hooke's Law,

$$F = -kx \tag{1}$$

Very simply, this means the extension or compression of a spring, x, is linearly proportional to the magnitude of the force (F) that is exerted upon it. The negative sign indicates that the direction of the restoring force F is always opposite to the direction of the extension/compression x, and the proportionality constant is k (the spring constant). You are a scientist at another university and are excitedly trying to reproduce his results. Quite frankly, you think the relation is too simple and you want to prove Hooke wrong so your name can be indelibly inscribed in every general physics book of the 21st century.

In your laboratory, you have springs, different weights, rulers, and a force sensor. You know enough about gravity to conclude that the force exerted downward by a mass is directly proportional to the mass. To measure this force, we will use the "force sensor". The force sensor can measure the pulling or pushing force exerted on it. To set it up, connect the force sensor to the 850 UNIVERSAL INTERFACE and open up the PASCO Capstone software on the computer. Locate the Tools tab and click Hardware setup, then choose the port the sensor is connected to, and select the correct sensor from the drop down menu (ask the lab instructor about using this software if you need assistance). Find th Displays tab in the far right side of the Capstone window, you can double click "digits" to view the force value or "graph" to plot the force as a function of time. Click "Record" to collect data. Note: before collecting any data, press the "zero"/tare button to set the sensor to zero.

With these materials devise an experiment that will allow you to test Hooke's Law and find the spring constant (k). Show your proposed procedure to the Lab Instructor and explain the data you plan to acquire. Include in your procedure the exact details of how you will analyze your data to test Hooke's Law. In your lab report, include a graph of Force versus Δx. What does the slope of this graph represent?

There are several questions that you should answer in your lab write-up:

1. Does Hooke's Law depend on the spring being used?

2. Does Hooke's Law hold for very large forces?

Tips To Write Laboratory Reports

The last part of this laboratory exercise will actually be done on your own. Since everyone is required to type their own laboratory reports, you will need to develop basic proficiency with: a word processor with an equation editor and a spreadsheet with graphing and at least linear regression capabilities. Openoffice.org has free programs which meet these criteria and they can be used on any operating system platform. If you prefer to use other programs of these types, that is also acceptable. The lab instructor will explain the proper lab-report format. You can find a link to a sample lab report on the Physics 123 Laboratory Manual Web page.

There are a few things that you must know to be able to efficiently write a polished laboratory report:

1. You should learn how to properly include (typeset) mathematical equations and Greek symbols.

2. You will be repeatedly required to fit your data with a best-fit straight line. You must know how to do this, including extracting the values of the slope, the y-intercept, and the "goodness-of-fit" value (R^2). R^2 ranges from 0 to 1, where 0 is a bad fit and 1 is a perfect fit. The R^2 value gives you an idea of how well the straight line represents your data points. R^2 is defined as:

$$R^2 = \frac{\sum(y_i^{fit} - \overline{y})^2}{\sum(y_i - \overline{y})^2} \tag{2}$$

   where y_i are the experimental data, y_i^{fit} are the fit values and $\overline{y} = \sum y_i/N$ is the mean of the experimental data. Note that this is not the same as drawing a line graph, which simply connects your data points with straight lines.

3. Find out how repeated calculations can be done faster using a spreadsheet. For example, if $T = \frac{1}{2}mv^2$, and you have 12 different measured values of v, learn how to make all of the calculations automatically.

4. Be careful with the number of significant figures you present in your report. This includes the data tables you present as part of your raw data and analysis. Figure out how to limit the number of significant figures or decimal places of the numbers you show.

5. Try including a graph whenever possible. Graphs are a great way of explaining your data and showing relationships you have obtained in the experiment. For example, try making a graph of F vs x for your Hooke's Law experiment, and then interpret the slope.

6. Always check your sig-figs and units in data tables and graphs and label axes correctly on your graphs.