UNIVERSITY PHYSICS

EXPERIMENT 1

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COLLIN COUNTY COMMUNITY COLLEGE

Getting to Know Data Studio

Produced by the Physics Staff at
Collin County Community College

Purpose

The purpose of this activity is to become familiar with the operation of Data Studio.

Equipment

- 1 Smart Pulley sensor (ME-9387)
- 1 1-m tall ringstand with flat base
- 1 Short aluminum bar
- 1 Right-angle clamp
- 1 Force sensor (CI-6537)
- 2 Mass hangers
- 1 Set of slotted masses
- 1 Meter stick
- 1 Roll of string
- 1 Roll of masking tape

Introduction

You will use both automated (computerized) and manual (non-computerized) instruments to perform each experiment in this course. You will use both computer sensors and manual instruments to measure different properties of objects and substances. You will analyze your measured data analytically and graphically (i.e., with equations and with graphs) and by computer analysis routines.

Each computer sensor is a transducer of some type. It produces a voltage signal that is proportional to the property being measured, and then feeds that signal into the Interface and then into the computer. The Data Studio program in the computer displays and records the value of the measured property.

Sensors are available to measure many different basic properties and derived properties (such as distance, time, speed, acceleration, rotary speed, force, pressure, brightness, frequency, temperature, and loudness).

To use Data Studio effectively, you must be familiar with the basic graphical user interface (GUI) used by computers operating under Windows. For example, you should be familiar with:

- Using windows and icons
- Using a mouse
- Opening, closing, and saving a file
- Selecting a window to make it active
- Dragging windows and icons with the mouse
- Using the scroll bars in an active window
- Using the Command Menu, the Title Bar, the Control-Menu Box, and the Minimize, Maximize, Restore, and Close buttons

Our computerized lab system uses various electronic sensors, a Model 700 Signal Interface unit, and the Data Studio program running on the computer. This program allows you to experimentally measure various basic properties, to calculate derived properties that cannot be directly measured, to display, manipulate, and analyze the measured data to obtain relationships between properties, and to obtain statistics on the precision of your measurement data.

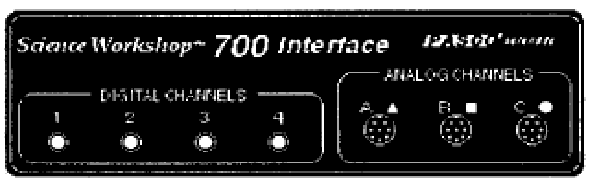
In this first experiment you will learn how to use the Data Studio sensors and program to collect and analyze data and how to report on the work you have done.

Theory

Setting up an Experiment

When you perform an automated experiment, you will measure the properties of interest with electronic sensors. The sensors are connected to the Model 700 Interface which is connected to the computer. The Data Studio computer program displays the collected data and performs the desired analysis. But it doesn't write your lab report; you have to do that yourself.

The Model 700 Interface, shown below, is already connected to the computer. It is the black box under or beside the monitor.



Digital sensors plug into the digital channels on the left side of the Interface, and analog sensors plug into the analog channels on the right side. The two types of sensor have different connectors, so it is impossible to plug a sensor into the wrong type of channel.

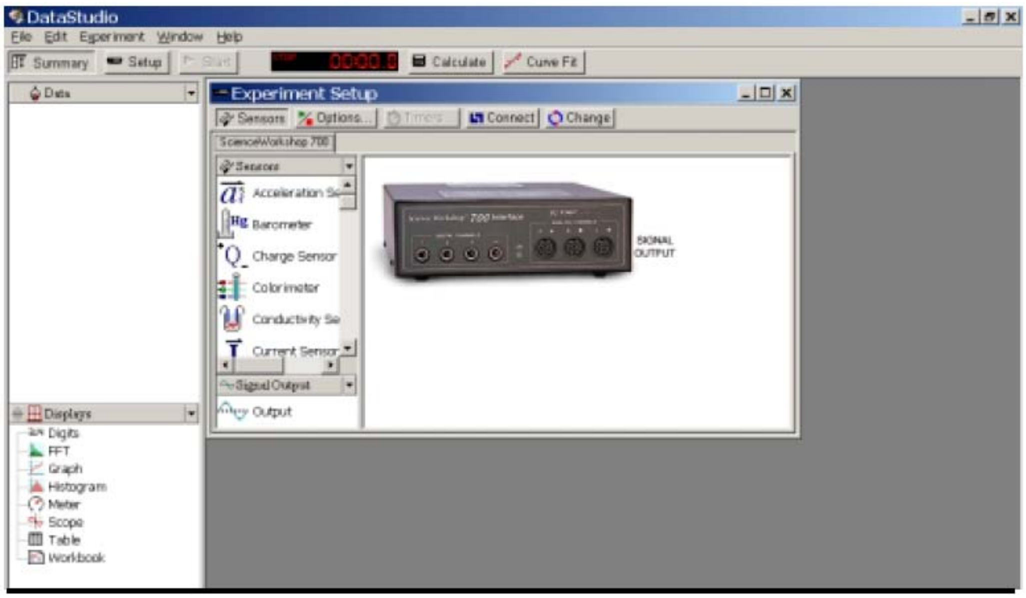
The Interface samples the output voltage signal from the sensor many times per second and feeds the resulting digital values to the Data Studio program in the computer. Data Studio then calculates the measurement values represented by the signal from the Interface and displays them on the monitor.

Data Studio can simultaneously accept samples from up to four digital sensors and up to three analog sensors. It also allows you to enter data from the keyboard to go with the data that is being collected by a sensor. For example, you might enter the sensor's position for Data Studio to use in its analysis of the data from the sensor.

Always connect the sensor(s) to the Interface ***before*** switching on the power to the equipment. Plug the cable(s) of the sensor(s) you will use (for example, the Motion sensor) into the appropriate channel socket(s) on the front of the Interface while its power is switched off.

Next, switch on the power to the computer and the Interface. When the computer completes its start-up routine, it will display the "desktop" on the monitor. Double-click on the *Data Studio* icon and the *Data Studio* window will appear and ask you how you want to use it. Click on *Create Experiment*.

The *Experiment Setup* window appears within the *Data Studio* window shown below.



The menu bar in the *Data Studio* window is similar to menu bars found in all Windows programs. Below that, Data Studio's tool bar shows buttons labeled *Summary, Setup, Start, Stop, Calculate,* and *Curve Fit*. You will learn to use these tools in this experiment.

Under the tool bar are the *Summary List* and the *Experiment Setup* window. If you have previously collected data, the *Summary List* shows that data as *Run #1, Run #2,* etc. Below that, it lists the displays that are available.

The *Experiment Setup* window shows the Model 700 Interface, the sensors that you can plug into it, and the signal output available from it. In addition, it has a button to open the *Sampling Options* window which lets you choose between manual and automated data sampling. It also has buttons to set start and stop times for automated sampling. Finally, it has buttons to let you connect Data Studio to the Model 700 Interface (if it is not already connected) or change to a different model Interface.

To create a new experiment, scroll down the list of sensors in the *Experiment Setup* window to find the sensor you plugged into the interface (for example, the Motion sensor) and double-click on it to select it. The *Motion sensor* icon appears below channels 1 and 2 of the Interface, and *Position*, *Velocity*, and *Acceleration* runs appear in the *Data List*.

Next, you select one or more displays from the Display list (for example, Graph). Now you are ready to start collecting measurement data by clicking on the Start button.

Displaying the Data

To see the data collected by a sensor, or entered from the keyboard, or calculated by Data Studio, you must select a display. Each display appears in its own window. Like windows in all programs, you can drag or size the display windows in Data Studio to suit your needs.

You may use all the displays simultaneously, or use more than one of each kind. You will use four kinds of display in Physics 2425 lab classes and six kinds in 2426 lab classes.

The *Digits* and *Meter* displays do not have a memory, i.e., they display only real-time data – they do not save a measured value after its initial display. In contrast, the *Table* and *Graph* displays not only show real-time values but continue to display all values that have been collected.

During a typical data run, more samples are collected than can be displayed in the *Table* at one time, but you can scroll down to see them all. You can rescale a *Graph* display so it will show either all the collected data or an expanded view of only a selected portion of the data.

In addition to showing data samples that you have collected, the *Table* and *Graph* displays can also provide a statistical analysis of the data. They can show the minimum, maximum, mean, and number of samples in a data run and the standard deviation of those samples. The *Graph* display can also determine a suitable equation (depending on the type of relationship) to a selected portion of the plot. This is called curve fitting.

The *Scope* display provides a real-time graph of Data Signal vs. Time; and the *FFT* display shows Data Signal vs. Frequency. You will use these displays in Physics 2426 lab classes.

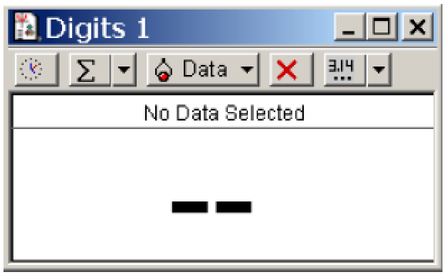
Selecting a Display

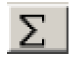
To view the data collected by any sensor in a particular display, double-click on that display icon in the Display List. Depending on the sensor you have selected, you will get either a window showing the type of display you selected or a window in which you are asked to select which sensor output you wish to display. For example, by differentiating the motion sensor's output signal, Data Studio can display velocity or acceleration rather than distance.

Digits Display

The *Digits* display (shown below) shows in a digital format values that the sensor is collecting in real time. When you stop recording data, the last measured value remains on view.

You can control many features on the display. You can show data values as they are being recorded, or show the current mean, maximum, standard deviation, or count of the data values. You can enlarge the display to fill the screen. You can open more than one *Digits* display at once – each displaying a different measurement.

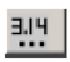


Click the *Statistics* button () to show or hide selected statistics calculations. To open the *Statistics* menu, click the down arrow button beside the *Statistics* button. On the resulting *Statistics* menu, you can specify what will be shown on the *Digits* display. You can select the Minimum, Maximum, Mean, Standard Deviation, Count, or Value being recorded. Click *Apply to All* if you have more than one *Digits* display open in the window and you want the statistic to be displayed on all of them.

While you are recording data, you can display a different statistic or the recorded values by selecting that feature on the *Statistics* menu. Only one statistic can be displayed at a time.

To change the precision of the measured values (the number of digits used to display the value) shown in the *Digits* display, click the down arrow button beside the *Settings* button.

To make the *Digits* display fill the main window, click the *Maximize* button on the display window. To change the size of the *Digits* display, hover the mouse pointer over to the edge of the display window. When the pointer changes to a double-headed arrow, click and drag the window horizontally, vertically, or diagonally until it is the desired size.

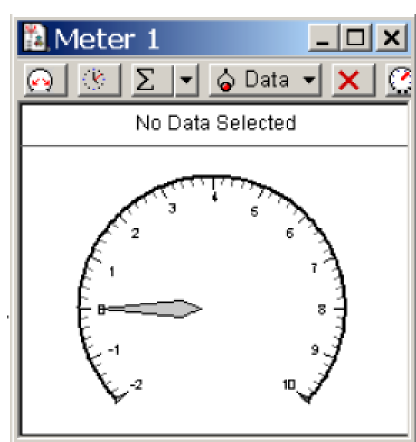
Click the *Digits Settings* button () at the right end of the toolbar to open the *Digit Settings* window. In this window, you can:

- specify the elements that will appear in the display,
- specify which tools will appear in the toolbar,
- specify whether to replace the existing measurements or to add a new *Digits* display to the window to display each new data run,
- specify how to arrange multiple *Digits* displays in the window,
- select *Apply to All* if you want the setting to apply to all *Digits* displays, or deselect *Apply to All* if you want the setting to apply only to the selected *Digits* display

You may need to resize the window in order to see all the digits.

Meter Display

The *Meter* display, shown, provides an analog indication (a pointer indicates the position on an arc) of the current measured value. When Data Studio is collecting data, the data is shown in real time on the *Meter* display. When you stop recording data, the last measured value is shown.

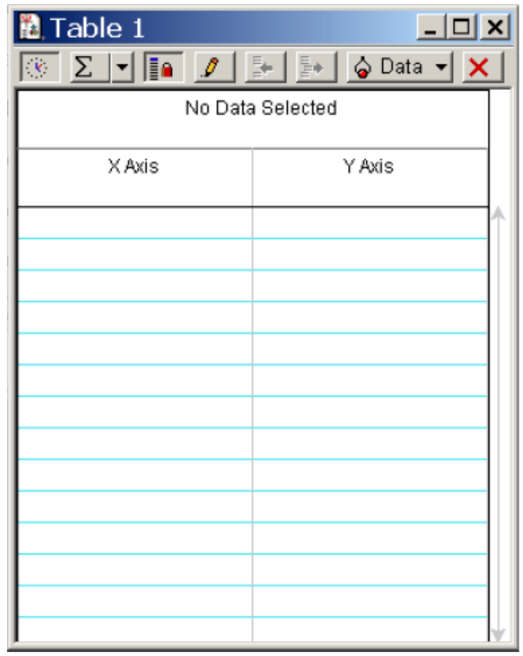


You can control many features on the *Meter* display, including showing or hiding the time, showing or hiding statistics, the legend, the font type, the toolbar, the display precision, and the display size.

With the *Meter* display, you can:

- show values as they are being recorded, or show the current mean, maximum, standard deviation, or count of the data samples,
- size the display to fit the screen,
- open more than one *Meter* display at once — each displaying a different measurement,
- change the minimum and maximum settings of the scale,
- change the sweep range of the scale

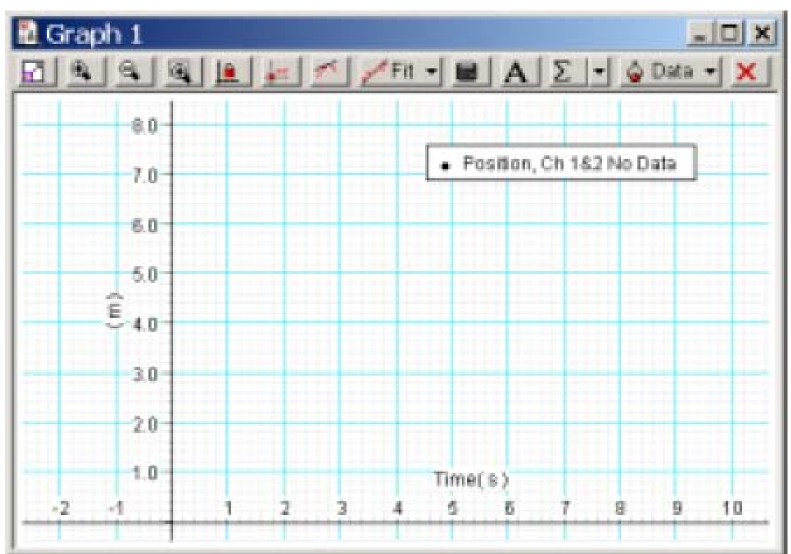
Table Display



The *Table* display, shown, is like a typical data table:

- it resembles a spreadsheet with rows and columns,
- it records all the data sampled so you can scroll up and down to see it,
- it displays as many as ten columns (based on screen space),
- it performs a statistical analysis of the data sampled (providing maximum, minimum, and mean values, and standard deviation), and
- it shows the time associated with each sample.

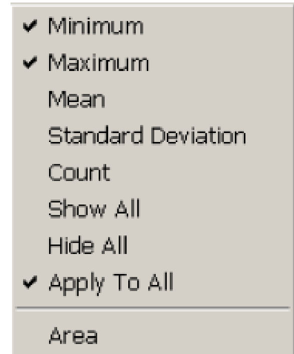
Graph Display



The *Graph* display is even more versatile than the *Table* display. It plots values of any dependent variable on the ordinate and values of any independent variable on the abscissa. In the example shown, Position is plotted against Time. The *Graph* display can show relationships between any two variables.

A single *Graph* display window can show multiple plots. For example, you can use the *Graph* display window to show position versus time data, velocity versus time data, and/or acceleration versus time data for a mass oscillating on a spring or for a freely falling object. The origin of the graph will be the intersection of the minimum values on the two scales.

Graphing Tools



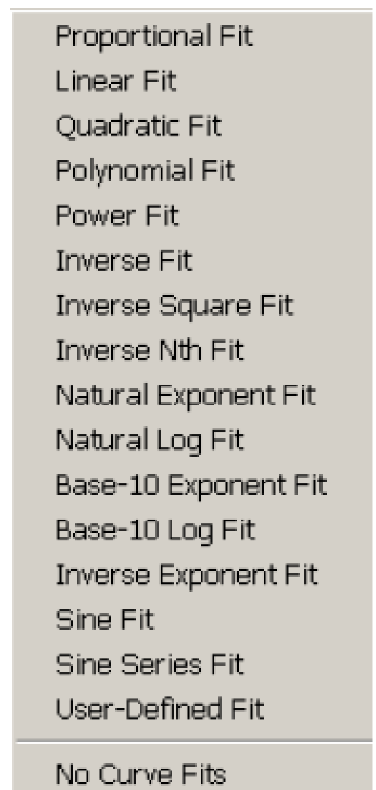
The buttons in the *Graph* display's toolbar provide tools to help you analyze the graph. Hold the mouse cursor over each button for two seconds to see the name of the button.

Click the down arrow to the right of the *Statistics* button to open the list of statistical tools, shown below. Choose the statistics you want from the list.

By default, the statistics being displayed apply to the entire graph. To display statistics for a specific portion of the curve, drag a rectangle to select the portion you want to examine.

Click the *Fit* button (

) to see the list of analytical relationships (mathematical formulas) for the plotted data, shown to the right. Each type of curve fit corresponds to a particular form of equation between *y* and *x*.



Data studio calculates the values of the coefficients (*a*1*, a*2*, a*3, etc.) that yield the best fit of the selected equation to the plotted data points.

When you select *Area* in the *Statistics* menu, the program calculates and displays the value of the area under the selected portion of the plotted curve (the integral of the dependent variable).

When you select the *Slope* tool, the program calculates and displays the value of the slope of the curve at the selected point (the derivative of the dependent variable).

Clicking the *Smart Tool* button lets you read the *x* and *y* coordinates of any data point. The cursor becomes a large plus sign that extends vertically and horizontally to both axes. The coordinates of the cursor appear in the label areas of each axis.

Click the *Magnifier* buttons to expand or contract a particular section of the graph. The cursor becomes a magnifying glass with a plus or a minus sign. Use the magnifier to drag a rectangle around the part of the graph you want to enlarge.

The default scale factors may be well above or well below the values needed to optimally display the recorded data. If so, click the *Autoscale* button to automatically rescale both axes so the collected data will fill the available space in the graph.

<u>Help in Using Data Studio</u>

If you ever are not sure what to do next or how to do something, click the *Help* menu in Data Studio. The four main categories under *Help* are:

Setup Information: Setting up to record data; Setting up a sensor; Displaying data.

Display Information: *Digits* display; *FFT* display; *Graph* display; *Histogram* display; *Meter* display; *Scope* display; *Table* display; *Workbook* display.

Procedure Information: Adding data manually; Calculate function; Creating a curve fit; Customizing DataStudio; Exporting data; Exporting pictures or displays; Manual sampling; Importing data; Manually triggering data recording; Modeling data; Printing; Remote data logging; Using the Signal Generator; Using the Workbook

Help and Troubleshooting Information: How to use the online help system; Getting help from Pasco; New features of DataStudio (compared to the old ScienceWorkshop program that it replaces); Hardware Installation; Troubleshooting hardware installation.

Procedure

To become familiar with Data Studio and its sensors, you will take measurements with one digital and one analog sensor and will analyze your measured data in various ways.

With the Computer and Interface switched off, connect the following two sensors to the Interface:

1. **Smart Pulley sensor**. Plug it into Digital Channel 1
2. **Force sensor**. Plug it into Analog Channel A.

A. Smart Pulley Sensor

This sensor consists of a low-friction pulley with a built-in infrared beam passing through its spokes to a detector on the other side. The sensor's output signal drops from 1 volt to 0 volt whenever a spoke blocks the beam. Data Studio measures the brief time interval between spokes as the pulley rotates.

Knowing the number of spokes in the pulley, Data Studio calculates the time interval for one complete rotation of the pulley (its period T). The inverse of T is the pulley's rotary frequency in rotations/sec ($f = 1/T$). Knowing the pulley's radius r, Data Studio then calculates the linear speed of the string passing over the pulley ($v = 2\pi r/T$).

1. Select *File* then *New Activity* from the menu bar. Select *Create Experiment*.
2. In the Sensors list, scroll down to Smart Pulley and double-click it. In the Experiment Setup window, double-click on the *Smart Pulley* icon. In the Sensor Properties window, click the *Measurement* tab. Select *Acceleration, Ch 1 (m/s/s)* and *Velocity, Ch 1 (m/s)*, and click *OK*.
3. In the Displays list, double-click on Graph, select *Velocity*, and click *OK*. This is ***Graph 1***. Then double-click on Graph again, select *Acceleration*, and click *OK*. This is ***Graph 2***. Drag Graph 2 directly below Graph 1.
4. Using the right-angle clamp, attach the smart pulley to the top of the ring-stand. Be careful not to unplug the smart pulley while doing this.

5. Cut a length of string about 1.5 meters long. Pass the string over the pulley and tie small loops in both ends. Hang mass hangers from both loops. Adjust the pulley height so that one hanger is a little bit below the pulley when the other hanger rests on the floor.
6. Stack 195 g of small-diameter slotted masses (not the larger-diameter ones) on the lower hanger. This is mass m_1. While holding your finger on the pulley to prevent it from rotating, stack 205 g on the upper hanger. This is mass m_2. Record the values of masses m_1 and m_2 (including the mass of the mass hangers) in Table 1.1.
7. Click *Start* and release the pulley. Observe the two graphs while the pulley is moving. If any masses fall off of there hanger while moving, stop the measurement, replace any masses that fall off the hangers, and start over.
8. When the heavier mass hits the floor, click the stop button. Click the *Scale to fit* button () on both graphs, then drag a rectangle to select the linear portion of the plotted line in each graph.
9. Click the down arrow to the right of the *Fit* button on the *Velocity* graph (*Graph 1*) and select *Linear Fit*. Data Studio writes a linear equation in its general form: $y = a_1 + a_2x$ and calculates the values of a_1 and a_2 for which the equation best fits the selected portion of the *Velocity* graph. In the *Velocity* graph, the coefficient a_2 (or slope) is the acceleration of the masses.
10. Next, Click the down arrow to the right of the *Fit* button on the *Acceleration* graph (*Graph 2*) and select *Linear Fit*. In the *Acceleration* graph, the coefficient a_1 (or y intercept) is the acceleration of the masses.
11. Record the value of a_2 from *Graph 1* and the value of a_1 from *Graph 2* in Table 1.1. Print the two graphs (*Velocity* and *Acceleration*) from Data Studio (be sure everyone in your group gets a copy).
12. Using the values of m_1 and m_2 and Newton's second law, *calculate* the value of the acceleration. Record this value in Table 1.1.
13. Calculate the percent difference between your calculated value of acceleration and each of the measured values of acceleration from your graphs. Record these percent differences in Table 1.1.
14. Remove the pulley and replace it with the short bar. Discard the string and set the pulley, mass hangers, and masses aside.

B. Force Sensor

This sensor is a small strain gauge that creates a voltage that is proportional to the applied force. Pulling on the hook creates a voltage of one polarity; pushing on it creates a voltage of the opposite polarity.

1. Clamp the force sensor to the short bar so that it hangs vertically, and hang the 1-kg mass on its hook.
2. Select *File* then *New Activity* from the menu bar. Select *Create Experiment*.
3. In the Sensors list, scroll down to *Force Sensor*, not Force Sensor (Student), and double-click it. In the Experiment Setup window, double-click on the *Force Sensor* icon. In the Sensor Properties window, click the *Measurement* tab. Select *Force*, Ch A (N). Do NOT click *OK*.
4. Click the *Calibration* tab. In the Sensitivity window, select *Low* (1×). Enter 9.800 as the Value under *High Point* and click the *Take Reading* button. Then remove the mass

to let the sensor hang with its hook empty. Enter 0.00 as the Value under *Low Point* and click the *Take Reading* button. Then click *OK*. The 1-kg mass has a weight of 9.80 N, so this two-point calibration lets Data Studio record the two voltages from the sensor that correspond to pulling forces of 9.8 N and 0.0 N. It can then use this linear relationship between force and voltage to calculate the force corresponding to any other voltage the sensor feeds to it.

5. In the Displays list, double-click on *Digits* and then on *Graph*. Arrange the *Graph* window below the *Digits* window on the screen.
6. You will now weigh a spiral notebook (if nobody in your group has a spiral notebook, ask to borrow one from another group). To weigh your notebook, loop a piece of string through the spiral binder and tie the two ends of the string together in a loop. Using this loop, hang the notebook on the sensor's hook.
7. Click the start button. After about 5 seconds, click the stop button. Record the reading, including units, from the *Digits* display in Table 1.2. Highlight the data in the Graph display. Click the down arrow on the statistics button and select *Show All*. Record the *Mean* value in Table 1.2. Print the graph from Data Studio (be sure everyone in your group gets a copy).
8. Weigh the notebook using a manually operated mass balance. Record the book's mass from this instrument in Table 1.2.
9. Remove the short rod from the ring-stand. One team member will hold the rod with the force sensor horizontal. Another member will grasp the hook so the two members can pull and push on the sensor.
10. Delete the previous data run, and delete the digits display (leave the graph display). Click on *Start*. The two members will pull and push on the sensor while watching the *Graph 2* display. Try to make the graph of force vs. time resemble a sine wave.
11. Push and Pull once every second for about 5 seconds; then click *Stop*. Print the resulting graph (be sure everyone in your group gets a copy).