ScienceWorkshop®

General Science Labs with Computers

Student Workbook

General Science experiments using the *ScienceWorkshop*® or DataStudio™ program and interfaces from PASCO scientific®

PASCO® scientific

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General Science Labs with Computers: Student Workbook
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Edited by David A. Griffith.

Contents

Physical Science

Preface

I. Overview of General Science Labs with Computers: Student Workbook (CI-7041A)

This manual has thirty activities in the following areas: scientific method, life science, earth science, and physical science. Most of these activities can be done with the sensors that are included in the General Science Bundles for the *ScienceWorkshop* 500 Interface.

Each activity has the following parts:

Equipment List	Procedure
Purpose (What Do You Think?)	Analyzing the Data
Background	Lab Report
Safety Reminders	

Equipment List

The list includes PASCO equipment (in **bold** font), other equipment, consumables (if any), and quantities.

Purpose (What Do You Think?)

The purpose includes a question for the student to answer in the Lab Report section.

Background

This section provides information about the concepts in the activity.

Safety Reminders

General safety reminders include following instructions for using the equipment and wearing protective gear (e.g., goggles, gloves, apron).

Procedure

The procedure is a *basic outline* of how to get started, how to set up equipment, and how to use *DataStudio* or *ScienceWorkshop* to record data. The procedure has four sections:

- Set up the interface.
- Open the *DataStudio* or *ScienceWorkshop* file.
- Set up the equipment.
- Do the experiment (record the data).

Analyzing the Data

This section outlines methods and makes suggestions for using built-in analysis tools in the software to analyze the data.

Lab Report

The Lab Report section is where students can record their data and answer the questions. The Student Workbook pages are perforated so the student can easily remove the Lab Report pages.

II. Safety Reminders

PASCO scientific assumes no responsibility or liability for use of the equipment, materials, or descriptions in this book.

- Take safety precautions to protect yourself during all activities in the lab, and especially during the lab activities in this manual.
- It is not possible to include every safety precaution or warning! Please use extra care when setting up and using the equipment.
- Be sure to wear protective gear such as goggles or safety glasses to protect your eyes and face.
- Be careful around open flames and when using a hot plate.
- Use tongs when handling anything hot. Before touching something that you think might be hot, place the back of your hand near the object to sense its temperature.
- If you have a question, please ask for help.

SAFETY REMINDERS

- Wear protective gear.
- Follow directions for using the equipment.

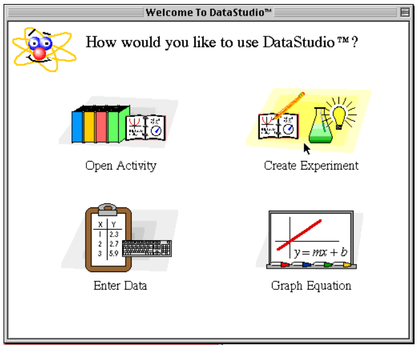
III. Acknowledgements

The editor thanks all of the people who helped in writing, revising or editing the activities in this manual.

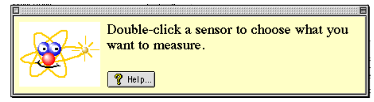
October 28, 1999.

Quick Reference Guide for *DataStudio*

Create an Experiment

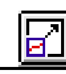
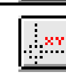
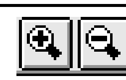
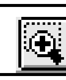
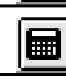
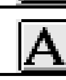
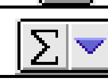
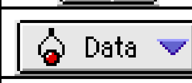
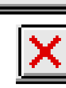
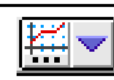


(1) Double-click a sensor.

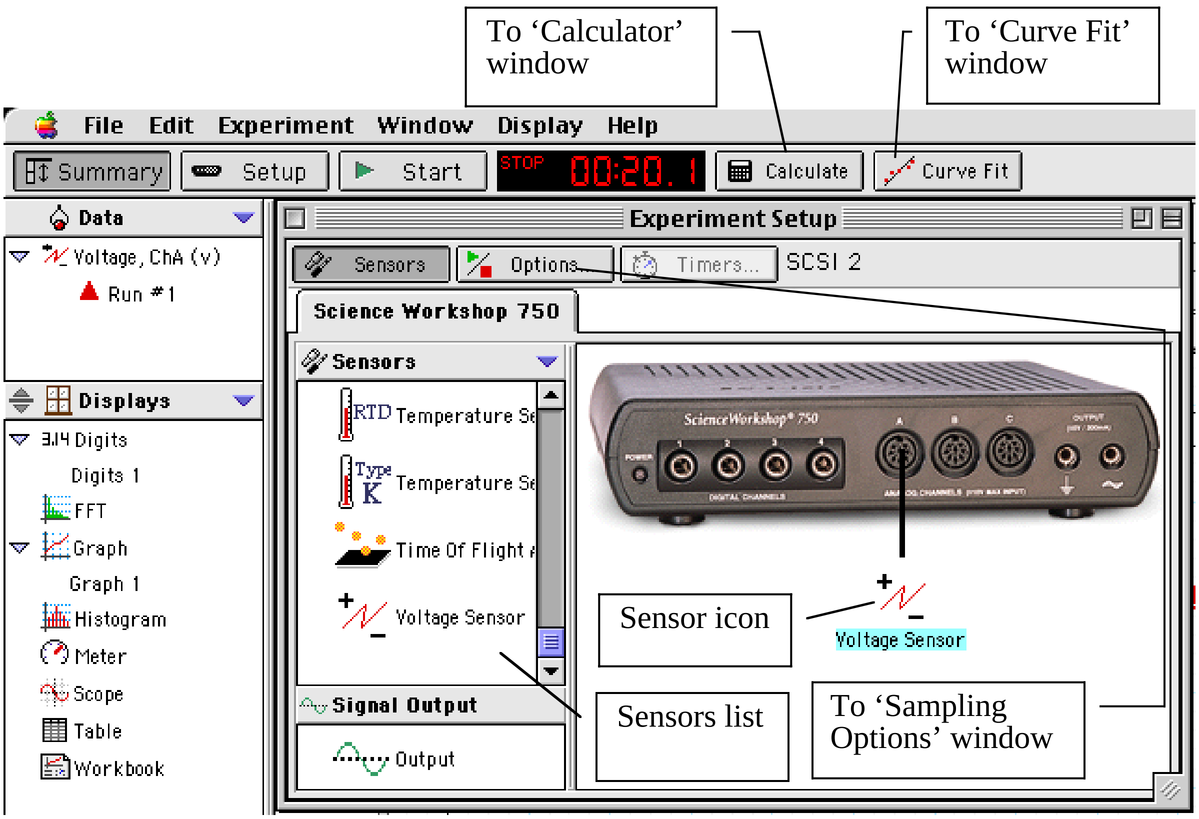


(2) Double-click a display.

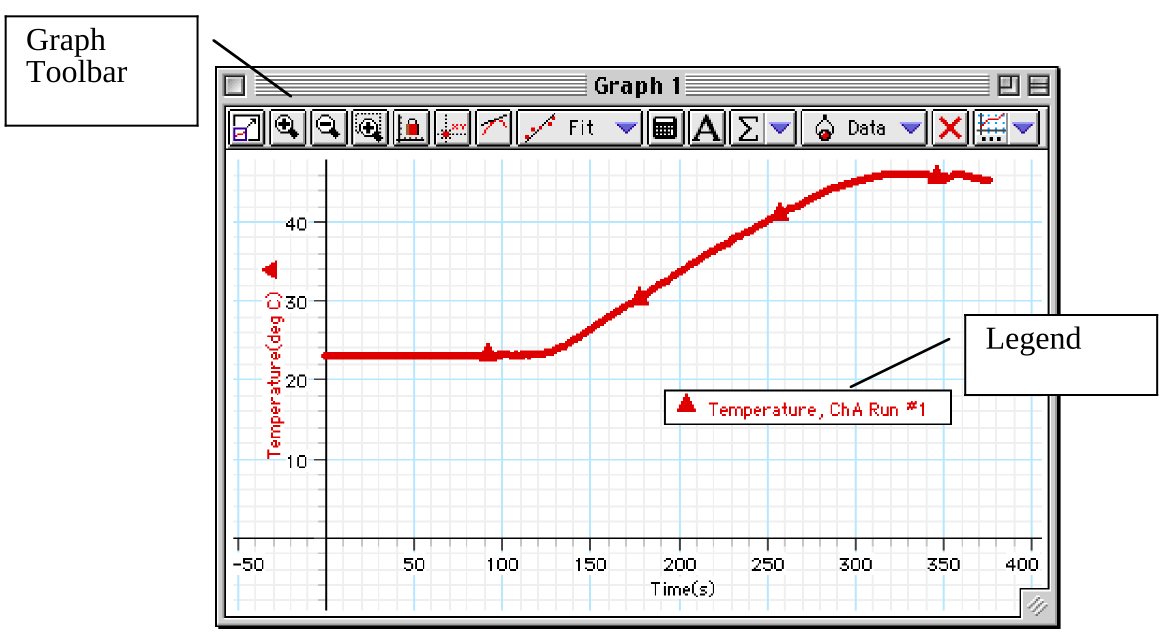
What You Want To Do	How You Do It	Button
Start recording data	Click the ‘Start’ button or select ‘Start Data’ on the Experiment menu (or on the keyboard press CTRL - R (Windows) or Command - R (Mac))	
Stop recording (or monitoring) data	Click the ‘Stop’ button or select ‘Stop Data’ on the Experiment menu (or on the keyboard press CTRL - . (period) (Win) or Command - . (Mac))	
Start monitoring data	Select ‘Monitor Data’on the Experiment menu (or on the keyboard press CTRL - M (Win) or Command - M (Mac))	**none**

On the Graph Display	In the Graph Toolbar	Button
Re-scale the data so it fills the Graph display window	Click the ‘Scale to Fit’ button.	
Pinpoint the x- and y-coordinate values on the Graph display	Click the ‘Smart Tool’ button. The coordinates appear next to the ‘Smart Tool’.	
‘Zoom In’ or ‘Zoom Out’	Click the ‘Zoom In’ or ‘Zoom Out’ buttons.	
Magnify a selected portion of the plotted data	Click the ‘Zoom Select’ button and drag across the data section be to magnified.	
Create a Calculation	Click the ‘Calculate’ button	
Add a text note to the Graph	Click the ‘Note’ button.	
Select from the Statistics menu	Click the Statistics menu button	
Add or remove a data run	Click the ‘Add/Remove Data’ menu button	
Delete something	Click the ‘Delete’ button	
Select Graph settings	Click the ‘Settings’ menu button	

Experiment Setup Window



Graph Display



Instructions – Using the Interface and *DataStudio*

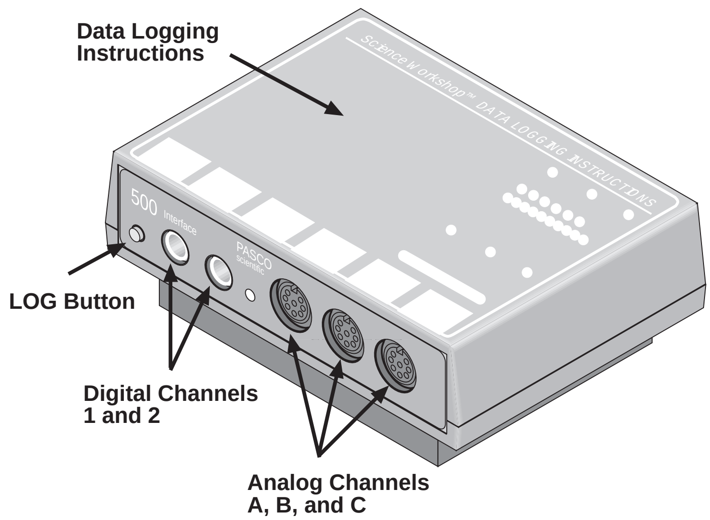
There are several features that make *DataStudio* a unique and powerful teaching tool for science and math. Section #1 covers the mechanics of the interface. Section #2 covers setting up an experiment with the software. Section #3 covers data analysis in more detail.

Hint: Working at a computer with *DataStudio* up and running while reading these instructions will bring a "hands-on" experience to the user and enhance the learning process.

Section # 1: ScienceWorkshop 500 Interface

Data Logging with the *ScienceWorkshop* 500 Interface Box

If you want to disconnect the interface box and use it for data logging, be sure to install four AA batteries in the bottom of the interface.



After you have set up an experiment in *DataStudio*, click the 'Logging' button in the Experiment Setup window in the software. Follow the instructions about saving your experiment. Disconnect the interface from the computer and the power supply. (Make sure that the switch on the back of the interface is in the ON position.)

After you have disconnected for logging, use the **LOG button** when you want to record data. Press the Log button once to begin data collection, and press it a second time to end that data run. Repeat this sequence to collect more sets of data points that will be called RUN #2, RUN #3, etc

Caution: In the remote data-logging mode, the ON switch at the back of the box must remain on at all times. Loss of power will result in loss of data.

After you have collected data, reconnect the interface to the computer and the power supply.

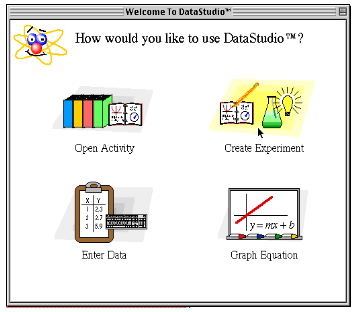
Click the 'Connect' button in the Experiment Setup window in the software. Your data will download automatically.

The **green LED (light-emitting diode)** on the front of the interface box indicates the mode of the interface box. A green light indicates that the power is ON. When you disconnect the interface for remote data logging the light will flash slowly when in the sleep mode and rapidly when you are collecting data. (Refer to the label on the top of the interface for details).
The **Analog Channels** allow up to three analog sensors to be plugged into the *500* interface. You can plug in an analog sensor's DIN plug in only one way. The Temperature Sensor is an example of an analog sensor.
The **Digital Channels** allow one or two digital sensors to be plugged into the *500* interface. The Photogate and Motion Sensor are examples of digital sensors. For example, you can connect two Photogates or one Motion Sensor to a *500* interface.

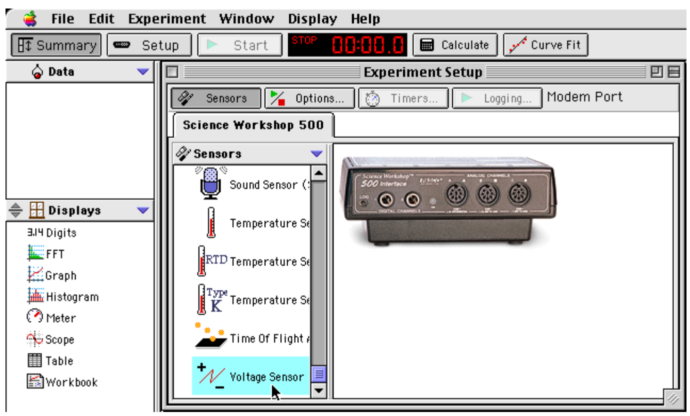
Section #2: Setting Up Your Own Experiment in DataStudio

The Summary List and the Setup Window

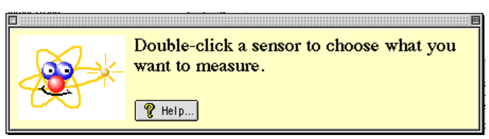
Start *DataStudio*. In the 'Welcome to DataStudio™' window, click 'Create Experiment'.



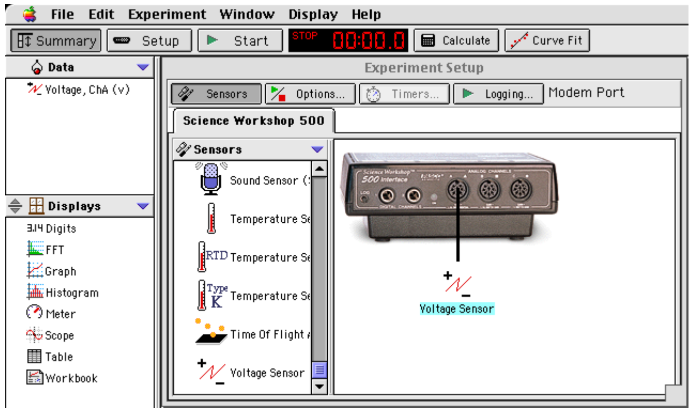
The first step to becoming proficient with *DataStudio* is to understand the Summary List and the Experiment Setup window. The Summary List shows runs of data (under 'Data') and the available displays (under 'Displays'). The Experiment Setup window shows the list of sensors (under 'Sensors') and the interface that is connected.



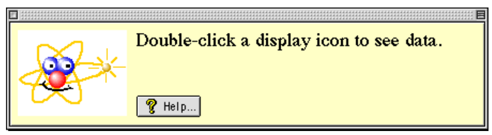
Select a sensor. The sensors are listed by name. Scroll through the list to find the 'Voltage Sensor', and then double-click the sensor to select it.



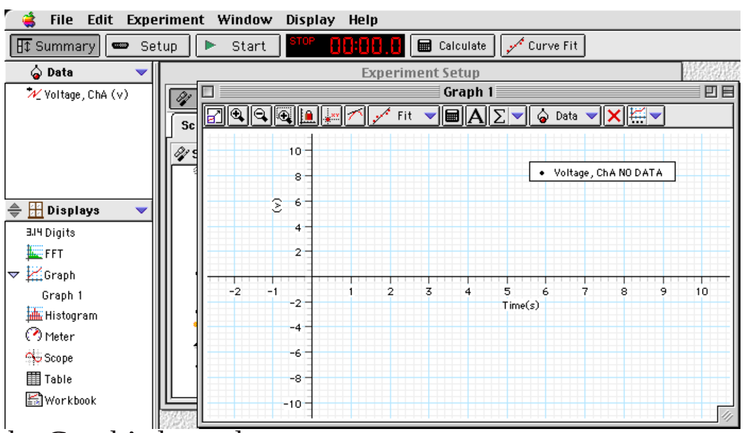
The Voltage Sensor icon appears below Channel A of the interface, and ‘Voltage, ChA (v)’ appears in the Data list.



Now, select a display. Double-click ‘Graph’ in the Displays list.



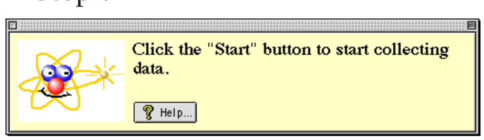
Graph 1 opens, and ‘Graph 1’ appears in the Displays list. Also, ‘Voltage, ChA NO DATA’



appears in the Graph’s legend.

Finally, click the ‘Start’ button () to begin recording data.

When you are finished, click ‘Stop’.

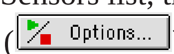


The Menu Bar 

The **menu bar** at the top of the Experiment Setup window is very similar to menus bars found in Macintosh® and Windows® programs.

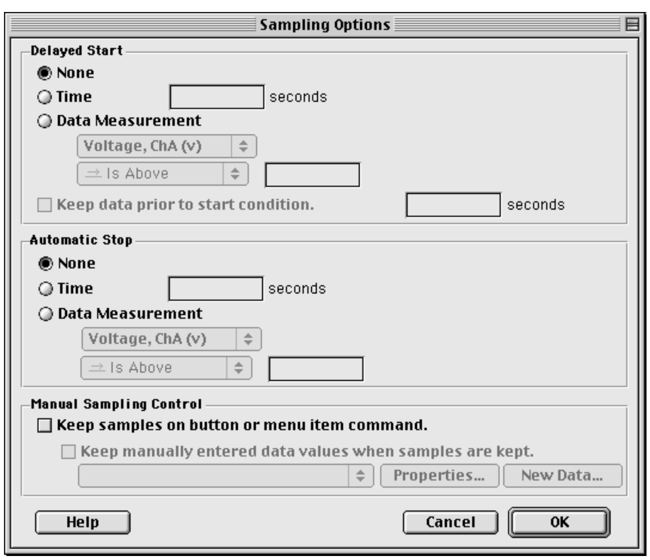
- Use the **File** menu to make a new activity, open an activity, save an activity, save an activity with a specific filename or in a specific location, import data, export data, select options (for saving *to* or opening *from* a particular directory), setup the page for printing, print, or quit.
- Use the **Edit** menu to undo, cut, copy, paste, delete, or select all.
- Use the **Experiment** menu to control the data collection, delete the last data run, disconnect for data logging or re-connect after data logging, set sampling options, open a new empty data table, or add a display.
- Use the **Window** menu to close, minimize, or maximize a window, to tile or cascade windows, or to select a window so it 'pops-to-the-top'.
- Use the **Display** menu to export data or a picture of a display or to activate any of the buttons in a display's toolbar.
- Use the **Help** menu to open the online help files, see the most recent help message, turn on or turn off the tips and confirmation windows, or change the license key.

Features of the Experiment Setup Window

In addition to the Sensors list, the Experiment Setup window has a button to open the 'Sampling Options' window (
), a button to open the 'Timers' window (
) (for use with Photogates), and a 'Logging' button (
) for use when you disconnect the interface for data logging.

Note: After you click the 'Logging' button, a 'Connect' button (
) appears. If you disconnect for data logging and then re-connect after collecting data, click the 'Connect' button after you re-connect the interface to the computer and power supply.

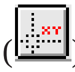
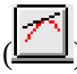
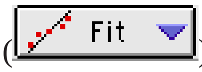
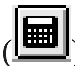
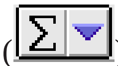
Use the 'Sampling Options' window to set a 'Delayed Start', an 'Automatic Stop' or to set the 'Manual Sampling Control'.

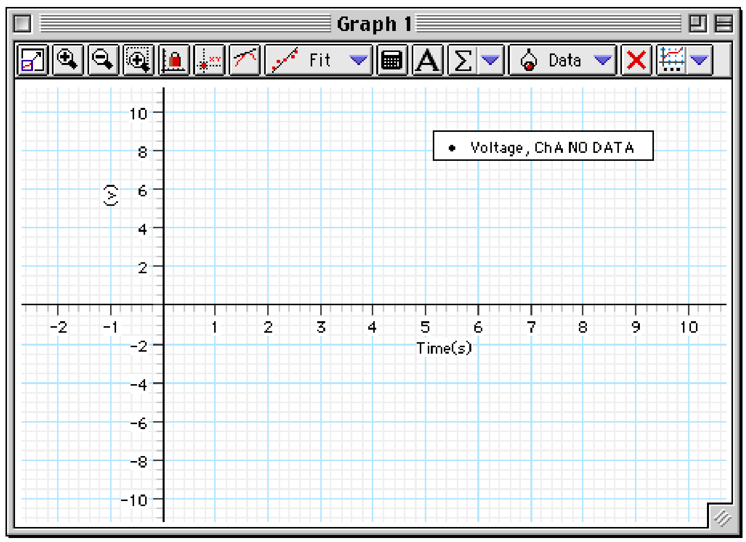


Section #3: Data Analysis

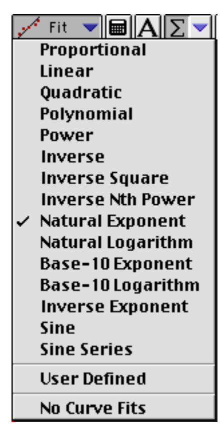
DataStudio offers several ways to analyze data:

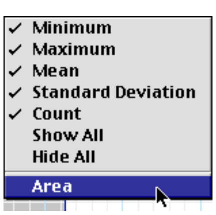
- Use the built-in analysis tools in the Graph display toolbar
- Use the 'Calculator' to create calculations based on your measured data or on a range of numbers that you select.
- Use the 'Curve Fit' to compare your data to mathematical models.

In the **Graph display toolbar**, the built-in analysis tools include the 'Smart Tool' button (), the 'Slope Tool' button (), the 'Fit' menu button (), the 'Calculate' button (), and the 'Statistics' menu button ().



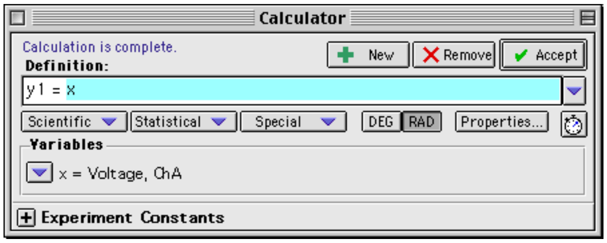
- Use the 'Smart Tool' to see the coordinates of any point.
- Use the 'Slope Tool' to see the slope of a line tangent to a point on a curve.
- Use the 'Fit' menu button to select a mathematical model.
- Use the 'Calculate' button to create a calculation on the data in your Graph.
- Use the 'Statistics' menu button to select basic statistics such as 'Minimum' or 'Maximum' or to find the area under a curve.



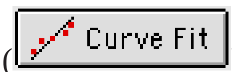


Click the 'Calculate' button in the main toolbar (

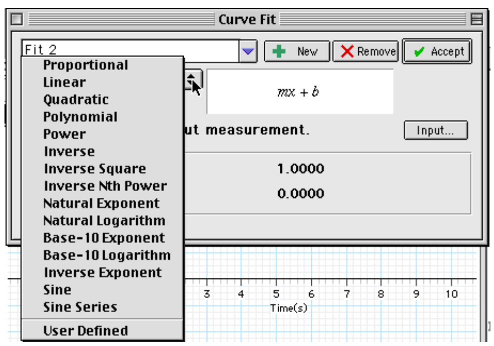
) to open the '**Calculator**' window:



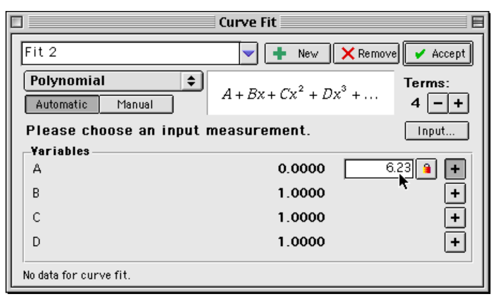
Use the 'Definition:' area to create your own calculation, or use the 'Scientific', 'Statistical', or 'Special' menus to select a specific calculation to apply to your data. After you have created the calculation, click 'Accept'. Your calculation will appear in the Data list. You can drag your calculation to a Graph display, for example

Click the 'Curve Fit' button in the main toolbar (

) to open the **'Curve Fit'** window. Click the 'New' button.



Select a mathematical model, or select 'User Defined' to create your own.



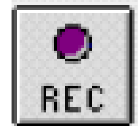
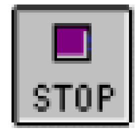
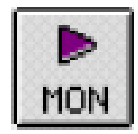
You can enter values for the coefficients or 'lock' a coefficient. After you have created the mathematical model, click 'Accept'. Your curve fit will appear in the Data list. You can drag your curve fit to a Graph display, for example.

Online Help

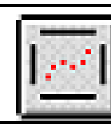
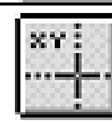
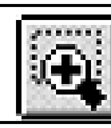
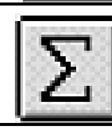
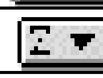
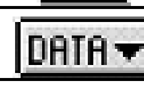
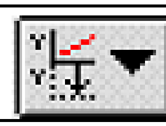
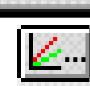
Click 'Contents' or 'Search…' in the Help menu to open the online help file. You can use the online help file to learn about any button, icon, menu, control, function or feature of the program.

Quick Reference Guide for *ScienceWorkshop*

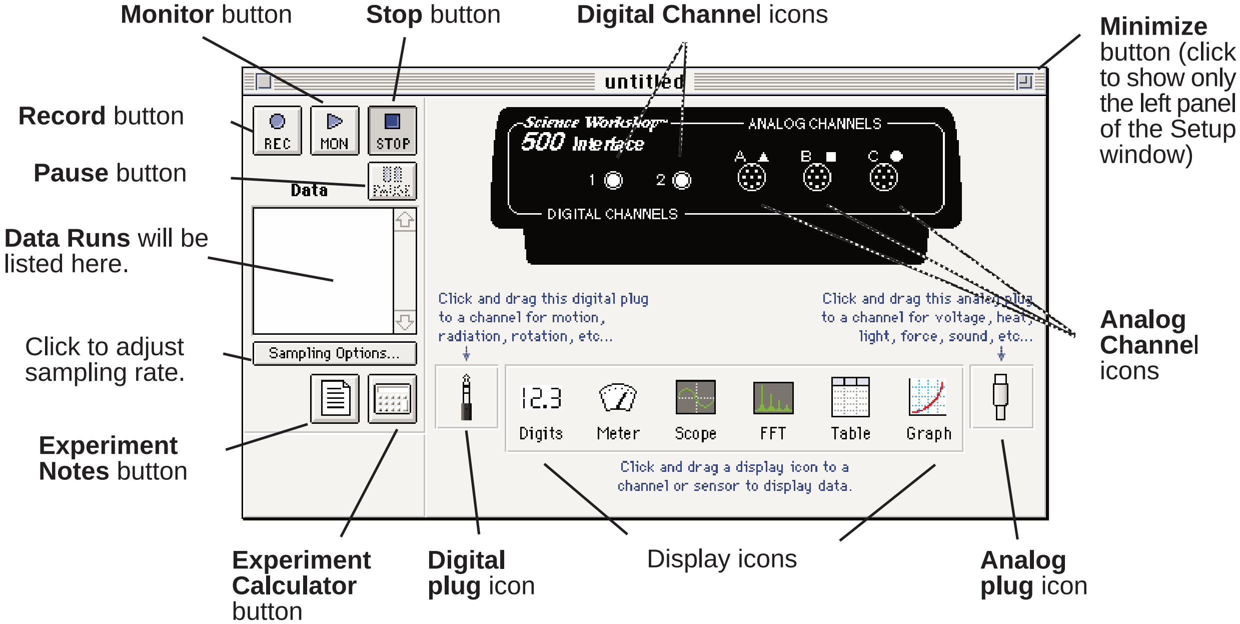
In the Experiment Setup Window:

What You Want To Do To	**How You Do It**	**What the Button Looks Like**
Begin recording data	Click the Record (REC) button or select Record on the Experiment menu (or on the keyboard press CTRL - R (Windows) or Command - R (Mac))	
Stop recording (or monitoring) data	Click the Stop (STOP) button or select Stop on the Experiment menu (or on the keyboard press CTRL - . (period) (Win) or Command - . (Mac))	
Begin monitoring data	Click the Monitor (MON) button or select Monitor on the Experiment menu (or on the keyboard press CTRL - M (Win) or Command - M (Mac))	

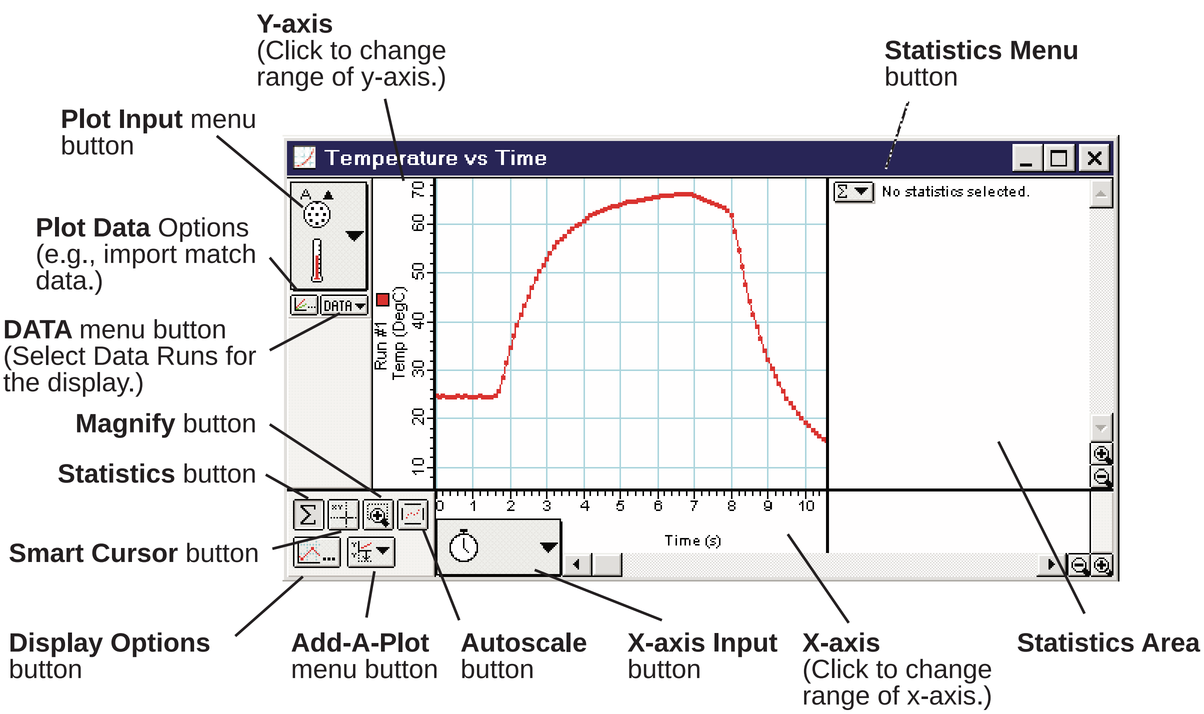
On the Graph Display:

Re-scale the data so it fills the Graph display window	Click the Graph display and click the Autoscale button	
Pinpoint the x- and y-coordinate values on the Graph display	Click the Smart Cursor button and move the cross hairs onto the graph (the exact values for the coordinates will appear next to each axis label)	
Magnify a selected portion of the plotted data	Click the Magnify button, and drag across the data section be to magnified	
Activate the Statistics Menu	Click the Statistics button	
Open the Statistics Menu	Click the Statistics Menu button	
See a list of all your Data Runs	Click the Data button	
Select Data Runs for display	Click the Run # in the Data menu (Shift-click to select more than one run)	
Add another plot to your Graph display	Click the Add-A-Plot button and select the desired input from the pop-up menu	
Import match data and plot it on the Graph display	Copy the match data to the clipboard, click the Plot Data Options button, and click Paste, OK, OK	

Experiment Setup Window



Graph Display



Instructions – Using *ScienceWorkshop®*

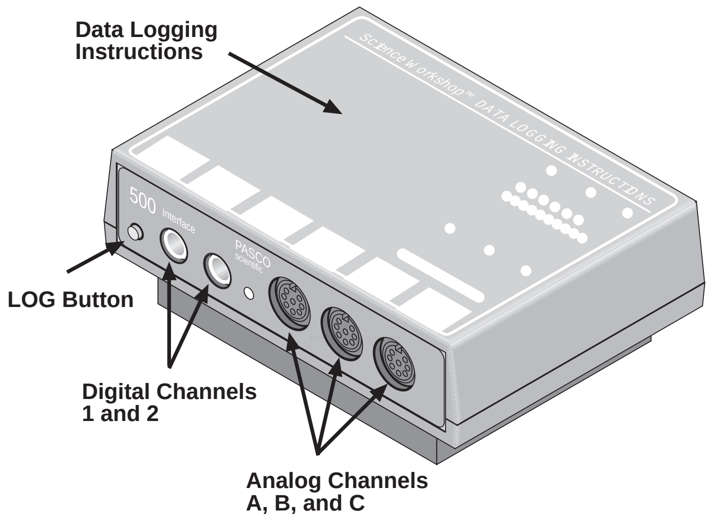
There are several features that make *ScienceWorkshop* a unique and powerful teaching tool for science and math. Section #1 covers the mechanics of the software and hardware. Section #2 covers the data analysis tools in more detail.

Hint: Working at a computer with *ScienceWorkshop* up and running while reading these instructions will bring a "hands-on" experience to the user and enhance the learning process. You should keep the *Quick Reference Guide for ScienceWorkshop* available as a reference.

Section # 1: Experiment Setup

The *ScienceWorkshop* 500 Interface Box

Use the **LOG button** when you want to disconnect the interface from the computer and take it into the field for data collection. Press it once to begin data collection, and press it a second time to end that data run. Repeat this sequence to collect more sets of data points that will be called RUN #2, RUN #3, etc. If you want to disconnect the interface box from the power supply, be sure to install four AA batteries in the bottom of the interface. (Make sure that the switch on the back of the interface is in the ON position.)

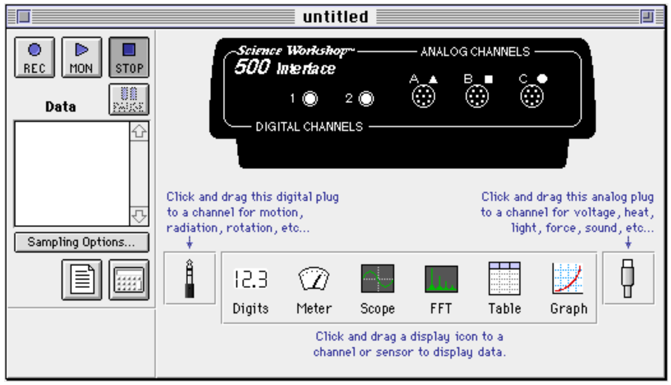


Caution: In the remote data logging mode, the ON switch at the back of the box must remain on at all times. Loss of power will result in loss of data.

The **green LED (light-emitting diode)** on the front of the interface box indicates the mode of the interface box. A green light indicates that the power is ON. When you disconnect the interface for remote data logging the light will flash slowly when in the sleep mode and rapidly when you are collecting data. (Refer to the label on the top of the interface for details).
The **Analog Channels** allow up to three analog sensors to be plugged into the *500* interface. You can plug in an analog sensor's DIN plug in only one way. The Temperature Sensor is an example of an analog sensor.
The **Digital Channels** allow one or two digital sensors to be plugged into the *500* interface. The Photogate and Motion Sensor are examples of digital sensors. For example, you can connect two Photogates or one Motion Sensor to a *500* interface.

The Experiment Setup Window

The first step to becoming proficient with *ScienceWorkshop* is to understand the various icon and buttons in the **Experiment Setup** window. The window is automatically displayed whenever a new *ScienceWorkshop* file is opened. If you get a “Can’t find interface box” message, the interface is either missing or not properly connected. Be sure that the power to the interface box is ON and that the connector cables are secure.



The Menu Bar

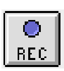
The **menu bar** at the top of the Experiment Setup window is very similar to menus bars found in Macintosh® and Windows® programs.

- Use the **File** menu to open, close, save, print, and import data.
- Use the **Edit** menu to copy, cut, clear, and paste data or runs of data.
- Use the **Experiment** menu to control the data collection.

  You can also use the Experiment menu to **Record**, **Monitor**, **Pause,** or **Stop** data collection (as if you had used the buttons in the Experiment Setup window). You can use this menu to access the sampling options, disconnect/connect (for remote data logging), display the Experiment Setup window, or go to the Experiment Notes and Calculator windows.

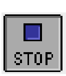
- Use the **Display** menu to select any of the six display windows (either to set up a new display or toggle to a display already in use).

Features of the Experiment Setup Window

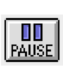


The **Record button** is in the top left corner of the Experiment Setup window. Press this button to collect data and store the data in memory. The flashing bar below the button shows when *ScienceWorkshop* is collecting data.

The M**onitor Data button** is next to the **Record** button. Press this button to collect and display data in a *view* mode only. None of the data are saved in memory. For example, use this feature when you want to check to see if a sensor is working properly, and also when viewing data in the Scope display.



Press the **Stop button** to stop data collection in both the record and monitor modes.

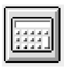


Press the **Pause button** to temporarily interrupt data collection. Press it again when you want to continue collecting data.

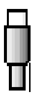
Press the **Sampling Option button** to open a window where you can select the Periodic Samples rate, the Start and Stop Conditions, and Keyboard Sampling. The default Periodic Samples rate is 10 samples per second (10 Hz) for an analog sensor and 10,000 samples per second for a digital sensor. You can vary the Periodic Samples rate from 20,000 Hz (Fast) to 3600 seconds (Slow).

Suggested Periodic Sampling rates for common measurements:

Temperature Sensor	2 – 10 Hz
Light Sensor	10 Hz
Voltage Sensor	10 Hz

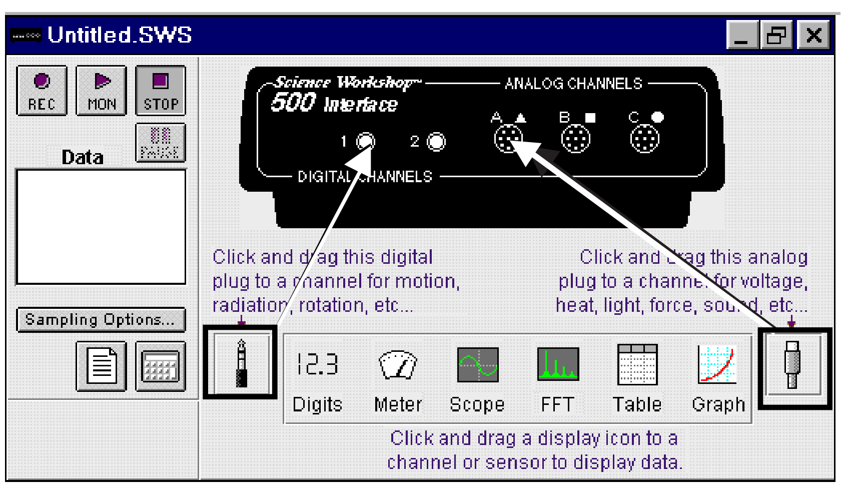

Press the **Experiment Calculator button** to open the Experiment Calculator window that allows you to do mathematical operations on collected data. You can also use it as a stand-alone calculator.


Drag the **digital plug icon** to Digital Channel 1 or 2 to add a digital sensor to the Experiment Setup window, and then select the correct digital sensor from the list of sensors that opens. Click **OK** to return to the Experiment Setup window.

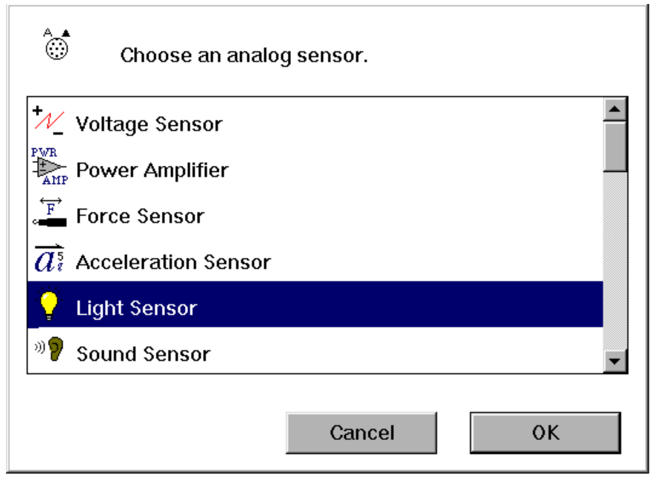

Drag the **analog plug icon** to Analog Channel A, B, or C to add an analog sensor to the Experiment Setup window. Then select the correct analog sensor from the list of sensors than opens. Click **OK** to return to the Experiment Setup window.

Setting Up Your Own Experiment in *ScienceWorkshop*

1. Drag an **analog plug icon** or a **digital plug icon** to the icon that corresponds to the channel on the *500* Interface box that you plugged the sensor into.

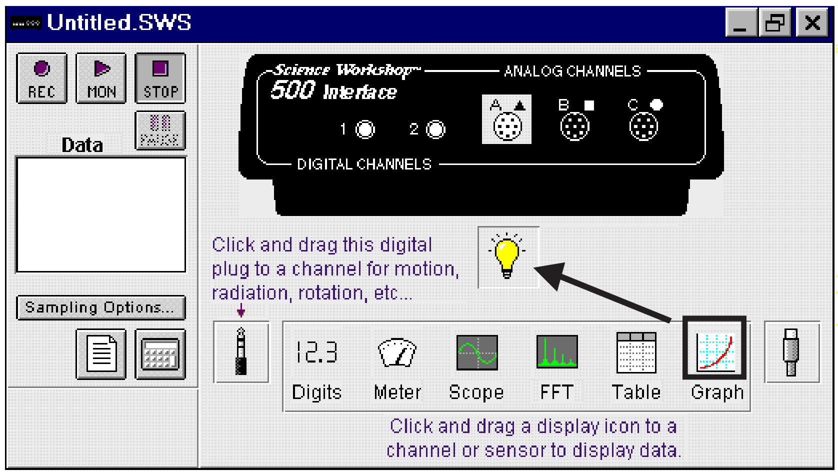


2. Choose the sensor from the sensor list that pops up. Click **OK** to return to the Experiment Setup window.



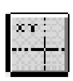
3. Drag a display icon to the Sensor icon.

You are ready to collect data!



Note: *ScienceWorkshop* has many advanced features. Refer to the *ScienceWorkshop* User's Guide that came with the interface for more information.

Section #2: Data Analysis

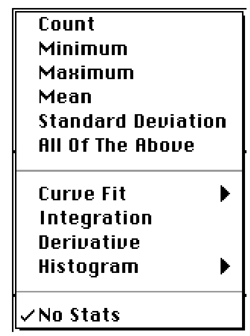
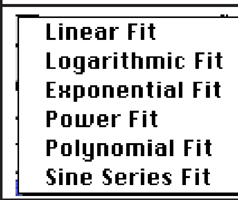
Analysis: The Smart Cursor 

The Smart Cursor allows you to investigate individual points on a graph.

Procedure: Click the **Smart Cursor** in any display that has the Smart Cursor icon (for example, the Graph display). The cursor changes to a cross hair and the y and x values for that individual position will be displayed on the y-axis and x-axis. If you desire to have the change in y or x coordinates displayed, click-and-drag the Smart Cursor over the desired area. The difference (y2 - y1 and x2 - x1) will be displayed on the y-axis and x-axis. (This ability to display the change in x and the change in y in a selected area is called the delta feature.)

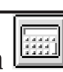
The Statistics Tool 

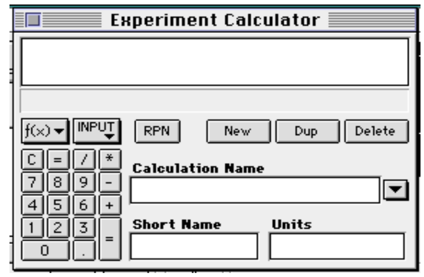
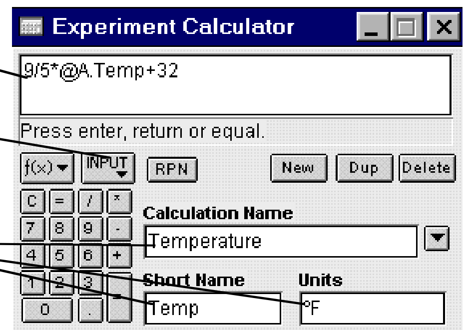
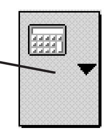
The Table and Graph displays have built-in statistics. Click the S**tatistics button** to open the statistics area at the bottom of a Table or on the right side of a Graph.

Statistics menu for a Table display	
In the Graph display, click the Statistics Menu button to see the statistics options.	
Statistics menu for a Graph display	
Curve Fit submenu	
Linear Fit will generate a basic slope equation with the slope of the best-fit line being the **a2** value in the display.	

The Experiment Calculator

Use the **Experiment Calculator** feature of *ScienceWorkshop* to create a new calculation that is based on the input data. For example, if data is displayed in degrees Celsius, you can use the calculator to create a calculation to display the temperature data in degrees Fahrenheit or degrees Kelvin.

To set up a calculation, click the **Calculator button**  in the Experiment Setup window. You can also open the Experiment Calculator by selecting **Calculator Window** from the **Experiment** menu.

Experiment Calculator window	
Example: Converting the temperature data from degrees Celsius to degrees Fahrenheit for plotting on the Graph display.	***1.*** Type the formula here (Select the variable to be modified from the Input Menu) ***2.*** Fill in these dialog boxes ***3.*** Click **=** or press ENTER 
Changing the plotting parameters of the Graph display	***4.*** On the Graph display, click the **Plot Input Menu** button, and select **Calculations, Temperature, (Temp ˚F)**  (Temperature will be plotted in ºF)

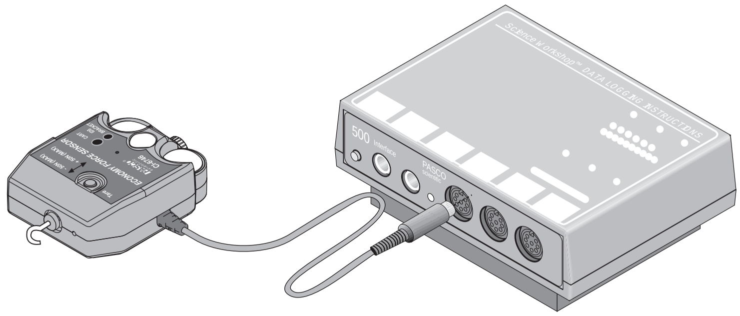
Note: The values for this calculation can also be displayed in any Table, Digits, or Meter display. To do this, select **Calculations, Temperature, (Temp ˚F)** from the **Input** menu of the display.

Tutorial Activities – Exploration of Sensors

Practice using the sensors included in the General Science Bundles.

- Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.

Economy Force Sensor



The Economy Force Sensor measures forces between +50 and –50 newtons. The sensor output is +8 volts for a force of +50 newtons and –8 volts for a force of –50 newtons. Pushing on the sensor's detachable hook produces a positive voltage and pulling produces a negative voltage.

The sensor has an attached cable for connecting to the interface. It also has a built-in over-limit protector in the case so the sensor will not be damaged if a force above 50 newtons is applied. The housing has a thumbscrew for mounting the sensor on a rod, and a long thumbscrew for mounting the sensor on a PASCO cart or onto the Accessory Bracket with Bumpers.

The sensor has one built-in control.

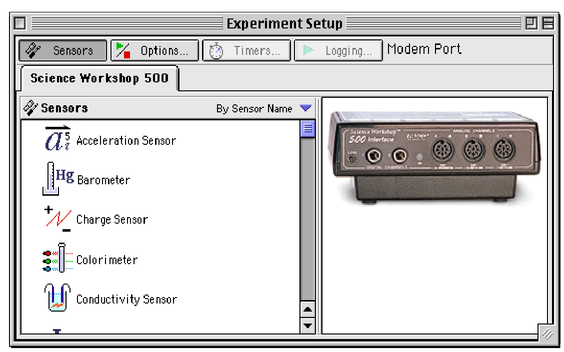
Tare Button: Use the tare button to zero the sensor before making measurements.

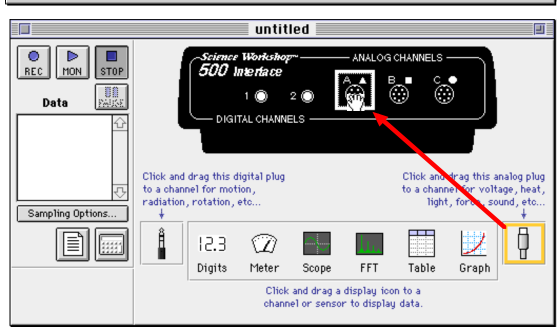
To calibrate the sensor you will need an object of known mass, such as one kilogram.

Set up the sensor with the interface

- Plug the sensor cable into **Analog Channel A** on the interface.

Set up the sensor in the software



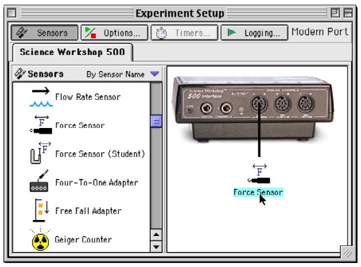


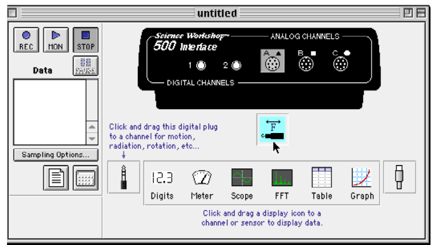
- In *DataStudio*, double-click the 'Force Sensor" in the Sensors list in the Experiment Setup window. **Result**: The sensor icon appears below Channel A of the interface. The sensor's parameters (e.g., Force) appear in the Data list.
- In *ScienceWorkshop*, click-and-drag the 'analog sensor plug' icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. **Result**: The sensor's icon appears below Channel A of the interface.

Calibrate the sensor

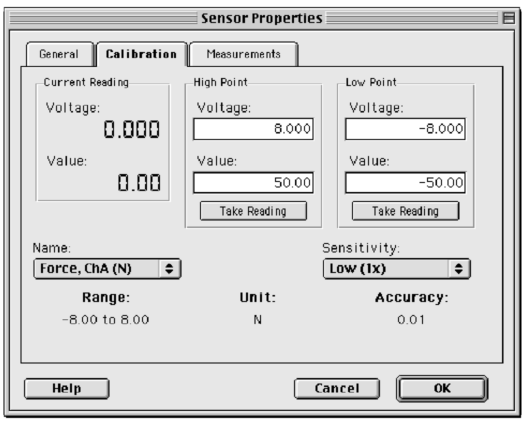
The general method for calibrating the force sensor is as follows:

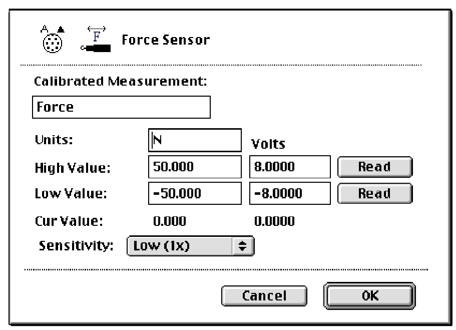
1. In the Experiment Setup window, double-click the sensor's icon.





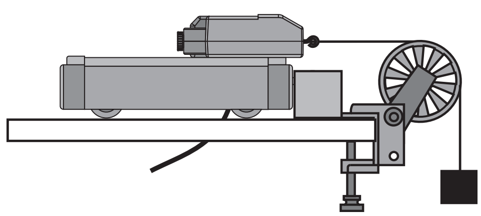
- **Result**: In *DataStudio*, the Sensor Properties window opens. Click the 'Calibration' tab. In *ScienceWorkshop*, the Sensor Setup window opens.

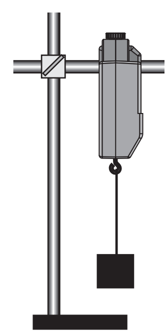




2. Calibrate the software.

- **First**, arrange the sensor as it will used for making measurements but DO NOT apply a force to the sensor. Press the 'tare' button to zero the sensor.



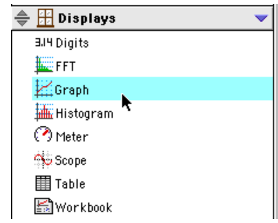


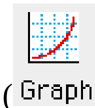
- **Second**, check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*. When the voltage stabilizes, click the 'Take Reading' button under 'Low Point' in *DataStudio* or the 'Read' button in the row for 'Low Value:' in *ScienceWorkshop*. Enter '0' as the force value.

- **Third**, use the object of known mass to apply a pulling force on the hook. When the voltage stabilizes, click the 'Take Reading' button under 'High Point' in *DataStudio* or the 'Read' button in the row for 'High Value:' in *ScienceWorkshop*. Enter the force value. For example, enter '9.8' for a one kilogram mass.

3. Click 'OK' to return to the Experiment Setup window.

Set up a display

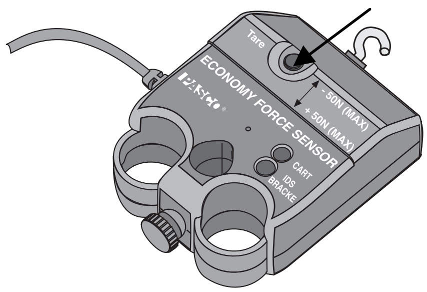


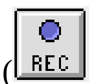
- In *DataStudio*, double-click ‘Graph’ in the Displays list. **Result**: The display automatically shows force.
- In *ScienceWorkshop*, click-and-drag the ‘Graph’ display icon () to the sensor’s icon in the Experiment Setup window.

Start recording data

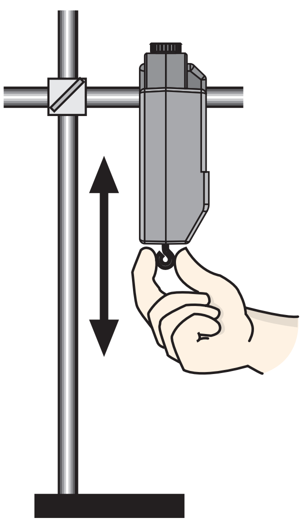
- Press the tare button on the sensor to zero it.

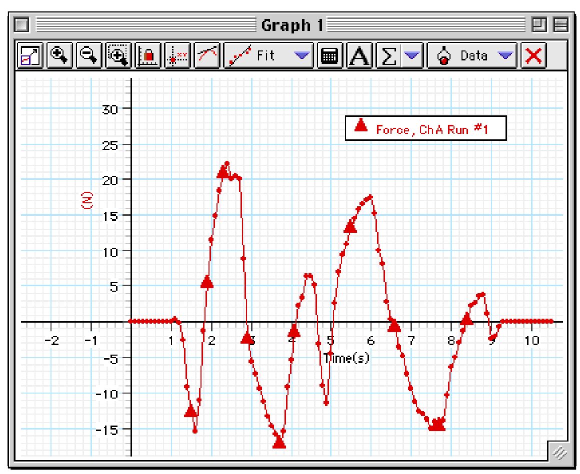
Tare button



- In *DataStudio*, click the ‘Start’ button (). In *ScienceWorkshop*, click the ‘REC’ button ().

- Pull and push the hook on the end of the sensor and watch the results on the Graph display.



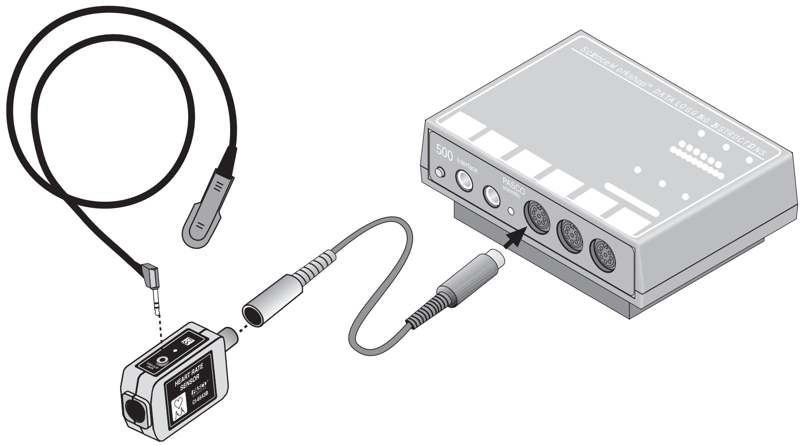


Stop recording data.

- Click ‘Stop’ to end data recording.

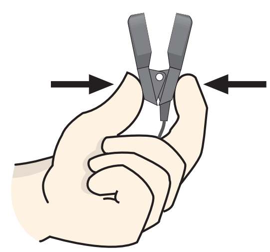
Heart Rate Sensor

The Heart Rate Sensor monitors the flow of blood through a part of the body, such as an ear lobe, by shining a light through it. The intensity of the light passing through the ear lobe depends on the amount of blood flowing through the blood vessels in the ear lobe. As the heart contracts and relaxes, the amount of blood flowing through the ear lobe changes and the light intensity transmitted through the ear lobe changes.



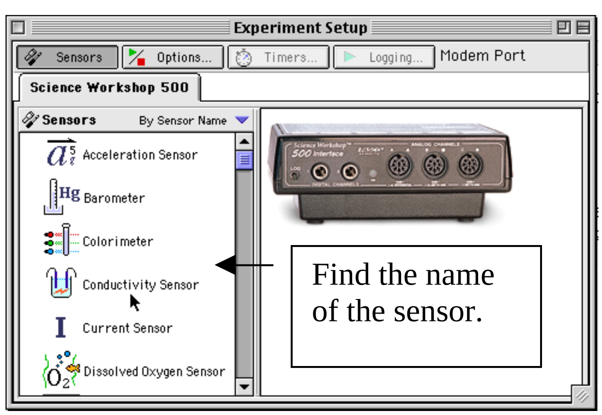
1. Set up the sensor.

- Plug the DIN connector cable into the sensor's DIN plug and then connect the cable into **Analog Channel A** on the interface.
- Connect the ear clip plug into the top of the sensor.
- Pinch the sides of the ear clip so it opens.
- Place the open ear clip on your ear lobe and release the sides of the clip.



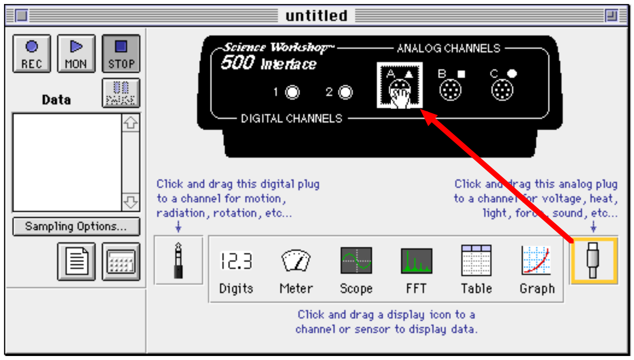
2. Set up the sensor in the software.

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window.

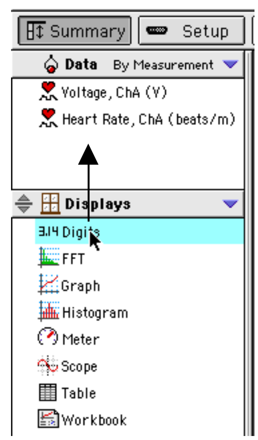


- The sensor icon will appear below Channel A of the interface. The sensor's parameters (e.g., Voltage, Heart Rate, etc.) will appear in the Data list.

- In *ScienceWorkshop*, click-and-drag the 'analog sensor plug' icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. The sensor's icon will appear below Channel A of the interface.

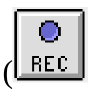


3. Set up a Digits display of 'Heart Rate'.



- In *DataStudio*, click-and-drag the 'Digits' icon from the Displays list and drop it on 'Heart Rate' in the Data list.
- In *ScienceWorkshop*, click-and-drag the 'Digits' display icon to the sensor's icon in the Experiment Setup window.

4. Start recording data.

- In *DataStudio*, click the 'Start' button (
). In *ScienceWorkshop*, click the 'REC' button (
).
- Note the heart rate in the Digits display.

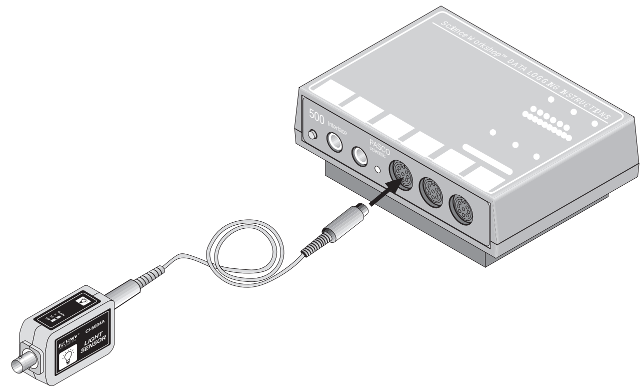
5. Stop recording data. (Click 'Stop' to end data recording.)

Light Sensor

The Light Sensor measures relative light intensity. The sensing element is a photodiode that produces a voltage proportional to the light intensity across a wide spectrum ranging from 350 nanometers to 100 nanometers (nm).

The sensor includes a cable for connecting to the interface. The sensor has one built-in control.

Gain Select Switch: Use the gain select switch to set the maximum input light levels of the sensor. The three settings are as follows.



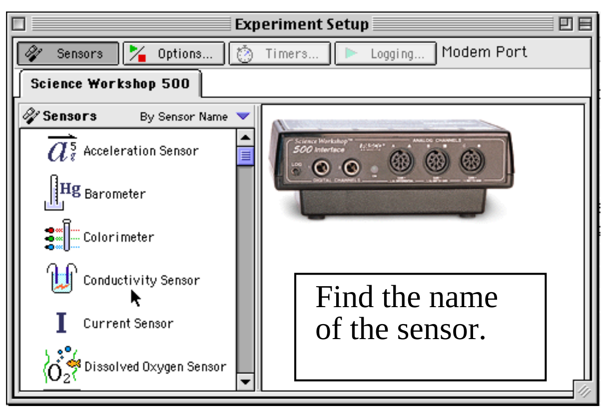
Gain Select setting	Maximum Input (lux)
1	500
10	50
100	5

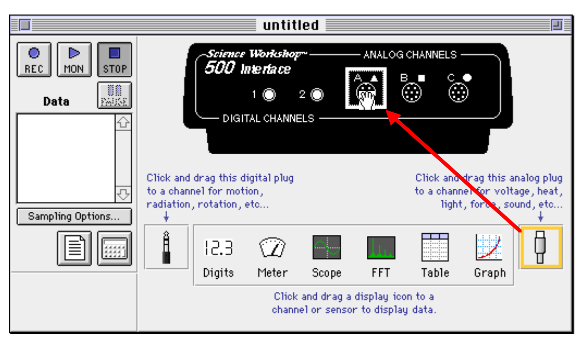
Set up the sensor with the interface

- Plug one end of the DIN-to-DIN cable into the sensor and then connect the other end of the cable into **Analog Channel A** on the interface.
- Note: You can connect the sensor directly into the interface if needed.

Set up the sensor in the software

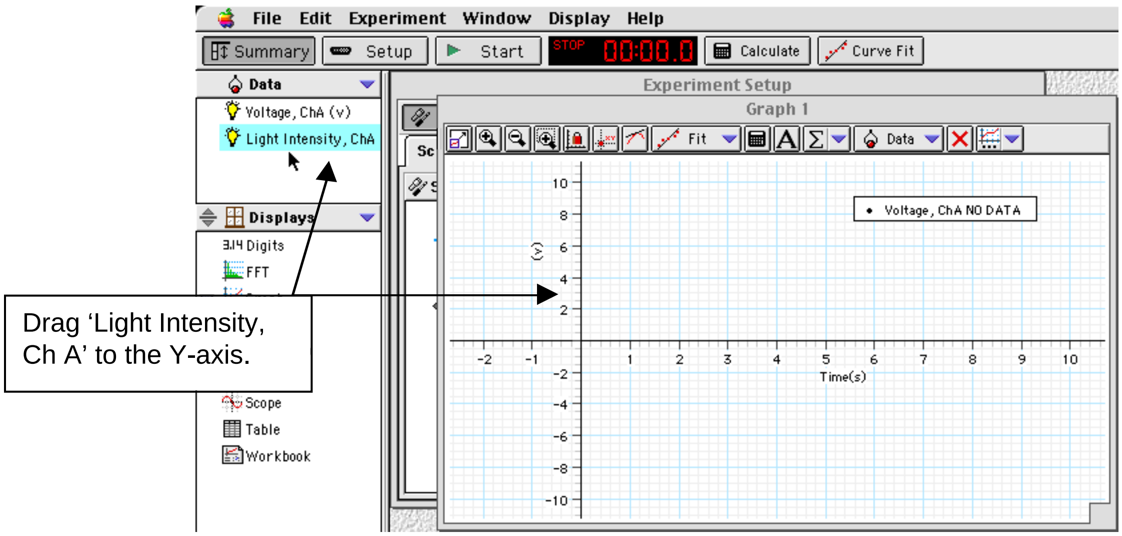
- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window. **Result**: The sensor icon appears below Channel A of the interface. The sensor's parameters appear in the Data list.
- In *ScienceWorkshop*, click-and-drag the 'analog sensor plug' icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. **Result**: The sensor's icon appears below Channel A of the interface.



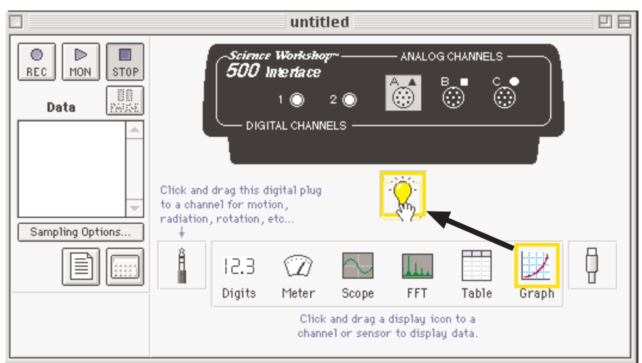


Set up a display

- In *DataStudio*, double-click the 'Graph' icon in the Displays list. **Result**: The display automatically shows voltage versus time. To make the Graph show light intensity instead of voltage, click-and-drag 'Light Intensity, ChA' from the Data list to the vertical axis of the Graph display.



- In *ScienceWorkshop*, click-and-drag the 'Graph display' icon to the Light Sensor icon in the Experiment Setup window. **Result**: The Graph display shows 'Intensity (% max)' versus Time (s).



Start recording data

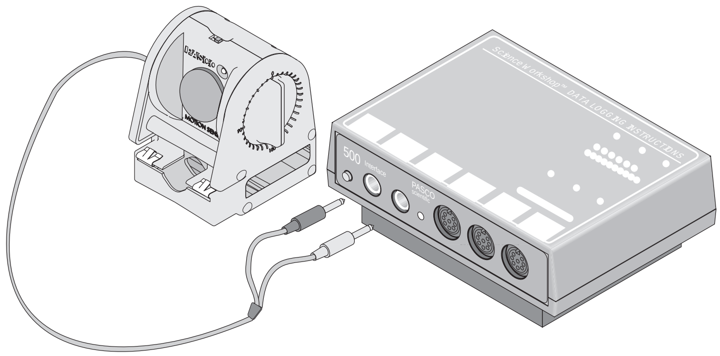
- Set the GAIN switch on the top of the Light Sensor to **1**
- In *DataStudio*, click the 'Start' button (). In *ScienceWorkshop*, click the 'REC' button ().
- Move your hand over the Light Sensor, point the sensor at different light sources, and watch the results on the Graph display.

Stop recording data.

- Click 'Stop' to end data recording.

Motion Sensor II

The Motion Sensor II is a sonar ranging device. It sends out ultrasonic pulses and detects echoes of these pulses that are reflected from an object. The sensor includes a cable for connecting to the interface. One end of the cable connects to the sensor. The other end has two stereo phone plugs that connect to the interface. The yellow plug carries the 'transmit pulse' signal from the interface. The other plug returns the echo to the interface.



The sensor can measure objects as close as 15 cm (0.15 m) or as far as 8 m. You can use the software to set the number of pulses (the 'trigger rate') from as few as five per second to as many as 120 per second.

The sensor has one built-in control.

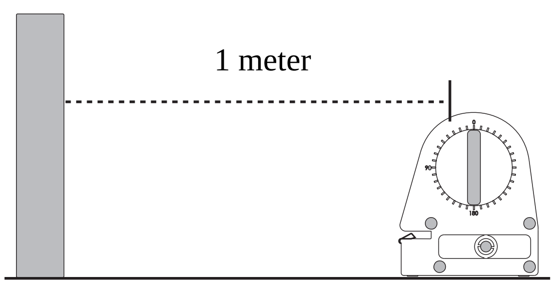
Narrow/Standard (Std.) Switch: Set the switch to *Narrow* for measuring highly reflective targets (such as a PASCO cart) at distances of 2 m or less. Set the switch to *Std* for measuring targets that are poor reflectors or for distances longer than 2 m.

Note: On the Standard setting, you may need to tilt the sensor up by five or ten degrees to avoid reflections from the front of the sensor housing or from a surface underneath the sensor.

For this activity you will need a meter stick and a highly reflective target, such as a book.

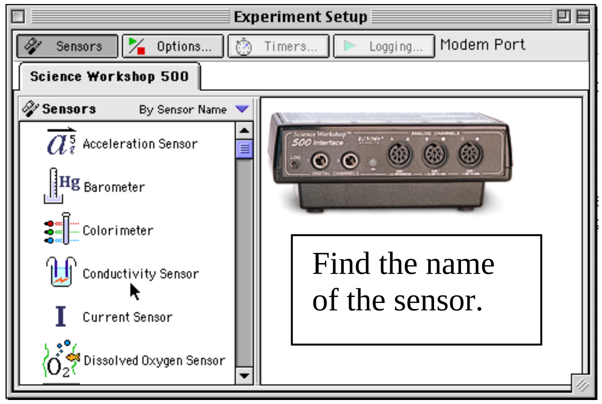
Set up the sensor

- Plug the modular connector on one end of the interface cable into the side of the Motion Sensor. Connect the yellow phone plug into **Digital Channel 1** on the interface. Connect the other phone plug into **Digital Channel 2**.
- Place the sensor exactly one meter away from a target. Arrange the sensor and target so the pulses from the sensor can reflect from the target and be detected by the sensor.

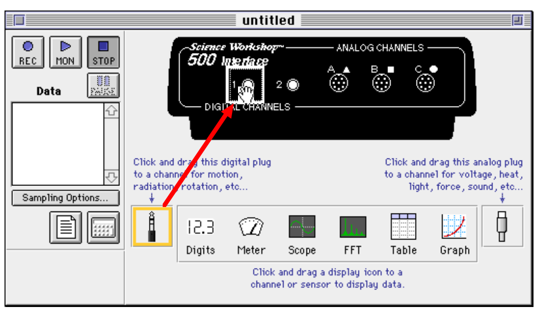


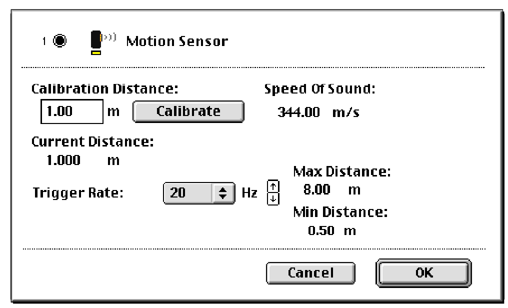
Set up the sensor in the software

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window. **Result**: The sensor icon appears below the digital channels of the interface. The sensor's parameters (e.g., Position, etc.) appear in the Data list.



- In *ScienceWorkshop*, click-and-drag the 'digital sensor plug' icon to the Channel 1 icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. **Result**: The sensor's calibration window opens and the sensor begins to click a few times per second.

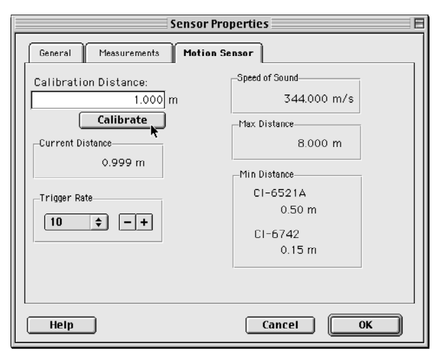




Calibrate the sensor

The general method for calibrating the motion sensor is as follows:

1. In the *DataStudio* Experiment Setup window, double-click the sensor's icon. **Result**: The Sensor Properties window opens.



2. Click the 'Motion Sensor' tab. **Result**: The calibration window opens and the sensor begins to click a few times per second.

3. Calibrate the software.

- **First**, make sure that the sensor is one meter from the target.
- **Second**, click the ‘Calibrate’ button in the Motion Sensor window. **Result**: The software calculates the speed of sound based on the calibration distance (one meter) and the round trip time of the pulse and echo

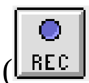
4. Click ‘OK’ to return to the Experiment Setup window.

Set up a display

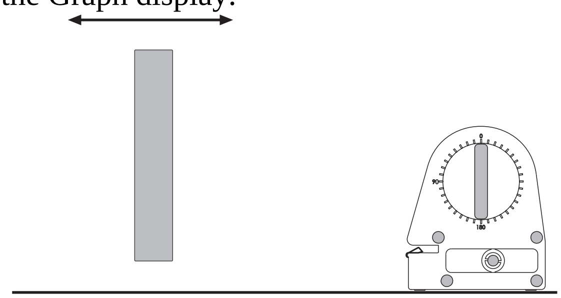
- In *DataStudio*, double-click the ‘Graph’ icon from the Displays list. **Result**: The Graph display shows position versus time.
- In *ScienceWorkshop*, click-and-drag the ‘Graph’ display icon to the sensor’s icon in the Experiment Setup window. Select ‘Position, x (m)’ from the list of and click ‘Display’. **Result**: The Graph display shows position versus time.

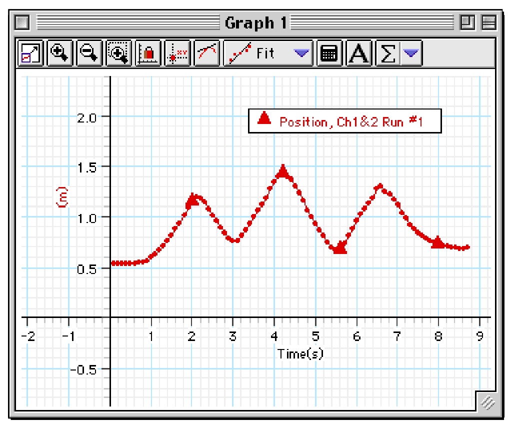
Start recording data

- In *DataStudio*, click the ‘Start’ button (

). In *ScienceWorkshop*, click the ‘REC’ button (

).
- Move a target (such as a book) back-and-forth in front of the sensor. Watch the results on the Graph display.



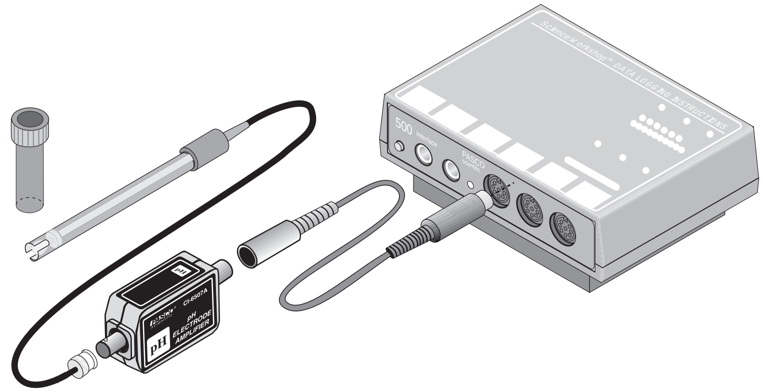


Stop recording data

- Click ‘Stop’ to end data recording.

pH Sensor

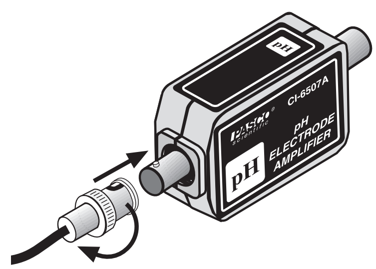
The pH Sensor has an amplifier and a pH electrode. The electrode produces a voltage that is proportional to the hydrogen ion concentration in a solution. (Store the electrode in its soaker bottle when you are not using it.) The amplifier converts the electrode voltages into the voltages required by the *ScienceWorkshop* interface.



For this activity you will need a cup or beaker, some cranberry juice (or other fruit juice), and an antacid tablet (e.g., Alka-Seltzer®). Fill the cup about half full with juice. Break the antacid tablet in half.

1. Set up the sensor.

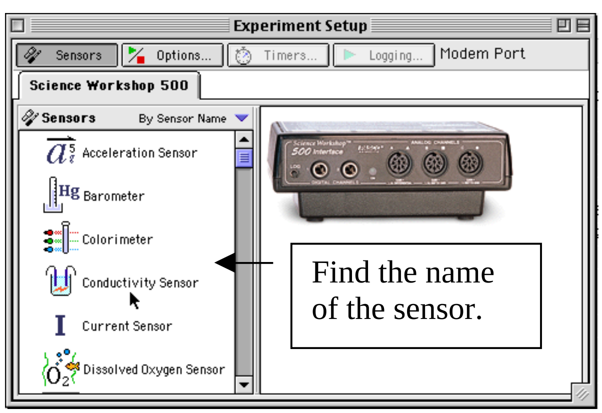
- Plug the DIN connector cable into the sensor's DIN plug and then connect the cable into **Analog Channel A** on the interface.
- Connect the pH electrode to the BNC port on the pH Sensor. Line up the connector on the end of the cable with the pin on the BNC port. Push the connector onto the port and then twist the connector clockwise about one-quarter turn until it clicks into place.



- Put the end of the pH electrode into the juice.

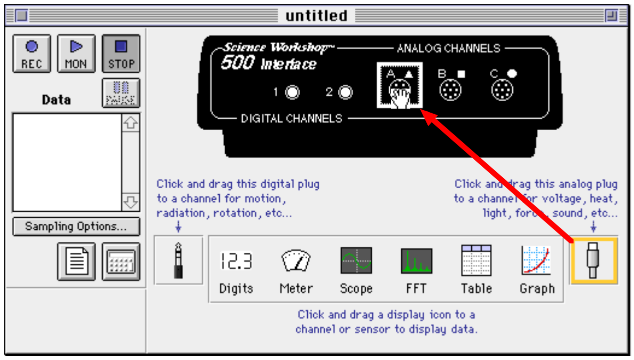
2. Set up the sensor in the software.

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window.

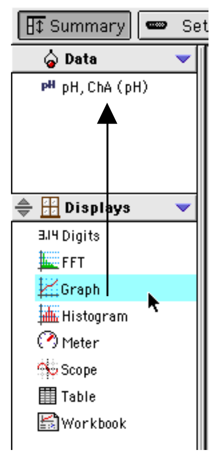


- The sensor icon will appear below Channel A of the interface. The sensor's parameters (e.g., pH, Voltage, etc.) will appear in the Data list.

- In *ScienceWorkshop*, click-and-drag the ‘analog sensor plug’ icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click ‘OK’ to return to the Experiment Setup window. The sensor’s icon will appear below Channel A of the interface.

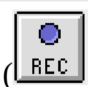


3. Set up a Graph display of pH versus Time.



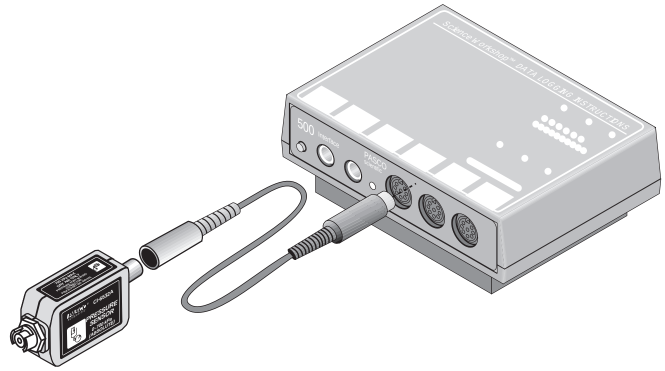
- In *DataStudio*, click-and-drag the ‘Graph’ icon from the Displays list and drop it on ‘pH’ in the Data list.
- In *ScienceWorkshop*, click-and-drag the ‘Graph’ display icon to the sensor’s icon in the Experiment Setup window. Select ‘pH (pH)’ and click ‘Display.

4. Start recording data.

- Put half of an antacid tablet into the fruit juice and stir with the end of the pH electrode.
- In *DataStudio*, click the ‘Start’ button (
). In *ScienceWorkshop*, click the ‘REC’ button (
).
- Note the change in pH in the Graph display.

5. After two minutes, stop recording data. (Click ‘Stop’ to end data recording.)

Pressure Sensor



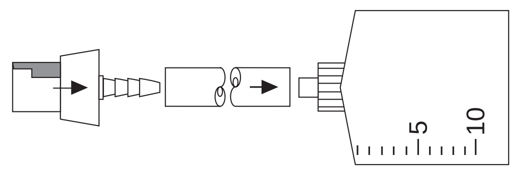
The Pressure Sensor includes a cable, a syringe, tubing, and connectors for the tubing.

The sensor can measure pressures as high as 700 kilopascals, or about seven atmospheres. It is designed for non-corrosive gases. Do not put liquids into the sensor.

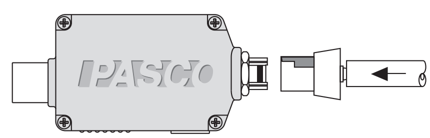
For this activity you will need two drops of glycerin, the syringe, a short piece of tubing, and a quick-release connector.

Set up the sensor

- Plug the DIN connector cable into the sensor's DIN plug and then connect the cable into **Analog Channel A** on the interface.
- Prepare the syringe. Cut a short piece of tubing (about 2 cm). Put a drop of glycerin on the barb end of a quick-release connector. Put the barb end of the connector into one end of the tubing. Put a drop of glycerin on the tip of the syringe. Put the tip of the syringe into the other end of the tubing. Pull out the piston so it is at about the 10 cc mark.

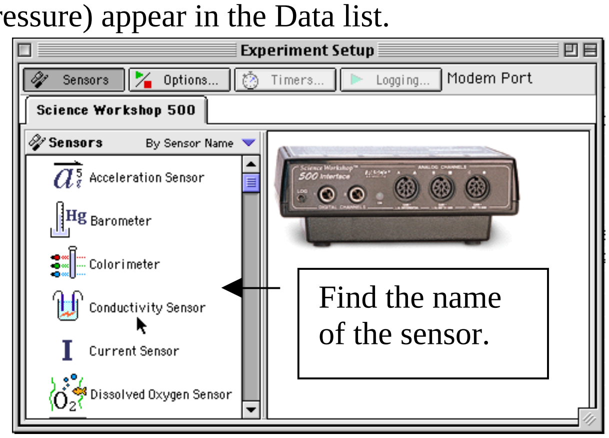


- Connect the syringe to the sensor. Line up the quick-release connector with the pressure port on the sensor. Push the connector onto the port and turn the connector clockwise until it clicks.

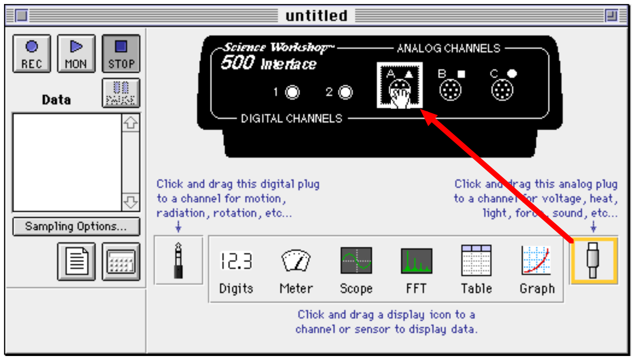


Set up the sensor in the software

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window.
- The sensor icon will appear below Channel A of the interface. **Result**: The sensor's parameters (e.g., Pressure) appear in the Data list.



- In *ScienceWorkshop*, click-and-drag the ‘analog sensor plug’ icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click ‘OK’ to return to the Experiment Setup window. Result: The sensor’s icon appear belows Channel A of the interface.

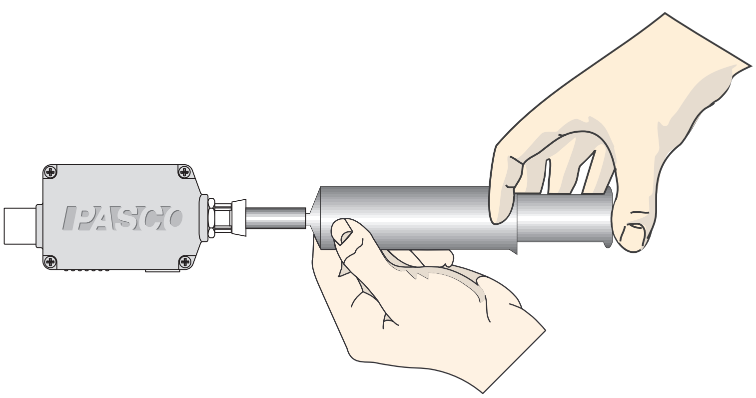


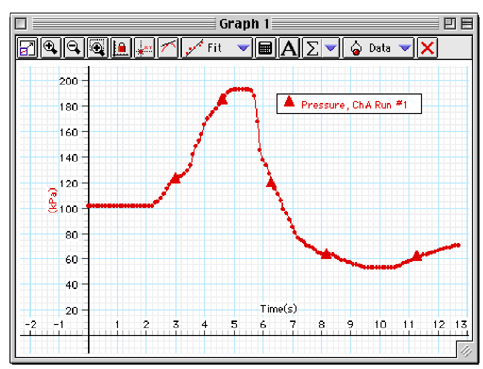
Set up a Graph display of Pressure versus Time

- In *DataStudio*, double click the ‘Graph’ icon in the Displays list. **Result**: The display automatically shows pressure versus time.
- In *ScienceWorkshop*, click-and-drag the ‘Graph’ display icon to the sensor’s icon in the Experiment Setup window. **Result**: The display automatically shows pressure versus time.

Start recording data

- In *DataStudio*, click the ‘Start’ button (
). In *ScienceWorkshop*, click the ‘REC’ button (
).
- After a few seconds, push the piston in so it is at the 5 cc mark. Then pull the piston out so it is at the 20 cc mark.



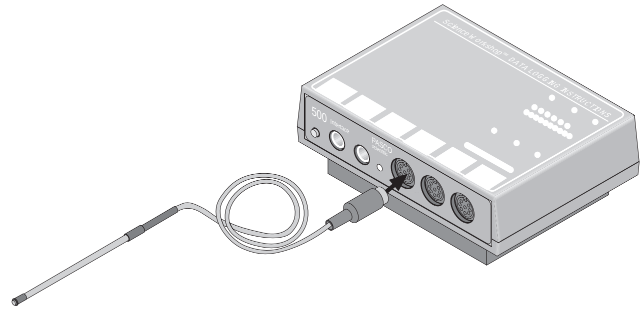


- Note the change in pressure in the Graph display.

Stop recording data

- Click ‘Stop’ to end data recording.

Temperature Sensor



The Temperature Sensor has a temperature sensitive integrated circuit in its tip that produces a voltage that is proportional to temperature. The sensor is covered with Teflon® tubing that is very chemical resistant. The sensor includes a removable Teflon sensor cover that is highly chemical resistant.

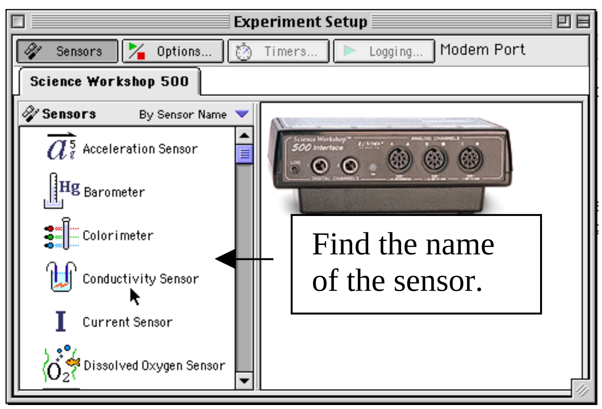
The sensor's operating range is from –5 ˚C to 105 ˚C. Do not use the sensor in a direct flame or on a hot plate.

Set up the sensor

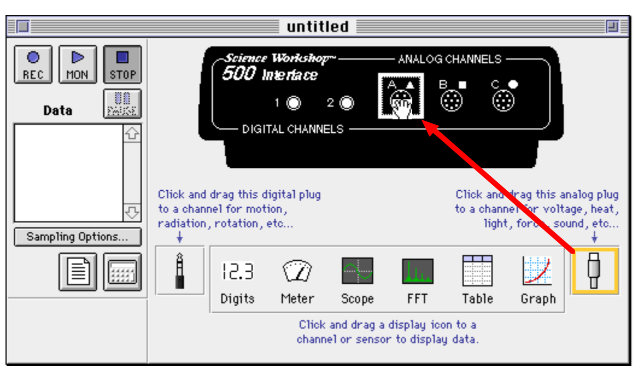
- Plug the sensor's DIN plug into **Analog Channel A** on the interface.

Set up the sensor in the software

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window. **Result**: The sensor's icon appears below Channel A of the interface. The sensor's parameter (e.g., Temperature) appears in the Data list.



- In *ScienceWorkshop*, click-and-drag the 'analog sensor plug' icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. **Result**: The sensor's icon appears below Channel A of the interface.

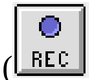


Set up a Graph display of Temperature versus Time

- In *DataStudio*, double-click the ‘Graph’ icon in the Displays list. **Result**: The Graph display automatically shows ‘Temperature’ versus ‘Time’.
- In *ScienceWorkshop*, click-and-drag the ‘Graph’ display icon to the sensor’s icon in the Experiment Setup window. Result: The Graph display automatically shows ‘Temperature’ versus ‘Time’.

Start recording data

- In *DataStudio*, click the ‘Start’ button (

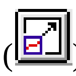
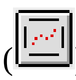
). In *ScienceWorkshop*, click the ‘REC’ button (

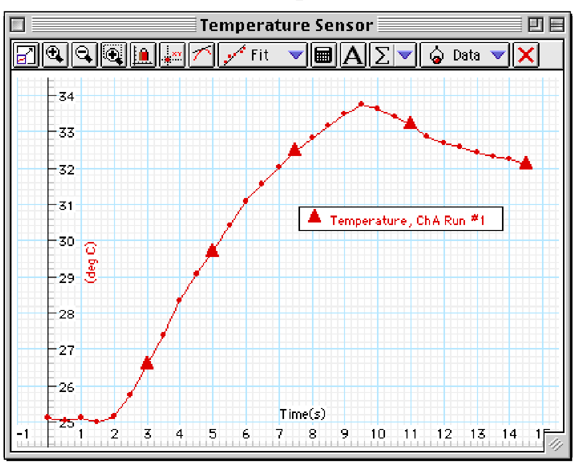
).
- Measure the temperature of your hand. Place the tip of the sensor in the palm of your hand and rub the sensor against your skin for several seconds. Note the temperature in the Graph display. Then move the tip of the sensor from the palm along one of your fingers to the end of the finger. Watch the change in temperature in the Graph display as you move the sensor.

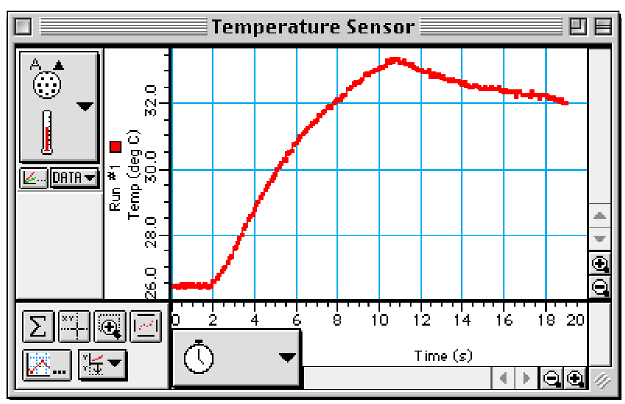
Stop recording data

- Click ‘Stop’ to end data recording.

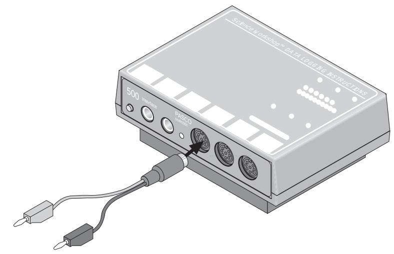
Rescale the Graph display

- In *DataStudio*, click the ‘Scale-to-Fit’ button () in the Graph display toolbar.
- In *ScienceWorkshop*, click the ‘Autoscale’ button () in the Graph tool palette.





Voltage Sensor

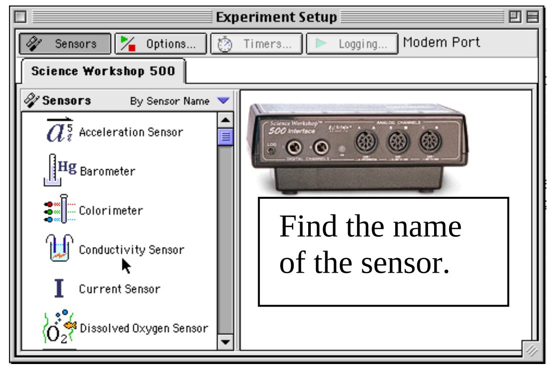


The Voltage Sensor measures voltages from –10 volts to +10 volts. The probe ends are stackable banana plugs. The sensor comes with two insulated alligator clips.

For this activity you need a 1.5 volt battery.

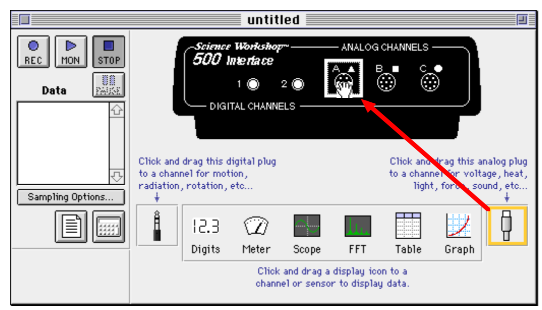
Set up the sensor with the interface

- Connect the Voltage Sensor's DIN plug into **Analog Channel A** on the interface.



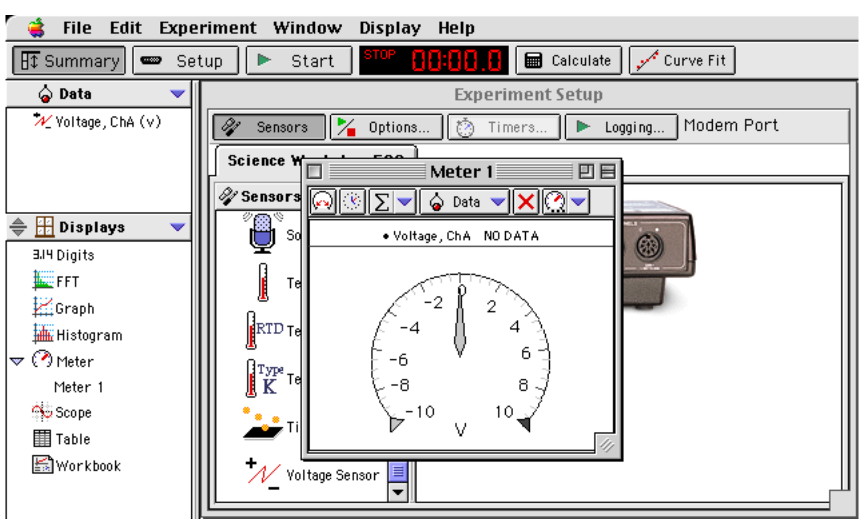
Set up the sensor in the software

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window. **Result**: The sensor icon appears below Channel A of the interface. The sensor's parameters appear in the Data list.
- In *ScienceWorkshop*, click-and-drag the 'analog sensor plug' icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. **Result**: The sensor's icon appears below Channel A of the interface.

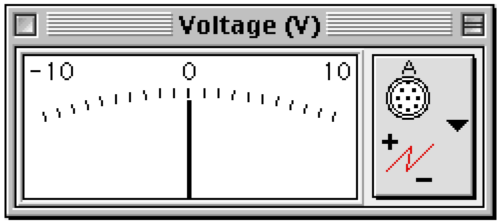


Set up a 'Meter' display

- In *DataStudio*, double-click the 'Meter' icon in the Display list. **Result**: The Meter display shows 'Voltage, ChA' and 'Meter 1' appears in the Display list.

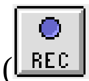


- In *ScienceWorkshop*, click and drag the 'Meter display' icon to the Voltage Sensor icon in the Experiment Setup window. The Meter display shows 'Voltage (V)'.



Start recording data

- In *DataStudio*, click the 'Start' button (

). In *ScienceWorkshop*, click the 'REC' button (

).
- Touch the red Voltage Sensor lead to one end of the battery and the black Voltage Sensor lead to the other end. If the Meter display shows negative volts, reverse the Voltage Sensor leads on the battery.

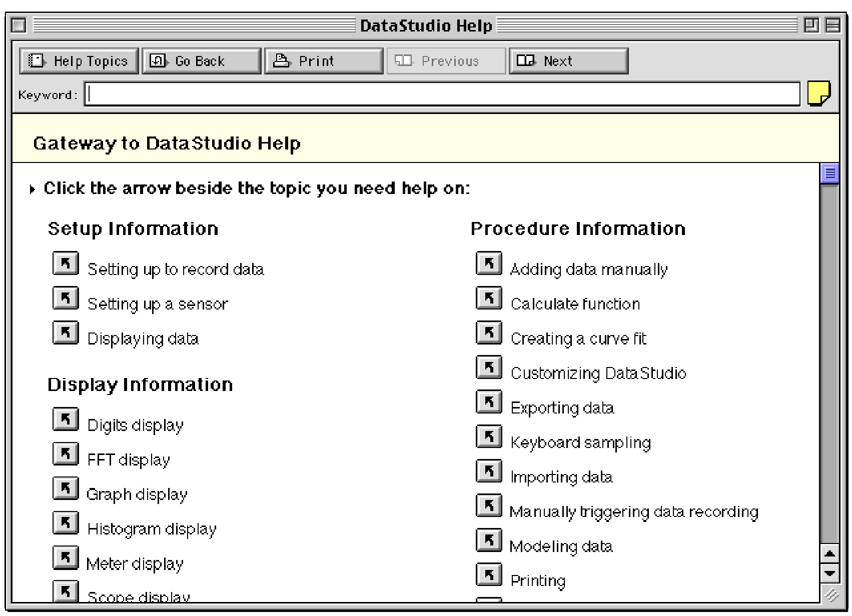
Stop recording data

- After about 90 seconds, stop recording data.
- Click 'Stop' to end data recording.

Remember to Use the Online Help

In *DataStudio*, click 'Contents' or 'Search…' in the Help menu to open the online help file. You can use the online help file to learn about any button, icon, menu, control, function or feature of the program.

In *ScienceWorkshop* for Macintosh, click 'Show Balloons' in the Help menu.



Name ____________________ Class _____________ Date _________

Activity GS01: Fruit Battery – Electricity
(Voltage Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Electricity	GS01 Fruit Battery.ds	G01 Fruit Battery	G01_BATT.SWS

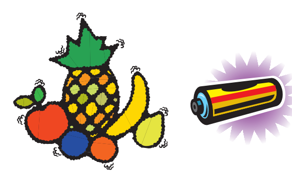
Equipment Needed	Qty	Consumables	Qty
Voltage Sensor (CI-6503)	1	Apple or other medium size fruit	1
Copper wire, 2 or 3 inches long	1		
Zinc (galvanized) nail	1		
Protective gear	PS		

What Do You Think?

In this activity you will measure the **voltage** of a "fruit battery*" using a Voltage Sensor. What type of fruit will produce the most voltage? (*In this activity, the word 'battery' will be used in place of 'cell'.)

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

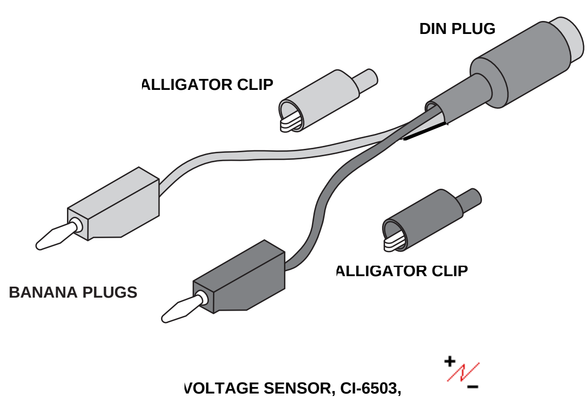
Background



One form of energy can be converted into another. For example, the energy stored in a piece of food can be converted into energy that helps you grow and move. The energy stored in certain kinds of food can also be converted into electricity. A piece of fruit such as an apple or orange can produce a **voltage** when **electrodes** made of different metals are placed into the fruit.

An electrode is made from a material that can conduct electricity.

For You To Do



The Voltage Sensor has a pair of flexible insulated wires joined by a type of plug called a **DIN plug**. The plugs at each end of the wires are called **banana plugs**. The Voltage Sensor comes with a pair of clips called **alligator clips** that can be slipped onto the end of the banana plugs.

For this activity, use the Voltage Sensor to measure the voltage (or potential difference) produced by a piece of fruit that has a copper electrode (copper wire) and a zinc electrode (galvanized nail) in it. Use *DataStudio* or *ScienceWorkshop* to record and display the measured voltages.

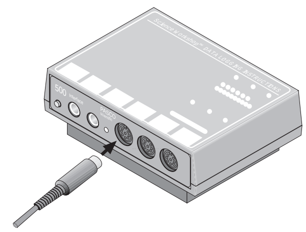
SAFETY REMINDERS	THINK SAFETY ACT SAFELY BE SAFE!
• Follow directions carefully when using the equipment for this activity. • Wear protective gear (e.g., goggles, gloves, apron).	

Prediction

Will the voltage from a piece of fruit be as much as the voltage from a D size dry cell battery (about 1.5 volts)? Predict what the voltage will be from the piece of fruit. Record your prediction and the type of fruit you are going to use.

Type of fruit	Predicted voltage (V)

PART I: Computer Setup



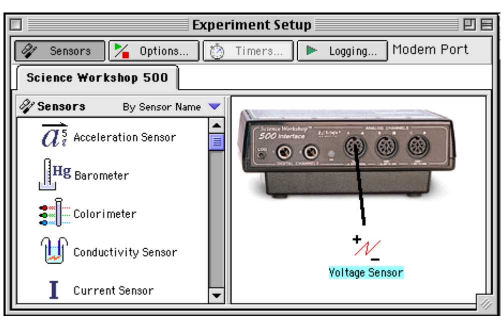
1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and then turn on the computer.
2. Connect the Voltage Sensor DIN plug into Analog Channel A on the interface.
3. Open the file as shown:

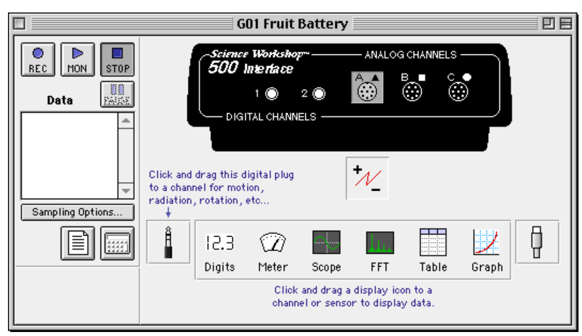
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS01 Fruit Battery.ds	G01 Fruit Battery	G01_BATT.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has an Experiment Setup window and an Experiment Notes window. It also has a Table display, a Digits display, and a Meter display, all showing voltage.
- Data recording is set for ten measurements per second, or 10 Hz.

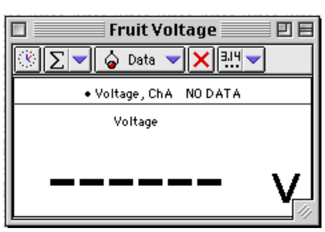
Experiment Setup window:

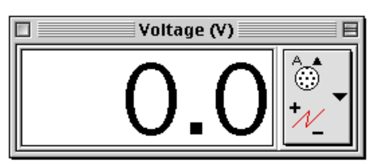
The window shows an icon for the kind of sensor. For this activity, the window shows the icon for the Voltage Sensor below Analog Channel A.



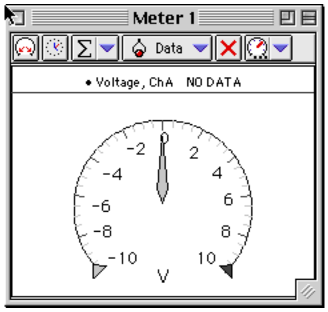


Digits display:





Meter display:



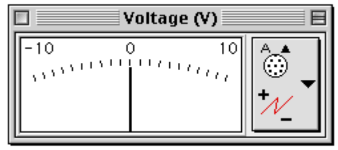
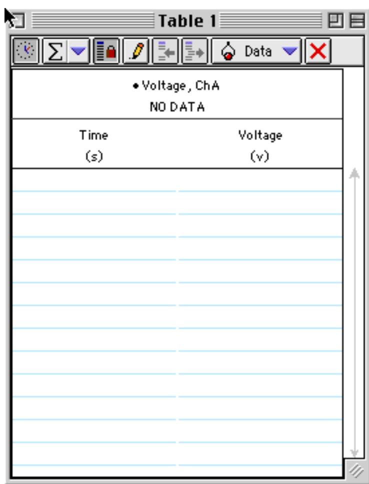
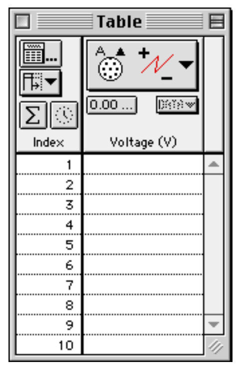


Table display:

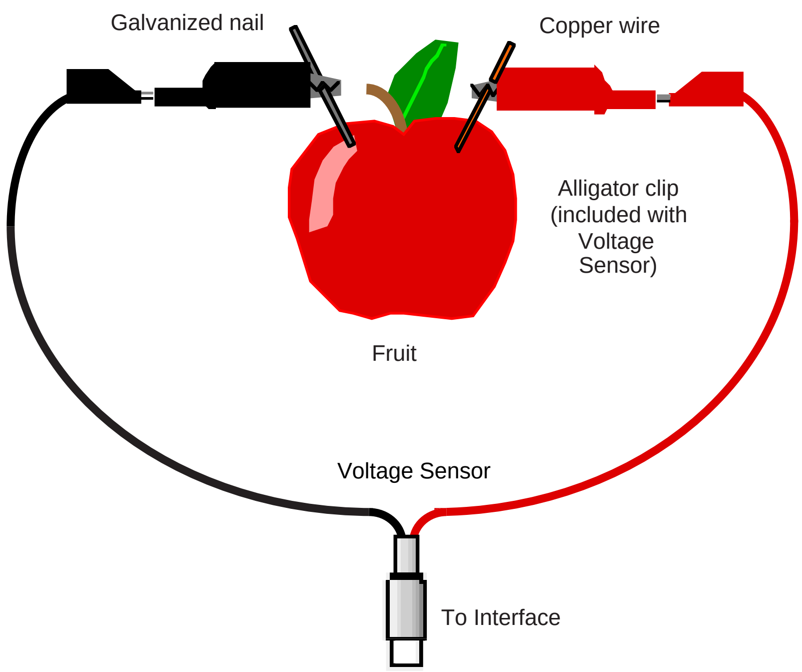
The Table display has a display area that is similar to columns in a spreadsheet.





PART II: Equipment Setup

1. Stick the piece of copper wire and the galvanized nail into the piece of fruit to turn it into a battery.



Fruit Battery

2. Put alligator clips on the ends of the Voltage Sensor leads. Connect the red end of the Voltage Sensor to the copper wire and the black end of the Voltage Sensor to the nail.

PART III: Data Recording

1. Start recording data.

- Watch the values of voltage in the Digits display and Meter display.

2. Record data for about 10 seconds.
3. Stop recording data.

Analyzing the Data

1. Set up the Table to show statistics.
2. Record the Max (maximum) value of voltage in the Data Table.

Record your results in the Lab Report section.

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Lab Report - Activity GS01: Fruit Battery

What Do You Think?

In this activity you will measure the **voltage** of a "fruit battery*" using a Voltage Sensor. What type of fruit will produce the most voltage? (*In this activity, the word 'battery' will be used in place of 'cell'.)

Data Table

Type of Fruit	Maximum Voltage (V)

Optional

- Try inserting the electrodes to different depths.
- Try inserting the electrodes closer to each other or farther away from each other.
- Try different kinds of fruit.
- Try different sizes of the same kind of fruit.

Questions

1. How does your prediction compare to the actual value of maximum voltage? (Was your prediction lower, higher, or very close?)

2. If you tried any of the optional activities, what were the results?

a. Did changing how far in the electrodes were make the voltage go up, go down, or stay the same?

b. Did putting the electrodes closer together make the voltage go up, go down, or stay the same?

c. Did putting the electrodes farther apart make the voltage go up, go down, or stay the same?

d. Did a different kind of fruit make any difference? If so, what was the kind of fruit, and was its voltage higher or lower than your first piece of fruit?

e. Did a different size of your kind of fruit make a difference? If so, did the voltage go up or go down?

Ending the Activity

- Check with your instructor about putting away the equipment for this activity.
- Check with your instructor about disposing of the pieces of fruit after you are done with them.

Computer Shutdown

When you have finished, you have several options.

1. You can select **Quit** from the **File** menu to end the activity.
2. You can select **Save** or **Save As…** from the File menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give <u>your</u> document a new filename.

3. If you wish to go on to the next activity, select **Open…** from the **File** menu, and find the document for the next activity.

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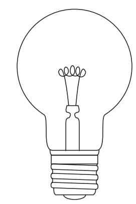
Activity GS02: Variation of Light Intensity – Optics (Light Sensor)

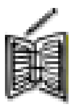
Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Optics	GS02 Vary Light.DS	G02 Light Bulb Intensity	G02_BULB.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Light Sensor (CI-6504A)	1	Fluorescent light source (AC)	1
Flashlight (or other DC light source)	1	Incandescent light source (AC)	1

What Do You Think?

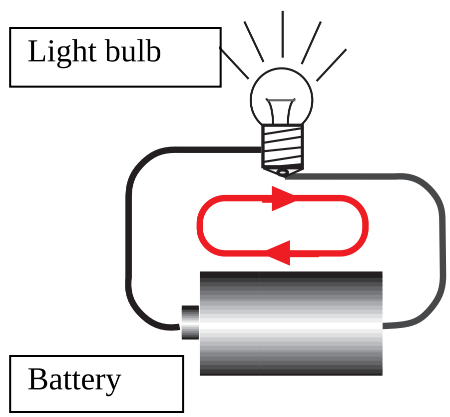


The purpose of this activity is to compare the variation in intensity (brightness) of light from different kinds of light sources. One light source is a flashlight powered by batteries (**direct current** (DC)). Another is a **fluorescent** light bulb that is powered by **alternating current** (AC) and a third is an **incandescent** light bulb that is powered by AC. How does the light from a DC light source compare to light from an AC light source? How does the light from a fluorescent tube compare to the light from an incandescent bulb?



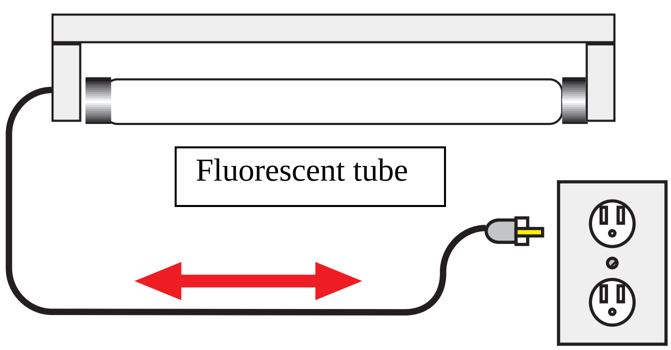
Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



Light bulbs convert electric energy into **thermal** energy and light energy. We can feel the thermal energy as heat coming from the light bulb. A flashlight bulb converts electric energy into thermal energy and light energy when moving electrons collide with the atoms of the small wire inside the flashlight bulb. A fluorescent light bulb converts electric energy when moving electrons collide with atoms of gas inside the fluorescent light bulb.

In a circuit with a flashlight bulb and a battery, the electron flow is in one direction. This type of electron flow is called direct current. Once the flashlight is turned on, the flashlight bulb shines steadily all the time that it is on.

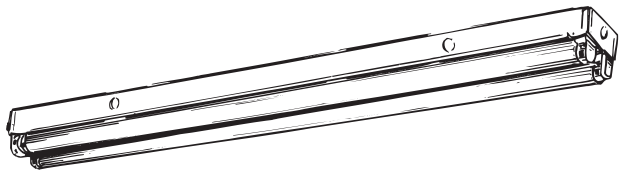


In a circuit with a fluorescent light bulb that is connected to an electric outlet, the electron flow is back-and-forth. This type of electron flow is called alternating current. Each back-and-forth movement of electrons is called a **cycle**. In the United States and other countries, the alternating current from an electric outlet has sixty cycles (back-and-forth) each second.

With alternating current (AC), the fluorescent light bulb will shine when the electron flow is in one direction (to the left, for example) and will not shine while the electron flow <u>changes</u> direction. It will shine again when the electron flow is in the opposite direction (to the right, for example). The electrons flow in one direction or the other TWICE per cycle. In the U.S. and other countries where the alternating current has sixty cycles each second, the fluorescent light bulb turns on and off 120 times each second. Therefore, the light from a fluorescent bulb has a maximum brightness 120 times each second.

One cycle each second is called one “hertz” (pronounced like “hurts”) and one hertz is abbreviated “Hz”. The number of cycles each second is called the **frequency**. An alternating current that has sixty cycles each second has a frequency of 60 hertz, or 60 Hz.

Fluorescent lights blink on and off at a particular frequency. The light intensity from incandescent bulbs powered by AC fluctuates as well. The light intensity from an incandescent bulb powered by DC should not vary.



SAFETY REMINDERS

- Follow directions for using the equipment.

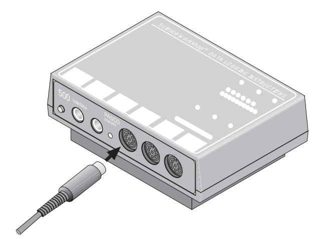
THINK SAFETY
ACT SAFELY
BE SAFE!

For You To Do

In this activity, use the Light Sensor to measure the intensity of light from light bulbs powered by AC or DC. There are three parts to the activity: Part A = Fluorescent bulb, AC; Part B = Incandescent bulb, AC; and Part C = Incandescent bulb, DC.

Use *DataStudio* or *ScienceWorkshop* to monitor and display the variations, if any, in the light intensity. Compare the light intensity of fluorescent and incandescent lights powered by AC, and an incandescent light powered by DC.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Light Sensor cable into Analog Channel A on the interface. Connect the Light Sensor to the cable.
3. Open the document titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS02 Vary Light.DS	G02 Light Bulb Intensity	G02_BULB.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document opens with a Scope display of voltage from the Light Sensor in Channel A and a Frequency Spectrum (FFT) display for the same sensor. It also has a Digits display for the voltage from the Light Sensor.
- The data measurement is set at 5000 Hz (set by the Sweep Speed control in the Scope display). The Frequency Spectrum (FFT) is set to 256 data points.

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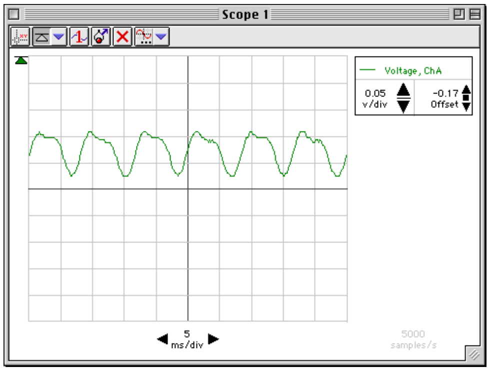
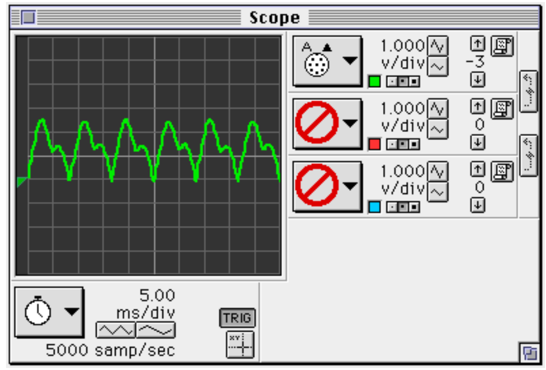
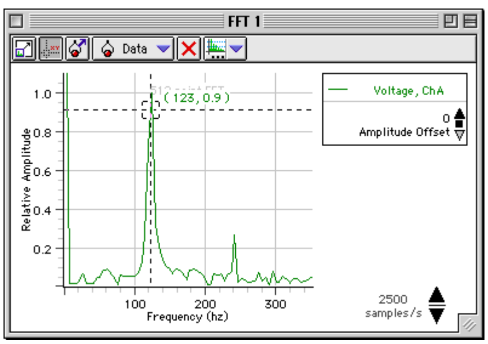
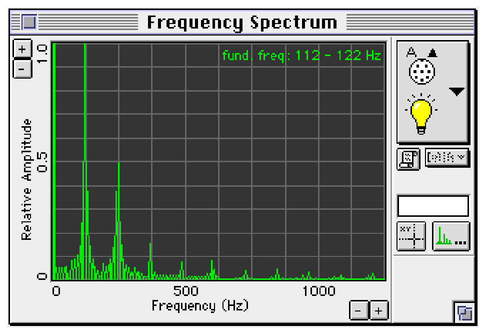
Remember, the Scope display is like an oscilloscope. An oscilloscope is a special instrument for measuring and showing voltage, especially the voltage from something that is changing quickly. The Scope display looks like a television screen.





The Frequency Spectrum (FFT) display is a special kind of graph. The Frequency Spectrum shows the frequency (number of cycles per second) of each part of the signal that is being measured by the *ScienceWorkshop* interface. The Frequency Spectrum sometimes looks like many mountain peaks. Each peak stands for the frequency of one part of the signal that is being measured.





PART II: Sensor Calibration & Equipment Setup

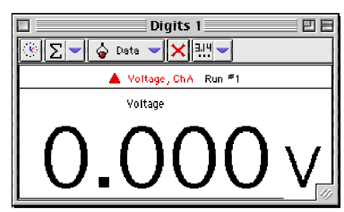
- You do not need to calibrate the Light Sensor. However, you may need to adjust the sensitivity of the sensor, depending on the brightness of the light source and how close the sensor is to the source.

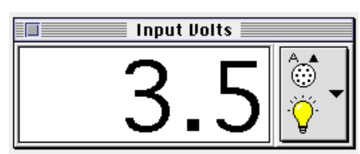
Adjusting Light Sensor Sensitivity

- The Light Sensor has a GAIN switch on the top of the sensor box. The GAIN switch selects the amount of amplification for the signal that is sent to the interface. The settings are 1, 10, and 100. The setting of 10 amplifies the signal ten times and the setting of 100 amplifies the signal one hundred times.

Try the following to become more familiar with the Light Sensor:

- Place the Light Sensor on a table so the port on the sensor is below an overhead light. Set the GAIN switch to 1.
- Start measuring data. Click ‘Start’ in *DataStudio* or click ‘MON’ in *ScienceWorkshop*. Move the Digits display of Input Volts so you can see it clearly.





- Switch the GAIN to 10 and observe the value of Input Volts in the Digits display. Then switch to 100 and observe the value of Input Volts.

NOTE: The maximum voltage from the sensor is 4.9 V for any GAIN setting.

- Cover the Light Sensor port and observe the value of Input Volts.
- Return the GAIN setting to 10. Pick up the sensor. Observe the value of Input Volts as you move the Light Sensor closer to the overhead light source. Observe what happens when you move the Light Sensor farther from the light source.
- Click STOP to stop measuring data.

Equipment Setup

1. Place the Light Sensor within a few feet of a fluorescent bulb that is powered by AC.
2. Turn on the fluorescent bulb.

PART IIIA: Data Recording – Fluorescent Bulb, AC

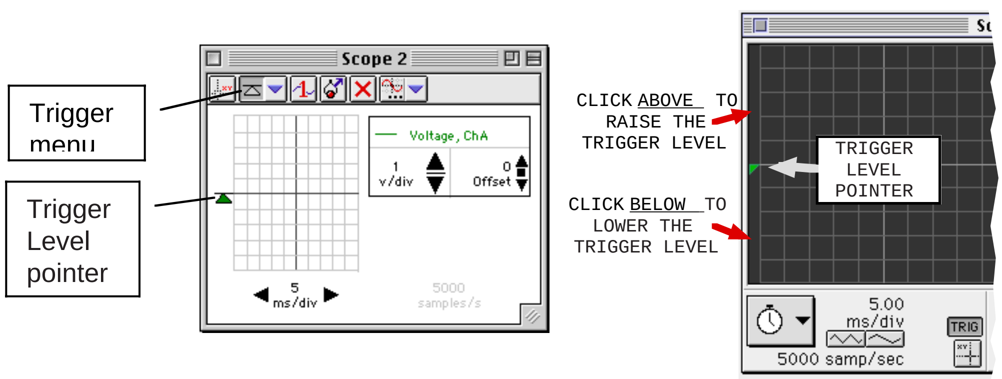
1. Start measuring data. (Hint: In *DataStudio*, click the ‘Start’ button (
). In *ScienceWorkshop*, click the ‘MON’ button.) Arrange the Scope display, the Digits display, and the Frequency Spectrum (FFT) so you can see them clearly.

- NOTE: It is likely that you will see a value in the Digits display, and a spectrum in the Frequency Spectrum display, but nothing in the Scope display. This is because the trigger control in the Scope is on, and the trigger level may be set too low for the voltage produced by the Light Sensor.

2. Adjust the Scope display until you see the trace of voltage from the Light Sensor:

- First, adjust the trigger level.

In *DataStudio*, move the small triangle (the ‘Trigger Level’ pointer) on the left side of the display up or down to the desired voltage level. In *ScienceWorkshop*, click in the space along the left edge of the Scope display that is above the Trigger Level pointer. When you



click above or below the Trigger Level Pointer, it “jumps” to the spot you clicked. The value in the Digits display will indicate the approximate trigger level you need.

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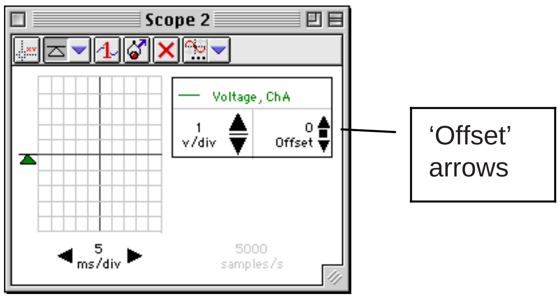
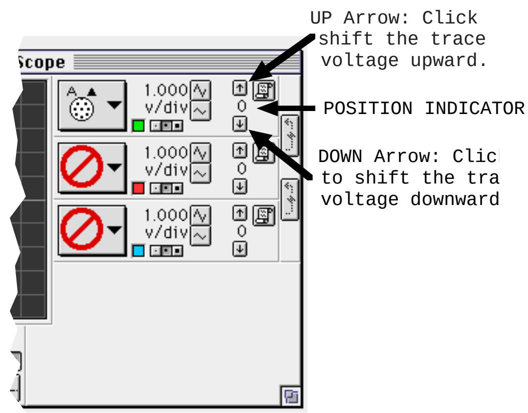
- Second, adjust the vertical position of the trace of voltage.

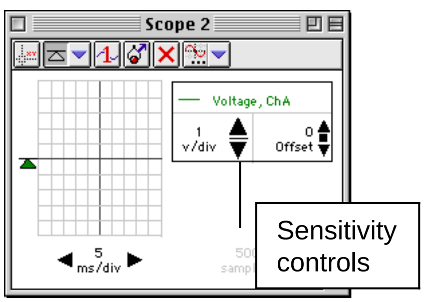
  In *DataStudio*, click the up or down arrows next to ‘Offset’. In *ScienceWorkshp*, click the ‘UP/DOWN Arrows’ in the right side of the Scope display.

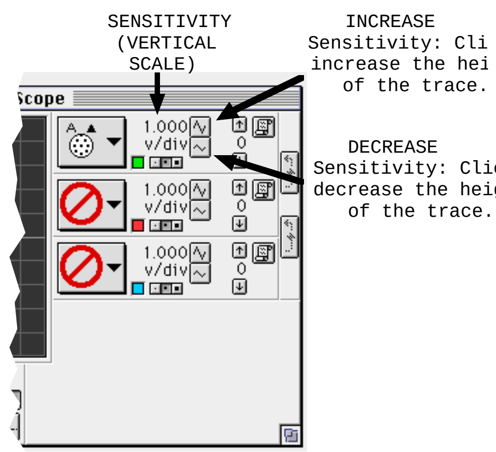


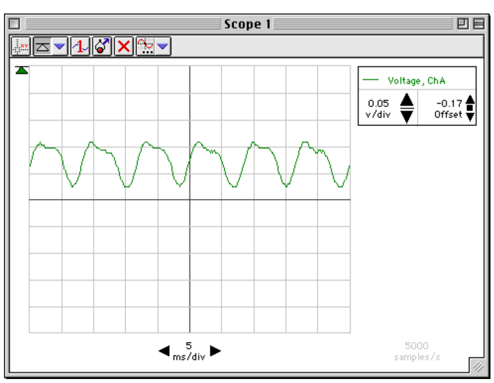


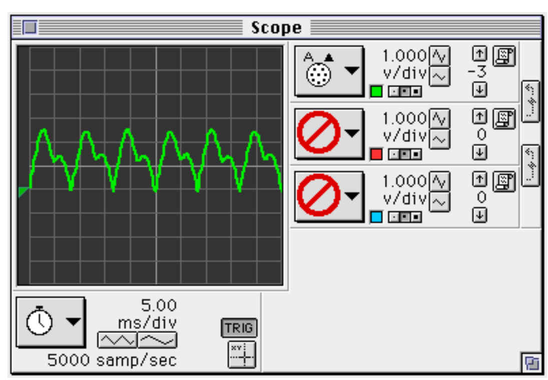
- Finally, adjust the Sensitivity (volts per division) if needed.

  In *DataStudio*, click the arrows to increase or decrease the sensitivity. In *ScienceWorkshop*, click the **Vertical Scale** buttons in the right side of the Scope display.





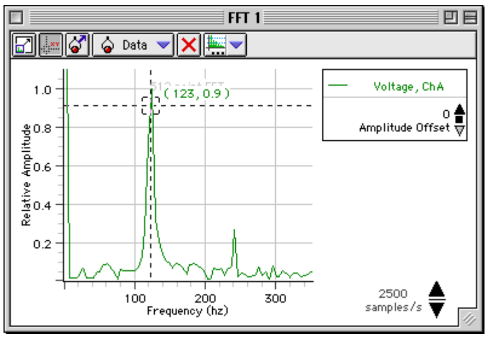


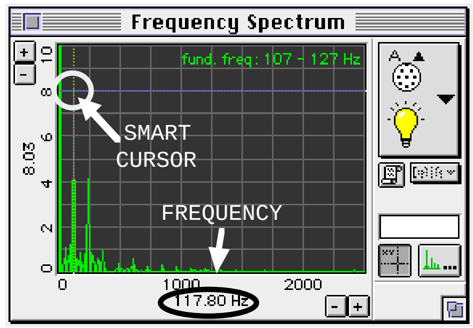


3. Use the Frequency Spectrum to measure the frequency of the signal from the Light Sensor. Record the value of the frequency in the Lab Report section.

- Make the FFT display (Frequency Spectrum) active. In *DataStudio*, click the 'Smart Tool' button. In *ScienceWorkshop*, click the 'Smart Cursor' button. Move the cursor/cross-hair to the top of the first peak in the display area. In *DataStudio*, the frequency is the first number in the ordered pair. In *ScienceWorkshop*, the frequency is shown below the horizontal axis.

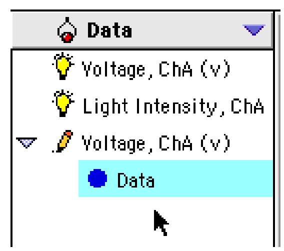
4. Click the STOP button to stop monitoring data.



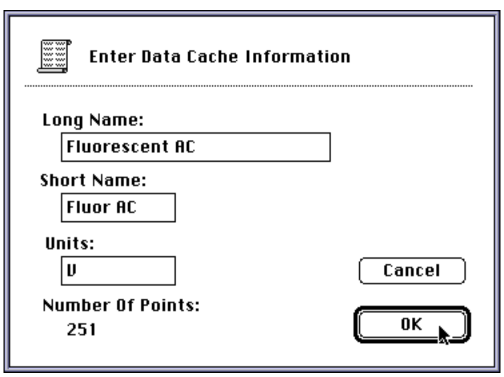


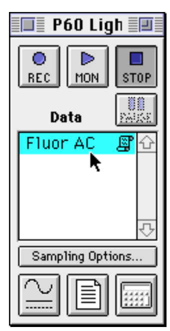
5. Save the trace that is displayed on the Scope. Click the Scope to make it active.

- In *DataStudio*, click the 'Transfer' button (). The data in the Scope is automatically added to the data list.



- In *ScienceWorkshop*, click the 'Data Snapshot' button () in the right side of the Scope display. The **Data Cache Information** window will open. Enter appropriate information for the **Long Name**, **Short Name**, and **Units**. Click **OK** to return to the Scope.





- The **Short Name** for the Data Cache will appear in the Data List in the Experiment Setup window. (NOTE: You can display and analyze the Data Cache in any display that can show recorded data such as the Graph, Table, or FFT.)

PART IIIB: Incandescent Light – AC

Repeat the activity using an incandescent light connected to an AC power supply.

PART IIIC: Incandescent Light – DC

Repeat the activity using a battery operated flashlight.

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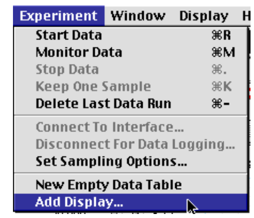
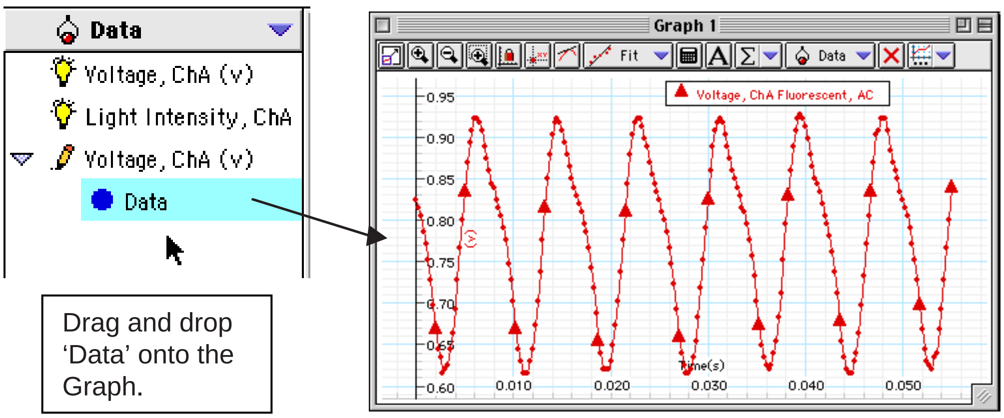
Analyzing the Data

1. Set up a Graph display to show data for the AC fluorescent light, AC incandescent light, and DC incandescent light.

- Hint: In *DataStudio*, do the following:



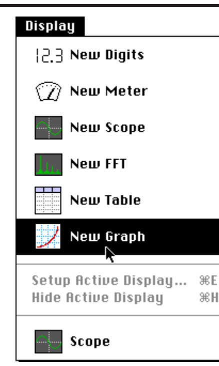
- Click 'Add Display…' from the Experiment menu.
- Select 'Graph' from the 'Please Choose…' window. Click 'OK'.
- Click and drag 'Data' from the Data list to the new Graph display.

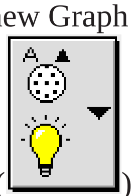


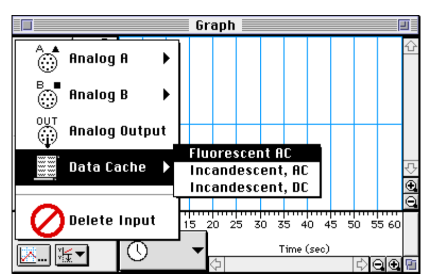
Drag and drop 'Data' onto the Graph.

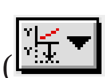
- The Graph automatically rescales to fit the data. Repeat the process for the other runs of data.

- Hint: In *ScienceWorkshop*, do the following:



- Click the **Display Menu**. Select **New Graph** from the Display Menu.
- In the new Graph display, click the **Vertical Axis Input Menu** button (). Select **Data Cache, Fluorescent AC** from the Input Menu.

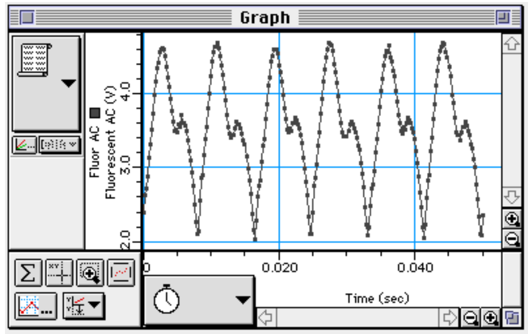


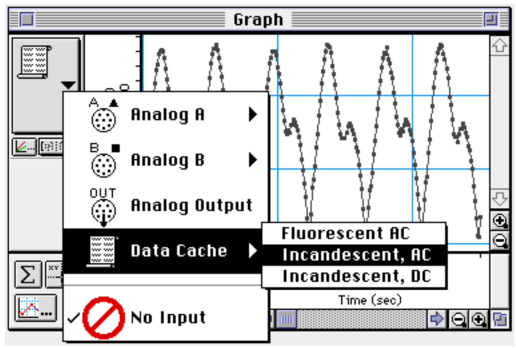
- The Graph will show the data seen in the Scope display for the fluorescent bulb powered by AC.
- Click the **Add Plot Menu** button () in the lower left corner of the Graph. Select **Data Cache, Incandescent AC** from the Add Plot Menu.

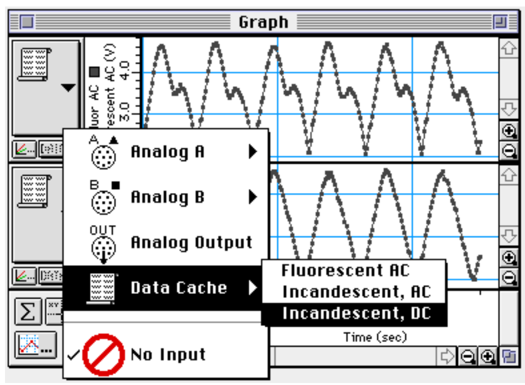
- A new plot will be added to the Graph. It will show the data seen in the Scope display for the incandescent bulb powered by AC.

- Click the **Add Plot Menu** button again. Select **Data Cache, Incandescent DC** from the Add Plot Menu.

- A third plot will be added to the Graph.







Use your results to answer the questions in the Lab Report section.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS02: Variation of Light Intensity

What Do You Think?

The purpose of this activity is to compare the variation in intensity (brightness) of light from different kinds of light sources. One light source is a flashlight powered by batteries (**direct current** (DC)). Another is a **fluorescent** light bulb that is powered by **alternating current** (AC) and a third is an **incandescent** light bulb that is powered by AC. How does the light from a DC light source compare to light from an AC light source? How does the light from a fluorescent tube compare to the light from an incandescent bulb?

Data Table

Light Source	Frequency
Fluorescent, AC	Hz
Incandescent, AC	Hz
Incandescent, DC	Hz

Questions

1. How does the frequency of light intensity variation for the fluorescent AC bulb and the incandescent AC bulb compare to the accepted value for AC frequency?

2. What happens to the relative brightness of a fluorescent light bulb powered by AC? How does the relative brightness of an incandescent bulb run on powered by AC differ from the fluorescent bulb?

3. What happens to the relative brightness of a flashlight bulb powered by DC?

Ending the Activity

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select **Quit** from the **File** menu to end the activity.
2. You can select **Save** or **Save As…** from the File menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select **Open…** from the **File** menu, and find the document for the next activity.

Name ____________________ Class _____________ Date _________

Activity GS03: Mixing Hot and Cold Water – Thermodynamics (Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Thermodynamics	GS03 Mix Hot and Cold.DS	G03 Hot and Cold	G03_HOT.SWS

Equipment Needed	**Qty**	**Consumables**	**Qty**
Temperature Sensor (CI-6505A)	1	Water, hot	150 mL
Beaker, 250 mL	2	Water, ice	200 mL
Graduated cylinder, 100 mL	1		
Protective gear	PS		

What Do You Think?

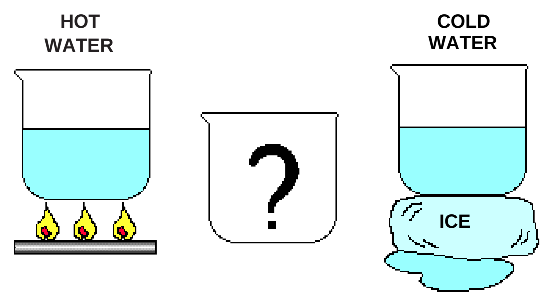
When masses of substances at different temperatures are mixed together, the hotter substance heats the cooler substance and the resulting final temperature is somewhere between the initial temperatures of the two substances. Can you predict the final temperature of a mixture of two substances?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

Temperature is a measure of the average **kinetic energy** (energy of motion) of the particles in a substance. The **thermal energy** in the substance is the total of all the kinetic energy of all the particles in the substance. The thermal energy in a substance depends on the mass of the substance, the **specific heat capacity** of the substance, and the temperature of the substance.

Heat is the name given to thermal energy when it moves from a substance with a high temperature to a substance with a lower temperature. Heat is energy in transit.



WHAT WILL THE TEMPERATURE OF THE MIXTURE BE COMPARED TO THE TEMPERATURE OF THE HOT WATER AND THE COLD WATER?

When substances of different temperatures are mixed, the hotter one heats the cooler one until the temperature of the mixture reaches a balance called **thermal equilibrium**.

The thermal energy in an object depends on the amount of mass, the specific heat of the object, and its temperature. In equation form:

$$\Delta Q \text{ (change in thermal energy)} = m\,c\,\Delta T$$

where **m** is the mass in grams, **c** is the specific heat and **ΔT** is the change in temperature.

The value for the specific heat, **c**, of water is 1.0 cal/g ˚C or 4.19 J/g ˚C. This value is constant between the temperatures of 0˚ C and 100 ˚C.

When a hot substance heats a cooler one, the energy 'lost" by the hot substance equals the energy 'gained' by the cooler one, or (in equation form):

$$Q_{lost} = Q_{gained}$$

For You To Do

For this activity, use mathematical logic and algebra to predict the final temperature of a mixture of hot and cold water. Then use the Temperature Sensor to measure the temperature of a hot liquid and the temperature of a cold liquid before they are mixed. Use the Temperature Sensor to measures the temperature of the mixture. Use insulated containers so that the containers will not gain or lose thermal energy during the activity.

This activity has two parts. In PART A, the amount of hot liquid is the same as the amount of cold liquid. In PART B, you will use different amounts of each liquid. You will make predictions for the final equilibrium temperature for the mixture based on the temperature of the hot and cold liquids before they are mixed.

Use *DataStudio* or *Science Workshop* to record, display, and analyze the data on a Graph.

Prediction: PART A

Will the temperature of a mixture of hot and cold water be the same as the temperature of the hot water by itself or the cold water by itself?

- Predict what the final temperature will be for the mixture of the hot and cold water compared to the temperature of either the hot water by itself or the cold water by itself. Imagine that the hot water is at 70 ˚C and the cold water is at 10 ˚C. For PART A assume that *equal* amounts of water are mixed together.

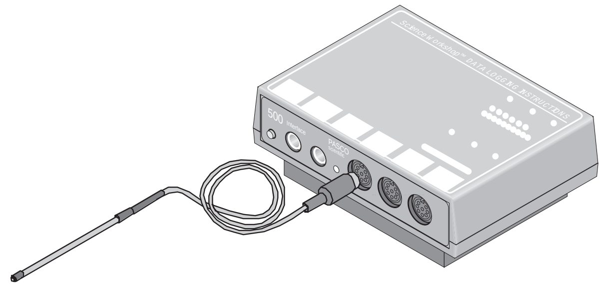
Starting temp. of hot water	Starting temp. of cold water	Predicted temp. of mixture
70 ˚C*	10 ˚C*	

(*These temperatures are just examples.)

SAFETY REMINDERS

- Wear protective gear while handling hot water containers.
- Follow directions for using the equipment.

PART I: Computer Setup

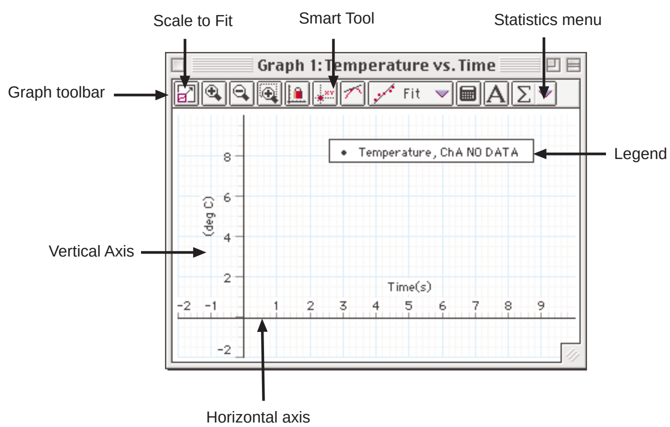


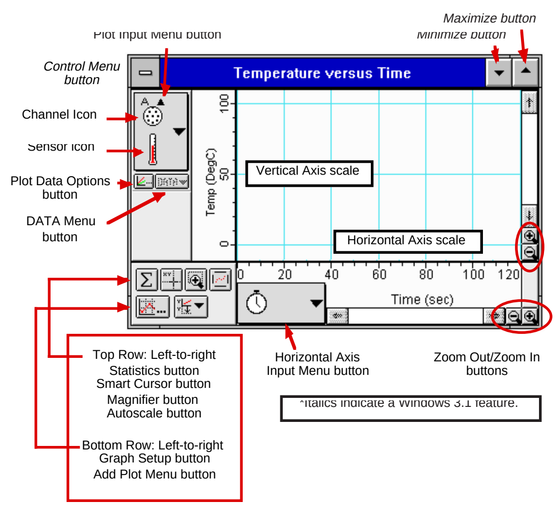
1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and then turn on the computer.
2. Connect the Temperature Sensor DIN plug into Analog Channel A on the interface.
3. Open the file as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS03 Mix Hot and Cold.DS	G03 Hot and Cold	G03_HOT.SWS

- The *DataStudio* document has a Graph display and a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Graph display of temperature versus time.
- Data recording is set for ten measurements per second (or 10 Hz).

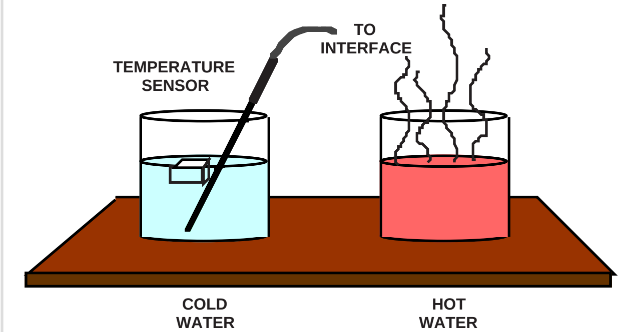
See the *DataStudio* Online Help file or the *ScienceWorkshop* User's Guide for more information about the Graph display.





PART IIA: Equipment Setup – Equal Amounts of Hot and Cold Water

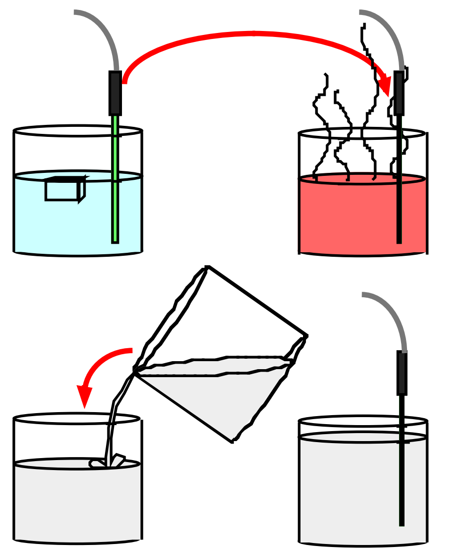
1. Put 100 mL (milliliters) of cold water into the first container so that it is slightly less than half full.
2. Put 100 mL of hot water into the second container so that is also slightly less than half full.



HOT AND COLD - THERMODYNAMICS (TEMPERATURE SENSOR)

PART IIIA: Data Recording – Equal Amounts of Hot and Cold Water

1. Place the Temperature Sensor into the cold water. Start recording data. Watch the values of temperature in the Graph display.
2. After about 40 seconds, move the Temperature Sensor to the hot water.
3. After a total of 80 seconds, <u>remove the Temperature Sensor from the hot water</u>. Pour the hot water into the cold water.
4. Quickly place the Temperature Sensor into the combined liquids. Stir to thoroughly mix the two liquids.
5. Stop data recording after 120 seconds.



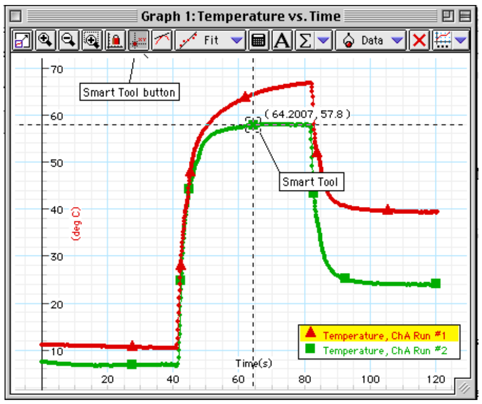
Name _____________________ Class ______________ Date _________

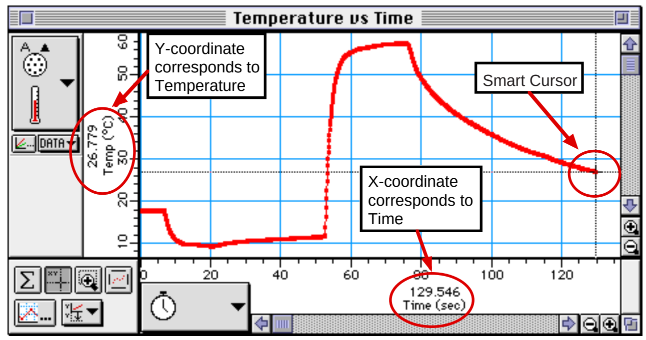
Analyzing the Data: PART A – Equal Amounts of Hot and Cold Water

1. Rescale the Graph to fit your data.
2. Find and record the LOWEST temperature in the Graph (the Y-coordinate of the lowest point in the Graph).

- Hint: Use the Smart Tool in *DataStudio* or the Smart Cursor in *ScienceWorkshop*.

3. Find and record the HIGHEST temperature in the Graph (the Y-coordinate of the highest point in the Graph).
4. Find and record the <u>final</u> temperature of the combined liquids (the Y-coordinate at the end of the plot).





Record your results in the Lab Report section.

Procedure: PART B – Unequal Amounts of Hot and Cold Water

For this part of the activity, measure the temperature of hot water and cold water before and after they are mixed, but use unequal amounts of hot and cold water.

Prediction: PART B – Unequal Amounts of Hot and Cold Water

Will the final temperature of unequal amounts of hot and cold water be the same as the final temperature of equal amounts of hot water and cold water?

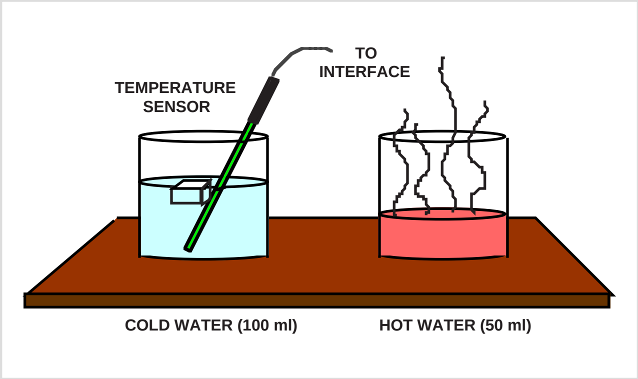
1. Predict what the final temperature will be for the mixture of the hot and cold water compared to the temperature of either the hot water by itself or the cold water by itself. (Imagine that you have 50 mL of hot water at 70 ˚C and 100 mL of cold water at 10 ˚C.)

Temp. of hot water (50 mL)	Temp. of cold water (100 mL)	Predicted temp. of mixture
70 ˚C*	10 ˚C*	

(*These temperatures are just examples.)

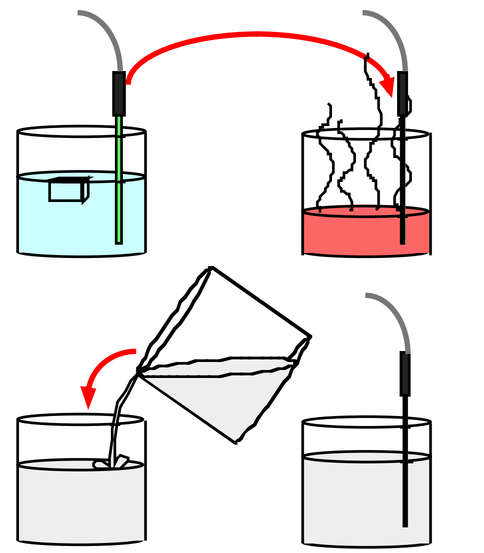
PART IIB: Equipment Setup – Unequal Amounts of Hot and Cold Water

1. Put 100 mL (milliliters) of cold water into the first container so that it is slightly less than half full.
2. Put 50 mL of hot water into the second container.



PART IIIB: Data Recording – Unequal Amounts of Hot and Cold Water

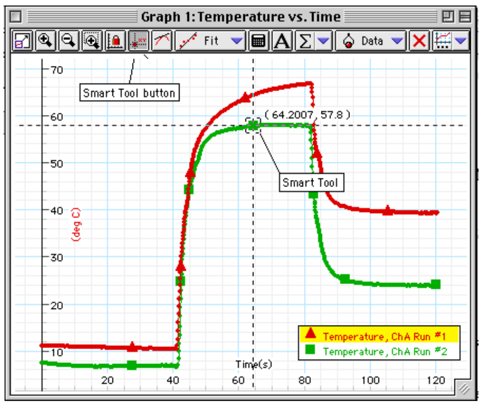
1. Place the Temperature Sensor into the cold water. Start recording data. Watch the values of temperature in the Graph display.
2. After about 40 seconds, move the Temperature Sensor to the hot water.
3. After a total of 80 seconds, <u>remove the Temperature Sensor from the hot water</u>. Pour the hot water into the cold water.
4. Quickly place the Temperature Sensor into the combined liquids. Stir to thoroughly mix the two liquids.
5. Stop end data recording after 120 seconds.

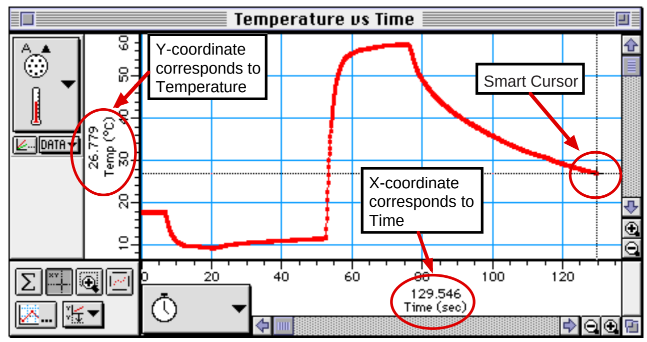


Name ____________________ Class ______________ Date _________

Analyzing the Data: PART B – Unequal Amounts of Hot and Cold Water

1. Rescale the Graph to fit your data.
2. Find and record the LOWEST temperature in the Graph (the Y-coordinate of the lowest point in the Graph).
3. Hint: Use the Smart Tool in *DataStudio* or the Smart Cursor in *ScienceWorkshop*.
4. Find and record the HIGHEST temperature in the Graph (the Y-coordinate of the highest point in the Graph).
5. Find and record the <u>final</u> temperature of the combined liquids (the Y-coordinate at the end of the plot).





Record your results in the Lab Report section.

Ending the Activity

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select **Quit** from the **File** menu to end the activity.
2. You can select **Save** or **Save As…** from the File menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select **Open…** from the **File** menu, and find the document for the next activity.

Name ______________________ Class _______________ Date _________

Lab Report - Activity GS03: Mixing Hot and Cold Water

What Do You Think?

When masses of substances at different temperatures are mixed together, the hotter substance heats the cooler substance and the resulting final temperature is somewhere between the initial temperatures of the two substances. Can you predict the final temperature of a mixture of two substances?

Prediction: PART A – Equal Amounts of Hot and Cold Water

Will the temperature of a mixture of hot and cold water be the same as the temperature of the hot water by itself or the cold water by itself?

- Predict what the final temperature will be for the mixture of the hot and cold water compared to the temperature of either the hot water by itself or the cold water by itself.

Starting temp. of hot water	Starting temp. of cold water	Predicted temp. of mixture

Data Table: PART A – Equal Amounts of Hot and Cold Water

LOWEST Temperature	HIGHEST Temperature	Final Temperature

Prediction: PART B – Unequal Amounts of Hot and Cold Water

Will the final temperature of unequal amounts of hot and cold water be the same as the final temperature of equal amounts of hot water and cold water?

- Predict what the final temperature will be for the mixture of the hot and cold water compared to the temperature of either the hot water by itself or the cold water by itself.

Temp. of hot water (50 mL)	Temp. of cold water (100 mL)	Predicted temp. of mixture

Data Table: PART B – Unequal Amounts of Hot and Cold Water

LOWEST Temperature	HIGHEST Temperature	Final Temperature

Questions

1. In PART A, how does the final temperature of the mixture compare to the lowest temperature of the 100 mL of cold water and the highest temperature of the 100 mL of hot water?

2. In PART B, how does the final temperature of the mixture compare to the lowest temperature of the 100 mL of cold water and the highest temperature of the 50 mL of hot water?

3. How does the final temperature in PART A compare to your prediction?

4. How does the final temperature in PART B compare to your prediction?

5. If the initial temperatures of the hot and cold water were increased by the same amount, how would this effect the final temperature of the new mixture?

Conclusion

- Write a sentence that describes how to predict a final temperature for a mixture of hot and cold liquids based on the amount of each liquid and the starting temperature of each liquid.

Optional

Predict the final temperature of these mixtures:

100 mL of 10 ˚C water and 100 mL of 40 ˚C water.

200 mL of 10 ˚C water and 100 mL of 40 ˚C water.

100 mL of 10 ˚C water and 200 mL of 40 ˚C water.

300 mL of 10 ˚C water and 100 mL of 40 ˚C water.

100 mL of 10 ˚C water and 300 mL of 40 ˚C water.

100 mL of 0 ˚C water and 100 mL of 100 ˚C water.

100 mL of 20 ˚C water and 200 mL of 50 ˚C water.

Name ____________________ Class ______________ Date _________

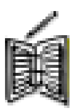
Activity GS04: pH of Household Chemicals – Chemistry (pH Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Chemistry	GS04 Household pH.DS	G04 pH of Chemicals	G04_PH.SWS

Equipment Needed	Qty	Chemicals and Consumables	Qty
pH Sensor (CI-6507)	1	Egg (raw)	50 mL
Beaker, 250 mL	4	Fruit juice	50 mL
Wash bottle	1	Lemon juice	50 mL
Protective gear	PS	Milk	50 mL
Chemicals and Consumables	**Qty**	Milk of magnesia	50 mL
Buffer solution: high pH	100 mL	Soda pop	50 mL
Buffer solution: low pH	100 mL	Tissues or paper towels	many
Bleach	50 mL	Water, distilled	1 L
Detergent (liquid)	50 mL	Water, tap	50 mL

What Do You Think?

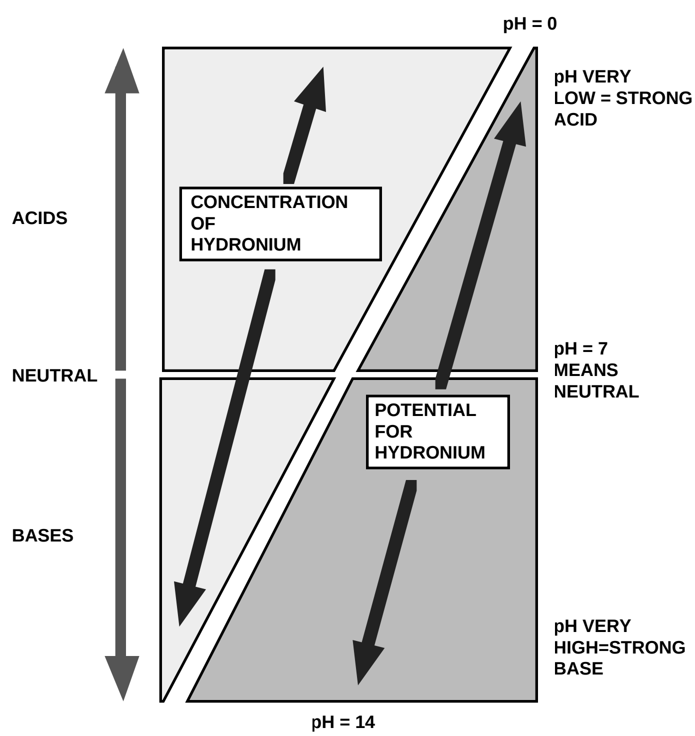
In this activity you will measure and record the **potential for hydronium (pH)** of several household chemicals such as bleach, lemon juice, and milk. You will put each chemical into a category: **acid**, **neutral**, or **base**. What is the category for each substance mentioned?



Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

One way to classify a chemical is to measure whether it is an acid, a base, or is neutral. Acids and bases have been known since early times. Acids (from Latin *acidus*, or sharp) have a sharp, sour taste (for example, vinegar). Bases have a bitter taste and **neutralize** the effects of acids. (Substances that are bases are sometimes called "alkaline".)



Whether a substance is an acid or a base or is neutral can be measured using the **pH scale**. The pH of a solution is a measure of the potential for adding more **hydronium (H_3O^+)** to the solution. Acid solutions already have a large amount of hydronium in them, so the potential for hydronium, or pH, is very low. Basic solutions have lots of **hydroxide (OH^-)** ions that would 'soak up' lots of hydronium, so the potential for hydronium is very high.

Most pH values range from 0 to 14. A pH value of 7 means a neutral solution. A pH value below 7 means an acid. A pH value above 7 means a base. Rainwater is slightly acidic. Blood is slightly basic.

SAFETY REMINDERS

- Wear protective gear (apron, gloves, goggles or splash shield).
- Follow directions for using the equipment.
- Handle and dispose of all chemicals and solutions properly.

For You To Do

Calibrate the pH Sensor before you begin to make measurements.

Use the pH Sensor to measure the pH of many common chemical solutions such as fruit juice, raw egg, and liquid detergent. Use *DataStudio* or *ScienceWorkshop* to record and display the values of pH. Use the software to assign a number to identify each chemical.

After you record data you can classify each substance as acid, base, or neutral.

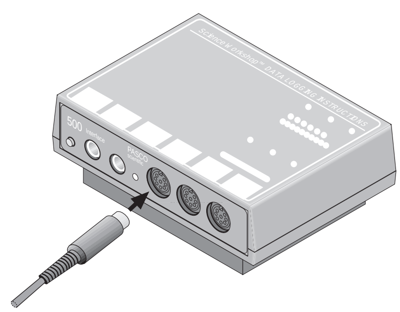
Prediction

Is lemon juice an acid, a base, or neutral? Is liquid detergent an acid, a base, or neutral? How about raw egg or milk?

- Predict which of the following substances will be acid (A), base (B), or neutral (N). Record your predictions in the table by putting a letter in the column next to the substance.

Substance	A-B-N	Substance	A-B-N	Substance	A-B-N
(1) bleach		(4) fruit juice		(7) milk of magnesia	
(2) egg (raw)		(5) lemon juice		(8) soda pop	
(3) detergent		(6) milk		(9) tap water	

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the pH Sensor to Analog Channel A on the interface.
3. Open the file titled as shown:

- The document has a Digits display showing pH and a Table display showing pH and the number of each chemical.

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS04 Household pH.DS	G04 pH of Chemicals	G04_PH.SWS

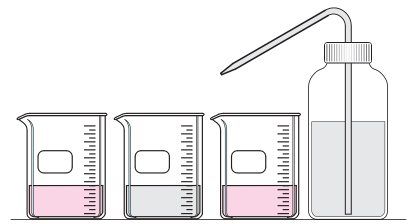
- The *DataStudio* document also has a Workbook display. Read the instructions in the Workbook.

PART II: Sensor Calibration and Equipment Setup

- Why is it important to calibrate the pH Sensor?

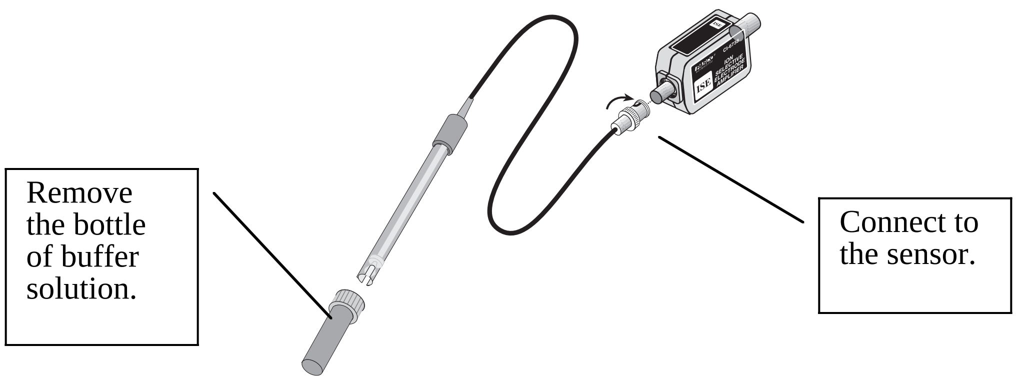
  When you calibrate a sensor, you use the sensor to make a measurement of something that you know is a certain value. For example, imagine that you put the pH Sensor into a solution that has a pH of exactly 7. When you calibrate the sensor, you put the sensor into the known solution and then tell the program that the sensor is measuring something with a pH of 7. Then you put the sensor into a solution with another known value of pH. You tell the program what the new value of pH is. From then on, the program can figure out the pH of any other solution you used based on what it ‘knows’ about the first two solutions.

- To calibrate the pH Sensor you will need the following: wash bottle, distilled water, three beakers, buffer solutions of high pH (e.g. pH 10) and low pH (e.g. pH 4), pH Sensor.

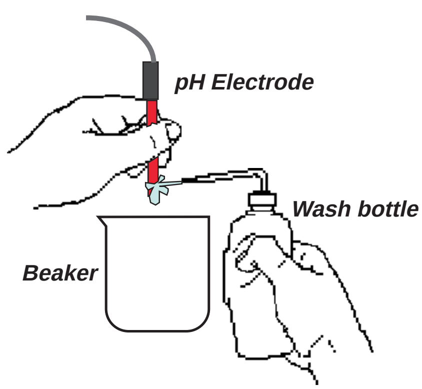


- Put distilled water into the wash bottle and into one of the beakers. Put about 100 mL of the high pH buffer solution in one of the other two beakers and about 100 mL of the low pH buffer solution into the third beaker.

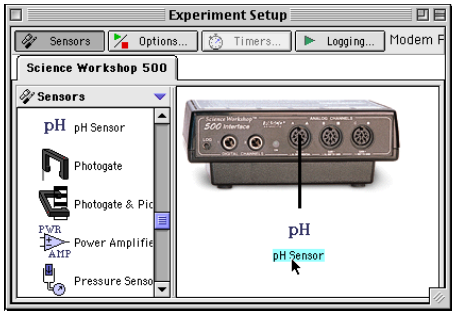
1. Remove the pH electrode from its bottle of buffer solution. Connect the electrode to the pH Sensor amplifier. To connect the electrode, push the BNC plug onto the receptacle on the Sensor amplifier and turn the BNC plug clockwise until it ‘clicks’ into place.

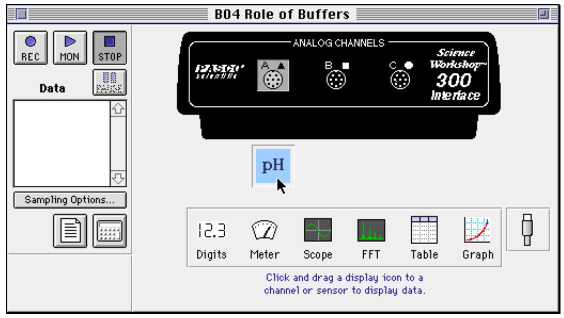


2. Use the wash bottle to rinse the end of the electrode. Soak the pH electrode in the beaker of distilled water for 10 minutes.

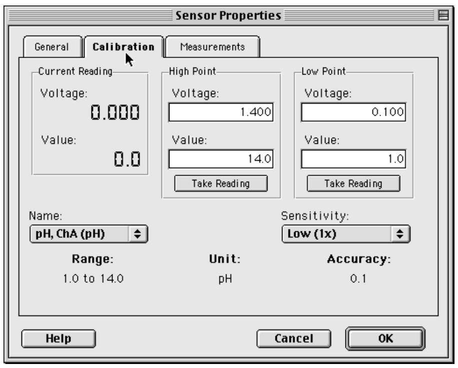


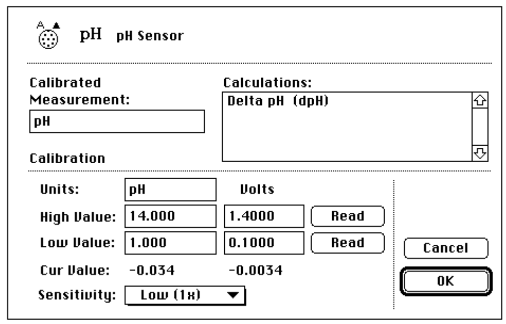
3. In the Experiment Setup window, double-click the pH Sensor icon.





- In *DataStudio*, the Sensor Properties window will open. Click the 'Calibration' tab. In *ScienceWorkshop*, the Sensor Setup window will open.





4. Calibrate with the high pH buffer solution.

- Put the end of the pH electrode into the high pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'High Point' in *DataStudio* or the 'Read' button in the row for 'High Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution.

5. Thoroughly rinse the pH electrode with distilled water and dry it with a tissue.

6. Calibrate with the low pH buffer solution.

- Put the end of the pH electrode in the low pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'Low Point' in *DataStudio* or the 'Read' button in the row for 'Low Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution. Click **OK** to return to the Experiment Setup window.

7. Thoroughly rinse the pH electrode with distilled water and dry gently.

Name ____________________ Class _____________ Date ________

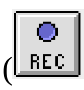
Equipment Setup

1. Put some of the first household chemical (bleach) you are going to measure in a clean, dry beaker.
2. Put the pH Electrode into the chemical.

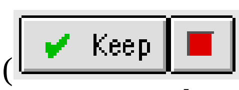
PART III: Data Recording

- Use the calibrated pH Sensor to measure the pH of each household chemical. Use *DataStudio* or *ScienceWorkshop* to also keep track of each chemical by typing in the following number of each chemical you measure.

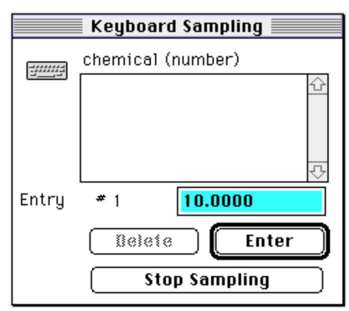
Number	Chemical
1	bleach
2	detergent (liquid)
3	egg (raw)
4	fruit juice
5	lemon juice
6	milk
7	milk of magnesia
8	soda pop
9	tap water

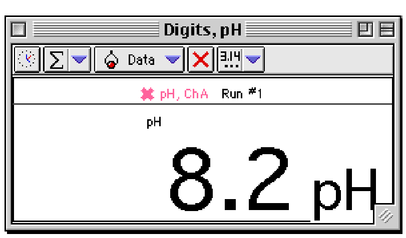
1. Make the Digits display active and move it so you can see it clearly.
2. Start measuring data. Click 'Start' in *DataStudio* or 'REC' (

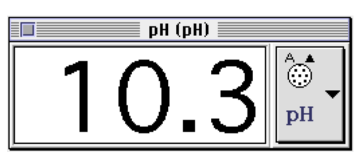
) in *ScienceWorkshop*.

- In *DataStudio*, the 'Start' button changes to 'Keep/Stop' (

Note: This button is explained a little later.) Also, the first value of pH appears in the Table display.
- In *ScienceWorkshop*, the 'Keyboard Sampling' window opens. (This window is where you can type in a number to label each chemical as you measure its pH value.) The box next to Entry #1 has a suggested number that you can ignore.
- The Digits display shows the pH value for the first chemical.

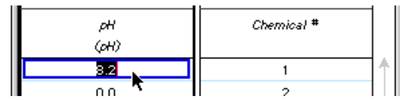




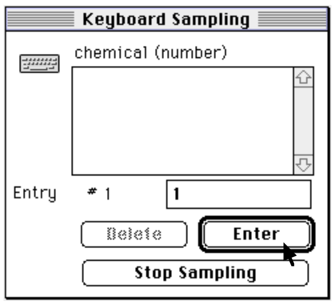


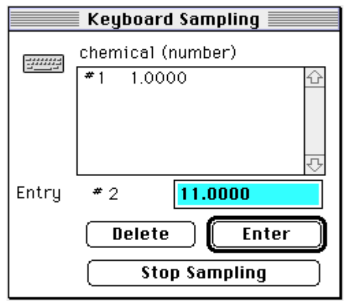
(Examples ONLY)

3. When the Digits display stabilizes after a few seconds, *record* the value.



- In *DataStudio*, click 'Keep' (). The program records the value of pH shown in the first row of the Table display.
- In *ScienceWorkshop*, type in **1** in the box next to Entry #1 in the 'Keyboard Sampling' window and then click (). The pH value of the first chemical is recorded along with the number you typed in. The 'Keyboard Sampling' window will change. The number you entered will appear in the list of chemicals. The Entry number will be #2. The entry box will have another suggested value.

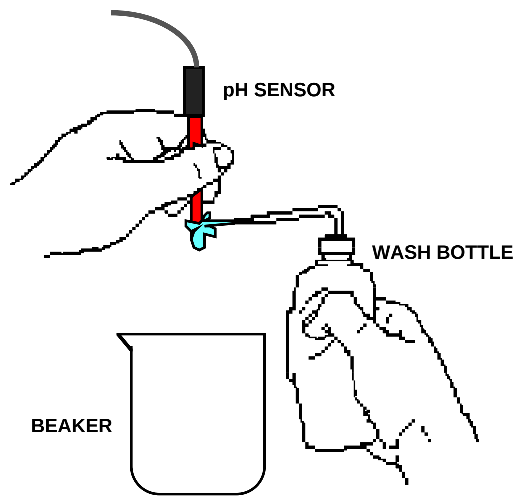




- Now you will need to get the second chemical ready so you can measure it.

4. Remove the pH Electrode from the beaker with the first chemical. Hold the pH Electrode over an empty beaker (or over a sink). Use the wash bottle with distilled water to thoroughly rinse off the pH Electrode.

5. Dispose of the first chemical as <u>instructed</u>. Don't pour the chemical into a sink unless you are told that it is okay to do so.

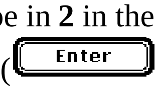


6. Rinse out the beaker. Dry the inside of the beaker. Put the second chemical (liquid detergent) into the clean beaker.

7. Put the pH Electrode into the second chemical (detergent).

- The Digits display will show a new value.

8. When the Digits display stabilizes, record the value.

- In *DataStudio*, click 'Keep'. In *ScienceWorkshop*, type in **2** in the box next to Entry #2 in the Keyboard Sampling window and then click Enter ().
- The pH value of the second chemical is recorded along with the number that identifies the chemical.

9. Remove the pH Electrode from the beaker with the second chemical. Hold the pH Electrode over an empty beaker (or over a sink). Use the wash bottle with distilled water to thoroughly rinse off the pH Electrode.

10. Dispose of the second chemical as instructed. Don't pour the chemical into a sink unless you are told that it is okay to do so.

11. Repeat the steps described above for the other household chemicals (fruit juice, lemon juice, etc.).

12. After you record the pH value for the last chemical, stop measuring data.

- In *DataStudio*, click the 'Stop' button next to 'Keep' (

). In *ScienceWorkshop*, click the 'Stop Sampling' button (

) in the Keyboard Sampling window.
- The Keyboard Sampling window will disappear. 'Run #1' will appear in the Data list in the Experiment Setup window.

ENDING THE ACTIVITY (See the section after Questions)

Analyzing the Data

- Now you can decide which chemicals are acids, which are bases, and which are neutral.

1. Click on the Table display to make it active. (NOTE: The numbers in this example are made up. Ignore them.)

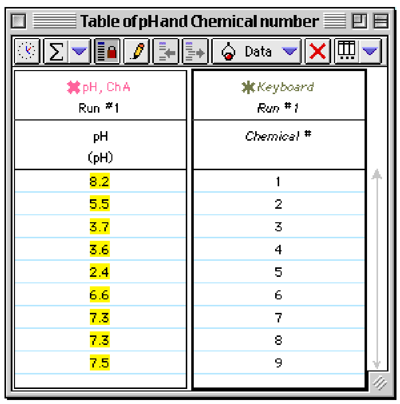
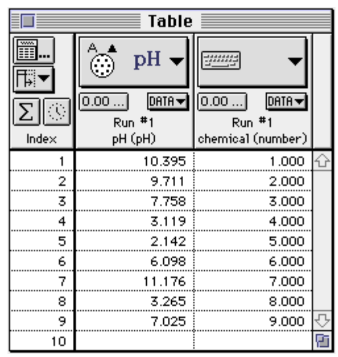


Table of pH and Chemical number

pH, ChA Run #1 pH (pH)	Keyboard Run #1 Chemical #
8.2	1
5.5	2
3.7	3
3.6	4
2.4	5
6.6	6
7.3	7
7.3	8
7.5	9



Table

Index	Run #1 pH (pH)	Run #1 chemical (number)
1	10.395	1.000
2	9.711	2.000
3	7.758	3.000
4	3.119	4.000
5	2.142	5.000
6	6.098	6.000
7	11.176	7.000
8	3.265	8.000
9	7.025	9.000
10		

- The first column in your Table display shows the pH values. The second column in your Table display shows the numbers used to label the chemicals.

2. Based on your measurements, classify each chemical as <u>acid</u>, <u>base</u>, or <u>neutral</u>.

Record your results in the Lab Report section.

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Lab Report - Activity GS04: pH of Household Chemicals

What Do You Think?

In this activity you will measure and record the **potential for hydronium (pH)** of several household chemicals such as bleach, lemon juice, and milk. You will put each chemical into a category: **acid**, **neutral**, or **base**. What is the category for each substance mentioned?

Data Table

Number	Chemical	pH Value	Acid, Base, Neutral
1	bleach		
2	detergent (liquid)		
3	egg (raw)		
4	fruit juice		
5	lemon juice		
6	milk		
7	milk of magnesia		
8	soda pop		
9	tap water		

Questions

1. Based on your data, how did your predictions compare to the measured values?

2. What are some characteristics that the acid solutions have in common?

3. What are some characteristics that the basic solutions have in common?

4. Which substance had the pH that surprised you the most?

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select ‘Quit’ from the ‘Fil’e menu to end the activity.
2. You can select ‘Save’ or ‘Save As…’ from the File menu to save your data for this activity. the changes you’ve made to the document.

- The original document is “locked”, so you should give <u>your</u> document a new filename.

3. If you wish to go on to the next activity, select ‘Open…’ from the ‘File’ menu, and find the document for the next activity.

Name ____________________ Class _____________ Date _________

Activity GS05: Mass on a Spring – Mechanics (Force Sensor, Motion Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Mechanics	GS05 Mass on a Spring.DS	G05 SHM Mass on a Spring	G05_MASS.SWS

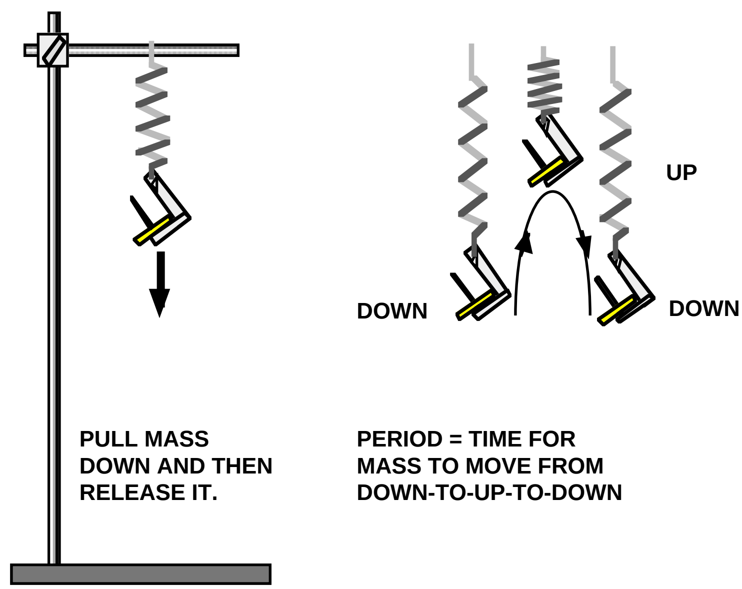
Equipment Needed	Qty	Equipment Needed	Qty
Economy Force Sensor (CI-6746)	1	**Mass and Hanger Set (ME-9348)**	1
Motion Sensor (CI-6742)	1	Meter stick	1
Balance (SE-8723)	1	**Support rod (ME-8736)**	1
Base and Support Rod (ME-9355)	1	**Spring, k ~ 2 to 4 N/m (632-04978)**	1
Clamp, right-angle (SE-9444)	1		

What Do You Think?

What is the motion of a mass oscillating on a spring? What other motions can you think of that are similar?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



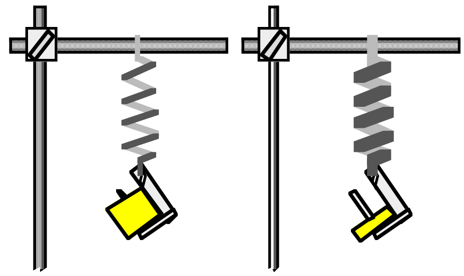
Imagine a spring that is hanging down. When no mass hangs at the end of the spring, the spring has a certain length L (called its rest length). When a mass is added to the spring, the spring is stretched a little bit to a new length. Add some more mass and the spring stretches some more.

If you pull the mass down to stretch the spring and then release the mass, it bobs up and down on the end of the spring. It takes a certain amount of time for the mass to go from the bottom position all the way up and back down again one time. This is called the **period of oscillation** (or **period** for short).

(Eventually the mass will stop moving. Its energy is converted into other forms as the spring stretches and compresses.)

There are two main factors that determine how long it takes for the mass on the spring to go from down-to-up-to-down (or one period).

One factor is the amount of mass that the spring has to lift when it moves up. The more mass, the longer the time. Another factor is the stiffness of the spring. If the spring is very stiff (strong) it can lift the mass more quickly. The stiffer the spring, the shorter the time.


MORE MASS <u>LENGTHENS</u> THE PERIOD

STIFFER SPRING <u>SHORTENS</u> THE PERIOD

When a spring is stretched or compressed, the spring exerts a **restoring force**. The restoring force causes the mass to bob up and down. The total amount of restoring force that the spring exerts depends on how strong (stiff) the spring is and the amount of distance that it is stretched or compressed. The formula for the total amount of restoring force is:

$$\mathbf{F = -kx}$$

where **F** is the amount of force, **x** is the distance the spring is stretched or compressed, and **k** is the <u>strength</u> of the spring, called the **spring constant**. (This formula is called Hooke's Law in honor of Robert Hooke, an English scientist who lived from 1635 to 1703.) The negative sign indicates that the force points opposite to the direction that the spring is stretched or compressed. This means that when you pull on the spring to stretch it, it pulls against you. When you push on the spring to compress it, it pushes against you again.

You can <u>predict</u> how long the period of oscillation will be if you know the <u>mass</u> on the end of the spring and the <u>spring constant</u>. The formula that gives the period when you know the mass and the spring constant is:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where **T** is the period of oscillation, π is the Greek letter "pi" and represents 3.1415…, **m** is the mass, and **k** is the string constant.

SAFETY REMINDER

- Follow the directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

Name ____________________ Class _____________ Date _________

Pre-Lab For You To Do

In the Pre-lab use the Force Sensor to measure the weight of a hanging mass. Use 'Keyboard Sampling' to enter the displacement of the spring from equilibrium. Use *DataStudio or ScienceWorkshop* to determine the spring constant k for the spring.

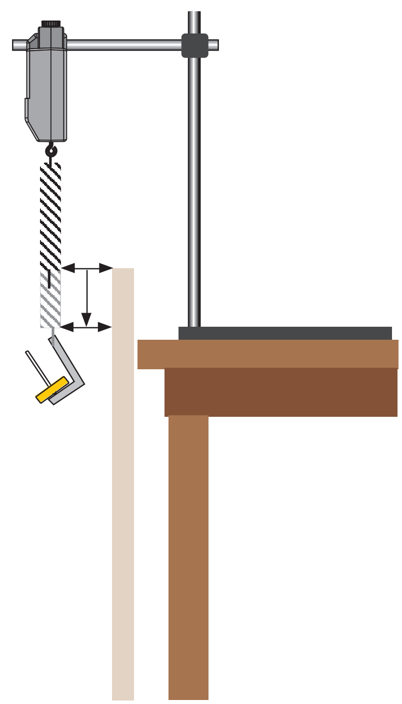
Pre-Lab PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Force Sensor to Analog Channel A.
3. Open the document titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
P14 Prelab SHM.DS	X19 Spring Constant	X19_SPNG.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Graph display of Force versus Stretch and a Digits display of Force.
- Data recording is set for 5 Hz. Use 'Keyboard Sampling' to enter the distance stretched in meters.

Pre-Lab PART II: Sensor Calibration and Equipment Setup



- To calibrate the Force Sensor, refer to the description in the Force Sensor Manual.

1. Using the rod and support stand, the clamp, and the second rod, mount the Force Sensor vertically so its hook end is down.
2. Suspend the spring from the Force Sensor's hook so that it hangs vertically.
3. Use the meter stick to measure the position of the bottom end of the spring (without any mass added to the spring). For your reference, record this measurement as the spring's equilibrium position in the Data Table in the Lab Report section.

Pre-Lab PART II: Data Recording

1. Press the tare button on Force Sensor to zero the Force Sensor.
2. Start data recording.

In *DataStudio*, move the Table display so you can see it. Click the 'Start' button to start recording data.

- The 'Start' button changes to a 'Keep/Stop' and a 'Stop' button (). The Force will appear in the first cell in the Table display. Click the 'Keep' button to record the force value.

In *ScienceWorkshop*, click the 'REC' button to begin collecting data.

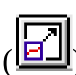
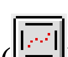
- The 'Keyboard Sampling' window will open. Move it so you can also see the Digits display. 'Entry #1' has a default value that you can ignore. Type in '0' as the stretch. Click 'Enter' to record the stretch and force values. The entered stretch value will appear in the Data list.

3. Add 20 grams of mass to the end of the spring (be sure to include the mass of the hanger).
4. Measure the new position of the end of the spring. Enter the difference between the new position and the equilibrium position as the Δ**x**, 'Stretch' (in meters), and record a Force value for this Stretch value by clicking on 'Keep' in *DataStudio*, or 'Enter' in *ScienceWorkshop*.
5. Add 10 grams to the spring (for a total of 30 g additional mass). Measure the new position of the end of the spring, enter the stretch value and click 'Keep' or 'Enter' to record the force value.
6. Continue to add mass in 10 gram increments until you have added 70 grams. Each time you add mass, measure and enter the new displacement value from equilibrium. Click 'Keep' in *DataStudio*, or 'Enter' in *ScienceWorkshop* to record the force value.
7. End data recording.

- In *DataStudio*, stop data recording by clicking on the 'Stop' button.
- In *ScienceWorkshop*, stop data recording by clicking the 'Stop Sampling' button in the Keyboard Sampling window.
- The data will appear as Run #1.

Pre-Lab Analyzing the Data

1. Determine the slope of the Force vs. Stretch Graph.

- In *DataStudio*, click the 'Scale to fit' button () to rescale the Graph axes to fit the data. Next, click the 'Fit' menu button (). Select 'Linear'.
- In *ScienceWorkshop*, click the 'Autoscale' button () to rescale the Graph axes to fit the data. Click the 'Statistics' button to open the Statistics area on the right side of the Graph. In the Statistics area, click the Statistics Menu button (). Select 'Curve Fit, Linear Fit' from the Statistics Menu.

2. Record the slope of the linear fit in the Data Table in the Lab Report section.

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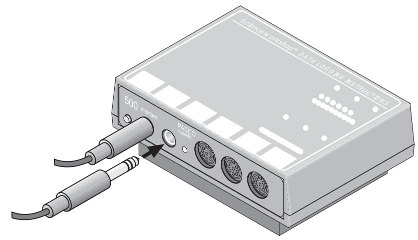
For You To Do

Use the Motion Sensor to record the motion of a mass on the end of the spring. Use *DataStudio or ScienceWorkshop* to determine the period of oscillation and compare the value to the theoretical period of oscillation.

PART I: Computer Setup

1. Unplug the Force Sensor's DIN plug from the interface.
2. Connect the Motion Sensor's stereo phone plugs into Digital Channels 1 and 2 of the interface. Plug the yellow-banded (pulse) plug into Digital Channel 1 and the second plug (echo) into Digital Channel 2.
3. Open the document titled as shown:



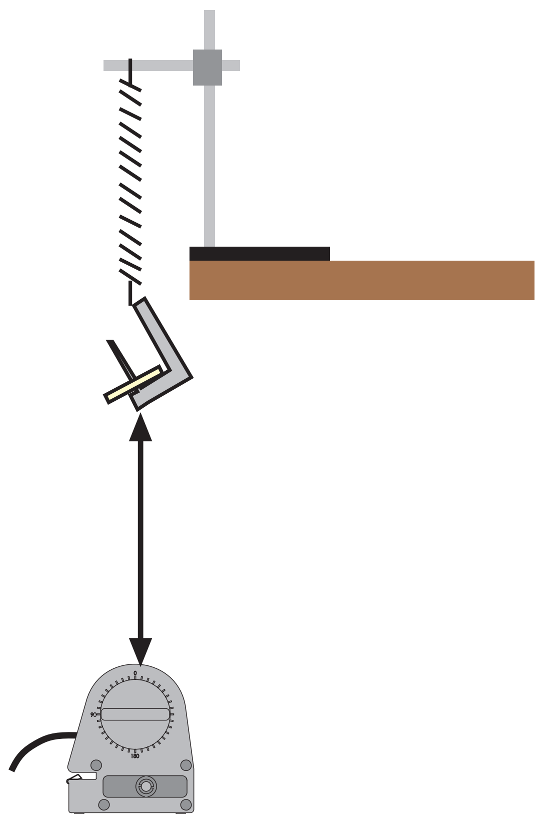
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS05 Mass on a Spring.DS	G05 SHM Mass on a Spring	G05_MASS.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Graph display of Position and Velocity vs. Time.

PART II: Sensor Calibration and Equipment Setup

- You do not need to calibrate the Motion Sensor.

1. Using a support rod and clamp, suspend the spring so that it can move freely up-and-down. Put a mass hanger on the end of the spring.
2. Add enough mass to the hanger so that the spring's stretched length is between 6 and 7 times its unloaded length (about 70 grams if you are using the harmonic spring from the PASCO Introductory Dynamics System.)
3. Remove the hanger and masses temporarily. Measure and record their total in the Data section. Return the hanger and masses to the end of the spring.
4. Place the Motion Sensor on the floor directly beneath the mass hanger.
5. Adjust the position of the spring so that the minimum distance from the mass hanger to the Motion Sensor is greater than the Motion Sensor's minimum distance at the maximum stretch of the spring.



PART III: Data Recording

1. Pull the mass down to stretch the spring about 20 cm. Release the mass. Let it oscillate a few times so the mass hanger will move up-and-down without much side-to-side motion.
2. Start recording data.

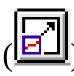
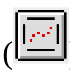
- The Graph displays the plots of the position and velocity of the mass as it moves up and down.

3. Continue recording for about 10 seconds and then 'Stop' data recording.

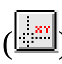
- The data will appear as 'Run #1'.
- The position curve should resemble the plot of a sine function. If it does not, check the alignment between the Motion Sensor and the bottom of the mass hanger at the end of the spring. You may need to increase the reflecting area of the mass hanger by attaching a circular paper disk (about 2" diameter) to the bottom of the mass hanger.
- To erase a run of data, select the run in the Data list and press the "Delete" key.

Analyzing the Data

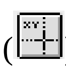
1. Rescale the Graph to fit the data.

- In *DataStudio*, click on the 'Scale to Fit' button ().
- In *ScienceWorkshop*, click on the 'Autoscale' button ().

2. Find the average period of oscillation of the mass.

In *DataStudio*, click the 'Smart Tool' button ().

- Move the Smart Tool to the first peak in the plot of position versus time and read the value of time. Record the value of time in the Data Table in the Lab Report section.
- Move the Smart Tool to each consecutive peak in the plot and record the value of time shown for each peak.

In *ScienceWorkshop*, in the Graph display, click the 'Smart Cursor' ().

- Move the Smart Cursor to the first peak in the plot of position versus time and read the value of time (shown below the horizontal axis). Record the value of time in the Data Table in the Lab Report section.
- Move the Smart Cursor to each consecutive peak in the plot and record the value of time shown below the horizontal axis for each peak.

3. Find the period of each oscillation by calculating the difference between the time for each successive peak. Find the average of the periods. Record your result in the Data Table.

Record your results in the Lab Report section.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS05: Mass on a Spring – Mechanics

What Do You Think?

What is the motion of a mass oscillating on a spring? What other motions can you think of that are similar?

Pre-Lab Data Table

Item	Value
Equilibrium Position	m
Spring Constant (slope)	N/m

Data Table

Mass = _____0.070 kg

Peak	1	2	3	4	5	6	7
Time (s)							
Period (s)							

Average period of oscillation = __________s

Questions

1. Calculate the theoretical value for the period of oscillation based on the measured value of the spring constant of the spring and the mass on the end of the spring.

$$T = 2\pi\sqrt{\frac{m}{k}}$$

2. How does your calculated value for oscillation compare to the measured value of the period of oscillation? What is the percent difference?

3. When the position of the mass is farthest from the equilibrium position, what is the velocity of the mass?

4. When the absolute value of the velocity of is greatest, where is the mass relative to the equilibrium position?

Ending the Activity

• Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select **Quit** from the **File** menu to end the activity.
2. You can select **Save** or **Save As…** from the File menu to save your data for this activity and the changes you've made to the document.

• The original document is "locked", so you should give <u>your</u> document a new filename.

3. If you wish to go on to the next activity, select **Open…** from the **File** menu, and find the document for the next activity.

Name ____________________ Class _____________ Date _________

Activity GS06: Boyle's Law – Gas Laws (Pressure Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Gas laws	GS06 Boyle's Law.DS	G06 Boyle's Law	G06_BOYL.SWS

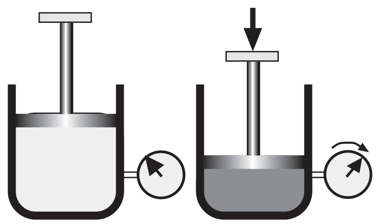
Equipment Needed	**Qty**	**Other**	**Qty**
Pressure Sensor (CI-6532)	1	Glycerin	1 mL
Coupling, quick-release (w/sensor)	1		
Syringe (w/sensor)	1		
Tubing (w/sensor)	1		

What Do You Think?

What happens to the pressure in a container of air as its volume is changed while the temperature remains constant?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



Robert Boyle was an English scientist who discovered a basic fact about gasses. When a gas is inside a cylinder and a piston moves up or down in the cylinder to change the volume of the gas, something also happens to the pressure of the gas.

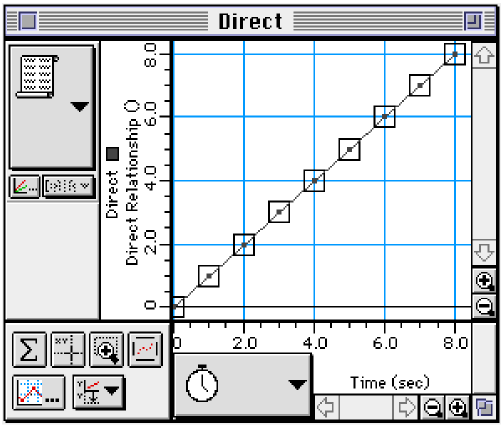
Boyle's Law states that the pressure of a gas in a container is related to the volume of the gas. In other words, as the volume changes, the pressure changes. For a given amount of a gas at a fixed temperature the pressure of the gas is inversely proportional to the volume. One way to verify this is to graph the inverse of gas volume versus gas pressure.

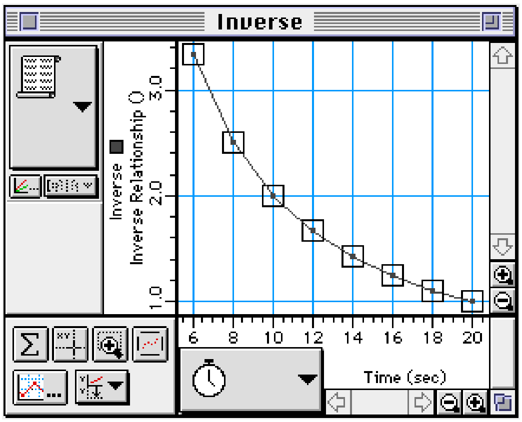
Prediction

Will the relationship between the volume and the pressure be a direct one or will it be something else? The shape of a graph of two quantities can tell what their relationship might be.

If the two quantities have a <u>direct</u> relationship, their formula might be **y = ax**, where **a** is a constant. If the two quantities have an <u>inverse</u> relationship, their formula might be **xy = b**, where **b** is a constant.

Here are two examples of 'Direct Relationship' (on the left) versus 'Inverse Relationship':





- Predict what the relationship will be between pressure and volume:

prediction _____________

SAFETY REMINDERS

- Wear protective gear.
- Follow directions for using the equipment.

For You To Do

Use the Pressure Sensor to measure the change in pressure of the air in a syringe as you change the volume of the air in the syringe. Use *DataStudio* or *ScienceWorkshop* to record and analyze the data. Determine the relationship of pressure to volume for the air in the syringe

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Pressure Sensor's DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS06 Boyle's Law.DS	G06 Boyle's Law	G06_BOYL.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The document has a Digits display of Pressure, a Graph display of Volume and Inverse Volume versus Pressure, and a Table of Pressure, Volume and Inverse Volume.
- Data recording is set for one measurement per second. Use the keyboard to enter the volume of the air inside the syringe (in milliliters).

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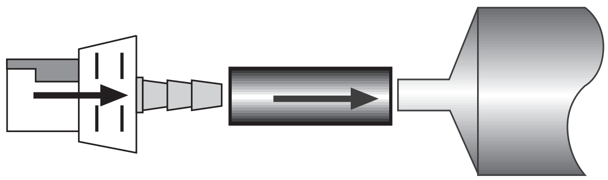
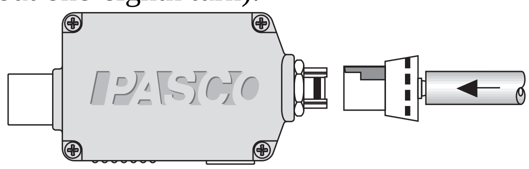
PART II: Sensor Calibration and Equipment Setup

You do not need to calibrate the sensor.

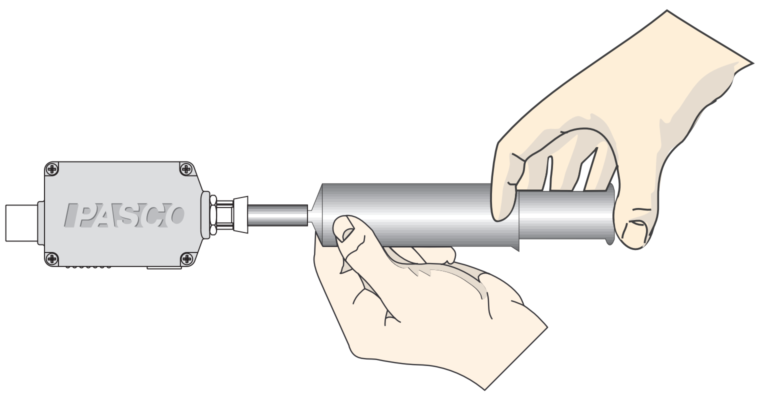
1. Put a drop of glycerin on the barb end of a quick release coupling. Put the end of the coupling into one end of a short piece (about 2.5 cm) of plastic tubing that comes with the Pressure Sensor.
2. Put a drop of glycerin on the end of the syringe. Connect the end of the syringe to the other end of the small piece of plastic tubing.



3. Align the quick-release coupling on one end of the plastic tubing with the pressure port of the Pressure Sensor. Push the coupling onto the port, and then turn the coupling clockwise until it clicks (about one-eighth turn).



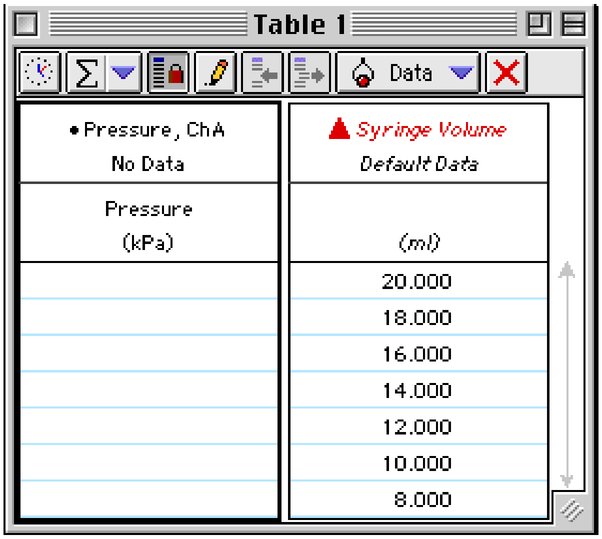
4. Check that the syringe and Pressure Sensor have a secure seal by adjusting the volume between 20 mL and 10 mL. It should get harder to push as the volume decreases.



5. Adjust the volume of air in the syringe to 20.0 mL. (Note: To set the initial position of the piston in the syringe, disconnect the quick-release connector from the sensor, move the piston to the first position (20 mL), and then re-connect the quick-release connector to the sensor.)

PART III: Data Recording (for *DataStudio*)

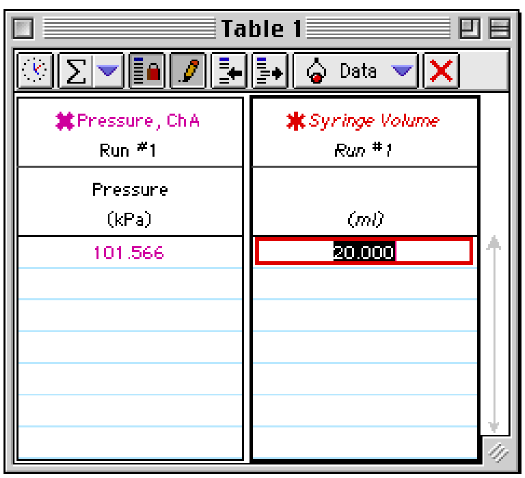
- In *DataStudio*, the Table display shows values for the gas volume in the syringe (for example, 20, 18, 16 and so on).

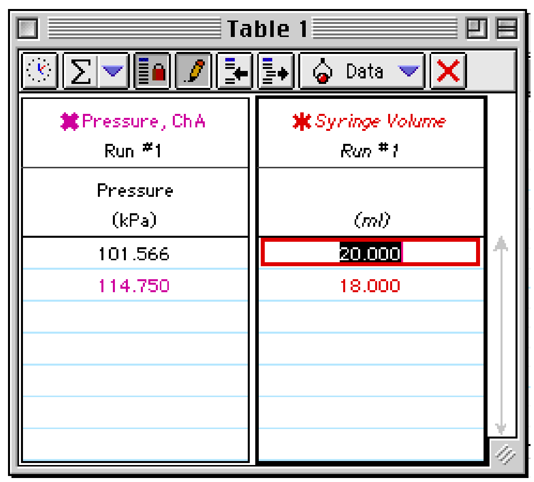


1. When everything is ready, start recording data. (Hint: In *DataStudio*, click 'Start').

- In *DataStudio*, the 'Start' button changes to 'Keep' (

) and the Table display shows the value of pressure next to the first volume (20 mL).





2. Click 'Keep' to record the pressure.

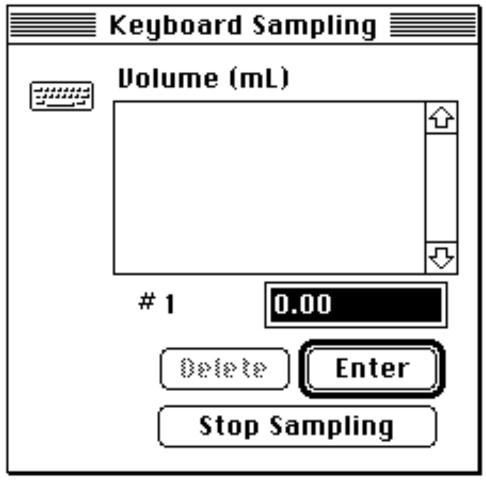
- The Table display changes to show the next value of volume (18 mL).

3. Move the piston to the 18 mL mark and click 'Keep' to record the pressure.
4. Continue to move the piston to each new position and then click 'Keep' to record the corresponding pressure.
5. After you record the pressure for the last volume, click 'Stop' () to end data recording.
6. If time permits, repeat the procedure.

PART III: Data Recording (for *ScienceWorkshop*)

1. In *ScienceWorkshop*, click 'REC' to start recording data.

- The Keyboard Sampling window opens.



2. When the pressure reading stabilizes, type "20" for the volume of air in the syringe and click 'Enter' to record the pressure.
3. Reduce the volume to 18 mL. Type 18 for the volume and click 'Enter'. (Note: *ScienceWorkshop* will prompt you for the third volume based on the pattern of the first two volumes.)
4. Continue reducing the volume by 2.0 mL each time, checking the pressure, and entering the new volume until your last entered volume is 10.0 mL.
5. After you enter the last volume, click 'Stop Sampling' to end data recording.
6. If time permits, repeat the procedure.

Analyzing the Data

1. Set up the Graph display so you can examine the plot of Volume versus Pressure and also the plot of Inverse Volume versus Pressure.
2. Set up the Table display so you can examine the Pressure, Volume and Inverse Volume.

Use your observations to answer the questions in the Lab Report.

Ending the Activity

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select **Quit** from the **File** menu to end the activity.
2. You can select **Save** or **Save As…** from the File menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give <u>your</u> document a new filename.

3. If you wish to go on to the next activity, select Open… from the File menu, and find the document for the next activity.

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Lab Report - Activity GS06: Boyle's Law – Gas Laws

What Do You Think?

What happens to the pressure in a container of air as its volume is changed while the temperature remains constant?

Questions

1. From looking at your data, do the pressure and volume seem to have a direction relationship or an inverse relationship? Does this agree with Boyle's Law?

2. What happened to the pressure when the volume went from 20 mL to 10 mL?

3. What are possible sources of error or limitations in this experiment? For each one, try to decide what effect it might have on the experimental results.

Name ____________________ Class _____________ Date _________

Activity GS07: Food Energy
(Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Biochemistry	GS07 Food Energy.DS	G07 Food Energy	G07_FOOD.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Temperature Sensor (CI-6505A)	1	Slit stopper	1
Balance (SE-8723)	1	Stirring rod	2
Base and Support Rod (ME-9355)	1	Protective gear	PS
Container (metal can), small	1	**Chemicals and Consumables**	**Qty**
Clamp, Buret (SE-9446)	1	Food samples	2
Food holder	1	Matches	2
Graduated cylinder, 100 mL	1	Water	100 mL
Ring, 4 inch	1	Wood splint	2

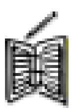
Imagine the Following

A sports team at your school needs to find out what kind of ‘snack food’ can give them the most energy. The team has asked you for help. Can you measure the amount of energy in a sample of food?

What Do You Think?

All human activity requires “burning” food for energy. When samples of different kinds of food are burned, which of the food samples will produce the most energy?

- **Marshmallow? Peanut? Cashew? Popcorn?**
- **How will you compare one food sample to another?**
- **Does the amount of the food sample make a difference?**
- **Does the time that the food takes to burn make a difference?**



Take time to answer the ‘What Do You Think?’ question(s) in the Lab Report section.

Background

When burning food heats a known quantity of water, the amount of heat given off by the food is theoretically equal to the amount of heat gained by the water. The following is an equation that describes this idea:

$$Q = m \times c \times \Delta T$$

where Q is the amount of heat, m is the mass of the water, c is the *specific* heat of the water, and ΔT is the change in temperature of the water.

The specific heat of water is:

$$c = 1\frac{\text{calorie}}{\text{gram}^\circ\text{C}} = 4.18\frac{\text{joule}}{\text{gram}^\circ\text{C}}$$

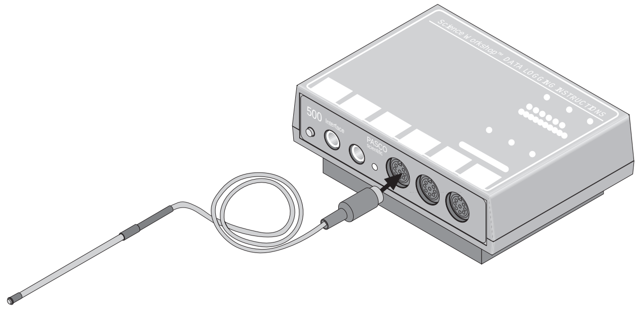
SAFETY REMINDERS	THINK SAFETY ACT SAFELY BE SAFE!
• Follow directions carefully when using the equipment for this activity.	
• Take care when using matches and wooden splints.	
• Wear protective gear (e.g., goggles, gloves, apron).	

For You To Do

In this activity, burn a sample of food under a container of water to heat the water. Use a Temperature Sensor to measure the change in temperature of the water as it is heated by the burning food. Use *DataStudio* or *ScienceWorkshop* to record and analyze the data.

Compare the amount of heat given off by one type of food to the amount of heat given off by a different type of food.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Temperature Sensor into Analog Channel A of the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B01 Food Energy.DS	B02 Food Energy	B02_FOOD.SWS

- The file has a Digits display, a Graph display, and a Table display of Temperature versus Time.
- The *DataStudio* file also has a Workbook display. Read the instructions in the Workbook.

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PART II: Sensor Calibration and Equipment Setup

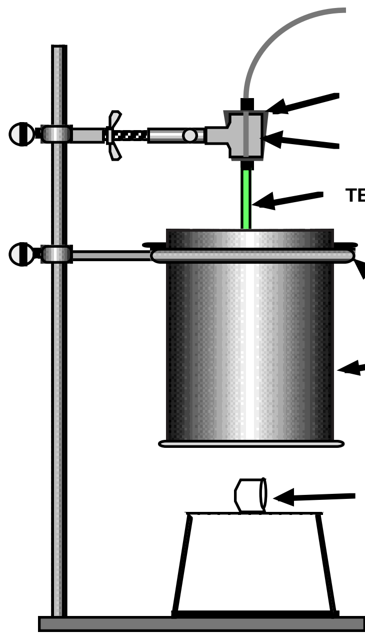
You do not need to calibrate the Temperature Sensor.

1. Set up the equipment as shown.
2. Put the bottom of the container about 2.5 cm above the food holder.

Do you need to measure the amount of water that will be heated?

Do you need to record the type of food being tested?

Do you need to measure the initial mass of the food sample that will be burned?



PART IIIA: Data Recording

1. Start recording data.
2. Light the wooden splint with a match and use the splint to light your food sample. Quickly place the burning food sample directly under the center of the container. Leave the sample under the container until the food sample stops burning.

CAUTION: Keep hair, clothing, and other items away from open flames.

3. Leave the sensor in the water for at least 45 seconds after the food has stopped burning. Stir the water until the temperature stops rising. *Stop* recording data when the temperature stops rising.

Do you need to measure the final mass of the remains of the burned food sample?

4. Repeat the data recording process for the second food sample. Use a new quantity of cold water.

What measurements do you need to record?

Analyze the Data

1. Use your recorded data to find the *change* in temperature of the water heated by the first food sample.

   What measurements do you need to record?

2. Repeat the analysis for the second run of data.
3. Calculate the heat absorbed by the water, ***Q*,** for each food sample. Remember the equation:

$$Q = m \times c \times \Delta T$$

   For water, the specific heat "*c*" is 4.18 J/g°C.

   How would you convert the heat absorbed from *joules* to *kilojoules* (kJ)?

4. Determine the mass of the food that burned.
5. Calculate the *energy content*, or *ratio* of heat (in kilojoules) divided by the mass of burned food (in grams), for each food sample.

   How do your results compare with others in your class?

Record your results in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS07: Energy Content of Foods

What Do You Think?

All human activity requires “burning” food for energy. When samples of different kinds of food are burned, which of the food samples will produce the most energy?

Data Table

Item	Sample 1 marshmallow	Sample 2 popcorn	Sample 3 __________	Sample 4 __________
mass of empty container	g	g	g	g
mass of container + water	g	g	g	g
mass of water	g	g	g	g
initial mass, sample + holder	g	g	g	g
final mass, sample + holder	g	g	g	g
change of mass, food sample	g	g	g	g
initial temperature	C	C	C	C
final temperature	C	C	C	C
temperature change, ΔT	C	C	C	C
heat, Q	kJ	kJ	kJ	kJ
energy content	kJ/g	kJ/g	kJ/g	kJ/g

Class Results Table: Average Energy Content for each food type:

Food Type	Marshmallows	Peanuts	Cashews	Popcorn
Energy content	kJ/g	kJ/g	kJ/g	kJ/g

Questions

1. Which food had the highest energy content?

2. Which food had the lowest energy content?

3. Food energy is expressed in a unit called a *Calorie*. There are 4.18 kilojoules (or 4180 joules) in one Calorie. Based on the class average for peanuts, calculate the number of Calories in a 50-gram package of peanuts.

4. Two of the foods in the activity have a high *fat* content (peanuts and cashews) and two have a high *carbohydrate* content (marshmallows and popcorn). From your results, what can you conclude about the relative energy content of *fats* and *carbohydrates*?

5. What advice would you give to a sports team about the energy content of these foods?

6. Do you think that *all* of the energy released by the burning food sample was absorbed by the water?

   Why or why not?

7. What are some things you would do to change the procedure in this activity?

Name ____________________ Class ______________ Date _________

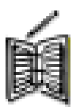
Activity GS08: Catalase Activity – Enzyme Action (Pressure Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Biochemistry	GS08 Catalase. ActivityDS	G08 Catalase Activity	G08_CATA.SWS

Equipment Needed	Qty	Chemicals and Consumables	Qty
Pressure Sensor – Abs. (CI-6532)	1	Chicken liver extract	10 mL
Balance (SE-8723)	1	Glycerin	1 mL
Connector (640-030)	1	Hydrogen peroxide, 3%	100 mL
Flask, 250 mL	1	Sodium fluoride, solid	0.1 g
Graduated cylinder, 100 mL	1	Sodium carbonate, solid	1 g
Magnetic stirrer & spin bar	1	Water, distilled	500 mL
Stopper, one hole, for flask	1		
Test tube	1		
Tubing (w/ sensor)	1		
Protective gear	PS		

What Do You Think

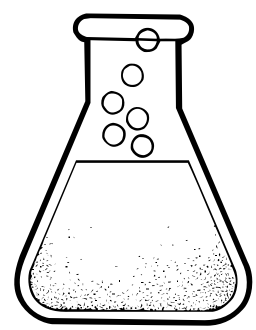
What are some factors that can influence the rate of enzyme activity in an organism?



Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

In this activity you will study some of the factors that influence the rate of reaction of an **enzyme** activity. The enzyme is called **catalase** . It changes poisonous **hydrogen peroxide** to water and oxygen.



When cells convert food into energy (in the process called cellular respiration), one of the by-products is hydrogen peroxide. Hydrogen peroxide is a very active chemical. It can poison other chemicals in a cell causing the cell to die. Catalase is an enzyme that can break down the poisonous hydrogen peroxide.

Catalase reduces the peroxide part of the hydrogen peroxide molecule into water and oxygen by the following reaction:

$$2H_2O_2 \xrightarrow{\text{Catalase}} 2H_2O + O_2\,(\text{gas})$$

(substrate) (enzyme) (products)

Since catalase is not used up in the chemical reaction, the same enzyme can start another reaction. This activity will measure the rate at which the catalase enzyme can reduce the toxic hydrogen peroxide to the harmless products of water and oxygen.

Since the breakdown of hydrogen peroxide produces oxygen gas, what is a way to measure the rate of the production of that gas?

Take time to write an answer to this question in the Lab Report section.

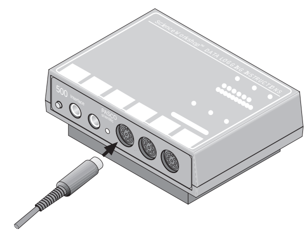
SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the Pressure Sensor to measure the change in gas pressure inside a flask containing hydrogen peroxide and a source of catalase enzyme. The first trial will show how pure crude catalase reacts with the hydrogen peroxide solution. The other three trials will show what happens if other chemicals are added to change the hydrogen peroxide or dilute the catalase. Use *DataStudio* or *ScienceWorkshop* to record and analyze the data.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Pressure Sensor DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown;

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS08 Catalase. ActivityDS	G08 Catalase Activity	G08_CATA.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook. The file has a Graph of Pressure versus Time and a Digits display of Pressure.
- The *ScienceWorkshop* document opens with a Graph display of Pressure (kPa) versus Time (s).
- Data recording is set for 1 measurement per second with a 'Stop' condition at 150 s.

Name ____________________ Class ______________ Date _________

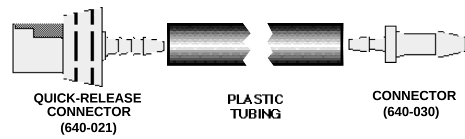
PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

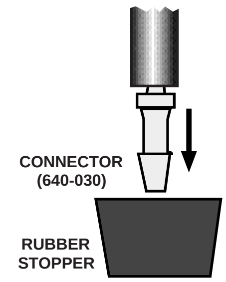
- **You do not need to calibrate the Pressure Sensor for this activity.**

Set Up the Equipment

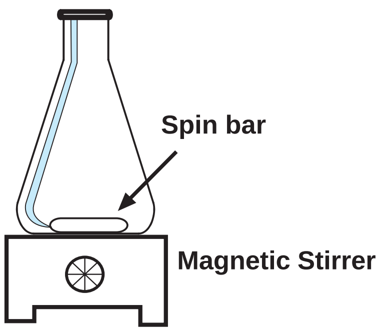
1. Put a drop of glycerin on the barb end of the quick-release connector and insert the barb into one end of the plastic tubing.



2. Put a drop of glycerin on the smaller diameter end of the connector that will go into the stopper. Insert the small diameter end into the plastic tubing.
3. Put a drop of glycerin on the larger diameter end of the connector that will go into the stopper, and insert the end into the stopper.



4. Carefully put a spin bar into the flask and place the flask on the magnetic stirrer.

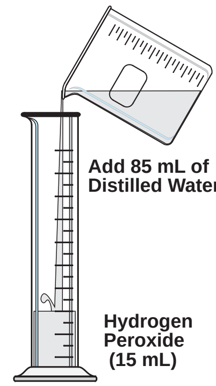


PART III: Data Recording

- **There are four parts to the data recording.**

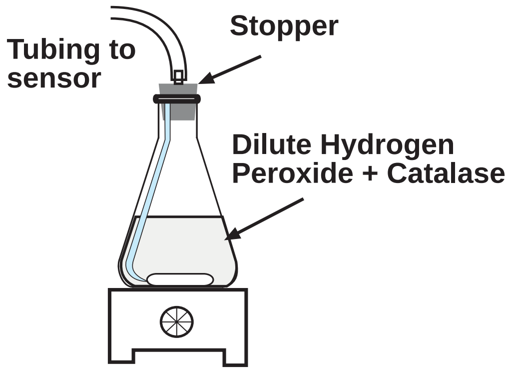
Part	Catalase	Sodium Fluoride	Sodium Carbonate	Hydrogen Peroxide
A	2 mL crude catalase	none	none	15 mL diluted to 100 mL
B	2 mL crude catalase	0.1 g	none	15 mL diluted to 100 mL
C	2 mL crude catalase	none	1.0 g	15 mL diluted to 100 mL
D	1 mL crude catalase diluted with 1 mL of distilled water	none	none	15 mL diluted to 100 mL

PART IIIA: Catalase + Hydrogen Peroxide

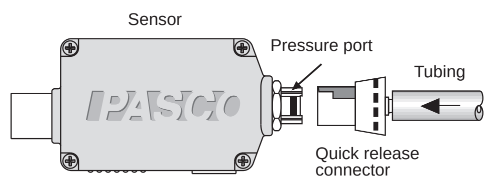


Prepare the Mixture

1. Pour 15 mL of 3% hydrogen peroxide in a 100 mL graduated cylinder. Fill the cylinder to the 100-mL mark with 85 mL of distilled water.
2. Transfer the diluted peroxide solution to the flask.
3. Turn on the stirrer.
4. Add 2 mL of catalase extract to the dilute peroxide solution in the flask.
5. Put the one-hole stopper into the flask.



6. Align the quick-release connector on the end of the plastic tubing with the connector on the pressure port of the Pressure Sensor. Push the connector onto the port, and then turn the connector clockwise until it clicks (about one-eighth turn).



Record the Data

7. Start recording data. (Hint: Click ‘Start’ in *DataStudio* or ‘REC’ in *ScienceWorkshop*.)

- Data recording will stop automatically at 150 seconds.

Clean Up

8. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
9. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

Part IIIB: Catalase + Hydrogen Peroxide + Sodium Fluroide

Make a prediction:

What effect do you think adding an inhibitor to the hydrogen peroxide will have on the enzymes’s ability to catalyze the breakdown of the peroxide? Put your prediction and a brief explanation in the Lab Report.

Prepare the mixture

1. Repeat the data recording procedure. Put 100 mL of dilute peroxide solution in the flask. Add the spin bar.
2. Add 0.1 g of sodium fluoride to the peroxide solution. Add 2 mL of catalase extract to the flask and stopper the flask.
3. Re-connect the tubing to the Pressure Sensor.

Record the data

4. Start recording data. (Data recording will stop automatically at 150 seconds.)

Clean Up

5. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
6. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

Part IIIC: Catalase + Hydrogen Peroxide + Sodium Carbonate

Make a prediction:

What effect do you think adding a base to the hydrogen peroxide will have on the enzymes's ability to catalyze the breakdown of the peroxide? Put your prediction and a brief explanation in the Lab Report.

Prepare the mixture

1. Repeat the data recording procedure. Put 100 mL of dilute peroxide solution in the flask. Add the spin bar.
2. Add 1.0 g of sodium carbonate to the peroxide before you add the catalase. Add 2 mL of catalase extract to the flask and stopper the flask.
3. Re-connect the tubing to the Pressure Sensor.

Record the data

4. Start recording data. (Data recording will stop automatically at 150 seconds.)

Clean Up

5. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
6. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

Part IIID: Diluted Catalase + Hydrogen Peroxide

Make a prediction:

What effect do you think diluting the catalase will have on the enzymes's ability to catalyze the breakdown of the peroxide? Put your prediction and a brief explanation in the Lab Report.

Prepare the mixture

1. Repeat the data recording procedure. Put 100 mL of dilute peroxide solution in the flask. Add the spin bar.
2. Put 1 mL of crude catalase extract into the test tube. Add 1 mL of distilled water to dilute the catalase. Add the diluted catalase extract to the flask and stopper the flask.
3. Re-connect the tubing to the Pressure Sensor.

Record the data

4. Start recording data. (Data recording will stop automatically at 150 seconds.)

Clean Up

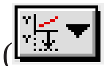
5. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
6. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

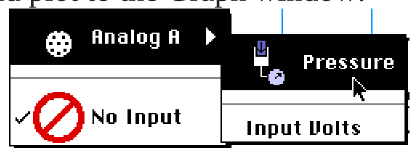
ENDING THE ACTIVITY (See the section after Questions)

Analyzing the Data

1. Set up the Graph display to show all your data

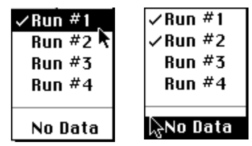
- Hint: *DataStudio* automatically shows all the runs of data. In *ScienceWorkshop*, do the following to put two runs of data in the top plot and two runs of data in the bottom plot.

- Click the ‘Add Plot Menu’ button () to add a second plot to the Graph window. Select **Analog Channel A, Pressure** from the Add Plot Menu.



- Click the ‘Add Plot Menu’ button again to add a third plot to the Graph window. Select **Analog Channel A, Pressure** from the Add Plot Menu.

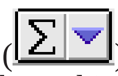
- Click the ‘DATA Menu’ button () in the top plot. Select **Run #1** from the DATA Menu. Repeat to select **Run #2** from the DATA menu.

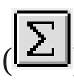


- Click the ‘DATA Menu’ button in the middle plot. Select **No Data** first.

- Use the Data Menu in the second plot to select **Run #3** and then **Run #4**.

2. Use the built-in statistics for the Graph display to find the minimum pressure and the maximum pressure for each run of data.

- Hint: In *DataStudio*, click the ‘Statistics Menu’ button (). The default statistics are ‘Minimum’ and ‘Maximum’. The values appear in the legend in the display area.

  In *ScienceWorkshop*, click the ‘Statistics’ button () to open the statistics area. Click the ‘Statistics Menu’ button (). Select ‘Maximum’ from the menu. Repeat and select ‘Minimum’ from the menu.

3. Record the minimum pressure as the starting pressure. Record the maximum pressure as the ending pressure.

4. Calculate the difference in pressure.

5. Calculate the enzyme activity. Divide the difference in pressure by the amount of time (in minutes).

$$\textbf{Catalase Activity} = \frac{\textbf{Ending Pressure - Starting Pressure}}{\textbf{2.5 minutes}}$$

Record your results in the Lab Report section.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS08: Catalase Activity – Enzyme Action

What Do You Think

What are some factors that can influence the rate of enzyme activity in an organism?

Since the breakdown of hydrogen peroxide produces oxygen gas, what is a way to measure the rate of the production of that gas?

Predictions

Part IIIB: Catalase + Hydrogen Peroxide + Sodium Fluoride

What effect do you think adding an inhibitor to the hydrogen peroxide will have on the enzymes's ability to catalyze the breakdown of the peroxide?

Part IIIC: Catalase + Hydrogen Peroxide + Sodium Carbonate

What effect do you think adding a base to the hydrogen peroxide will have on the enzymes's ability to catalyze the breakdown of the peroxide?

Part IIID: Diluted Catalase + Hydrogen

What effect do you think diluting the catalase will have on the enzymes's ability to catalyze the breakdown of the peroxide?

Data Table

Item	Part IIIA	Part IIIB Sodium Fluoride	Part IIIC Sodium Carbonate	Part IIID Diluted
Starting Pressure	kPa	kPa	kPa	kPa
Ending Pressure	kPa	kPa	kPa	kPa
Pressure Difference	kPa	kPa	kPa	kPa
Activity (kPa/min)				

Questions

1. What happens to the pressure inside the flask when pure crude catalase is added to diluted hydrogen peroxide?

2. What is the effect of adding sodium fluoride to the solution of hyrodgen peroxide? Is there as much reaction, more reaction, or less reaction than without the sodium fluoride?

3. What is the effect of adding sodium carbonate to raise the pH of the solution of hydrogen peroxide? Is there as much reaction, more reaction, or less reaction than without the sodium carbonate?

4. What is the effect of diluting the catalase before you added it to the solution of hydrogen peroxide? Is there as much reaction, more reaction, or less reaction than when you used pure crude catalase?

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select ‘Quit’ from the ‘File’ menu to end the activity.
2. You can select ‘Save’ or ‘Save As…’ from the File menu to save your data for this activity. the changes you’ve made to the document.
- The original document is “locked”, so you should give <u>your</u> document a new filename.
3. If you wish to go on to the next activity, select ‘Open…’ from the ‘File’ menu, and find the document for the next activity.

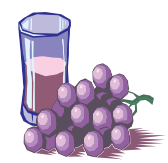
Name ____________________ Class _____________ Date _________

Activity GS09: Fermentation in Grape Juice
(Pressure Sensor – Absolute, Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Cellular respiration	GS09 Fermentation. DS	G09 Glycolysis	G09_GLYC.SWS

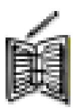
Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Pressure Sensor – Abs. (CI-6532)	1	Stopper, one hole, for flask	1
Temperature Sensor (CI-6505)	1	**Tubing (w/ sensor)**	
Balance (SE-8723)	1	Protective gear	PS
Beaker, 250 mL	1	**Chemicals and Consumables**	**Qty**
Connector (640-030)	1	Glycerin	1 mL
Flask, 250 mL	1	Grape juice	300 mL
Graduated cylinder	1	Sodium fluoride, solid	1 g
Hot plate	1	Weighing paper	1
Magnetic stirrer & spin bar	1	Yeast suspension	20 mL

What Do You Think?



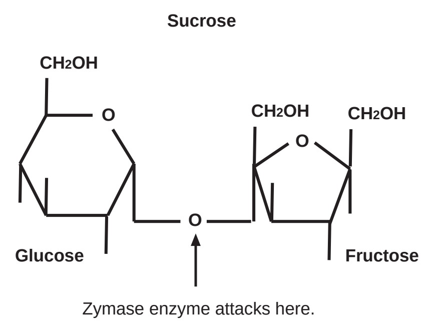
How does the pressure inside a closed vessel change as yeast converts the sucrose in grape juice into ethanol and carbon dioxide?

What factors can alter the rate of the fermentation of grape juice and what changes would you expect to see as you apply those factors?



Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

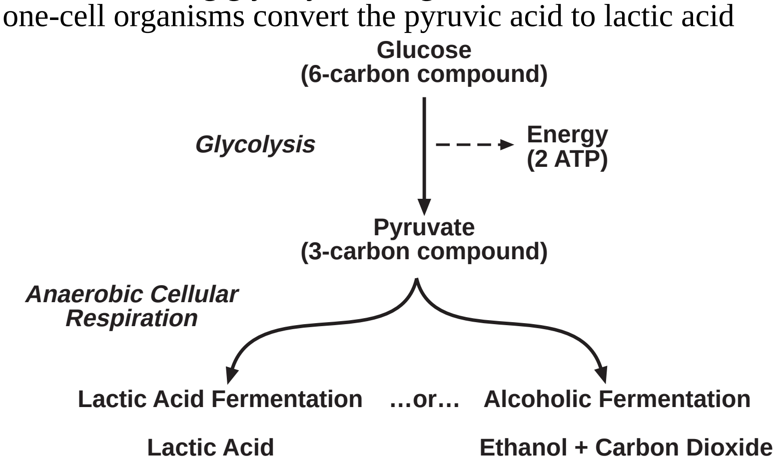
Background



All life forms need to convert or transform energy-rich organic molecules like sugars into forms of energy that can be used to perform cell work. **Cellular respiration** is the set of chemical reactions during which molecules are broken down to release energy. For example, yeast cells break down sugar (sucrose) in grape juice. They produce carbon dioxide gas and alcohol (ethanol).

There are two types of cellular respiration – aerobic and anaerobic – and both begin with glycolysis. Prior to glycolysis, an enzyme (zymase) breaks a molecule of sucrose into glucose and fructose. During glycolysis, the glucose breaks down into pyruvic acid. Animal cells and some one-cell organisms convert the pyruvic acid to lactic acid (lactic acid fermentation). Some plant cells and one-cell organisms convert the pyruvic acid to alcohol (ethanol) and carbon dioxide gas (alcoholic fermentation).

As in most biological reactions, cellular respiration is controlled by a series of enzymes (such as zymase). The enzymes that help this system of chemical events are often sensitive to physical and chemical conditions such as temperature and pH.



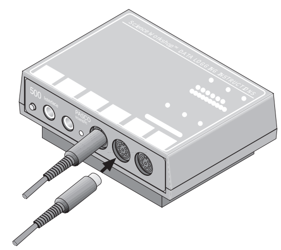
SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the Pressure Sensor to measure the change in pressure in a flask containing a mixture of activated yeast and grape juice. Then repeat the measurement for a mixture of activated yeast, grape juice, and a small amount of a chemical – sodium fluoride. Use *DataStudio* or *ScienceWorkshop* to record and display the data. Use the software to analyze the data.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Pressure Sensor DIN plug into Analog Channel A on the interface.
3. Connect the Temperature Sensor DIN plug into Analog Channel B on the interface.
4. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS09 Fermentation. DS	G09 Glycolysis	G09_GLYC.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* file has a Graph display of Pressure versus Time.
- Data recording for the Pressure Sensor is set at 1 measurement per five seconds.

NOTE: In the *DataStudio* file, data recording for the Temperature Sensor is set at 2 measurements per second (or 2 Hz). See the pages at the end of the activity for instructions about how to set up the *ScienceWorkshop* file to measure temperature.

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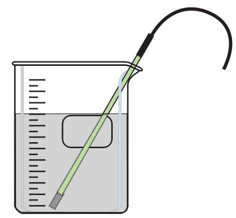
PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

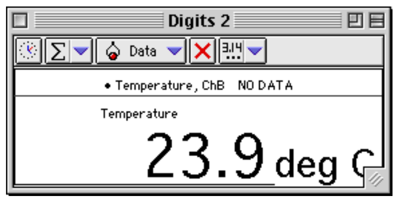
- **You do not need to calibrate the Pressure Sensor for this activity since you will measure the change in pressure.**

Prepare the Grape Juice



1. Put 150 mL of grape juice in a beaker. Place the beaker on a hot plate. Place the Temperature Sensor in the grape juice.
2. Turn on the hot plate. Warm the juice to a temperature of 35˚ Celsius. Use the software to monitor the temperature of the grape juice.

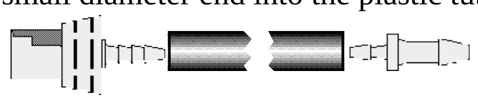
- Hint: In *DataStudio*, click ‘Monitor’ in the Experiment menu. In *ScienceWorkshop*, click the MON button. Watch the temperature in the Digits display.

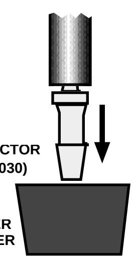


- Do not warm the grape juice above 40°C. The yeast will begin to die at around 42°C. The optimum temperature for the yeast is around 35°C.

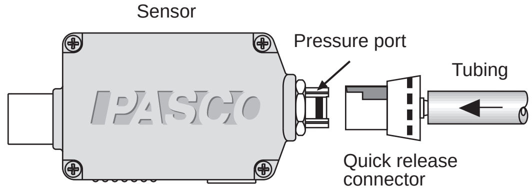
Set Up the Equipment

3. Put a drop of glycerin on the barb end of the quick-release connector and insert the barb into one end of the plastic tubing.
4. Put a drop of glycerin on the smaller diameter end of the connector that will go into the rubber stopper. Insert the small diameter end into the plastic tubing.



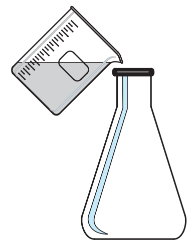


5. Put a drop of glycerin on the larger diameter end of the connector that will go into the rubber stopper, and insert the end into the rubber stopper.
6. Align the quick-release connector on the end of the plastic tubing with the connector on the pressure port of the pressure sensor. Push the connector onto the port, and then turn the connector clockwise until it clicks (about one-eighth turn).

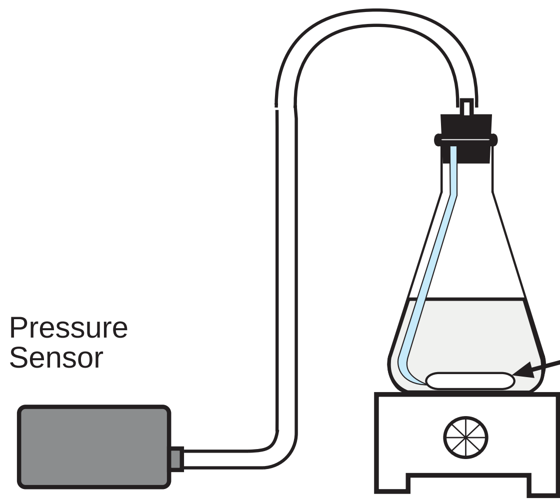


Part IIIA: Data Recording – Graph Juice and Yeast Suspension

1. Remove the Temperature Sensor from the beaker. In the software, stop monitoring the temperature of the grape juice.
2. Transfer the warmed grape juice to the flask. Add a spin bar to the flask.



3. Gently add 10 mL of yeast suspension to the juice. (Remember, the yeast are alive!)
4. Stopper the flask with the rubber stopper. Use a twisting motion to get a tight fit. Place the flask on the magnetic stirrer. Turn on the stirrer and adjust to a moderately fast stirring rate.



5. Start recording data.

- Hint: In *DataStudio*, click the 'Start' button (). In *ScienceWorkshop*, click the 'REC' button ().
- What happens to the pressure in the flask? What do you think the yeast are doing to the grape juice that causes this effect?

6. Allow the yeast to metabolize the grape juice for about 40 minutes and then stop recording data.

- **Be sure you have stopped recording before you carefully remove the stopper from the flask.**

7. Dispose of the grape juice/yeast mixture as instructed.

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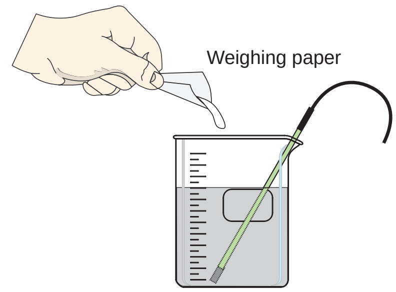
Part IIIB: Data Recording – Grape Juice, Yeast Suspension and Sodium Fluoride

Prepare the Grape Juice and Sodium Fluoride



1. Put 150 mL of grape juice in a beaker. Add 1.0 g of sodium fluoride to the grape juice.
2. Place the beaker on a hot plate. Place the Temperature Sensor in the grape juice.
3. Turn on the hot plate. Warm the juice to a temperature of 35˚ Celsius. Use the software to monitor the temperature of the grape juice.

- Hint: In *DataStudio*, click 'Monitor' in the Experiment menu. In *ScienceWorkshop*, click the MON button. Watch the temperature in the Digits display.

- Do not warm the grape juice above 40°C. The yeast will begin to die at around 42°C. The optimum temperature for the yeast is around 35°C.

Record Data

1. Remove the Temperature Sensor from the beaker. In the software, stop monitoring the temperature of the grape juice.
2. Transfer the warmed grape juice/sodium fluoride mixture to the flask. Add a spin bar to the flask.
3. Gently add 10 mL of yeast suspension to the juice. (Remember, the yeast are alive!)
4. Stopper the flask with the rubber stopper. Use a twisting motion to get a tight fit. Place the flask on the magnetic stirrer. Turn on the stirrer and adjust to a moderately fast stirring rate.
5. Start recording data.

- What happens to the pressure in the flask?

6. Allow the yeast to metabolize the grape juice for about 40 minutes and then stop recording data.

- **Be sure you have stopped recording before you carefully remove the stopper from the flask.**

7. Dispose of the grape juice/yeast mixture as instructed.

Optional

- Variations to this activity can be performed by different lab teams and the results can be shared and analyzed by the entire class.

1. Vary the pH Level: Vary the pH level in the yeast/juice mixture by adding 25 mL of any of the following buffer solutions to 125 mL of grape juice: (a) pH buffer 2, (b) pH buffer 3, (c) pH buffer 4, and (d) pH buffer 6. (e) pH buffer 10
2. Vary the Yeast Concentration: Vary the amount of yeast by mixing and using suspensions of 100 mL of water and (a) 1 g, (b) 3 g, (c) 6 g, (d) 12 g, or (e) 20 g of dry yeast.

Analyzing the Data:

1. Set up your Graph display so it shows your data.
2. Use the Graph display's built-in statistics to determine the Ending Pressure, the Starting Pressure, the Ending Time and the Starting Time for the first run of data.

- Hint: In *DataStudio*, click the 'Statistics' menu button (Σ ▼) and select 'Show All'. In *ScienceWorkshop*, click the 'Statistics' button to open the statistics area of the Graph.

  Click the 'Statistics Menu' button (Σ ▼) and select 'All of the Above' from the Statistics menu.

3. Record the minimum X as Starting Time in the Data Table in the Lab Report section. Record the maximum X as Ending Time.
4. Record the minimum Y as Starting Pressure in the Data Table. Record the maximum Y as Ending Pressure.
5. Calculate the difference/change in pressure and record it in the Data Table. Calculate the difference/change in time and record it in the Data Table.
6. Calculate the rate of production of carbon dioxide by the yeast from grape juice and record the rate.

   Divide the difference in Pressure readings by the difference in Time.

$$\text{Rate of Carbon Dioxide Production} = \frac{\text{Ending Pressure} - \text{Starting Pressure}}{\text{Ending Time} - \text{Starting Time}}$$

7. Repeat the process for the second run of data (grape juice and sodium fluoride).

Optional:

- Collect the data from the other experimental runs conducted in class and record them. Calculate the rate of production of carbon dioxide for each of the experimental runs.

Record your results in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

Name ____________________ Class _____________ Date _________

Lab Report - Activity B02: Fermentation of Grape Juice

How does the pressure inside a closed vessel change as yeast converts the sucrose in grape juice into ethanol and carbon dioxide?

What factors can alter the rate of the fermentation of grape juice and what changes would you expect to see as you apply those factors?

Data Table

Item	Initial Trial	With NaF
Starting Time	min	min
Ending Time	min	min
Difference in Time	min	min
Starting Pressure	kPa	kPa
Ending Pressure	kPa	kPa
Difference in Pressure	kPa	kPa
Rate of CO_2 Production	kPa/min	kPa/min

Questions

1. What is the rate of production of carbon dioxide gas for the grape juice and yeast mixture?

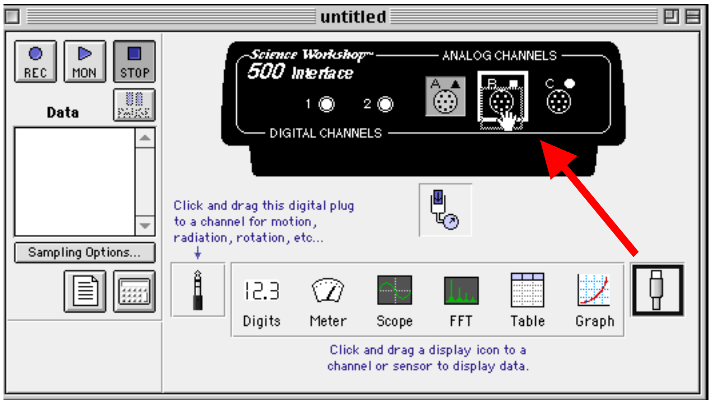
2. What happens to the rate of carbon dioxide production in the flask when the sodium fluoride is added to the grape juice?

Appendix: Set Up *ScienceWorkshop*

Modify the *ScienceWorkshop* file to monitor temperature as you warm the grape juice.

Set Up the Sensor

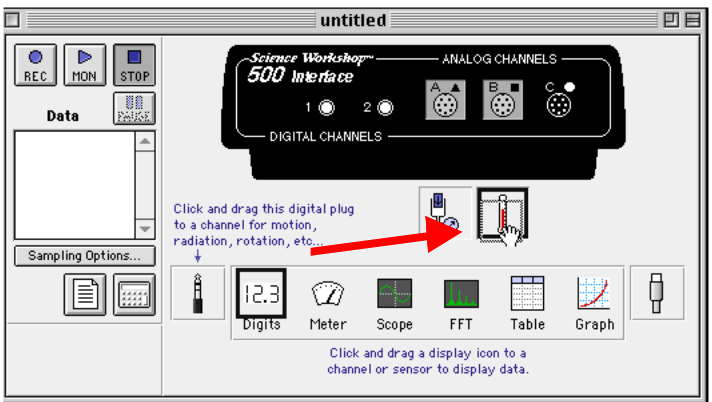
In the Experiment Setup window, click and drag the analog sensor plug to Channel B.



Select 'Temperature Sensor' from the list of sensors. Click 'OK' to return to the Experiment Setup window

Set Up the Display

In the Experiment Setup window, click and drag the Digits display icon to the Temperature Sensor icon.



Arrange the windows so you can see the Digits display of temperature.

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Activity GS10: Heart Rate, Carbon Dioxide, and Exercise
(Heart Rate Sensor, pH Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Physiology	GS10 Heart Rate. DS	G10 Heart Rate	G10_RATE.SWS

Equipment Needed	**Qty**	**Chemicals and Consumables**	**Qty**
Heart Rate Sensor (CI-6543B)	1	Buffer solution: high pH	100 mL
pH Sensor (CI-6507A)	1	Buffer solution: low pH	100 mL
Balance (SE-8723)	1	Straw	1
Beaker, 250 mL	3	Water, distilled	500 mL
Cup	1		
Wash bottle	1		
Protective gear	PS		

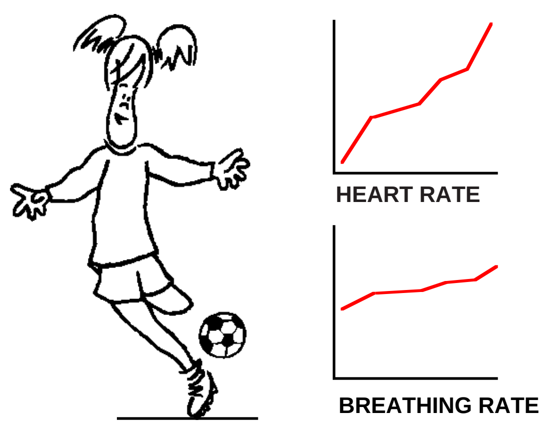
NOTE: This activity requires the person whose heart rate is being measured to perform exercise (e.g., jogging in place) for several minutes. Do NOT perform this activity if vigorous activity will cause discomfort or be hazardous to the health of the person.

What Do You Think?

How will mild exercise affect your heart rate and recovery time and how will it affect the amount of carbon dioxide in your breath?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



You probably have experienced the sensation of your heart beating strongly and your chest heaving after you participate in strenuous physical activity.

Your nervous system monitors your entire body and signals your heart to beat faster in response to increased activity. You also increase your rate of breathing in order to keep up with your body's demands for more oxygen and for the removal of carbon dioxide.

Pulse rate, as measured by a Heart Rate Sensor using the *ScienceWorkshop* interface or manually at the wrist, measures how fast your heart is beating. Recovery time is how long it takes for the heart to return to its normal resting rate. If you blow through a straw into water, some of the carbon dioxide in your exhaled breath is dissolved into the water and changes the **pH** (measure of acidness) of the water.

The Heart Rate Sensor is a small device that sends light through your ear lobe. As your heart pumps blood through your ear, the sensor measures changes in the amount of light transmitted through your ear lobe. The measurements correspond to beats of your heart and are recorded as voltage changes that the program can use to calculate your pulse rate.

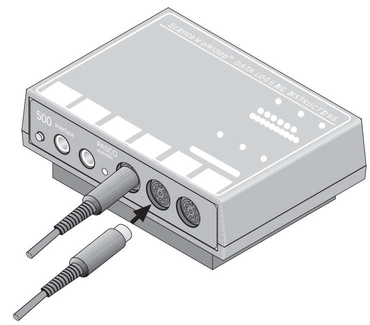
The pH Sensor is a special type of **electrode** that measures the **pH** (**potential of hydronium**) of a substance. The pH of a substance is a measure of whether it is an acid, a base, or neutral. When carbon dioxide gas dissolves in water, it turns the water into a weak acid. The pH Sensor measures the change in pH of the water.

For You To Do

Use the Heart Rate Sensor to measure the heart rate of a person before and after mild exercise. Record the resting heart rate, the heart rate after mild exercise, and the amount of time it takes for the person's heart rate to return to normal after exercise (called the recovery time).

Use the pH Sensor to measure the change in the pH of water that the same person will blow through before and after mild exercise. The carbon dioxide gas in the person's breath will dissolve in the water and turn it into a weak acid.

PART I: Computer Setup



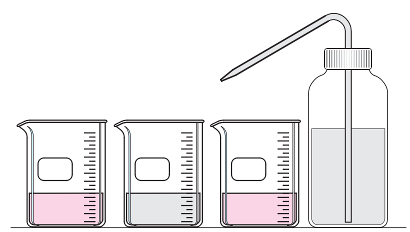
1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Heart Rate Sensor to Analog Channel A on the interface.
3. Connect the DIN plug of the pH Sensor to Analog Channel B on the interface.
4. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS10 Heart Rate. DS	G10 Heart Rate	G10_RATE.SWS

- The document will open with a Digits display for heart rate, a Digits display for pH, a Table display for heart rate and pH, and a Graph display for heart rate and pH versus time.

  The *DataStudio* file also has a Workbook display. Read the instructions in the display.
- Data recording is set at 50 measurements per second (50 Hz) and will stop automatically at 60 seconds.

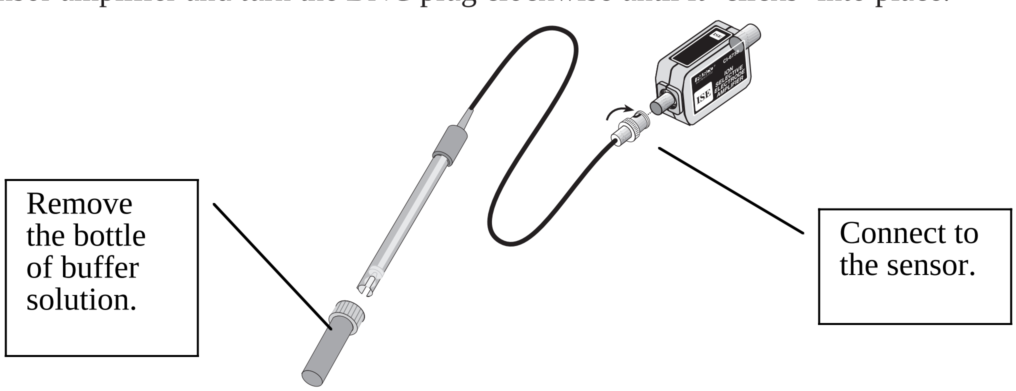
PART II: Sensor Calibration and Equipment Setup



Sensor Calibration: pH Sensor

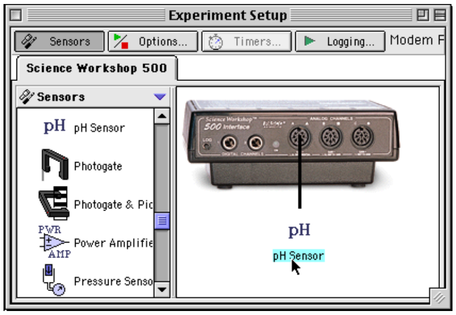
- To calibrate the pH Sensor you will need the following: wash bottle, distilled water, three beakers, buffer solutions of high pH (e.g. pH 10) and low pH (e.g. pH 4), pH Sensor.
- Put distilled water into the wash bottle and into one of the beakers. Put about 100 mL of the high pH buffer solution in one of the other two beakers and about 100 mL of the low pH buffer solution into the third beaker.

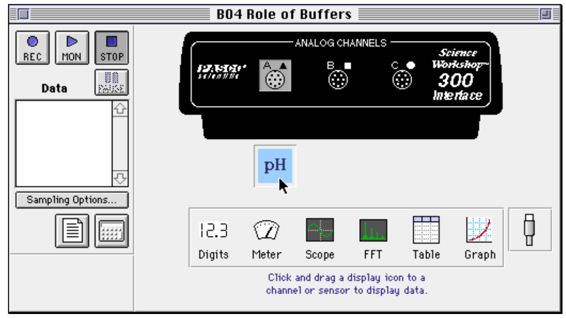
1. Remove the pH electrode from its bottle of buffer solution. Connect the electrode to the pH Sensor amplifier. To connect the electrode, push the BNC plug onto the receptacle on the Sensor amplifier and turn the BNC plug clockwise until it 'clicks' into place.



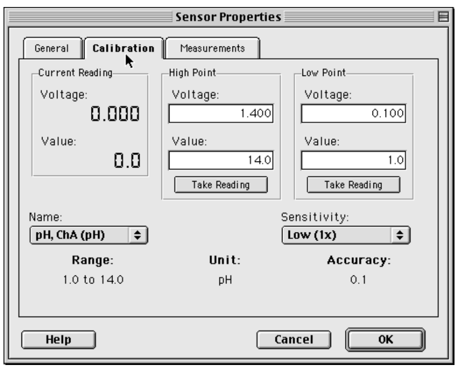
2. Use the wash bottle to rinse the end of the electrode. Soak the pH electrode in the beaker of distilled water for 10 minutes.

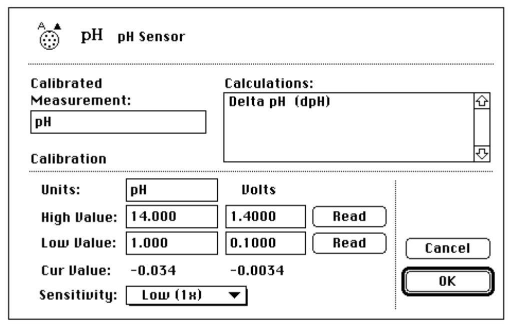
3. In the Experiment Setup window, double-click the pH Sensor icon.





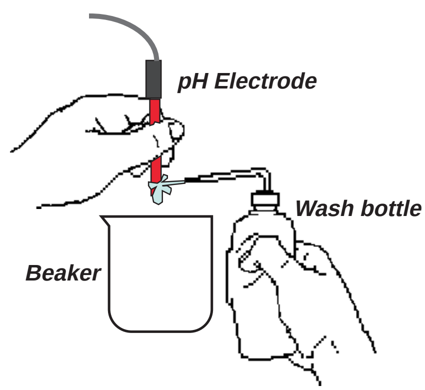
- In *DataStudio*, the Sensor Properties window will open. Click the ‘Calibration’ tab. In *ScienceWorkshop*, the Sensor Setup window will open.





4. Calibrate with the high pH buffer solution.

- Put the end of the pH electrode into the high pH buffer solution.
- Check the voltage under ‘Current Reading’ in *DataStudio* or next to ‘Cur Value:’ in *ScienceWorkshop*.
- When the voltage stabilizes, click the ‘Take Reading’ button under ‘High Point’ in *DataStudio* or the ‘Read’ button in the row for ‘High Value:’ in *ScienceWorkshop*.
- Enter the pH value of the buffer solution.



5. Thoroughly rinse the pH electrode with distilled water and dry it with a tissue.

6. Calibrate with the low pH buffer solution.

- Put the end of the pH electrode in the low pH buffer solution.
- Check the voltage under ‘Current Reading’ in *DataStudio* or next to ‘Cur Value:’ in *ScienceWorkshop*.
- When the voltage stabilizes, click the ‘Take Reading’ button under ‘Low Point’ in *DataStudio* or the ‘Read’ button in the row for ‘Low Value:’ in *ScienceWorkshop*.

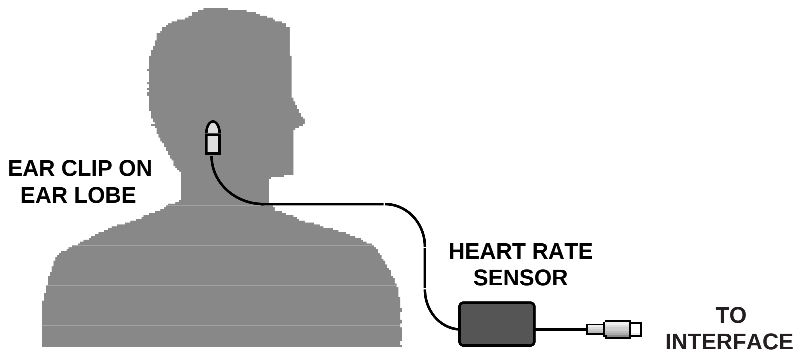
- Enter the pH value of the buffer solution. Click **OK** to return to the Experiment Setup window.

7. Thoroughly rinse the pH electrode with distilled water and dry gently.

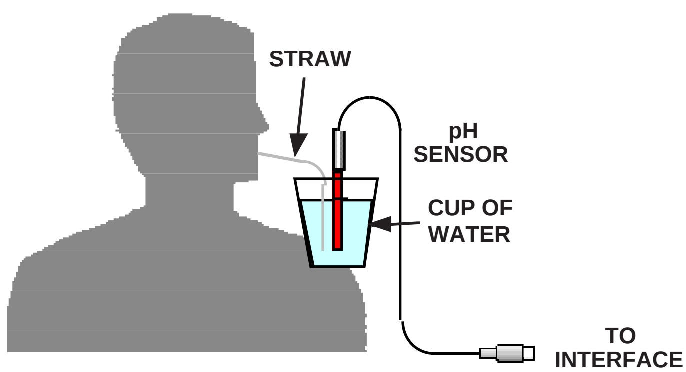
- You do not need to calibrate the Heart Rate Sensor. You will have a chance to check the Heart Rate Sensor before you begin recording data.

Equipment Setup

1. Gently put the ear clip of the Heart Rate Sensor onto an ear lobe of the person who is to be tested. Connect the phone plug on the end of the ear clip cable into the side of the Heart Rate Sensor box.



2. Put distilled water into the cup. Put a straw into the water. Put the pH Electrode into the water.



Sensor Check

DO NOT blow into the straw during the Sensor Check.

1. Monitor data to check the Heart Rate Sensor and the pH Sensor. (In *DataStudio*, select ‘Monitor Data’ in the Experiment menu. In *ScienceWorkshop*, click ‘MON’.)
2. Watch the Digits displays for Heart Rate and pH. The Digits display for Heart Rate may take a few moments before it shows a number. Be patient.
3. After a few moments, click the STOP button to end the Sensor Check.

- If the Heart Rate value remains at zero, try adjusting the ear clip on the ear lobe.

Name ____________________ Class _____________ Date _________

PART IIIA. Data Recording for Resting Heart Rate

1. Have the person who is being tested relax in a chair for about a minute. When the person is ready, begin recording data while the person is at rest.

- Data recording begins immediately, but the value of Heart Rate in the Digits display may not change for a few seconds.

2. Have the person take a few relaxed, deep breaths and then blow through the straw into the cup of water that has the pH Sensor in it. The person should blow at a steady rate for as long as possible without feeling uncomfortable.

- Data recording will end automatically after 60 seconds.
- Run #1 will appear in the Data list.

PART IIIB. Data Recording After Mild Exercise

- In this part of the activity you will measure Heart Rate and the change in pH of the water after the person being tested has done mild exercise.

1. Remove the ear clip from the ear lobe of the person being tested.
2. Have the person stand up and do mild exercise such as "jogging in place" to raise the heart rate and the breathing rate for at least one minute.
3. After one minute of exercise, have the person sit down again. Quickly put the ear clip back on the person's ear lob and begin recording data again.

- Data recording begins immediately, but the value of Heart Rate in the Digits display may not change for a few seconds.

4. Have the person take a few deep breaths and then blow through the straw into the cup of water that has the pH Sensor in it. The person should blow at a steady rate for as long as possible without feeling uncomfortable.

- Data recording will end automatically after 60 seconds.
- Run #2 will appear in the Data list.

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give <u>your</u> document a new filename.

Analyzing the Data

1. Rescale the Graph display to fit the data. (Click 'Scale to Fit' in *DataStudio* or 'Autoscale' in *ScienceWorkshop*.)
2. Use the 'Statistics' feature in the Table display to find the 'Mean' heart rate and the 'Min' (minimum) value of pH for each run of data. (Click the 'Statistics' menu in *DataStudio*, or the 'Statistics' button (Σ) in *ScienceWorkshop*. The bottom part of the Table will show the values. Note: The numbers in this example are "made up". Your numbers will probably be very different.)

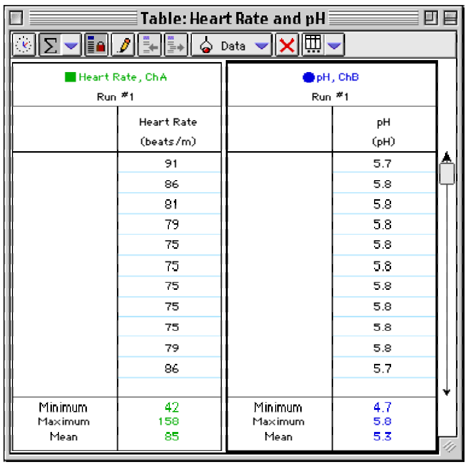
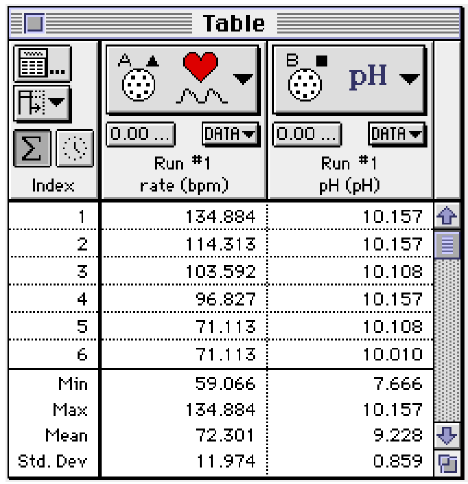


Table: Heart Rate and pH

Heart Rate, ChA Run #1	Heart Rate (beats/m)	pH, ChB Run #1	pH (pH)
	91		5.7
	86		5.8
	81		5.8
	79		5.8
	75		5.8
	75		5.8
	75		5.8
	75		5.8
	75		5.8
	79		5.8
	86		5.7
Minimum	42	Minimum	4.7
Maximum	158	Maximum	5.8
Mean	85	Mean	5.3



Table

Index	Run #1 rate (bpm)	Run #1 pH (pH)
1	134.884	10.157
2	114.313	10.157
3	103.592	10.108
4	96.827	10.157
5	71.113	10.108
6	71.113	10.010
Min	59.066	7.666
Max	134.884	10.157
Mean	72.301	9.228
Std. Dev	11.974	0.859

3. Record the Mean heart rate for both runs of data. Record the Min (minimum) value of pH for both runs of data.

Record your results in the Lab Report section.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS10: Heart Rate, Carbon Dioxide, and Exercise

What Do You Think?

How will mild exercise affect your heart rate and recovery time and how will it affect the amount of carbon dioxide in your breath?

Data Table

Trial	Mean heart rate (bpm)	Minimum pH
Run #1 (rest)		
Run #2 (post-exercise)		

Questions

1. What was the control in your experiment?

2. What is the influence of exercise on your heart rate?

3. What is the influence of exercise on the amount of carbon dioxide gas in your exhaled breathe?

4. Are there any differences between male and female heartbeat rates and carbon dioxide amounts among the students of your class?

5. How do you explain the pH value in the water before exercise to the pH value in the water after exercise?

Name ____________________ Class ______________ Date _________

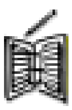
Activity GS11: The Effect of Respiration on Dissolved O_2 Concentrations (Dissolved Oxygen Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Environment	GS11 Dissolved O2.DS	(See end of activity)	(See end of activity)

Equipment Needed	Qty	Chemicals and Consumables	Qty
Dissolved Oxygen Sensor (CI-6542)	1	Sugar	5 g
Temperature Sensor (CI-6505A)	1	Water, distilled or deionized	400 mL
Balance (SE-8723)	1	Weighing paper	1
Beaker, 600 mL	1	Yeast suspension	5 mL
Bottle, about 1 L, with cap	1		
Graduated cylinder	1		
Stirring rod	1		
Protective gear	PS		

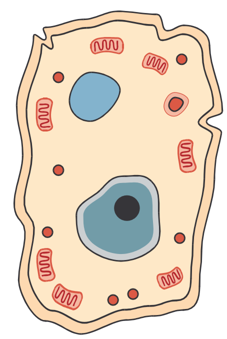
What Do You Think?

The purpose of this activity is to study the effect of respiration on dissolved oxygen concentrations. What effect do you think yeast will have on the dissolved oxygen concentration in water?



Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



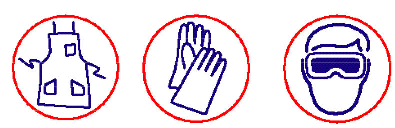
During cellular respiration, organisms break apart carbohydrates (such as sugar) to release energy. There are two types of cellular respiration – anaerobic and aerobic. Both types begin with glycolysis in which glucose is converted to pyruvic acid.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + energy$$

Aerobic cellular respiration requires oxygen. If yeast in a sugar solution break down the sugar during aerobic cellular respiration, the concentration of oxygen in the solution should decrease.

Yeast are **ectotherms** whose metabolism is determined in part by the temperature of their surroundings. The aerobic cellular respiration in yeast is particularly sensitive to temperature.

SAFETY REMINDERS



- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

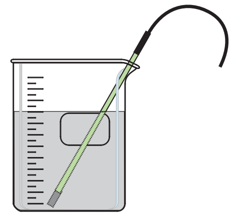
For You To Do

Use a Dissolved Oxygen Sensor to measure the concentration of dissolved oxygen in a dilute sugar solution before and after a small amount of yeast suspension is added to the solution. Use *DataStudio* or *ScienceWorkshop* to record and display the measured data.

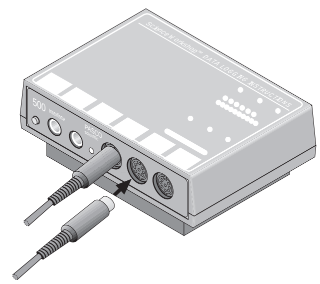
Compare the concentration of dissolved oxygen in the solution before and after the yeast are added.

Pre-Lab

Put 400 mL of room temperature deionized or distilled water into a beaker. Put the Temperature Sensor into the water.



PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Dissolved Oxygen Sensor DIN plug into Analog Channel A on the interface.
3. Connect the Temperature Sensor DIN plug into Analog Channel B.
4. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS11 Dissolved O2.DS	(See end of activity)	(See end of activity)

- The *DataStudio* file has a Digits display of temperature, a Graph display of dissolved oxygen concentration versus time, and a Workbook display. Read the instructions in the Workbook.

NOTE: If you use *ScienceWorkshop* you need to create the *ScienceWorkshop* document before you record data. See the pages at the end of the activity.

- Data recording is set at 10 measurements per second (10 Hz).

PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

- For calibration you will need the following: one-liter bottle, Dissolved Oxygen Sensor and soaker bottle, graduated cylinder, Temperature Sensor, water, and the table of ‘Concentration (mg/L) of Dissolved O_2 at Saturation by Temperature and Barometric Pressure’ (see the last page of the Instruction Manual for the Dissolved Oxygen Sensor).

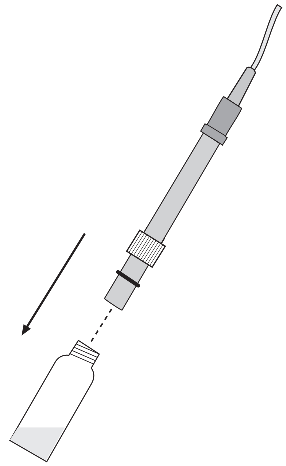
1. Use the software to measure the temperature of the water in the beaker.

- Hint: In *DataStudio*, select ‘Monitor Data’ from the Experiment menu. In *ScienceWorkshop*, click the ‘MON’ button ().

  Monitor the temperature for about thirty seconds and then record the value of the temperature. Stop measuring temperature and then remove the Temperature Sensor.

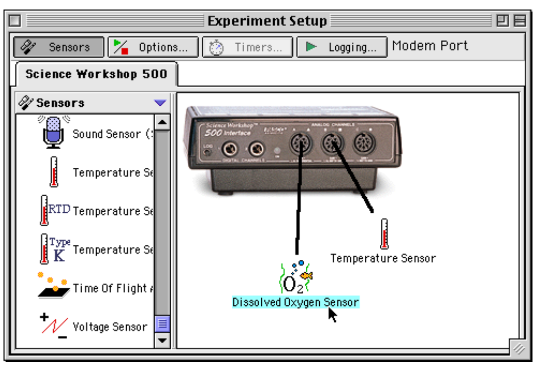
2. Pour the 400 mL of room temperature deionized or distilled water into the bottle. Cap the bottle and shake it vigorously for about 10 seconds to oxygenate the water.

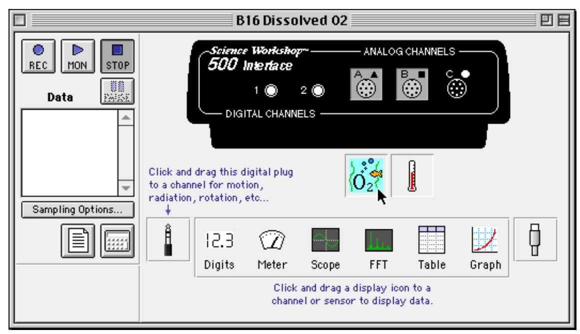
3. Put 5 mL of the oxygenated water from the bottle into the Dissolved Oxygen Sensor's soaker bottle. Insert the end of the sensor into the bottle and screw on the lid. Adjust the end of the sensor to about 2-cm above the water in the soaker bottle.



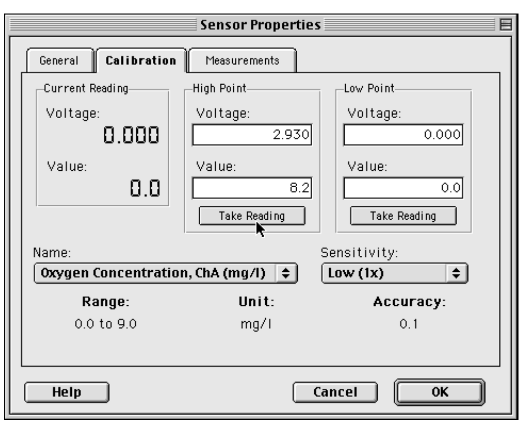
4. Use the software to calibrate the Dissolved Oxygen Sensor.

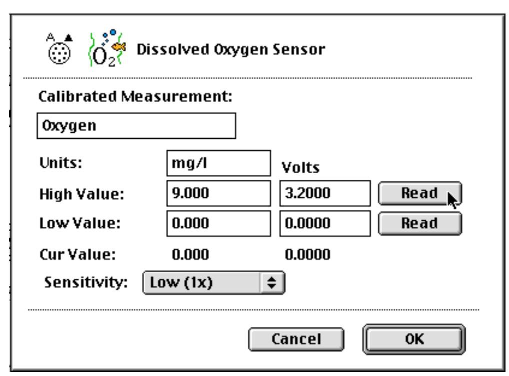
- In the Experiment Setup window, double-click the Dissolved Oxygen Sensor icon.

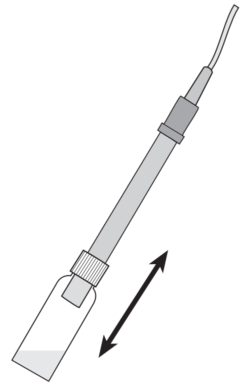




- In *DataStudio*, the Sensor Properties window will open. Click the 'Calibration' tab.
- In *ScienceWorkshop*, the Sensor Setup window will open.







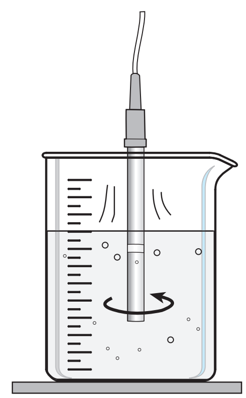
5. Shake the soaker bottle vigorously for about ten seconds. Shake off any large water drops from the membrane on the end of the sensor.

- Check the voltage under ‘Current Reading’ in *DataStudio* or next to ‘Cur Value:’ in *ScienceWorkshop*.
- When the voltage stabilizes, click the ‘Take Reading’ button under ‘High Point’ in *DataStudio* or the ‘Read’ button in the row for ‘High Value:’ in *ScienceWorkshop*.
- Refer to the table of Concentration (mg/L) of Dissolved O_2 at Saturation by Temperature and Barometric Pressure. Find the value of concentration that matches the temperature of the water. (If you know the barometric pressure, use it. Otherwise, use 760 mm Hg as the pressure). Enter the value in the Sensor Setup window under ‘High Point’ in *DataStudio* or in the row labeled ‘High Value’ in *ScienceWorkshop*.
- Click OK to return to the Experiment Setup window.

Equipment Setup

1. Pour the water from the bottle back into the beaker. Dissolve 5 g of sugar into the water.
2. Prepare to put 5 mL of the activated yeast suspension into the water.

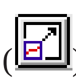
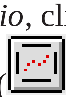
PART III: Data Recording



1. Put the Dissolved Oxygen Sensor into the beaker with the sugar solution and begin stirring gently.
2. Start recording data. Hint: In *DataStudio*, click ‘Start’. In *ScienceWorkshop*, click ‘REC’).
3. After 30 seconds, add the activated yeast suspension to the beaker. Continue to stir the solution with the sensor while you are recording data.
4. Record data for ten minutes or until the dissolved oxygen level reaches a minimum value and stops changing.

Analyzing the Data

1. Use the Graph display to view your data.

- Hint: In *DataStudio*, click ‘Scale to Fit’ () in the Graph toolbar. In *ScienceWorkshop*, click ‘Autoscale’ () in the lower left corner of the display.

2. Determine the minimum and maximum values of dissolved oxygen.

- Hint: In *DataStudio*, click the ‘Statistics Menu’ button () in the Graph toolbar. The minimum and maximum values appear in the Graph legend. Hint: In *ScienceWorkshop*, click the ‘Statistics’ button () to open the statistics area. In the statistics area, click the ‘Statistics Menu’ button (). Select ‘Minimum’, open the menu again, and select ‘Maximum’.

Record your results in the Lab Report Section

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS11: The Effect of Respiration on Dissolved O_2 Concentrations

What Do You Think?

The purpose of this activity is to study the effect of respiration on dissolved oxygen concentrations. What effect do you think yeast will have on the dissolved oxygen concentration in water?

Data Table

Item	Maximum	Minimum
Dissolved O_2 Concentration	mg/L	mg/L

Questions

1. What is the evidence that the yeast cells are alive and respiring?

2. What happens to the yeast when the dissolved oxygen concentration reaches a minimum? Is there any evidence that the yeast cells are still alive?

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select ‘Quit’ from the ‘File’ menu to end the activity.
2. You can select ‘Save’ or ‘Save As…’ from the File menu to save your data for this activity. the changes you’ve made to the document.

- The original document is “locked”, so you should give <u>your</u> document a new filename.

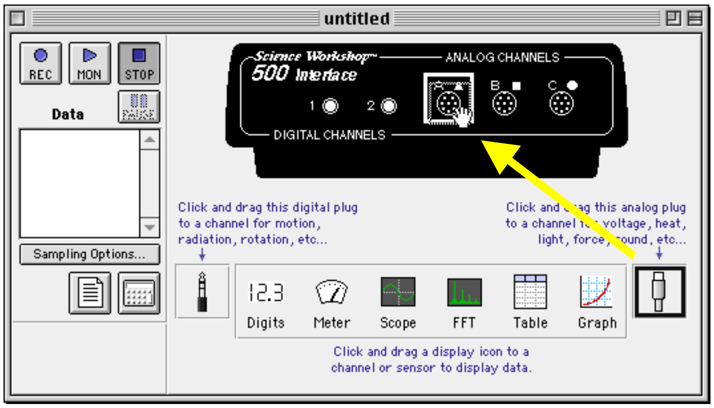
3. If you wish to go on to the next activity, select ‘Open…’ from the ‘File’ menu, and find the document for the next activity.

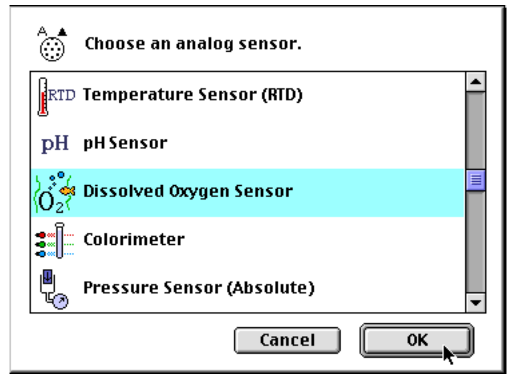
Name ____________________ Class ______________ Date _________

Appendix: Create a *ScienceWorkshop* document for GS11 Dissolved O2

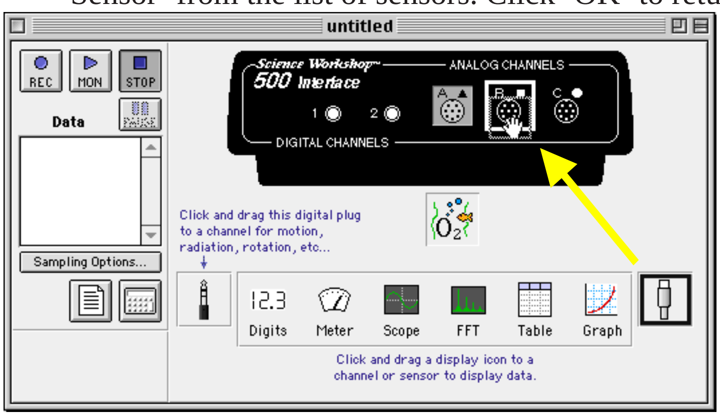
Set Up the Sensors

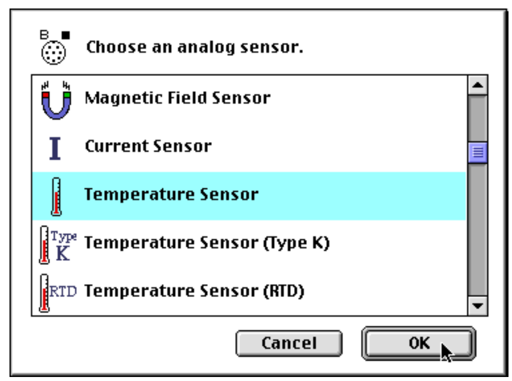
1. In the Experiment Setup window, click-and-drag the analog sensor plug icon to Analog Channel A. Select ‘Dissolved Oxygen Sensor’ from the list of sensors. Click ‘OK’ to return to the Experiment Setup window.





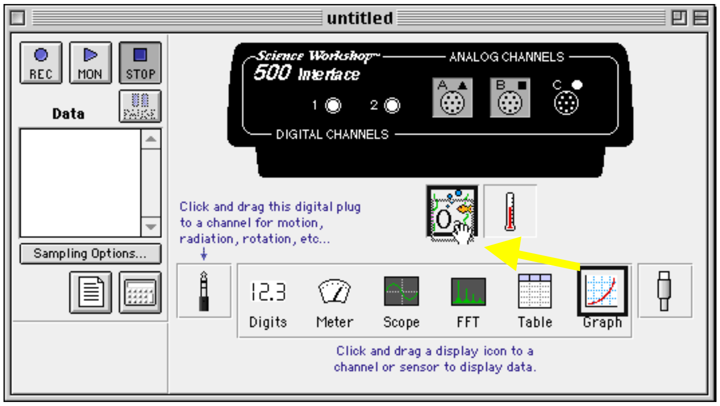
2. Click-and-drag the analog sensor plug icon to Analog Channel B and select ‘Temperature Sensor’ from the list of sensors. Click ‘OK’ to return to the Experiment Setup window.



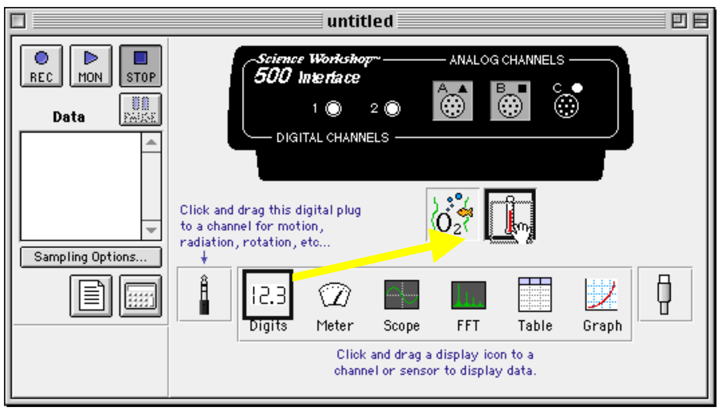


Set Up the Displays

3. In the Experiment Setup window, click-and-drag the Graph display icon to the Dissolved Oxygen Sensor icon.



4. Return to the Experiment Setup window and click-and-drag the Digits display icon to the Temperature Sensor icon.



Name ____________________ Class ______________ Date _________

Activity GS12: Organisms and pH (pH Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Biochemistry	GS12 Organisms and pH.DS	(See end of activity)	(See end of activity)

Equipment Needed	**Qty**	**Chemicals and Consumables**	**Qty**
pH Sensor (CI-6507A)	1	Buffer solution, high pH	100 mL
Base and support rod (ME-9355)	1	Buffer solution, low pH	100 mL
Beaker, 50 mL	1	Egg white, diluted 1:5 with water	50 mL
Beaker, 250 mL	3	Gelatin suspension, 2%, warm	50 mL
Buret, 50 mL	1	Hydrochloric acid (HCl), 0.1M	10 mL
Clamp, buret (SE-9446)	2	Liver homogenate	50 mL
Graduated cylinder, 50 mL	1	Potato homogenate	50 mL
Stir rod	1	Sodium hydroxide (NaOH), 0.1M	10 mL
Wash bottle	1	Sodium phosphate buffer solution, pH 7	50 mL
Protective gear	PS	Water	50 mL
		Water, distilled	500 mL

For instructions on preparing the solutions and materials, see the Notes section at the end of this lab.

What Do You Think

Which of the following substances can act as a buffer (maintain its pH within a relatively narrow range)? The substances are egg white, gelatin, liver, potato and water.

How do organisms maintain a stable internal environment?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

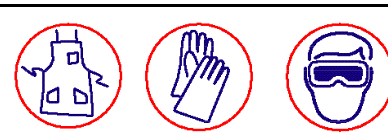
Background

In order to survive, living organisms must maintain a relatively stable internal environment. Both organisms and cells have learned to adapt to many environmental factors that would normally affect their internal environment.

The pH in the organism's environment is determined by the concentration of hydrogen ions (H^+) and hydroxide ions (OH^-). The pH plays an important role in many biochemical processes and can affect internal and external environments of living tissue. Living organisms have developed mechanisms to maintain a normal pH for each cell or organ system (usually between pH 6 and pH 8).

A buffer is a solution of a weak acid in the presence of its salt. A buffer maintains its pH within a relatively narrow range despite changes in the concentration of hydrogen ions or hydroxide ions.

SAFETY REMINDERS



- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the pH Sensor to measure the change in pH of water, a buffer solution, and a variety of biological materials when a strong acid or strong base is added to them. Use *DataStudio* or *ScienceWorkshop* to record and analyze the data.

PART I: Computer Setup

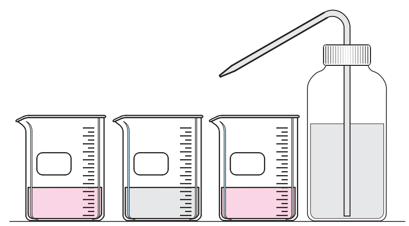
1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the pH Sensor into Analog Channel A of the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS12 Organisms and pH.DS	(See end of activity)	(See end of activity)

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- See the pages at the end of the activity for information about setting up a *ScienceWorkshop* file with a Digits display, a Table display, and a Graph display of pH.
- Data recording is set at ten measurements per second (10 Hz).

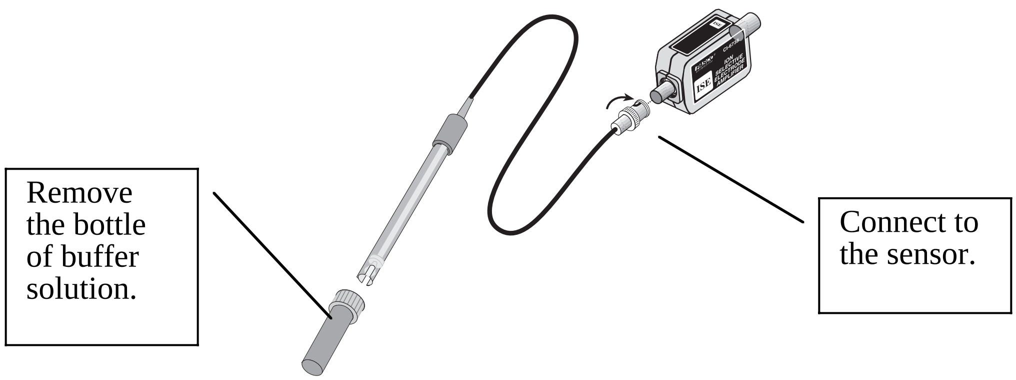
PART II: Sensor Calibration and Equipment Setup

Calibrate the Sensor



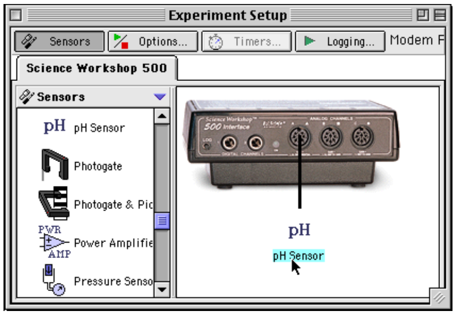
- To calibrate the pH Sensor you will need a wash bottle, distilled water, three beakers, and buffer solutions of high pH (e.g. pH 10) and low pH (e.g. pH 4). Put distilled water into the wash bottle and into one of the beakers. Put buffer solutions in the other two beakers.

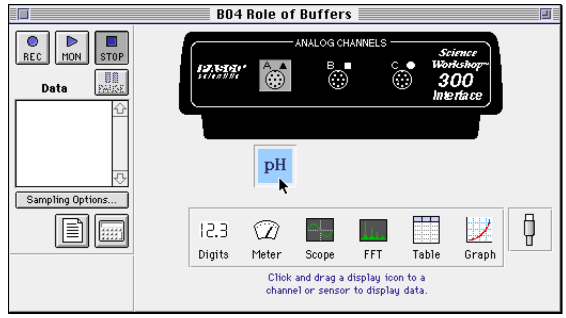
1. Remove the pH electrode from its bottle of buffer solution. Connect the electrode to the pH Sensor amplifier. To connect the electrode, push the BNC plug onto the receptacle on the Sensor amplifier and turn the BNC plug clockwise until it 'clicks' into place.

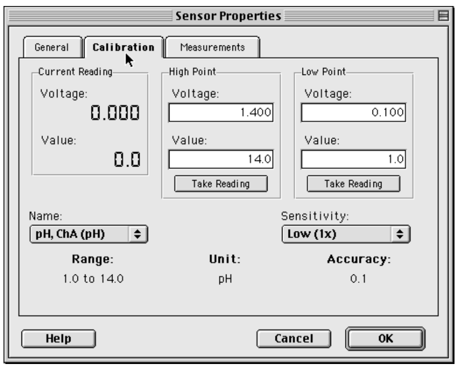


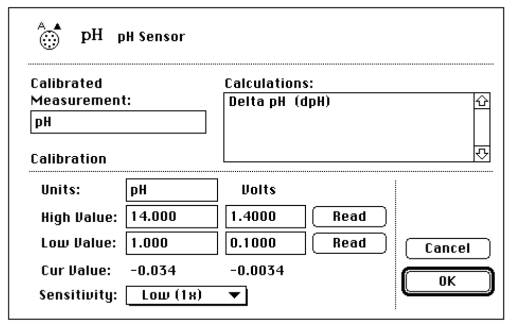
2. Use the wash bottle to rinse the end of the electrode. Soak the pH electrode in the beaker of distilled water for 10 minutes.

3. In the Experiment Setup window, double-click the pH Sensor icon.









- In *DataStudio*, the Sensor Properties window will open. Click the 'Calibration' tab. In *ScienceWorkshop*, the Sensor Setup window will open.

4. Calibrate with the high pH buffer solution.

- Put the end of the pH electrode into the high pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'High Point' in *DataStudio* or the 'Read' button in the row for 'High Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution.

5. Thoroughly rinse the pH electrode with distilled water and dry it with a tissue.

6. Calibrate with the low pH buffer solution.

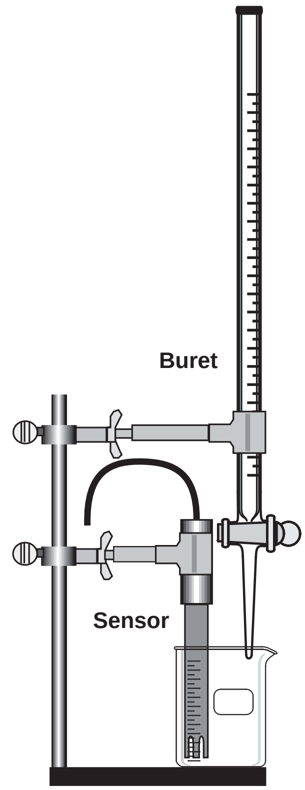
- Put the end of the H electrode in the low pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'Low Point' in *DataStudio* or the 'Read' button in the row for 'Low Value:' in *ScienceWorkshop*.

- Enter the pH value of the buffer solution. Click **OK** to return to the Experiment Setup window.

7. Thoroughly rinse the pH electrode with distilled water and dry gently.

Set Up the Equipment

1. Set up the pH electrode in a 50-mL beaker. Use a base and support rod and a clamp to mount the pH electrode so the end of the electrode is in the beaker.
2. Set up the buret so it is above the 50-mL beaker. Use a clamp to mount the buret so the tip of the buret is over the mouth of the beaker.
3. Put a stir rod in the beaker.



PART III: Data Recording

There are six parts to data recording.

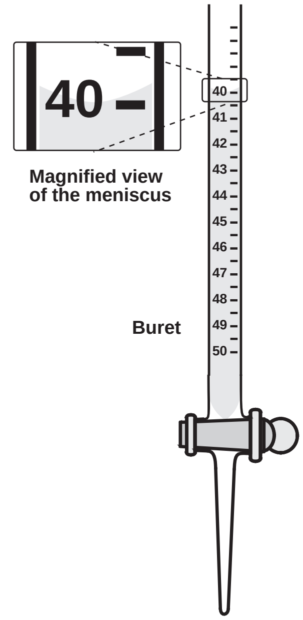
Part	Description
A	Add 1.5 mL of hydrochloric acid to tap water
B	Add 1.5 mL of hydrochloric acid to sodium phosphate buffer solution
C	Add 1.5 mL of hydrochloric acid to a biological material
D	Add 1.5 mL of sodium hydroxide to tap water
E	Add 1.5 mL of sodium hydroxide to sodium phosphate buffer solution
F	Add 1.5 mL of sodium hydroxide to a biological material

Follow the same basic procedure in each part:

- Put 25 mL of the substance to be tested into the beaker.
- *Slowly* but steadily add 1.5 mL of the acid (Parts A, B, and C) or base (Parts D, E, and F) *drop-by-drop* into the substance that is being tested.
- Stir the substance as you slowly add the acid or base. Use the sensor to record the pH.

Name ____________________ Class _____________ Date _________

Using the Buret



Turn the valve on the buret to the 'off' position. Carefully pour enough acid into the buret so the level of the liquid is 10 mL above the lowest mark on the buret. For example, in a 50-mL buret, add fluid so the bottom of the meniscus is at the 40 mL mark.

When you are ready to begin adding the acid (or the base) to the substance you are testing, open the valve just enough so that the fluid drips into the substance one drop at a time.

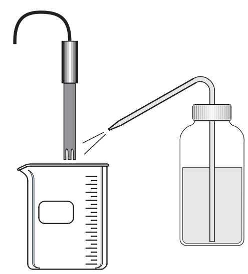
PART IIIA: Add Hydrochloric Acid to Tap Water

First, fill the buret with acid so the level of the acid is 10 mL above the lowest mark on the buret.

Make a prediction:

What will happen to the pH of the water as you add the acid? Write your prediction and a brief explanation in the Lab Report.

1. Put 25 mL of tap water into the beaker.
2. When everything is ready, start recording data. (Hint: In *DataStudio*, click 'Start'. In *ScienceWorkshop*, click 'REC'.)
3. After 5 seconds, open the valve on the buret enough so the acid can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of acid (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the tap water/acid mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.



PART IIIB: Add Hydrochloric Acid to A Buffer Solution

Make a prediction:

What will happen to the pH of the buffer solution as you add the acid? Write your prediction and a brief explanation in the Lab Report.

1. Put the beaker back under the pH electrode and buret. Put 25 mL of sodium phosphate buffer solution into the beaker.
2. When everything is ready, start recording data.
3. After 5 seconds, open the valve on the buret enough so the acid can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of acid (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the buffer solution/acid mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

PART IIIC: Add Hydrochloric Acid to A Biological Material

1. Select one biological material (egg white, liver homogenate, potato homogenate, or warm gelatin). Note: Your teacher may select the biological material for you or your group to use.

   Record the type of biological material you are testing.

   Substance = ________________________________

Make a prediction:

What will happen to the pH of the biological material as you add the acid? Write your prediction and a brief explanation in the Lab Report.

2. Put the beaker back under the pH electrode and buret. Put 25 mL of your biological material into the beaker.
3. When everything is ready, start recording data.
4. After 5 seconds, open the valve on the buret enough so the acid can begin dripping into the substance. Stir the mixture with the stir rod.
5. Add 1.5 mL of acid (or 30 drops) and then close the buret valve.
6. Stop data recording.
7. Dispose of the material/acid mixture as directed. Rinse and clean the beaker and the stir rod.
8. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

PART IIID: Add Sodium Hydroxide to Tap Water

First, fill the buret with sodium hydroxide solution so the level of the solution is 10 mL above the lowest mark on the buret.

Make a prediction:

What will happen to the pH of the water as you add the sodium hydroxide? Write your prediction and a brief explanation in the Lab Report.

1. Put the beaker back under the pH electrode and buret. Put 25 mL of tap water into the beaker.
2. When everything is ready, start recording data.
3. After 5 seconds, open the valve on the buret enough so the base (sodium hydroxide) can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of base (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the tap water/base mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

Name ____________________ Class _____________ Date ________

PART IIIE: Add Sodium Hydroxide to A Buffer Solution

Make a prediction:

What will happen to the pH of the buffer solution as you add the base? Write your prediction and a brief explanation in the Lab Report.

1. Put the beaker back under the pH electrode and buret. Put 25 mL of sodium phosphate buffer solution into the beaker.
2. When everything is ready, start recording data.
3. After 5 seconds, open the valve on the buret enough so the base can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of base (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the buffer solution/base mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

PART IIIF: Add Sodium Hydroxide to A Biological Material

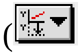
Note: Use the same biological material for Part IIIF that you used in Part IIIC.

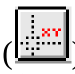
Make a prediction:

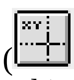
What will happen to the pH of your biological material as you add the base? Write your prediction and a brief explanation in the Lab Report.

1. Put the beaker back under the pH electrode and buret. Put 25 mL of your biological material into the beaker.
2. When everything is ready, start recording data.
3. After 5 seconds, open the valve on the buret enough so the base can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of base (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the material/base mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

Analyzing the Data

1. Set up your Graph display so you can see all your data. (Hint: In *DataStudio* the Graph already shows all the runs. In *ScienceWorkshop*, use the 'Add a Plot' menu () to add a second plot to the Graph. Then use the 'Data' menu in each plot to select Runs #1, #2, and #3 for one plot and Runs #4, #5, and #6 for the other plot.)
2. Set up your Table display so you can see all your data. (Hint: In *DataStudio*, use the 'Data' menu button () to select each run. In *ScienceWorkshop*, click the 'Add a Column' menu button () to add more columns to the Table. Then click the 'Data' menu () to select Run #1 for the first column, Run #2 for the second column, and so on for all the data.)
3. Use the built-in analysis tools of the Graph or Table display to find the beginning pH and the ending pH for each trial.

- Hint for Graph display: In *DataStudio*, click the 'Smart Tool' button () in the Graph. The 'Smart Tool' displays the coordinates of its position as you move it to any position in the Graph display. When the 'Smart Tool' is on a data point, the 'y' coordinate is the pH value at that point.

  In *ScienceWorkshop*, click the 'Smart Cursor' button () and move the cursor into the display area. The coordinates of the cursor are displayed in the label area of the Y-axis and the X-axis.

- Hint for Table display: Look at the beginning value of pH and then scroll to the end of the column to see the ending value of pH.

4. Record the values of the beginning pH and the ending pH for each of your runs of data.
5. Obtain the pH data for other biological materials from your classmates and record them in your data table in the Lab Report.
6. Calculate the change in pH (if any) for each substance. Record the change in the data table.
7. Finally, calculate the percent difference between the beginning pH and the ending pH for each substance (tap water, buffer solution, egg white, gelatin, liver and potato). Record the percent difference in the data table.

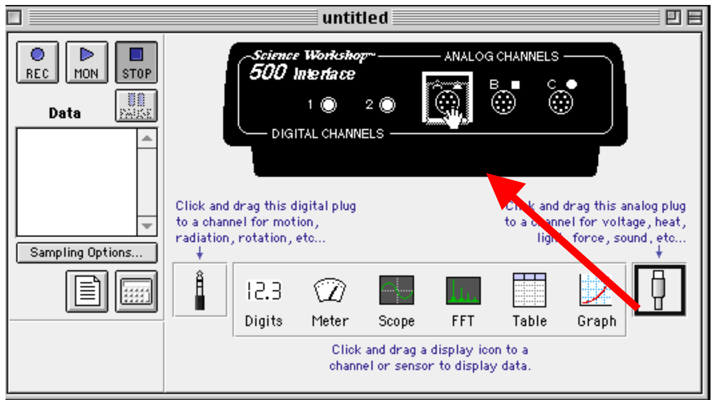
Record your results in the Lab Report section.

Appendix: Set Up *ScienceWorkshop*

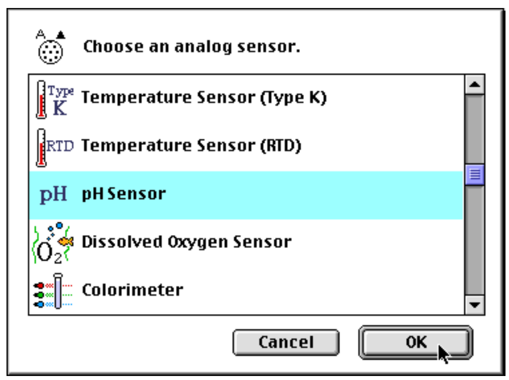
Create a *ScienceWorkshop* file to measure pH.

Set Up the Sensor

In the Experiment Setup window, click and drag the analog sensor plug to Channel A.

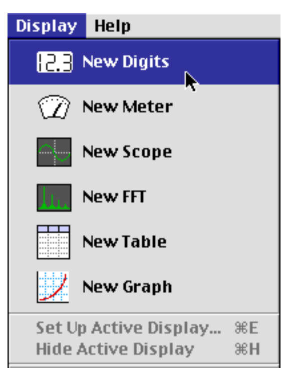


Select 'pH Sensor' from the list of sensors. Click 'OK' to return to the Experiment Setup window.



Set Up the Displays

In the Display menu, select 'New Digits' from the list of displays. Return to the Display menu and select 'New Table'. Finally, return to the menu and select 'New Graph'.



Arrange the windows so you can see the Digits display of pH.

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS12: Organisms and pH

What Do You Think?

Which of the following substances can act as a buffer (maintain its pH within a relatively narrow range)? The substances are egg white, gelatin, liver, potato and water.

How do organisms maintain a stable internal environment?

Predictions:

Part IIIA: What will happen to the pH of the water as you add the acid?

Part IIIB: What will happen to the pH of the buffer solution as you add the acid?

Part IIIC: What will happen to the pH of the biological material as you add the acid?

Part IIID: What will happen to the pH of the water as you add the base (sodium hydroxide)?

Part IIIE: What will happen to the pH of the buffer solution as you add the base?

Part IIIF: What will happen to the pH of the biological material as you add the base?

Data Table

	0.1 M hydrochloric acid (HCl)				0.1 M sodium hydroxide (NaOH)			
Substance	Begin pH	End pH	ΔpH	% diff.	Begin pH	End pH	ΔpH	% diff.
Tap Water								
Buffer								
Egg White								
Gelatin								
Liver								
Potato								

Questions

1. What was the total pH change when HCl is added to your biological material? Compare this change to the pH change for the tap water and acid.

2. What was the total pH change when NaOH is added to your biological material? Compare this change to the pH change for the tap water and base.

3. Describe how each biological material responded to changes in pH.

4. How does the buffer solution respond to HCl and NaOH? Is it more like the tap water or a biological material?

5. Suggest a mechanism for pH regulation in organisms.

Name ____________________ Class _____________ Date _________

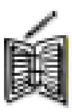
Activity GS13: Acid Rain (pH Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Environment	GS13 Acid Rain.DS	G13 Acid Rain	G13_RAIN.SWS

Equipment Needed	Qty	Chemicals and Consumables	Qty
pH Sensor (CI-6507A)	1	Buffer solution: high pH	100 mL
Base and support rod (ME-9355)	1	Buffer solution: low pH	100 mL
Beaker, 250 mL	3	Sodium hydrogen carbonate, $NaHCO_3$, solid	5 g
Beaker, 100 mL	4	Sodium hydrogen sulfite, $NaHSO_3$, solid	5g
Berol-type pipette, 15 cm stem	3	Sodium nitrite, $NaNO_2$, solid	5g
Berol-type pipette, 2 cm stem	3	Water	12 mL
Berol-type pipette with 1.0 M HCl	1	Water, distilled	1 L
Clamp, buret (SE-9446)	1		
Test tube, 20 by 150 mm	1		
Wash bottle	1		
Protective gear	PS		

What Do You Think?

The purpose of this activity is to “create” acid rain. What is acid rain and what causes it? How much will the pH of water be changed by different gases such as carbon dioxide and nitrogen dioxide?



Take time to answer the ‘What Do You Think?’ question(s) in the Lab Report section.

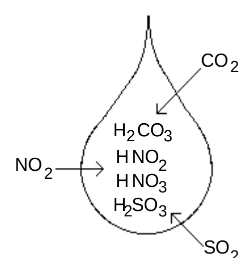
Background

Water vapor in the air can combine with other gases found in the air. You may be surprised to learn that rain water is slightly acidic. One reason is that water vapor can combine with carbon dioxide gas to form carbonic acid. The natural pH value of rainwater is usually between 6.0 and 6.9. Rainfall accumulates in rivers and streams causing a slight acidification.

Other gases found in the air can also combine with water vapor to form “acid rain”. For example, gases in automobile exhaust and other gases given off by combustion of fossil fuels can combine with water vapor to form sulfurous acid, nitrous acid, and nitric acid.

You will produce four of the constituents of acid rain and monitor their effect on the pH of water samples.

- **carbonic acid, H_2CO_3**
- **nitrous acid, HNO_2**
- **nitric acid, HNO_3**
- **sulfurous acid, H_2SO_3**



Carbonic acid is formed when carbon dioxide gas dissolves in rain droplets of unpolluted air:

$$CO_{2(g)} + H_2O_{(l)} \;=====>\; H_2CO_{3(aq)}$$

Nitrous acid and nitric acid result from a common air pollutant, nitrogen dioxide (NO_2). Most nitrogen dioxide in our atmosphere is produced from automobile exhaust. Nitrogen dioxide gas dissolves in rain drops and forms nitrous and nitric acid:

$$\mathbf{2\ NO_{2(g)} + H_2O_{(l)}\ =====>\ HNO_{2(aq)} + HNO_{3(aq)}}$$

Sulfurous acid is produced from another air pollutant, sulfur dioxide (SO_2). Most sulfur dioxide gas in the atmosphere results from burning coal containing sulfur impurities. Sulfur dioxide dissolves in rain drops and forms sulfurous acid:

$$\mathbf{SO_{2}(g) + H_2O(l)\ =====>\ H_2SO_3(aq)}$$

If large amounts of these gases are in the air, the pH of rainwater can drop drastically. Rainfall of low pH values directly affects the aquatic life in the rivers and streams where this water accumulates. Acid rain can also cause damage to plant life.

SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

CAUTION: Hydrochloric acid is an irritant and can ruin clothing. Avoid contact to eyes or skin. Do Not Drink. Immediately flush spills with water for 15 minutes. Notify your instructor of any contact on your skin with these chemicals.

For You To Do

First, calibrate the pH Sensor. Then build three ‘gas generators’ using Berol-type pipettes partially filled with three different compounds: sodium hydrogen carbonate, sodium hydrogen sulfite, and sodium nitrite. Each compound produces a different gas when hydrochloric acid is added (carbon dioxide from the sodium hydrogen carbonate, sulfur dioxide from the sodium hydrogen sulfite, and nitrogen dioxide from the sodium nitrite).

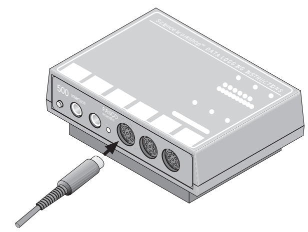
In the second part of the activity, add a small amount of hydrochloric acid to each gas generator to activate each generator.

Finally, collect the gas produced by each generator and bubble the gas through tap water. Use the pH Sensor to measure the change in pH of the water as the gas mixes with it.

Use *DataStudio* or *ScienceWorkshop* to record and display the pH. Compare the change in pH created by carbon dioxide gas to the change in pH created by sulfur dioxide gas and nitrogen dioxide gas.

Name ____________________ Class _____________ Date ________

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the pH sensor DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS13 Acid Rain.DS	G13 Acid Rain	G13_RAIN.SWS

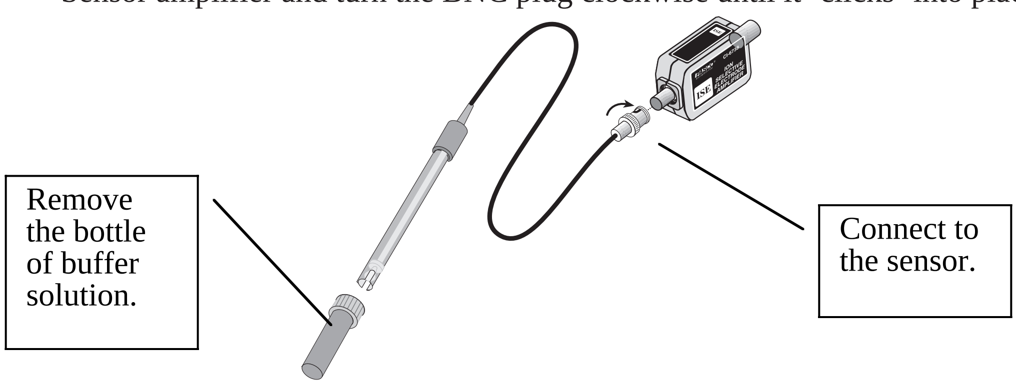
- The *DataStudio* file has a Workbook display, a Graph display, and a Table display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Graph of pH versus Time and a Table display of pH.
- Data recording is set at ten measurements per second (10 Hz) and a 'Stop Condition' at 100 seconds.

PART II: Sensor Calibration and Equipment Setup

Calibrate the Sensor

- To calibrate the pH Sensor you will need a wash bottle, distilled water, three beakers, and buffer solutions of high pH (e.g. pH 10) and low pH (e.g. pH 4). Put distilled water into the wash bottle and into one of the beakers. Put buffer solutions in the other two beakers.

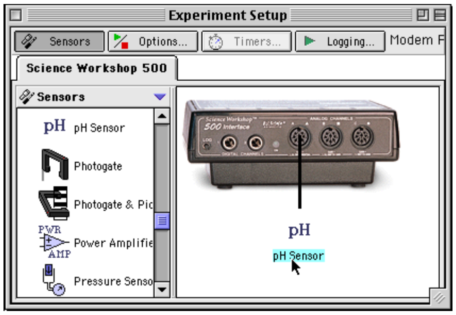
1. Remove the pH electrode from its bottle of buffer solution. Connect the electrode to the pH Sensor amplifier. To connect the electrode, push the BNC plug onto the receptacle on the Sensor amplifier and turn the BNC plug clockwise until it 'clicks' into place.

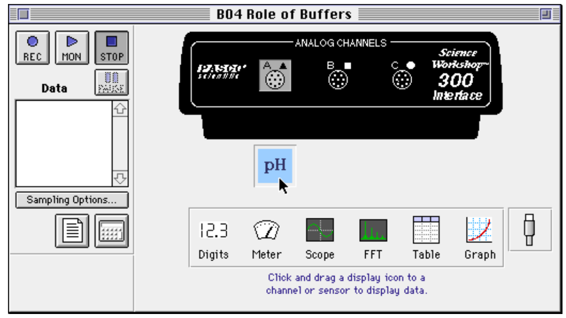


2. Use the wash bottle to rinse the end of the electrode. Soak the pH electrode in the beaker of distilled water for 10 minutes.

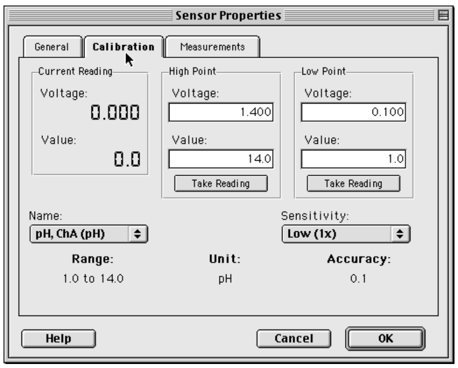
- NOTE: While the electrode is soaking you can set up the equipment.

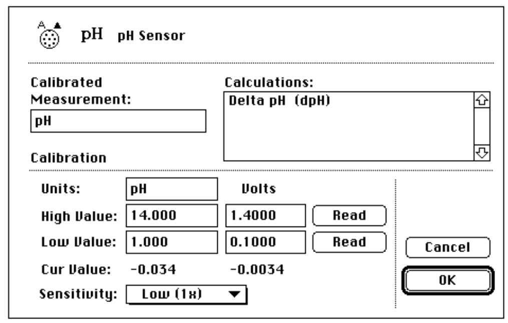
3. In the Experiment Setup window, double-click the pH Sensor icon.





- In *DataStudio*, the Sensor Properties window will open. Click the 'Calibration' tab. In *ScienceWorkshop*, the Sensor Setup window will open.





4. Calibrate with the high pH buffer solution.

- Put the end of the pH electrode into the high pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'High Point' in *DataStudio* or the 'Read' button in the row for 'High Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution.

5. Thoroughly rinse the pH electrode with distilled water and dry it with a tissue.

6. Calibrate with the low pH buffer solution.

- Put the end of the H electrode in the low pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'Low Point' in *DataStudio* or the 'Read' button in the row for 'Low Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution. Click 'OK' to return to the Experiment Setup window.

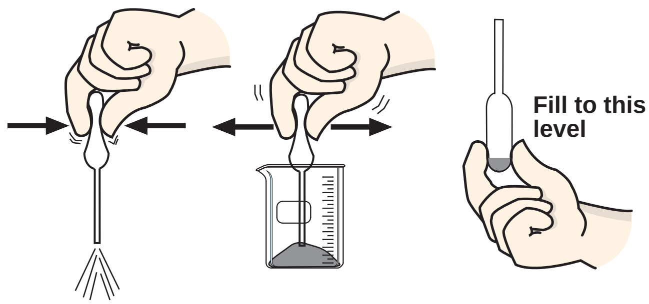
7. Thoroughly rinse the pH electrode with distilled water and dry gently.

Name ____________________ Class ______________ Date _________

Equipment Setup

[ ] Prepare the gas generators.

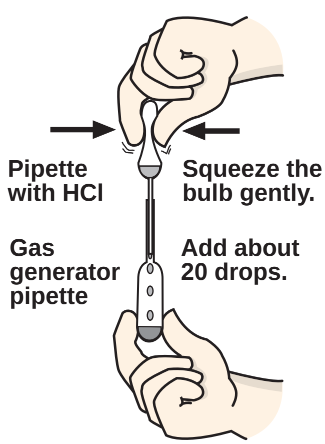
1. Label three *short-stem* Berol pipettes with the formula of the solid they will contain: "$NaHCO_3$" (for sodium hydrogen carbonate), "$NaNO_2$" (for sodium nitrite) and "$NaHSO_3$" (for sodium hydrogen sulfite).
2. Label three *long-stem* Berol pipettes with the formula of the gas they will contain: "CO_2" (for carbon dioxide), "NO_2" (for nitrogen dioxide) and "SO_2" (for sodium dioxide). Use the 100-mL beaker to support the pipettes.
3. Your teacher will supply a beaker containing powdered $NaHCO_3$ (sodium hydrogen carbonate). Squeeze the bulb of the *short-stem* pipette labeled "$NaHCO_3$" to push the air out of the bulb. Place the open end of the pipette into the powdered $NaHCO_3$. Release the bulb to draw some of the powdered $NaHCO_3$ into the pipette. Draw the powder into the pipette until there is just enough powder to fill the curved end of the bulb of the pipette when you hold the pipette with the bulb end down (see the diagram).



4. Repeat the previous step to fill the "NaNO2" and "NaHSO3" short-stem Berol pipettes with the corresponding powdered compounds.
5. Get a Berol pipette with 1.0 Molar hydrochloric acid (HCl) from your teacher.

- Caution: HCl is a strong acid. Hold the pipette gently, with the stem pointing up, so that HCl doesn't drip out.

Insert the narrow stem of the HCl pipette into the larger opening of the pipette with the $NaHCO_3$ (see the diagram.) Gently squeeze the HCl pipette to add about 20 drops of HCl solution to the powdered $NaHCO_3$.



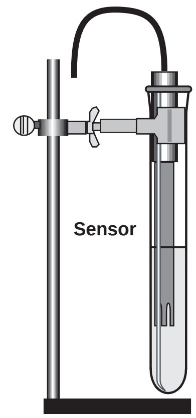
When finished, remove the HCl pipette. Gently swirl the pipette that contains $NaHCO_3$ and HCl.

Carbon dioxide gas, CO_2, is generated in this pipette. Place the pipette *bulb down* in the 100-mL beaker to prevent spillage.

6. Repeat this same procedure to add HCl to the pipette with the powdered $NaHSO_3$ (sodium hydrogen sulfite). Sulfur dioxide, SO_2, is generated in this pipette. Place this pipette *bulb down* in the 100-mL beaker to prevent spillage

7. Repeat this procedure a third time to add HCl to the powdered $NaNO_2$ (sodium nitrite) pipette. Nitrogen dioxide, NO_2, is generated in this pipette. Return the HCl pipette to your teacher. Leave the three gas-generating pipettes in a 100-mL beaker until needed.

[ ] Set up the pH Sensor



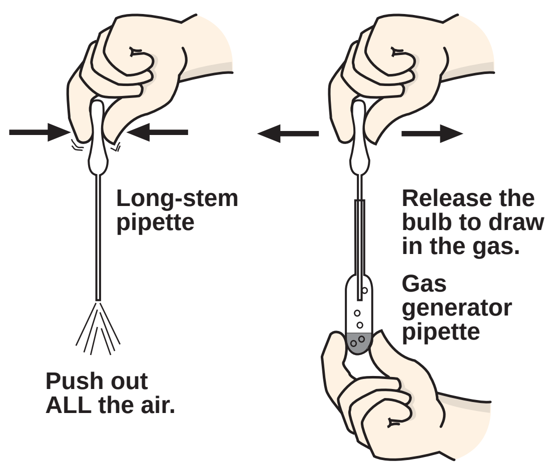
8. Attach a 20 by 150 mm test tube to the base and support rod using a clamp. Add about 4 mL of tap water to the test tube. Rinse the pH electrode with distilled water and place the electrode into the tap water in the test tube.

[ ] Collect the gas

9. Squeeze all of the air from the bulb of the long-stem pipette labeled "CO_2". Keep the bulb completely collapsed and insert the long stem of the pipette down into the gas-generating "$NaHCO_3$" pipette. The tip of the long-stem pipette should not touch the liquid in the "$NaHCO_3$" pipette (see the diagram). Release the pressure on the bulb so that it draws gas up into it. Store the long-stem pipette and the "$NaHCO_3$" pipette in the 100-mL beaker.

10. Repeat the 'gas collection procedure' using the "$NaNO_2$" and "NO_2" pipettes.

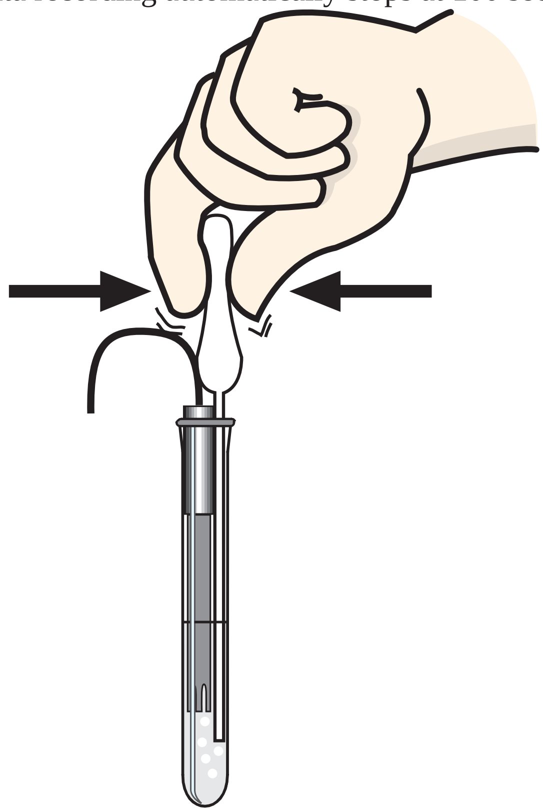
11. Repeat the 'gas collection procedure' using the "$NaHSO_3$" and "SO_2" pipettes.



Name ____________________ Class ______________ Date _________

PART III: Data Recording

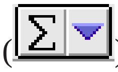
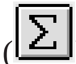
1. Insert the long-stem pipette labeled "CO_2" into the test tube, alongside the pH sensor, so that its tip extends into the water near the bottom of the test tube (see the diagram.)
2. Start recording data. After 15 seconds, gently squeeze the bulb of the pipette so that bubbles of CO_2 *slowly* bubble up through the solution. Use both hands to squeeze *all* of the gas from the bulb. Data recording automatically stops at 100 seconds.



3. Remove the pH electrode from the test tube and rinse the electrode thoroughly with distilled water and return it to the sensor storage solution.
4. Discard the contents of the test tube as directed by your teacher. Rinse the test tube *thoroughly* with tap water.
5. Add 4 mL of tap water to the test tube.
6. Repeat the data recording process using NO_2 gas.
7. Repeat the data recording process using SO_2 gas.
8. When you are finished, rinse the pH electrode with distilled water and return it to the sensor storage bottle. Dispose of the six pipettes as directed

Analyzing the Data

1. Examine each run of data in your Table display to determine the minimum pH value and maximum pH value for the water for each gas. Record the values.

- Hint: In *DataStudio*, click the 'Statistics Menu' button (). In *ScienceWorkshop*, click the 'Statistics' button ().

2. For each of the three gases, calculate the change in pH and record it.
3. Record your conclusion and answer the questions in the Lab Report.

Record your results in the Lab Report Section

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS13: Acid Rain

What Do You Think?

The purpose of this activity is to "create" acid rain. What is acid rain and what causes it? How much will the pH of water be changed by different gases such as carbon dioxide and nitrogen dioxide?

Data Table

Gas	Initial pH	Final pH	Change in pH (ΔpH)
CO_2			
NO_2			
SO_2			

Questions

1. In this activity, which gas caused the smallest change in pH?

2. Which gas (or gases) caused the largest change in pH?

3. Coal from western states, like Montana and Wyoming, has a lower percentage of sulfur impurities than coal found in the eastern United States. How would burning low-sulfur coal decrease rainfall acidity? Use specific information about gases and acids to answer this question.

4. High temperatures in the automobile engines cause nitrogen and oxygen gases from the air to react and form nitrogen oxides. What two acids in acid rain result from the nitrogen oxides found in automobile exhaust?

5. Which gas and resulting acid in this experiment would cause rainfall in *unpolluted* air to have a pH value less than 7 (sometimes as low as 5.6)?

6. Why would acidity levels usually be lower (pH higher) in actual rainfall than the acidity levels you recorded in this experiment? Rainfall in the United States generally has a pH between 4.5 and 6.0.

Name ____________________ Class _____________ Date _________

Activity GS14: Acceleration Due to Gravity (Motion Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Linear motion	GS14 Gravity.ds	G14 Gravity	G14_GRAV.SWS

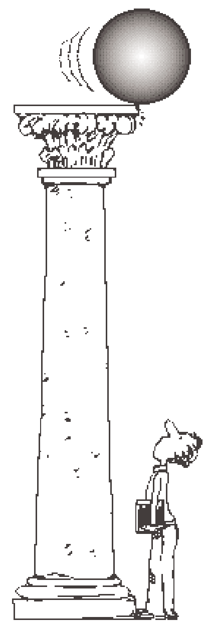
Equipment Needed	Qty	Other	Qty
Motion Sensor (CI-6742)	1	Ball, rubber	1
Base and Support Rod (ME-9355)	1	*Level (optional)*	1
Meter stick	1		

What Do You Think?

How can a Motion Sensor be used to measure the acceleration due to gravity of a falling object?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



Over twenty-two centuries ago, a Greek philosopher and scientist named Aristotle proposed that there is a natural force that causes heavy objects to fall toward the center of Earth. He called this force "gravity". In the seventeenth century, the English scientist Isaac Newton was able to show that gravity is a universal force that extends beyond Earth. It is the force that causes the moon to orbit the Earth and the Earth to orbit the Sun.

When an object is in "free fall", it means that the only force acting on it is the force of gravity. As an object falls freely, it accelerates. For a falling object near the surface of Earth, the rate of change of velocity is a constant value. This value is the acceleration due to gravity. If you ignore air resistance, a falling ball accelerates as if it is in free fall. You can measure the motion of the falling ball to find the value of the acceleration due to gravity.

SAFETY REMINDER.

- Follow directions for using the equipment.

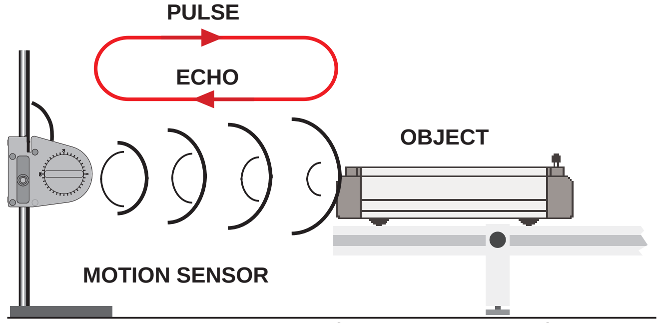
THINK SAFETY
ACT SAFELY
BE SAFE!

For You To Do

Use the Motion Sensor to measure the motion of a ball as it falls and bounces. Use *DataStudio* or *ScienceWorkshop* to record and display the position and velocity of the ball. Examine the slope of the line on a velocity versus time graph to find the acceleration of the ball.

About the Motion Sensor

The Motion Sensor sends out pulses of ultrasound and picks up the echoes of ultrasound that bounce back from objects in front of it.

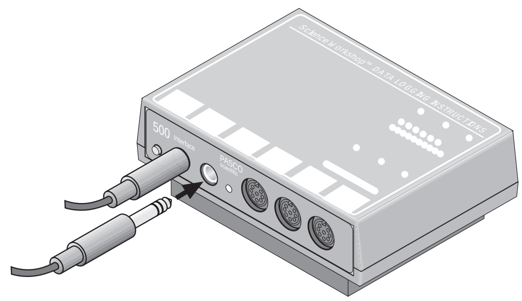


The software program keeps track of the time when the pulses go out and the time when the echoes come back. One-half of the round trip time is the time that it took for the ultrasound to reach the object. Since ultrasound travels at the speed of sound, or about 344 meters per second (or about 700 miles per hour), the program figures out how far away the object is as follows:

$$\textbf{distance to object} = \frac{\textbf{round - trip time}}{\textbf{2}} \times \textbf{speed of sound}$$

The speed of sound through air depends on several factors, including the temperature of the air. Because the temperature of air can change, the speed of sound can change. You can calibrate the Motion Sensor so it uses an accurate measurement of the speed of sound.

PART I: Computer Setup



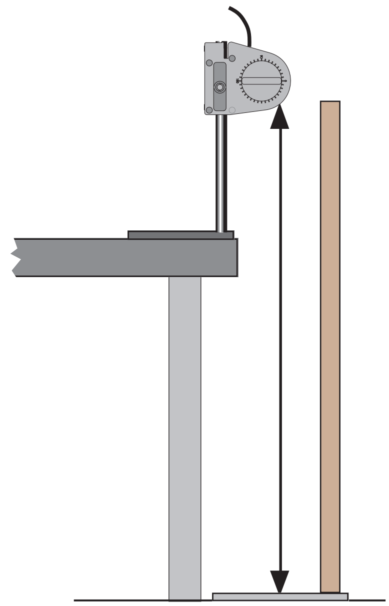
1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Plug the modular connector on one end of the interface cable into the side of the Motion Sensor. Connect the stereo phone plugs of the Motion Sensor to Digital Channels 1 and 2 on the interface. Connect the yellow plug to Digital Channel 1 and the other plug to Digital Channel 2.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS14 Gravity.ds	G14 Gravity	G14_GRAV.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorksho*p document has a Graph display of Position and Velocity versus Time.
- The Trigger Rate for the Motion Sensor is 60 times per second (60 Hz).

PART II: Sensor Calibration and Equipment Setup

Sensor Calibration



- Calibrate the Motion Sensor so it can use an accurate measurement of the speed of sound in air. You will need a meter stick and a flat surface that can be used as a target to reflect the pulses from the Motion Sensor.

Set Up the Sensor

1. Place the Motion Sensor so it is exactly one meter away from a flat surface that can reflect the pulses from the Motion Sensor. Set the range select switch on top of the sensor to ‘Far’.

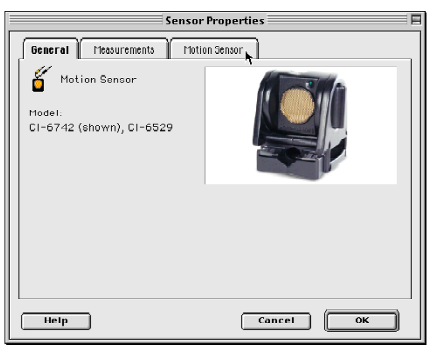
- For example, put the Motion Sensor on a support rod near the edge of a table. Aim the Motion Sensor so it sends pulses down to the floor. If the floor has a rug or carpet on it, put a flat, smooth piece of wood or some other flat surface on the floor directly below the Motion Sensor.

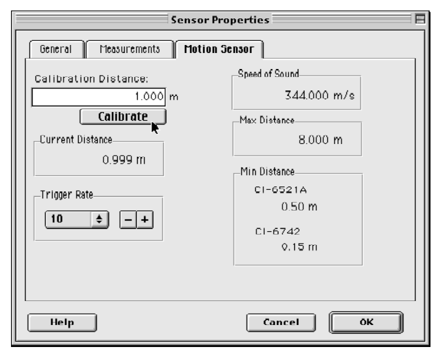
(• NOTE: Remove the meter stick after you use it to measure the distance from the Motion Sensor to the reflector.)

Calibrate the Software

2. In the Experiment Setup window, double-click the sensor’s icon.

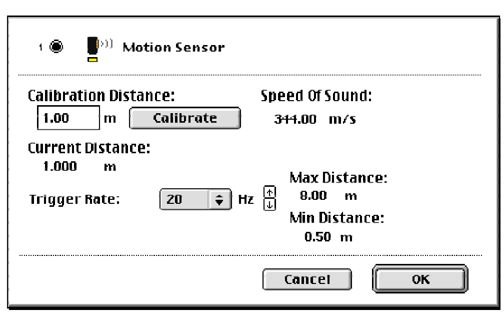
- **Result**: In *DataStudio*, the Sensor Properties window opens.





Click the ‘Motion Sensor’ tab. **Result**: The calibration window opens and the sensor begins to click a few times per second.

- **Result**: In *ScienceWorkshop*, the sensor’s calibration window opens and the sensor begins to click a few times per second.

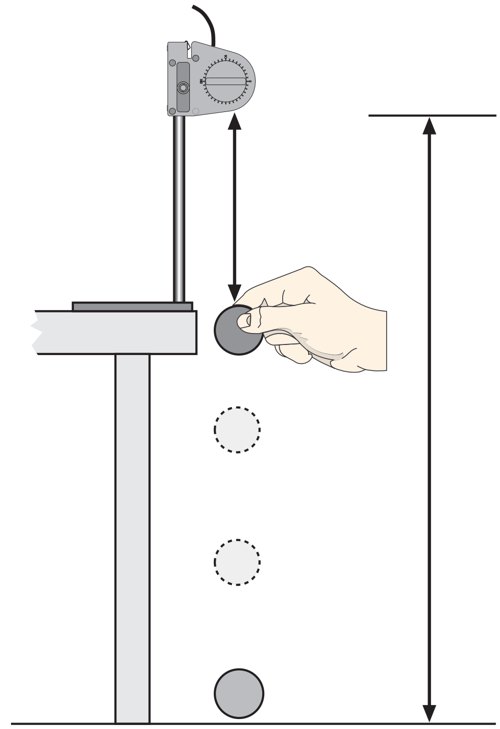


3. Calibrate the software.

- **First**, make sure that the sensor is one meter from the target.
- **Second**, click the 'Calibrate' button in the Motion Sensor window. **Result**: The software calculates the speed of sound based on the calibration distance (one meter) and the round trip time of the pulse and echo

4. Click 'OK' to return to the Experiment Setup window.

Equipment Setup



- Make sure that the floor is level. If it is not, put a hard flat surface on the floor and put pieces of paper or shims under the edges of the hard flat surface to level it.

1. Put a base and support rod near the edge of a table. Mount the Motion Sensor on the support rod so the Motion Sensor is aimed downward at the floor.
2. Adjust the position of the Motion Sensor on the support rod so that there is about 1.5 meters between the Motion Sensor and the floor.

PART III: Data Recording

1. Prepare to drop the ball so it falls straight down beneath the Motion Sensor. Hold the ball between your finger and thumb under the Motion Sensor no closer than 15 cm (about 6 inches) below the Motion Sensor.
2. Start recording data. (Hint: In *DataStudio*, click 'Start'. In *ScienceWorkshop*, click 'REC'.) Drop the ball. Let the ball bounce several times.

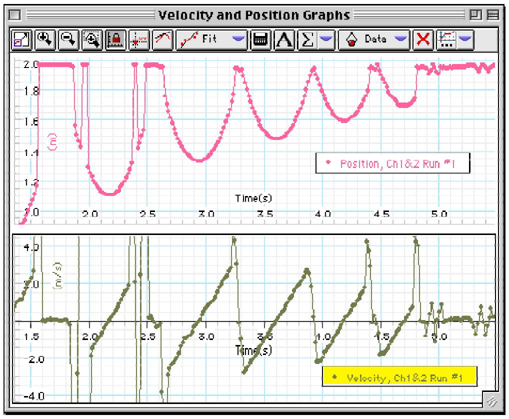
- NOTE: Be sure to move your hand out of the way as soon as you release the ball.

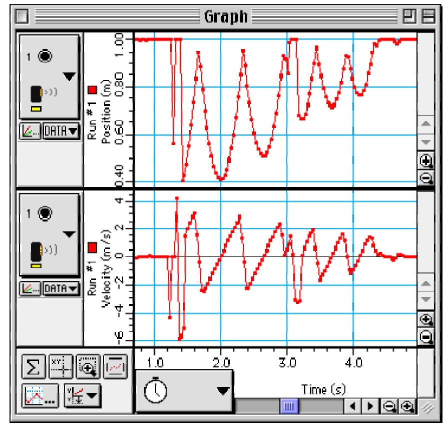
3. After the ball bounces several times on the floor, stop recording data.

Name ____________________ Class _____________ Date _________

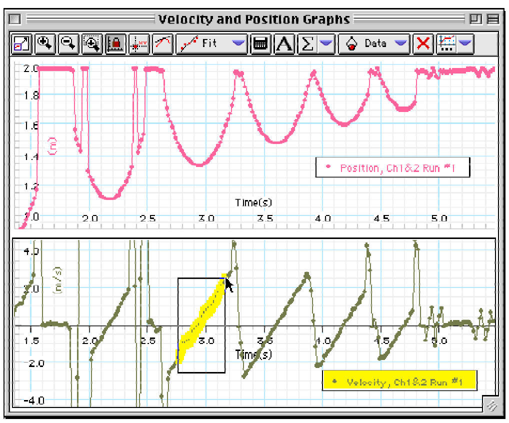
Analyzing the Data

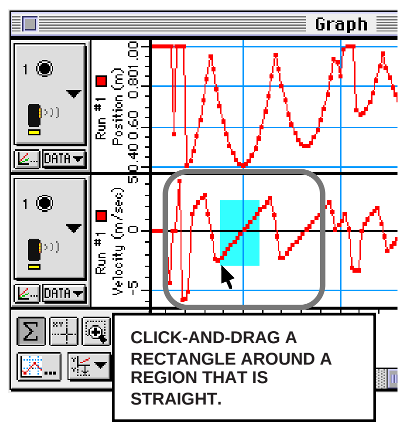
- The position plot of the Graph shows a “mirror image” of a ball bouncing on a flat surface. The velocity plot shows a “sawtooth” pattern. Notice in the velocity plot that the velocity of the ball is positive part of the time and negative part of the time. The Motion Sensor records motion away from it as positive and motion towards it as negative.



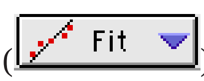


1. In the plot of Velocity versus Time, use the cursor to click-and-draw a rectangle around a region that is relatively straight.





2. Use the Graph display’s built-in analysis tools to determine the slope of the region you selected.

- Hint: In *DataStudio*, select ‘Linear’ from the ‘Fit’ menu (
).

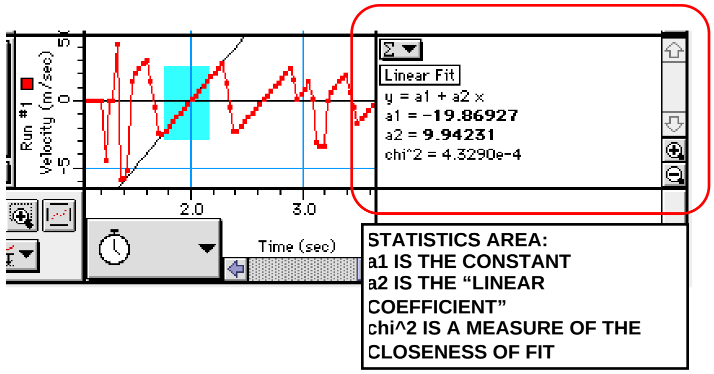
- Hint: In *ScienceWorkshop*, click the ‘Statistics’ button () to open the statistics area. Select ‘Curve Fit, Linear Fit’ from the ‘Statistics Menu’ ().

3. Record the value of the slope in the Data Table. This is the value for the acceleration due to gravity on the falling object.

• Hint: In *DataStudio*, the slope appears in the ‘Fit’ window.

• Hint: In *ScienceWorkshop*, the Statistics area shows the general formula for a line (y = a1 + a2 x), the constant a1, and the linear coefficient a2. The linear coefficient is the slope of the line.

Linear Fit	
m (Slope)	9.7239
b (Y Intercept)	-28.5941
r	0.9976
Standard Deviation m	0.1379
Standard Deviation b	0.4109



Ending the Activity

Equipment Clean Up

• Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select ‘Quit’ from the ‘File’ menu to end the activity.

2. You can select ‘Save’ or ‘Save As…’ from the File menu to save your data for this activity. the changes you’ve made to the document.

• The original document is “locked”, so you should give <u>your</u> document a new filename.

3. If you wish to go on to the next activity, select ‘Open…’ from the ‘File’ menu, and find the document for the next activity.

Record your results in the Lab Report section.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS14: Acceleration Due to Gravity

What Do You Think?

How can a Motion Sensor be used to measure the acceleration due to gravity of a falling object?

Data Table

'g' (slope of velocity versus time) = _________

Questions

1. How does your value for 'g' (slope of velocity versus time) compare to the accepted value of the acceleration of a free falling object (9.8 m/s^2)?

- Reminder: percent difference = $\left|\frac{accepted\ value - experimental\ value}{accepted\ value}\right| x100\%$

2. What factors do you think may cause the experimental value to be different from the accepted value?

Name ______________________ Class _______________ Date __________

Activity GS15: Oxygen Content of Air
(Pressure Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Gas laws	C12 Partial Pressure.DS	C12 Dalton's Law	C12_DALT.SWS

Equipment Needed	**Qty**	**Chemicals and Consumables**	**Qty**
Pressure Sensor (CI-6532A)	1	Calcium hydroxide solution	15 mL
Bottle (or flask), 250 mL	1	Candle	1
Connector, rubber stopper (w/sensor)	1	Clay, modeling	10 g
Graduated cylinder	1	Matches	1 bk
Rubber stopper, one-hole	1	Tape	1 roll
Tubing, plastic (w/sensor)	1		
Protective gear	PS		

(*SAFETY CAUTION! Be very careful around any flame!)

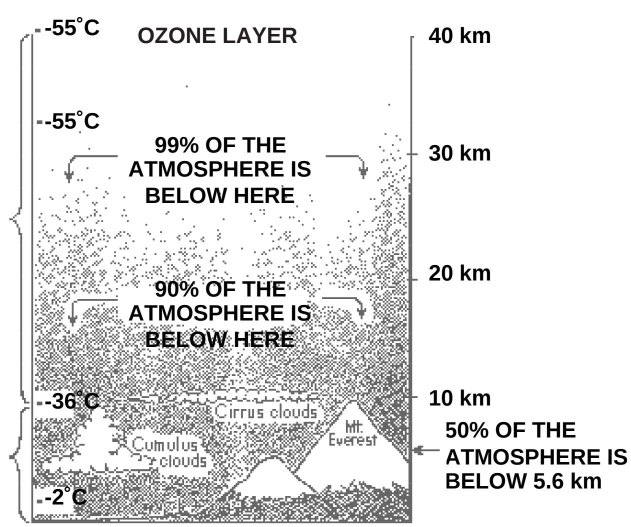
What Do You Think?

The purpose of this activity is to use Dalton's Law of Partial Pressure for a gas to determine the approximate percentage of oxygen and nitrogen in the air. What do you think is the approximate percentage of oxygen in the air?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

The Earth's atmosphere is a complex multi-layered blanket of air that surrounds our planet. Most of the air is concentrated in the lowest levels of the atmosphere. For example, over ninety percent of the mass of the atmosphere is in the bottom twenty kilometers (about twelve miles) of the atmosphere.



The air is made up of different gasses such as oxygen, nitrogen, and water vapor. There are several other gases in the atmosphere but they make up a very minor amount of the air.

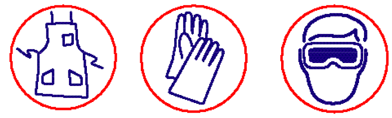
Dalton's Law of Partial Pressure states that the total pressure of a gas is equal to the sum of each of the individual gases' pressures at a specific temperature.

The sum of all the partial pressures of the gases that make up the atmosphere gives the total pressure of the atmosphere. The average pressure of the atmosphere is 101,000 pascals where 1 pascal is 1 newton per square meter. This translates to about 14.7 pounds per square inch. Most of the total pressure is due to the nitrogen in the air. The second most common gas in the atmosphere is oxygen. The other gases such as water vapor, carbon dioxide, argon, helium and xenon add very little to the overall pressure of the atmosphere.

Remove the oxygen in the atmospheric mixture in order to determine the amount of nitrogen in the atmosphere.

Caution! Be careful with matches and be careful with the burning candle.

SAFETY REMINDERS

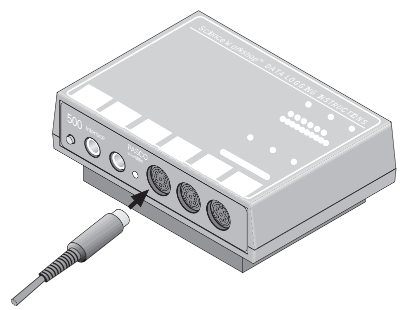


- Wear protective gear.
- Follow directions for using the equipment.
- Handle and dispose of all chemicals and solutions properly.

For You To Do

A burning candle consumes oxygen. If the candle burns in a closed container and you use a chemical to remove the carbon dioxide produced, the pressure in the container should decrease due to the removal of oxygen. The remainder of the partial pressure will be assumed to be due to nitrogen.

Use the Pressure Sensor to measure the change in pressure as a candle burns inside a container. Use calcium hydroxide to absorb carbon dioxide gas released during combustion. Use *DataStudio* or *ScienceWorkshop* to record and display the data. Use your data to determine the approximate percentage of oxygen in air.



PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Pressure Sensor to Analog Channel A on the interface.
3. Open the file titled as shown;

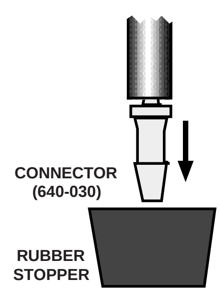
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
C12 Partial Pressure.DS	C12 Dalton's Law	C12_DALT.SWS

- The *DataStudio* file has a Graph display. Read the Workbook display for more information.
- The *ScienceWorkshop* document has a Graph display with a plot of the pressure versus time.
- Data recording is set at two measurements per second (2 Hz).

PART II: Sensor Calibration and Equipment Setup

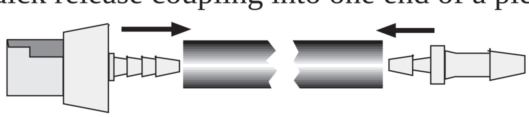
You do not need to calibrate the sensor.

Set Up the Equipment

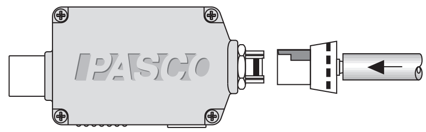


- For this part you will need the following: glycerin, quick-release coupling, connector, plastic tubing, one-hole rubber stopper, Pressure Sensor, clay, straw, tape, candle.

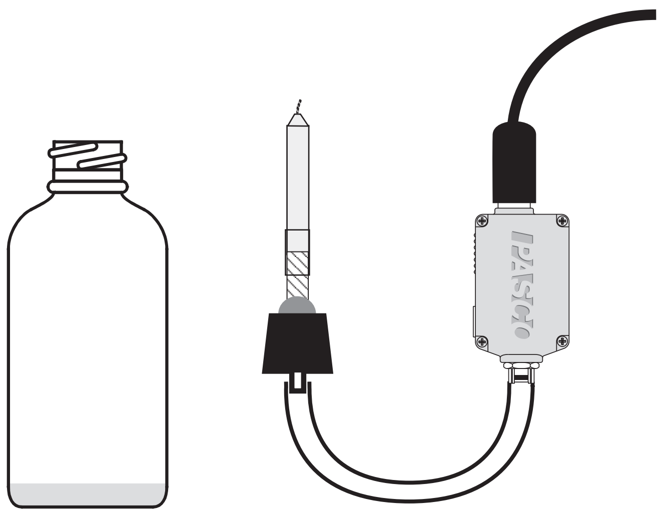
1. Put a drop of glycerin on the barb end of a quick release coupling. Put the end of the quick release coupling into one end of a piece of plastic tubing (about 15 cm) that comes with the Pressure Sensor.



2. Put a drop of glycerin on the barb end of the connector. Push the barb end of the connector into the other end of the plastic tubing.
3. Fit the end of the connector into the hole in the rubber stopper.
4. Align the quick-release coupling on the end of the plastic tubing with the pressure port of the Pressure Sensor. Push the coupling onto the port, and then turn the coupling clockwise until it clicks (about one-eighth turn).



5. Use a piece of clay to attach the candle to bottom of the rubber stopper. (Note: Do not let the clay cover the hole.) Make sure that when the rubber stopper is put into the bottle (or flask), the tip of the candle is at least halfway into the bottle. (Note: Use a straw and tape to extend the distance of the candle into the bottle if needed.)



Set Up the Bottle

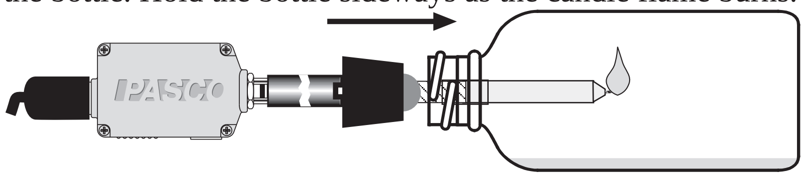
6. Put 15 mL of saturated calcium hydroxide solution into the bottle.

- When you are ready to record data you will hold the bottle sideways. Then you will light the candle and put the candle/rubber stopper into the bottle.

PART III: Data Recording

1. When you are ready, light the candle. Start recording data. (Hint: Click ‘Start’ in *DataStudio* or click ‘REC’ in *ScienceWorkshop*.)

2. Tilt the bottle sideways. Insert the burning candle and then CAREFULLY but quickly force the rubber stopper into the top of the bottle. Be sure there is a tight seal between the rubber stopper and the bottle. Hold the bottle sideways as the candle flame burns.



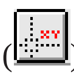
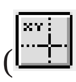
3. When the candle flame is completely extinguished, stop recording data.

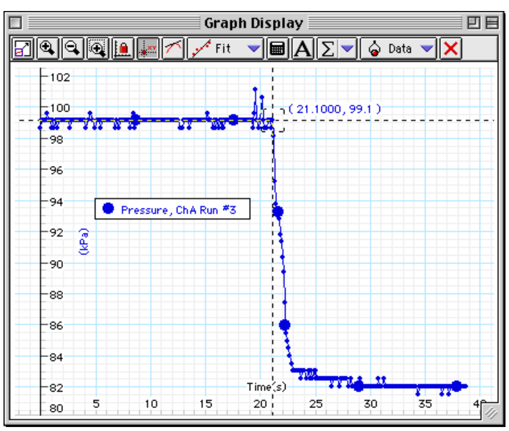
4. Remove the candle/rubber stopper from the bottle. Fill the bottle with water to rinse out the products of combustion.

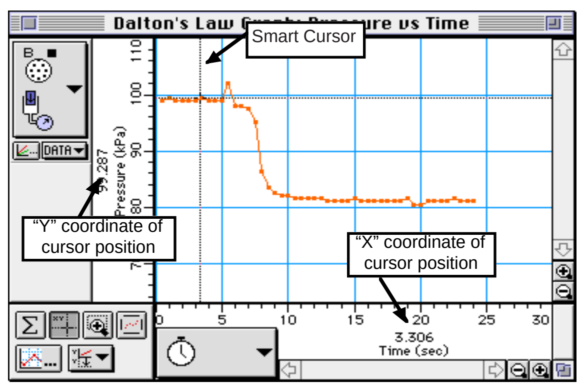
5. Dispose of the water as instructed.

Analyzing the Data

1. Use the Graph display to find the initial pressure inside the bottle and the final pressure after the candle flame went out.

- (Hint: Use the ‘Smart Tool’ () in *DataStudio* or the ‘Smart Cursor’ () in *ScienceWorkshop*.)





2. Record the initial and final pressures in the Lab Report section.

Record your results in the Lab Report section.

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Lab Report - Activity GS15: Oxygen Content of Air

What Do You Think?

The purpose of this activity is to use Dalton's Law of Partial Pressure for a gas to determine the approximate percentage of oxygen and nitrogen in the air. What do you think is the approximate percentage of oxygen in the air?

Data Table

Data	Measurement	Value
1	Starting pressure (O_2 + N_2)	kPa
2	Ending pressure (N_2 alone)	kPa
3	Change in pressure (O_2 alone)	kPa
4	Percentage of O_2 in air (Data 3 ÷ Data 1)	
5	Percentage of N_2 in air (Data 2 ÷ Data 1)	

Questions

1. How does your calculated value for the percentage of oxygen in air compare to the accepted value?

2. How does your calculated value for the percentage of nitrogen in air compare to the accepted value?

3. What are possible sources for error in this experiment?

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

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Activity GS16: Insolation – Solar Radiation
(Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Energy	GS16 Insolation.DS	G16 Insolation	G16_SUN.SWS

Equipment Needed	Qty	Chemicals and Consumables	Qty
Temperature Sensor (CI-6505A)	1	Cardboard, 15 by 15 cm	1
Clock	1	Ice, cube	2 – 3
Cup	1	Paper towel	1
Lamp (optional), 100 or 150 W	1	Straw	1
Protractor (for measuring angles)	1	Tape	1 roll
		Water	100 mL

This activity can be done outdoors on a sunny day. The best time is at noon.

What Do You Think?

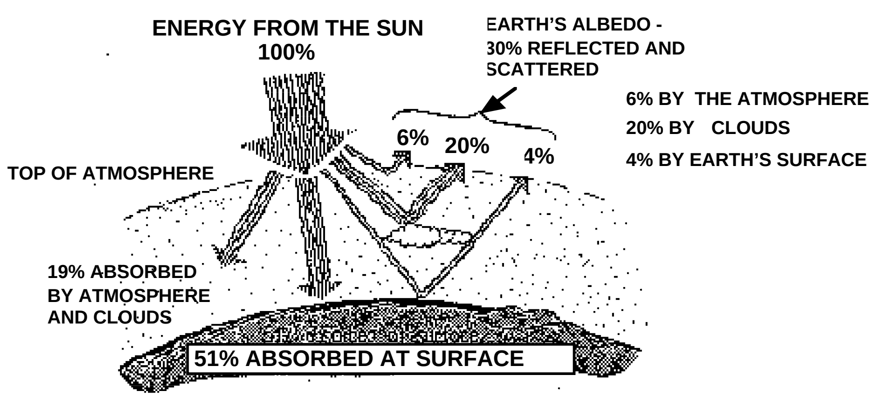
Skin doctors warn us that over exposure to the radiation from the sun is harmful to our skin and can possibly lead to skin cancer. What time of the day are the sun’s rays most absorbed by our skin? What do you think? Is there a relation to the amount of radiation absorbed and the angle at which the sun’s rays strike the skin?

Take time to answer the ‘What Do You Think?’ question(s) in the Lab Report section.

Background

The Sun accounts for 99.9% of the energy that Earth gets at its surface. (Heat moving upward from Earth’s core makes up the small remainder). **Insolation** is solar radiation, or energy received from the Sun. Insolation is made up of **ultraviolet** and visible light and **infrared** solar radiation.

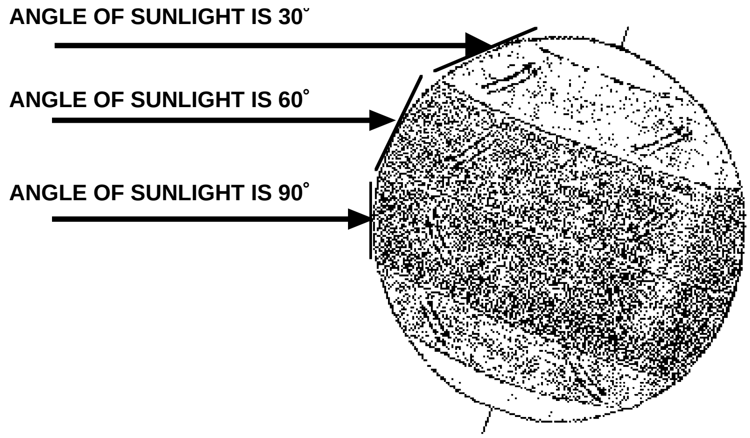
The amount of energy that the entire Earth receives from the Sun remains fairly constant from year to year, but the amount of energy that a particular spot on Earth receives may change a great deal from day to day. One thing that makes a difference is the angle of the sunlight that hits the Earth’s surface.



If the angle at which the sunlight hits the Earth’s surface is almost vertical (90˚), the amount of energy that is soaked up by a square meter of area at that part of the Earth’s surface is a maximum. If the sunlight hits the Earth’s surface at a smaller angle than ninety degrees, the amount of energy that is soaked up by a square meter of area is less.

At higher latitudes on the Earth’s surface, the angle can be very small, so the amount of energy that is soaked up can also be very small.

If three surfaces of equal area start with the same temperature and are exposed to sunlight for the same amount of time, but the three surfaces are at different angles to the sunlight, the change in temperature for each surface should also be different.



(The amount of solar radiation, or insolation, received by the Earth is enormous. The amount of energy received each second over each square meter of area that is at right angles (90˚) to the Sun's rays at the top of the atmosphere is 1400 joules. In power units, this is 1400 watts per square meter, or 1.4 kilowatts per square meter.)

SAFETY REMINDERS

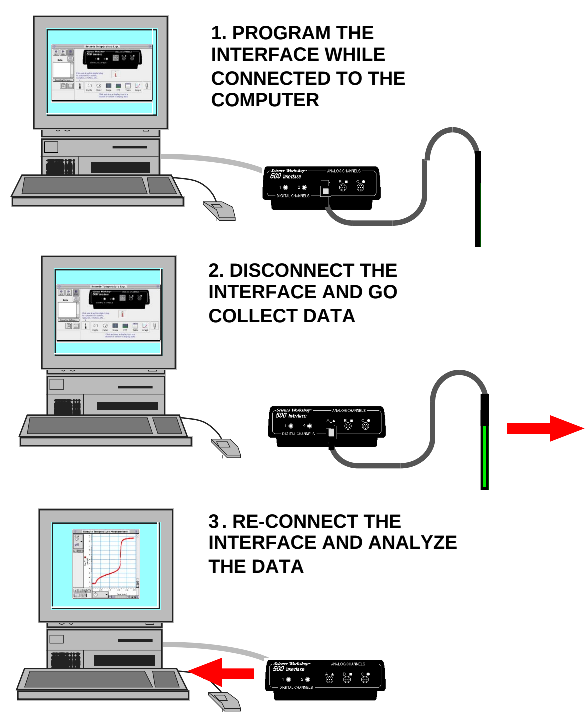
THINK SAFETY
ACT SAFELY
BE SAFE!

- Protect your eyes and skin from direct sunlight.
- Follow directions for using the equipment.
- If you do this activity using a lamp, be careful not to tough it when it gets hot.

For You To Do

In this activity, measure the amount of energy from the sun's rays as it strikes a piece of paper at different angles. Use a temperature sensor to measure the temperature of the paper and compare data of angle of incidence and temperature. Use *DataStudio* or *ScienceWorkshop* to record and display your data.

NOTE: One option for this activity is to use the *ScienceWorkshop 500 Interface* out-of-doors. The *ScienceWorkshop 500 Interface* can be programmed to record data, and then disconnected from the computer. You can carry it outdoors, record the data, and then re-connect it to the computer to analyze the data.



This procedure will describe how to use the *Science Workshop 500 Interface* and the Temperature Sensor to measure the insolation (solar radiation) outdoors. The last section of this activity will describe how to record data using a lamp as a simulation of the Sun.

In this activity the Temperature Sensor measures the temperature at the surface of a piece of cardboard that is exposed to solar radiation (sunlight) at three different angles.

You will use the protractor and straw to measure the angle that the sunlight makes with the piece of cardboard.

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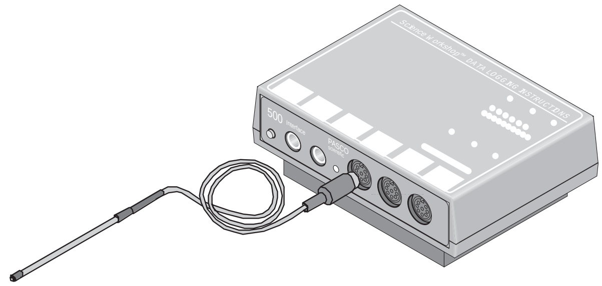
The *Science Workshop 500 Interface* records the temperature data. The program downloads the data from the interface and then displays the data for analysis.

PART I: Computer Setup



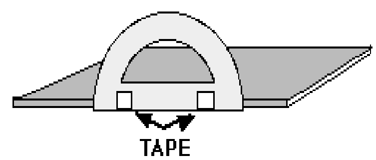
1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Temperature Sensor into Analog Channel A on the interface.
3. Open the file titled as shown;

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS16 Insolation.DS	G16 Insolation	G16_SUN.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The ScienceWorkshop document has a Graph display of Temperature versus Time.
- Data recording is set at 1 sec (or one measurement per second).

PART II: Sensor Calibration and Equipment Setup

- You do not need to calibrate the Temperature Sensor.



1. Use a piece of cardboard that is approximately square and about 15 x 15 cm (or 6 x 6 inches). Tape the protractor at the center of one edge of the piece of cardboard so the protractor is at right angles to the piece of cardboard.
2. Put some ice and water into the cup.

- You will use the ice water to cool the tip of the Temperature Sensor before each trial of data recording.

PART III: Data Recording

NOTE: Data recording for this activity has several steps:

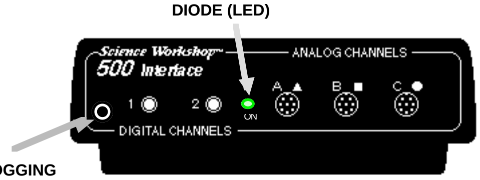
- The first step in data recording is to get the interface ready to make measurements and disconnect it from the computer.
- The second step in data recording is to line up the Temperature Sensor and cardboard with the sunlight.
- The third step in data recording is to make measurements of the change in temperature for three different angles of sunlight. You will do this by lining up the cardboard at 90˚, 60˚, and 30˚ to the sunlight.
- The final step in data recording is to reconnect the interface to the computer.

Prepare the Interface

- Make sure that there are four AA alkaline batteries in the interface battery compartment.
- Make sure that the POWER switch on the back panel of the interface is **ON**.

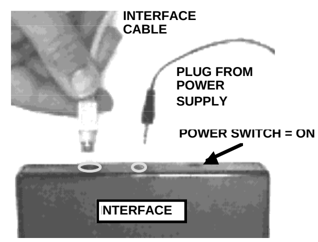
1. Click the **Experiment** menu in the menu bar. Select **Disconnect for Logging…** from the **Experiment** menu.

- The Data Logging Setup window will open. If your computer is connected to a printer, click **Print Checklist**.



2. Click **Begin Logging**.

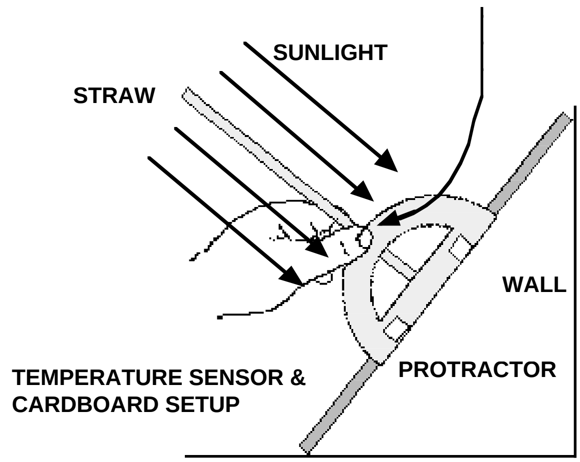
- The interface goes into "sleep" mode. The green light-emitting diode (LED) on the front panel of the interface will go out, and then will blink once every five seconds.



3. Disconnect the interface from the computer. Unplug the power cord and the interface cable from the back of the interface box.
4. Take the interface with Temperature Sensor, a straw, the cup of ice water, tape, paper towels, the clock, and the protractor/cardboard setup outside. Find an open area next to a sunny, south-facing wall.

√ Line Up the Temperature Sensor

1. Place the protractor/cardboard setup at the base of the wall so that the cardboard is at about right angles to the sunlight.

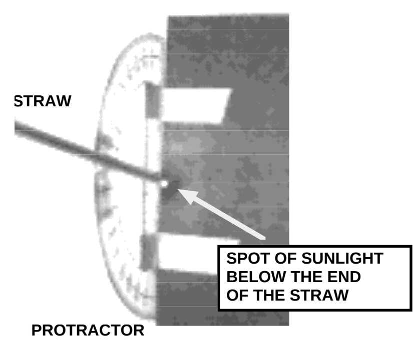


2. Hold the straw against the side of the protractor. Put the end of the straw next to the center line of the protractor.

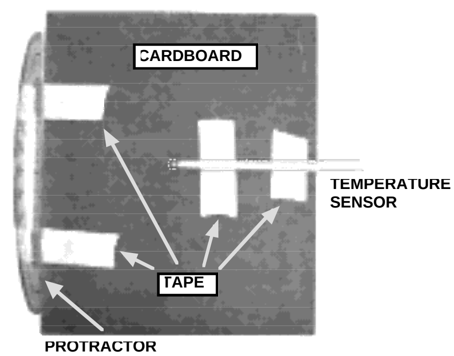
- Keep a small gap between the end of the straw and the cardboard. Line up the straw with the 90 degree mark along the curved edge of the protractor. Use a piece of tape to help hold the straw in place.

3. Adjust the protractor/cardboard setup up or down along the wall until the straw makes no shadow and is directly in line with the sunlight.

- When the straw is directly in line with the sunlight, a spot of sunlight shows up on the cardboard below the end of the straw.



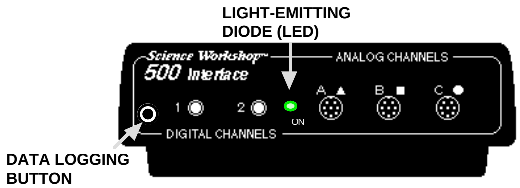
4. Put pieces of tape at the top and bottom edges of the cardboard to temporarily hold it in place against the wall.
5. Put the end of the Temperature Sensor into the cup of ice water for about ten seconds to cool it down. Remove the Temperature Sensor and dry it off.
6. CAREFULLY tape the Temperature Sensor onto the cardboard so the tip of the sensor is about in the center of the piece of cardboard. (See the diagram.)



7. Get the clock ready to keep track of the time. You will record data for ten minutes for each angle.

√ Record the Data

1. When you are ready to record data, press the Data Logging button on the front panel of the interface to "wake up" the interface.



- The green LED on the interface will blink once per second for ten seconds as the interface wakes up.

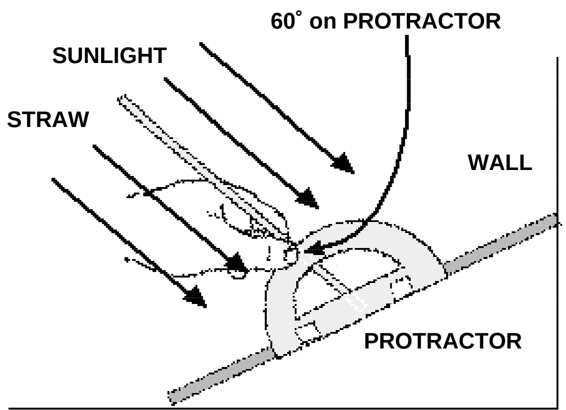
Get ready to record the time on the clock when the LED begins to blink rapidly.

- The green LED will blink rapidly (several times per second) when the interface starts to record data.

2. Record the starting time for data recording. Let the interface record data for ten minutes.
3. At the end of ten minutes, press and hold the Data Logging button until the LED goes out to stop recording data.

- The green LED will blink once every five seconds. The interface is in "sleep" mode.

4. Remove the Temperature Sensor from the protractor/cardboard setup.
5. Remove the tape from the straw. Move the straw so the end of the straw is next to the center line of the protractor, but the straw is lined up with 60˚ on the curved edge of the protractor. Re-attach the tape to the straw to hold the straw in place.



6. Remove the tape from the top and bottom edges of the cardboard. Adjust the cardboard until the straw makes no shadow and a spot of sunlight shines through the straw onto the cardboard. Re-attach the tape to hold the cardboard in place.
7. Put the Temperature Sensor into the ice water for about ten seconds to cool it down. Remove the sensor and dry it off.
8. CAREFULLY tape the Temperature Sensor back into position on the cardboard.
9. Get ready to record data for ten minutes.
10. Press the Data Logging button to "wake up" the interface.

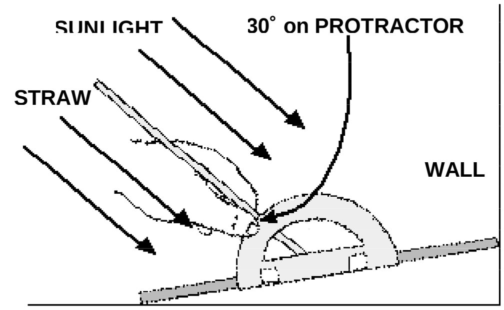
- The green LED will blink once per second for ten seconds as the interface "wakes up".

11. Data recording begins when the LED starts blinking rapidly. Let the interface record for ten minutes.
12. At the end of ten minutes, press and hold the Data Logging button until the LED goes out to stop data recording.

- The green LED will blink once every five seconds. The interface is in "sleep" mode.

13. Remove the Temperature Sensor from the protractor/cardboard setup.

14. Remove the tape from the straw. Move the straw so the end of the straw is next to the center line of the protractor, but the straw is lined up with 30˚ on the curved edge of the protractor. Re-attach the tape to the straw to hold the straw in place.



15. Remove the tape from the top and bottom edges of the cardboard. Adjust the cardboard until the straw makes no shadow and a spot of sunlight shines through the straw onto the cardboard. Re-attach the tape to the wall to hold the cardboard in place.
16. Put the Temperature Sensor into the ice water for about ten seconds to cool it down. Remove the sensor and dry it off.
17. CAREFULLY tape the Temperature Sensor back into position on the cardboard.
18. Get ready to record data for ten minutes.
19. Press the Data Logging button to "wake up" the interface.

- The green LED will blink once per second for ten seconds as the interface "wakes up".

20. Data recording begins when the LED starts blinking rapidly. Let the interface record for ten minutes.
21. At the end of ten minutes, press and hold the Data Logging button until the LED goes out to stop data recording.

- The green LED will blink once every five seconds. The interface is in "sleep" mode.

22. Take the interface and the rest of your equipment indoors.

√ **Re-connect the Interface**

1. Plug the interface cable and the power cord into the back panel on the interface.

NOTE: The LED will continue to blink once every five seconds.

2. Download the data from the interface box to your computer.

- In the program, select **Connect To Interface** from the **Experiment** menu.
- The green LED will stay ON.

Analyzing the Data

1. Set up you Graph display to show Statistics for the Minimum and Maximum values of temperature.

- Hint: In *DataStudio*, click the Statistics Menu button. In *ScienceWorkshop*, click the Statistics button to open the Statistics area on the right side of the Graph. Then click the Statistics Menu button.

2. Record the Minimum y as the Initial Temperature for Run #1. Record the Maximum y as the Final Temperature for Run #1.
3. Repeat the procedure to find the initial and final temperatures for Run #2.
4. Repeat the procedure to find the initial and final temperatures for Run #3.
5. Calculate the Change in Temperature for each run by subtracting the initial temperature from the final temperature.

Record your results in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give <u>your</u> document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

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Lab Report - Activity GS16: Insolation – Solar Radiation

What Do You Think?

Skin doctors warn us that over exposure to the radiation from the sun is harmful to our skin and can possibly lead to skin cancer. What time of the day are the sun's rays most absorbed by our skin? What is the relationship between the amount of radiation absorbed and the angle at which the sun's rays strike the skin?

Data Table

The data for this activity are dependent on the location, time of year, weather conditions, etc. The following are typical changes in temperature for each angle:

Angle	Initial Temp.	Final Temp.	Change in Temp.
90˚			
60˚			
30˚			

Questions

1. Which angle exposed the cardboard to the MOST solar radiation?

2. Which angle exposed the cardboard to the LEAST solar radiation?

3. Which angle best represents the Earth in the summer?

4. Which angle best represents the Earth in the winter?

Ending the Activity

- Check with your instructor about putting away the equipment for this activity.

Alternate Method

- If you cannot go outdoors to record data, use a 100-watt or 150 watt lamp as a substitute for the Sun.

1. Place the protractor/cardboard setup 25 cm (or about 10 inches) from the lamp.
2. Do not select **Disconnect for Logging…** from the **Experiment** menu.
3. Record and analyze data as described before.

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Activity GS17: Half-Life of a Radioactive Substance (Nuclear Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Radioactivity	GS17 Half-Life.DS	G17 Half-Life	G17_HALF.SWS

Equipment Needed	Qty	Equipment Needed	Qty
Nuclear Sensor (SN-7927)	1	Graduated cylinder	1
Base and Support Rod (ME-9355)	2	Watch glass	1
Beaker, 50 mL	1	Protective gear	PS
Clamp, buret (SE-9446)	1	**Other Equipment and Consumables**	**Qty**
Clamp, right angle (SE-9444)	1	**Isogenerator (SE-7995)**	1
Clamp, three-finger (SE-9445)	1	Water, de-ionized or distilled	10 mL

What Do You Think?

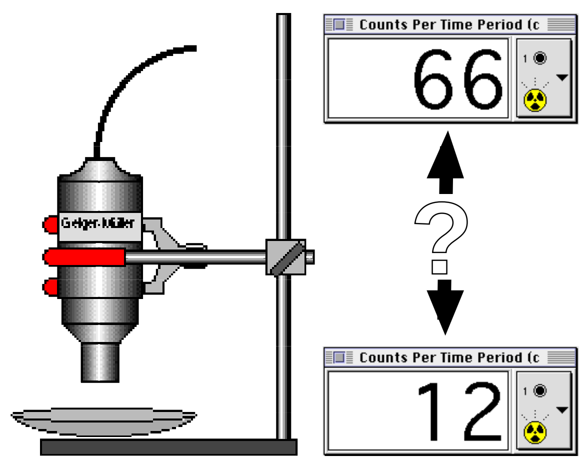
The purpose of this activity is to determine the **half-life** of a **radioactive** substance. How can you use a nuclear sensor (like a Geiger-Müller tube) to determine the half-life of a substance?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

Radioactive substances randomly give off high-energy bits of matter and high-intensity bits of energy. **Alpha** particles and **beta** particles are examples of the high-energy bits of matter. **Gamma rays** are high-intensity bits of energy. Nuclear sensors such as Geiger-Müller tubes can detect these forms of radioactivity. Each detected bit of radioactivity is called an "event". The number of events can be counted over a period of time to get an idea of how radioactive one substance is relative to another.

The **half-life** of a radioactive substance is the time required for the number of "counts" from a radioactive substance to go down to half of its original value. For example, if the original number of counts is 70, the half-life is the time it takes for the number of counts to become 35.



All radioactive substances have count rates which decrease toward zero counts per time period. Eventually, even the most dangerous radioactive substance becomes safe. This might take only minutes, or it could take thousands or even millions of years, depending on the kind of substance involved.

Think about popping popcorn. The number of kernels of popcorn that pop is fairly constant as the corn starts to pop, but soon the popping decreases until just a few kernels explode per second. For popcorn, the same **fraction** of **un-popped** kernels will pop during each time period. For example, let's assume that one half of the un-popped kernels pop each minute. If you start with 100 kernels, then 50 kernels will pop and 50 kernels will not pop by the end of one minute. In the next minute, half of the un-popped 50 kernels will pop, and half will not, so there are 25 kernels left un-popped, and so on. Fewer kernels per second actually pop but the same fraction of un-popped kernels pop each second. This is similar to the way that radioactive substances give off radioactivity. In each period of time, the same **fraction** of **unchanged** radioactive atoms give off radioactivity and change into different elements. Half-life is the time required for the counts per time period of a radioactive sample to fall to half of its original value.

SAFETY REMINDERS

- Wear protective gear.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

Caution! Do not let radioactive substances get on your skin or into your eyes or mouth. Inform your instructor of any spills or if you come in contact with the radioactive substance.

For You To Do

In the Pre-Lab for this activity, prepare an "isotope generator" (called an isogenerator). This device produces the radioactive substance that you will measure. The Pre-Lab takes about ninety minutes.

In the Procedure for this activity, use the Nuclear Sensor to measure the counts (radioactive "events") from a radioactive substance that has a short half-life. Use *DataStudio* or *ScienceWorkshop* to record and display the data from the Nuclear Sensor.

Use a Graph of counts and time to determine the initial number of counts per time period, and then find the time at which the number of counts is one-half of the inital number. This time is the half-life of the radioactive substance.

Pre-Lab

About the SN-7995 Isogenerator

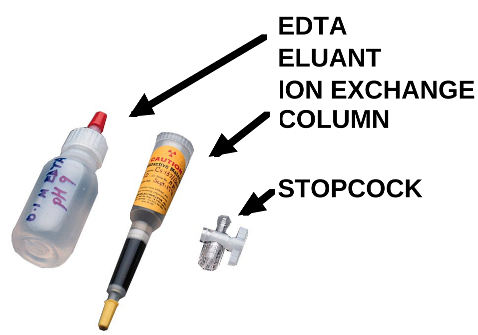
The **isogenerator** (short for "isotope generator") is a device that has a radioactive substance cemented into a porous plug of epoxy. The radioactive substance itself cannot come out of the plug of epoxy. However, the radioactive substance (**Cesium-137**) produces a radioactive by-product (**Barium-137**) that has a short half-life. The Barium-137 can be "flushed" out of the plug of epoxy using a special liquid. You can measure the half-life of the Barium-137 by measuring the counts of radioactivity coming from the liquid.

NOTE: Because the special liquid drains through the isogenerator and picks up the radioactive Barium-137 along the way, the isogenerator is sometimes referred to as a "nuclear cow".

The isogenerator kit includes three parts:

- ion exchange column
- stopcock
- 0.1 Molar EDTA eluant (special liquid) with pH = 9

The ion exchange column is filled with de-ionized water when it is shipped from the factory.

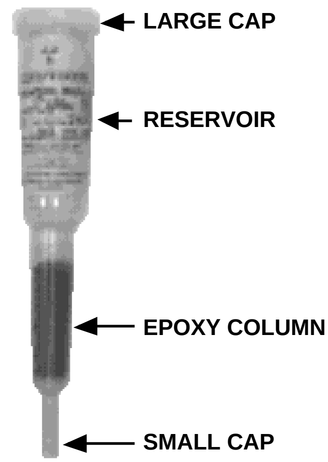


Name ____________________ Class _____________ Date _________

Preparing the Isogenerator

REMINDER: Be sure to wear protective clothing (gloves, apron, goggles) when handling or using the isogenerator or the special liquid after it drains through the isogenerator. Follow all instructions for handling and using the isogenerator.

You will need the following items: isogenerator kit, 50-mLbeaker, base and support rod, buret clamp.



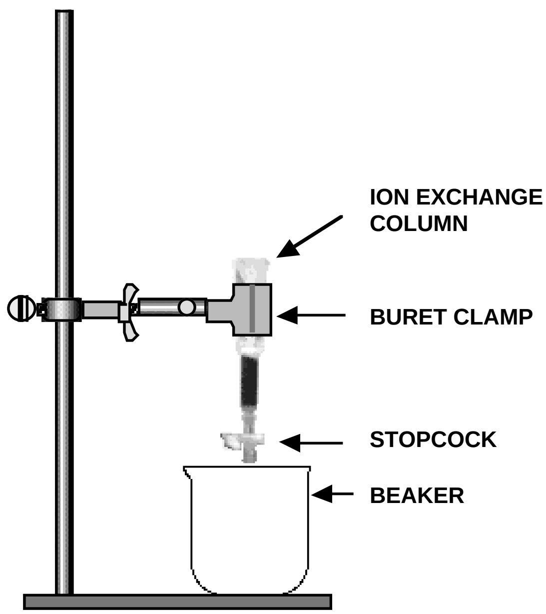
1. Remove the large cap at the top of the reservoir on the ion exchange column. Hold the column upright securely in one hand. Use your thumb to push the large cap upward. Do this slowly so that none of the liquid inside spills out.

- Keep the large cap so you can cover the ion exchange column again when you are done with it.

2. Put a buret clamp on a base and support rod. Put the ion exchange column into the buret clamp. Turn the ion exchange column so you can see the small marks that are on the back of the reservoir.

3. Place the beaker under the small cap at the bottom of the ion exchange column.

4. Carefully remove the small cap from the bottom of the ion exchange column. Let the de-ionized water drain out of the ion exchange column into the beaker.



5. Put the stopcock onto the end of the ion exchange column. Turn the valve on the stopcock so the valve is horizontal and the stopcock is <u>closed</u>.

6. Remove the small cap from the top of the squeeze bottle that contains the EDTA eluant. Fill the ion exchange column with the EDTA eluant to the 5 mL mark on the reservoir of the ion exchange column.

7. Allow the ion exchange column to sit for one hour with the EDTA eluant in it. (This allows more of the Barium-137 to move down the column.)

Computer and Equipment Setup

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface and then turn on the computer.
2. Connect the Nuclear Sensor stereo phone plug to Digital Channel 1.
3. Open the file titled as shown;

DataStudio	*ScienceWorkshop* (Mac	*ScienceWorkshop* (Win)
GS17 Half-Life.DS	G17 Half-Life	G17_HALF.SWS

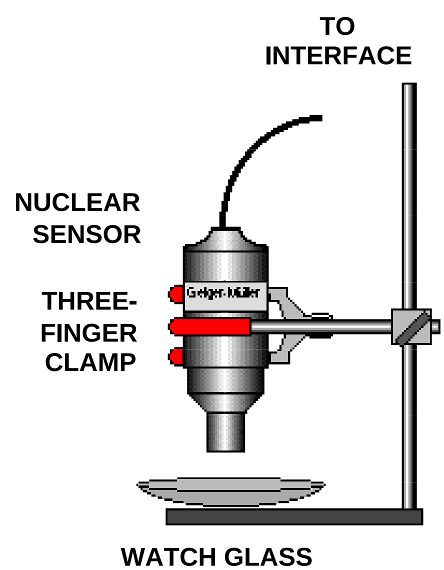
- The document opens with a Digits display and a Graph display of Counts versus Time.
- The *DataStudio* document also has a Workbook display. Read the instructions in the display.
- Data recording is set at one sample per second and will stop automatically at 600 seconds.

PART II: Sensor Calibration and Equipment Setup

- You do not need to calibrate the Nuclear Sensor.

Equipment Setup

1. Put the Nuclear Sensor into a three-finger clamp. Use a right angle clamp to mount the Nuclear Sensor on a base and support rod. Turn the Nuclear Sensor so it is vertical and the Geiger-Müller tube is pointing down.
2. Carefully remove the protective plastic cap from the end of the Nuclear Sensor. Place the watch glass below the end of the Nuclear Sensor.
3. Adjust the position of the Nuclear Sensor so that the end of the sensor is 1 or 2 cm above the watch glass.
4. Remove the watch glass temporarily and place it under the stopcock at the bottom end of the ion exchange column that has 5 ml of EDTA eluant in it. Adjust the ion exchange column so the bottom end is 3 to 4 cm (less than 2 inches) above the watch glass.



5. Open the stopcock and let 2 ml of eluant drain down into the watch glass. Close the stopcock again as soon as the eluant drains out.

- If the isogenerator is going to be used again right away, refill the reservoir with eluant to the 5 ml mark. Wait between 15 and 30 minutes before draining more of the eluant out of the ion exchange column.
- If the isogenerator is NOT going to be used again right away, drain the rest of the eluant into a beaker. Close the stopcock. Fill the reservoir to the 10 ml (top mark) mark with de-ionized water. Put the large cap back on the reservoir tightly. Store the isogenerator in an air tight container.

6. Put the watch glass back underneath the end of the Nuclear Sensor.

PART III: Data Recording

1. Start recording data. (Click ‘Start’ in *DataStudio* or click ‘REC’ in *ScienceWorkshop* .)

- Data recording will stop automatically after ten minutes. Run #1 will appear in the Data list.

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Follow all instructions for the handling and disposal of the chemical used in this activity. DO NOT pour any chemicals down the drain unless you are told to do so.

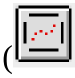
Computer Shutdown

When you have finished, you have several options.

1. You can select ‘Quit’ from the ‘File’ menu to end the activity.
2. You can select ‘Save’ or ‘Save As…’ from the ‘File’ menu to save your data for this activity and the changes you’ve made to the document.

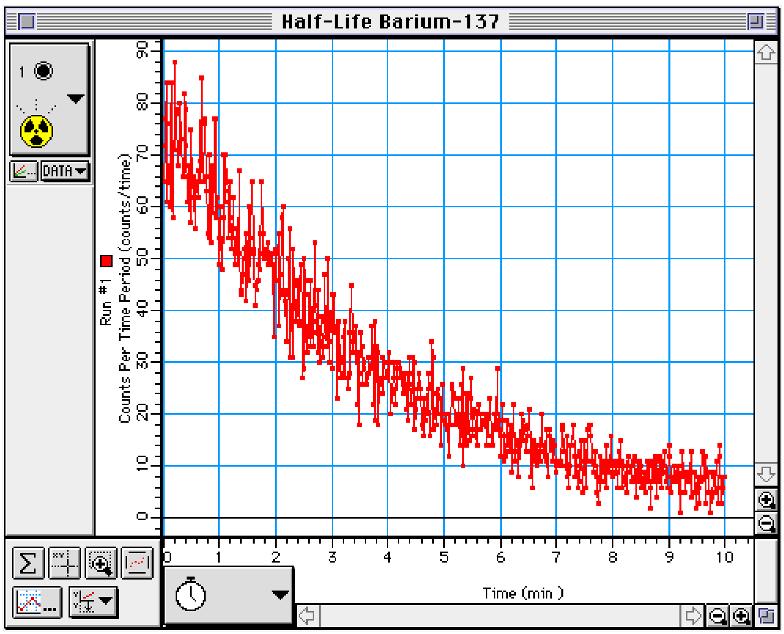
- The original document is “locked”, so you should give <u>your</u> document a new filename.

Analyzing the Data

1. Rescale the Graph to fit the data. (Use ‘Scale to Fit’ in DataStudio or ‘Autoscale’ () in ScienceWorkshop.)
2. Use the Graph’s built-in analysis tools to find the half-life of the substance.

- Hint: Use the ‘Smart Tool’ or ‘Smart Cursor’ to find the value of counts at the beginning of the run. Move the ‘Smart Tool’ or ‘Smart Cursor’ along the plot of counts until the ‘Y’ coordinate is approximately one-half of the original value. Record the value of the ‘X’ coordinate as the ‘half-life’ time.

Record your results in the Lab Report section.



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Lab Report - Activity GS17: Half-Life of a Radioactive Substance

What Do You Think?

The purpose of this activity is to determine the **half-life** of a **radioactive** substance. How can you use a nuclear sensor (like a Geiger-Müller tube) to determine the half-life of a substance?

Data Table

Initial Count	counts per second
Half-Life	minutes

Questions

1. How does your value of half-life time for the Barium-137 compare to the accepted value (about 2.6 minutes)?

2. How long will it take for counts from the Barium-137 to decrease to 1/4th of the original counts?

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Activity GS18: Understanding Motion – Position vs. Time (Motion Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Linear motion	GS18 Understand Motion.DS	G18 Understanding Motion	G18_MOTN.SWS

Equipment Needed	Qty	Equipment Needed	Qty
Motion Sensor (CI-6742)	1	***Base and Support Rod (ME-9355)***	1

What Do You Think?

What is the relationship between the motion of an object – YOU – and a graph of position and time for the moving object?

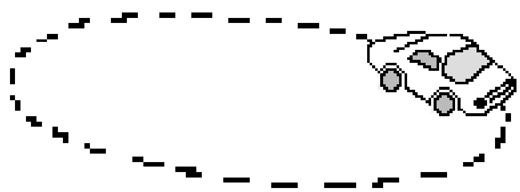
Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

When describing the motion of an object, knowing where it is relative to a reference point, how fast and in what direction it is moving, and how it is accelerating (changing its rate of motion) is essential.

A sonar ranging device such as the PASCO Motion Sensor uses pulses of ultrasound that reflect from an object to determine the position of the object.

As the object moves, the change in its position is measured many times each second. The change in position from moment to moment is expressed as a velocity (meters per second). The change in velocity from moment to moment is expressed as an acceleration (meters per second per second).



The position of an object at a particular time can be plotted on a graph. You can also graph the velocity and acceleration of the object versus time.

A graph is a mathematical picture of the motion of an object. For this reason, it is important to understand how to interpret a graph of position, velocity, or acceleration versus time. In this activity you will plot a graph of position in real-time, that is, as the motion is happening.

SAFETY REMINDER

- Follow all safety instructions.
- Keep the area clear where you will be walking.

THINK SAFETY
ACT SAFELY
BE SAFE!

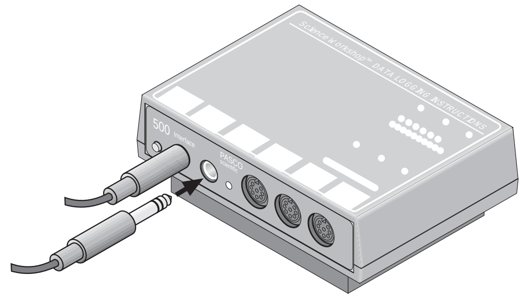
For You To Do

- **This activity is easier to do if you have a partner to run the computer while you move.**

For this activity, you will be the object in motion. Use the Motion Sensor to measure your position as you move in a straight line at different speeds. Use *DataStudio* or *ScienceWorkshop* to plot your motion on a graph of position and time.

The challenge in this activity is to move in such a way that a plot of your motion on the same graph will "match" the line that is already there.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the stereo phone plugs of the Motion Sensor to Digital Channels 1 and 2 on the interface. Connect the yellow plug to Digital Channel 1 and the other plug to Digital Channel 2.
3. Open the file titled as shown:

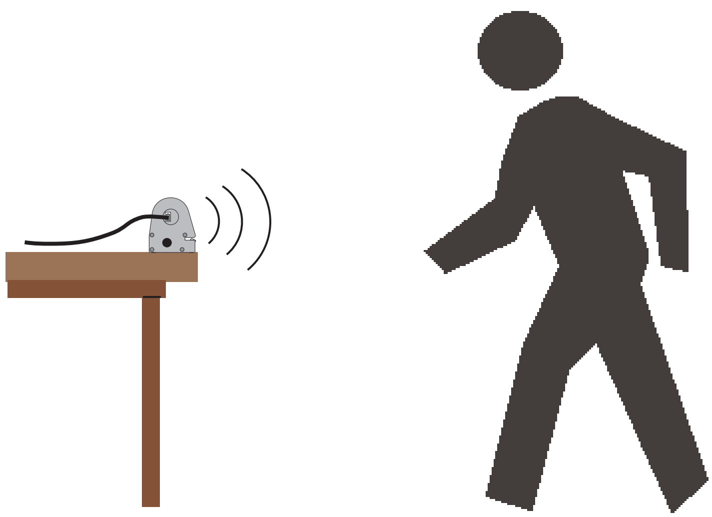
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS18 Understand Motion.DS	G18 Understanding Motion	G18_MOTN.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Graph display of Position versus Time.
- The Graph shows Position and Time values that were entered into the Graph.
- Data recording is set to stop automatically at 10 seconds. In the *DataStudio* file there is a 'countdown' before data recording begins.

PART II: Sensor Calibration and Equipment Setup

- **You do not need to calibrate the Motion Sensor.**

1. Set the range select switch on the Motion Sensor to 'Far'.
2. Mount the Motion Sensor so that it is aimed at your midsection when you are standing in front of the sensor. Make sure that you can move at least 2 meters away from the Motion Sensor.
3. Position the computer monitor so you can see the screen while you move away from the Motion Sensor.



- **You will be moving backwards for part of this activity. Clear the area behind you for at least 2 meters (about 6 feet).**

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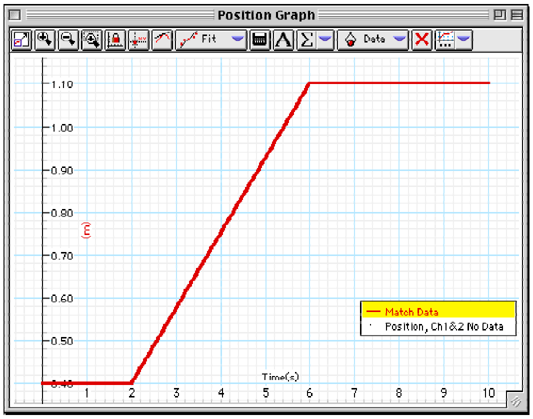
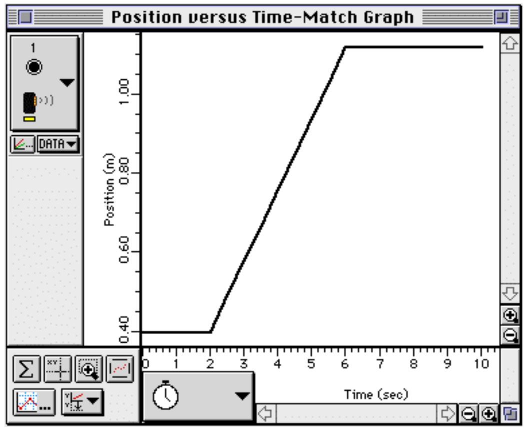
PART III: Data Recording

1. Enlarge the Graph display until it fills the monitor screen.
2. Study the plot of Position versus Time in order to determine the following:

- How close should you be to the Motion Sensor at the beginning? _______ (m)
- How far away should you move? _______ (m)
- How long should your motion last? _______ (s)





3. When you are ready, stand in front of the Motion Sensor.

- **WARNING: You will be moving backward, so be certain that the area behind you is free of obstacles.**

4. When everything is ready, start recording data.

- In *DataStudio*, click 'Start'. There is a three-second countdown before data recording begins. The 'cursor' on the vertical axis of the Graph will move up and down as you move forward and backward relative to the sensor. Use the feedback from 'cursor' to find your best starting position.
- In *ScienceWorkshop*, click 'REC'. Data recording will begin almost immediately.
- The Motion Sensor will make a faint clicking noise.

5. Watch the plot of your motion on the Graph and try to move so the plot of your motion matches the Position versus Time plot already there.

If the Motion Sensor is having difficulty picking up the echo, use a notebook as a reflector. Hold the notebook at the same height as the sensor.

6. Repeat the data recording process a second and a third time. Try to improve the match between the plot of your motion and the plot already on the Graph.

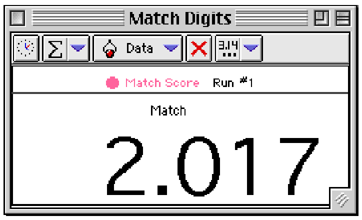
- The Graph can show more than one run of data at the same time.

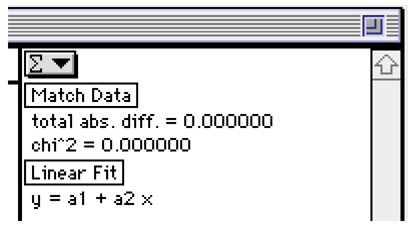
Analyzing the Data

1. Determine the slope of the best-fit line for the middle section of your best position versus time plot. You may want to resize the graph to fit the data.

- The slope of this part of the position versus time plot is the velocity during the selected region of motion.

2. Determine how well your plot of motion fits the plot that was already in the Graph. (Hint: In *DataStudio*, examine the 'Match Data' calculation. In *ScienceWorskhop*, examine the 'total abs. diff.' (total absolute difference) and the chi^2 (goodness of fit) terms from the Statistics area.)





Use your results to answer the questions in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the 'File' menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

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Lab Report - Activity GS18: Understanding Motion – Position vs. Time

What Do You Think?

What is the relationship between the motion of an object – YOU – and a graph of position and time for the moving object?

Questions

1. In the Graph, what is the slope of the line of best fit for the middle section of your plot?

2. What is the description of your motion? (Example: “Constant speed for 2 seconds followed by no motion for 3 seconds, etc.”)

3. What would be the physical meaning of a steeper slope on the graph?

4. What would be different about the motion if the slope were negative?

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Activity GS19: Acceleration of a Cart
(Motion Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Linear motion	GS19 Accelerate a Cart.DS	G19 Cart Acceleration	G19_CART.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Motion Sensor (CI-6742)	1	**Dynamics Cart (inc. w/ Track)**	1
Block (or book)	1	**1.2 m Track System (ME-9429A)**	1

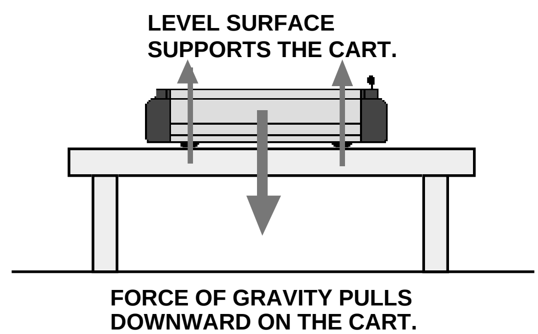
What Do You Think?

What happens to the acceleration of a cart as it moves up and down an inclined plane?

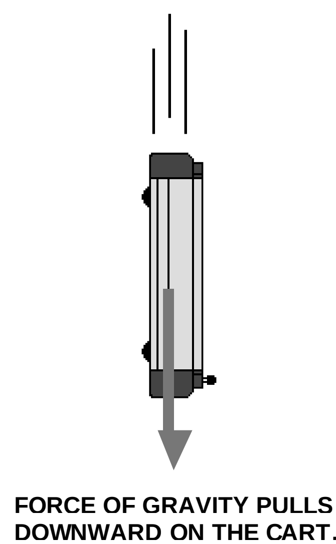
Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

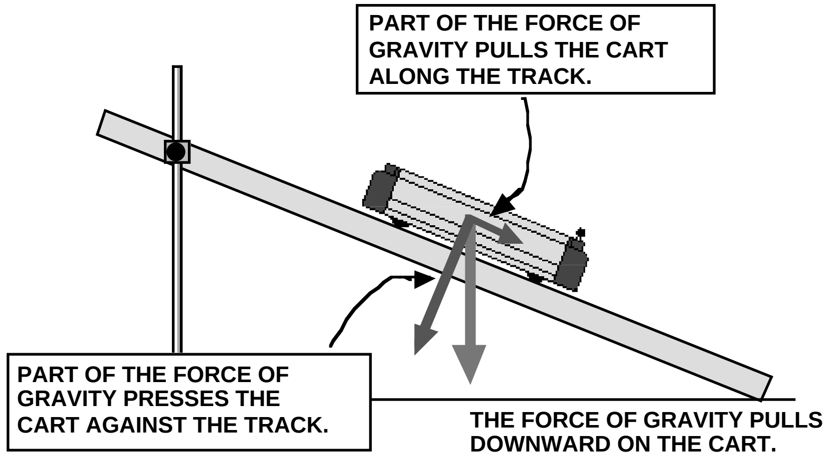
A cart on a perfectly level surface is pulled downward by the force of gravity on it. The surface balances the force of gravity. Since there is no net force up or down on the cart, the cart doesn't move.



A cart that is dropped vertically is also pulled downward by the force of gravity. If you ignore the small amount of air resistance on the cart, the only force acting on the cart IS gravity. Since there is a net force pulling downward on the cart, the cart moves downward. Not only that, it gains speed as it falls. In fact, it gains speed at a constant rate of 9.8 meters per second each second! This change in speed is called the acceleration due to gravity.



If a cart is on a surface that is not level but is not vertical, it is still pulled downward by the force of gravity. What is different is that part of the force of gravity presses the cart against the track. Another part of the force of gravity pulls the cart along the track. Each part is called a **component** of the force.



(Mathematically, the part of the force of gravity that pulls the cart along the track is **mg sin** θ, where **m** is the mass of the cart, and **g** is the acceleration due to gravity and θ, is the angle of the track.)

If you put a cart at the bottom of the track and give it a push up the track, it will slow down as it goes up the track and speed up as it comes back down the track.

In theory, the acceleration (change in speed) going up the track is the same as the acceleration coming back down the track.

SAFETY REMINDER

- Follow all safety instructions.

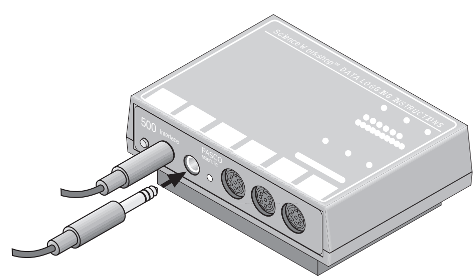
THINK SAFETY
ACT SAFELY
BE SAFE!

For You To Do

Use a Motion Sensor to measure the motion of a cart that is pushed up an inclined plane. Use *DataStudio* or *ScienceWorkshop* to record the motion and calculate the velocity and acceleration of the cart as it moves up and down the inclined plane.

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and then turn on the computer.
2. Connect the Motion Sensor's phone plugs to Digital Channels 1 and 2 on the interface. Plug the yellow-banded (pulse) plug into Digital Channel 1 and the second plug (echo) into Digital Channel 2.
3. Open the file titled as shown:



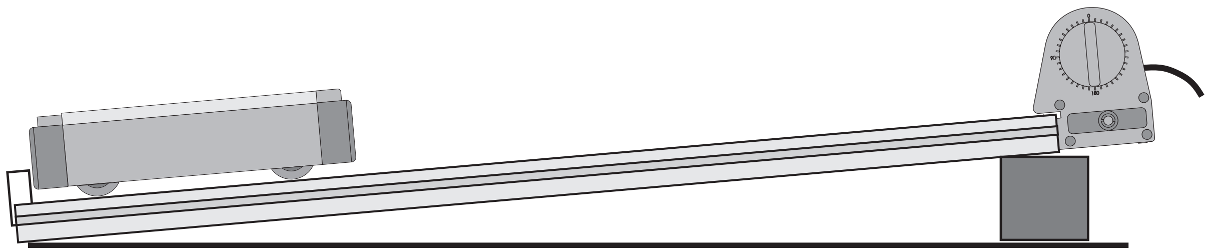
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
P07 Accelerate Cart.ds	(See end of activity)	(See end of activity)

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- Data recording is set so the Trigger Rate for the Motion Sensor is 10 samples per second (10 Hz).

PART II: Sensor Calibration and Equipment Setup

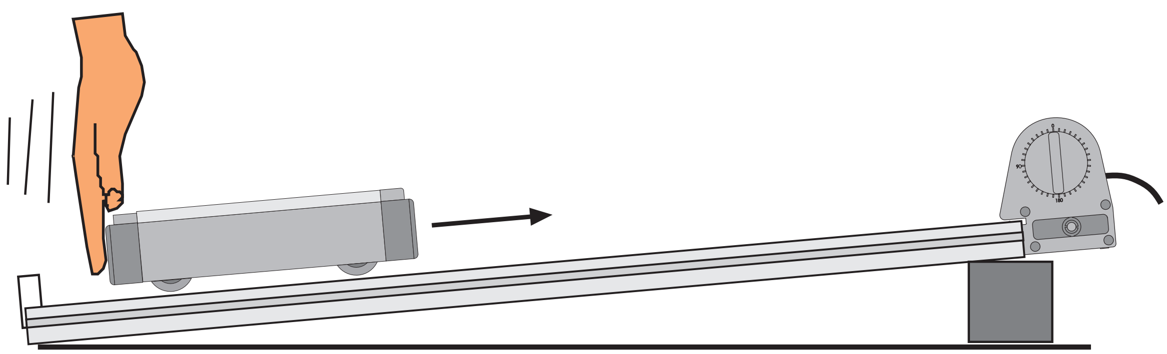
- You do not need to calibrate the sensor for this activity.

1. Place the track on a horizontal surface. Use a block or book at one end of the track to raise that end.
2. Mount the Motion Sensor at the high end of the track. Put a mark on the track 15 cm from the Motion Sensor.



Preparing to Record Data

1. Before recording any data for later analysis experiment with the Motion Sensor to make sure it is aligned and can "see" the cart as it moves.
2. Place the cart on the low end of the track (i.e., the end opposite to the Motion Sensor).
3. When everything is ready, start recording data.
4. Give the cart a firm push up the track so the cart will move up the inclined plane toward and then away from the Motion Sensor.



- **BE CAREFUL! Don't push the cart so firmly that it gets closer than 15 cm to the sensor.**

Remember: The minimum distance between the cart and the Motion Sensor should be 15 cm.

5. Stop recording when the cart returns to the bottom of the track.

- **You may want to rescale the Graph.**

6. If the plot of data is not smooth, check the alignment of the Motion Sensor and repeat the above procedure until the plot is smooth.
7. Erase your sample run of data.

PART III: Data Recording

1. Prepare to measure the motion of the cart as it moves toward the Motion Sensor and then back down the track. Place the cart at the low end of the track.
2. When everything is ready, start recording data. Give the cart a firm push toward the Motion Sensor. Continue collecting data until the cart has returned to the bottom of the track.

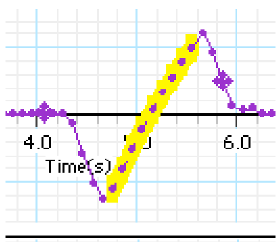
- **If the data points do not appear on the graph, check the alignment of the Motion Sensor and try again.**

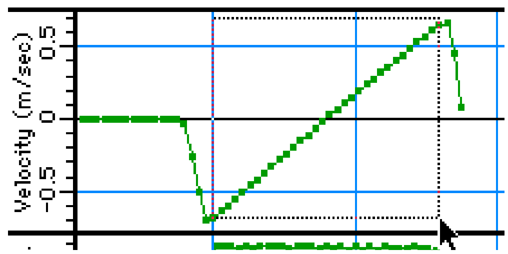
Optional

- Set the track to a steeper angle (e.g., 10 degrees) and repeat the data recording.

Analyzing the Data

1. In the Motion Sensor's plot of velocity, use the cursor to select the region of the plot that shows the cart's motion after the push and before it stopped at the bottom of the track.

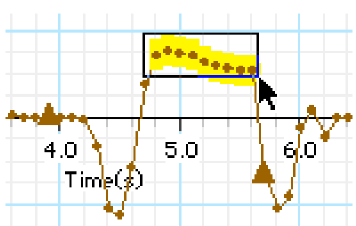


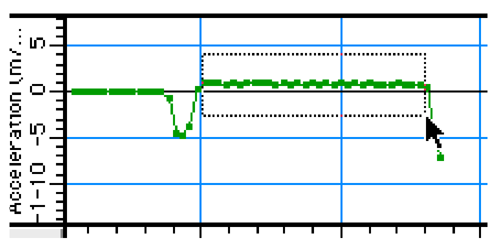


2. Use the Graph display's built-in analysis tools to apply a linear curve fit.

- Hint: In *DataStudio*, select 'Linear' from the 'Fit' menu. In *ScienceWorkshop*, click the 'Statistics' button and then select 'Curve Fit, Linear Fit' from the 'Statistics' menu ().

3. The *slope* of the best-fit line is the average acceleration. Record the value in the Data Table.
4. In the Motion Sensor's plot of acceleration, select the region of the plot that corresponds to the cart's motion after the push and before it stopped at the bottom of the track.





5. Use the 'Statistics' tool to find the mean value of the acceleration as measured by the Motion Sensor for your selected region. Record the mean of the acceleration in the Data Table.

Record your results in the Lab Report section.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS19: Acceleration of a Cart

What Do You Think?

What happens to the acceleration of a cart as it moves up and down an inclined plane?

Data Table

Item	Value
acceleration (slope)	m/sec^2
acceleration (mean)	m/sec^2

Questions

1. Describe the position versus time plot of the Graph display. Why does the distance begin at a maximum and decrease as the cart moves up the inclined plane?

2. Describe the velocity versus time plot of the Graph display.

3. Describe the acceleration versus time plot of the Graph display.

4. Is the acceleration of the cart going up the track the same as the acceleration of the cart coming down the track? Why or why not?

Optional: How did the acceleration change when the track became steeper?

Ending the Activity

Equipment Clean Up

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select ‘Quit’ from the ‘File’ menu to end the activity.
2. You can select ‘Save’ or ‘Save As…’ from the ‘File’ menu to save your data for this activity and the changes you’ve made to the document.

- The original document is “locked”, so you should give your document a new filename.

Name ____________________ Class ______________ Date _________

Activity GS20: Newton’s Second Law - Push / Pull a Cart
(Force Sensor, Motion Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Motion	GS20 Push Pull a Cart.DS	G20 Push-Pull a Cart	G20_PUSH.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Economy Force Sensor (CI-6746)	1	**Dynamics Cart (inc. w/ Track)**	1
Motion Sensor (CI-6742)	1	**1.2 m Track System (ME-9429A)**	1
Balance (SE-8723)	1		

What Do You Think?

The purpose of this activity is to find the relationship between a force pushing or pulling a cart, the mass of the cart, and the acceleration of the cart. Can erratic pushing and pulling of the cart show the relationship?

Take time to answer the ‘What Do You Think?’ question(s) in the Lab Report section.

Background

Isaac Newton described the relationship of acceleration to net force and mass of an object as follows:

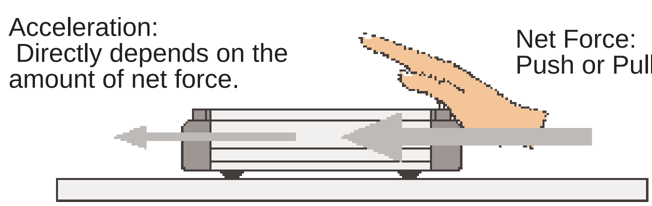
The acceleration of an object is directly proportional and in the same direction as the net force on the object, but inversely proportional to the mass of the object.

$$a = \frac{F_{net}}{m}$$

- For this activity you will be verifying Newton’s Second Law in the form $m = \frac{F_{net}}{a}$.

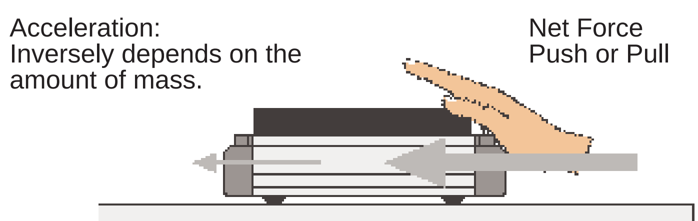
where m is the mass of the object, F_{net} is the net force (push or pull) on the object, and a is the acceleration of the object.

The first part of Newton’s statement means that the <u>more</u> net force, the <u>more</u> acceleration for a given amount of mass.



The more net force, the more acceleration for a given amount of mass.

The second part of Newton’s statement means that the <u>more</u> mass, the <u>less</u> acceleration for a given amount of net force.



The more mass, the less acceleration for a given amount of net force.

SAFETY REMINDER

- Do not let the cart hit the Motion Sensor.
- Follow directions for using the equipment.

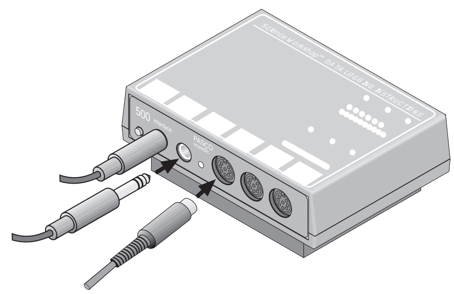
THINK SAFETY
ACT SAFELY
BE SAFE!

For You To Do

For this activity, push and pull a Dynamics Cart back-and-forth on a level Dynamics Track. Use the Motion Sensor to measure the motion of a cart, and the Force Sensor to measure the force you exert on the cart. Use *DataStudio* or *ScienceWorkshop* to calculate the acceleration of the cart as it moves. (Hint: The slope of the graph of force versus acceleration is the mass of the moving object.)

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Motion Sensor's phone plugs to Digital Channels 1 and 2 on the interface. Plug the yellow-banded (pulse) plug into Digital Channel 1 and the second plug (echo) into Digital Channel 2.
3. Connect the DIN plug of the Force Sensor to Analog Channel A.
4. Open the document titled as shown:



DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS20 Push Pull a Cart.DS	G20 Push-Pull a Cart	G20_PUSH.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorksho*p document has a Graph display of Force versus Acceleration.
- Data recording is set at 100 Hz for the Force Sensor and the Trigger Rate for the Motion Sensor is 20 times per second.
- The calibration for the Force Sensor has been changed so that a push to the left is negative and a pull to the right is positive.

PART II: Sensor Calibration and Equipment Setup

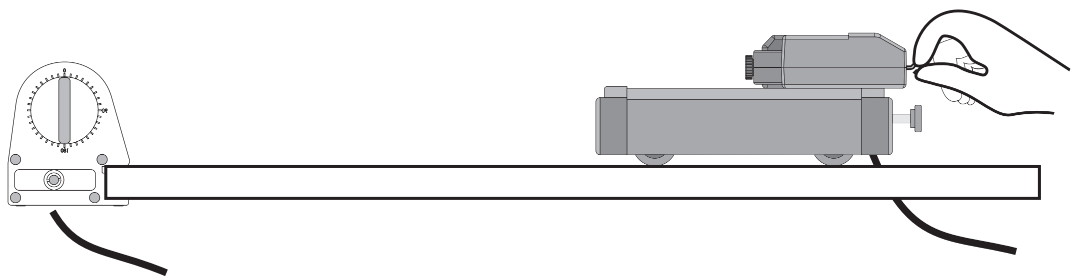
- You do not need to calibrate the Motion Sensor.
- To calibrate the Force Sensor, refer to the description in the introduction of this manual.

1. Place the track on a horizontal surface. Level the track by placing the cart on the track. If the cart rolls one way or the other, use the adjustable feet at one end of the track to raise or lower that end until the track is level and the cart does not roll one way or the other.
2. Mount the Force Sensor onto the accessory tray of the cart.
3. Measure and record the mass of the cart plus Force Sensor in the Data Table in the Lab Report section.
4. Position the Motion Sensor at the left end of the track. Place the cart on the track so the hook end of the Force Sensor points away from the Motion Sensor. The cart must remain a minimum distance away from the sensor (15 cm for the Motion Sensor II). Put a mark on the track at the minimum distance from the Motion Sensor (15 cm).

Name ____________________ Class ______________ Date _________

Trial Run of Data

1. Before recording data for later analysis, record a trial run with the Motion Sensor to make sure it is aligned and can "see" the cart as it moves.
2. Place the cart on one end of the Dynamics Track. Press the <u>tare button</u> on the side of the Force Sensor to zero the Force Sensor.
3. Firmly grasp the hook of the Force Sensor and pull and push the Force Sensor to make the cart move back and forth. Make sure the cart does not come too close to the Motion Sensor.



4. Start recording data. (Click 'Start' in *DataStudio* or 'REC' in *ScienceWorkshop*.)
5. After about 10 seconds, stop recording data.
6. Adjust the position of the Motion Sensor if necessary.

PART III: Data Recording

1. Prior to recording each data run, press the tare button on the side of the Force Sensor to zero the Force Sensor.
2. After the Force Sensor has been zeroed, begin pulling and pushing on the hook of the Force Sensor to make the cart move back and forth.
3. Start recording data.
4. Push and pull the cart back and forth four or five times, then stop the recording.

- Run #1 will appear in the Data list. If the data points do not appear on the graph, check the alignment of the Motion Sensor and try again.

Analyzing the Data

1. Click-and-draw a rectangle around the region of the force versus acceleration plot that shows the movement of the cart. Release the mouse button, and the area will be highlighted.
2. Select the Linear curve fit.

- In *DataStudio*, click the 'Fit' menu button (

). Select 'Linear'.
- In *ScienceWorkshop* click the 'Statistics' button to open the Statistics area on the right side of the Graph. In the Statistics area, click the Statistics Menu button (). Select 'Curve Fit, Linear Fit' from the Statistics Menu.

3. Record the slope of the linear fit in the Data Table in the Lab Report section.

Record your results in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the 'File' menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

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Lab Report - Activity GS20: Newton's Second Law – Push/Pull a Cart

What Do You Think?

The purpose of this activity is to find the relationship between a force pushing or pulling a cart, the mass of the cart, and the acceleration of the cart. Can erratic pushing and pulling of the cart show the relationship?

Data Table

Item	Value
Mass of cart and Force Sensor (measured)	kg
Mass of cart & Force Sensor (slope)	kg

Questions

1. Why does the slope of the force versus acceleration plot equal the object's mass?

2. What is the percentage difference between the actual and experimental mass? Remember,

$$\textbf{percent difference} = \left|\frac{\textbf{theoretical} - \textbf{actual}}{\textbf{theoretical}}\right| \times \mathbf{100\%}$$

Name ____________________ Class _____________ Date _________

Activity GS21: Conservation of Energy – PE to KE (Motion Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Energy	GS21 Conserve Energy.DS	G21 Conserve Energy	G21_ENER.SWS

Equipment Needed	Qty	Equipment Needed	Qty
Motion Sensor (CI-6742)	1	Masses	~2 kg
Balance (SE-8723)	1	Meter stick	1
Base and Support Rod (ME-9355)	1	Ruler, metric (15 cm)	1
Block	1	**1.2 m Track System (ME-9429A)**	1
“C” clamp	1	Tape	1 roll
Dynamics Cart (inc. w/ Track)	1		

What Do You Think?

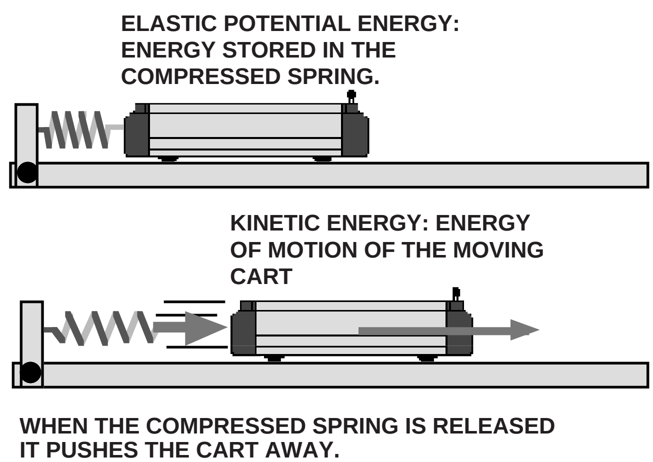
How well is energy conserved when the **elastic potential energy** of a spring is transformed into **kinetic energy** of a moving cart?

Take time to answer the ‘What Do You Think?’ question(s) in the Lab Report section.

Background

Potential energy is sometimes called stored energy. A compressed spring has stored potential energy called elastic potential energy. Kinetic energy is called the energy of motion. An object in motion has kinetic energy.

The amount of force that a spring can push with depends on how far it is compressed and how strong the spring is (called the **spring constant**). Likewise, the amount of elastic potential energy (stored energy) a spring has depends on how far it has been compressed and the spring constant.



A spring that is compressed a distance **x** from its normal position has an amount of elastic potential energy given by:

$$PE_{elastic} = \frac{1}{2}kx^2$$

where $PE_{elastic}$ stands for “elastic potential energy”, k is the spring constant and x is the distance that the spring is compressed.

The amount of kinetic energy that an object has depends on how much mass it has and how fast it is moving. The formula for kinetic energy is:

$$KE = \frac{1}{2}mv^2$$

where KE stands for “kinetic energy”, m is the mass of the object, and v is the speed of the object.

If energy is conserved, the elastic potential energy in the compressed spring will be completely transformed into kinetic energy when the spring pushes an object of mass **m**.

SAFETY REMINDER

- Do not let the cart hit the Motion Sensor.
- Follow directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

For You To Do

In the Pre-Lab for this activity, measure the spring constant of the plunger spring in a dynamics cart. Put heavy masses on the end of the plunger to force the spring to compress. Measure the amount of distance that the spring compresses. Use *DataStudio* or *ScienceWorkshop* to make a Graph of force and position that will give you the value of the spring constant ***k***.

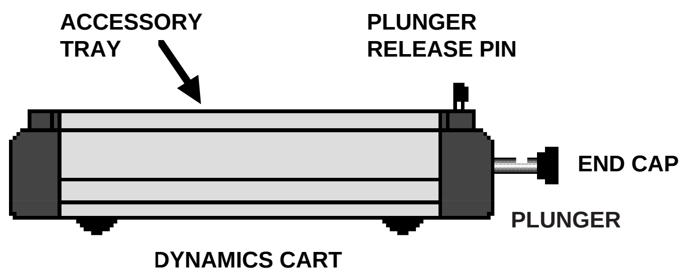
In the Procedure for this activity, use the Motion Sensor to measure the motion of a cart after it is pushed by the plunger spring as the spring de-compresses. Use *DataStudio* or *ScienceWorkshop* to record the motion and display the initial velocity and maximum kinetic energy of the cart.

Use your data to compare the measured kinetic energy to the calculated elastic potential energy.

Pre-Lab

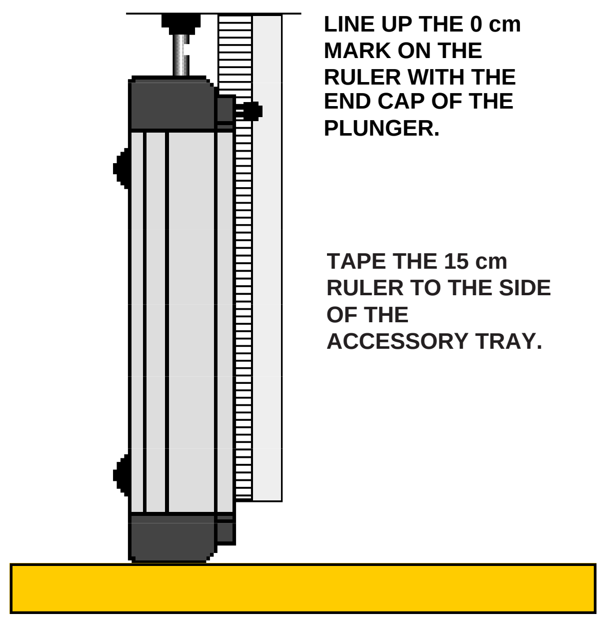
Equipment Setup and Data Recording

The dynamics cart has a spring-loaded plunger that can be used to push the cart to get it moving. The plunger has three notches so the plunger spring can be compressed to three different distances.



When the plunger spring is fully compressed, the end cap is even with the end of the cart. When it is not compressed at all, it goes out about 3 cm.

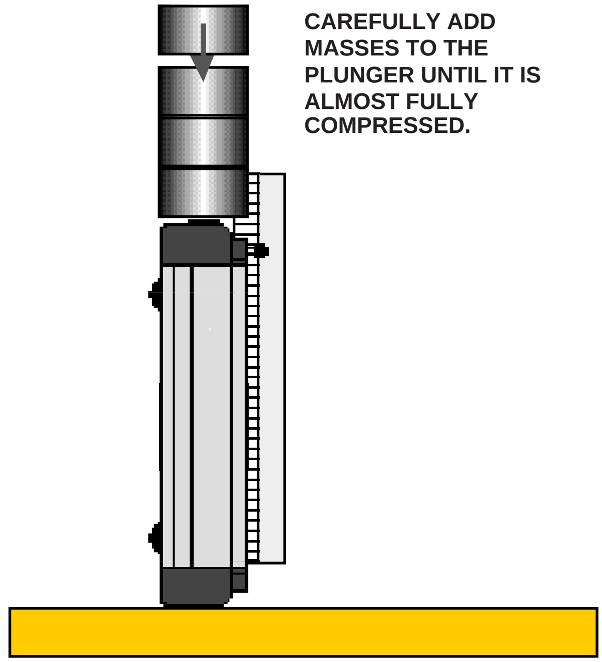
1. Put the dynamics on end with the plunger at the top. Place the 15-cm metric ruler on the side of the cart and line up the 0 cm mark on the ruler with the end cap of the plunger. Tape the metric ruler to the side of the cart.



Name ____________________ Class _____________ Date _________

2. Carefully add masses on top of the plunger until the plunger spring is almost fully compressed. Add up the total mass that it took to compress the spring. Use the ruler to measure the position of the end cap. Record the total mass and the position in the Data Table.

- You may need to steady the dynamics cart and the pile of masses to keep them from leaning.



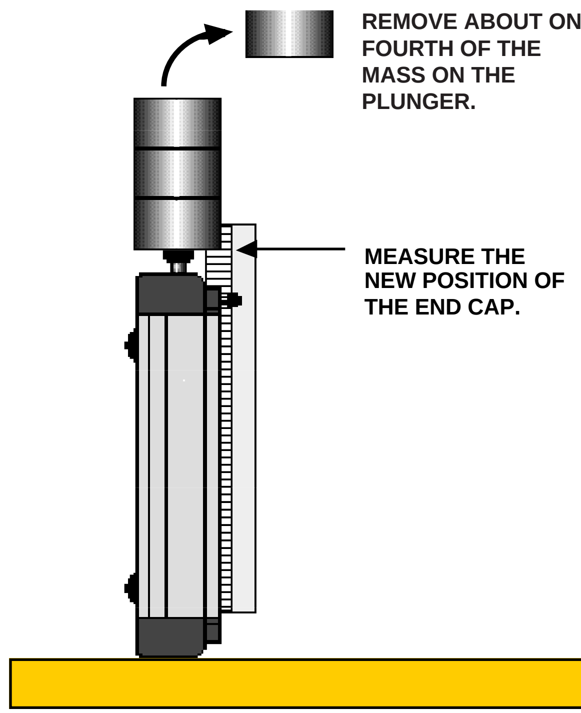
3. Remove approximately one-fourth of the mass you used in the previous step. Measure the new position of the end cap. Record the amount of mass and the position in the Data Table.

4. Repeat the previous step. Remove another one-fourth of the original mass (so one-half the original mass remains). Measure the new position of the end cap. Record the amount of mass and the new position in the Data Table.

5. Remove another one-fourth (so one-fourth remains). Measure the position. Record the amount of mass and the new position in the Data Table.

6. Remove the final amount of mass. Remove the metric ruler from the cart.

7. In the Data Table, convert the positions from centimeters to meters (divide by 100).



8. Convert the mass from grams to kilograms (divide by 1000). Convert from mass to force by mutlitplying the mass in kilograms by **9.8 newtons per kilogram** (the strength of gravity at Earth's surface).

Pre-Lab: Data Table

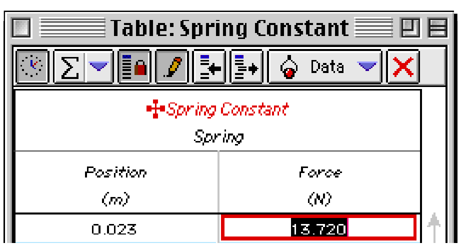
	Position (cm)	Position (m)	Mass (g)	Mass (kg)	Force (N)
All mass					
3/4 mass					
1/2 mass					
1/4 mass					
no mass	0	0	0	0	0

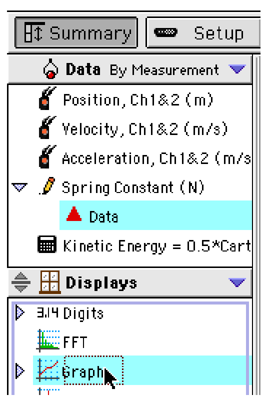
Pre-Lab: Analyze the Data

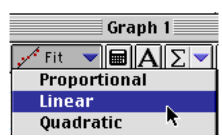
1. Use *DataStudio* or *ScienceWorkshop* to create a graph of Force versus Position in order to determine the spring constant from your data.

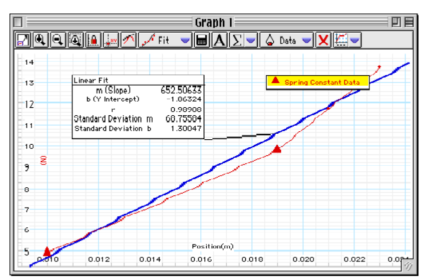
In *DataStudio*, do the following:

- Open the file titled 'GS21 Conserve Energy.DS'
- In the Table display, type in your recorded values for position in *meters* and force in *newtons*. (Use the <tab> or <return> key to move from one cell to the next.) After you are done, click the 'Edit Data' tool (). 'Data' will appear in the Summary list.
- Drag 'Data' to the Graph icon in the Display list.



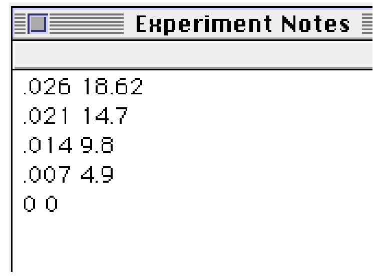






- In the Graph display, select 'Linear' from the 'Fit' menu.
- The value of the slope is the **spring constant, k**.

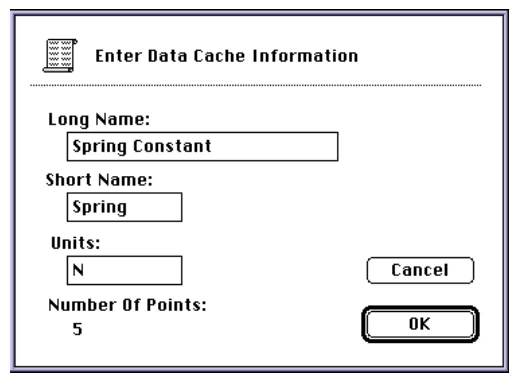
In *ScienceWorkshop*, do the following:



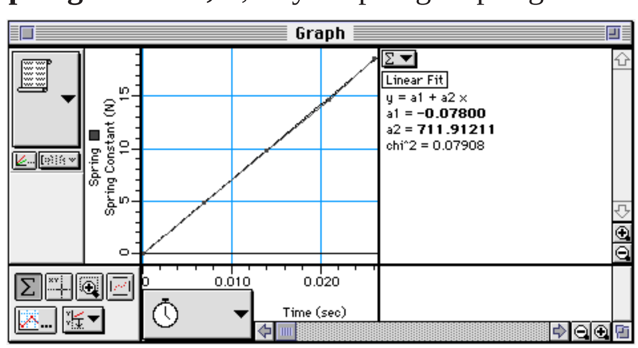
- Click the 'Notes' window button in the Experiment Setup window to open a blank Experiment Notes window. You can import data into *ScienceWorkshop* using the Experiment Notes window.
- Type in your recorded values for position in *meters* and force in *newtons*. Use the following format:

  first number <TAB> second number <RETURN>

- In this case, the first number is the value of position and the second number is the value of force. (Note: The numbers in the example are "made up". Your numbers will probably be different.)
- Use the cursor to highlight your numbers in the Experiment Notes window, or click the 'Edit' menu and pick 'Select All'.
- Click the 'Edit' menu and select 'Copy'.
- Click the Experiment Setup window to make it active. Click the 'Edit' menu and select 'Paste'.



- The 'Enter Data Cache Information' window will open.
- Type in 'Spring Constant' for the 'Long Name', 'Spring' for the 'Short Name', and 'N' for 'Units'. Click 'OK' when you are done.
- The 'Short Name' appears in the Data list in the Experiment Setup window.
- Click the 'Display' menu and select 'New Graph'. The Graph display will show your data, but you may need to rescale the Graph in order to see it.
- Click the 'Statistics' button to open the Statistics area on the right side of the Graph. Click the 'Autoscale' button to rescale the Graph to fit the data.
- Click the 'Statistics Menu' button (). Select 'Curve Fit, Linear Fit' from the Statistics menu. The Statistics area will show the formula of a line, the constant **a1**, and the slope **a2**. The slope is the **spring constant, k**, of your plunger spring.

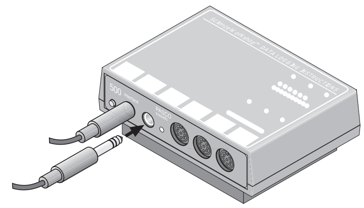


2. Record the value of your **spring constant, k**, in the Lab Report section.

Procedure

Remember, use the Motion Sensor to measure the motion of a cart just after it is pushed by the plunger spring as the spring de-compresses. Use *DataStudio* or *ScienceWorkshop* to record and display the motion and the kinetic energy of the cart. Compare the measured kinetic energy to the calculated elastic potential energy.

PART I: Computer Setup



1. Connect the Motion Sensor stereo phone plugs to Digital Channels 1 and 2 on the *ScienceWorkshop* interface. Put the yellow-banded phone plug into Digital Channel 1. Put the other phone plug into Digital Channel 2.
2. Open the document titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS21 Conserve Energy.DS	G21 Conserve Energy	G21_ENER.SWS

- Note: ‘GS21 Conserve Energy.DS’ may already be open because it was used during the Pre-Lab.
- The document opens with a Graph display. The *DataStudio* document also has a Table display and a Workbook display. Read the instructions in the Workbook display.

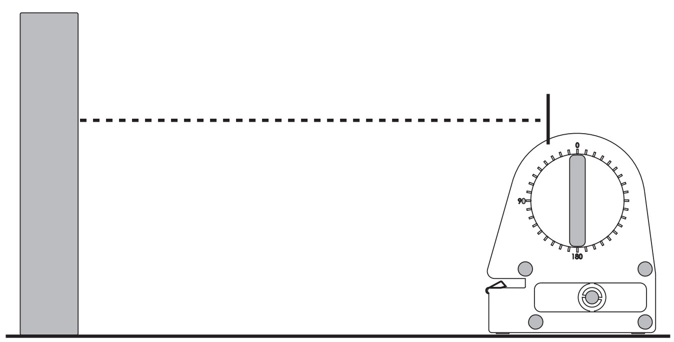
PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

- You should calibrate the Motion Sensor so it can use an accurate measurement of the speed of sound in air. You will need a meter stick and a flat surface that can be used as a target to reflect the pulses from the Motion Sensor.

1. Place the track on a horizontal surface. Put the cart near the middle of the track and level the track by raising or lowering one end so the cart will not roll one way or the other. Remove the cart when the track is level.

2 Put the Motion Sensor at one end of the track. Place a flat surface (such as a book) exactly one meter away from the Motion Sensor. Adjust the target so that it can reflect the pulses from the Motion Sensor.



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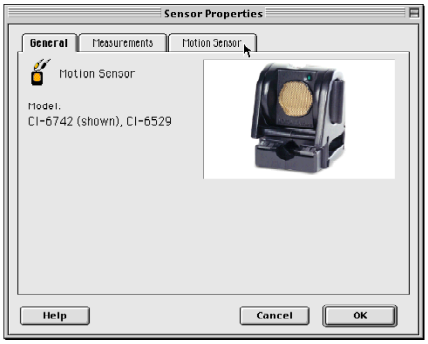
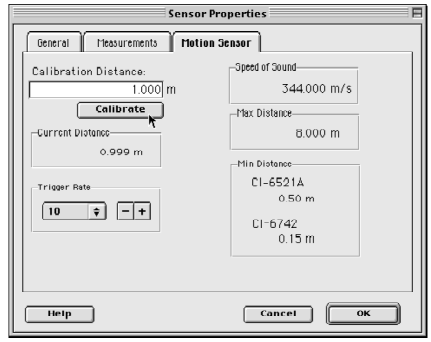
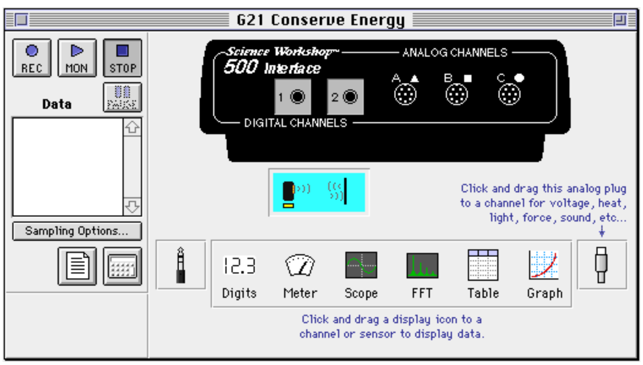
3. In the *DataStudio* Setup window, double-click the sensor's icon. **Result**: The Sensor Properties window opens.

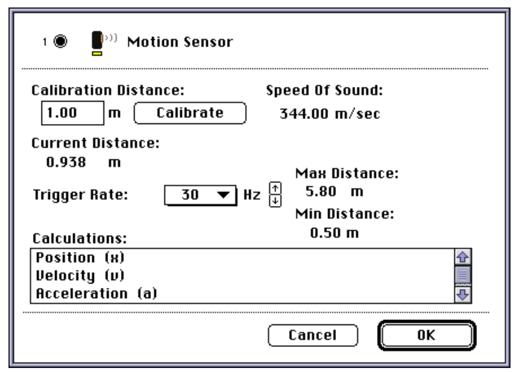
4. Click the 'Motion Sensor' tab. **Result**: The calibration window opens and the sensor begins to click a few times per second.





5. In the *ScienceWorkshop* Experiment Setup window, double-click the Motion Sensor icon. **Result**: The Calibration window opens.





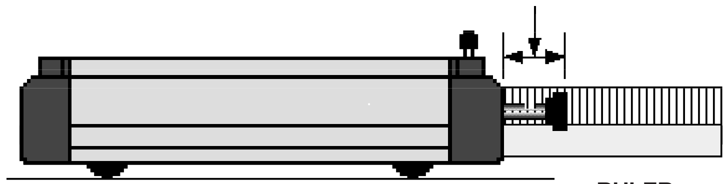
6. Calibrate the software.

- **First**, make sure that the sensor is one meter from the target.
- **Second**, click the 'Calibrate' button in the Motion Sensor window. **Result**: The software calculates the speed of sound based on the calibration distance (one meter) and the round trip time of the pulse and echo

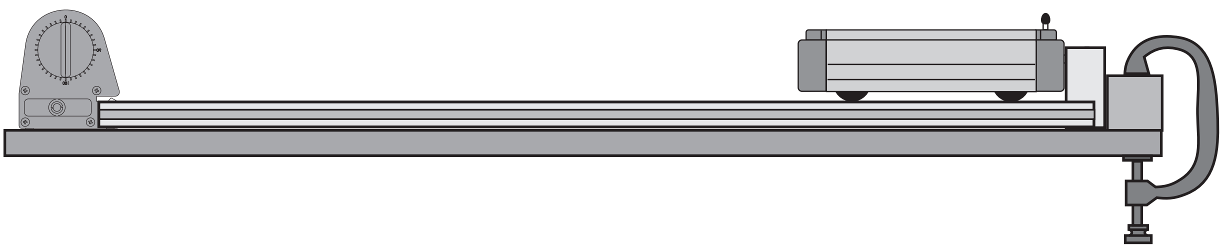
7. Click 'OK' to return to the Experiment Setup window.

Equipment Setup

1. Clamp a block onto the table next to the end stop at one end of the track.
- The block will keep the track from sliding one way when the plunger spring pushes the cart the opposite direction.
2. Put the Motion Sensor at the other of the track.
3. Put a pencil mark on the edge of the track 15 cm in front of the Motion Sensor.
4. Measure the mass of the cart. Record the mass **m** in the Lab Report.
5. Measure the length of the plunger relative to the end cap of the dynamics cart. Record the plunger length **x** in the Lab Report.



6. Fully compress the plunger spring on the cart, and lock the spring in position by pulling the end of the plunger bar upward slightly so one of its notches will 'catch' on the metal rail inside the cart's end cap.
7. Put the cart on the track so the end of the plunger bar is against the end-stop.



PART III: Data Recording

1. Start recording data. (Click 'Start' in *DataStudio* or click 'REC' in *ScienceWorkshop*.)
2. Use the end of a pencil or similar object to tap down on the plunger release pin.
- Avoid getting your hand in the way of the pulses from the Motion Sensor.
- The cart will be pushed away from the end-stop by the plunger spring.
3. Stop recording data when the cart gets about 15 cm from the Motion Sensor.
- Catch the cart so it doesn't run into the Motion Sensor.
- Run #1 will appear in the Data list in the Experiment Setup window.
4. Repeat the data recording process two more times.

Optional: Data Recording – Cart and Extra Mass

1. Put a mass bar in the accessory tray of the cart and measure the mass of the cart plus bar. Record the mass in the Lab Report.
2. Repeat the data recording process as in Part III.

Ending the Activity (See the section after Questions)

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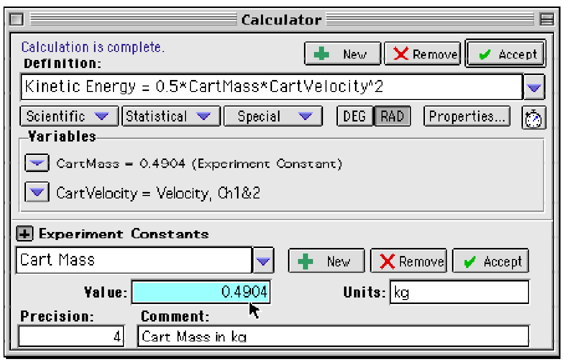
Analyzing the Data

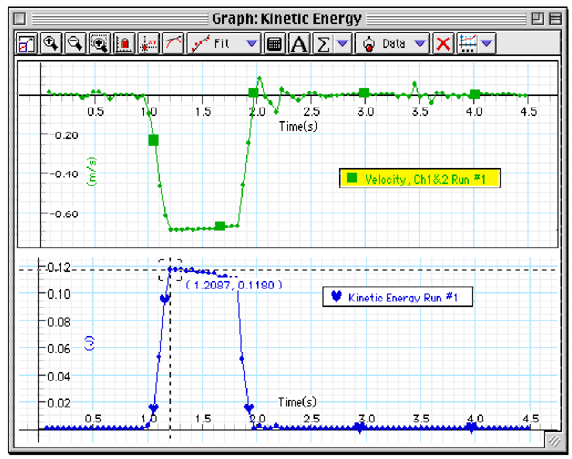
1. Use *DataStudio* or *ScienceWorkshop* to calculate and display the kinetic energy of the cart.

In *DataStudio*, do the following:

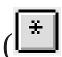
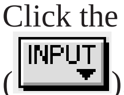
- Open the ‘Calculator’ window. The window already has a calculation of kinetic energy based on a ‘Cart Mass’ of 0.4904 kg.
- Enter the value of the mass of your cart under ‘Cart Mass’ in the ‘Calculator’ window. Click ‘Accept’ to record the change you made.
- In the Graph of Kinetic Energy, use the built-in analysis tools to find the maximum KE.

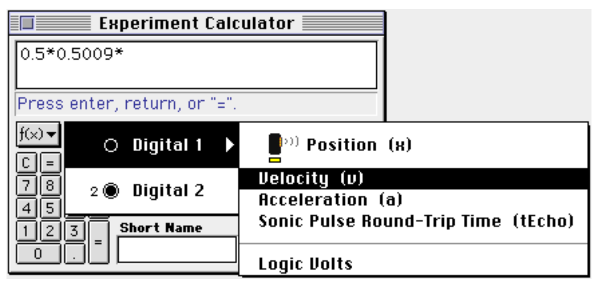
  (Hint: Use the ‘Smart Tool’ to find the maximum KE.)

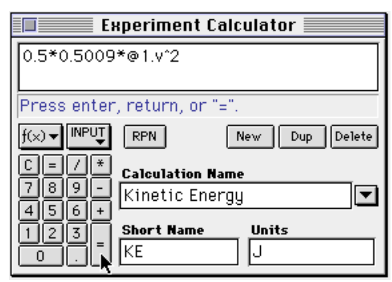


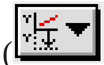


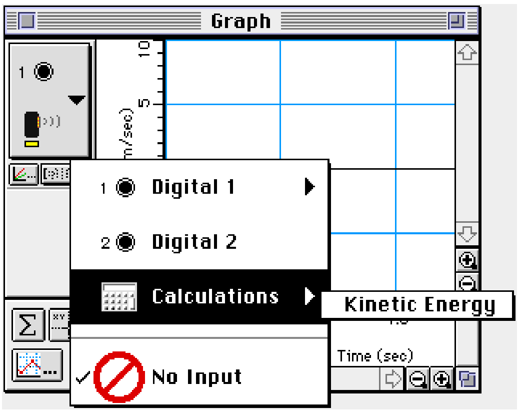
In *ScienceWorkshop*, do the following:

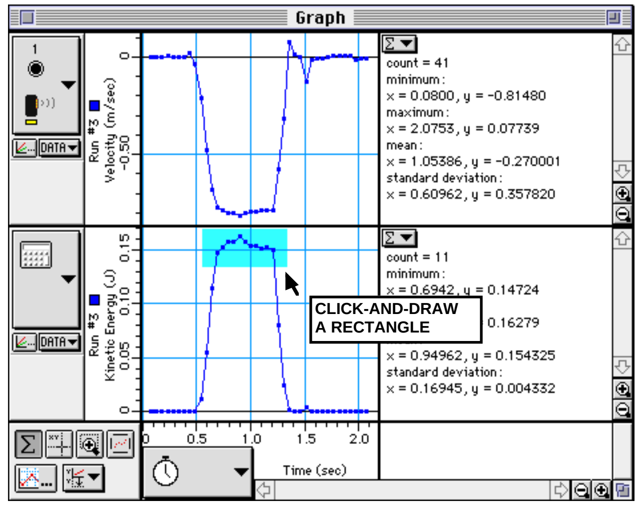
- Open the ‘Experiment Calculator’ window.
- In the formula area, type **0.5** and then click the ‘multiplication’ button ().
- Type the value for the mass of your cart (0.5009 in the example), and click the ‘multiplication’ button again.
- Click the ‘INPUT Menu’ button (). Select ‘Digital 1, Velocity (v).
- Type **^2**, which means to square the speed, after **@1.v** (the symbol for Digital 1, Velocity (v)).
- Type **‘Kinetic Energy’** in the Calculation Name area. Type ‘KE’ in the Short Name area. Type ‘J’ in the Units area.
- Click the **equals** button (=), or press <enter> or <return> on the keyboard.





- Click the Graph display to make it active.
- Click the ‘Add Plot’ menu button () at the bottom of the Graph and select ‘Calculations, Kinetic Energy’. The Graph will show Velocity and Kinetic Energy for the data from Run #1.





- Use the built-in analysis tools to find the maximum kinetic energy.

  (Hint: Click the ‘Statistics Menu’ button in the Statistics area of the plot of <u>Kinetic Energy</u>. Select ‘All Of The Above’ from the Statistics Menu.)

2. Record the values of the maximum kinetic energy in the Lab Report.
3. Calculate the elastic potential energy based on **k** and **x**. Record the value in the Lab Report.

Record your results in the Lab Report section.

Name ______________________ Class _______________ Date __________

Lab Report - Activity GS21: Conservation of Energy – PE to KE

Data Table

Item	Value
Mass (cart)	kg
Spring constant "k"	N/m
Plunger length "x"	m

Run #	1	2	3	Average
KE (J)				J

Elastic Potential Energy = $PE_{elastic} = \frac{1}{2}kx^2$ = ________ J

Questions

1. What is the difference between your value for the average kinetic energy and the elastic potential energy?

2. Which energy was larger in each case, the elastic potential energy or the kinetic energy of the cart?

3. What are possible reasons for the differences, if any?

Ending the Activity

Equipment Clean Up

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select Quit from the File menu to end the activity.
2. You can select Save or Save As… from the File menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

Name ____________________ Class ______________ Date _________

Activity GS22: Heat vs. Temperature
(Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Energy	GS22 Heat v Temperature.DS	G22 Heat v. Temperature	G22_TEMP.SWS

Equipment Needed	**Qty**
Temperature Sensor (CI-6505A)	1
Graduated cylinder, 100 mL	1
Heating resistor, 10 Ω, 1 W	1
Power supply, DC, 10 W (SE-9720)	1
Protective gear	1

Chemicals and Consumables	**Qty**
Styrofoam cup with lid	1
Water	300 mL

(*such as the heating resistor that is part of the PASCO CI-6514 Thermodynamics Kit)

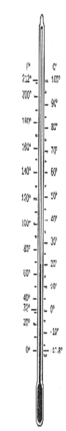
What Do You Think?

What is the relationship between **heat**, **thermal energy**, and **temperature**?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

Heat is energy in transit between two or more objects. When the energy is inside an object, it is sometimes called internal energy or thermal energy. The **thermal energy** in an object is the total kinetic energy of all the particles that make up the object.

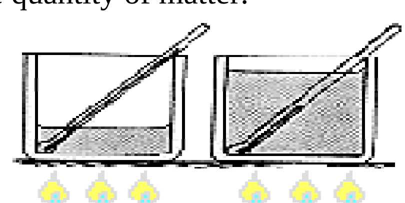


Temperature is a measure of the average kinetic energy of all the particles in the object. The number for the temperature of an object doesn't tell you much about the actual kinetic energy of a particle inside the object. The number comes from a temperature scale such as the kind found on a common thermometer.

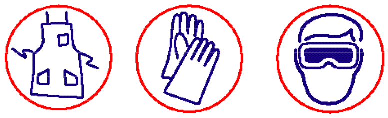
A thermometer measures temperature by means of the expansion and contraction of a liquid, usually mercury or colored alcohol. The reason that this works is that the liquid in a thermometer expands or contracts in a predictable, repeatable way when it gains or loses thermal energy. For example, the mercury in a thermometer always expands to the same level when the end of the thermometer is in boiling water. It always shrinks to the same level when the end of the thermometer is in ice-cold water. The number on the temperature scale is a way to make comparisons. If we say that a certain liquid has a temperature of 0˚ C, it means that the mercury in a thermometer put into this liquid would shrink to the same level as it did when the thermometer was put into ice-cold water.

The amount of thermal energy in an object is related to temperature, but temperature by itself can't tell you have much thermal energy is in an object. For example, a bed of glowing coals in a fireplace might have a temperature of 600 ˚C while a single spark from the fire might have a temperature of 2000˚ C. The single "hot" spark gives off very little heat while the bed of relatively "cool" coals gives off a large amount of heat. The difference between the bed of coals and the single spark has to do with both the temperature and the quantity of matter.

Identical thermometers in two pots of water on a hot stove will show different temperatures even if the pots have been on the stove for the same time if the amount of water in one pot is different than the amount in the other.



SAFETY REMINDERS



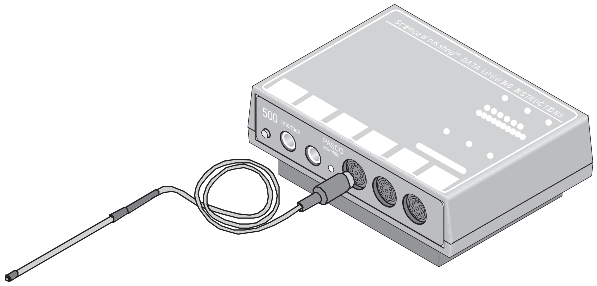
- Wear protective gear.
- Follow directions for using the equipment.
- Be sure that the heating resistor is in the water before you turn on the power supply.

For You To Do

Use the Temperature Sensor to measure the temperature of 100 mL water as a heating resistor heats it for a set amount of time. Then use the sensor to measure the temperature of 200 mL of water as the same resistor heats it for the same amount of time. Both measurements start at the same temperature.

Use *DataStudio* or*ScienceWorkshop* to record and display the data. Compare the final temperature of the 100 mL sample of water to the final temperature of the 200 mL sample of water.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Temperature Sensor into Analog Channel A on the interface.
3. Open the document titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS22 Heat v Temperature.DS	G22 Heat v. Temperature	G22_TEMP.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document opens with a Graph display of Temperature versus Time, a Digits display of Temperature, and a Table display of Temperature.
- Data recording is set for 1 second per measurement, a ‘Start Condition’ = Channel A at 0.20 volts, and a ‘Stop Condition’ = Time at 600 seconds (or 10 minutes).

Name ____________________ Class ______________ Date _________

PART II: Sensor Calibration and Equipment Setup

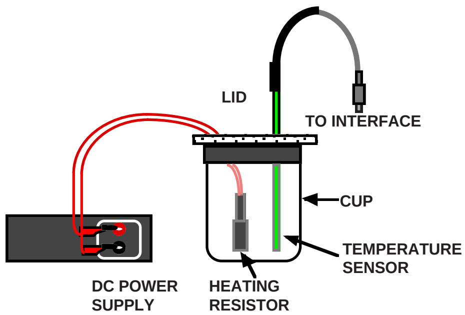
- You do not need to calibrate the Temperature Sensor.

1. If you have a lid that will fit over the top of the cup, make one hole in the lid for the Temperature Sensor, and a second hole in the lid for the heating resistor.
2. Put 100 mL of water in the foam cup.

- NOTE: Start with water that is about two degrees below 20 ˚C. The program will begin recording data when the water warms up to 20 ˚C.

3. Connect the banana plugs of the heating resistor into the output jacks of the power supply.
4. Put the heating resistor through its hole in the lid. Submerge the resistor in the water.
5. Put the Temperature Sensor through its hole in the lid of the cup.

- CAUTION: Be sure the resistor is submerged in water when the current is flowing through it. Otherwise it can burn up!



PART III: Data Recording

1. Set the DC power supply to output 10 volts. The current through the resistor will be 1 amp. Turn on the power supply.
2. Start recording data. (Click 'Start' in *DataStudio* or click 'REC' in *ScienceWorkshop*.) Data recording <u>begins</u> when the temperature of the water reaches 20 ˚C.

- Watch the Digits display to keep track of the temperature.

IMPORTANT: While the power supply is ON, gently swirl the water in the cup so the water will be heated evenly.

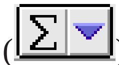
3. Data recording stops automatically at ten minutes. When data recording stops, turn off the DC power supply.
4. Remove the sensor and heating resistor from the cup. Pour out the 100 mL of warmed water.
5. Put 200 mL of water into the cup. Use water that is about two degrees below 20 ˚C.
6. Put the sensor and heating resistor back into the cup.
7. Turn on the power supply.
8. Start the second measurement. Data recording <u>begins</u> when the temperature of the water reaches 20 ˚C.
9. Watch the Digits display to keep track of the temperature.

- IMPORTANT: While the power supply is ON, gently swirl the water in the cup so the water will be heated evenly.

10. Data recording stops automatically at ten minutes. When data recording stops, turn off the DC power supply.
11. Remove the sensor and heating resistor from the cup. Pour out the 200 mL of warmed water.

Analyzing the Data

1. Set up the Graph to show statistics such as Minimum and Maximum.

- Hint: In *DataStudio*, click 'Statistics' () in the Graph toolbar. In *ScienceWorkshop*, click the 'Statistics' button to open the Statistics area on the right side of the Graph. Then click the 'Statistics Menu' button.

2. Set up the Table to show statistics such as Minimum and Maximum
3. Record the Minimum and Maximum temperatures for the first run of data.
4. Record the Minimum and Maximum temperatures for the second run of data.
5. Record the amount of water used for each run.
6. Find the change in temperature for each run and record it.

Record your results in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the 'File' menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give <u>your</u> document a new filename.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS22: Heat vs. Temperature

What Do You Think?

What is the relationship between **heat**, **thermal energy**, and **temperature**?

Data Table

Item	Run #1	Run #2
Amount of Water	mL	mL
Temperature (maximum)	˚C	˚C
Temperature (minimum)	˚C	˚C
Change in Temperature (ΔT)	˚C	˚C

Questions

1. What is the change in temperature for the 100 mL of water in Run #1?

2. What is the change in temperature for the 200 mL of water in Run #2?

3. How does the change in temperature for Run #1 compare to the change in temperature for Run #2?

4. Did the 100 mL of water receive the same, more than, or less thermal energy than the 200 ml of water? Why?

5. Why is the final temperature for the 200 mL of water different than the final temperature for the 100 mL of water?

Name ____________________ Class _____________ Date _________

Activity GS23: Heat Transfer
(Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Energy	GS23 Heat Transfer.DS	G23 Heat Transfer	G23_HEAT.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Temperature Sensor (CI-6505A)	2	Thermal insulation pads	2
Aluminum can, black (TD-8570A)	1	Tongs (for handling cans with hot water)	1
Aluminum can, plain (TD-8570A)	1	Protective gear	PS
Fan (optional)	1	**Consumables**	**Qty**
Heat lamp (optional)	1	Water, hot (90˚C)	800 mL

What Do You Think?

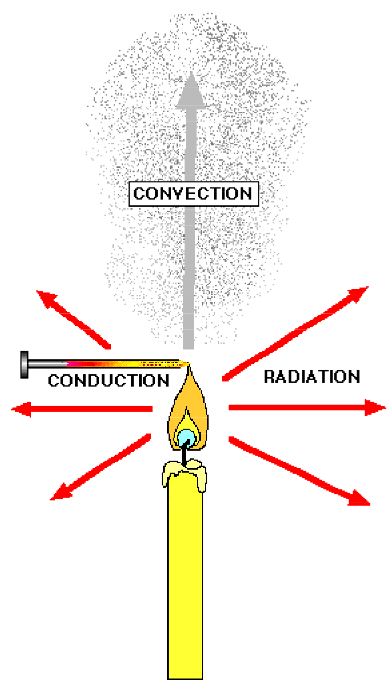
Parts of robot spacecraft are painted black while other parts are left unpainted. Part of the reason is that unpainted sections of the spacecraft hull absorb energy more slowly than sections that are painted black. Do you think the reverse is possible, will an unpainted aluminum can emit energy faster or slower than a black colored aluminum can?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

Heat is energy in transit. Heat transfer happens when two objects are at different temperatures.

Heat is transferred in three ways: **conduction**, **convection**, and **radiation**. When an aluminum can full of hot water sits in a room, the water loses heat by conduction through the aluminum sides (by direct contact with cooler molecules), by convection as air molecules collide with the aluminum, and by radiation as electromagnetic waves are emitted from the can's surface.



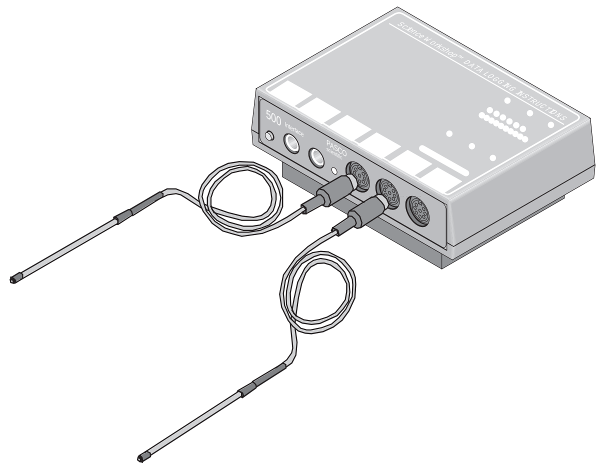
SAFETY REMINDERS			
• Wear protective gear. • Follow directions for using the equipment. • Wear gloves and use tongs when handling the cans with hot water in them.			

For You To Do

In this activity, put hot water into two aluminum cans, one unpainted and the other painted black. Use the Temperature Sensors to measure the temperature of the water in each can as it cools. Use *DataStudio* or *ScienceWorkshop* to record and display the temperatures for each can.

Examine the plot of temperature versus time to find can transfers heat fastest.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect one Temperature Sensor to Analog Channel A. Connect the second Temperature Sensor to Analog Channel B on the interface box.
3. Open the document titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS23 Heat Transfer.DS	G23 Heat Transfer	G23_HEAT.SWS

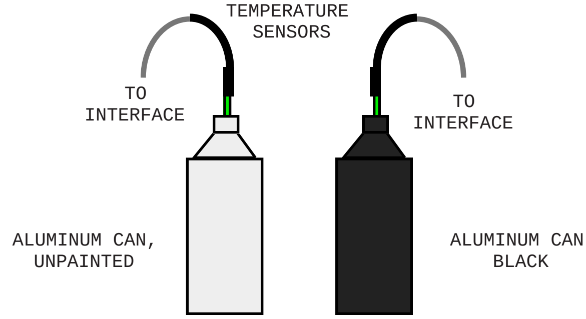
- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document opens with a Graph display showing plots of Temperature vs. Time for each Temperature Sensor. .
- Data recording is set for one measurement each 10 seconds and a 'Stop Condition' = Time at 900 seconds (15 minutes).

Name ____________________ Class ______________ Date _________

PART II: Sensor Calibration and Equipment Setup

- You do not need to calibrate the Temperature Sensors.

1. Prepare the two aluminum cans (one unpainted and one painted black). Heat approximately 800 milliliters of water to 90˚ C, but don't fill the cans with water yet. Place each can on an insulated pad. Keep the cans away from drafts.



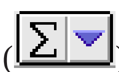
2. Fill each can to the same level with hot (90 C) water (approximately 200 ml). Put Temperature Sensor A into the unpainted can and Temperature Sensor B into the black can.

PART III: Data Recording

1. When you are ready, start recording data. Data points will begin to appear in the graph every 10 seconds.
2. Swirl the water in the cans continuously for 15 minutes. Data collecting will stop automatically at 15 minutes.

Analyzing the Data

1. Set up your Graph to show statistics

- Hint: In *DataStudio*, click 'Statistics' () in the Graph toolbar. In *ScienceWorkshop*, click the Statistics button to open the Statistics area on the right side of the Graph. Then click the Statistics Menu button.

2. Record the maximum y value as the Maximum temperature. Record the minimum y value as the Minimum temperature.

Record your results in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the 'File' menu to save your data for this activity and the changes you've made to the document.

- The original document is "locked", so you should give <u>your</u> document a new filename.

Name ____________________ Class ______________ Date _________

Lab Report – Activity GS23: Heat Transfer

What Do You Think?

Parts of robot spacecraft are painted black while other parts are left unpainted. Part of the reason is that unpainted sections of the spacecraft hull absorb energy more slowly than sections that are painted black. Do you think the reverse is possible, will an unpainted aluminum can emit energy faster or slower than a black colored aluminum can?

Data Table

Can	Maximum temperature	Minimum temperature
Unpainted	˚C	˚C
Black	˚C	˚C

Questions

1. Which can cooled down faster?

2. When the cans are cooling, which processes transfer heat? Which process do you think is dominant?

3. When a can is cooling, does it cool faster at the beginning of the experiment or toward the end of the experiment? Why?

Optional: Save Your Data

NOTE: You may want to save the original experiment and data before beginning the optional activities.

Optional: Cooling With A Fan

Repeat the experiment but put a fan next to the cans so the air blows equally on each of the cans. Turn on the fan and begin recording data.

Optional: Heating With A Lamp

Fill the cans with room temperature water. Put the Temperature Sensors in each can as before. Place a heat lamp near the cans so that the cans are equally illuminated. Turn on the lamp and begin recording data.

Optional Questions

1. How much faster does each can cool when the fan is on? (To compare the cooling times, find out how much time it took for each can to cool from about 85 ˚C to 80 ˚C with and without the fan. Divide the cooling time without the fan by the cooling time with the fan for each can.)

2. When the can is cooling with the fan, what processes transfer heat? Which process is dominant?

3. Which can heated faster?

4. When the can is being heated with a lamp, which processes transfer heat? Which process is dominant?

Name ____________________ Class ______________ Date _________

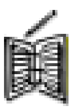
Activity GS24: Pressure vs. Temperature
(Pressure Sensor, Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Gas laws	GS24 Pres and Temp.DS	G24 Pressure & Temp	G24_PAT.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Pressure Sensor (CI-6532A)	1	Tongs	1
Temperature Sensor (CI-6505A)	1	**Tubing, plastic (w/sensor)**	1
Beaker, 1 L	1	Turkey baster	1
Connector, rubber stopper (w/sensor)	1	Protective gear	PS
Coupling, quick-release (w/sensor)	1	**Other**	**Qty**
Flask, Erlenmeyer, 125 mL	1	Glycerin	1 mL
Hot plate (for hot water bath)	1	Ice, crushed	1 L
Rubber stopper, one-hole	1	Water	3 L

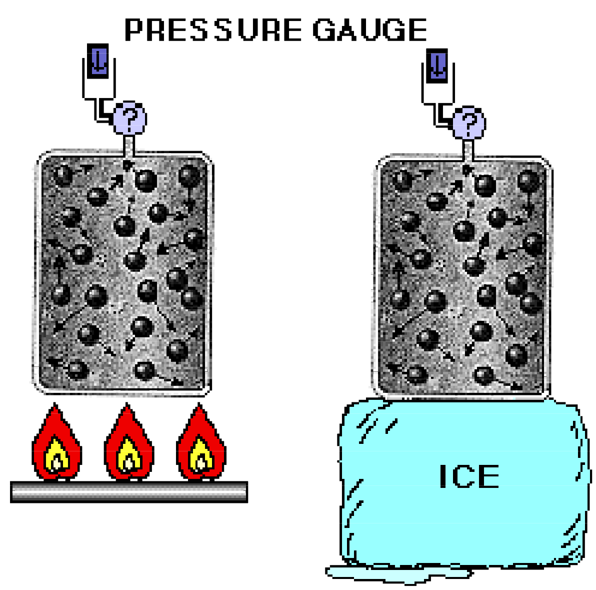
What Do You Think?

What is the relationship between the pressure of a gas and the temperature of a gas if its volume remains constant as the temperature changes?



Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



Solid, liquid and gas are the most common states of matter found on this planet. The only difference among all these states is the amount of movement of the particles that make up the substance.

Temperature is a measure of the relative movement of particles in a substance because temperature is a measure of the average kinetic energy of the particles. In a gas at high temperature, the molecules of gas move around very fast. In a gas at lower temperature, the molecules do not move as rapidly.

Pressure is a ratio of the force applied to a surface divided by the area of the surface.

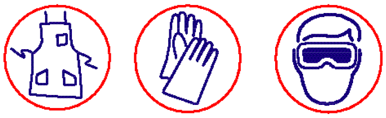
The pressure from our atmosphere is about 100,000 newtons per square meter (14.7 pounds per square inch). This is because the weight of air above a one square meter surface is 100,000 newtons (or about 10 tons).

For a gas in a container, molecules collide with the inside surface of the container. Each colliding molecule exerts force against the surface.

If the molecules in a high temperature gas move fast, they have more speed (on average) when they collide with the inside surface of the container. Molecules in a lower temperature gas have less speed when they collide. The force exerted by the high-speed colliding molecules is greater than the force exerted by the low-speed molecules.

A pressure gauge on a container of hot gas will measure a different pressure than a gauge on a container of cooler gas, assuming that the volume of gas is the same in both containers.

SAFETY REMINDERS



- Wear protective gear.
- Follow directions for using the equipment.
- Be very careful when you heat water.

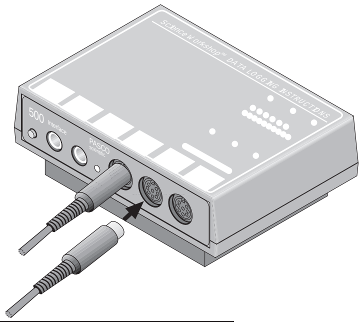
For You To Do

Start Heating the Water Bath

- Put about 600 mL of water into a large beaker and put the beaker on a hot plate. Start to heat the water to *almost* boiling. Check the water bath occasionally as you set up the rest of the equipment.

Use the Pressure Sensor to measure the pressure inside a flask and use the Temperature Sensor to measure the temperature of the water bath in which the flask is immersed. Use *DataStudio* or *ScienceWorkshop* to plot the pressure and temperature data onto a graph. Use the graph to determine the relationship of pressure and temperature.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Temperature Sensor to Analog Channel A on the interface. Connect the DIN plug of the Pressure Sensor to Analog Channel B on the interface.
3. Open the file titled as shown;

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS24 Pres and Temp.DS	G24 Pressure & Temp	G24_PAT.SWS

- The file has displays of the gas pressure and the temperature of the water bath.
- The *DataStudio* file also has a Workbook display. Read the instructions in the Workbook.
- Data recording is set at one measurement every 10 seconds.

Name ____________________ Class _____________ Date _________

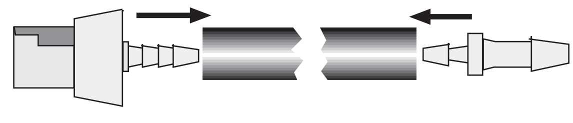
PART II: Sensor Calibration and Equipment Setup

You do not need to calibrate the sensors.

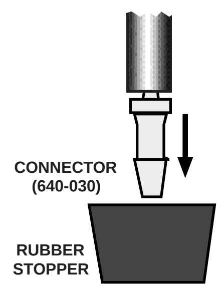
Set Up the Equipment

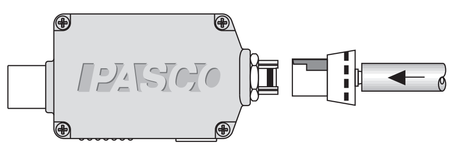
- For this part you will need the following: glycerin, quick-release coupling, connector, plastic tubing, rubber stopper, flask, and Pressure Sensor

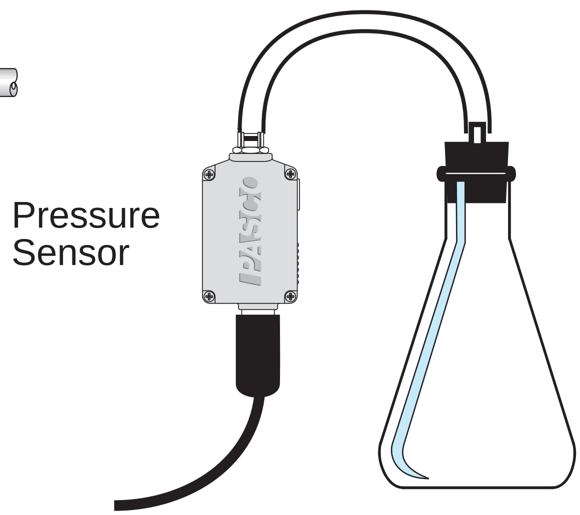
1. Put a drop of glycerin on the barb end of a quick release coupling. Put the end of the quick release coupling into one end of a piece of plastic tubing (about 15 cm) that comes with the Pressure Sensor.



2. Put a drop of glycerin on the barb end of the connector. Push the barb end of the connector into the other end of the plastic tubing.
3. Fit the end of the connector into the one-hole rubber stopper.
4. Push the rubber stopper firmly into the flask.
5. Align the quick-release coupling on the end of the plastic tubing with the pressure port of the Pressure Sensor. Push the coupling onto the port, and then turn the coupling clockwise until it clicks (about one-eighth turn).





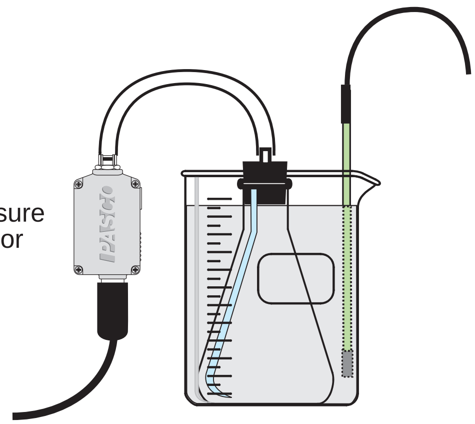


PART III: Data Recording

1. Carefully remove the beaker from the hot plate. Turn off the hot plate.
2. Put the flask into the beaker of hot water. Use tongs to hold the flask down in the water.
3. Put the Temperature Sensor into the hot water.
4. When you are ready, record pressure and temperature measurements.

- (Hint: Click 'Start' in *DataStudio* or 'REC' in *ScienceWorkshop*.)

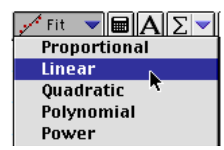
5. Watch the Digits display to check the pressure and temperature.
6. Add ice to the hot water to lower the temperature.



7. As the ice melts, add more to the water. Use the turkey baster to remove extra water so the level in the container stays about the same.
8. Continue to add ice to the water until the temperature reaches about 20˚ C, and then stop recording data.

Analyzing the Data

1. Use the Graph display to determine whether or not the relationship of pressure and temperature is linear.



- In *DataStduio*, click 'Fit' and select 'Linear' from the menu. In *ScienceWorkshop*, click 'Statistics' and select 'Curve Fit, Linear Fit' from the 'Statistics Menu'.
- If the relationship is linear, the data will fit a straight line closely. In *DataStudio*, if the coefficient 'r' (coefficient of linear regression) is close to 1, the relationship is linear. In *ScienceWorkshop*, if the chi^2 value is close to zero, the relationship is linear.

2. Use the Graph display's built-in statistics to find the minimum and maximum temperature and the minimum and maximum pressure.
3. Use your observations and data to answer the questions in the Lab Report.

Record your results in the Lab Report section.

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'File' menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS24: Pressure versus Temperature

What do you think?

What is the relationship between the pressure of a gas and the temperature of a gas if its volume remains constant as the temperature changes?

Data Table

	minumum	maximum
Temperature	˚C	˚C
Pressure	kPa	kPa

Questions

1. What happens to the pressure as the temperature drops?

2. Based on the Graph of Pressure vs. Temperature, what is the relationship between the pressure of a gas and the temperature of a gas that has a constant volume?

3. If a gas is inside a closed container and the temperature of the gas increases, what do you predict will happen to the pressure of the gas?

Name ____________________ Class _____________ Date _________

Activity GS25: Endothermic and Exothermic Reactions (Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Chemistry	GS25 Endo and Exo React.DS	G25 Endo-Exo Reactions	G25_ENDO.SWS

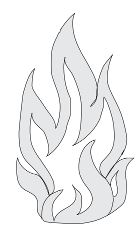
Equipment Needed	**Qty**	**Chemicals and Consumables**	**Qty**
Temperature Sensor (CI-6505A)	1	Citric acid ($H_3C_6H_5O_7$), 1.5 Molar	30 mL
Balance (SE-8723)	1	Hydrochloric acid (HCl), 0.5 Molar	30 mL
Beaker, 250 mL	1	Baking soda ($NaHCO_3$)	10.0 g
Graduated cylinder, 50 mL	1	Magnesium ribbon (Mg)	20.0 cm
Protective gear	PS	Styrofoam cup	1
		Weighing paper	1

What Do You Think?

Many familiar chemical reactions involve the release of energy, such as combustion. Are there any chemical reactions that involve the absorption of energy?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



Many chemical reactions give off energy. Chemical reactions that release energy are called exothermic reactions. These reactions often require a small amount of energy to get started.

Some chemical reactions absorb energy and are called endothermic reactions. The first-aid device called a 'cold pack' uses a type of endothermic reaction. Ammonium nitrate mixes with water when the inner seal inside the cold pack is broken. As the ammonium nitrate dissolves, a chemical reaction takes place and the temperature of anything in contact with the pack – such as a sprained ankle – goes down.

You will study one exothermic and one endothermic reaction in this activity.

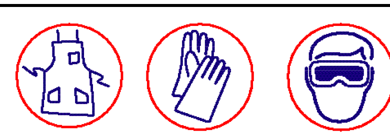
First, you will study the reaction between citric acid solution and baking soda. An equation for the reaction is:

$$H_3C_6H_5O_7(aq) + 3\ NaHCO_3(s) \text{ ---> } 3\ CO_2(g) + 3\ H_2O(l) + Na_3C_6H_5O_7(aq)$$

Next, you will study the reaction between magnesium metal and hydrochloric acid. An equation for this reaction is:

$$Mg(s) + 2\ HCl(aq) \text{---> } H_2(g) + Mg\ Cl_2\ (aq)$$

SAFETY REMINDERS

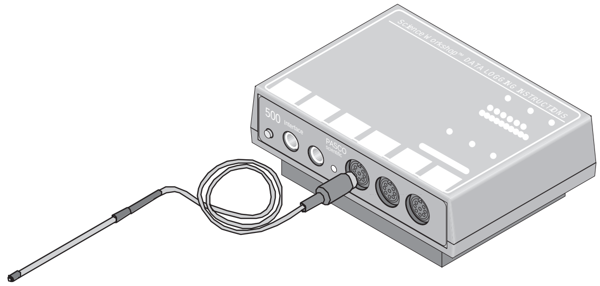


- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the Temperature Sensor to measure the change in temperature of a chemical reaction that releases energy. Then measure the change in temperature of a chemical reaction that absorbs energy. Use *DataStudio* or *ScienceWorkshop* to record and analyze the data.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Temperature sensor's DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown:

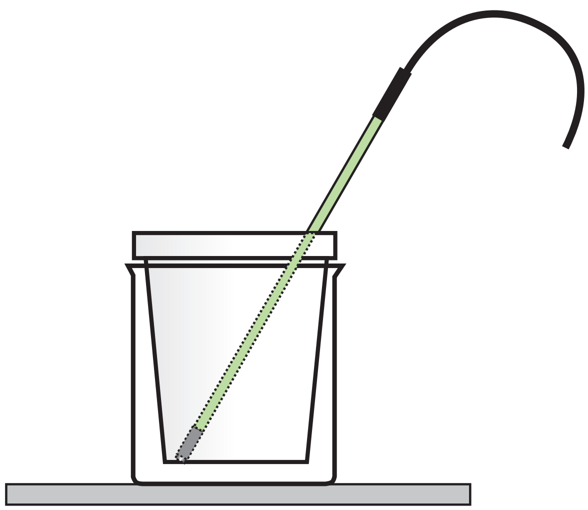
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS25 Endo and Exo React.DS	G25 Endo-Exo Reactions	G25_ENDO.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Graph display of Temperature versus Time.
- Data recording is set for one measurement per second. Data recording stops automatically at 250 seconds (about 4 minutes).

PART II: Sensor Calibration and Equipment Setup

You do not need to calibrate the sensor.

1. Place a Styrofoam cup into the 250 mL beaker as shown in the diagram. Put 30 mL of 1.5 Molar citric acid into the cup. Place the Temperature Sensor into the citric acid solution.
2. Weigh out 10.0 g of solid baking soda on a piece of weighing paper.



Name ____________________ Class ______________ Date _________

PART IIIA: Data Recording - Reacting Citric Acid and Baking Soda

1. Get ready to record data. The Temperature Sensor must be in the citric acid solution for a few seconds before you begin recording data.
2. When everything is ready, start recording data.
3. After about 20 seconds, add the baking soda to the citric acid solution.
4. Gently stir the solution with the Temperature Sensor to ensure good mixing.
5. Record data until a minimum temperature has been reached and temperature readings begin to increase or let the computer automatically end it after 250 seconds.
6. Dispose of the reaction products as directed by your teacher. Rinse the cup.

PART IIIB: Data Recording - Reacting Magnesium and Hydrochloric Acid

1. Measure out 30 mL of HCl solution into the Styrofoam cup. Place the Temperature Sensor into the HCl solution.
2. Obtain a 20.0 cm piece of shiny magnesium metal from the teacher.
3. Get ready to record data. Note: The Temperature Sensor must be in the HCl solution for a few seconds before you begin recording data.
4. When everything is ready, begin data recording.
5. After about 20 seconds, add the magnesium ribbon to the acid solution.
6. Gently stir the solution with the Temperature Sensor to ensure good mixing.
7. Record data until a maximum temperature has been reached and temperature readings begin to decrease or let the computer automatically end it after 250 seconds.
8. Dispose of the reaction products as directed by your teacher. Rinse the cup.

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select ‘Quit’ from the ‘Fil’e menu to end the activity.
2. You can select ‘Save’ or ‘Save As…’ from the File menu to save your data for this activity. the changes you’ve made to the document.

- The original document is “locked”, so you should give your document a new filename.

3. If you wish to go on to the next activity, select ‘Open…’ from the ‘File’ menu, and find the document for the next activity.

Analyzing the Data

1. Set up your Table display so it shows both runs of data (that is, Run #1 for Citric Acid and Baking Soda and Run #2 for Magnesium and Hydrochloric Acid).

- Use the Table's analysis tools to find the minimum and maximum values for temperature for Run #1. Hint: Look at the graph to determine if the minimum or maximum occurred first. Record the initial temperature. Record the other as the final temperature.

2. Find the minimum and maximum values for temperature for Run #2. Look at the graph to determine if the minimum or maximum occurred first. Record this value as the initial temperature in the Data Table. Record the other as the final temperature.
3. Calculate the temperature change for each reaction by subtracting the initial temperature from the final temperature.

Record your results in the Lab Report section.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS25: Endothermic and Exothermic Reactions

What Do You Think?

Many familiar chemical reactions involve the release of energy, such as combustion. Are there any chemical reactions that involve the absorption of energy?

Data Table

	Run #1: Citric Acid - Baking Soda	Run #2: Hydrochloric Acid - Magnesium
Final temperature (°C)		
Initial temperature (°C)		
Temperature change (°C)		

Questions

1. Which reaction had a negative temperature change (ΔT)? Is the reaction endothermic or exothermic? Explain.

2. For each reaction, describe three ways you could tell a chemical reaction was taking place.

3. Which reaction took place at a greater rate? Explain your answer.

Name ____________________ Class ______________ Date _________

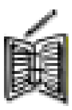
Activity GS26: Freezing and Melting of Water (Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Phase change	GS26 Freeze Melt Water.DS	G26 Freeze & Melt Water	G26_MELT.SWS

Equipment Needed	Qty	Chemicals and Consumables	Qty
Temperature Sensor (CI-6505A)	1	Ice, cube	12 - 15
Base and Support Rod (ME-9355)	1	Salt	40 mL
Beaker, 500 mL	1	Water	500 mL
Clamp, Buret (SE-9446)	1		
Clock	1		
Graduated cylinder, 100 mL	1		
Slit stopper	1		
Stirring rod	1		
Test tube	1		
Protective gear	PS		

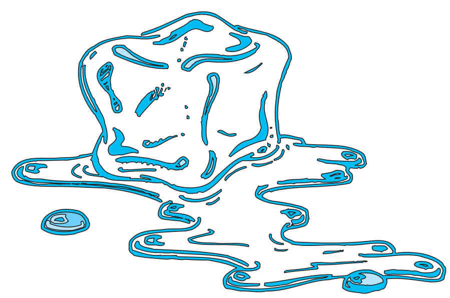
What Do You Think?

How does the freezing temperature of water compare to the melting temperature of ice? Are they the same or not?



Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



When a substance changes from solid to liquid or vice versa, or from liquid to gaseous or vice versa, the substance goes through a phase change. **Freezing temperature** is the temperature at which a substance turns from liquid to solid. For example, the temperature at which liquid water turns into solid ice is the freezing temperature of water.

Melting temperature is the temperature at which a substance turns from a solid to a liquid. For example, the temperature at which solid ice turns into liquid water is the melting temperature of ice.

These temperatures are characteristic physical properties of a substance

SAFETY REMINDERS

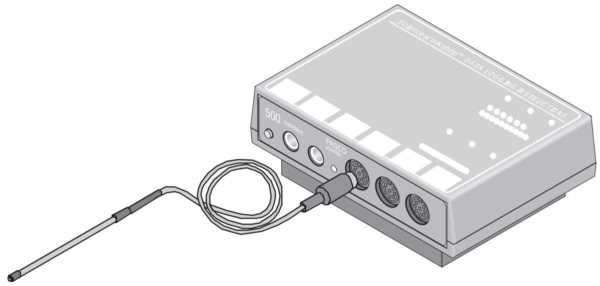
- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the Temperature Sensor to measure the change in temperature of a sample of water as it freezes in an ice water bath. Then measure the change in temperature as the frozen water melts after being removed from the water bath. Use *DataStudio* or *ScienceWorkshop* to record and analyze the data.

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Temperature Sensor into Analog Channel A of the interface.



3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS26 Freeze Melt Water.DS	G26 Freeze & Melt Water	G26_MELT.SWS

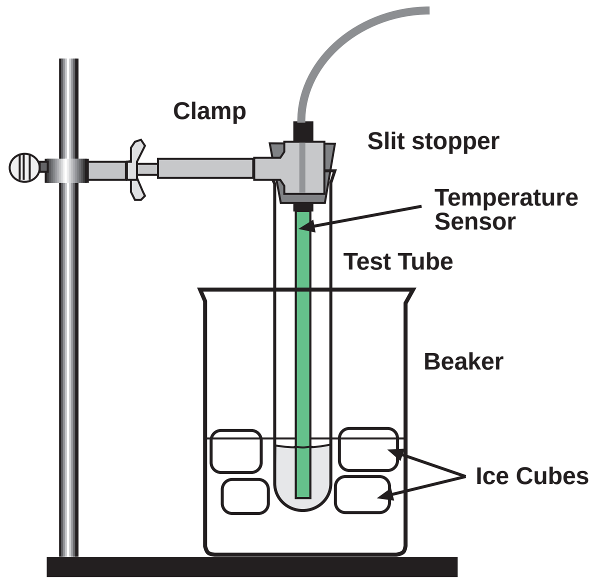
- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* file has a Digits display, a Graph display, and a Table display of Temperature versus Time.
- Data recording is set for one measurement per 30 seconds. Data recording stops automatically at 1800 seconds (30 minutes).

Name ____________________ Class _____________ Date _________

PART II: Sensor Calibration and Equipment Setup

You do not need to calibrate the sensor.

1. Set up the equipment as shown. Put about 100 mL of water and 5 or 6 ice cubes into a 500-mL beaker.



2. Put 5 mL of water into a test tube. Set up the test tube so it is *above* the ice water bath at the beginning.
3. Place the Temperature Sensor into a slit stopper and place the stopper in the test tube so the end of the sensor is in the water inside the test tube.

PART IIIA: Data Recording for Freezing

1. When everything is ready, start recording data. Then *lower the test tube* into the ice-water bath. (The computer will record data for a total of 30 minutes.)
2. Soon after lowering the test tube, begin to add salt to the beaker while stirring with a stirring rod. Add salt until the temperature goes down to about –5 ˚C.

Note: Continue to stir the ice-water bath during this part of the procedure.

3. Gently but continuously move the sensor during the first 10 minutes of this part.

   Be careful to keep the sensor in, and not above, the ice as it forms.

4. When 10 minutes have gone by, stop moving the sensor and allow it to freeze into the ice.

   Observe how the ice forms in the test tube as the water freezes.

   Add more ice cubes to the beaker as the original ice cubes get smaller.

5. Continue recording data until the data recording stops automatically at 30 minutes.
6. Keep the test tube submerged in the ice-water bath for now.

PART IIIB: Data Recording for Melting

1. Get ready for a second run of data recording.
2. Start recording data. Then raise the test tube and fasten it into position *above* the edge of the beaker.
3. Do not move the sensor during this part of the procedure. (Let it stay in the ice.)
4. Dispose of the ice water in the beaker as directed.
5. Put about 250 mL of warm water in the beaker and get ready to place the beaker under the test tube. *When 10 minutes have passed*, lower the test tube and its contents into this warm-water bath.
6. When 15 minutes have passed, stop the data recording.

Analyzing the Data

1. Set up your Table display so it shows both runs of data (that is, Run #1 for freezing and Run #2 for melting).

   Hint: Drag data runs to the Table display in *DataStudio* to add data runs to the Table. Use the 'Add Column' menu in *ScienceWorkshop* to add data runs to the Table.

2. Set up your Graph display so it shows both runs of data.

   (If desired, rescale the Graph to fit the data.)

Record your results in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'Fil'e menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give <u>your</u> document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

Name ____________________ Class ______________ Date _________

Lab Report - Activity GS26: Freezing and Melting of Water

What Do You Think?

How does the freezing temperature of water compare to the melting temperature of ice? Are they the same or not?

Questions

1. What happened to the water temperature during freezing? What happened to the water temperature during melting?

2. According to your data and graph, what is the freezing temperature of water?

   Hint: Use the Smart Tool in DataStudio or the Smart Cursor in *ScienceWorkshop* in order to determine the coordinates at any particular point.) What seems to be the melting temperature? Express your answers to the nearest 0.1 C.

3. How does the freezing temperature of water compare to its melting temperature?

4. What happens to the kinetic energy of the water in the test tube during each of the following parts of the activity? (Does it increase, decrease, or remain the same?)

   a. when temperature changes at the beginning and end of Part IIIA

   b. when temperature remains constant in Part IIIA

   c. when temperature changes at the beginning and end of Part IIIB

   d. when temperature remains constant in Part IIIB

Name ____________________ Class _____________ Date _________

Activity GS27: Chemical Equilibrium (Pressure Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Rate of reactions	C18 Equilibrium.DS	C19 Chemical Equilibrium	C19_CHEM.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Pressure Sensor (CI-6532A)	1	**Tubing (w/sensor)**	1
Connector, rubber stopper (w/sensor)	1	Protective gear	PS
Coupling, quick release (w/sensor)	1	**Chemicals and Consumables**	**Qty**
Flask, 250 mL	1	Glycerin	1 mL
Graduated cylinder	1	Soda water, cold	100 mL
Rubber stopper, one-hole	1	Soda water, warm	100 mL

What Do You Think?

The purpose of this activity is to find out if a system in chemical equilibrium is sensitive to temperature. For example, will cold soda water or warm soda water reach chemical equilibrium faster?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

The process of chemical equilibrium is dynamic. The term dynamic means that even though no macroscopic chemical changes are noticeable, microscopic chemical changes are occurring constantly.

In any chemical reaction, the substances that react (called the **reactants**) combine with each other to form products. A general reaction could be written:

A + B ======> C

The equation states that "chemical A reacts with chemical B at a set rate to produce C". This is a **kinetic** reaction which proceeds in only one direction. This is not a system in equilibrium.

Suppose that chemical C breaks down at certain rate to reform chemicals A and B. This is also a reaction in only one direction so the system is not in equilibrium.

C ======> B + A

When the two reactions are combined and the rate of the forward reaction equals the rate of the reverse reaction the two opposing reactions are said to be at equilibrium.

A + B <=======> C

Carbonic acid decomposes to form carbon dioxide and water in the following equilibrium system:

$$H_2CO_{3(aq)} \Longleftrightarrow CO_{2(g)} + H_2O_{(aq)}$$

carbonic acid carbon dioxide water

The carbon dioxide then reacts with water to reform carbonic acid. The forward reaction occurs every time you open a soda bottle or pour soda into a glass. The carbonic acid **decomposes** to form the 'fizz' that we associate with most soft drinks.

When you cap the bottle, the carbon dioxide gas begins to re-dissolve in the soda water to reform carbonic acid. If the reverse reaction (called **reformation**) also takes place inside a closed container, the pressure inside the container will stop increasing. The reactions still occur at the microscopic level but there is no evidence of any macroscopic change. You will know when the carbonic acid/carbon dioxide system has reached equilibrium when there is no further change in the pressure in the soda bottle.

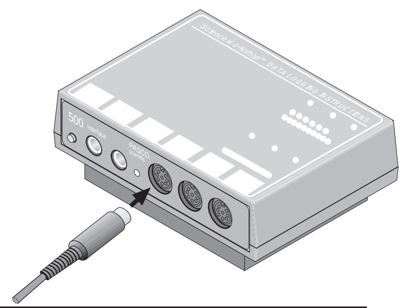
SAFETY REMINDERS

- Wear protective gear.
- Follow directions for using the equipment.
- Handle and dispose of all chemicals and solutions properly.

For You To Do

Use the Pressure Sensor to measure the change in pressure inside a rigid container as a small amount of soda water decomposes. Use *DataStudio* or *ScienceWorkshop* to record and display the data. Compare the data collected for cold soda water to the data collected for warm soda water.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Pressure Sensor's DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
C18 Equilibrium.DS	C19 Chemical Equilibrium	C19_CHEM.SWS

- The *DataStudio* file has a Graph display of pressure versus time. Read the instructions in the Workbook display.
- The *ScienceWorkshop* document has a Graph display of pressure versus time.
- Data recording is set for one measurement per second.

Name ____________________ Class _____________ Date ________

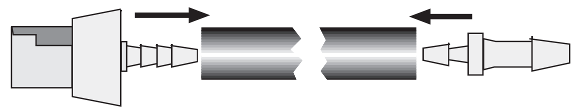
PART II: Sensor Calibration and Equipment Setup

You do not need to calibrate the sensor.

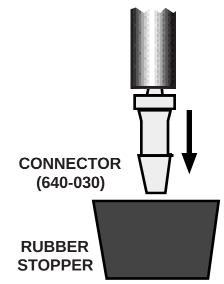
Set Up the Equipment

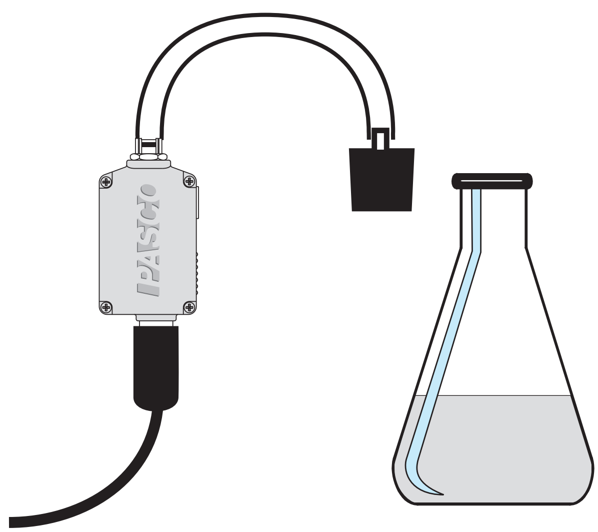
- For this part you will need the following: glycerin, quick-release coupling, connector, plastic tubing, rubber stopper, flask, graduated cylinder, and warm (room temperature) soda water.

1. Put a drop of glycerin on the barb end of a quick release coupling. Put the end of the quick release coupling into one end of a piece of plastic tubing (about 15 cm) that comes with the Pressure Sensor.



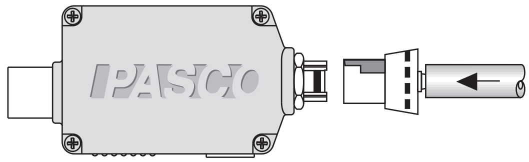
2. Put a drop of glycerin on the barb end of the connector. Push the barb end of the connector into the other end of the plastic tubing.
3. Fit the end of the connector into the one-hole rubber stopper.
4. Put 100 mL of warm (room temperature) soda water in the flask.





PART IIIA: Data Recording – Warm Soda Water

1. Put the rubber stopper firmly into the top of the flask.
2. Align the quick-release coupling on the end of the plastic tubing with the pressure port of the Pressure Sensor. Push the coupling onto the port, and then turn the coupling clockwise until it clicks (about one-eighth turn).



3. When everything is ready, begin data recording. (Hint: Click ‘Start’ in *DataStudio* or ‘REC’ in *ScienceWorkshop*.)

   What do you predict the graph of pressure versus time will look like?

• Observe the change in pressure as the carbonic acid decomposes in the flask.

4. Continue collecting data for about 6 minutes and then stop recording data.
5. Slowly remove the rubber stopper from the bottle. Disconnect the quick-release coupling from the Pressure Sensor.
6. Dispose of the soda water. Rinse the flask with cold water.

PART IIIB: Data Recording – Cold Soda Water

1. Put 100 mL of cold soda water in the flask. Put the rubber stopper firmly into the top of the flask.
2. Align the quick-release coupling on the end of the plastic tubing with the pressure port of the Pressure Sensor. Push the coupling onto the port, and then turn the coupling clockwise until it clicks (about one-eighth turn).
3. When everything is ready, begin data recording.

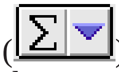
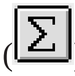
   How will the graph of the cold soda water differ from the graph of the room temperature soda water?

4. Continue collecting data for about 6 minutes and then stop recording data.
5. Slowly remove the rubber stopper from the bottle. Disconnect the quick-release coupling from the Pressure Sensor.
6. Dispose of the soda water. Rinse the flask.

Name ____________________ Class _____________ Date _________

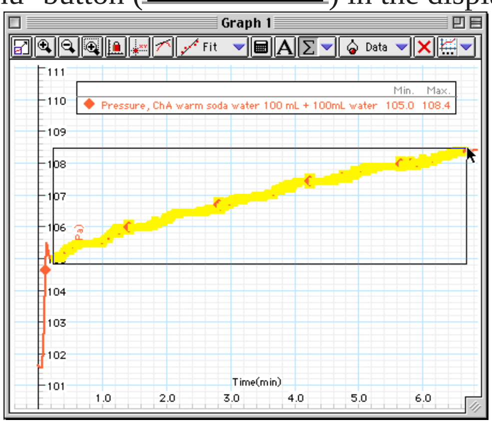
Analyzing the Data

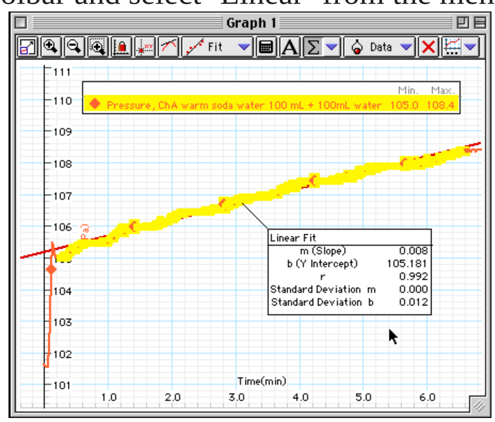
1. Use the built-in statistics tools in the Graph display to find the minimum and maximum values for pressure for each run of data.

- Hint: In *DataStudio*, click the ‘Statistics menu’ button () in the display toolbar. The legend in the Graph display will show the minimum and maximum pressure.
- Hint: In *ScienceWorkshop*, click the ‘Statistics’ button () to open the statistics area. Click the ‘Statistics menu’ button () in the statistics area and select Minimum and Maximum from the menu.

2. Record the values in the Lab Report section.
3. Use the built-in analysis tools in the Graph display to find the slope of the pressure versus time.

- Hint: In *DataStudio*, use the cursor to select a region of the plot of pressure. Click the ‘Fit menu’ button () in the display toolbar and select ‘Linear’ from the menu.





- Hint: In *ScienceWorkshop*, use the cursor to select a region of the plot of pressure. Click the ‘Statistics menu’ button in the statistics area and select ‘Curve Fit, Linear Fit’ from the menu.

4. Record the slope of each run of data as the rate of decomposition.

Record your results in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about cleaning and putting away the equipment for this activity.
- Check with your instructor about disposing of the chemicals that you used in the activity. DO NOT pour the chemicals down the sink unless you are told it is all right to do so.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'Fil'e menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

Name ______________________ Class _______________ Date __________

Lab Report - Activity GS27: Chemical Equilibrium

What Do You Think?

The purpose of this activity is to find out if a system in chemical equilibrium is sensitive to temperature. For example, will cold soda water or warm soda water reach chemical equilibrium faster?

Data Table

Trial	Pressure (maximum)	Pressure (minimum)	Slope
Warm soda water	kPa	kPa	
Cold soda water	kPa	kPa	

Questions

1. Is there a difference in the rate to reach equilibrium?

2. What is the relationship of temperature to the rate to reach equilibrium?

3. Explain what is happening on a molecular level.

Name ____________________ Class ______________ Date _________

Activity GS28: Light Intensity vs. Distance
(Light Sensor, Motion Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Optics	GS28 Light vs Distance.DS	G28 Light vs. Distance	G28_LTVD.SWS

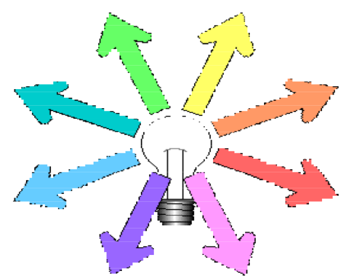
Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Light Sensor (CI-6504A)	1	**Dynamics Cart (inc. w/ Track)**	1
Motion Sensor (CI-6742)	1	Reflector (e.g., index card)	1
Base and Support Rod (ME-9355)	1	Tape	1 roll
Basic Optics Light Source (OS-8517)	1	**1.2 m Track System (ME-9429A)**	1

What Do You Think?

What is the relationship between **light intensity** and the distance from a light source?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



The light from a point light source spreads out uniformly in all directions.

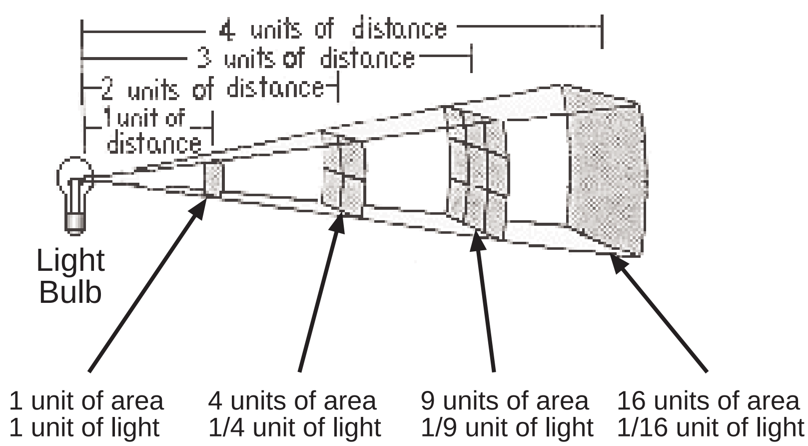
The **light intensity** is a measure of how much light energy covers a certain amount of area.

The intensity at a given distance **r** from the light will be equal to the power output (amount of energy per second) of the light divided by the surface area of the sphere through which the light has spread.

Since the area of the sphere varies as the square of its radius, **r**, the intensity should vary as $\mathbf{1/r^2}$ (one divided by the distance squared).

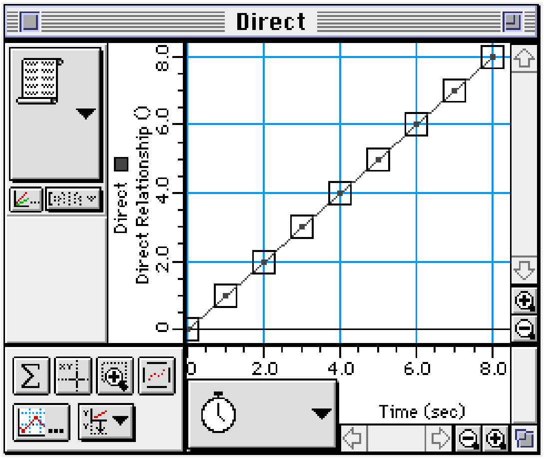
$$I = \frac{1}{r^2}$$

If light intensity and distance have a <u>direct</u> relationship, their formula might be $\mathbf{y = ax}$, where **a** is a constant. If light intensity and distance have an <u>inverse</u> relationship, their formula might be $\mathbf{xy = b}$, where **b** is a constant. If light intensity and distance have an <u>inverse square</u> relationship, their formula might be $\mathbf{x^2y = c}$, where **c** is a constant.

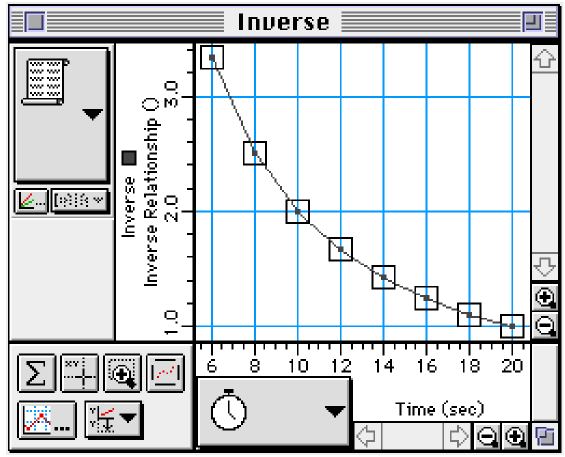


Here are three examples:

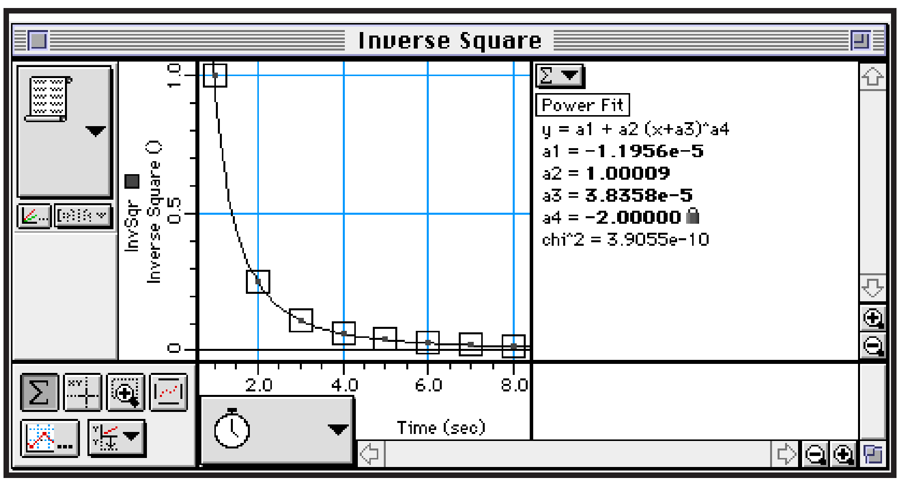
Direct Relationship



Inverse Relationship



Inverse Square Relationship



SAFETY REMINDER

- Follow directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

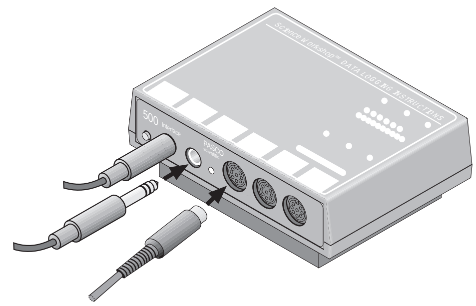
For You To Do

Use the Light Sensor to measure the intensity of light as a light source moves slowly away from the Light Sensor. Use the Motion Sensor will measure the position of the light source as it moves.

Use *DataStudio* or *ScienceWorkshop* to record and display the light intensity versus the position. Use the graph of light intensity vs. position to find out what kind of relationship light intensity has to distance: direct, inverse, or inverse square.

Name ______________________ Class _______________ Date _________

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface and then turn on the computer.
2. Connect the Motion Sensor stereo phone plugs to Digital Channels 1 and 2 on the interface. Put the yellow-banded phone plug into Digital Channel 1. Put the other phone plug into Digital Channel 2.
3. Connect the Light Sensor's DIN plug into Analog Channel A on the interface.
4. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS28 Light vs Distance.DS	G28 Light vs. Distance	G28_LTVD.SWS

- The document opens with a Graph display of light intensity (%) vs. position (m). The DataStudio document also has a Workbook display. Read the instructions in the display.

PART II: Equipment Setup and Sensor Calibration

Equipment Setup

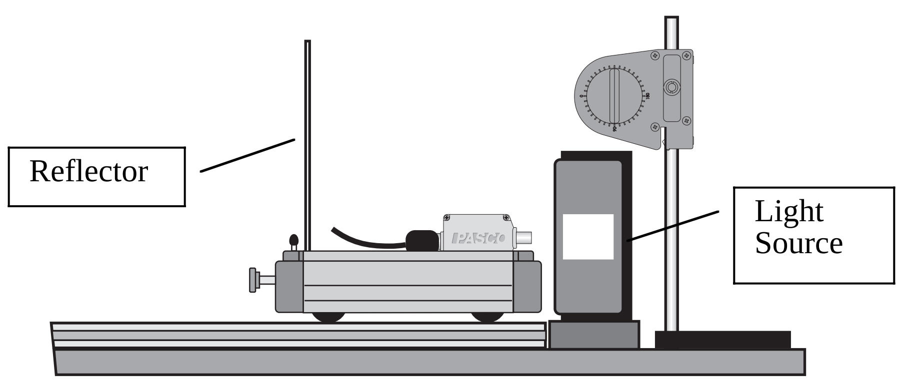
1. Set up the track. Place the track on a horizontal surface and level the track.
2. Set up the cart and Light Sensor.

- Tape a vertical reflector (such as an index card) onto the cart so the Motion Sensor's signal is able to reflect from the reflector.
- Put the Light Sensor in the accessory tray at one end of the cart. Use tape to secure the sensor in place.

3. Set up the light source.

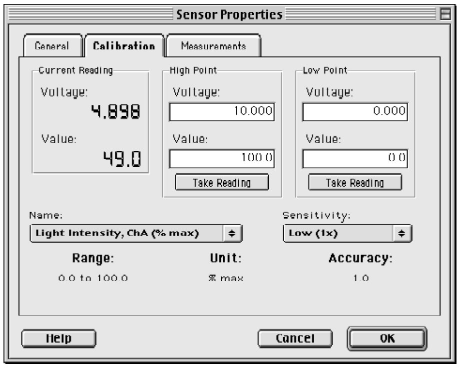
- Place the light source on its side at one end of the track.
- Arrange the light source so the 'Point Source' opening on one side of the light source is at the same level as the port on the Light Sensor and points toward the sensor.

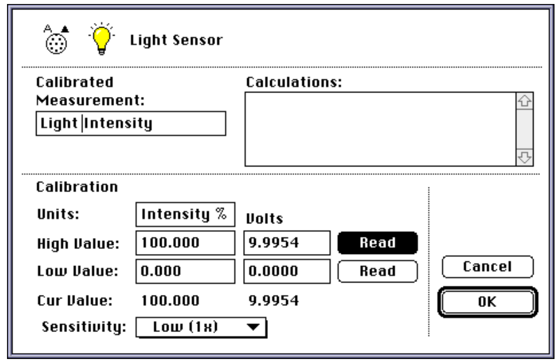
4. Set up the Motion Sensor. Use a support rod to position the Motion Sensor so it can measure the motion of the cart as it moves down the track.



Sensor Calibration

1. Set the GAIN switch on the top of the Light Sensor to '**1**'.
2. Turn on the light source. Turn off the room lights.
3. In the Setup window, double-click the Light Sensor icon. **Result**: In *DataStudio*, the 'Sensor Properties' window opens. Click the 'Calibrate' tab. In *ScienceWorkshop*, the 'Sensor Setup' window opens.





- The current value of the voltage from the Light Sensor appears under 'Current Reading' (in *DataStudio*) or next to 'Cur Value' (in *ScienceWorkshp*).

4. Prepare to calibrate. Put the port of the Light Sensor as close to the light source opening as possible.

- If the voltage reading is under 4.9 volts, calibrate the software. In *DataStudio*, click the 'Take Reading' button under the 'High Point' column. In *ScienceWorkshop*, click the 'Read' button at the right end of the 'High Value' row.
- If the voltage reading is 4.9 volts or higher, slowly move the cart with the Light Sensor away from the light source until the reading drops to 4.9 volts. Hold the cart at that position while you make a mark on the track next to one end of the cart. Calibrate the software. In *DataStudio*, click the 'Take Reading' button under the 'High Point' column. In *ScienceWorkshop*, click the 'Read' button at the right end of the 'High Value' row.

5. Click 'OK' to return to the Experiment Setup window.

Name ____________________ Class _____________ Date _________

PART III: Data Recording

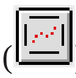
- Put the Motion Sensor at least 15 cm from the starting position of the cart and aim the sensor at the reflector on the cart.

1. When you are ready, start recording data. (Click ‘Start’ in *DataStudio* or ‘REC’ in *ScienceWorkshop*).
2. Slowly and steadily pull the cart with the Light Sensor away from the light source. (Note: Keep your hand out of the way so the pulses from the Motion Sensor to not reflect from it.)
3. Stop recording data when the cart reaches the end of the track.

- Run #1 will appear in the Data list in the Experiment Setup window.

4. Turn off the light source.

Analyzing the Data

1. Click the Graph to make it active.
2. Click the ‘Scale to Fit’ button in *DataStudio* or the ‘Autoscale’ button () in *ScienceWorkshop* to rescale the Grraph to fit the data.

Use your results to answer the questions in the Lab Report section.

Ending the Activity

Equipment Clean Up

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select ‘Quit’ from the ‘File’ menu to end the activity.
2. You can select ‘Save’ or ‘Save As…’ from the File menu to save your data for this activity and the changes you’ve made to the document.

- The original document is “locked”, so you should give your document a new filename.

Name ______________________ Class _______________ Date __________

Lab Report - Activity GS28: Light Intensity vs. Distance

What Do You Think?

What is the relationship between **light intensity** and the distance from a light source?

Questions

1. Describe how your Graph looks:

2. Based on your Graph, what is the relationship between light intensity and distance: direct, inverse, or inverse square?

Name ____________________ Class _____________ Date _________

Activity GS29: Induction – Magnet through a Coil (Voltage Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Electromagnetism	GS29 Induction.DS	G29 Induction - Magnet	G29_INDU.SWS

Equipment Needed	Qty
Voltage Sensor (CI-6503)	1
Coil	1
Bar magnet, alnico (EM-8620)	2

(*such as on the AC/DC Electronics Lab (EM-8656) board, or the Basic Electricity Board (EM-8622) or the Coils and Core Set (SF-8616)

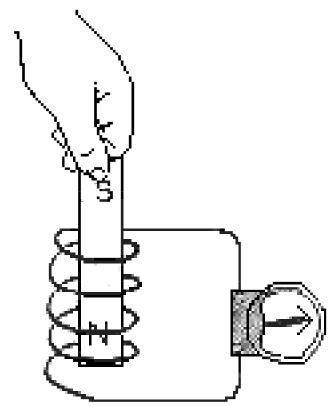
What Do You Think?

The purpose of this activity is to measure the **voltage** created in a coil by a magnet dropping through the center of the coil. Will the voltage be different if the magnet falls faster through the same coil?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

Connect a coil of wire to a sensitive meter that can measure tiny amounts of electric current. Set the coil so you can move a bar magnet back and forth through the center of the coil. When the bar magnet moves through the coil, the sensitive meter will show that a current is flowing through the coil. The current flows through the wire of the coil because the magnet caused (induced) a **voltage**.



The amount of voltage depends on how many turns of wire are in the coil, and the rate at which the magnet is moved back-and-forth through the coil of wire. In other words, the more turns of wire in the coil, the more voltage it puts out. The faster the magnet moves through the coil, the more voltage the coil puts out.

The direction of the voltage (positive or negative) depends on which end of the magnet (called the magnetic **pole**) is going through the coil of wire, and in which direction. A bar magnet has both a north magnetic pole and a south magnetic pole. If the bar magnet falls through the coil of wire, the voltage will be positive when one end of the bar magnet moves through the coil, and negative when the other end of the bar magnet moves through the pole.

Both ends of a magnet usually have the same magnetic strength. If you put the north end of the magnet into the coil, it should create the same voltage as when you put the south end of the magnet into the coil, assuming that you put both ends into the coil with the same speed. If one end of the magnet moves faster, it produces more voltage. However, because the magnet moves faster, the amount of time that it is in the coil is shorter.

The amount of voltage multiplied by the amount of time that the voltage lasts is called the **flux**. If a magnet moves slowly, the voltage is low, but the amount of time is longer. If the magnet moves quickly, the voltage is higher, but the amount of time is shorter.

Theoretically, the amount of flux produced by a magnet moving slowly is the same as the amount of flux produced by the same magnet when it moves quickly.

SAFETY REMINDERS

- Follow directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

For You To Do

Use the Voltage Sensor to measure the voltage induced in the coil by a magnet as the magnet falls through the coil. Use *DataStudio* or *ScienceWorkshop* to record and display the induced voltage. Use the plot of voltage versus time to find out whether the flux created by one end of the magnet is the same as the flux created by the other end of the magnet.

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Voltage Sensor DIN plug into Analog Channel A.
3. Open the document titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS29 Induction.DS	G29 Induction - Magnet	G29_INDU.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document opens with a Graph display of Voltage vs. Time and a Meter display of Voltage.

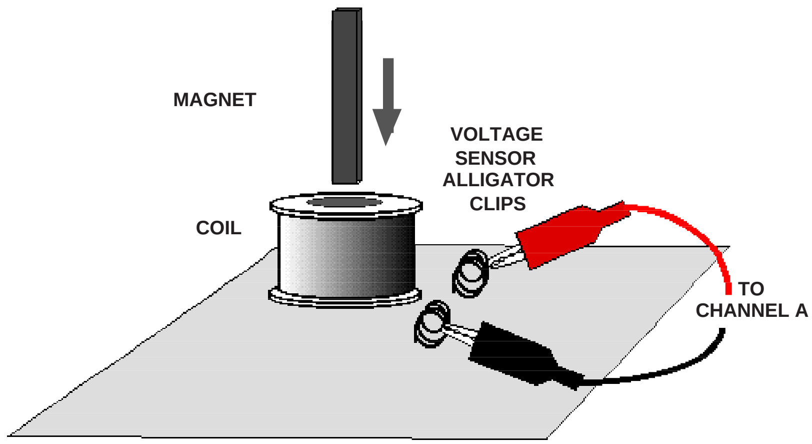
4. Data recording is set at 200 Hz (200 measurements per second), ‘Start Condition’ = Channel A = 0.05 V, and ‘Stop Condition’ = Time at 0.5 seconds.

Name ____________________ Class ______________ Date _________

PART II: Sensor Calibration and Equipment Setup

- You do not need to calibrate the Voltage Sensor.

1. Put alligator clips on the ends of the voltage sensor leads.
2. Attach a voltage sensor lead to one component spring next to the inductor coil on the circuit board. Attach the other lead to the other component spring next to the coil.
3. Arrange the circuit board so the corner with the coil is beyond the edge of the table and a magnet dropped through the coil can fall freely.



The bar magnet will be dropped through the coil. Make sure that the magnet does not strike the floor, or it may break.

Part III: Data Recording

1. Hold the magnet so that the south end is about 2 cm above the coil.
2. Start recording data. Let the magnet drop through the coil.

- Data recording begins when the magnet falls through the coil and the induced voltage reaches 0.05 volts.
- Data recording ends automatically after 0.5 seconds.

3. Repeat data recording, but release the magnet from about 5 cm above the coil so the magnet falls through the coil faster.

Analyzing the Data

1. Set up your Graph so it shows the area between the curve of voltage and the X-axis.

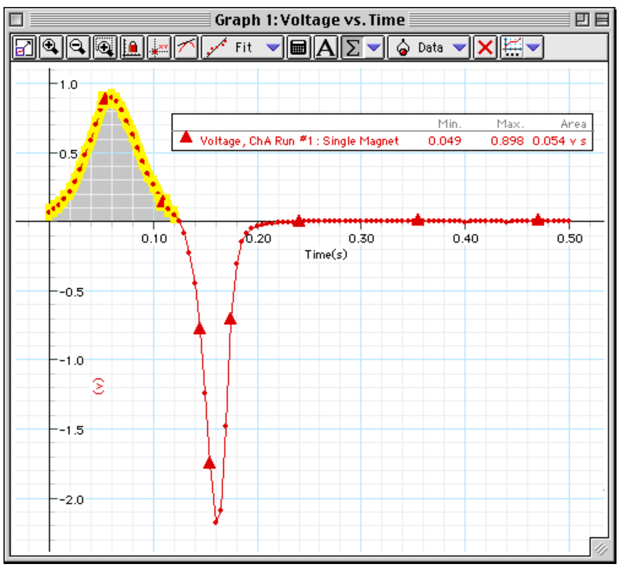
- Hint: In *DataStudio*, select **Area** from the Statistics menu in the Graph toolbar.
- Hint: In *ScienceWorkshop*, click the Statistics button to open the Statistics area on the right side of the graph. In the Statistics area, click the Statistics Menu button. Select **Integration** from the menu.

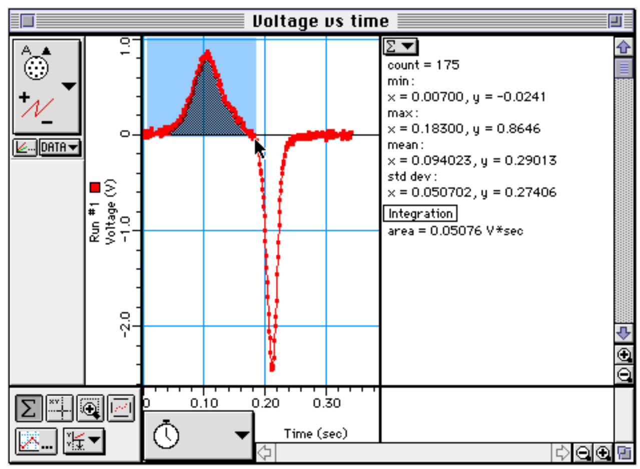
2. In the Graph display, use the cursor to click-and-draw a rectangle around the first peak of the voltage plot.

- The Statistics will show the area under the curve for the first peak.

3. Record the value of Integration for the first peak.
4. Repeat the process to find the area under the second peak. Record the value.
5. Repeat the data analysis for the second run of data (magnet falling faster).

Record your results in the Lab Report section.





Ending the Activity

Equipment Clean Up

- Check with your instructor about putting away the equipment for this activity.

Computer Shutdown

When you have finished, you have several options.

1. You can select 'Quit' from the 'Fil'e menu to end the activity.
2. You can select 'Save' or 'Save As…' from the File menu to save your data for this activity. the changes you've made to the document.

- The original document is "locked", so you should give your document a new filename.

3. If you wish to go on to the next activity, select 'Open…' from the 'File' menu, and find the document for the next activity.

Name ______________________ Class _______________ Date _________

Lab Report - Activity GS29: Induction - Magnet through a Coil

What Do You Think?

The purpose of this activity is to measure the **voltage** created in a coil by a magnet dropping through the center of the coil. Will the voltage be different if the magnet falls faster through the same coil?

Data Table – Run #1

Peak	Integration
First	V*s
Second	V*s

Data Table – Run #2

Peak	Integration
First	V*s
Second	V*s

Questions

1. Is the first peak of flux (V*s) equal to the second peak of flux?

2. Why is the second peak taller than the first peak?

3. Why are the peaks in opposite directions?

4. How does the voltage in the second run compare to the voltage in the first run?

Optional

Repeat the data recording and data analysis procedures for the following optional setups:

- Tape two bar magnets together so both south ends are together.

- Re-arrange the two bar magnets so that the south end of one is with the north end of the other.

Name ____________________ Class _____________ Date _________

Activity GS30: Photoelectric Effect (Voltage Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Nature of light	GS30 Photoelectric Effect.DS	G30 Photoelectric Effect	G30_PHOT.SWS

Equipment Needed	Qty	Equipment Needed	Qty
Voltage Sensor (CI-6503)	1	**Optics & Alignment Kit (AP-9369)**	1
Photoelectric Head (AP-9368)	1	**Mercury Vapor Light (OS-9286)**	1

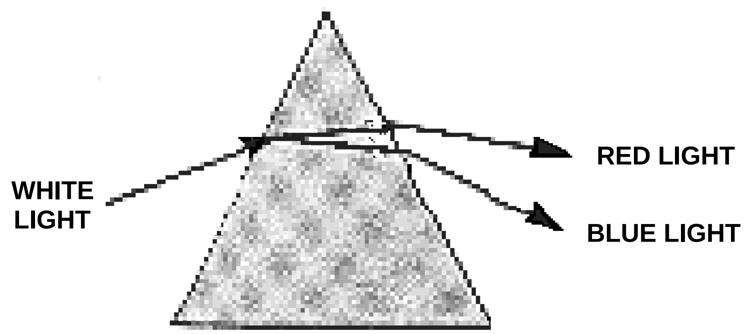
What Do You Think?

The purpose of this activity is to measure the **voltage** produced when different colors of light fall on a photoelectric tube and to find out the relationship between the wavelength of light and the amount of voltage it produces. What do you think is the relationship between the wavelength (color) of light and the amount of voltage it produces?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

White light (such as sunlight) is a mixture of all the colors of light in a rainbow. You can see the colors of light in a rainbow by shining white light through a prism. Each color of light travels in a slightly different path through the prism, so the colors spread away from each other when they come out of the prism.

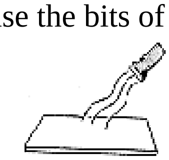


Red light travels through the prism with the least amount of change in its direction. Blue light travels through the prism and changes its direction by a greater angle. This change in direction of the different colors of light is called **dispersion**. It is caused by **refraction**.

Refraction happens when light is traveling through something and then meets something new. If the light is at an angle to the boundary between the old region and the new region, the light must change its direction as it goes through the new region.

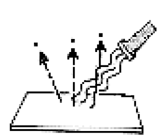
Each color of light in the rainbow has a different amount of energy. Each color also has a certain **wavelength**. Blue light has a <u>shorter</u> wavelength than red light. If a color of light that has the right amount of energy strikes a metal surface, the light can knock electrons out of the metal.

This is called the **photoelectric effect** because the bits of energy that make up light are called photons, and photons with the right amount of energy can knock electrons out of the metal surface ("photon-electron" or photoelectric effect).



PHOTONS THAT DO NO HAVE THE RIGHT ENERGY, NO MATTER HOW BRIGHT, CANNOT KNOCK ELECTRONS OUT OF THE PLATE OF METAL.

When electrons get knocked out of the metal by photons of light, the metal can produce a **voltage**. The amount of voltage depends on the number of electrons that get knocked out of the metal. The number of



PHOTONS OF THE RIGHT ENERGY CAN KNOCK ELECTRONS OUT OF THE PLATE OF METAL.

electrons depends on the energy of the light. The energy of the light depends on the wavelength. The color of the light tells you whether the wavelength is long or short.

Albert Einstein knew the relationship between the color of light (or its wavelength) and the amount of energy in the light. He used the relationship between color and energy to explain the photoelectric effect (for which he won the Nobel Prize).

Does a short wavelength color like blue light have more energy, or does a long wavelength color like red light?

SAFETY REMINDERS

THINK SAFETY
ACT SAFELY
BE SAFE!

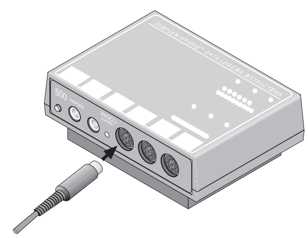
- Follow directions for using the equipment.
- Be careful not to touch the mercury vapor light source after it gets hot.

For You To Do

Use the Voltage Sensor to measure the voltage produced by the photoelectric effect.

Use *DataStudio* or *ScienceWorkshop* to record and display the voltage produced by each color of light you measure. Use a plot of voltage versus wavelength (color) to find the relationship between the voltage and the wavelength. Determine the relationship between the color of light (the wavelength) and the amount of voltage the light produces.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Voltage Sensor DIN plug into Analog Channel A.
3. Open the document titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
GS30 Photoelectric Effect.DS	G30 Photoelectric Effect	G30_PHOT.SWS

- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document opens with a Graph display of Voltage vs. Wavelength and a Meter display of Voltage.
- Data recording is set at 10 Hz. You will enter the wavelength of each color of light into *DataStudio* using ‘Manual Sampling’ or into *ScienceWorkshop* using ‘Keyboard Sampling’ with Parameter = Wavelength (color) and Units = nm.
- The ‘Default Data’ numbers under ‘Wavelength’ in the *DataStudio* Table are the wavelengths of the colors of light from a mercury light source. The colors of are as follows: violet, blue, green, and yellow.
- This table shows the wavelength for each color:

Color	Wavelength	Color	Wavelength
violet	404.656	green	546.074
blue	435.835	yellow	576.960

Name ____________________ Class _____________ Date _________

PART II: Sensor Calibration and Equipment Setup

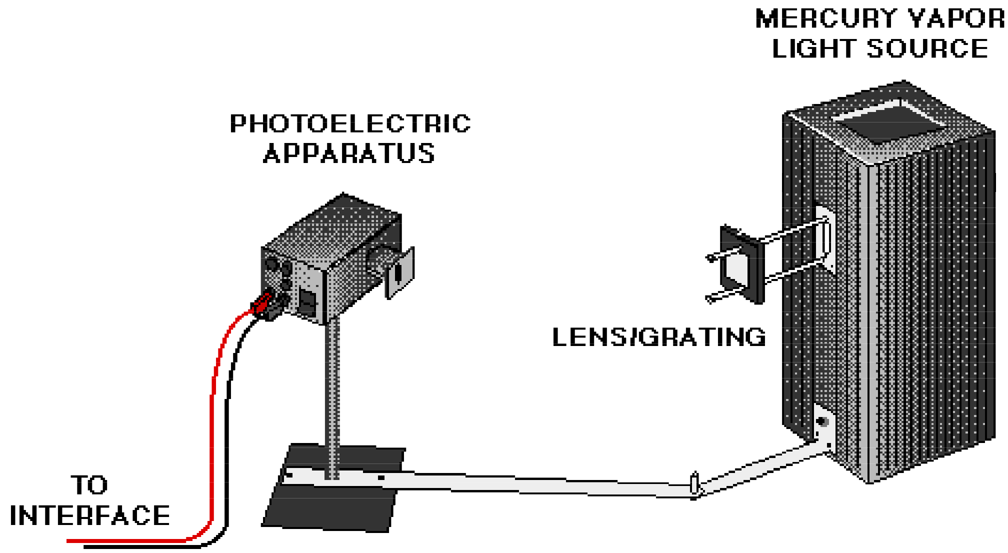
- You do not need to calibrate the Voltage Sensor.

NOTE: Read the instruction manual that comes with the PASCO Photoelectric Effect Apparatus before you do the equipment setup.

1. Install the two 9 volt batteries that come with the Photoelectric Apparatus into the battery compartment on the apparatus.
2. Put the Photoelectric Apparatus onto the support base assembly.
3. Put the light block into the slot on the back of the mercury vapor light source.
4. Put the coupling bar assembly onto the bottom of the slot on the front of the mercury vapor light source.
5. Put the light aperture assembly in the middle of the slot on the front of the mercury vapor light source.

- Be sure that the light aperture assembly is lined up with the opening on the front of the light source.

6. Put the lens/grating assembly onto the ends of the horizontal rods on the light aperture assembly.
7. Put the hole at the end of the support base assembly over the pin on the end of the coupling bar assembly.8. Put the Voltage Sensor banana plugs into the output jacks on the side of the Photoelectric Apparatus.
9. Turn on the light source so it has time to warm up before you make measurements.



Part III: Data Recording

Color	Wavelength (nm)
violet	404.656
blue	435.835
green	546.074
yellow	576.960

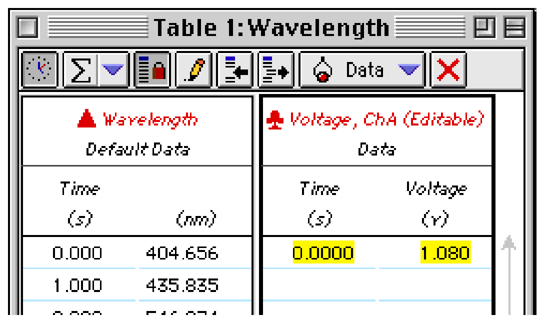
1. Adjust the position of the Photoelectric Apparatus so that only the *violet* color light from the mercury light source goes through the slot on the front of the apparatus and shines on the photodiode tube inside.
2. Turn on the Photoelectric Effect Apparatus. Press the PUSH TO ZERO button on the side of the apparatus.
3. Start recording data. In *DataStudio*, the 'Start' button changes to a 'Keep' button 

.

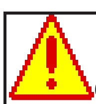
• Note: For *ScienceWorkshop* instructions, see the page at the end of the activity.

4. When the voltage stops going up, click 'Keep' to record the voltage in the Table next to the wavelength of violet light.

• The Table in DataStudio will show the value of voltage for violet light in the first row.



5. Adjust the position of the Photoelectric Apparatus so that only the blue color light goes through the slot on the front of the apparatus and shines on the photodiode tube inside.
6. Click 'Keep' to record the value of voltage for blue light.
7. Put the green filter on the front of the Photoelectric Apparatus. Adjust the apparatus so that only the green light goes through the slot and shines on the photodiode tube inside.
8. Click 'Keep' to record the value of voltage for green light.
9. Replace the green filter with the yellow filter. Adjust the Photoelectric Apparatus so that only the yellow light goes through the slot and shines on the photodiode tube inside.
10. Click 'Keep' to record the value of voltage for yellow light.
11. Stop data recording
12. Turn off the Photoelectric Effect Apparatus and the light source. Remove the yellow filter.


CAUTION! The light source can be very hot. Let it cool down before you take the apparatus apart.

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Analyzing the Data

1. Set up the Graph to show a ‘Linear’ curve fit for the voltage and wavelength data.

- Hint: In *DataStudio*, select ‘Linear’ from the ‘Fit’ menu. In *ScienceWorkshop*, click the ‘Statistics’ button to open the Statistics area on the right side of the graph. Click the ‘Autoscale’ button to rescale the graph to fit the data. In the Statistics area, click the ‘Statistics Menu’ button. Select ‘Curve Fit, Linear Fit’ from the menu.

Answer the questions in the Lab Report section.

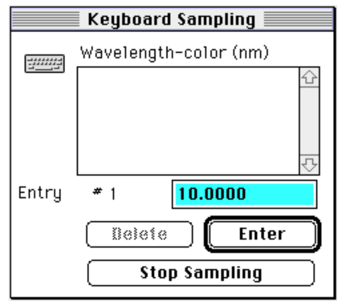
Ending the Activity

- Check with your instructor about putting away the equipment for this activity. Remember; wait until the light source cools down before taking the apparatus apart.

Data Recording (*ScienceWorkshop*)

1. When you are ready, start recording data. In *ScienceWorkshop*, the Keyboard Sampling window will open. Adjust its position on your screen so you can also see the Digits display of temperature.

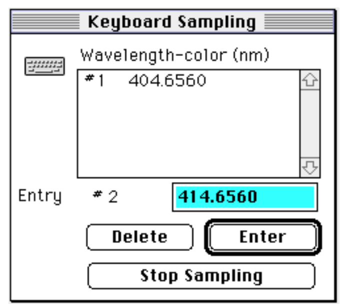
- **The Keyboard Sampling window will open. Move it so you can see the Digits display of Voltage at the same time.**
- **It may take a few moments for the voltage to reach its maximum value.**



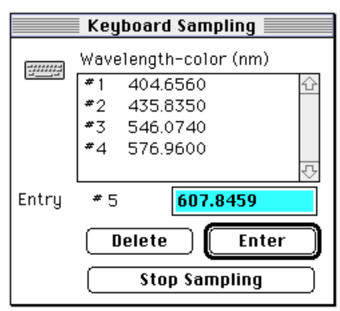
2. When the voltage stops going up, type in the wavelength for violet light. Click **Enter** to record your typed in value.

- **The Keyboard Sampling window will show your first value in the Data list.**

3. Adjust the position of the Photoelectric Apparatus so that only the blue color light goes through the slot on the front of the apparatus and shines on the photodiode tube inside.



4. Type in the wavelength for blue light in the **Keyboard Sampling** window. Click **Enter** to record your value.
5. Put the green filter on the front of the Photoelectric Apparatus. Adjust the apparatus so that only the green light goes through the slot and shines on the photodiode tube inside.
6. Type in the wavelength for green light and click **Enter** in the **Keyboard Sampling** window.
7. Replace the green filter with the yellow filter. Adjust the Photoelectric Apparatus so that only the yellow light goes through the slot and shines on the photodiode tube inside.



8. Type in the wavelength for yellow light and click **Enter** in the **Keyboard Sampling** window.

- **Your Keyboard Sampling window will show four wavelengths in the data list.**

9. Click **Stop Sampling**.

- **The Keyboard Sampling window will disappear. Run #1 will appear in the Data list in the Experiment Setup window.**

10. Turn off the Photoelectric Effect Apparatus. Remove the yellow filter.

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Lab Report - Activity GS30: Photoelectric Effect

What Do You Think?

The purpose of this activity is to measure the **voltage** produced when different colors of light fall on a photoelectric tube and to find out the relationship between the wavelength of light and the amount of voltage it produces. What do you think is the relationship between the wavelength (color) of light and the amount of voltage it produces?

Questions

1. Based on your Graph, is the relationship between voltage and wavelength direct, inverse, inverse square, or something else?

2. Which color produces the highest voltage?

3. Which color produces the lowest voltage?

4. Based on your data, what is the relationship between wavelength (color) and energy of the photons?