

Activity P06: Acceleration Due to Gravity (Motion Sensor)

Concept	<i>DataStudio</i>	<i>ScienceWorkshop</i> (Mac)	<i>ScienceWorkshop</i> (Win)
Linear motion	P06 Gravity.ds	G14 Gravity	G14_GRAV.SWS

Equipment Needed	Qty	Other	Qty
Motion Sensor (CI-6742)	2	Ball, rubber	1
Base and Support Rod (ME-9355)	1	<i>Level (optional)</i>	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?

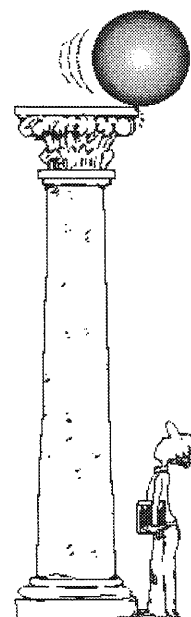


Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

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.

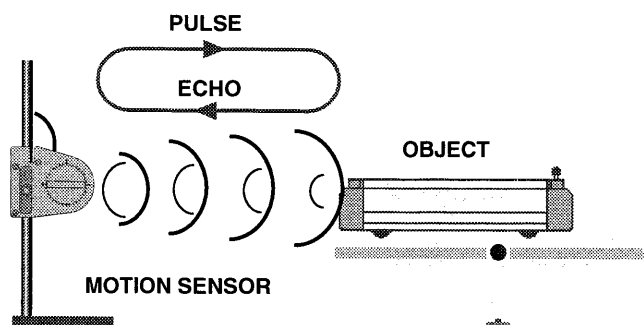
**THINK SAFETY
ACT SAFELY
BE SAFE!**

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.



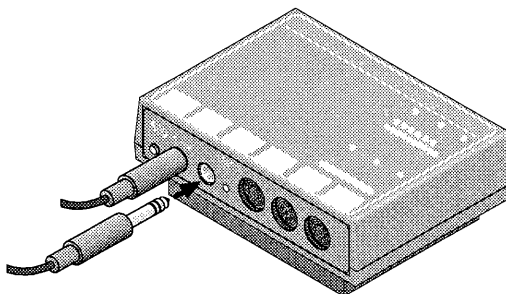
The software program keeps track of the time when the pulses go out and the time when the echoes come back. One-half of the round trip time is the time that it took for the ultrasound to reach the object. Since ultrasound travels at the speed of sound, or about 344 meters per second (or about 700 miles per hour), the program figures out how far away the object is as follows:

$$\text{distance to object} = \frac{\text{round - trip time}}{2} \times \text{speed of sound}$$

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:



<i>DataStudio</i>	<i>ScienceWorkshop</i> (Mac)	<i>ScienceWorkshop</i> (Win)
P06 Gravity.ds	G14 Gravity	G14_GRAV.SWS

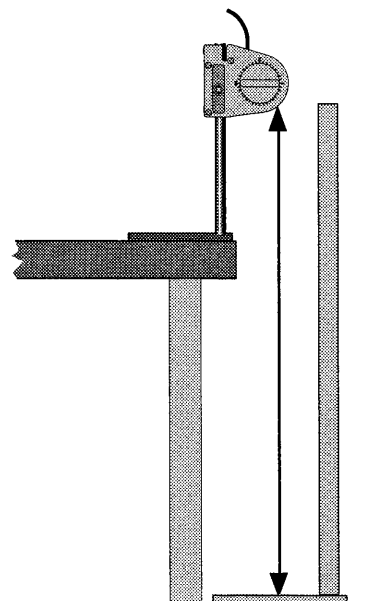
- The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Graph display of Position and Velocity versus Time.
- The Trigger Rate for the Motion Sensor is 60 times per second (60 Hz).

PART II: Sensor Calibration and Equipment Setup**Sensor Calibration**

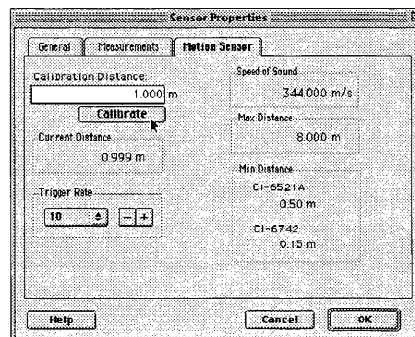
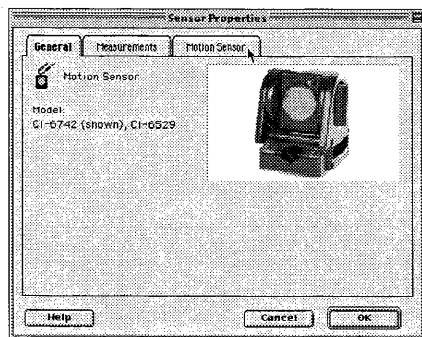
- Calibrate the Motion Sensor so it can use an accurate measurement of the speed of sound in air. You will need a meter stick and a flat surface that can be used as a target to reflect the pulses from the Motion Sensor.

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.
- 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.)

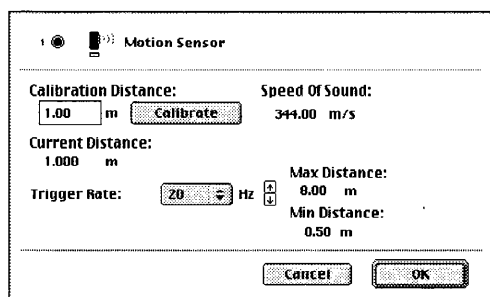
**Calibrate the Software**

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.

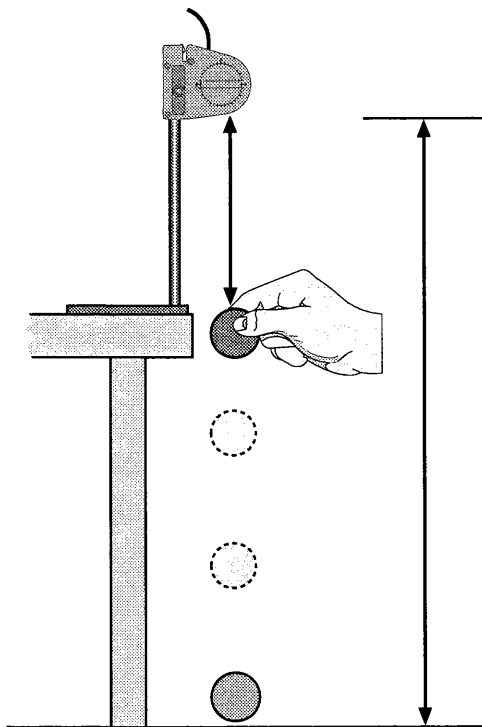
- **Result:** In *ScienceWorkshop*, the sensor's calibration window opens and the sensor begins to click a few times per second.



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

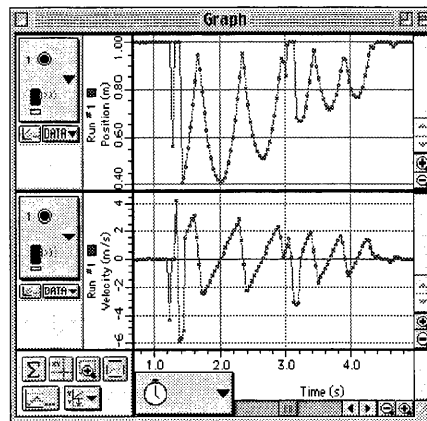
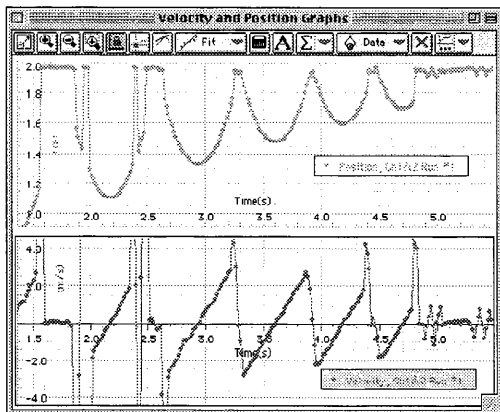
1. Prepare to drop the ball so it falls straight down beneath the Motion Sensor. Hold the ball between your finger and thumb under the Motion Sensor no closer than 15 cm (about 6 inches) below the Motion Sensor.
2. Start recording data. (Hint: In *DataStudio*, click 'Start'. In *ScienceWorkshop*, click '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.

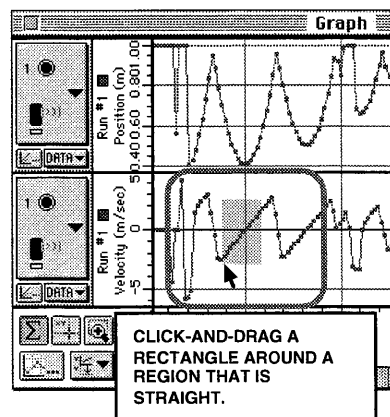
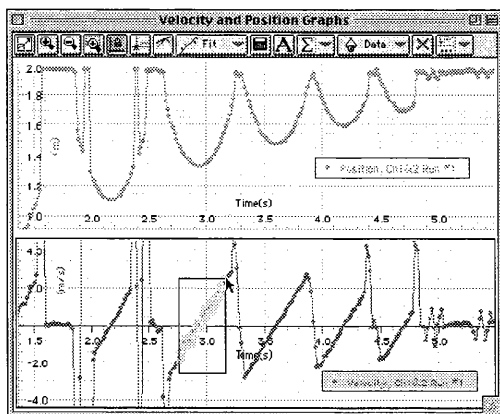
3. After the ball bounces several times on the floor, stop recording data.

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.



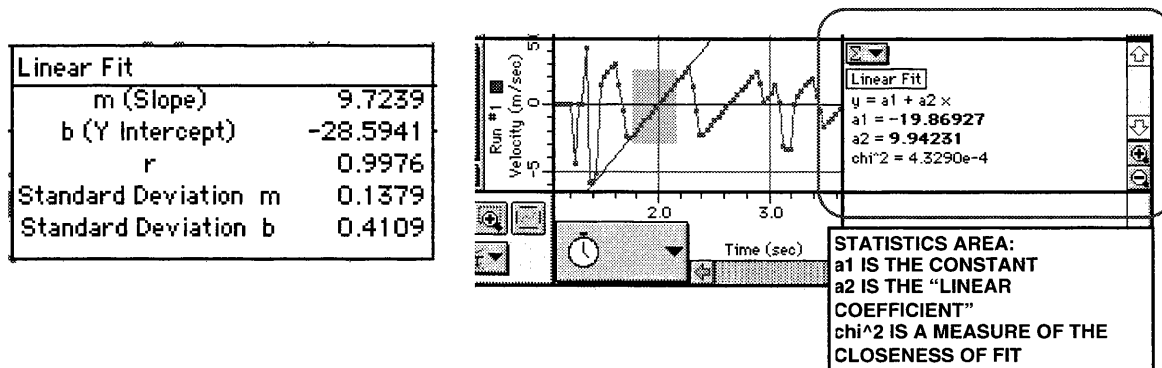
- In the plot of Velocity versus Time, use the cursor to click-and-draw a rectangle around a region that is relatively straight.



- 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.



Record your results in the Lab Report section.

Lab Report - Activity P06: 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 = $\left| \frac{\text{accepted value} - \text{experimental value}}{\text{accepted value}} \right| \times 100\%$
2. What factors do you think may cause the experimental value to be different from the accepted value?