Experiment P01: Understanding Motion I – Distance and Time
(Motion Sensor)

PURPOSE:

The purpose of this activity is to introduce the relationships between the motion of an object – YOU – and a Graph of position and time for the moving object.

Apparatus:

Science Workshop™ Interface, base and support rod, motion sensor and file: file: P01_MOT1.

NOTE: This activity is easier to do if you have a partner to run the computer while you move.

THEORY

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 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 in real-time, that is, as the motion is happening.

PROCEDURE

For this activity, you will be the object in motion. The Motion Sensor will measure your position as you move in a straight line at different speeds. The *Science Workshop* program will 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 *Science Workshop* interface to the computer, turn on the interface, and turn on the computer.

2. Connect the motion sensor’s stereo phone plugs to Digital Channels 1 and 2 on the interface. Connect the yellow-taped plug to Digital Channel 1 and the other plug to Digital Channel 2.

3. Open the *Physics lab folder* on the desktop screen and open file titled as shown: P01_MOT1

- The document has a Graph display of Position (m) and Time (sec). The Graph shows Position and Time values that were put into the Graph using the “Load Data…” feature (see the User’s Guide for *Science Workshop*).

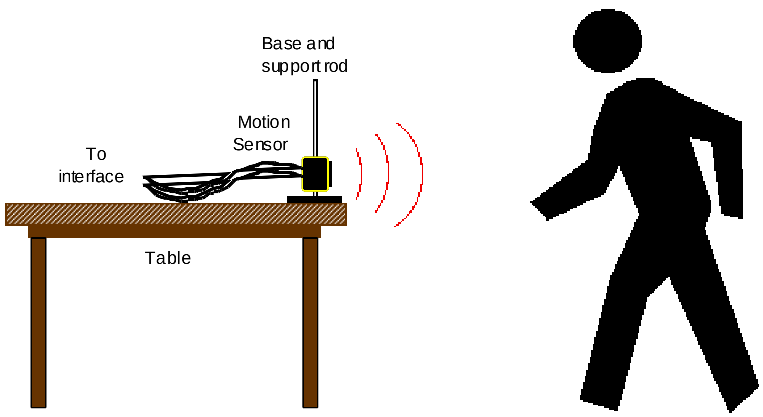
- (Note: For quick reference, see the Experiment Notes window. To bring a display to the top, click on its window or select the name of the display from the list at the end of the Display menu. Change the Experiment Setup window by clicking on the “Zoom” box or the Restore button in the upper right hand corner of that window.)

PART II: Equipment Setup

1. Mount the motion sensor on a support rod 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.

- NOTE: You will be moving backwards for part of this activity. Clear the area behind you for at least 2 meters (about 6 feet).

2. Position the computer monitor so you can see the screen while you move away from the motion sensor.



Understanding Motion 1: Position and Time

PART III: Data Recording

1. Click on the Graph to make it active. Enlarge the Graph until it fills the monitor screen.

2. Study the Position versus Time plot 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? _______ (sec)
- How fast should you move while you are walking? _______ (m/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. Click the "START" button to begin recording data. (Data recording will begin almost immediately. The motion sensor will make a faint clicking noise.)

5. Watch the plot of <u>your</u> motion on the Graph, and try to move so that the plot of your motion matches the Position vs. Time plot that is already there.

- Data recording will end automatically after a certain amount of time, or click on “STOP” to end sooner. Run #1 will appear in the Data list in the Experiment Setup window.

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 that is already on the Graph.

OPTIONAL

The Graph can show more than one run of data at the same time. You can display up to three runs simultaneously. If you record more than three runs, use the DATA menu along the vertical axis to select the runs you want to see. To delete a run of data, click on the run in the Data list in the Experiment Setup window and press the “delete” key on the keyboard.

ANALYZING THE DATA

1. Use the mouse to click-and-draw a rectangle around the middle section of your plot (generally between 2-6 seconds). A small box containing curve information will appear on the graph. Use the “FIT” menu button in the tool bar of the Graph. Select “Linear Fit” from the Curve Fit menu to display the slope of the selected region of your position vs. time plot.

2. The “m” term of the equation in the Stats area is the slope of the selected region of motion. The slope of this part of the position vs. time plot is the velocity during the selected region of motion.

QUESTIONS

1. In the Graph, what is the slope of the line of best fit for the middle section of your plot?

2. Describe your motion. Start at time = 0 and end when the data recorder stopped (Example: “Constant speed for 2 seconds followed by no motion for 3 seconds, etc.”)

Experiment P02: Understanding Motion II – Velocity and Time
(Motion Sensor)

Objective:

The purpose of this activity is to introduce the relationships between the motion of an object – YOU – and a Graph of velocity and time for the moving object.

Apparatus:

Science Workshop Interface, base and support rod, motion sensor, program file: MOT2_PLT

Note: this activity is easier to do if you have a partner to run the computer while you move.

THEORY

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 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 in real-time, that is, as the motion is happening.

PROCEDURE:

For this activity, you will be the object in motion. The Motion Sensor will measure your velocity as you move in a straight line at different speeds. The *Science Workshop* program will plot your motion on a graph of velocity 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 *Science Workshop* interface to the computer, turn on the interface, and turn on the computer.

2. Connect the motion sensor's stereo phone plugs to Digital Channels 1 and 2 on the interface. Connect the yellow-tape plug to Digital Channel 1, and the other plug to Digital Channel 2.

3. Open the *Physics lab folder* found on the desktop screen, then open the file: MOT2_PLT

- The document has a Graph display of Velocity (m) and Time (sec). The Graph shows Velocity and Time values that were put into the Graph using the "Load Data…" feature (see the User's Guide for *Science Workshop*).

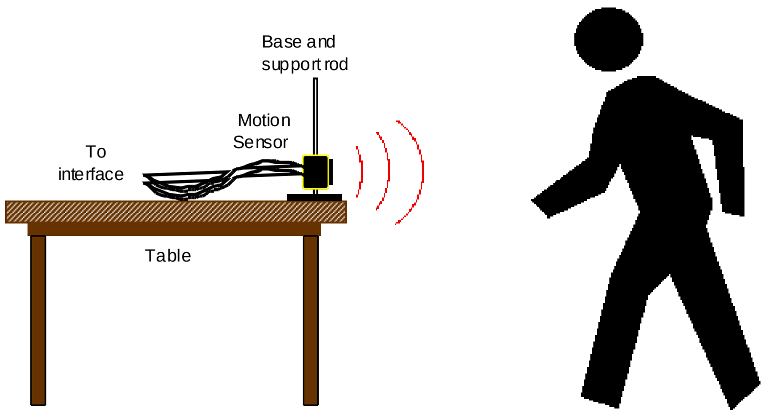
PART II: Sensor and Equipment Setup

- Motion that increases the distance from the motion sensor is considered "positive" motion. Motion that decreases the distance from the motion sensor is considered "negative" motion.

1. Mount the motion sensor on a support rod 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.

NOTE: You will be moving backwards for part of this activity. Clear the area behind you for at least 2 meters (about 6 feet).

2. Position the computer monitor so you can see the screen while you move away from the motion sensor.



Understanding Motion 2: Velocity and Time

PART III: Data Recording

1. Click on the Graph of Velocity versus Time to make it active. Enlarge the Graph until it fills the monitor screen.

2. Study the Velocity versus Time plot in order to determine the following:

- Which direction (increasing or decreasing separation) should you go at the beginning? _______
- What is the maximum speed (positive or negative) you must achieve? _______ (m/s)
- How long should the positive velocity portions of your motion last? _______ (sec)
- What was your total acceleration during the positive velocity portions of your motion? ______(m/s^2)
- Where should you end up, closer or further from the sensor? _______

3. Check that the setup timing is correct: delay is set to 3 sec and the sample rate is set 5 Hz.

4. When you are ready, stand in front of the motion sensor about 0.4 meters away. WARNING: You will be moving backward, so be certain that the area behind you is free of obstacles.

5. Click the “START” button to begin recording data. (Data recording will begin almost immediately. The motion sensor will make a faint clicking noise.)

6. Watch the plot of <u>your</u> motion on the Graph, and try to move so that the plot of your motion matches the Velocity vs Time plot that is already there.

- The aim of this activity is to understand the relationship between the velocity and time. Therefore, first try to move watching the velocity vs time plot, which is the upper graph on the screen. If you have difficulty in matching the plot, then try to move watching the position vs time plot, which is the lower graph on the screen. The lower graph is the integrated velocity of the upper one with respect to time.

- Data recording will end automatically after a certain amount of time, or click on “STOP” to end sooner. Run #1 will appear in the Data list in the Experiment Setup window.

6. Repeat the data recording process a second and a third time. Try to improve the match between the plot of <u>your</u> motion and the plot that is already on the Graph.

OPTIONAL

The Graph can show more than one run of data at the same time. You can display up to three runs simultaneously. If you record more than three runs, use the DATA menu along the vertical axis to select the runs you want to see. To delete a run of data, click on the run in the Data list in the Experiment Setup window and press the “delete” key on the keyboard.

<u>ANALYZING THE DATA</u>

1. Use the mouse to click-and-draw a rectangle around the middle of the positive velocity portion of your motion. Use the “FIT” menu button in the tool bar area of the Graph. Select “Linear Fit” from the Curve Fit menu to display the slope of the selected region of your velocity vs time plot.

2. Examine the slope m, what is the average acceleration of your motion.

<u>QUESTION</u>

1. For your best attempt, how well did <u>your</u> plot of motion fit the plot that was already on the Graph? Calculate the percent difference of the linear slope of your motion and the slope of the given graph.

Expected acceleration a ________(m/s^2)
Actual acceleration a2 ________(m/s^2)

Percent error= $\dfrac{|a - a2|}{a} \times 100\%$ = **______%**

Experiment P06: Measuring the Acceleration of a Freely Falling Picket Fence (Photogate)

Object:

The purpose of this laboratory activity is to measure the acceleration due to gravity by measuring the time of fall of a “picket fence” dropped through a photogate.

EQUIPMENT NEEDED

Science Workshop™ Interface, picket fence, photogate or Smart Pulley, table clamp (optional), and program file:P06_FALL.

THEORY

As an object falls freely, it accelerates due to the applied net force. If air resistance is neglected, and the speed of the object is measured over several short, consecutive intervals as it falls, the differences in the speed of the object can be used to determine the acceleration due to gravity.

PROCEDURE

In this activity, you will drop a “picket fence” (a clear plastic strip with uniformly spaced opaque bands) through a photogate. The photogate beam is blocked by each opaque band and the time from one blockage to the next becomes increasingly shorter. Knowing the distance between the leading edge of each opaque band, the *Science Workshop* program calculates the average speed of the picket fence from one band to the next. A graph of average speeds versus time can give the acceleration due to gravity of the falling object.

PART I: Computer Setup

1. Connect the *Science Workshop* interface to the computer, turn on the interface and then turn on the computer.

2. Connect the photogate’s stereo phone plug to Digital Channel 1 on the interface.

3. Open the physics lab folder found on the desktop screen and open file titled as shown; P06_FALL.

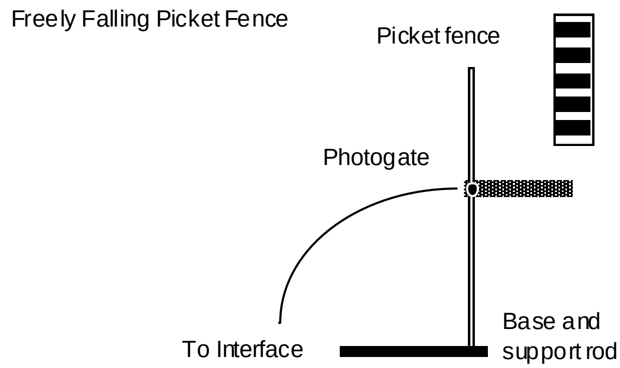
- The document will open with a Graph display that has plots of Position and Velocity versus Time and a Table of Position, Velocity, and Acceleration versus Time.

- (Note: For quick reference, see the Experiment Notes window. To bring a display to the top, click on its window or select the name of the display from the list at the end of the Display menu. Change the Experiment Setup window by clicking on the “Zoom” box or the Restore button in the upper right hand corner of that window.)

PART II: Equipment Setup

- The *Science Workshop* program assumes a 5 cm (0.05 m) spacing, leading-edge-to-leading-edge, for the opaque bands on the picket fence. To change the default setting to another value, double-click on the icon of the photogate in the Experiment Setup window. Enter the correct value for the spacing of the opaque bands on your picket fence. Click OK.

1. Turn the photogate head of the accessory photogate sideways so that you can drop a picket fence vertically from above the photogate and have the picket fence move through the photogate's opening without hitting the photogate.



(If you are using a Smart Pulley photogate, you may want to put the Smart Pulley's mounting rod horizontally in a table clamp and then fasten the clamp on the edge of a table. Again, turn the Smart Pulley photogate so that a picket fence can be dropped through the photogate's opening.)

Preparing to Record Data

- Before recording any data for later analysis, you should experiment with the photogate and picket.

- Click the "Start" button in the Experiment Setup window. Drop the picket fence vertically through the photogate. Data recording begins when the photogate beam is first blocked. Click "STOP" to end recording of your sample data. Click the "Autoscale" button in the Graph display.

- To erase a trial run of data, select "Run #1" in the Data Sets list …

…and press the "Delete" key.

PART III: Data Recording

1. Prepare to drop the picket fence through the photogate beam. Hold the picket fence at one end between your thumb and forefinger so the bottom edge of the picket fence is just above the photogate beam.

2. Click the "start" button and then drop the picket fence through the photogate beam. Remember, data collection begins when the photogate beam is first blocked.

3. When the picket fence is through the beam, click "STOP" to end recording. (The position, velocity, and acceleration values should appear in the Table display and "Run #1" should appear in the Data Sets list.).

DATA ANALYSIS

1. The coefficient **m** is the slope of the 'best fit' line. This slope is the value of the acceleration of the falling picket fence. Record this value in the Data Table.

2. Click on the Table displayed. Click the ∑ button. Statistics for minimum, maximum, mean, and standard deviation will appear in the bottom rows of each table column.

3. Record the displayed value for the Mean of the acceleration of the picket fence in the Data Table.

DATA TABLE

slope of velocity versus time = ______ (from Graph display)

acceleration (mean) = ______ (from Table display)

QUESTIONS

1. How does the slope of your velocity versus time plot compare to the accepted value of the acceleration of a free falling object (g = 9.8 m/s^2)?

- Reminder: percent-discrepancy $= \left| \dfrac{\textit{accepted value} - \exp\textit{erimental value}}{\textit{accepted value}} \right| x100\%$

2. How does the mean of the acceleration from the table compare to the accepted value of the acceleration of a free falling object (g = 9.8 m/s^2)?

3. What factors do you think may cause the experimental value to be different from the accepted value?