Experiment P14: Collision – Impulse & Momentum (Force Sensor, Motion Sensor)

Concept	Time	SW Interface	Macintosh® file	Windows® file
Newton's Laws	45 m	500 or 700	P14 Collision	P14_COLL.SWS

EQUIPMENT NEEDED	
• *Science Workshop™ Interface*	• balance (to measure mass)
• ±50 Newton force sensor	• collision cart (with magnets)
• motion sensor	• force sensor bracket & bumpers
• adjustable feet, track (two)	• track, 2.2 meter

PURPOSE

The purpose of this laboratory activity is to study an elastic collision and to measure the change in momentum during the collision and the integral of the force over the time of the collision.

THEORY

When an object strikes a barrier, the force on the object varies as the collision occurs. The change of momentum of the object can be calculated in two ways:

- Using the initial and final velocities: $\Delta \boldsymbol{p} = m\vec{v}_f - m(-\vec{v}_i) = m\vec{v}_f + m\vec{v}_i$
- Using the net force and time of impact: $\Delta \boldsymbol{p} = \int \boldsymbol{F}dt$

An abrupt hard collision takes less time than a cushioned collision but the force is greater for the hard collision than for the soft collision. It is possible for the object to undergo the same change in momentum independent of the type of collision.

PROCEDURE

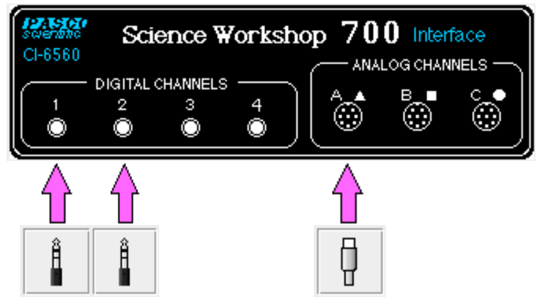
For this activity, the motion sensor measures the motion of a cart before and after it collides with a bumper that is mounted on the front of a force sensor. The force sensor measures the force during the collision. The *Science Workshop* program calculates the velocity of the cart before and after the collision, and the integral of force over time during the collision.

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 stereo phone plugs of the motion sensor 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 on the interface.

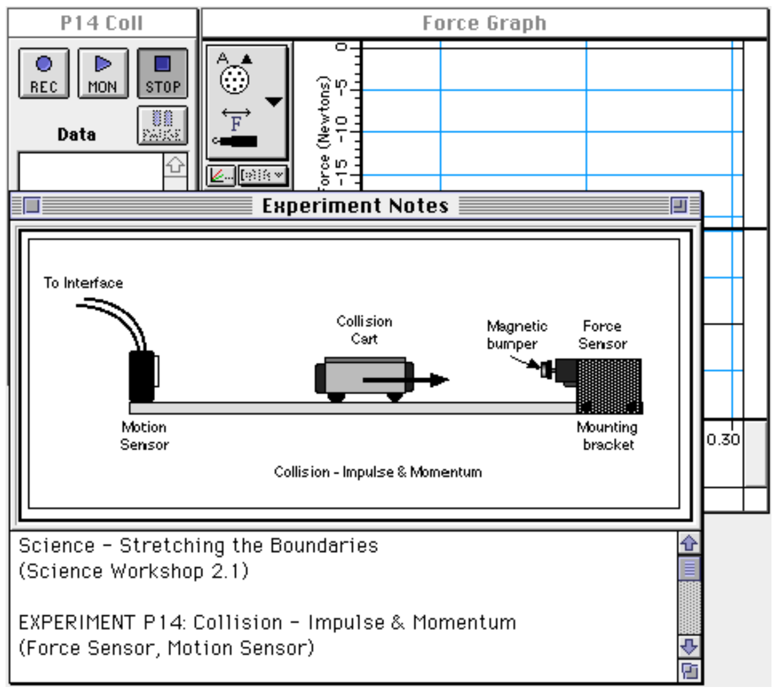


4. Open the *Science Workshop* file titled as shown:

Macintosh	Windows
P14 Collision	P14_COLL.SWS

- The document will open with a Graph display showing a plot of Force (Newtons) and a plot of Velocity (m/sec) versus Time (sec).

- 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** or **Maximize** button in the upper right hand corner of that window.



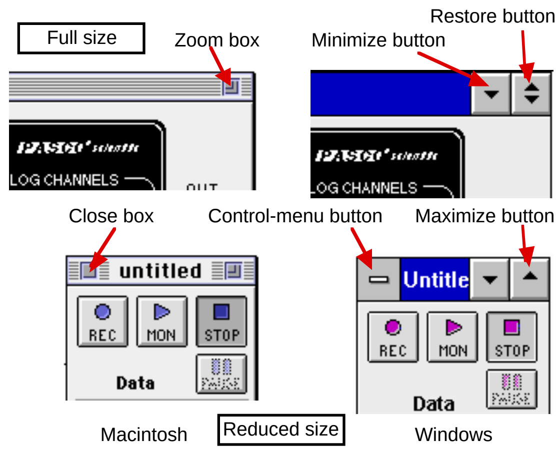
5. The **Sampling Options…** are: **Periodic Samples = Fast at 500 Hz** and **Digital Timing = 10000 Hz**.

PART II: Sensor Calibration and Equipment Setup

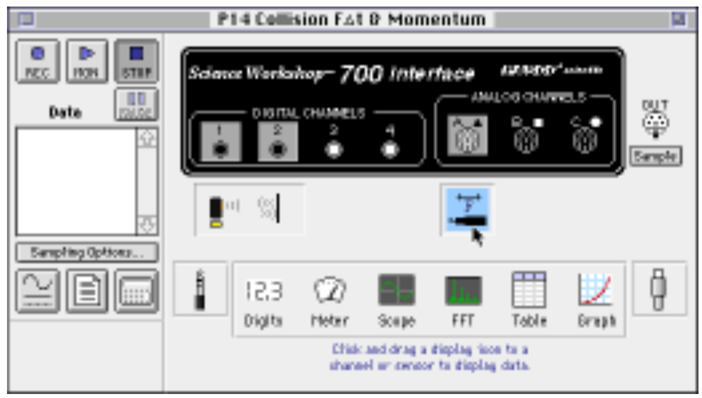
Sensor Calibration

- You do not need to calibrate the motion sensor.

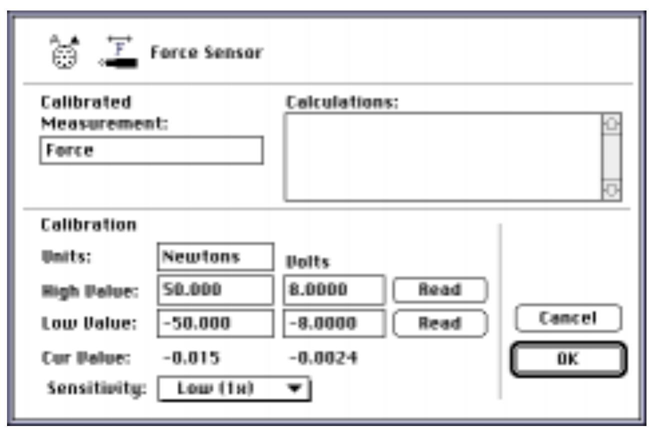
1. To calibrate the <u>force</u> sensor, change the Experiment Setup window to full size by clicking on the **Zoom** box or the **Maximize** button in the upper right hand corner of that window.



2. In the Experiment Setup window, double-click on the force sensor's icon to open the Force Sensor setup window.

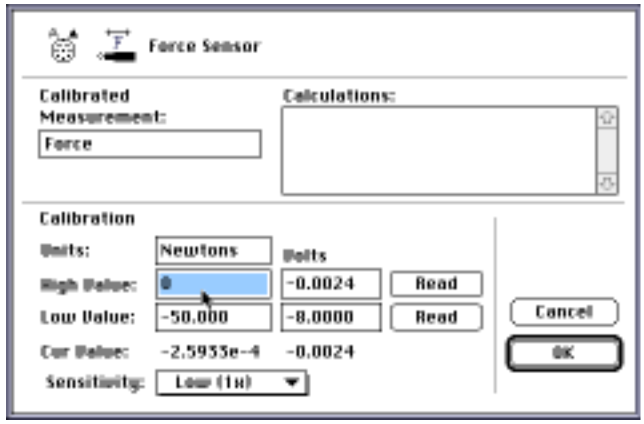


- The Force Sensor setup window shows the default calibration values (50 Newtons produces 8 Volts, -50 Newtons produces -8 Volts). The force sensor is set up so that a pull away from the sensor is a 'negative' force. For example, if a one kilogram object is hung vertically from the hook, the force sensor measures -9.8 Newtons (since the force is downward).



3. Mount the force sensor on a horizontal rod so the force sensor's hook is down. Do NOT put an object on the force sensor's hook yet.

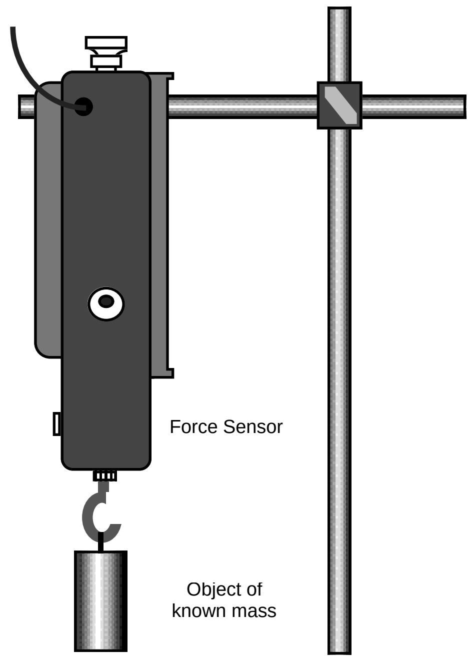
4. For the **High Value** calibration point, press the tare button on the side of the force sensor to zero the sensor. Click the **Read** button for **High Value**. Since there is no object on the sensor's hook, type **0** as the **High Value**.



5. For the Low Value calibration, hang an object of known mass on the sensor's hook.

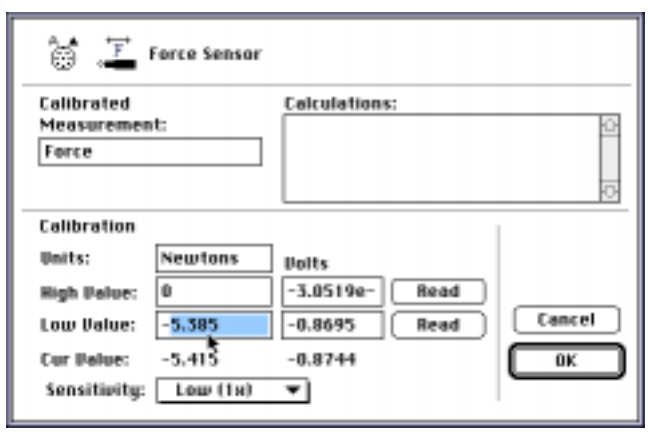
6. Click the **Read** button for **Low Value**. Enter the object's weight in Newtons (mass in kilogram x 9.8 N/kg).

- Remember, enter the object's weight as a <u>negative</u> value (a force pulling away from the sensor).



- In this example, the object has a mass of 549.5 grams (0.5495 kg), or a weight of 5.385 Newtons (entered as -5.385).

7. Click **OK** to return to the Experiment Setup window.



Equipment Setup

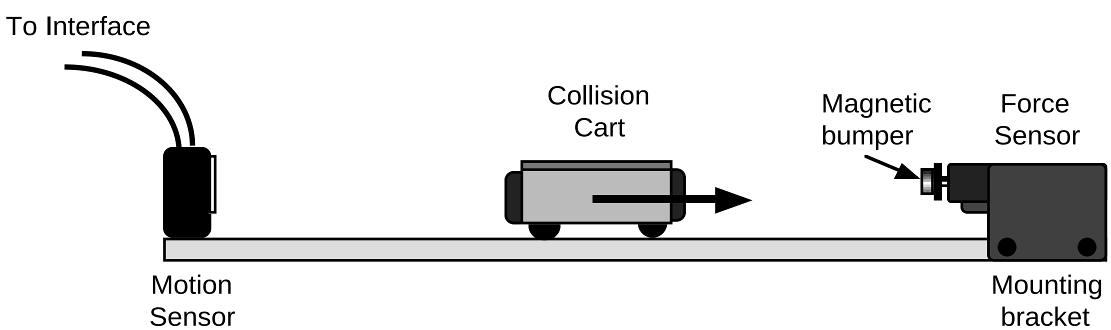
1. Mount the ±50 Newton force sensor on the force sensor bracket. Mount the bracket in the T-slot on the side of the track.

2. Raise the end of the track that is opposite to the end with the force sensor about 1.5 cm so the cart will have about the same initial speed for each trial.

3. Place the motion sensor at one end of the track so it can measure the motion of the cart. Put a mark on the track 40 cm from the front of the motion sensor.

4. Brace the force sensor end of the track against a heavy mass so the track will not move during the collision.

5. Carefully measure the mass of the cart. Record the mass in the Data section.



6. Replace the detachable hook on the force sensor with the magnetic bumper from the force sensor bracket and bumpers set.

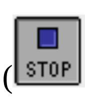
- Note: If the magnetic bumper is not available, leave the hook on the force sensor. Cut a small slit in a rubber stopper, and place the rubber stopper over the hook.

PART III: Data Recording

1. When you are ready to begin recording data, press the tare button on the side of the force sensor to “zero” the sensor.

2. Place the cart on the track at least 40 cm from the front of the motion sensor.

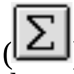
3. Click the **REC** button (
) to begin recording data and at the same time release the cart so that it rolls toward the force sensor.

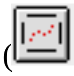
4. Click the **STOP** button (
) to end data recording after the cart has rebounded from the collision with the force sensor’s magnetic bumper.

- **Run #1** will appear in the Data list in the Experiment Setup window.

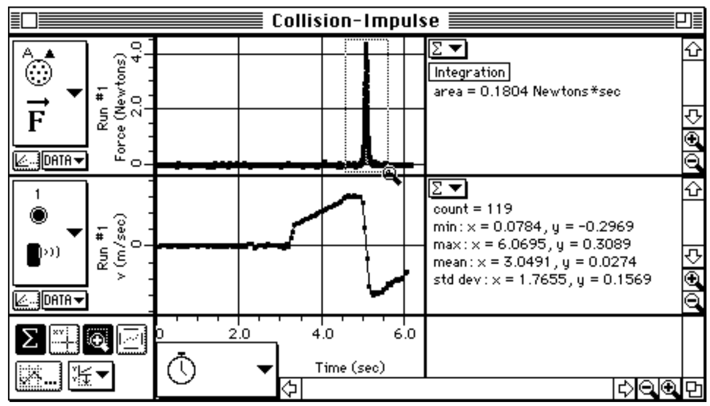
ANALYZING THE DATA

1. Record the mass of the cart in the Data Table below:

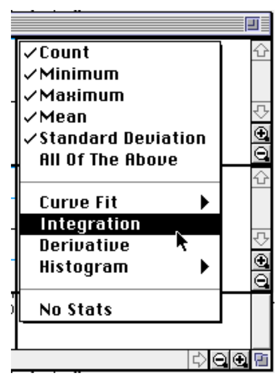
2. Click the **Statistics** button () in the lower left corner of the Graph to open the Statistics area at the right of the Graph.

3. Click on the **Autoscale** button () in the lower left area of the Graph to rescale the graph to fit the data.

4. Select the **Magnifier** tool () in the lower left corner of the Graph. The cursor changes to a magnifying glass shape. Use the cursor to click-and-draw a rectangle over the region of the force versus time plot that corresponds to the collision.



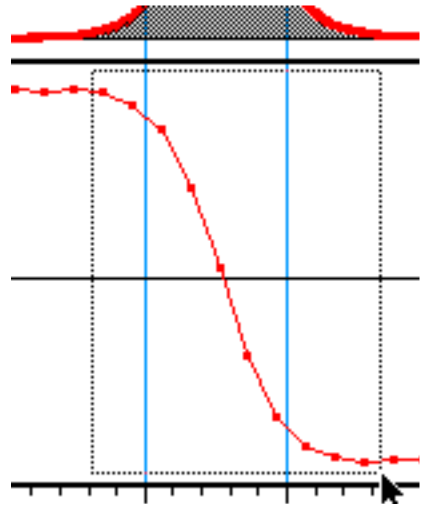
- The selected region will expand to fill the plot area. This will more clearly show the force versus time curve during the collision and the velocity of the cart before and after the collision.



5. Click the **Statistics Menu** button () in the force plot. Select **Integration** from the Statistics menu.

6. Record the value of the area under the curve (the Integration value) of Force (Newtons) versus Time (sec) in the Data section.

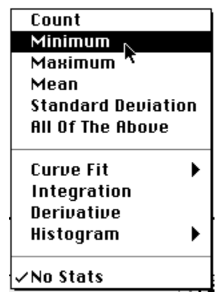
7. To find the velocity just before the collision and the velocity just after the collision, use the cursor to click-and-draw a rectangle around the region of the Velocity versus Time plot that corresponds to the collision.



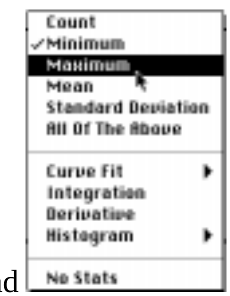
8. Click the **Statistics Menu** button () in the velocity plot. Select **Minimum** from the Statistics menu. Click the Statistics Menu button again and select **Maximum**.

9. Examine the statistics area at the right hand side of the velocity plot. Record the **"maximum"** value of y as the velocity before the collision and the **"minimum"** value of y as the velocity after the collision.

10. Compute the momenta before and after the collision.



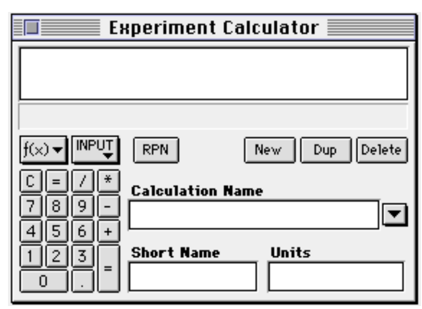
and

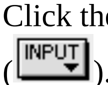


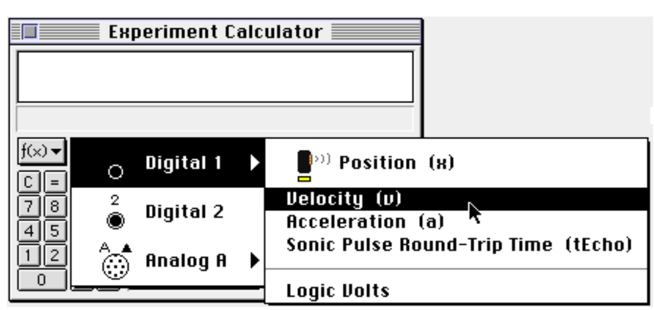
(• NOTE: You can use *Science Workshop* to create a calculation for momentum.)

Create a Calculation (Optional)

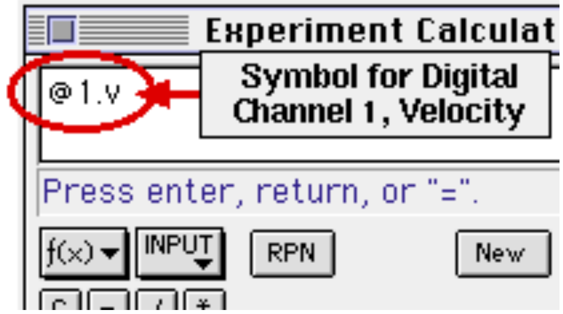
1. In the Experiment Setup window, click the **Calculator** button () to open the Experiment Calculator.



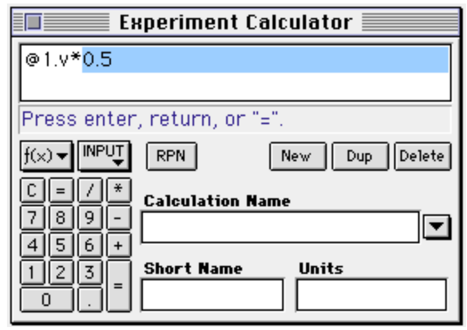
2. Click the **INPUT Menu** button (). Select **Digital 1, Velocity** from the INPUT Menu. ("Digital 1" is the channel to which the motion sensor is connected, and "Velocity" is the value needed in order to calculate momentum.)



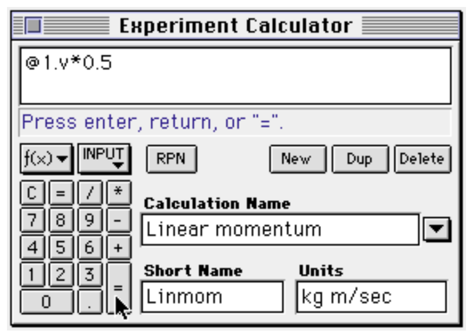
- The symbol for **Digital 1, Velocity** will appear in the display area of the Calculator.



3. Click in the display area at the <u>right end</u> of the symbol for **Digital 1, Velocity**. Click the **multiplication** key () in the keypad area, and then enter the measured value for the mass of the cart in kilograms (for example, "0.5" if the mass is 0.5 kilogram).

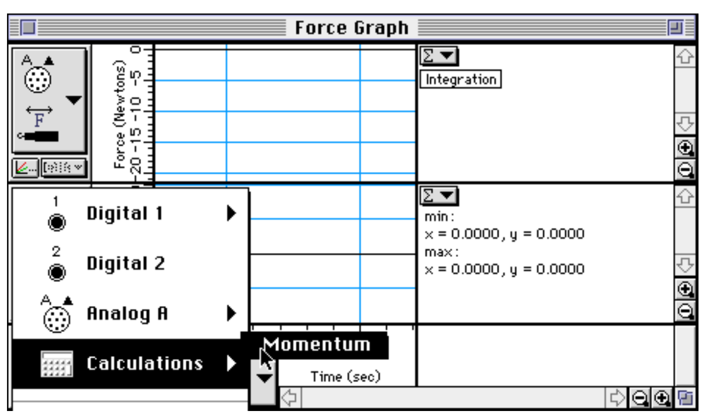


4. Enter a label for the calculation (e.g., **Linear momentum**) in the **Calculation Name** area. Enter an abbreviation for the calculation (e.g., **Linmom**) in the **Short Name** area. The Short Name cannot have blank spaces, numerals, or symbols. Enter appropriate units (e.g., **kg m/sec**) in the **Units** area.



5. When finished, press <enter> or <return> on the keyboard, or click the **equals** key () in the keypad area.

6. To view the plot of calculated momentum in the Graph, click on the **Plot Input Menu** button () in the plot of Velocity versus Time. Select **Calculations, Momentum** from the Plot Input Menu.



7. The plot of Velocity versus Time will become a plot of **Momentum** versus Time. The maximum and minimum values of "y" in the Statistics area represent the momentum before and after the collision.

8. Find the change in momentum. Since the two momenta are oppositely directed vector quantities, the magnitude of the change is the sum:

$$\Delta\ \textbf{momentum} = mv'_f + mv'_i$$

DATA TABLE

Item	Value
Mass of cart	kg
Impulse	Newtons*sec
Velocity before collision	m/sec
Velocity after collision	m/sec
Momentum before collision	kg m/sec
Momentum after collision	kg m/sec
Change in momentum	kg m/sec

QUESTIONS

1. How does the change in momentum compare to the impulse?

2. What possible reasons could cause the change in momentum to be different from the measured impulse?

EXTENSIONS

- Try different amounts of mass on the cart.
- Replace the magnetic bumper with one of the spring bumpers or with the “no-bounce” rubber bumper.
- Try an inelastic collision. Put the clay holder on the front of the force sensor. Mold a small amount of soft clay onto the clay holder so that the cart will stop when it collides with the clay.
- Remove the force sensor from the bracket and mount the force sensor on top of the cart. Turn the bracket around so that the end of the force sensor can collide with the end stop on the force sensor bracket. Repeat the experiments, but with the force sensor on the cart instead of on the bracket.

