# Impulse and Change in Momentum

| Mechanics: momentum, impulse, change in momentum | GLX setup file: **impulse** |
|---|---|

| Qty | Equipment and Materials | Part Number |
|---|---|---|
| 1 | PASPORT Xplorer GLX | PS-2002 |
| 1 | PASPORT Motion Sensor | PS-2103 |
| 1 | PASPORT Force Sensor | PS-2104 |
| 1 | 1.2 m PASCO Track | |
| 1 | GOcar | ME-6951 |
| 1 | Accessory Bracket with Bumpers | CI-6545 |
| 1 | Hooked Mass Set | SE-8759 |
| 1 | Balance | SE-8723 |
| 2 | Book (heavy) | |

## Purpose

The purpose of this activity is to investigate the change in momentum and the impulse (net force multiplied by time) in a collision.

## Background

$$\text{Impulse} = F\Delta t$$

Impulse is the net force applied to an object multiplied by the amount of time during which the net force acts. Impulse is a vector quantity and has the same direction as the net force. The unit of impulse is the newton•second (N•s).

When a net force acts on an object, the object's momentum changes. For example, when an object collides with an obstacle, its momentum changes. The amount of change in momentum is the same whether the collision is abrupt or is spread out over an interval of time. The difference between a quick, hard collision and the slower collision is the amount of force that is applied. During a quick collision, the amount of force is greater than during a slower collision.

When a net force acts on an object, the change in momentum is equal to the impulse:

$$\text{Impulse} = F\Delta t = \Delta mv = mv_{final} - mv_{initial}$$

## Safety Precautions

- Follow all directions for using the equipment.

## Preview

Use a Motion Sensor to measure the motion of a cart during a collision and use a Force Sensor to measure the force during the collision. Compare the change in momentum of the cart to the impulse.

## Prediction

How does the change in momentum of a cart during a collision compare to the impulse during the collision?

# Procedure

## GLX Setup

1. Turn on the GLX (⏻).
2. Open the GLX setup file labeled **impulse**. (Check the Appendix at the end of this activity.)

- The file is set up so that motion is measured 50 times per second (50 Hz) and force is measured 500 times per second (500 Hz). The Graph screen opens with a graph of Velocity (m) versus Time (s) and a graph of Force (N) versus Time (s). In other words, the graph shows the measurements from both sensors.

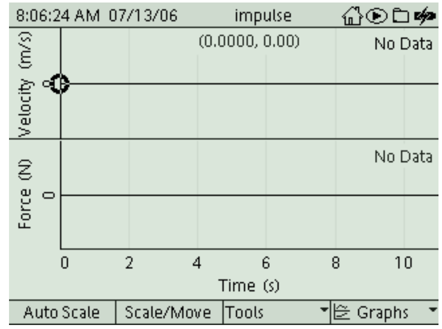
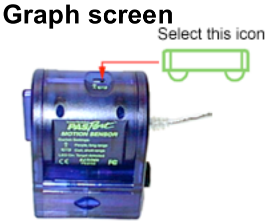



**Fig. 1: Graph screen**

3. Connect the Motion Sensor to sensor port 1 on the top of the GLX. Connect the Force Sensor to sensor port 2 on the GLX. Set the range selection switch on the Motion Sensor to 'near' (cart).




## Equipment Setup

1. Mount the Force Sensor on the Accessory Bracket. Attach one of the spring bumpers from the bracket onto the front end of the sensor.
2. Mount the Accessory Bracket in the T-slot on the side of the track.
3. Attach the Motion Sensor at the other end of the track and raise that end of the track about 5 cm (0.05 m). Aim the sensor at the other sensor. Put a mark on the track about 20 cm in front of the Motion Sensor.

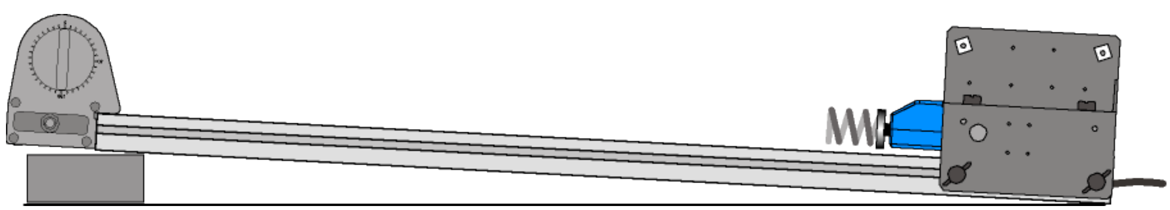


**Fig. 2 Equipment setup**

4. Brace the lower end of the track against a heavy object, such as a thick book, so the track will not move during the collision.
5. Measure and record the total mass of the cart.

- NOTE: The procedure is easier if one person handles the cart and a second person handles the Xplorer GLX.

### Record Data

1. Place the cart on the track at the 20 cm mark in front of the Motion Sensor.
2. Press the ZERO button on top of the Force Sensor to zero the sensor.
3. Press Start (▶) to start recording data. Release the cart so it rolls down the track.
4. Press ▶ to stop recording after the cart collides with the bumper.

## Analysis

Use the Graph screen to examine the velocity versus time for the cart. Determine the velocity *before* the collision and *after* the collision. Use your data to calculate the change in momentum.

Use the Graph screen to examine the force versus time. Determine the area under the curve for the collision. The area is the impulse.

Compare the change in momentum of the cart to the impulse

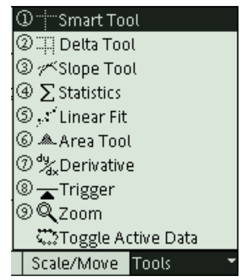



**Fig. 3: Select 'Smart Tool'**

5. Press *F2* to activate 'Scale/Move'. Toggle between 'Scale' and 'Move' and use the left-right arrow keys to stretch out the horizontal scale of the Graph screen.
6. To find the velocity of the cart, use the Smart Tool. Press *F3* (F3) to open the 'Tools' menu. Select 'Smart Tool' and press ✓ to activate your choice. Use the arrow keys to move the 'Smart Tool' to the velocity of the cart before the collision. Record the value in the Data Table.

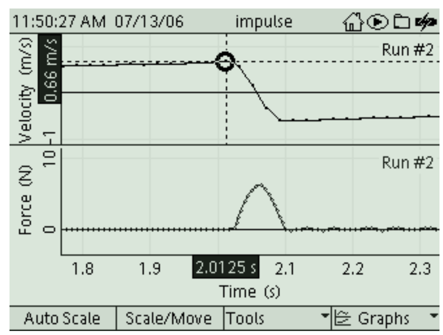



**Fig. 4: Velocity 'before'**

7. Next, use the arrow keys and 'Smart Tool' to find the velocity of the cart after the collision. Record the value.
8. To see the data for Force Sensor, press F3 to open the 'Tools' menu. Use the arrow keys to select 'Toggle Active Data' and press ✓ to activate your choice.

- The *active cursor* will switch to the plot of force data.

9. Use the arrow keys to move the cursor to the point in the force data at the beginning of the collision. Open the 'Tools' menu and select 'Area Tool'. Press ✓ to activate your choice. Use the arrow keys to move the cursor to the end of the collision.

- The graph will display the area under the curve of force versus time.

10. Record the area under the curve as the impulse.


**Fig. 5: 'Toggle Active Data'**

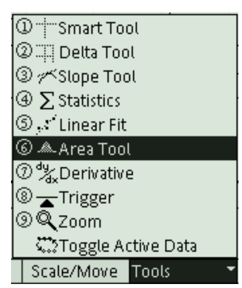



**Fig. 6: 'Area Tool'**

### Record Data: Try *Other* Types of Collisions

1. Repeat the data recording and analysis for other collisions.

- Vary the mass of the cart.
- Change the type of bumper.

2. Record your values for the masses and velocities of the cart and the amount of impulse in the Data Table.

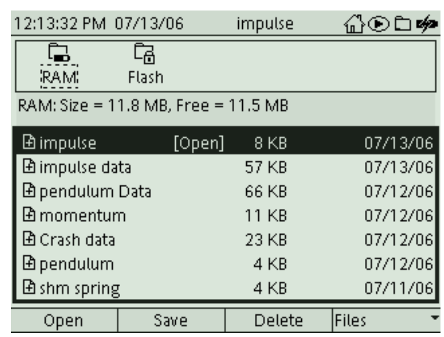
## Analysis

1. To change the Graph screen to show a specific run of data, press to activate the vertical axis menu. Press the arrow keys () to move to 'Run #_' in the upper left hand corner. Press to open the menu, select the data run in the menu, and press to activate your choice.
2. Repeat the analysis process for each of your runs of data.

**Record your results and answer the questions in the Lab Report section.**

## Appendix: Opening a GLX File

To open a specific GLX file, go to the Home Screen (). In the Home Screen, select Data Files and press to activate your choice. In the Data Files screen, use the arrow keys to navigate to the file you want. Press to open the file. Press the Home button to return to the Home Screen. Press to open the Graph.



## Lab Report – Activity 15: Impulse and Change in Momentum

**Name ____________________________________ Date ____________**

### Prediction

How does the change in momentum of a cart during a collision compare to the impulse during the collision?

### Data

Sketch a graph for one run of velocity versus time and force versus time. Include units and labels for your axes.

## Data Table

| Item | Mass (kg) | Velocity, before (m/s) | Velocity, after (m/s) | Momentum, before (kg•m/s) | Momentum, after (kg•m/s) |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

## Calculations

Calculate the momentum *before* and the momentum *after* and find the change in momentum.

$$\Delta mv = mv_{after} - mv_{before}$$

Compare the change in momentum (Δ momentum) to the impulse (area under the curve).

Calculate the percent difference of the change in momentum ($\Delta mv$) and the impulse.

$$\%diff = \left| \frac{\Delta mv - impulse}{\left( \frac{\Delta mv + impulse}{2} \right)} \right| \times 100\%$$

| Item | Δ Momentum (kg•m/s) | Impulse (N•s) | Percent Difference |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

## Questions

1. Why does the velocity of the cart change from a positive value before the collision to a negative value after the collision?

2. Why can you use the area under the curve of force versus time to get the value of the impulse?

3. What are possible reasons why the change in momentum is different from the measured impulse?

4. In general, how does the change in momentum compare to the impulse?

5. Do your results support your prediction?

6. The units of momentum are kg•m/s and the units of impulse are N•s. Show how these two units are equivalent. (Hint: What is the definition of the newton, N?)