Measuring Impulse and Momentum Change in 1 Dimension – Procedure

OBJECTIVE

In this lab, you will do the following.

- Use a computer interface to collect and display data
- Simultaneously use a motion sensor and a force sensor
- Use your measurements to relate impulse to change in momentum

Some useful equations and constants are given at the end of this document.

EQUIPMENT

Track

Cart

Fan

Motion sensor with stand

Force sensor with soft spring

PASCO ScienceWorkshop® Interface

PROCEDURE

Please print the worksheet for this lab. You will need this sheet to record your data.

Experimental Setup

Equipment Setup

1 A motion sensor should be placed at one end of the track and connected to Digital Channels 1 and 2 of the interface (colored plug in Channel 1).

2 A force sensor, mounted on a bracket, should be firmly attached to the *other* end of the track and connected to Analog Channel A of the interface.

3 Open the appropriate Capstone file for this experiment.

4 You should see a display that includes a single window containing two empty graphs: the left one with y-axis labeled "Force" and the right one with y-axis labeled "velocity." (Note that these labels should really be "F_x" and "v_x"!)

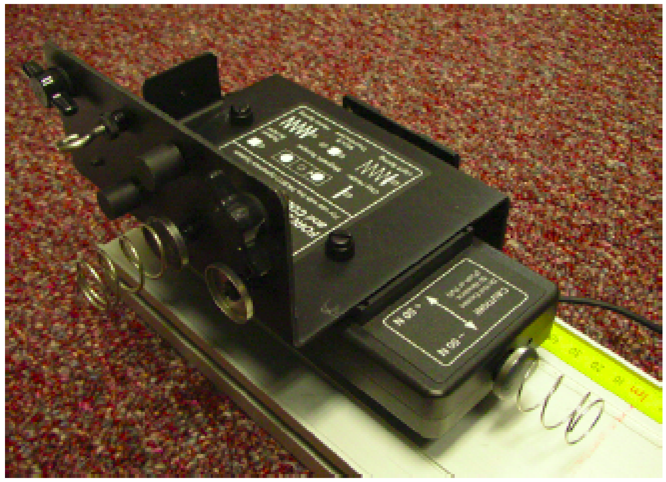

Figure 1: Force sensor

Force Sensor Setup

Different objects (springs, hooks, rubber disks) can be attached to the force sensor. For the first part of this experiment, make sure the *soft* spring is attached to the sensor. (There are two springs, one stiff and the other soft.) If a different object is attached, take it off and put it into an empty slot in the mounting bracket, then attach the spring to the force sensor.

Examining How the Equipment Works

1 Click **Record** in Capstone, then press gently on the spring on the force sensor. Try compressing the spring slowly and rapidly to see what kind of graph is produced.

2 If the force does not read zero when the spring is not compressed, press the "tare" button by inserting the screwdriver through the hole in the mounting bracket.

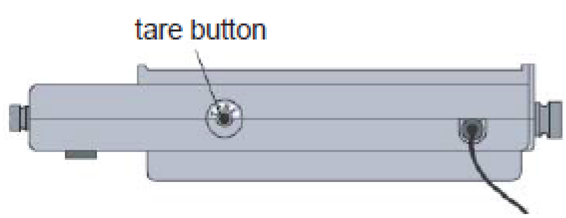

Figure 2

3 Roll the cart gently so it bounces off the spring on the force sensor. Find a speed that produces a clearly visible signal but does not flatten out at the top (this indicates a force too large to measure with these settings).

4 Ensure you understand the graphs of F_x vs. t and v_x vs. t that are produced simultaneously.

5 Look at your graphs, and make sure you can answer the following questions. If necessary, do further experiments to make sure you understand. Write the answers in your notes.

- **a** What location in space is considered to be the origin?

- **b** In which direction (in your actual experimental setup) does the positive x-axis run?
- **c** When v_x is positive, is the cart traveling toward the sensor or away from the sensor?
- **d** Does the graph of F_x vs. t show the force on the sensor due to the cart, or the force on the cart due to the sensor? (Think about the sign of F_x.)
- **e** How can you expand the x-axis of the graph?
- **f** How can you move the graphs to center the section of interest in your field of view?

6 Once you understand how the setup works, choose "Delete ALL data runs" from the menu at the bottom of the screen.

Note About Reciprocity of Forces

The interaction between the cart and the force sensor is due to electric interactions between the protons and electrons in the cart and those in the sensor. It is a property of the electric interaction that the electric forces exerted by two objects on each other are equal and opposite. Therefore, the graph of F_x on the cart versus t would be the same as the one you see, but the values of F_x would be negative.

Average Force

Clearly, F_x in this experiment is not constant; it varies with time. However, an *average* value of F_x can be estimated by examining your Capstone graph.

1 First, discuss with your group why F_x is *not* constant. Clearly explain your reasoning.

2 Examine the sample graph below and discuss, with your group, which value (A, B, C, D, or E) best represents the *average* value of F_x.

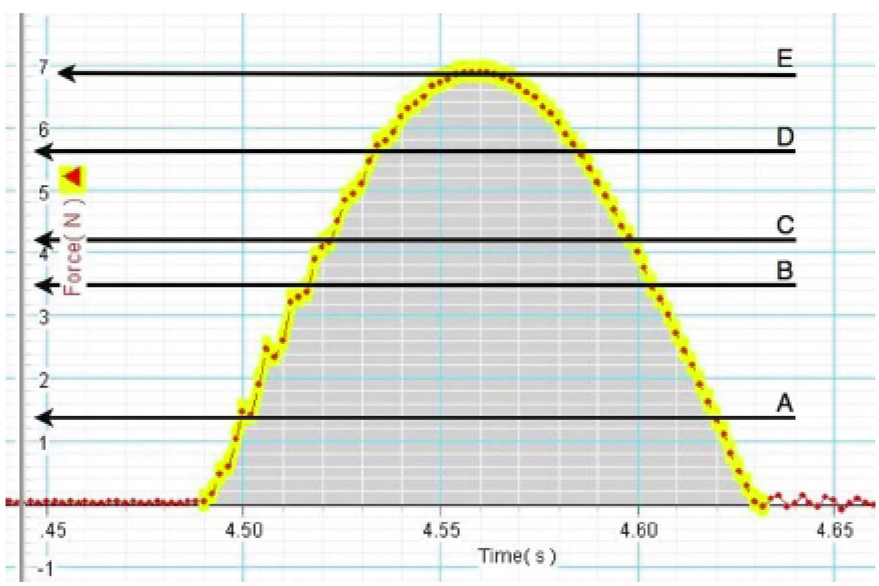

Figure 3: Sample force versus time graph

Simultaneous Measurement of F_x and Δp_x

1 Use your equipment to measure F_x vs. t and v_x vs. t while the cart rolls toward the force sensor, collides, and bounces off, rolling backward toward your hand. Do not let the cart hit the motion sensor.

> **CHECKPOINT:** Compare your graph with another group to make sure it is reasonable.

2 Do the following analyses on a whiteboard.

- **a** From the graph of v_x vs. t generated by the motion detector (along with any other necessary data you may need), determine the change in the x-component of the cart's momentum from just before the collision starts to just after it ends. Record this as Δp_x.
- **b** From your graphs, estimate the total duration of the collision, Δt.
- **c** From the graph of F_x vs. t generated by the force sensor, estimate the average value of F_x during this interval.
- **d** Using this average value, estimate the impulse, $F_x \Delta t$, applied by the sensor on the cart during the collision (with correct sign).
- **e** How does your calculated value of Δp_x compare to your estimated value of $F_x \Delta t$?
- **f** How would you expect these values to compare?

Finding Impulse Using Area Under the Curve

There is a more accurate way to determine the actual impulse on the cart. In the first short time interval Δt_1, the spring is only slightly compressed, and the force F_{x1} on the cart is small. The small impulse $F_{x1}\Delta t_1$ makes a small change Δp_{x1} in the momentum. But $F_{x1}\Delta t_1$ can be thought of as the area of a rectangle shown on the diagram, whose base is Δt_1 and height is F_{x1}. So the area of the rectangle is equal to the impulse during Δt_1 and also equal to the change in momentum Δp_{x1} during that short time interval.

In the next time interval Δt_2, we can again represent the impulse (and the change in momentum) as the area of the next rectangle shown on the diagram. We can continue through the entire collision with the spring, and we see that the total area under the curve is equal to the total impulse (and the total change in the momentum, which is the sum of all the changes to the momentum). We're approximating the area under the curve by a bunch of rectangles, but if the little Δt's are small enough that the force isn't changing much during that short time interval, the total area of our rectangles is approximately equal to the area under the curve.

This is an example of an "integral," which can often be thought of as the area under a curve. More generally, an "integral" is the sum of a large (infinite) number of very small (infinitesimal) quantities. The integral of impulse is written <s:int>$F_x dt$, where the integral sign is a distorted "S" meaning "sum" and the "dt" stands for "extremely small (infinitesimal) time interval."

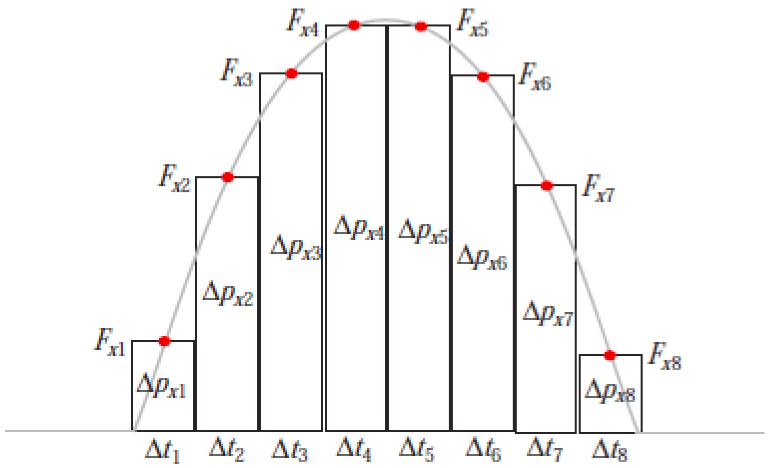

Figure 4

Capstone can calculate the area under the F_x vs. t curve for you.

1 Click on the "Area" function button on the tool bar. The area under the curve will be displayed.

Figure 5

2 Save your graph including the area calculation so that you can submit it to WebAssign.

- **a** Click on the plot, then on the Display menu, and choose "Copy."
- **b** Open Microsoft Paint and paste the picture.
- **c** **Save it as a .jpg file.** This is a manageably small file. You will upload your file in WebAssign.

Analysis

- How does the x-component of the net impulse found using <s:int>$F_x dt$ compare to the x-component of the change in the cart's momentum? (Remember that the actual value of the impulse applied to the cart is negative.)
- When F_x is the biggest it ever gets, what is p_x? Is p_x also at a maximum? Is p_x proportional to F_x? Relate your answers to the Momentum Principle.

CHECKPOINT: Compare your graph, data, and analysis with another group. Then have your instructor check both groups' work.

