Impulse and Momentum

Equipment

Includes:

1	Dynamics System	ME-6955
1	Photogate Head	ME-9498A
1	Photogate Bracket	(in ME-8998)
1	Picket Fence	ME-8933
1	Force Sensor	PS-2189
1	Force Bracket	CI-6545
1	Table Clamp	ME-9472
1	Dynamics System	ME-6955
	Required, but not included:	
1	Balance Scale	SE-8723

Introduction

A cart collides with a Force Sensor equipped with either a spring bumper, clay bumper, or magnetic bumper. The cart experiences a variable force during the time of the collision, causing it to change its velocity. In this experiment, the relationship between momentum, force, and impulse is explored.

Theory

According to Newton's Second Law,

$$\vec{F} = \frac{\vec{dp}}{dt} \qquad (1)$$

where F is the force on an object, p is the momentum of the object, and t is time. Rearranging and solving for the impulse (Δp) gives

$$\vec{\Delta p} = \vec{p_f} - \vec{p_i} = \int \vec{F}\, dt \qquad (2)$$

In this lab, the change in momentum is calculated using

$$\vec{\Delta p} = m\vec{v_f} - m\vec{v_i} \qquad (3)$$

where m is the mass, v_f is the final velocity, and v_i is the initial velocity. We define the direction of positive velocity to be to the right, in the direction of the initial velocity.

And finally, for a Force vs. Time graph, the area under the curve is the integral of the force.

$$\int \vec{F}\, dt = Area \qquad (4)$$

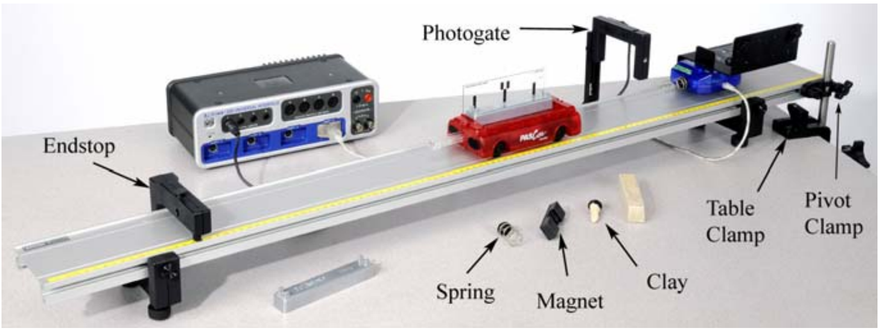

Figure 1: The speed of the cart is measured using a photogate.

Setup

1. Attach the Photogate, feet and endstop to the track as shown in Figure 1. Plug the Photogate into Digital Input #1.

2. Connect the Force Sensor near the end of the track using the Force Bracket as shown in Figure 2. Plug the Force Sensor into the interface and **zero** the sensor.

3. Place the cart on the track with one Mass Bar. Level the track.

4. Attach the Table Clamp with the 45 cm Rod at the end of the table as shown in Figure 1. Fasten the track to the rod using the track Pivot Clamp. This will keep the track from moving during collisions.

5. Attach the weak spring bumper to the Force Sensor. The Clay Bumper (see Fig. 3) will be used later.

6. Mount the Photogate Picket Fence in the cart with the double-flag **up** as shown in Figure 2. Set the position of the Photogate in the vertical direction so the Photogate will be blocked by the double flag.

7. Adjust the position of the Photogate Bracket horizontally on the track so that it is **just** far enough away from the Force Sensor so the flag on the cart will pass through the Photogate before the cart hits the spring (see Figure 2).

8. Compress the cart plunger to the 2nd position and place it against the Endstop as shown in Figure 4. This will be the starting point of the cart for every run. Practice hitting the trigger to launch the cart. One way is to use the spare mass bar to tap the trigger.

9. Use a Balance Scale to determine the mass of "cart + Picket Fence+ mass bar" and record on the next page.

10. In PASCO Capstone, create a graph of Force vs. time.

11. Open the Hardware Setup and click on photogate #1 port on the 850 interface. Select "One Photogate (Double Flag)".

12. Create a table and select Speed in the first column. Then delete the second column.

13. Set the sample rate for the force sensor to 1000 Hz.

14. Click on Recording Conditions and set the start condition for Measurement Based on the State of the Photogate is above zero. Then set the stop condition on Time Based for 0.3 seconds. You can modify this to see more or less after the collision.

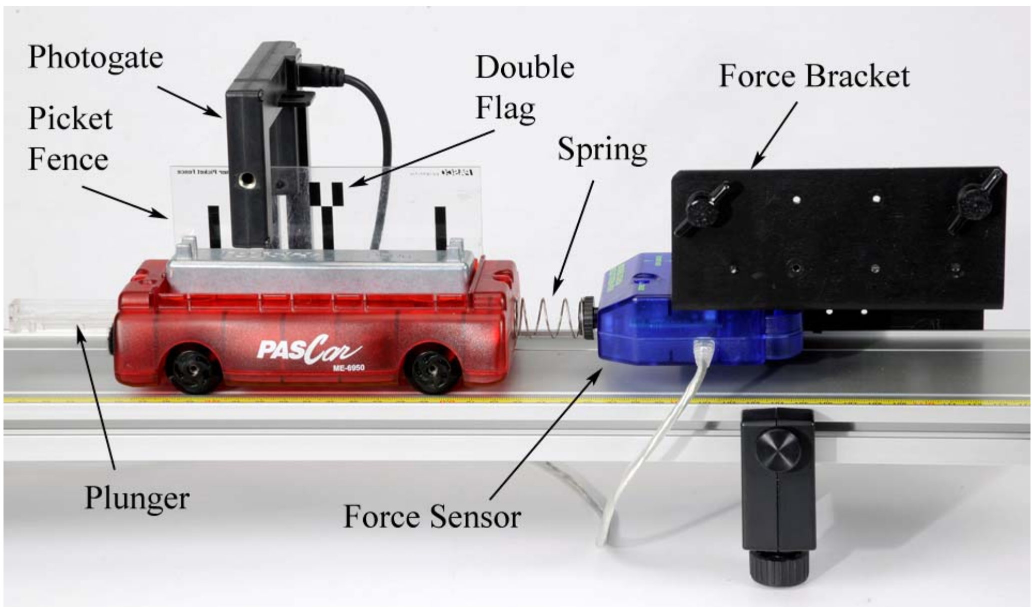

Figure 2: Collision Setup for Spring Bumper

Figure 3: Clay Bumper

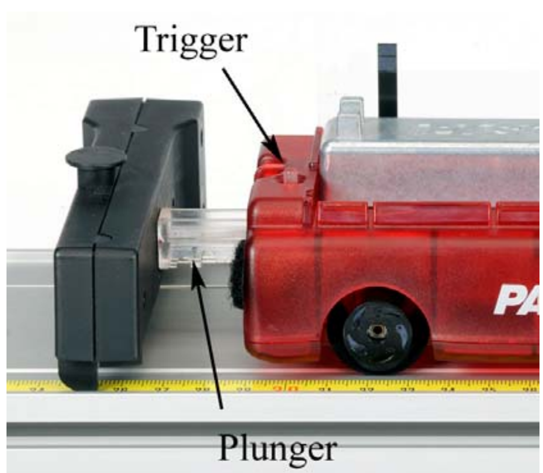

Figure 4: Using plunger to launch cart.

Spring Procedure

1. Make sure the plunger is on the second position, and is resting against the Endstop. Zero the Force Sensor. Click on Record and launch the cart.

2. Get one good run. Rename this run "Light Spring"

3. Record the initial and final velocities. The Photogate only measures the speed of the cart, and the sign must be determined by the student. It is easiest to assign the direction of motion **towards** the Force Sensor as being positive. Record the proper sign.

4. Using Equation (3), calculate the change in momentum, Δp.

Momentum and Energy Procedure

5. Measure the area under the force curve. The spring will vibrate after the collision. You can try using the smoothing function, or use the Highlight tool to select only the area you want.

6. What is the physical significance of the area? Look at Equations (2) and (4). Compare to the expected value using the % error calculation.

7. Calculate the kinetic energy of the cart before and after the collision.

8. What type of collision was this? Elastic, inelastic, or completely inelastic?

9. Replace the Light Spring with the Heavy Spring and repeat the collision. Rename this run "Heavy Spring"

10. How does the shape of the collision curve change?

11. Is the area under the curves for the two springs **about** the same? Should they be?

Clay:

12. Replace the spring with the clay bumper and repeat the collision. The cone shape shown in Figure 3 is just a suggestion. Rename this run "Clay".

13. Record the velocities and calculate the change in momentum, Δp.

14. Measure the area under the force curve, and compare to expected value.

15. Calculate the kinetic energy of the cart before and after the collision. What type of collision was this? Elastic, inelastic, or completely inelastic?

16. How does the shape of the clay collision curve compare to the springs? Is the area under the curves for the springs about the same as the clay? Should they be?

Further Study:

17. Try changing the shape of the Clay Bumper. Who can create a shape that causes the **least** maximum force for the same speed collision?

18. Try the Magnetic Bumper. You will need to remove the mass bar and use a **much** slower speed. Try using the plunger on its lowest setting. How is the shape of this curve different from the spring?

19. Create your own bumper! The example shown in Figure 5 is made with thin graph paper rolled into a tube. It was then taped to the base used for the clay bumper. Have a contest!

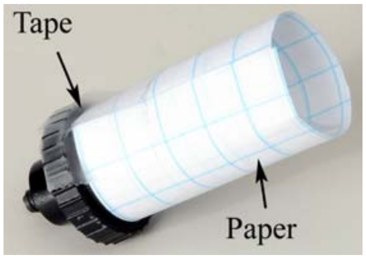

Figure 5. Paper Bumper