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Impulse and Momentum

Driving Question | Objective

What is momentum? How does a force acting on an object affect it? What is an impulse? The purpose of this lab is to attempt to answer these questions by determining some type of relationship between and object's mass, velocity, force, and time experiencing that force.

Materials and Equipment

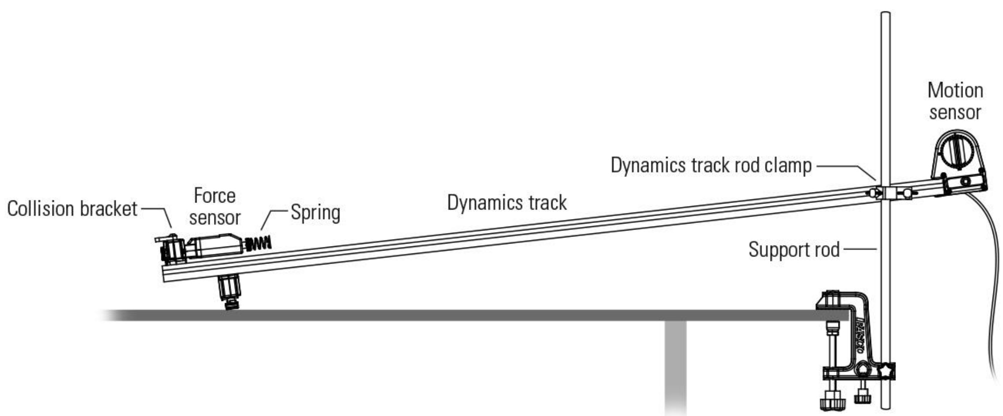
- Data collection system
- PASCO Motion Sensor
- PASCO Force Sensor
- Ring Stand
- PASCO Dynamics Track
- PASCO Dynamics Cart

Procedure

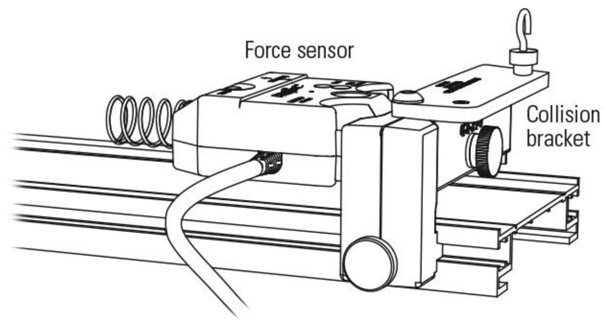
SET UP

1. Attach one end of the dynamics track to the support rod using the dynamics track rod clamp, inclining the track just slightly (less than or equal to 10°).

2. Mount the motion sensor to the raised end of the track with the front of the sensor pointing down the track. Make certain the switch on the top of the sensor is set to the cart icon.



3. Screw the softest spring bumper from the collision bracket to the front of the force sensor, and then attach the force sensor to the bracket using the large thumbscrew on the bracket.



4. Connect both sensors to the data collection system and then create two graph displays: one graph display of force (inverted) versus time, and the second graph display of velocity versus time.

5. Open the pre-made Capstone sensor file.

COLLECT DATA

1. The mass of the cart is 0.25 kg. This will need to be known for the data tables below.

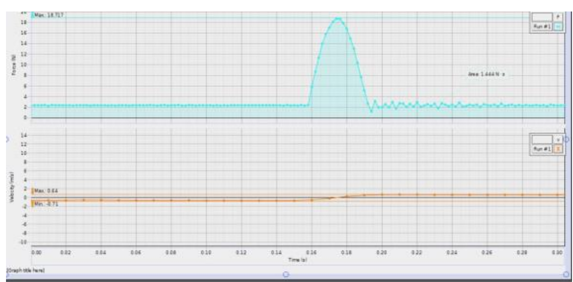
2. Select a location on the ramp in which the cart will begin to roll down. Start off with a small distance around 20 cm from the force sensor. Hold the cart at this position.

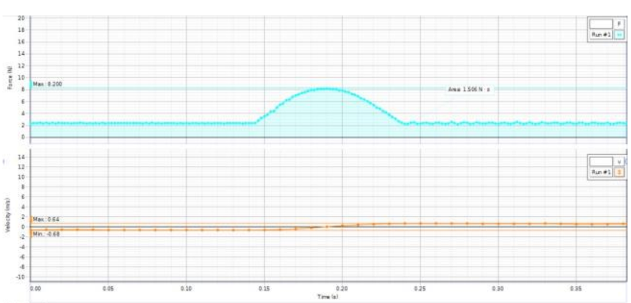
3. Click "record." You should notice nothing is being recorded while you are holding the cart in place. This is fine, data will automatically begin recorded just before it collides with the spring in will automatically stop recording data just after the collision. You do not need to press Stop yourself.

4. Release the cart and allow it to bounce off the spring. Prevent the cart from striking the spring multiple time. Afterward, gather the following information: The area underneath the Force vs. Time graph, maximum force, and the minimum/maximum velocities before and after the collision.

5. Conduct multiple trials changing variables of your choosing: release position on ramp, mass of cart, and type of spring. Be sure to have some trials for both springs that have the same release point and mass for comparison.

6. Please attach a screenshot of 1 example of your two graphs below.





Data Analysis

1. Using the tools on your data collection system, determine the velocity of the cart just before (initial velocity) and just after (final velocity) the collision for each trial, and then record each value in Table 1.

   NOTE: Make sure the signs of the velocities are correct

2. Using the tools on your data collection system, determine the time interval and average force of the collision in each trial. Record each value in Table 1.

Table 1: Impulse and momentum of a cart undergoing a collision

- Cart Mass: 0.25 kg

	Trial	Initial Velocity (m/s)	Final Velocity (m/s)	Change in Velocity (m/s)	Max Force (N)	Approximate Time Interval (s)	Area of Force Graph (N·s)	Mass * Change in velocity (kg·m/s)
Soft Spring	1	-0.68	0.64	1.32	8.200	0.1	1.506	0.33
	2	-0.67	0.65	1.32	8.067	0.1	1.501	0.33
	3	-0.68	0.67	1.35	8.094	0.2	1.531	0.338
	4	-0.70	0.65	1.40	8.094	0.1	1.526	0.35
Hard Spring	1 (30)	-0.69	0.60	1.29	17.652	0.02	1.485	0.3225
	2(40)	-0.74	0.68	1.42	18.557	0.03	1.419	0.355
	3 (50)	-0.71	0.67	1.38	17.891	0.02	1.422	0.345
	4	-0.71	0.64	1.35	18.717	0.03	1.444	0.338

Analysis Questions

- 1. Based on your measurements, how does the area of the force graphs compare to the mass*change in velocity values in each case?

The area of the force graphs compared to the mass*change in velocity is much larger than that of the mass *change graph. This means that there is more impulse than momentum

Important note: From now on, the area of a Force vs. Time graph (the product of force and time) will be called IMPULSE (Variable: *J*). And the product for mass and velocity will be called MOMENTUM (Variable: *p*).

- 2. Was there ever a case in which the peak force on the soft spring was larger than the peak force on the hard spring even when the release conditions were identical? If so, when did this happen and how could you explain this?

No because the soft spring always had more contact time with the cart and therefore always had less peak force than the hard spring even when conditions were identical.

- 3. If the cart is released from the **same starting point**, but collides with the two different springs in two separate scenarios, how does the IMPULSE (area of the Force vs. Time graph) compare?

The impulse of the two carts will be the same because momentum is the same and impulse is equal to the change in momentum.

The impulse of the cart that collided with the hard spring would be greater than the impulse of the cart that collided with the soft spring.

Synthesis Questions

- 1. If an object experiencing a collision was to hit a soft cushion rather than a rigid surface, would the impulse be different? Assume the object's initial and final velocities are the same in both collisions. Justify your answer. If possible, try this with your lab setup.

The impulse of the object is defined by the integral of what is force over time, which is equivalent to the change in momentum of an object. Impulse will always be the same if the initial and final momentum are the same because it is just final velocity – initial velocity.

- 2. Near the exits of many highways are yellow plastic barrels filled with sand called "Fitch barriers" after the inventor, race car driver John Fitch. How do these barrels reduce injury to vehicle occupants if their car crashes into them on exiting the freeway?

When the vehicle crashes into the Fitch Barriers, net change in momentum is the same as if it would have crashed to a rigid surface, but the damage doesn't depend only on change in momentum, it also depends on the time interval. Fitch barriers are filled with sand hence they can be compressed and momentum can be distributed to the sands.

- 3. A 50-kg rock climber accidentally falls from the side of a rock and free falls until she is stopped by her 9-m safety rope. Assuming that the rope stops her completely, with no rebound, what is the impulse imparted on her body by the rope? Show your work.

$m = 50kg, h = 9m$

$Ei = Ef, Ei = mgh$

$Ef = \frac{1}{2mv^2}$, v=13.3m/s

$I = change\ in\ P\ (momentum); I = Mv - Mvi; I = (50)(13.3$

- 4. Passengers on a commercial jet experience changes in horizontal force as the jet accelerates and decelerates in mid-flight without changing altitude. If the 90,000.0-kg jet experiences an average force of 37,500 N over 60.0 seconds as it accelerates from an initial velocity of 187.8 m/s to its final cruising velocity, what is the final cruising velocity of the jet? Show your work.

$$V = \frac{impulse}{mass} = area\ under \frac{fscurve}{mas} = \frac{\frac{1}{2(60)(30)(50 * 10^3)}}{90000} = \frac{5000m}{s}$$

$$Vf = Vi + change\ in\ v = 687.8m/s$$