Group Members: Tanisi Tripathi, Pooja Birla, Gigi Gong, Junyu Xu, Maddy Xiong

Momentum Lab - Collisions

Driving Question | Objective

How is the total linear momentum and kinetic energy of an isolated two-object system affected by a collision? How do Newton's Laws help us understand properties of momentum?

Materials and Equipment

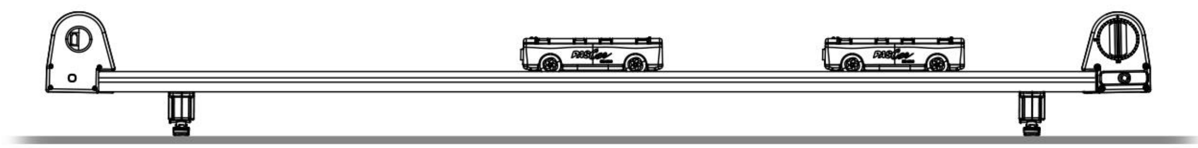
- Data collection system
- PASCO Motion Sensor (2)
- PASCO Dynamics Cart (2)
- PASCO Raised Dynamics Track
- 0.5 kg Cart Masses

Procedure

Part 1 – Elastic Collision

SET UP

1. Set the track on a level surface with one motion sensor attached to each end as in the diagram below. Adjust the sides of the track to assure it is perfectly level.



2. Connect both motion sensors to the data collection system.

NOTE: The sensors are facing in opposite directions, so the software must be configured to account for this when determining whether velocities are "positive" or "negative."

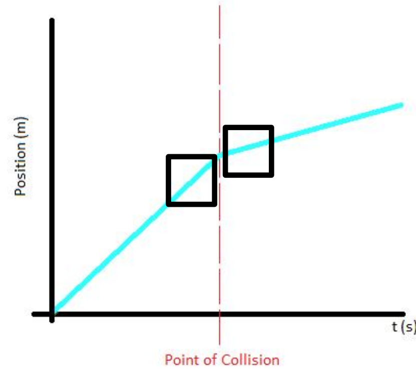
3. Display 2 graphs of position vs. time. Make sure that the sampling rate is set to at least 20 samples per second for each motion sensor. The motion sensors have a selector switch; make sure that they are in the cart mode.

4. Experiment a bit to determine which sensor corresponds to which graph and make a personal note.

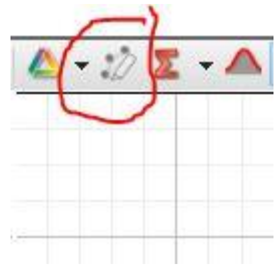
5. Once you have confirmed which sensor is which, you are ready to proceed to collecting data. To do this, first clear all of your practice runs.

DATA

Part 1 – Elastic Collisions



6. Measure the mass of each cart and place them on the track in such a way that they magnetically repel one another.
7. Start collecting data and give an initial push to one cart to have it begin moving toward the other cart. Your hand should not be on the cart when they collide. After the collision occurs, catch both carts before they hit either motion sensor and stop the data collection.
8. The resulting graph should look similar to the one on the top right.
9. Measure the velocity of the <u>each</u> cart <u>before</u> and <u>after</u> the collision (that 4 numbers!). To do this, place a linear regression and record the slope.



10. To minimize the effects of friction and to get the two separate velocities of each graph, measure <u>only</u> the portion of the graph right before and right after the collision occurred, as indicated by the black squares on the graph above. To do this please press the icon indicated in the image to the right and adjust the rectangle that appears to only include the data you want to measure the slope of.
11. Once you have measured the initial and final velocities for both cars/graphs, record them for trial 1 below.
12. For trials 2 and 3, collide the two carts again, but with different starting conditions. These can be determined by you, but some things you could try would include: changing the mass of one or both carts, changing which cart starts off in motion (or both in motion) before the collision. Or even affecting mass and cart motion at the same time.

Table 1: Cart 1 Elastic collision data (blue)

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1	0.25	0	0.19	0	1.316	0	0.0045
2	0.25	0	0.35	0	0.714	0	0.015

Table 2: Cart 2 Elastic collision data (steel)

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1	0.5	0.13	0.09	0.065	0.045	0.0085	0.405
2	0.5	0.26	0.17	0.13	0.085	0.0338	0.01445

Table 3: Total Momentum and Kinetic Energy Comparisons

Trial	Total Initial Momentum (kg m/s)	Total Final Momentum (kg m/s)	Total Initial Kinetic Energy (J)	Total Final Kinetic Energy (J)
1	0	1.316	0	0.0045
2	0.0665	0.714	0.0085	0.4135

15. In these trials, how did the initial and final <u>*total momentum*</u> ($\vec{p}_1 + \vec{p}_2$) compare? How did the initial and final <u>*total kinetic energy*</u> ($K_1 + K_2$) compare?

After the elastic collision, the momentum and kinetic energy increase.

Part 2 – Perfectly Inelastic Collision

16. The conditions of this part of the experiment will be almost identical to the 1st part, only this time, orient the carts in such a way in which they will stick together with Velcro when they collide.
17. Collide the carts with 2 different starting conditions (mass of carts and which cart(s) are moving).
18. Record the same data as in part 1 in the tables below.

Table 4: Cart 1 Perfectly inelastic collision data

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1	0.5	0.13	0.065	0.045	0.0325	0.0085	0.0021
2							

Table 5: Cart 2 Perfectly inelastic collision data

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1	0.25	0	0.19	0	0.0475	0	0. 009
2							

Table 6: Total Momentum and Kinetic Energy Comparisons

Trial	Total Initial Momentum (kg m/s)	Total Final Momentum (kg m/s)	Total Initial Kinetic Energy (J)	Total Final Kinetic Energy (J)
1	0.045	0.0325	0.0085	0.0021
2	0	0.0475	0	0.009

19. In these trials, how did the initial and final *total momentum* ($\vec{p}_1 + \vec{p}_2$) compare? How did the initial and final *total kinetic energy* ($K_1 + K_2$) compare?

The final momentum decreases when there is an initial velocity and increases when the cart starts at rest. The total kinetic energy decreases unless the car starts at rest.

Part 3 – Explosions

20. For this portion, orient the carts to where the extending plunger it facing the other cart and place the carts in contact with each other.
21. To initiate the explosion, press down on the plunger pin with something ridged (like one of the cart masses), but not directly with your finger as this introduces friction.
22. Create 2 starting conditions of your choice and record the same data as in part 1 &2 in the tables below.

Table 7: Cart 1 Explosion data

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1	0.5	0	1.21	0	0.605	0	0.732
2							

Table 8: Cart 2 Explosion data

Trial	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)	Initial Kinetic Energy (J)	Final Kinetic Energy (J)
1	0.25	0	-1.05	0	0.2625	0	0. 2756
2							

Table 9: Total Momentum and Kinetic Energy Comparisons

Trial	Total Initial Momentum (kg m/s)	Total Final Momentum (kg m/s)	Total Initial Kinetic Energy (J)	Total Final Kinetic Energy (J)
1	0	0.605	0	0.732
2	0	0.2625	0	0.2756

15. In these trials, how did the initial and final *total momentum* ($\vec{p}_1 + \vec{p}_2$) compare? How did the initial and final *total kinetic energy* ($K_1 + K_2$) compare?

The momentum and kinetic energy increased.

Analysis Questions

- 1. In the table below, complete teach of the statements by stating whether the total momentum and total kinetic energy of **increase**, **decreases**, or **remains constant**.

Type of Collision		
Elastic	Total Momentum… increases	Total Kinetic Energy… increases
Perfectly Inelastic	Total Momentum… decreases	Total Kinetic Energy… decreases
Explosion	Total Momentum… increases	Total Kinetic Energy… increases

- 2. Thinking back to Newton's 3rd law, $F_{A\ on\ B} = -F_{B\ on\ A}$, which means that both carts should experience the same force as each other, but in opposite directions. Each cart should also experience this force for the same amount of time as the other. So if the Impulse $J_1 = F\Delta t$ on one cart is $5\ N \cdot s$, what will the impulse on the other cart be? Keep direction in mind.

$J_2 = -5\ N \cdot s$

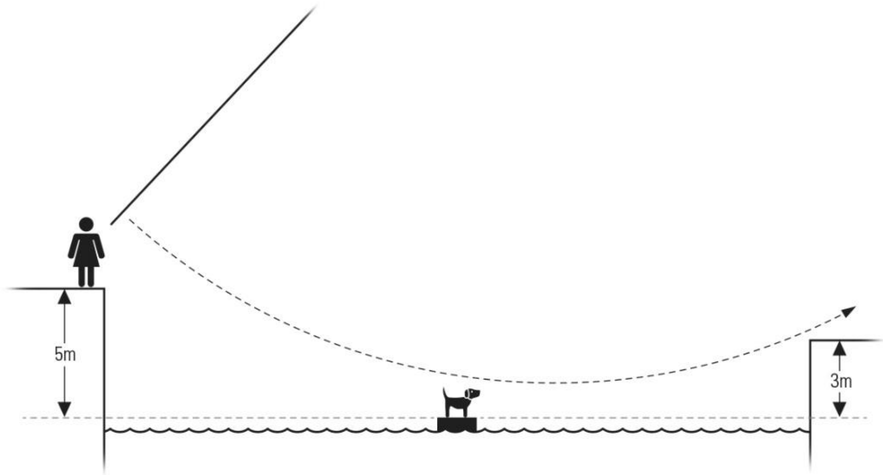
- 3. Building on this, what would be the total impulse on the two-cart system? Keep in mind that the Impulse is equivalent to the change in momentum.

$$\vec{J}_{total} = \vec{J}_1 + \vec{J}_2 = \Delta\vec{p}_{total} = 5\ N \cdot s - 5\ N \cdot s = 0$$

Hopefully this helps to explain why you have found this property in the total momentum of the system experimentally.

Synthesis Question

- 1. Samantha sees a poor dog floating away to his doom in the middle of a river. Luckily, there is a rope she can swing on to save the dog. However, as Samantha swings and picks up the dog, she notices she reaches a new final height that is less than her original starting height.



Ignoring air resistance or other forms of friction, why would Samantha's final height be less than her initial height? Be sure to use physics concepts as part of your reasoning.

As the angle between the string and its connector decreases, the vertical length of the string increases, causing Samantha's height to decrease.