Conservation of Momentum

EQUIPMENT

1	Smart Cart - Red	ME-1240
1	Smart Cart - Blue	ME-1241
1	250 g Mass Bars (Set of 2)	ME-6757A
1	1.2 m Dynamics Track	ME-9493
1	Track End Stops (Set of 2)	ME-8971
1	Track Feet (Set of 2)	ME-8972
	Required, but not included:	
1	Mass Balance	SE-8723
1	850 Universal Interface	UI-5000
1	PASCO Capstone Software	

INTRODUCTION

Elastic and inelastic collisions are performed with two dynamics carts of different masses. Magnetic bumpers are used in the elastic collision and Velcro® bumpers are used in the completely inelastic collision. In both cases, momentum is conserved.

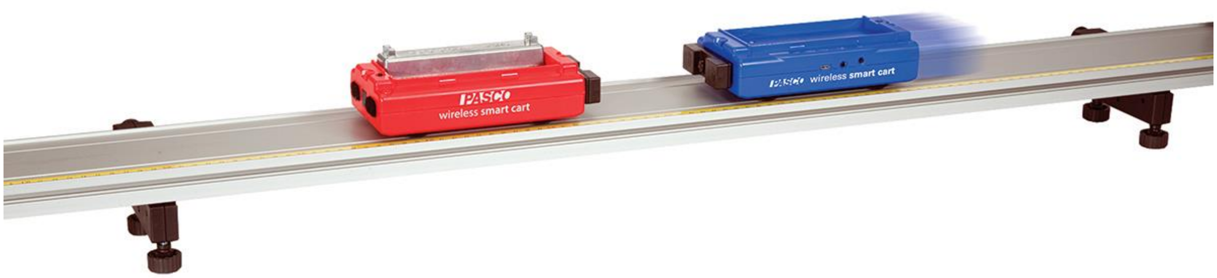


Figure 1: Setup

Cart velocities are recorded using two Rotary Motion Sensors connected to the carts by string wrapped around pulleys. This measurement method adds very little friction to the experiment and, since the velocities are continuously monitored, any deceleration due to friction can be measured. The total kinetic energy before and after the collision is also studied.

THEORY

The momentum of a cart depends on its mass and velocity.

$$\text{Momentum} = \vec{p} = m\vec{v} \qquad (1)$$

The direction of the momentum is the same as the direction of the velocity. During a collision, the total momentum of the system of both carts is conserved because the net force on the two-cart system is zero. This means that the total momentum just before the collision is equal to the total momentum just after the collision. If the momentum of one cart decreases, the momentum of the other cart increases by the same amount. This is true regardless of the type of collision, and even in cases where kinetic energy is not conserved. The law of conservation of momentum is stated as

$$\vec{p}_{\text{Total Before Collision}} = \vec{p}_{\text{Total After Collision}} \qquad (2)$$

The kinetic energy of a cart also depends on its mass and speed but kinetic energy is a scalar.

$$KE = \frac{1}{2}mv^2 \qquad (3)$$

The total kinetic energy of the system of two carts is found by adding the kinetic energies of the individual carts.

SET-UP

1. Install the magnetic bumpers on the carts.

2. Level the track using the leveling screws on the track feet. When you place a cart at rest on the track, give it a little push in each direction. It should not accelerate in either direction.

3. Use the balance to find the mass of each cart.

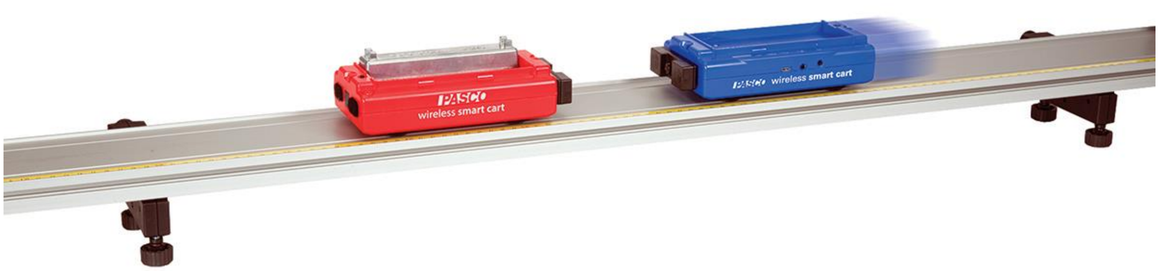


Figure 2: Complete Setup

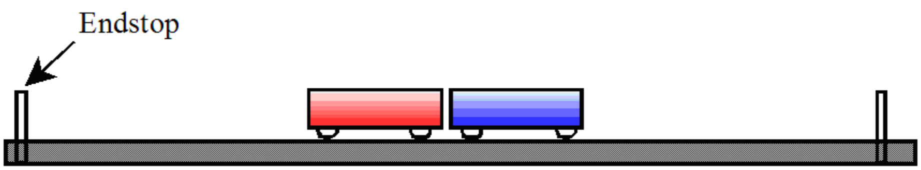
4. Create a graph of velocity vs. time, putting both the Red Cart Velocity and the Blue Cart Velocity on the same vertical axis.

5. Check the signs of the velocities. The goal is to have the velocities of both carts be positive to the right.
    a. With the red cart to the left of the blue cart, face both carts with their magnetic bumpers to the right. Start recording and push both carts to the right. Both velocities should be positive.
    b. This establishes the coordinate system to have positive x to the right for both carts.

PROCEDURE

I. Explosions

A. Equal Mass Carts



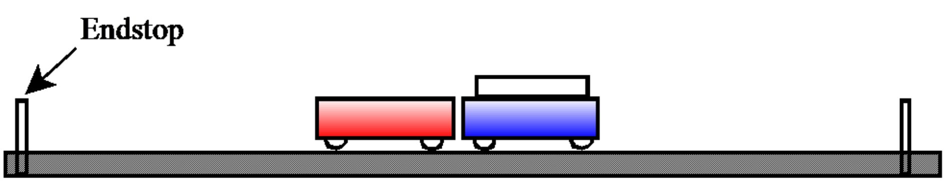
1. Depress the plunger on one cart to position #2. Does it matter which cart has its plunger depressed as long as it is in contact with the other cart? Place the two carts in contact with other in the center of the track.

2. Start recording and tap the trigger release to launch the carts. Hitting the trigger with a mass bar works well.

3. Stop recording before either cart reaches the end of the track.

4. On the velocity vs. time graph, use the Multi-Coordinates Tool to find the velocity of the red and blue carts just after the explosion.

B. Unequal Mass Carts

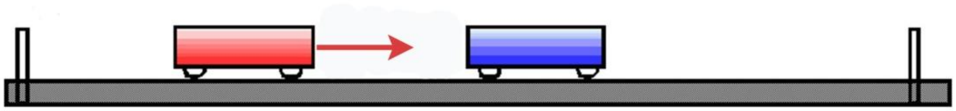


Use the balance to find the mass of two mass bars, and then place them both in the blue cart. Repeat steps 1 through 4 of part A.

II. Completely Inelastic Collisions

Velcro® Bumpers for Inelastic Collisions

A. Equal Mass Carts



1. Place the red and blue carts at rest on the track as shown above, with the Velcro® bumpers facing each other.

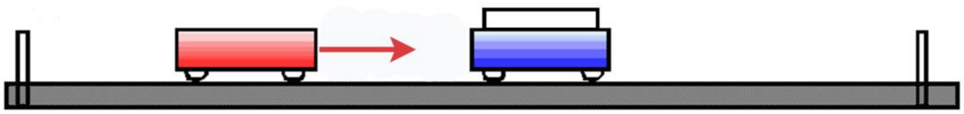
2. Because we are reversing the red cart, to keep the same frame of reference, open the Data Summary and click on the properties button next to the Red Smart Cart Position Sensor and select Change Sign.

3. Start recording and give the red cart a push toward the blue cart. Stop recording before either cart reaches the end of the track.

4. On the velocity vs. time graph, find the velocity of the red cart just before and just after the collision. It may be helpful to expand the graph, to see just that area you are interested in.

5. The initial velocity of the blue cart is zero and its final velocity is the same as the red cart because they stick together.

B. Unequal Mass Carts



1. Place the two mass bars in the blue cart.

2. Repeat the procedure from Part A.

III. Elastic Collisions

Magnetic Bumpers for Elastic Collisions

A. Equal Mass Carts

1. Place the red and blue carts at rest on the track as shown above, with the magnetic bumpers facing each other. Now the red cart is in the original positive direction and the blue cart has been reversed so open the Data Summary and click on the properties button next to the Red Smart Cart Position Sensor and deselect Change Sign and open the Blue Smart Cart Position Sensor properties and select Change Sign.

2. Place the red and blue carts at rest on the track, with the magnetic bumpers facing each other.

3. Start recording and give the red cart a push toward the blue cart.

4. Stop recording before either cart reaches the end of the track.

5. On the velocity vs. time graph, find the velocity of the red cart just before and just after the collision. It may be helpful to expand the graph, to see just that area you are interested in.

6. The initial velocity of the blue cart is zero. Find the final velocity blue cart.

B. Unequal Mass Carts

1. Place the two mass bars in the blue cart.

2. Repeat the procedure from Part A.

ANALYSIS

1. Calculate the initial and the final momentum for each cart for each of the collisions.

2. Calculate the percent difference between the total initial momentum and the total final momentum for each collision.

$$\%difference = \frac{p_{before} - p_{after}}{p_{before}} x100\%$$

3. Calculate the initial and the final kinetic energy for each cart for each of the collisions.

4. Calculate the percent of the total kinetic energy lost for each collision.

IV. Total Momentum and Total Energy

1. Create these calculations in PASCO Capstone:
   p_total=m_1 v_1+m_2 v_2
   KEtotal=KE_1+KE_2
   KE_1=1/2*m_1 v_1^2
   KE_2=1/2*m_2 v_2^2
   v_1=[Red Velocity, Ch P1(m/s)]
   v_2=[Blue Velocity, Ch P2(m/s)]
   m_1= mass of Red cart
   m_2= mass of Blue cart

2. Graph p_{total} vs. time and add a second plot area for KE_{total} vs. time.

3. Examine the graphs to see what happens before, during, and after the collisions. Look at each type of collision and record your observations. You will have to change the masses in the calculations when you look at the unequal mass collisions.

CONCLUSION

In general, what did you learn about conservation of momentum and kinetic energy in different types of collisions?

1. Was momentum conserved for all types of collisions?

2. Was total velocity conserved for all types collisions?

3. Was energy conserved for all types of collisions? Where did the extra kinetic energy come from in the explosions? What happens to the initial kinetic energy that is lost in a collision?