17.3 Lab: Conservation of Momentum in Collisions and Explosions

Class Set: Do not remove!!!

Objectives

· Collect velocity-time data for two carts experiencing different types of collisions and an explosion.
· Compare the system momentum before and after collisions and explosions.
· Compare the kinetic energy of the system before and after collisions.

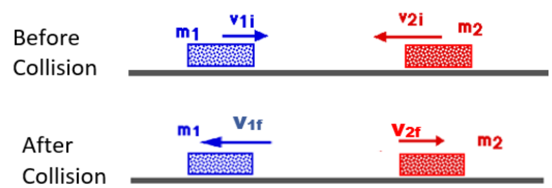
Background

When bodies collide with each other, the total momentum is always conserved regardless of the type of collision provided no external forces are present. There are two types of collisions. In an *elastic* collision, both the kinetic energy and the momentum are conserved. An *inelastic* collision is one in which only the momentum is conserved. Most collisions observed in nature are inelastic. A collision is *perfectly inelastic* when the bodies stick together after a collision. Another type of momentum transfer is an explosion. In this type of momentum transfer, one body breaks up into two or more pieces. The sum of the momenta of all the pieces is equal to the momentum of the original body.

In this experiment, we will use two carts rolling on an aluminum track to study two-body interactions in one dimension. We will consider elastic and inelastic collisions as well as explosions.

Theory

Elastic Collisions

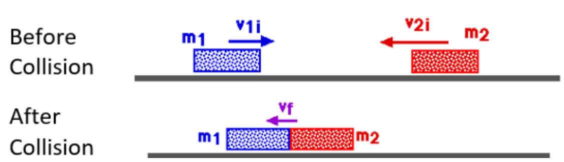


The conservation of momentum before and after an elastic collision can be written as follows:

$$\mathbf{p_i = p_f}$$
$$\mathbf{p_{1i} + p_{2i} = p_{1f} + p_{2f}}$$
$$\mathbf{m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}}$$

where m_1 and m_2 are the mass of the carts, and v_i and v_f correspond to initial and final velocities.

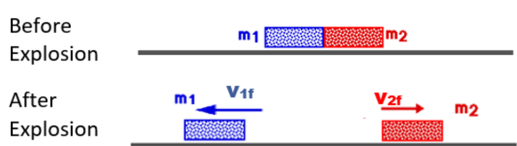
Inelastic Collisions



The conservation of momentum before and after this inelastic collision can be written as follows:

$$\mathbf{p_i = p_f}$$
$$\mathbf{p_{1i} + p_{2i} = p_{1f} + p_{2f}}$$
$$\mathbf{m_1v_{1i} + m_2v_{2i} = (m_1+m_2)v_f}$$

Explosions

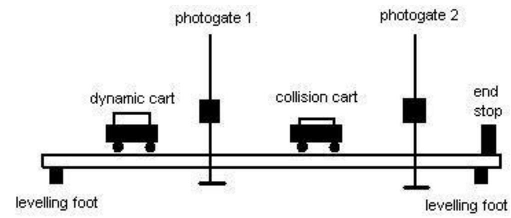


The conservation of momentum before and after this explosion can be written as follows:

$$\mathbf{p_i = p_f}$$
$$\mathbf{p_{1i} + p_{2i} = p_{1f} + p_{2f}}$$
$$\mathbf{(m_1+m_2)v_i = m_1v_{1f} + m_2v_{2f}}$$

Procedure

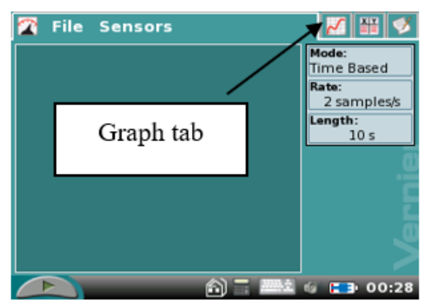
Part 1



1. Level the track by setting a cart on the track to see which direction it rolls. Use the leveling feet at the end of the track to raise or lower that end of the track. Check that the guards are installed with the magnets on the outside. Measure the mass of the two carts. One is called the Collision cart and the other is called the Dynamics cart.
2. First, you will perform a few trails to observe the qualitative behavior as the carts collide *elastically*. Place the carts on the track with the magnetic bumpers facing each other. The carts should repel as they are brought close to each other. (Push the plunger all the way in on the collision cart so that it is out of the way.) Experiment with the following situations.
   a) Place one of the carts near the mid-point of the track. Push the second cart with an initial velocity towards the stationary cart.
   b) Next, push the two carts towards each other with approximately the same speed.
   c) Push one cart with a slow velocity and a second one with a faster velocity so that it catches up with the slower cart.
   d) Place four mass bars on one of the carts, so that that cart weighs three times the other cart. Place the heavy cart at the center of the track and push the other cart with an initial velocity so that it collides with the heavier cart.
   e) Place the lighter cart at the center and push the heavier cart with an initial velocity so that it collides with the lighter cart.
3. Next, do a few trials to observe the qualitative behavior for a *perfectly inelastic* collision. Remove the additional masses from the cart, and turn the carts around so that the magnetic bumpers are no longer facing each other and the Velcro ends are towards each other. Repeat the procedures listed in step 2.

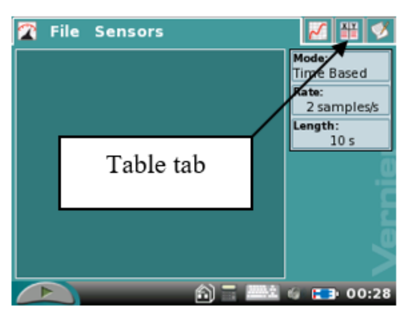
Part 2

4. Now you will make quantitative observations by *measuring* the velocities before and after the collisions as well as an explosion using the photogate timers. Measure the length of a notecard in centimeters. Convert this value to meters and write the length down in your data section. Attach one of the notecards to the Dynamics cart as shown by your teacher and the other one to the Collision cart. The velocities of the carts will be determined by the LabQuest which will divide the length of the notecard by the time it takes for the card to pass through a photogate.
5. Place the first photogate at approximately the 35 cm mark and the second photogate 85 cm from the end stop (see figure above.)
6. Turn on your LabQuest device. Plug the photogate at the 35 cm mark into DIG 1 and the photogate at 85 cm into DIG 2. Click on the "Mode:" box on the screen. In the "Photogate Mode:" dropdown menu, select the GATE mode. In the "Length of Object:" box, enter the length of your index cards in meters. Click OK.



7. Click on the Graph tab at the top of the screen. The velocities of the objects moving through the photogates will be shown in the bottom right corner. The velocity recorded at the 35 cm photogate is shown in the top velocity box. The velocity recorded at the 85 cm photogate is shown in the bottom velocity box.
8. Now, you will make quantitative measurements corresponding to *elastic* collisions. Press the collect button on the LabQuest. Place the collision cart in the middle of the track with its magnetic side facing the dynamic cart, and give the dynamic cart an initial velocity so that it passes through the first photogate timer and collides with the second cart with its magnetic side. You will observe that after the collision, the second cart moves forward and passes the second photogate. Press the stop button on the LabQuest. Record the velocities (from the LabQuest) in data table 1. **Be sure to include the appropriate sign to indicate the direction of the motion!**

> **IMPORTANT**: The collisions must occur after the first cart has passed completely through the photogate, and after the collision the carts must be fully separated before either cart interrupts a photogate.
> **NOTE**: Immediately after the final times are recorded, the carts must be stopped to prevent them from triggering the photogate again due to rebounds.



9. Repeat step 8 for two more trials with different masses for the carts. Record your results in data table 1. In this case the dynamic cart might pass through a gate a second time. That's ok. Both velocities will be recorded by the LabQuest. Press the stop button after the collision has occurred and both carts have passed through the photogates. To find your data, click on the table tab at the top of the screen. You will see the velocities for each

photogate recorded there. Record the correct velocities in your data table. **Be sure to add positives and negatives to indicate direction on the velocities!** (Use + for movement forward and – for movement backward).

10. Perform calculations to fill out Results Table 1.
11. a) Next, make measurements corresponding to a ***completely inelastic*** collision of two equal mass cart by turning the carts around so that their Velcro sides will collide and removing all mass bars from the carts. Arrange the height of the second gate so that its beam is **not** interrupted by the shorter of the two cards. Record your results in data table 2.

    b) Repeat 11a for two more trials with different cart masses.

    c) Perform calculations to fill out Results Table 2.
12. a) Next, make measurements corresponding to an ***explosion*** of two equal mass carts. To do this, press in the plunger on the cart with the plunger. You will then need to flip the Velcro inserts on both carts so there is smooth plastic exposed.

    b) Next, place the carts together so that they are touching in the middle of the track. Push the plunger button to eject the plunger and separate the carts. Record your results in data table 3.

    b) Repeat 12b for two more trials with different cart masses.

    c) Perform calculations to fill out Results Table 3.

Data and Results

Length of notecards: ______________

Data Table 1: Elastic Collision Measurements

	Cart 1			Cart 2		
Run	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)
1						
2						
3						

Results Table 1: Elastic Collision Results

	Before Collision			After Collision			Ratio
Run	p of cart 1 (kg·m/s)	p of cart 2 (kg·m/s)	p of system (kg·m/s)	p of cart 1 (kg·m/s)	p of cart 2 (kg·m/s)	p of system (kg·m/s)	$\frac{p\ after}{p\ before}$
1							
2							
3							

Data Table 2: Inelastic Collision Measurements

	Cart 1			Cart 2		
Run	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)
1						
2						
3						

Results Table 2: Inelastic Collision Results

	Before Collision			After Collision			Ratio
Run	p of cart 1 (kg·m/s)	p of cart 2 (kg·m/s)	p of system (kg·m/s)	p of cart 1 (kg·m/s)	p of cart 2 (kg·m/s)	p of system (kg·m/s)	$\frac{p\ after}{p\ before}$
1							
2							
3							

Data Table 3: Explosion Measurements

	Cart 1			Cart 2		
Run	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)	Mass (kg)	Initial Velocity (m/s)	Final Velocity (m/s)
1						
2						
3						

Results Table 3: Explosion Results

	Before Collision			After Collision			Ratio
Run	p of cart 1 (kg·m/s)	p of cart 2 (kg·m/s)	p of system (kg·m/s)	p of cart 1 (kg·m/s)	p of cart 2 (kg·m/s)	p of system (kg·m/s)	$\frac{p\ after}{p\ before}$
1							
2							
3							

Analysis

Elastic Collisions

1. How does the total momentum of the system after the collision compare with that before the collision? Do your results agree with your expectations? Explain.

2. Calculate the total kinetic energy, $K = 1/2mv^2$, of the system both before and after each of the collisions. How do these quantities compare?

Inelastic Collisions

3. How does the total momentum of the system after the collision compare to that before the collision? Is the agreement in these inelastic collisions as good as that in the elastic collisions? Try to account for any differences.

4. Calculate the total kinetic energy of the system both before and after each of the collisions. How do these quantities compare? Compare your findings with those of others in your class.

Explosions

5. How does the total momentum of the system after the explosion compare to that when the carts were stationary? Report any discrepancy as a percentage of the momentum of one of the carts.

6. Calculate the total kinetic energy of the system both before and after each of the explosions. How do you account for the increase in kinetic energy?