Experiment: Conservation of Linear Momentum (with a Photogate)

Concept: Newton's Laws, Conservation of Momentum
SW Interface: 500 or 700

EQUIPMENT NEEDED

- *Science Workshop™ Interface*
- five pattern picket fence (two)
- photogate (two)
- balance (for measuring mass)
- dynamics track
- collision cart with mass (two)

PURPOSE

The purpose of this laboratory activity is to investigate the momentum of two carts before and after an elastic collision.

THEORY

When objects collide, whether locomotives, shopping carts, or your foot and the sidewalk, the results can be complicated. Yet even in the most chaotic of collisions, as long as there are no external forces acting on the colliding objects, one principle always holds and provides an excellent tool for understanding the dynamics of the collision. That principle is called the conservation of momentum. For a two-object collision, momentum conservation is easily stated mathematically by the equation:

$$m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}_1' + m_2\vec{v}_2'$$

If external forces such as friction are ignored, the sum of the *momenta* of two carts prior to a collision is the same as the sum of the *momenta* of the carts after the collision.

PROCEDURE

*Before doing anything select the "Save As" command from the File Menu and save this file into YOUR folder (Make sure that the path is to YOUR folder before pressing "Save" or "OK". Do the same thing with the Science Workshop File entitled**: Lab – Cons. Of Momentum.**

For this activity, photogates will measure the motion of two carts before and after an elastic collision. The *Science Workshop* program calculates speed for each cart.

PART I: Computer Setup

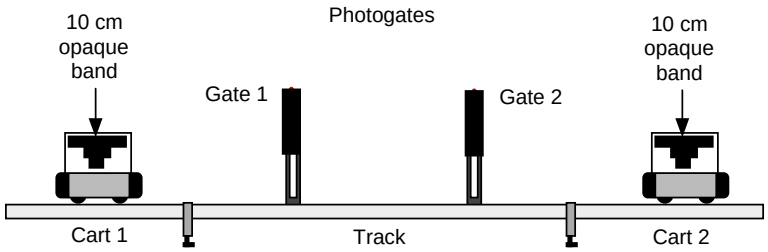
1. Connect the *Science Workshop* interface to the computer, turn on the interface, and turn on the computer.

2. Connect one photogate's stereo phone plug into Digital Channel 1 on the interface. The photogate connected to Digital Channel 1 will be "Gate 1".
3. Connect the second photogate's stereo phone plug into Digital Channel 2 on the interface. The photogate connected to Digital Channel 2 will be "Gate 2".
4. Go to the class web site and download the data studio file into your server space.
5. Open Data Studio, choose you r interface, then select File→Open and choose the file you saved to your server space.

- The document will open with a Table display of "Velocity" (m/sec) for two objects.
- The Experiment Setup window has been resized. If you want to expand the Experiment Setup window to its original size, click on the "Zoom" box in the upper right hand corner of the window. (Note: To bring a display to the top, click on its window or select the name of the display from the list at the end of the Display menu. To resize a display click and hold on the bottom right hand corner of the window and move your mouse)

PART II: Equipment Setup

1. Place the track on a horizontal surface.
2. Level the track by placing a collision cart on the track. If the cart rolls one way or the other, use the adjustable feet at one end of the track to raise or lower that end until the track is level and the cart will not roll one way or the other.
3. Put a five pattern picket fence in the notches at each end of the accessory tray of each collision cart. (Note: the picket fences have a number of patterns on them. Using the "five pattern" means adjusting the height of the photogate to read the part of the picket fence that has five opaque black bands) Use the balance to find the mass of each cart and record the values in the Data Table.
4. Mount the photogate that is connected to Digital Channel 1 ("Gate 1") on the left side of the track. Mount the other photogate ("Gate 2") on the right side of the track.
5. Place the carts together at the middle of the track. Position the photogates so that "Gate 1" is beyond the left end of the two carts, and "Gate 2" is beyond the right end of the two carts. Adjust the photogates so that the distance between 'gates is a few centimeters greater than the total length of both collision carts.
7. Adjust the height of each photogate so that as a cart moves through the photogate, the 10 centimeter opaque band on the five pattern picket fence blocks the photogate beam.



Conservation of Linear Momentum in Elastic Collisions

8. Move the carts to each end of the track. You will need to ensure that they go through the gates before and after the collsions.

PART III: Data Recording

1. Prepare to measure the motion of each cart as it moves toward the other cart and then collides elastically. (Be sure the magnetic ends of the collision carts will repel.)
2. Click the "REC" to begin data recording. Gently push the carts toward each other at the same time so that they will collide in the space between the two photogates.

   • Let the data recording continue until the carts have collided and returned to the ends of the track.
3. Click the "STOP" button to end data recording.

   • "Run #1" will appear in the Data list in the Experiment Setup window.
4. Repeat the data recording procedure a total of five times.

   • "Run #5" will be the last to appear in the Data list in the Experiment Setup window.
5. Record the values for mass (kg) and velocity (m/s) in your data table. (Note: Momentum is a vector so you must choose a positive direction and use +/- signs for your velocities appropriately.)
6. Repeat the above procedure for the five scenarios below:

HEAD ON TRIALS
1. Elastic Collision – Equal Mass
2. Elastic Collision – Unequal Mass
3. Inelastic Collision – Equal Mass
4. Inelastic Collision – Unequal Mass
5. Explosion Collision

REAR END TRIALS (OPTIONAL)
6. Elastic Collision – Equal Mass
7. Elastic Collision – Unequal Mass
8. Inelastic Collision – Equal Mass
9. Inelastic Collision – Unequal Mass

DATA TABLE 1

	Mass 1 kg	Init. Vel 1 m/s	Final Vel 1 m/s	Mass 2 kg	Init. Vel 2 m/s	Final Vel 2 m/s
1						
2						
3						
4						
5						

DATA TABLE 2

	P1-bef kg·m/s	P2-bef kg·m/s	P1-aft kg·m/s	P2-aft kg·m/s
1				
2				
3				
4				
5				

DATA TABLE 3

	Ptot-bef kg·m/s	Ptot-aft kg·m/s	% Diff
1			
2			
3			
4			
5			

ANALYSIS

1. Use the data in table one to fill out tables two and three. Be sure to keep in mind the vector nature of momentum. You will have to choose a positive direction and make your velocities positive or negative according to your choice (watch signs!).

2. Calculate the percentage difference between the total momentum before and the total momentum after the collision.

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

QUESTIONS

1. How does the total momentum before the collision compare to the total momentum after the collision?

2. What factors do think may cause there to be a difference between the momentum before and the momentum after collision?
3. Explain the difference between *elastic* and *inelastic* collisions.

4. Is **energy** conserved in your collisions? How could you tell? Do it!

5. Is momentum only conserved in head on collisions?

6. What happens when an object collides head on, inelastically, with another object at rest with equal mass?

7. What, if any, generalizations can you make about momentum and energy in *elastic* collisions? Be specific.

Error Analysis

What reasons can you offer for why momentum was not perfectly conserved?

Conclusions

What did you do? What did you find? What generalizations can you make?