**Lab 5: Momentum**

**Objective:** To investigate the momentum of moving objects in the laboratory in order to verify the momentum conservation law.

**Procedure**

**Part I: Two Carts Springing Apart**

1. Acquire a collision cart, a plunger cart, a weight bar, and two picket fence cards. Set up two photogates so they are blocked by the widest (10-cm) pattern on the picket fence on either side of the carts, as shown below. Plug the photogates into channels 1 and 2 in the interface. Take note of which is which. Double-click on the configuration file called “Two-Photogates” in the Phys 109 folder to launch the software.

   ![Diagram](image)

2. Set the photogates about 50 cm apart. Level your track. Push the plunger completely into the cart and slightly up to latch it. To release the plunger, set the cart on the track and gently tap the pin with a meter stick. Practice releasing the plunger so you don’t affect the motion of the cart. Place the second cart right next to the plunger cart so that the plunger will push against this second cart when released. Now release the plunger (don’t worry about the photogates yet).

3. Question: Describe all that you observe.

4. Question: Give two examples from everyday life that demonstrate behavior similar to that which you just observed.

5. Now we will measure the momenta of the two carts. Repeat the experiment, this time pushing **Record** before you release the plunger. Press **STOP** after measurements have been made. The velocities of the two carts should be displayed on your computer screen (in chronological order by row). Complete the table below, which quantitatively describes what has just happened. Use the electronic balance at the front of the room to measure the masses of the carts (with cards). Calculate the momentum of each cart by multiplying the mass and speed of the corresponding cart. Watch sig-figs!

<table>
<thead>
<tr>
<th>Mass 1 (kg)</th>
<th>Mass 2 (kg)</th>
<th>Speed 1 (m/s)</th>
<th>Speed 2 (m/s)</th>
<th>Momentum 1 (kg m/s)</th>
<th>Momentum 2 (kg m/s)</th>
</tr>
</thead>
</table>
6. Question: What do you expect to be true about the momentum values in the last two columns? Why? Did you obtain the values you expected?

7. Repeat this procedure, but add a bar mass to one of the carts (and re-weigh) before you release the plunger.
8. Question: Which cart moves slower? Why?

9. Complete the table below.

<table>
<thead>
<tr>
<th>Mass 1 (kg)</th>
<th>Mass 2 (kg)</th>
<th>Speed 1 (m/s)</th>
<th>Speed 2 (m/s)</th>
<th>Momentum 1 (kg m/s)</th>
<th>Momentum 2 (kg m/s)</th>
</tr>
</thead>
</table>

10. Question: How close are the momentum values this time?

Part II: Springy Collisions

1. Plug a motion sensor into channels 1 (yellow) and 2 and a single photogate into channel 3. Open the configuration file called “Motion_Sensor- Photogate.” Set up your kinematics track as shown below.

2. Place a bar mass in Cart 2. Give Cart 1 a push so that it collides with Cart 2.
3. Question: Describe what you observe.

4. Press Start to take data and repeat the collision. You should see a smooth graph of motion for Cart 1, and a single velocity displayed in the table for Cart 2. Adjust the instruments if necessary to obtain a good run. Make sure the Motion Sensor is on “narrow beam” setting.
5. We now wish to calculate the momenta of the carts as they interacted. There will now be three speeds to measure, since the carts didn’t stick together. Let’s call them Speed 2, Speed 1 Before, and Speed 1 After. Speed 2 can simply be taken from the onscreen photogate data table. The two speeds for Cart 1 need to be extracted from its position-time graph. Make a rough sketch of this graph below, labeling the parts of the graph that correspond to these three time segments: Speed 1 Before, Speed 1 After, and Collision. Have a lab assistant check your graph.

6. To measure the two speeds for Cart 1, curve fit the proper sections of the position-time graph. Complete the two tables below. Make sure that you have measured the correct masses for the carts you are now using. Weigh the carts if necessary.

<table>
<thead>
<tr>
<th>Cart</th>
<th>Mass (kg)</th>
<th>Speed (m/s)</th>
<th>Mom. (kg m/s)</th>
<th>Cart</th>
<th>Mass (kg)</th>
<th>Speed (m/s)</th>
<th>Mom. (kg m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1</td>
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</table>

7. Note that the speed and momentum for Cart 1 after the collision are both negative, since the cart was moving backwards at that time.

8. Question: Calculate the total momentum before and after the collision, and compare them.

9. Repeat the previous procedure, but remove the 500-g mass bar from Cart 2 and place it on Cart 1. Complete the table below. This time, the speed and momentum for Cart 1 after the collision will be positive, but different than before the collision.

<table>
<thead>
<tr>
<th>Cart</th>
<th>Mass (kg)</th>
<th>Speed (m/s)</th>
<th>Mom. (kg m/s)</th>
<th>Cart</th>
<th>Mass (kg)</th>
<th>Speed (m/s)</th>
<th>Mom. (kg m/s)</th>
</tr>
</thead>
<tbody>
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</table>

10. Question: Calculate the total momentum before and after the collision, and compare them.
11. Repeat the previous procedure one more time, with no mass bars on either cart. Complete the table below. Caution: make sure the speeds you measure are consistent with what you observe.

<table>
<thead>
<tr>
<th>Cart</th>
<th>Mass (kg)</th>
<th>Speed (m/s)</th>
<th>Mom. (kg m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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</table>

12. Question: Calculate the total momentum before and after the collision, and compare them. What was unusual about this collision?

The Last Question: In your own words, state the law of momentum conservation. How was this law demonstrated in today’s lab exercise?