Conservation of Momentum
Using PASCO™ Carts and Track to Study Collisions in One Dimension

When two objects collide momentum is transferred between them. Momentum **p** is defined as the product of mass and velocity of an object ($\mathbf{p} = m\mathbf{v}$), and like velocity, momentum is a vector. The law of conservation of momentum states that in the absence of any external forces, the total momentum before a collision is equal to the total momentum after the collision. In this activity you will observe and determine the momentum transferred for an inelastic collision (in which the carts stick together), an elastic collision (in which the carts bounce off each other), and a recoil interaction (in which the carts "explode" apart).

PURPOSE
In this activity you will determine the total momentum before and after three interactions of carts: an inelastic collision, an elastic collision, and a recoil interaction. You may be placed in a group to investigate just one of the interactions, and then asked to share your data with the other groups.

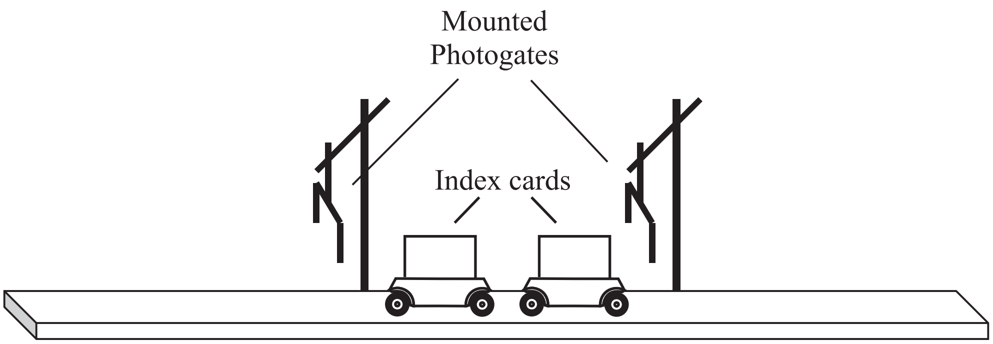
MATERIALS
- PASCO™ track
- 2 PASCO collision carts and bar masses
- 2 photogates or 2 motion detectors
- masking tape
- Vernier LabPro® or PASCO interface devices
- computer with Vernier Logger *Pro*® data collection software or graphing calculator
- 2 ring stands and/or clamps to mount photogates
- 2 3" × 5" index cards

PROCEDURE
GROUP I – INELASTIC COLLISION

1. Place the two carts on the track. The ends with the Velcro® should be facing each other so that when the carts collide they will stick together. The carts will be referred to as the incident cart (first) and the target cart (hit by the incident cart).

2. Attach an index card of known length to each cart so that the card will pass through a photogate before and after the collision.

3. Mount the photogates above or beside the carts so that the attached index cards will pass through the photogates before and after the collision, as shown in Figure 1.



PASCO track and carts

Figure 1

4. Connect the two photogates into the DIG/SONIC 1 and DIG/SONIC 2 ports on the LabPro interface. Open the Logger *Pro* data collection software, go to **File, Open**, **Probes and Sensors**, **Photogate**, **Two Gate Timing**. You should see a graph like the one in Figure 2 below.

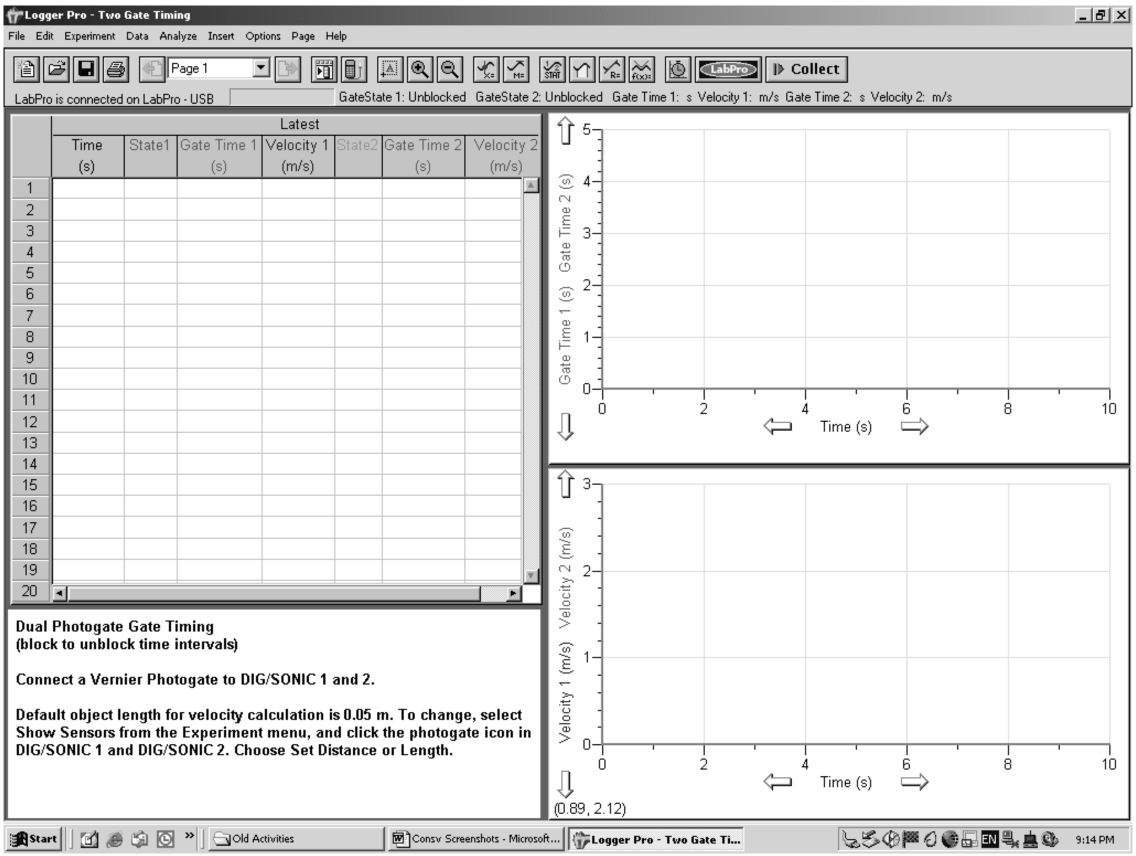


Figure 2

5. Measure the length of the card attached to each cart. A typical 3" × 5" index card has a length of 0.126 m.

6. Follow the instructions on the screen to calibrate the photogate to the length of the card mounted on the cart. If the computer knows the length of the card and the time it takes the card to pass through the photogate, it can calculate the average velocity of the cart as it passes through the photogate. Figures 3 and 4 show the pictures you will see as you calibrate the photogates.

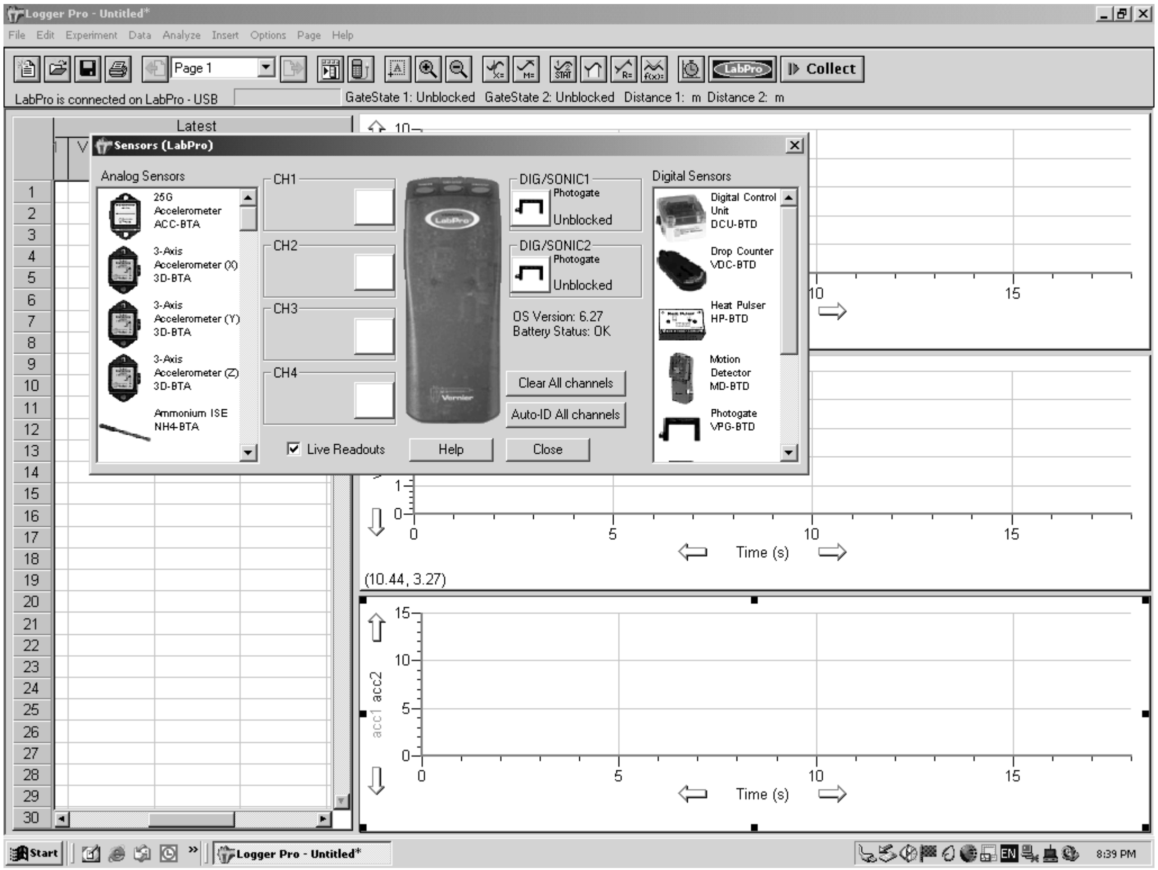


Figure 3

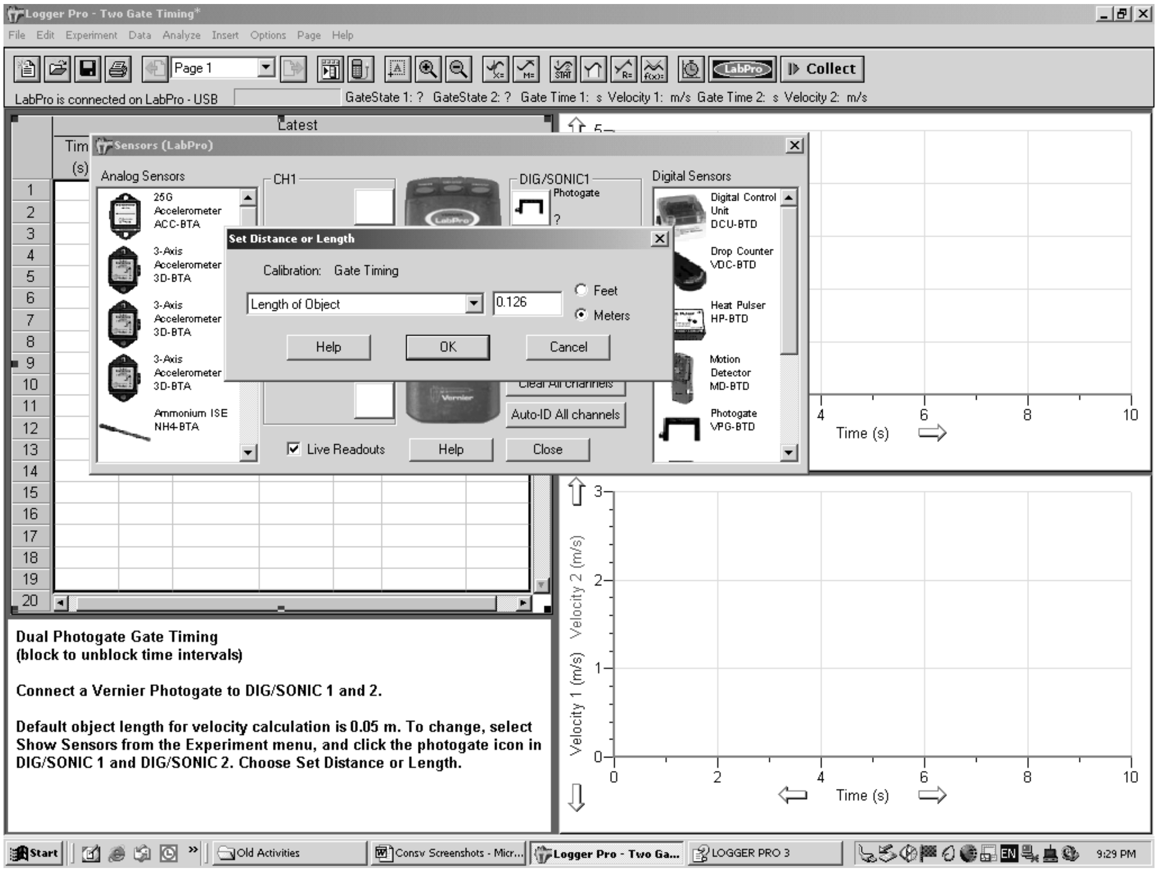


Figure 4

7. Place one cart on the track between the two photogates, and the other cart on the track outside the photogates. Arrange the carts so that the incident cart will pass through the first photogate, collide with the target cart, and then the target cart will pass completely through the second photogate. When you are ready to collect data, click on the **Collect** button on the toolbar and roll the incident cart toward the first photogate. The cart should pass completely through the photogate and collide with the target cart. You may want to stop the carts as soon as the target cart passes through the photogate so that the second photogate will not record the velocity of the incident cart. However, if both carts pass through the photogate after the collision, we are only interested in the velocity recorded for the target cart passing through the photogate. Record the before and after velocities of the carts in the data table for inelastic collision on your student answer page.

8. Repeat the experiment for several more runs, adding various amounts of mass to each cart to see how the amount of mass affects the velocity and momentum of the carts before and after the collision. Remember to record the data in such a way that another lab group can understand how you have organized your data and use it to answer questions about your data.

GROUP II – ELASTIC COLLISION

1. Place the two magnetic carts on the track so that they repel each other when they collide.

2. Follow steps 2–6 listed in the procedure for Group I.

3. Place one cart on the track between the two photogates and the other cart on the track outside the photogates. Arrange the carts so that the incident (first) cart will pass through the first photogate, collide with the target cart (the cart which is hit by the incident cart), and then the target cart will pass completely through the second photogate. Depending on the masses and speeds of the carts, the second cart may pass through the second photogate, or reverse its direction and pass back through the first photogate again.

4. When you are ready to collect data, click on the **Collect** button on the toolbar and roll the incident cart toward the first photogate so that it passes completely through it and collides with the target cart. Record the before and after velocities of the carts in the data table for elastic collision on your student answer page.

5. Repeat the experiment for several more runs, adding various amount of mass to each cart to see how the amount of mass affects the velocity and momentum of the carts before and after the collision. Remember to record the data in such a way that another lab group can understand how you have organized your data and use it to answer questions about your data.

GROUP III – RECOIL

1. Using one cart with a retractable "plunger" and another cart without a plunger, place the two carts on the track between the two photogates. Push the retractable plunger into the plunger cart so that it locks and does not pop out. Place the plunger end of the plunger cart up against the other cart so that when you tap the peg on the top of the plunger cart, the spring-loaded plunger pops out and pushes the two carts apart, each passing through a photogate.

2. Follow steps 2–6 listed in the procedure for Group I.

3. When you are ready to collect data, click on the **Collect** button on the toolbar and lightly tap the peg on the top of the plunger cart so that the spring-loaded plunger pops out and pushes the two carts apart causing each cart to pass through a photogate.

4. Record the velocity of the carts in the data table for recoil on your student answer page for the time just after they recoil away from each other.

5. Repeat the experiment for several more runs, adding various amount of mass to each cart to see how the amount of mass affects the velocity and momentum of the carts before and after the collision. Remember to record the data in such a way that another lab group can understand how you have organized your data and use it to answer questions about your data.

Name ______________________________

Period ______________________________

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DATA AND OBSERVATIONS

After you have taken all of the data for your group, obtain the data taken by the other two groups and enter the results in the tables below.

Mass of one empty cart: ______________________ kg

Mass of one "black bar" mass: __________________ kg

Length of card: _______________ m

Data Table 1: Inelastic Collision

Run	Mass of Incident Cart, m_1 (kg)	Mass of Target Cart, m_2 (kg)	Velocity v_1 of m_1 Before Collision (m/s)	Velocity v_2 of m_2 Before Collision (m/s)	Velocity v_1' of m_1 After Collision (m/s)	Velocity v_2' of m_2 After Collision (m/s)
1						
2						
3						
4						
5						

Data Table 2: Elastic Collision						
Run	**Mass of Incident Cart, m_1 (kg)**	**Mass of Target Cart, m_2 (kg)**	**Velocity v_1 of m_1 Before Collision (m/s)**	**Velocity v_2 of m_2 Before Collision (m/s)**	**Velocity v_1' of m_1 After Collision (m/s)**	**Velocity v_2' of m_2 After Collision (m/s)**
1						
2						
3						
4						
5						

Data Table 3: Recoil						
Run	**Mass of Plunger Cart, m_1 (kg)**	**Mass of Second Cart, m_2 (kg)**	**Velocity v_1 of m_1 Before Collision (m/s)**	**Velocity v_2 of m_2 Before Collision (m/s)**	**Velocity v_1' of m_1 After Collision (m/s)**	**Velocity v_2' of m_2 After Collision (m/s)**
1						
2						
3						
4						
5						

ANALYSIS

In the tables below, calculate the momentum for each cart before and after the collision or recoil. Be sure to indicate and the velocity of any cart which reverses its direction with a negative sign.

Momentum for Inelastic Collision

Run	Momentum p_1 of m_1 Before Collision (kg·m/s)	Momentum p_2 of m_2 Before Collision (kg·m/s)	Total Momentum p_T of the System Before Collision (kg·m/s)	Momentum p_1' of m_1 After Collision (kg·m/s)	Momentum p_2' of m_2 After Collision (kg·m/s)	Total Momentum p_T' of the System After Collision (kg·m/s)
1						
2						
3						
4						
5						

Momentum for Elastic Collision

Run	Momentum p_1 of m_1 Before Collision (kg·m/s)	Momentum p_2 of m_2 Before Collision (kg·m/s)	Total Momentum p_T of the System Before Collision (kg·m/s)	Momentum p_1' of m_1 After Collision (kg·m/s)	Momentum p_2' of m_2 After Collision (kg·m/s)	Total Momentum p_T' of the System After Collision (kg·m/s)
1						
2						
3						
4						
5						

Momentum for Recoil						
Run	**Momentum p_1 of m_1 Before Recoil (kg·m/s)**	**Momentum p_2 of m_2 Before Recoil (kg·m/s)**	**Total Momentum p_T of the System Before Recoil (kg·m/s)**	**Momentum p_1' of m_1 After Recoil (kg·m/s)**	**Momentum p_2' of m_2 After Recoil (kg·m/s)**	**Total Momentum p_T' of the System After Recoil (kg·m/s)**
1						
2						
3						
4						
5						

CONCLUSION QUESTIONS

Using the data obtained in all three groups, answer the following questions.

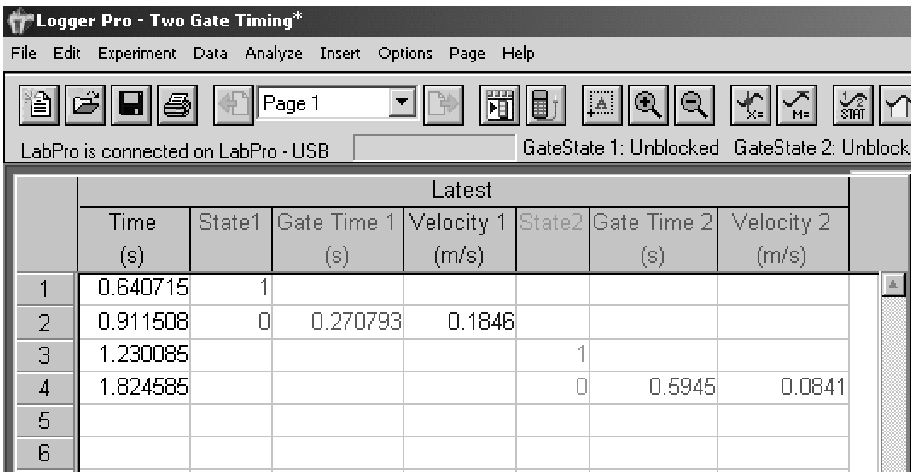
1. In general, does the data collected for the inelastic collision seem to verify the law of conservation of momentum? Explain your answer and indicate which run of the inelastic collision best conserves momentum.

2. In general, does the data collected for the elastic collision seem to verify the law of conservation of momentum? Explain your answer and indicate which run of the elastic collision best conserves momentum.

3. In general, does the data collected for the recoil of the two carts seem to verify the law of conservation of momentum? Explain your answer and indicate which run of the recoil of the two carts best conserves momentum.

4. List two sources of error and explain how each affected the results of your experiments.

5. The screenshot below represents the interaction of two carts in either an inelastic collision, elastic collision, or the recoil of the two carts. The target cart is initially at rest. Answer the questions that follow.



	Latest						
	Time (s)	State1	Gate Time 1 (s)	Velocity 1 (m/s)	State2	Gate Time 2 (s)	Velocity 2 (m/s)
1	0.640715	1					
2	0.911508	0	0.270793	0.1846			
3	1.230085				1		
4	1.824585				0	0.5945	0.0841
5							
6							

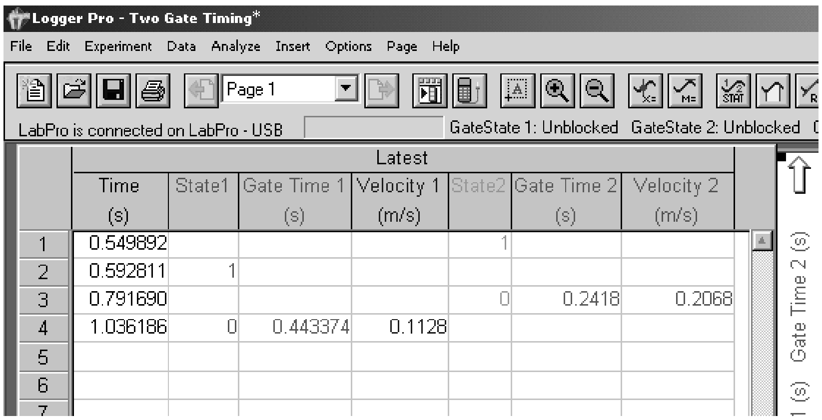
a. Which type of interaction does the data table represent? Check the appropriate answer below, and justify your answer.

_____ inelastic collision _____ elastic collision _____ recoil

b. If the carts each have a mass of 0.500 kg, and the only bar masses available are 0.500 kg each, how is the mass most likely distributed in this interaction? Explain your answer.

c. Assuming that your answer to part b is correct, how much momentum is lost in the interaction? Show your calculation in the space below.

6. The screenshot below represents the interaction of two carts in either an inelastic collision, elastic collision, or the recoil of the two carts. The target cart is initially at rest. Answer the questions that follow.



	Latest						
	Time (s)	State1	Gate Time 1 (s)	Velocity 1 (m/s)	State2	Gate Time 2 (s)	Velocity 2 (m/s)
1	0.549892				1		
2	0.592811	1					
3	0.791690				0	0.2418	0.2068
4	1.036186	0	0.443374	0.1128			
5							
6							
7							

a. Which type of interaction does the data table represent? Check the appropriate answer below, and justify your answer.

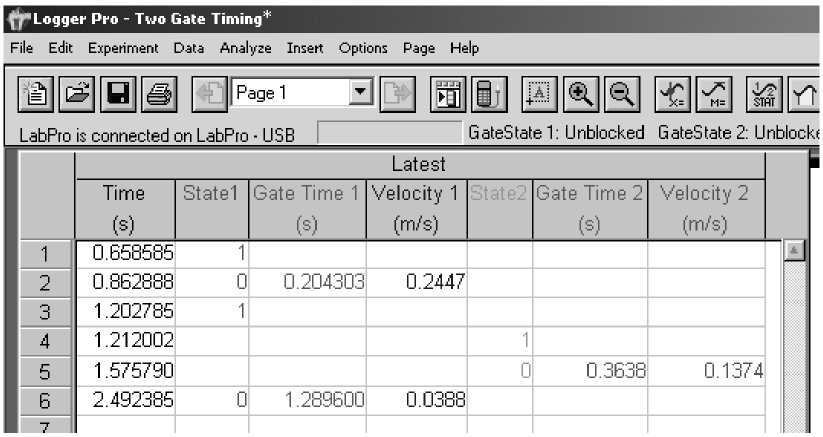
_____ inelastic collision _____ elastic collision _____ recoil

b. If the carts each have a mass of 0.500 kg, and the only bar masses available are 0.500 kg each, how is the mass most likely distributed in this interaction? Explain your answer.

c. Assuming that your answer to part b is correct, how much momentum is lost in the interaction? Show your calculation in the space below.

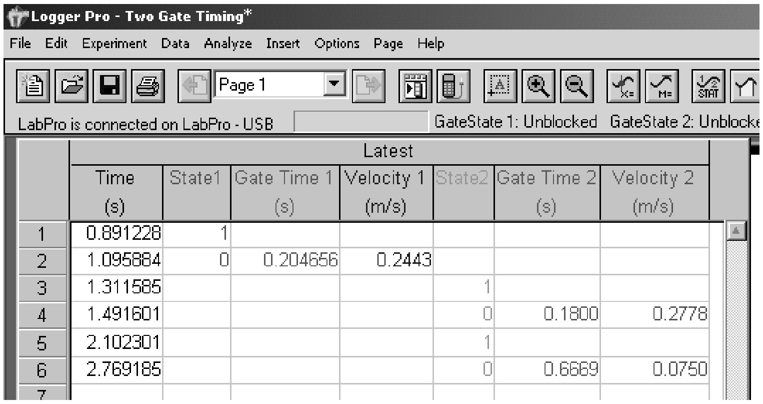
7. Consider the two screenshots A and B below, which represent two different elastic collisions. In each case, the target cart is initially at rest, and one cart is twice as massive as the other cart.

Screenshot A



	Latest						
	Time (s)	State1	Gate Time 1 (s)	Velocity 1 (m/s)	State2	Gate Time 2 (s)	Velocity 2 (m/s)
1	0.658585	1					
2	0.862888	0	0.204303	0.2447			
3	1.202785	1					
4	1.212002				1		
5	1.575790				0	0.3638	0.1374
6	2.492385	0	1.289600	0.0388			
7							

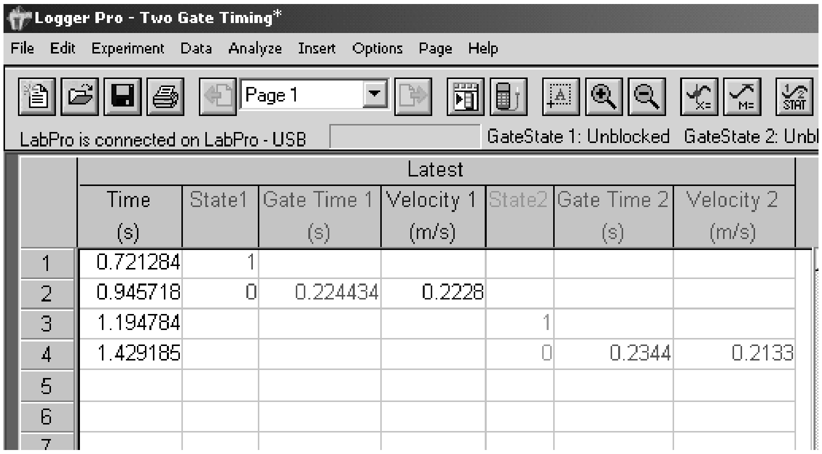
Screenshot B



	Latest						
	Time (s)	State1	Gate Time 1 (s)	Velocity 1 (m/s)	State2	Gate Time 2 (s)	Velocity 2 (m/s)
1	0.891228	1					
2	1.095884	0	0.204656	0.2443			
3	1.311585				1		
4	1.491601				0	0.1800	0.2778
5	2.102301				1		
6	2.769185				0	0.6669	0.0750
7							

Which screenshot represents an elastic collision in which the incident cart is more massive than the target cart? Explain your answer.

8. The screenshot below represents the elastic collision between two carts of equal mass. Each cart has a mass of 0.500 kg.

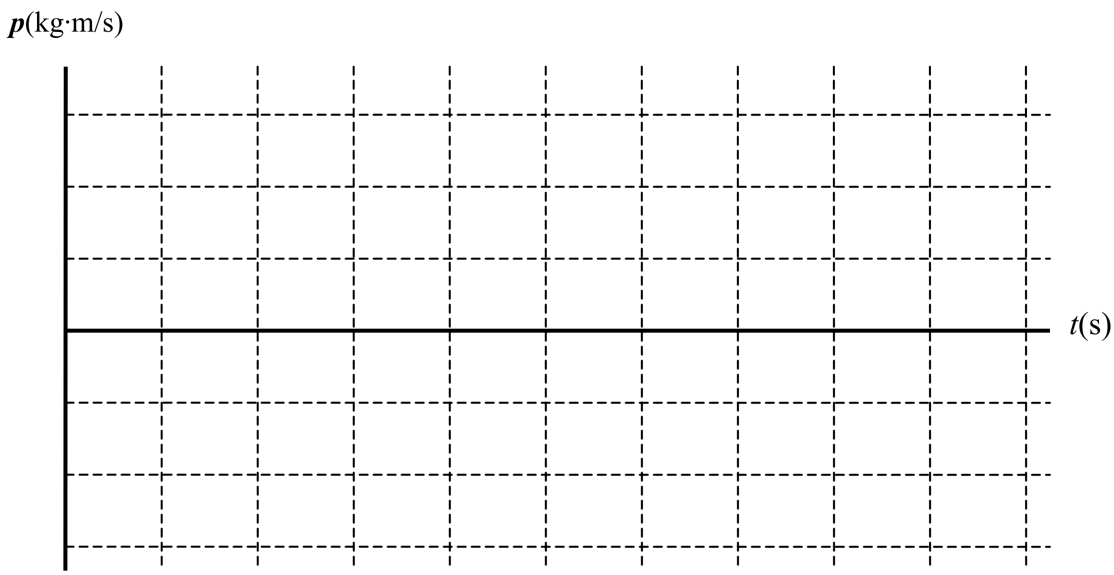


	Latest						
	Time (s)	State1	Gate Time 1 (s)	Velocity 1 (m/s)	State2	Gate Time 2 (s)	Velocity 2 (m/s)
1	0.721284	1					
2	0.945718	0	0.224434	0.2228			
3	1.194784				1		
4	1.429185				0	0.2344	0.2133
5							
6							
7							

a. On the axes below, sketch a graph of momentum *p* vs. time *t* for the incident and target carts. Be sure to indicate important values on both the horizontal and vertical axes.

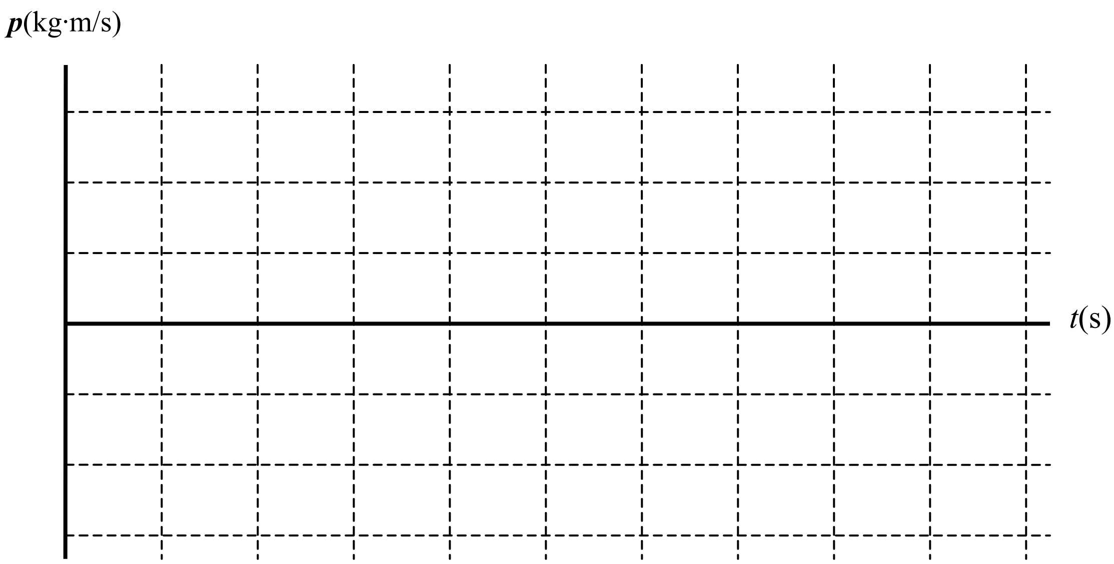
Incident Cart:

Momentum vs. Time



Target Cart:

Momentum vs. Time



b. Calculate the amount of momentum lost in this collision. Show your work in the space below.