EXPERIMENT 6
CONSERVATION OF LINEAR MOMENTUM

I. INTRODUCTION

THEORY

The collision of two carts on a track can be described in terms of momentum conservation and, in some cases, energy conservation. If there is no net external force experienced by the system of two carts, then we expect the total momentum of the system to be conserved. This is true regardless of the force acting between the carts. In contrast, energy is only conserved when certain types of forces are exerted between the carts.

Collisions are classified as *elastic* (kinetic energy is conserved), *inelastic* (kinetic energy is lost) or *completely inelastic* (the objects stick together after collision). Sometimes collisions are described as *super-elastic*, if kinetic energy is gained. In this experiment, you will observe elastic and completely inelastic collisions and test for the conservation of momentum and energy in each case.

PRELIMINARY QUESTIONS

These questions should be answered BEFORE coming to lab.

1. Consider an elastic head-on collision between two billiard balls with equal mass. One is initially at rest and the other moves toward it. On a single set of axes, sketch the position of each ball as a function of time, starting at a short time before the collision and ending a short time afterward.

2. Is momentum conserved in this collision? Is kinetic energy conserved?

II. LABORATORY PROCEDURE

Note: Steps 2, 3, 5, and 6 may have been done by your instructor prior to the lab period.

1. Measure the masses of your carts and the load mass and record them in your data table. Select which cart will be cart 1. Make sure you do not switch cart 1 and 2 during the experiment!

2. Turn on the laptop.

3. Set up the track so that it is horizontal. Using the two-way level, level the track crosswise and lengthwise at its center. Test the lengthwise leveling by releasing a cart from rest near the center of the track. The cart should not move.

4. Practice creating gentle collisions by placing cart 2 at rest near the middle of the track, and pushing cart 1 so it rolls toward the first cart, magnetic bumper toward magnetic bumper. The carts should smoothly repel one another without physically touching.

5. Connect the LabPro to the laptop with the USB cable. Connect the power supply to the LabPro and plug it in. You should hear a series of beeps. Place a Motion Detector at each end of the track. Connect the detectors to the ports on the LabPro labeled

DIG/SONIC 1 and DIG/SONIC 2. Connect the detector that cart 1 will roll away from into DIG/SONIC 1.

6. Prepare the computer for data collection by opening the file named "collision" located in the "physics" folder. Logger Pro, the data collection program, will be set up to collect data from two Motion Detectors, plotting position vs. time and velocity vs. time.

7. Click ▐▶ Collect ▐ to begin taking data. Repeat the collision you practiced above and use the position graphs to verify that the Motion Detectors track each cart properly throughout the entire range of motion. The detector may not read correctly while the cart is closer than 0.15 m. The position and/or angle of one or both of the Motion Detectors may need to be adjusted. Ask your instructor for assistance.

8. Place the two carts at rest in the middle of the track, with their Velcro bumpers toward one another and in contact. Keep your hands clear of the carts and click ▐ Zero ▐. Click on All Sensors to zero both Motion Detectors. This procedure will establish the same coordinate system for both Motion Detectors. Verify that the zeroing was successful by clicking ▐▶ Collect ▐ and allowing the still-linked carts to roll slowly across the track. The graphs for each Motion Detector should be nearly the same while they are near the center of the track. If not, repeat the zeroing process.

Part I: Magnetic Bumpers

9. Reposition the carts so the magnetic bumpers are facing one another. Click ▐▶ Collect ▐ to begin taking data and repeat the collision you practiced in Step 4. Make sure you keep your hands out of the way of the Motion Detectors after you push the cart.

10. From the velocity graphs you can determine an average velocity immediately before and immediately after the collision for each cart. To measure the average velocity during a time interval, drag the cursor across the interval. Click the Statistics button ▣ to read the average value. To clear the statistics floating box, click the box in the upper right corner. Measure the average velocity for each cart, before and after collision, and enter the four values in the data table. If your graph is smooth (without a lot of "noise"), it may be better to just read one value of the velocity immediately before the carts begin to interact and one value of the velocity of the carts immediately after the stop interacting. Record all velocities in m/s to three decimal places.

11. Repeat Step 9 and 10 as a second run with the magnetic bumpers, recording the velocities in the data table.

12. Place your load mass on cart 1 and repeat Steps 9 and 10.

13. Repeat the previous step with the load mass placed in cart 2.

14. Repeat the previous step, but with both cars initially moving toward each other. The load mass should still be in cart 2.

Part II: Velcro Bumpers

15. Remove the load mass. Change the collision by turning the carts so the Velcro bumpers without magnets face one another. The carts should stick together after collision. Practice making the new collision, again starting with cart 2 at rest.

16. Click [▶ Collect] to begin taking data and repeat the new collision. Using the procedure in Step 9, measure and record the cart velocities in your data table.

17. Repeat the previous step as a second run with the Velcro bumpers.

18. Place your load mass on cart 1 and repeat Step 16.

19. Repeat the previous step with the load mass placed in cart 2.

20. Repeat the previous step, but with both cars initially moving toward each other. The load mass should still be in cart 2.

21. If time permits, you may want to repeat Steps 14 and/or 20 with both carts initially moving in the same direction. This will take some practice to get the carts to collide near the center of the track. Again, you should have the load mass in cart 2.

III. CALCULATIONS AND ANALYSIS

1. For each run: Determine the momentum of each cart (including any load) before the collision and after the collision. Determine the total momentum of the system before and after the collision. Calculate the ratio of the total momentum after the collision to the total momentum before the collision. Present these values in the table provided in Section IV or your own table using a spreadsheet program.

2. For each run: Determine the kinetic energy of each cart before and after the collision. Determine the total kinetic energy of the system before and after the collision. Calculate the ratio of the total kinetic after the collision to the total kinetic energy before the collision. Present these values in the provided table or your own table using a spreadsheet program.

3. If momentum were conserved in each collision, what would you expect the ratio of the total momentum before the collision to the total momentum after the collision to be? You may find a small difference between the momentum before and the momentum after the collision due to uncertainty in the measurements or a small external force on the carts during the collision (rolling friction, friction in the axles, or a slight angle of the track). Are there any of your collisions where momentum is not conserved? Is this expected?

4. If energy were conserved in each collision, what would you expect the ratio of the total kinetic after the collision to the total kinetic energy before the collision to be? Are there any of your collisions where energy is not conserved? Is this expected? Are there any collisions for which energy is conserved? Is this expected? You will probably find there is some energy loss in every collision. If this amount is a small percent of the initial kinetic energy, the collision can be considered to be ***nearly*** elastic. Based on your calculations, which of your collisions were *elastic* or *nearly elastic*? Which were *inelastic*?

IV. TABLES

Data Tables

Object	Mass (g)
Cart 1	
Cart 2	
Load Mass	

Collision in Step Number	Velocity of cart 1 before collision (m/s)	Velocity of cart 2 before collision (m/s)	Velocity of cart 1 after collision (m/s)	Velocity of cart 2 after collision (m/s)
10		0		
11		0		
12		0		
13		0		
14				
16		0		
17		0		
18		0		
19		0		
20				

Calculation Tables

Collision in Step Number	Momentum of cart 1 before collision (kg·m/s)	Momentum of cart 2 before collision (kg·m/s)	Momentum of cart 1 after collision (kg·m/s)	Momentum of cart 2 after collision (kg·m/s)	Total momentum before collision (kg·m/s)	Total momentum after collision (kg·m/s)	Ratio of the Total Momentum After the Collision to Before the Collision
10		0					
11		0					
12		0					
13		0					
14							
16		0					
17		0					
18		0					
19		0					
20							

Collision in Step Number	KE of cart 1 before collision (J)	KE of cart 2 before collision (J)	KE of cart 1 after collision (J)	KE of cart 2 after collision (J)	Total KE before collision (J)	Total KE after collision (J)	Ratio of the Total Kinetic Energy After the Collision to Before the Collision
10		0					
11		0					
12		0					
13		0					
14							
16		0					
17		0					
18		0					
19		0					
20							