LabQuest **18B**

Momentum, Energy, and Collisions (Motion Detector)

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 can observe elastic and inelastic collisions and test for the conservation of momentum and energy.

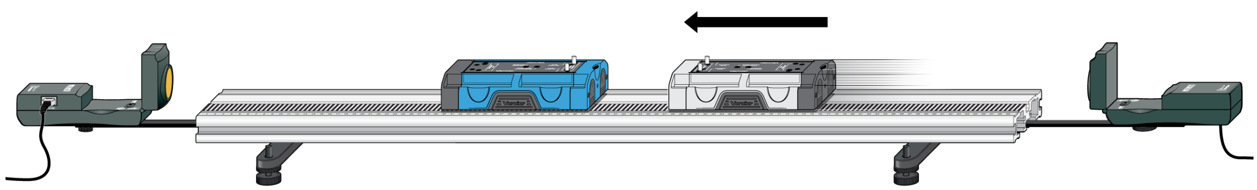


Figure 1

OBJECTIVES

- Observe collisions between two carts, testing for the conservation of momentum.
- Measure energy changes during different types of collisions.
- Classify collisions as elastic, inelastic, or completely inelastic.

MATERIALS

LabQuest
LabQuest App
two Vernier Motion Detectors
Vernier Dynamics Track
two Vernier Dynamics Carts with magnetic and hook-and-pile strip bumpers

PRELIMINARY QUESTIONS

1. Consider a head-on collision between two identical billiard balls. Ball 1 is initially in motion toward ball 2, which is initially at rest. After the collision, ball 2 departs with the same

velocity that ball 1 originally had. Disregard any friction between the balls and the surface. What happens to ball 1? What happens to ball 2?

2. Sketch a position *vs.* time graph for each ball in Preliminary Question 1, starting with the time before the collision starts and ending a short time after the collision.

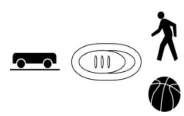
3. Based on your graph from Preliminary Question 2, is momentum conserved in this collision? Is kinetic energy conserved?

PROCEDURE

1. Set up the carts with the hook-and-pile pads facing each other. Measure the masses of the carts and record the values in Table 1. Label the carts as cart 1 and cart 2.

2. Set up the Dynamics Track so that it is horizontal. Test this by releasing a cart on the track from rest. The cart should not move.

3. Set the Motion Detector sensitivity switches to Track. Place a Motion Detector at each end of the track, allowing for the 0.15 m minimum distance between detector and cart, as shown in Figure 1. Connect the Motion Detectors to the digital (DIG) ports of the LabQuest and choose New from the File menu.



4. Practice creating a gentle collision. Position cart 2 at rest in the middle of the track. Release cart 1 so it rolls toward cart 2 with the hook-and-pile pads toward one another. The carts should collide, stick together, and roll together.

5. Start data collection. Repeat the collision you practiced above and use the position graphs to verify that the Motion Detectors can track each cart properly throughout the entire range of motion. You may need to adjust the position of one or both of the Motion Detectors.

6. Reverse the coordinate system in LabQuest for one Motion Encoder. Do this by tapping the meter on the Meter screen for the second Motion Encoder and selecting Reverse.

7. Place the two carts at rest in the middle of the track, with their hook-and-pile bumpers toward one another and in contact. Choose Zero ► All Sensors from the Sensors menu. This procedure will establish the same coordinate system for both Encoder Receivers. Verify that the zeroing was successful by starting data collection and allowing the still-linked carts to roll slowly along the track. The graphs for each Motion Encoder should be nearly the same. If not, repeat the zeroing process.

Part I Hook-and-pile bumpers

8. Reposition the carts as in Step 4. Click ▶ Collect to begin taking data and repeat the collision. Keep your hands out of the way of the Motion Detectors after you push the cart.

9. From the velocity graphs, you can determine a mean velocity before and after the collision for each cart. To measure the mean velocity during a time interval, tap and drag across the interval. Choose Statistics from the Analyze menu to read the mean value, and then close the statistics box. Measure the mean velocity for each cart, before and after collision, and enter the four values in Table 2..

10. Repeat the previous step to collect a second run with the hook-and-pile bumpers.

Part II Hook-and-pile to empty bumpers

11. Remove the hook-and-pile inserts from one cart. Measure the mass of this cart and record it in Table 1. The other cart's mass should stay the same.

12. Face the hook-and-pile bumper on one cart to the empty bumper on the other. Practice this collision, again starting with cart 2 at rest. The carts will not stick, but they will not smoothly bounce apart either.

13. Start data collection and repeat the new collision. Use the procedure in Step 9 to measure and record the cart velocities in Table 2.

14. Repeat the previous step to collect a second run with the hook-and-pile to empty bumpers.

Part III Magnetic bumpers

15. Insert magnets into both carts, set so the carts will repel. Measure the masses of the carts and record in Table 1.

16. Place the carts on the track with the magnetic bumpers facing each other. Practice making this new gentle collision, again starting with cart 2 at rest. The carts should smoothly repel each other without physically touching.

17. Start data collection and repeat the collision you practiced in Step 16. Use the procedure in Step 9 to measure and record the cart velocities in Table 2.

18. Repeat the previous step as a second run with the magnetic bumpers.

DATA TABLE

Table 1	
Mass of cart 1 (kg)	Mass of cart 2 (kg)

Table 2							
Bumper type		Run 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)
Part I:	Hook-and-pile	1		0		
	Hook-and-pile	2		0		
Part II:	Mixed	3		0		
	Mixed	4		0		
Part III:	Magnetic	5		0		
	Magnetic	6		0		

Table 3							
Run 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 total momentum after/before
1		0					
2		0					
3		0					
4		0					
5		0					
6		0					

Table 4							
Run 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 total KE after/before
1		0					
2		0					
3		0					
4		0					
5		0					
6		0					

ANALYSIS

1. For each run, determine the momentum (mv) of each cart before the collision, after the collision, and the total momentum before and after the collision. Calculate the ratio of the total momentum after the collision to the total momentum before the collision. Enter the values in Table 3.

2. For each run, determine the kinetic energy ($KE = \frac{1}{2}mv^2$) for each cart before and after the collision. Calculate the ratio of the total kinetic energy after the collision to the total kinetic energy before the collision. Enter the values in Table 4.

3. If the total momentum for a system is the same before and after the collision, we say that momentum is *conserved*. If momentum were conserved, what would be the ratio of the total momentum after the collision to the total momentum before the collision?

4. If the total kinetic energy for a system is the same before and after the collision, we say that kinetic energy is *conserved*. If kinetic energy were conserved, what would be the ratio of the total kinetic energy after the collision to the total kinetic energy before the collision?

5. Inspect the momentum ratios in Table 3. Even if momentum is conserved for a given collision, the measured values may not be exactly the same before and after due to measurement uncertainty. The ratio should be close to one, however. Is momentum conserved in your collisions?

6. Repeat the preceding question for the case of kinetic energy, using the kinetic energy ratios in Table 4. Is kinetic energy conserved in the magnetic bumper collisions? How about the hook-and-pile collisions? Is kinetic energy consumed in the third type of collision studies? Classify the three collision types as elastic, inelastic, or completely inelastic.

EXTENSIONS

1. Using the magnetic bumpers, consider other combinations of cart mass by adding weight to one cart. Is momentum or energy conserved in these collisions?

2. Using the magnetic bumpers, consider other combinations of initial velocities. Begin with having both carts moving toward one another initially. Are momentum and energy conserved in these collisions?