Experiment
11A

Momentum and Collisions

INTRODUCTION

You may have learned that a moving object possesses kinetic energy. Momentum is another property of an object, related to its mass and velocity, that is useful to describe its behavior. Momentum, p, is the product of the mass and velocity of an object, $p = mv$.

You may have learned an external force produces a change in the momentum of an object. If we consider as our system two carts that undergo a collision, then any forces they exert on one another are *internal* to the system. In this experiment you will examine the momentum of both carts before and after collisions to see what effect, if any, these forces have on the momentum of a *system*.

OBJECTIVES

In this experiment, you will

- Collect velocity-time data for two carts experiencing different types of collisions.
- Compare the system momentum before and after collisions.
- Compare the kinetic energy of the system before and after collisions.

MATERIALS

Vernier data-collection interface	Vernier Dynamics Track
Logger *Pro* or LabQuest App	standard cart
two Vernier Motion Detectors	plunger cart
two Motion Detector brackets	500 g standard lab mass
neodymium magnets and Velcro® patches for carts	

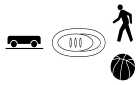
PRE-LAB QUESTION

Consider a head-on collision between a cue ball and a billiard ball initially at rest. Sketch a velocity-time graph for each ball for the interval shortly before until shortly after the collision. Justify your predictions for the final velocity of each billiard ball.

PROCEDURE

1. Attach the Motion Detectors to the brackets and position them at opposite ends of the Dynamics Track.

2. If your motion detectors have a switch, set each of them to Track.



3. Adjust the leveling screws on the feet as needed to level the track. To make sure the track is level, place a cart on the track and give it a gentle push. It should not slow more in one direction than in the other.

4. Connect both motion detectors to the interface and start the data-collection program. Make the necessary adjustments so that a velocity *vs*. time graph for each detector is shown in the graph window.

5. Make sure that each of your carts has the neodymium magnets at one end and the Velcro patches at the other. Place both carts, linked with their Velcro patches, in the center of the track. Zero both motion detectors and reverse the direction of one of them.

6. Begin collecting data, then gently push the linked carts towards one of the motion detectors (see Figure 1). Be sure to keep your hands out of the way of the motion detectors. Catch the carts before they run off the track. The velocity-time graphs from each detector should be nearly mirror images of one another; they will also show a slight decrease in velocity due to friction. Adjust the level of the track until this decrease appears to be nearly the same in both directions.

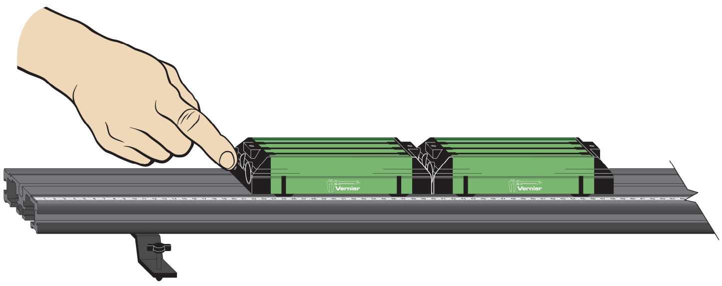


Figure 1

Part 1 Elastic collisions

7. Reverse the carts so that their magnet ends face one another. Separate them by about 40 cm. Practice launching one cart toward the other so that at closest approach they exert forces on each other without touching. A jarring collision will not yield satisfactory data.

8. Place the target cart in the middle of the track. Position the other cart at least 20 cm in front of one of the motion detectors.

9. Start data collection. Then, when you hear the motion detectors clicking, launch one of the carts toward the other. Because momentum, like velocity, is a vector quantity, check to see if the signs of the velocities match your experimental setup. If necessary, reverse the direction of one or both sensors.

10. In this experiment you are concerned with changes in momentum due to the collisions of the carts. Some slowing due to friction is inevitable. To minimize the effect of frictional losses in

your analysis, you should select short intervals of the *velocity-time* graphs just before and just after a collision. Then, choose Statistics from the Analyze menu and record the mean velocity of each cart for these intervals.

A data table has been provided for you. You may wish to use Logger *Pro* to help you record and analyze your data.

11. Collect data for up to six elastic collisions, varying the initial velocity and the mass of either cart. Try a collision in which both carts have an initial velocity, but different masses.

Part 2 Inelastic collisions

1. Reverse the carts so that the ends with the Velcro patches face one another. Practice launching one cart toward the other so that when they collide, the carts link smoothly and continue moving without a noticeable bounce. A jarring collision will not yield satisfactory data.

2. Collect data as before for at least three inelastic collisions, varying the initial velocity and the mass of either cart. Determine the velocity of the carts before and after the collision as you did in Part 1. Since both motion detectors provide velocity data after the collision, you will have to decide how to record the velocity of the linked carts.

Part 3 Explosions

1. Place the carts in the center of the track with the plunger end of one cart facing the other. Depress and lock the mechanism on the plunger cart. Position the carts so that they are touching.

2. Begin data collection, then give a quick tap to the release pin with something hard, such as the support rod for a force sensor, as shown in Figure 2. Catch the carts before they run off the track.

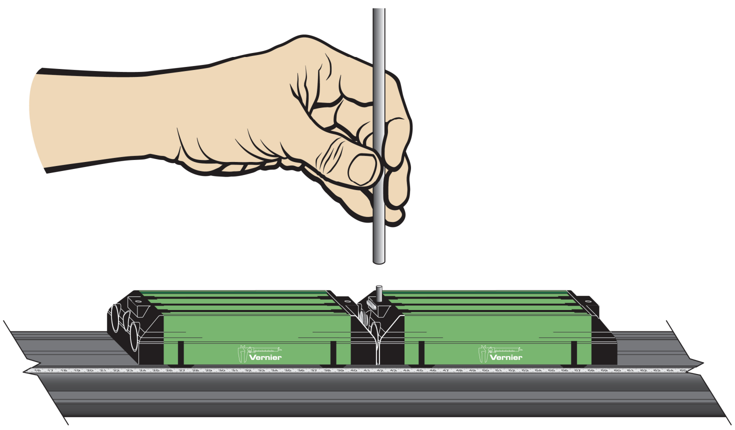


Figure 2

3. Repeat, varying the mass of either cart. Determine the velocity of the carts after the explosion as you did in Part 1.

EVALUATION OF DATA

Part 1 Elastic collisions

1. You can use the tables below to help with your evaluation of the momentum before and after the collisions of the carts.

	Cart 1			Cart 2		
Run	Mass (kg)	Initial velocity (m/s)	Final velocity (m/s)	Mass (kg)	Initial velocity (m/s)	Final velocity (m/s)
1						
2						
3						
4						
5						
6						

	Before			After			Ratio
Run	*p* of cart 1 (kg-m/s)	*p* of cart 2 (kg-m/s)	*p* of system (kg-m/s)	*p* of cart 1 (kg-m/s)	*p* of cart 2 (kg-m/s)	*p* of system (kg-m/s)	*p* after / *p* before
1							
2							
3							
4							
5							
6							

Another approach is to use Logger *Pro* to help you organize your calculations.

2. How does the total momentum of the system after the collision compare with that before the collision? Do your results agree with your expectations? Explain.

3. Calculate the total kinetic energy, $E_k = \frac{1}{2} m v^2$, of the system both before and after each of the collisions. How do these quantities compare?

Part 2 Inelastic collisions

1. You can use the tables below to help with your analysis of the momentum before and after the collision.

	Cart 1			Cart 2		
Run	Mass (kg)	Initial velocity (m/s)	Final velocity (m/s)	Mass (kg)	Initial velocity (m/s)	Final velocity (m/s)
1						
2						
3						

	Before			After			Ratio
Run	*p* of cart 1 (kg-m/s)	*p* of cart 2 (kg-m/s)	*p* of system (kg-m/s)	*p* of cart 1 (kg-m/s)	*p* of cart 2 (kg-m/s)	*p* of system (kg-m/s)	*p* after / *p* before
1							
2							
3							

How does the total momentum of the system after the collision compare to that before the collision? Is the agreement in these inelastic collisions as good as that in the elastic collisions? Try to account for any differences.

2. Calculate the total kinetic energy of the system both before and after each of the collisions. How do these quantities compare? Compare your findings with those of others in your class.

3. We have used “elastic” to describe collisions in which the objects bounce, and “inelastic” to describe collisions in which the objects stick. Based on your comparison of the kinetic energy before and after collisions, provide a more conceptual definition of these descriptors.

Part 3 Explosions

1. You can use the tables below to help with your analysis of the momentum before and after the collision.

	Cart 1			Cart 2		
Run	Mass (kg)	Initial velocity (m/s)	Final velocity (m/s)	Mass (kg)	Initial velocity (m/s)	Final velocity (m/s)
1						
2						
3						

	Before			After			Ratio
Run	*p* of cart 1 (kg-m/s)	*p* of cart 2 (kg-m/s)	*p* of system (kg-m/s)	*p* of cart 1 (kg-m/s)	*p* of cart 2 (kg-m/s)	*p* of system (kg-m/s)	% diff
1							
2							
3							

How does the total momentum of the system after the explosion compare to that when the carts were stationary? Report any discrepancy as a percentage of the momentum of one of the carts.

2. Calculate the total kinetic energy of the system both before and after each of the explosions. How do you account for the increase in kinetic energy?