Name **Period** **Date**

14. Impulse Momentum

Driving Questions

How is the change in momentum of an object during a collision related to the impulse associated with the collision?

Background

In general, when two bodies collide, they will strike one another exerting equal and oppositely directed forces on one another. In an elastic collision, the two bodies strike and bounce away from one another. In an inelastic collision, the two bodies collide and stick to one another. The force imparted at the moment of collision occurs over a small time interval. If that force is constant, the product of the force and time is called the impulse. We know from Newton's Second law that the net force is the product of mass and acceleration, and acceleration is the change of velocity over time. Because momentum is the product of mass and velocity, it stands to reason that momentum and impulse are related.

Materials and Equipment

For each student or group:

- Data collection system
- Motion sensor
- Force sensor
- Force accessory bracket
- Dynamics cart
- Dynamics track
- Balance (1 per classroom)

Safety

Follow all standard laboratory procedures.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

Subtract the initial momentum from the final momentum to find the change in momentum.	Determine the velocity of the cart before the collision from the Velocity versus Time graph.	Start recording data, and then push the cart toward the force accessory bracket.	Level the track by adjusting the feet.	Calculate the momentum of the cart before the collision.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect a force sensor and a motion sensor to the data collection system. �(2.2)

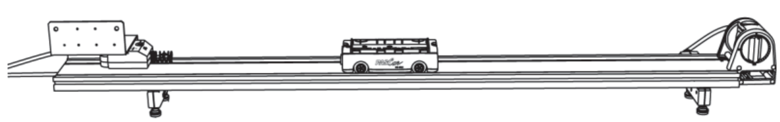
3. ☐ Set the track on a table and level the track. Use a bubble level or observe a cart on the track and adjust the track feet until the track is level and the cart does not move.

4. ☐ Connect the force accessory bracket to one end of the track.

5. ☐ Connect the motion sensor to the other end of the track with the face of the sensor pointed toward the force accessory bracket. Be sure the switch on the sensor is in the cart position.

Note: You may need to move the accessory bracket closer to the motion sensor depending on the length of track you are using.

6. ☐ Mount the force sensor to the force accessory bracket in the lower position, and attach the weaker of the two spring bumpers to the force sensor.



7. ☐ Display both Velocity and Force pull positive on the y-axis of a graph with Time on the x-axis so that they can be compared. �(7.1.10)

8. ☐ Why is it important to use the *pull positive* measurement from the force sensor?

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____

9. ☐ Ensure that the sample rate is set to at least 100 samples per second. �(5.1)

Note: If your data collection system allows the sample rate of the sensors to be adjusted separately, set the force sensor to 500 samples per second and the motion sensor to 50 samples per second.

10. ☐ Why do you think a high sample rate is necessary?

____

____

____

11. ☐ Push the zero button on the force sensor.

12. ☐ Determine the mass of the cart with a balance, and record the mass in Table 1.

13. ☐ Place the cart on the track just over 15 cm away from the motion sensor.

Collect Data

14. ☐ Start data recording. �(6.2)

15. ☐ Push the cart toward the force accessory bracket. Allow the cart to collide with the force sensor and return.

16. ☐ Catch the cart, and stop data recording. �(6.2)

Analyze Data

17. ☐ Adjust the scale of the graph to show the region around the collision. �(7.1.2)

18. ☐ Sketch your graph of Velocity versus Time and Force versus Time in the space provided in the Data Analysis section.

19. ☐ Use the Velocity versus Time graph on your data collection system to find the velocity of the cart just before the collision, and enter the value in Table 1. �(9.1)

20. ☐ Use the mass of the cart and the velocity just before the collision to determine the momentum of the cart before the collision, and enter the value in Table 1.

21. ☐ Use the Velocity versus Time graph on your data collection system to find the velocity of the cart after the collision, and enter the value in Table 1. �(9.1)

22. ☐ Use the mass of the cart and the velocity before the collision to determine the momentum of the cart after the collision, and enter the value in Table 1.

23. ☐ Calculate the change in momentum by subtracting the final momentum from the initial momentum, and enter the value in Table 1.

24. ☐ What are the units for change in momentum?

25. ☐ Select the data points on the Force versus Time graph that represent the force applied during the collision. �(7.1.4)

26. ☐ Find the area under the curve of the region you selected on the Force versus Time graph, and record the value in Table 1. �(9.7)

27. ☐ What are the units for the area under the curve?

28. ☐ Are the units of the area under the curve equivalent to the units of momentum? Explain.

29. ☐ What do you think the area under the curve represents?

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30. ☐ Save your experiment as instructed by your teacher. �(11.1)

Data Analysis

Velocity versus Time and Force versus Time Graph

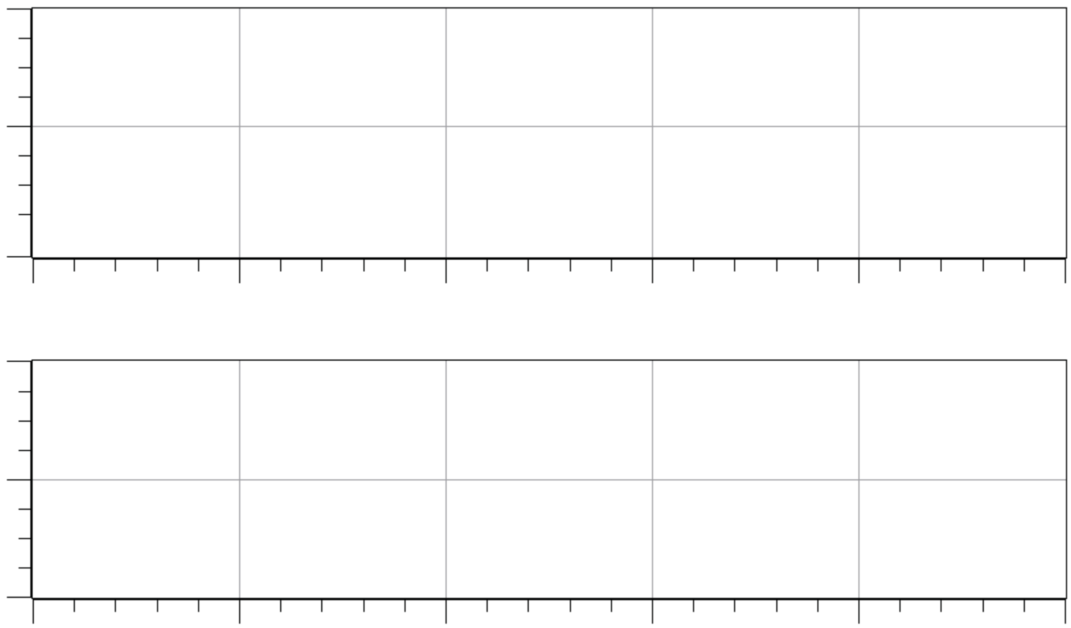

Table 1: Collision Data

Parameters	Value
Cart Mass	
Velocity before collision	
Momentum before collision	
Velocity after collision	
Momentum after collision	
Change in momentum	
Area under the force curve	
Percent difference	

Analysis Questions

1. **How does the momentum before the collision compare to the momentum after the collision? What is the percent difference between the two?**

2. **How does the change in momentum that resulted from the collision compare to the impulse of the collision? What is the percent difference between the two? Add this answer to Table 1.**

3. **Why do you think we use the weaker spring to do this experiment?**

4. **What could be done to improve the accuracy of the value for change in momentum?**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **In an automotive crash test, a 1,000 kg car impacts a test barrier, that does not move, and comes to a complete stop. The sensors in the barrier indicate an impulse of 20,000 N·s was associated with the crash. What was the initial velocity of the car in kilometers per hour?**

2. **What does the sign of your answer from the previous question tell you about the orientation of the force sensor in the barrier and the motion of the car?**

____

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3. **A ball bounces off a solid wall, but it has half the momentum leaving the wall that it did heading toward the wall. What does this tell you about the ball? And where did the kinetic energy of the ball go?**

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Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. **Which of the following equations describes the change in momentum during a collision?**

- **A.** Speed × Time
- **B.** Distance × Time
- **C.** Force × Position
- **D.** Mass × Velocity

2. Which of the following is not a vector (directional) quantity?

- **A.** Mass
- **B.** Velocity
- **C.** Momentum
- **D.** Force

3. When a moving automobile collides with a parked automobile such that they crunch together and continue moving together a short distance after the collision, this kind of collision is called?

- **A.** An inelastic collision
- **B.** An elastic collision
- **C.** A collision of cultures
- **D.** When worlds collide

4. Which of the following equations best represents the impulse during a collision?

- **A.** Position × Time
- **B.** Velocity × Time
- **C.** Force × Time
- **D.** Speed × Time

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. ____________ imparted to an object during a collision is equal to the area under a Force versus Time graph. ____________ is defined as the product of the ____________ and velocity of an object. When two objects collide, a ____________ is imparted by both objects onto each other during the collision. In an ____________ collision, the impulse imparted to one of the objects will be equal to the change in the object's momentum.

Key Term Challenge Word Bank

Paragraph 1

Time

Force

Elastic

Collision

Impulse

Mass

Momentum

Displacement

Velocity

Inelastic