Impulse and Momentum
Inelastic Collisions

CONCEPT EXPLORATION

You have had the chance to explore collisions in which the objects bounced off of each other. These were called elastic collisions. Now you will have the opportunity to investigate collisions where the two bodies stick together after the collision. These are called **inelastic** collisions.

Engagement Question

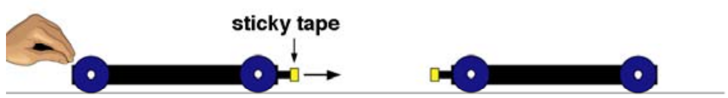
A quarterback takes the football from the center and before he can begin to move he is immediately tackled by a linebacker, moving at a high rate of speed, who wraps his arms around the quarterback.

1. If the linebacker is able to hold on to the quarterback what do you predict will happen to each of these two players immediately after the initial contact? Assume that these two football players have the same mass.

At each lab station you will find the following materials:
2 lab carts with sticky tape attached to the front

The Investigation

a. Place one of the lab carts on the table top approximately 50 cm away from the other lab cart.
b. Both carts should be placed so that the sticky tape on their bumpers face one another.
c. Make sure that there is at least 1 meter of counter space behind the target cart.
d. Push on one of the lab carts so that it moves directly towards the other cart so that their bumpers will make contact with one another and the carts will stick together.
e. Stop both carts after they have traveled a short distance.



2. Describe what happened to the two carts <u>after</u> the collision. Be sure to take note of the relative speed of the moving cart <u>before</u> the collision, compared to the speed of the two carts together <u>after</u> the collision. Was the initial speed of the moving cart <u>before</u> the collision considerably bigger or was it about the same as the final speed of the two carts together?

3. What was the momentum of <u>each</u> cart <u>before</u> the collision? This would be the momentum they <u>each</u> had after you had pushed on one cart but before the collision took place. Assume that each cart has mass, m, and the velocity of the moving cart was v_0 before the collision.

4. What was the total momentum of this system <u>before</u> the collision? This would be the sum of the momenta for the two carts <u>before</u> the collision.

5. After the two carts had stuck together you only had one combined mass that was moving. What was the mass of this single object <u>after</u> the collision? Remember that each cart had a mass of m.

6. If momentum was conserved during this collision what must have been the velocity of the single two-cart mass <u>after</u> the collision? Hint: if the "moving" mass doubled after the collision, what must have happened to the velocity of the moving mass in order for momentum to be conserved? Express this finalvelocity in terms of the initial velocity (v_0) of the cart that was moving before the collision.

7. Evaluate the following student statement. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

"If momentum was conserved during the collision, then when the moving mass doubled in size, the velocity would have been cut in half."

Check your work with your teacher

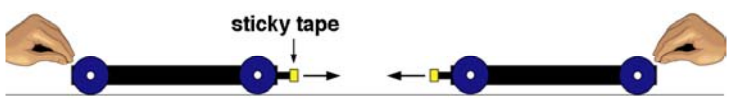
The Challenge

You will investigate how equal-mass objects behave when they're involved in a head-on collision in which they stick together after the collision.

Your Ideas about the Challenge

Two carts, moving at the same speed in the opposite direction, are involved in a head-on collision in which they stick together after the collision.

8. Predict what you think will happen to the two carts after the collision.



The Investigation (continued)

a. Place the lab carts so that their bumpers with the sticky tape are facing each other on the table top approximately 50 cm apart.

b. Using both hands, one student should push both carts towards one another so that they have the same approximate speed before they collide.

c. Make sure that the two carts stick together after the collision.

9. How did the momentum of each cart compare <u>before</u> they collided? Did they have approximately the same momentum or did one cart have a lot more momentum than the other before the collision?

10. How should you show mathematically that the two carts were traveling in the opposite direction before the collision? Hint: is momentum a vector quantity? What do you do with the signs of oppositely directed vector quantities?

11. What must have been an approximate value for the total momentum of this "system" <u>before</u> the two carts collided? Explain your answer.

12. What happened to the velocity of each cart after the collision?

13. What must have been an approximate value for the total momentum of this "system" after the two carts collided?

14. Was momentum conserved during this collision? Explain how you know.

15. Evaluate the following student statement about the investigation you performed. Identify ideas that are consistent with your observations and others that are not consistent with your observations.

"The total momentum for the two carts was zero both before and after the collision."

Check your work with your teacher ☐

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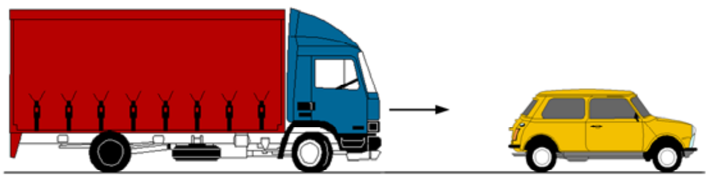
CONCEPT DEVELOPMENT

During the exploration activity you determined that momentum is also conserved for inelastic collisions. During this development exercise you will investigate the same sort of inelastic collision by collecting data and using a different form of the equation for the conservation of momentum.

Engagement Question

A big truck runs into the rear of a small car that was at rest and had its parking brake off and it's transmission in neutral.

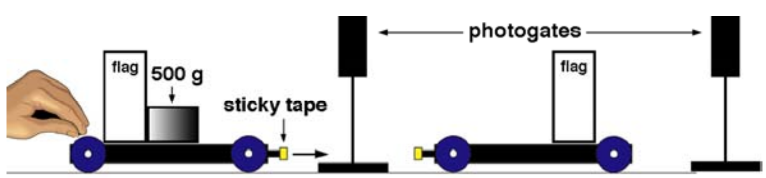


1. What do you think will happen to these two vehicles after they collide if they lock bumpers so that they stick together after the collision?

At each lab station you will find the following:
A computer with an interface, two photogates, and two lab carts with flags affixed to the top and sticky tape attached to the bumpers. One cart will have an additional 500 g mass on top.

The Investigation

a. Find the mass of each cart using the electronic balance. Cart 1 has the additional 500 g on top. Record their masses in kilograms in the data table that follows.
b. The carts should be placed so that the sticky tape on their bumpers face one another approximately 0.5 meters apart.
c. One of the photogates should be placed between the carts so that the flag on cart 1 will pass completely through the photogate <u>before</u> the carts collide.
d. The other photogate should be placed on the opposite side of the target cart so that the flag on that cart will pass through this gate followed by the flag on the more massive cart <u>after</u> the carts have collided together.
e. Start the data collection program.
f. Gently push cart 1 so that it passes through the first photogate and then strikes cart 2. Cart 2 should then pass through the second photogate followed by cart 1.
g. Record the velocities that you receive in the data table that follows.



Data Tables

Cart 1 (kg)	Cart 2 (kg)

Cart 1 initial velocity (v_{01}, m/s)	Cart 2 final velocity (v_2, m/s)	Cart 1 final velocity (v_1, m/s)

2. Calculate the momentum for cart 1 <u>before</u> the collision. Be sure to label your answer with appropriate units.

$p_{01} = m_1 v_{0\,1} =$

3. What was the momentum for cart 2 <u>before</u> the collision? Explain how you know.

4. What was the total momentum for your system <u>before</u> the collision? This would be the sum of the two momenta of the carts <u>before</u> the collision.

5. What was the total mass of your system <u>after</u> the collision. This would be the sum of the masses for the two cars. Be sure to use appropriate units.

total mass $= m_1 + m_2 =$

The final velocities for the two carts should have been the same <u>after</u> the collision since they were stuck together.

6. Were the two final velocities approximately the same after the collision? Why were the two velocities not exactly the same <u>after</u> the collision?

7. Calculate the momentum for the two carts <u>after</u> the collision. Use the final velocity for the target cart (v_2), after the collision, for your common final velocity. Be sure to label your answer with appropriate units.

$p_{total} = (m_1 + m_2) \cdot v =$

8. Was the total momentum for your system <u>before</u> the collision approximately the same as the total momentum for the system <u>after</u> the collision?

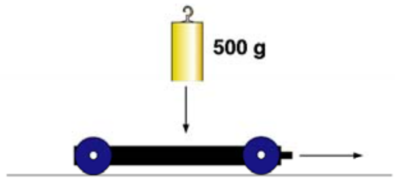
9. Why wasn't the total momentum <u>before</u> the collision exactly equal to the total momentum <u>after</u> the collision?

Check your work with your teacher.

The Challenge

You will investigate how the momentum of a moving object is affected by a sudden increase in the mass of the object.

10. A cart is moving at a constant velocity in a straight line when 500 g is dropped on top of it. What do you think will happen to the velocity of this cart after the 500 g is added to it?



The Investigation

a. Use cart 2 for this investigation. Record the mass of cart 2 in kilograms in the data section that follows.
b. Place the cart on the counter top. Make sure there is at least 1 meter of clear counter space in front of the cart.
c. One of the photogates should be placed so that the cart will pass completely through the photogate <u>before</u> the mass is added. The other photogate should be placed so that it will determine the velocity of the cart <u>after</u> the mass is added to the cart.
d. Start the data collection program.
e. After the flag on the cart has cleared the first photogate, gently drop the 500 g mass onto the bed of the cart.
f. Stop the data collection program after the flag on the cart has completely cleared the 2nd photogate.

Data

Cart 2 (kg)

Velocity before the mass (v_0, m/s)

Velocity after the mass (v, m/s)

11. Calculate the momentum of the cart <u>before</u> the mass was added.

$p = mv_0 =$

12. What was the mass of this "system" after 500 g was added?

$m_{new} = m + 0.5\ kg =$

13. Calculate the momentum of the cart <u>after</u> the mass was added.

$p_{new} = m_{new} \cdot v =$

14. Was momentum conserved during this experiment? Explain how you know. If not, why do you think that momentum was not conserved?

15. Evaluate the following student statements. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

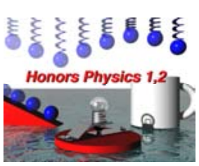
<u>Student A</u>

"Momentum wasn't conserved because the falling mass exerted an external force on the cart."

<u>Student B</u>

"The falling mass didn't exert a force in the direction that the cart was moving so it shouldn't have caused any change in the total momentum of this system."

Check your work with your teacher



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CONCEPT REFINEMENT

Review

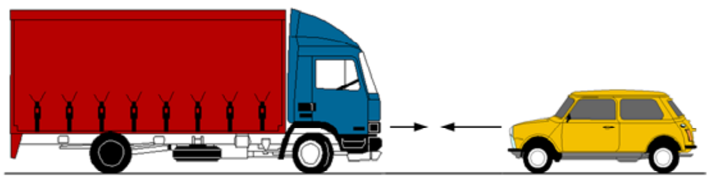
In the following set of exercises you will be using the idea of conservation of momentum in order to make predictions about the velocities and momenta for either of the two bodies involved in the problem. We will only consider two-body systems that are involved in one-dimensional collisions in which the bodies stick together after the collision.

An equation that you can use for inelastic collisions also uses the idea of conservation of momentum. If momentum is conserved, then the total momentum before the collision is equal to the total momentum after the collision. If the collision between two bodies is inelastic then the objects will stick together after the collision. The equation that results is similar to the one that you used for partially elastic collisions except for the right side of the equation. The right side of the equation shows the sum of the two masses that have stuck together multiplied by the final velocity that they both have.

total momentum before = total momentum after

$$m_1v_{0\,1} + m_2v_{0\,2} = (m_1 + m_2)v$$

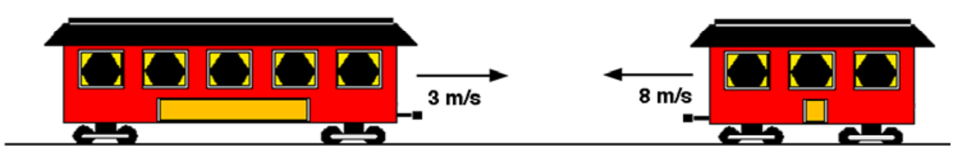
A 10,000 kg truck and a 5,000 kg car are involved in a head on collision in which the vehicles stick together after the collision.



1. If the two vehicles come to a complete halt <u>after</u> they have collided and stuck together, what would their final velocity be? What would their final momentum be? Explain your answer.

2. If the car was moving at 20 m/s before the collision, how fast was the truck moving before the collision? Be sure to show your calculations and to label the answer with the appropriate units.

3. Why do you get the positive or negative sign on the initial velocity of the truck? What does this sign mean?



A 20,000 kg railroad car moving at 3 m/s collides head on with a 5,000 kg railroad car moving at 8 m/s in the opposite direction.

4. If the two cars link together after the collision, what would be the magnitude <u>and</u> direction for the final velocity of this system? Be sure to show your calculations and to label the answer with appropriate units.

Check your work with your teacher.