



Activity 8

The Rear-End Collision



GOALS

In this activity you will:

- Evaluate from simulated collisions, the effect of rear-end collisions on the neck muscles.
- Understand the causes of whiplash injuries.
- Understand Newton's Second Law of Motion.
- Understand the role of safety devices in preventing whiplash injury.



What Do You Think?

Whiplash is a serious injury that is caused by a rear-end collision. It is the focus of many lawsuits, loss of ability to work, and discomfort.

- **What is whiplash?**
- **Why is it more prominent in rear-end collisions?**

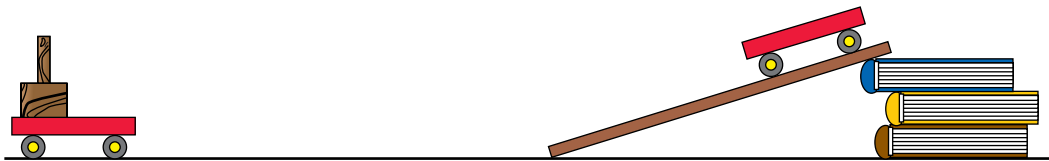
Record your ideas about these questions in your *Active Physics* log. Be prepared to discuss your responses with your small group and the class.

For You To Do

- You will use two pieces of wood to represent the torso (the trunk of the body) and the head of a passenger. Attach a small piece of wood (about 1" x 2" x 2") to a larger piece of wood (about 1" x 3" x 10") with some duct tape acting like a hinge between the two pieces.
 - Make a sketch to show your passenger. Label what each part of the model passenger represents.
- Set up a ramp against a stack of books about 40 cm high, as shown in the diagram below. Place the wooden model passenger at the front of a collision cart positioned about 50 cm from the end of the ramp. Release a second cart from a few centimeters up the ramp.
 - In your log record what happens to the head and torso of the wooden model.
- With the first cart still positioned about 50 cm from the end of the ramp, release the second cart from the top of the ramp.
 - Describe what happens to the head of the model passenger in this collision.
 - Use Newton's First Law of Motion to explain your observations.







Perform the activity outside of traffic areas. Do not obstruct paths to exits. Do not leave carts lying on the floor.





- The duct tape represents the neck muscles and bones of the vertebral column. How large a force do the neck muscles exert to keep the head from flying off the body, and to return the head to the upright position? To answer this question, begin by estimating the mass of an average head.
 - Estimate and record in your log the mass of an average human head. The mass would be close to the mass of a filled water container of the same size.



5. Mark off a distance about 30-cm long on the lab table or the floor. Obtain a piece of wood and attach it to a spring scale. Pull the wooden mass with the spring scale over the distance you marked.
-  a) In your log record the force required to pull the mass and the time it took to cover the distance.
 -  b) Repeat the step, but vary the time required to pull the mass over the distance. Record the forces and the times in your log.
 -  c) Use your observations to complete the following statement:
The shorter the time (that is, the greater the acceleration) the the force required.
6. The ratio of the mass of the wood to the estimated mass of the head is the same as the ratio of the forces required to pull them.
-  a) Use the following ratio to calculate how large a force the neck muscles exert to keep the head from flying off the body, and to return the head to the upright position under different accelerations.

$$\frac{\text{mass of head}}{\text{mass of wood}} = \frac{\text{force to move head}}{\text{force to move wood}}$$

7. Whiplash is a serious injury that can be caused by a rear-end collision. The back of the car seat pushes forward on the torso of the driver and the passengers and their bodies lunge forward. The heads remain still for a very short time. The body moving forward and the head remaining still causes the head to snap backwards. The neck muscles and bones of the vertebral column become damaged. The same muscles must then snap the head back to its place atop the shoulders.
-  a) What type of safety devices can reduce the delay between body and head movement to help prevent injury?
 -  b) What additional devices have been placed in cars to help reduce the impact of rear-end collisions?



FOR YOU TO READ

Newton's Second Law of Motion

Newton's First Law of Motion is limited since it only tells you what happens to objects if net force acts upon them. Knowing that objects at rest have a tendency to remain at rest and that objects in motion will continue in motion does not provide enough information to analyze collisions. Newton's Second Law allows you to make predictions about what happens when an external force is applied to an object. If you were to place a collision cart on a level surface, it would not move. However, if you begin to push the cart, it will begin to move.

Newton's Second Law states:

If a body is acted on by a force, it will accelerate in the direction of the unbalanced force. The acceleration will be larger for smaller masses. The acceleration can be an increase in speed, a decrease in speed, or a change in direction.

Newton's Second Law of Motion indicates that the change in motion is determined by the force acting on the object, and the mass of the object itself.

Analyzing the Rear-End Collision

This activity demonstrated the effects of a rear-end collision. Newton's First Law and Newton's Second Law can help explain the "whiplash" injury that passengers suffer during this kind of collision.

Imagine looking at the rear-end collision in slow motion. Think about all that happens.

1. A car is stopped at a red light. This is the car in which the driver is going to be injured with whiplash. The driver is at rest within the car.
2. The stopped car gets hit from the rear.
3. The car begins to move. The back of the seat pushes the driver forward and his torso moves with the car. The driver's head is not supported and stays back where it is.
4. The neck muscles hold the head to the torso as the body moves forward. The muscles then "whip" the head forward. The head keeps moving until it gets ahead of the torso. The head is stopped by the neck muscles. The muscles pull the head back to its usual position. Ouch!



Let's repeat the description of the collision and insert all of the places where Newton's First Law applies. Newton's First Law states that *an object at rest stays at rest and an object in motion stays in motion unless acted upon by an unbalanced, outside force.*

1. A car is stopped at a red light. This is the car in which the driver is going to be injured with whiplash. The driver is at rest within the car. *Newton's First Law: an object (the driver) at rest stays at rest.*





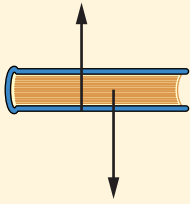
2. The stopped car gets hit from the rear.
3. The car begins to move. The back of the seat pushes the driver forward and his torso moves with the car. *Newton's First Law: an object (the driver's torso) at rest stays at rest unless acted upon by an unbalanced, outside force.* The driver's head is not supported and stays back where it is. *Newton's First Law: an object (the driver's head) at rest stays at rest.*
4. The neck muscles hold the head to the body as the body moves forward. The muscles then "whip" the head forward. *Newton's First Law: an object (the head) at rest stays at rest unless acted upon by an unbalanced, outside force.* The head keeps moving until it gets ahead of the torso. *Newton's First Law: an object (the head) in motion stays in motion unless acted upon by an unbalanced, outside force.* The muscles pull the head back to its usual position. *Newton's First Law: an object at rest stays at rest unless acted upon by an unbalanced, outside force.* Ouch!

Let's repeat the description of the collision and insert all of the places where Newton's Second Law applies. Newton's Second Law states that *all accelerations are caused by unbalanced, outside forces, $F = ma$.* An acceleration is any change in speed.

1. A car is stopped at a red light. This is the car in which the driver is going to be injured with whiplash. The driver is at rest within the car.
2. The stopped car gets hit from the rear.
3. The car begins to move. *Newton's Second Law: the car accelerates because of the unbalanced, outside force from the rear; $F = ma$.* The back of the seat pushes the driver forward and his torso moves with the car. *Newton's Second Law: the torso accelerates because of the unbalanced, outside force from the back of the seat; $F = ma$.* The driver's head is not supported and stays back where it is.
4. The neck muscles hold the head to the torso as the body moves forward. The muscles then "whip" the head forward. *Newton's Second Law: the head accelerates because of the unbalanced force of the muscles; $F = ma$.* The head keeps moving until it gets ahead of the torso. The head is stopped by the neck muscles. *Newton's Second Law: the head accelerates (slows down) because of the unbalanced force from the neck muscles; $F = ma$.* The muscles pull the head back to its usual position. *Newton's Second Law: the head accelerates because of the unbalanced force from the rear; $F = ma$.* Ouch!

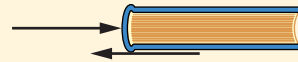
Newton's Second Law informs you that all accelerations are caused by *unbalanced, outside forces*. It does not say that all forces cause accelerations. An object at rest may have many forces acting upon it. When you hold a book in

your hand, the book is at rest. There is a force of gravity pulling the book down. There is a force of your hand pushing the book up. These forces are equal and opposite. The “net” force on the book is zero because the two forces balance each other. There is no acceleration because there is no “net” force.



Both forces act through the center of the book. They are shifted a bit in the diagram to emphasize that the upward force of the hand acts on the bottom of the book and the downward force of gravity acts on the middle of the book.

As a car moves down the highway at a constant speed, there are forces acting on the car but there is no acceleration. This indicates that the net force must be zero. The force of the engine on the tires and road moving the car forward must be equal and opposite to the force of the air pushing the car backward. These forces balance each other in this case, where the speed is not changing. There is no net force and there is no acceleration. The car stays in motion at a constant speed. A similar situation occurs when you push a book across a table at constant speed. The push is to the right and the friction is to the left, opposing motion. If the forces are equal in size, there is no net force on the book and the book does not accelerate—it moves with a constant speed.



Reflecting on the Activity and the Challenge

The vertebral column becomes thinner and the bones become smaller as the column attaches to the skull. The attachment bones are supported by the least amount of muscle. Unfortunately, the smaller bones, with less muscle support, make this area particularly susceptible to injury. One of the greatest dangers following whiplash is the damage to the brainstem. The brainstem is particularly vital to life support because it regulates blood pressure and breathing movements. Consider how your safety device will help prevent whiplash following a collision. What part of the restraining device prevents the movement of the head?





Be sure the outside of the jar is dry so it does not slip out of your hands.

Physics To Go

1. Why are neck injuries common after rear-end collisions?
2. Explain why the packages in the back move forward if a truck comes to a quick stop.
3. As a bus accelerates, the passengers on the bus are jolted toward the back of the bus. Indicate what causes the passengers to be pushed backward.
4. Why would the rear-end collision demonstrated by the laboratory experiment be most dangerous for someone driving a motorcycle?
5. Would headrests serve the greatest benefit during a head-on collision or a rear-end collision? Explain your answer.
6. A cork is attached to a string and placed in a jar of water as shown by the diagram to the right. Later, the jar is inverted.
 - a) If the glass jar is pushed along the surface of a table, predict the direction in which the cork will move.
 - b) If you place your left hand about 50 cm in front of the jar and push it with your right hand until it strikes your left hand, predict the direction in which the cork will move.

