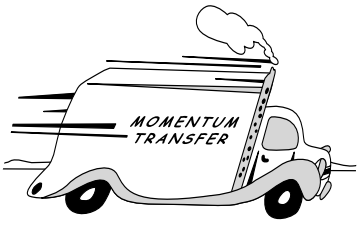


"CRASH COURSE" ACTIVITY

Momentum Bashing

TEACHER LESSON 2

Crash Course Definitions

momentum: the product of the mass and the velocity of an object (p = mv)

velocity: the speed of an object and its direction of motion

acceleration: the rate at which velocity is changing

Key question(s)

- What determines if one car has more momentum than another in a two-car collision?
- Does increasing an object's mass increase its momentum or "bashing power?"

Grade levels: 6–12
Time required: 30–40 minutes

Objectives

Students will:

- determine if increasing an object's mass increases its momentum.
- explain how two vehicles of different mass can achieve the same momentum.

National Science Education Standards

Standard A: Science as Inquiry
- Identify questions and concepts that guide scientific investigations
- Design and conduct scientific investigations

Standard B: Physical Science
- Motion and forces
- Conservation of energy

Standard F: Science in Personal and Social Perspectives
- Natural and human-induced hazards

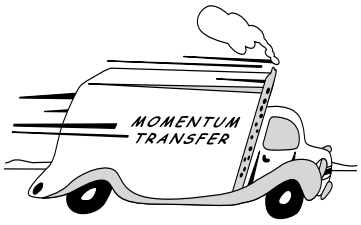
Standard G: Nature of Science
- Nature of scientific knowledge
- Historical perspectives

Background information

Science is a process that is performed not only by individuals but by a "scientific community." One of the first groups to represent the scientific community was the Royal Society of London for Improving Natural Knowledge, founded in 1660. The group evolved from informal meetings where the members discussed and performed simple scientific experiments. Led by a soon-to-be-famous member named Isaac Newton, they began to explore the topic of motion and collisions. Drawing on previous work from the "scientific community" and his own observations, Newton deduced his three simple laws of motion.

Newton's Second Law of Motion states that if you wish to accelerate something, you must apply a force to it. **Newton's First Law of Motion** then says, once an object is moving it will remain moving (unless friction or another outside force, like a wall, stops it). This is inertia of motion, or **momentum**.

The momentum of a moving object is related to its mass and velocity. A moving object has a large momentum if it has a large mass, a large velocity, or both. A marble can be stopped more easily than a bowling ball. Both balls have momentum. However, the bowling ball



Momentum Bashing

has more momentum than a marble. Momentum changes if the velocity and/or mass changes. (For more on momentum see background information from Lesson #5.)

Materials needed

For each group:

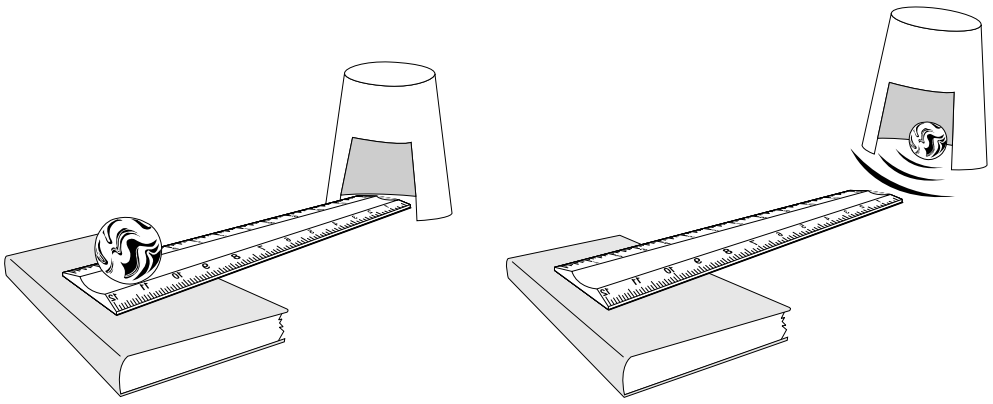
- ruler with center groove
- 4 marbles, same size
- 5-ounce (148 ml) paper cup
- scissors
- meter sticks (2)
- book to support track (3–4 cm height)

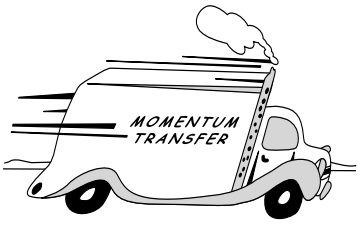
Procedure

1. Explain how scientific knowledge changes by evolving over time, almost always building on earlier knowledge (refer to background information). Tell students this lesson builds on their knowledge of force, inertia, and speed to better understand what happens in a crash. Begin the activity with a discussion of the following open-ended question on momentum.
   - Momentum is often used by sports commentators or political analysts to describe a team's or candidate's performance, yet in physics it has a specific meaning. Can they explain the difference?

2. Explain that momentum has often been loosely defined as the amount of "oomph" or "bashing power" of a moving object , and in this activity they will investigate how an object's mass affects its "bashing power" or momentum.

3. Distribute "Momentum Bashing" activity sheets and supplies to each group. Instruct each group to cut the section from their paper cup and set up their ramp. Long flat tables or tile floors work well for this activity.





Momentum Bashing

4. Circulate and assist groups. Have students measure the distance the cup moves to the nearest 0.1 cm.

5. Guide students through the data analysis and interpretation. With good technique, this simple experiment can produce consistent results allowing students to correctly conclude that increasing the mass or number of marbles increases their overall momentum (see sample data).

number of marbles	trial 1 cm	trial 2 cm	trial 3 cm
1	5.0	5.0	5.7
2	12.5	13.0	12.5
3	19.5	19.2	19.0
4	24.0	24.1	24.8

sample data for distance cup moved (with ruler height 3.0 cm)

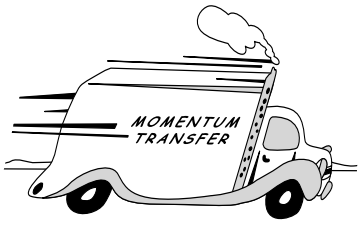
6. Discuss Analysis Questions 2, 3, and 4. Help students understand that the escaping marbles are a source of error in the experiment's design. Encourage them to find evidence of this in their data. Many students find the average distance gained with the fourth marble is less than when the second and third marble were added (i.e., 5.8 cm compared to 6.8 cm and 6.5 cm, respectively). In discussing possible design solutions for their revised experiment, remind students that there is another quantity in addition to an object's mass that determines its momentum. The other quantity is the object's velocity. By incrementally raising the starting height of the ruler (i.e., 2cm, 4cm, 6cm, 8cm), one marble may be used to incrementally increase the momentum during the collision. Review the equation to calculate an object's momentum: momentum = mass x velocity

Answers to analysis questions

1. Describe the relationship between the number of marbles hitting the cup and the distance the cup moves.
   As the number of marbles increase the distance the cup moves increases. The average increase in distance was 6.8 cm, 6.5, and 5.8 for each additional marble: 1–2, 2–3, 3–4 respectively.

2. As the marbles collided with cup, did you encounter any problems with the marbles staying in the cup? If yes, describe what happened.
   Yes, as the marbles collided with the cup, the cup would often spin causing some of the marbles to roll out of the cup.

3. Explain how marbles escaping the cup during the collision affected your results. Can you find evidence of this in your data?
   If the marbles escape the cup during the collision they take "their" momentum with them. This reduces the momentum transferred to the cup therefore the cup does not travel as far as it would if all the marbles stayed in the cup during the collision. Many students find the average distance gained with the fourth marble is less than the average distance gained by the second and third marble (i.e., 5.8cm compared to 6.8cm and 6.5cm, respectively).



4. How would you revise this investigation to increase the momentum of the collision using only ONE marble?
I would raise the starting height of the ruler incrementally so the marble's velocity increases incrementally (i.e.,2 cm, 4 cm, 6 cm, then 8 cm). As the marble's velocity increases so does its momentum. This is shown in the equation for momentum: object's momentum = object's mass x object's velocity

Answers to Crash questions

1. Explain why an 80,000-lb big rig traveling 2 mph has the same momentum as a 4,000-lb sport utility vehicle (SUV) traveling 40 mph. Or in the approximate metric units, explain why a 36,000-kg big rig traveling 3 km/h has the same momentum as an 1800-kg SUV traveling 60 km/h.
Since momentum is the product of mass and velocity, the truck's large mass and slow speed is matched by the SUV's smaller mass but greater speed.

momentum = mass x velocity
p = mv

Big Rig's momentum = SUV's momentum
mv = mv
(80,000 lbs.)(2 mph) = (4,000 lbs.)(40 mph)
160,000 (lbs.)(mph) = 160,000 (lbs.)(mph)

Or in approximate metric units:

(36,000 kg)(3 km/h) = (1800 kg)(60 km/h)

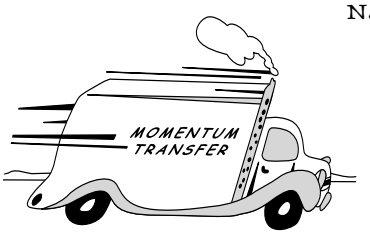
The SI unit for momentum is the kilogram x meter/second or in metric symbols (kg x m/s). To correctly calculate the momenta of the truck and SUV, you must convert their velocity from kilometers/hour to meters/second.

Truck momentum = (36,000 kg)(0.89 m/s) = 32,000 kg x m/s
SUV momentum = (1,800 kg)(18 m/s) = 32,000 kg x m/s

Extension(s)

1. Have students conduct Momentum Bashing II (Student Activity #5) to revise this investigation to increase the momentum of the collision using only ONE marble. Using the same equipment from Momentum Bashing students investigate the relationship between the release height of the marble on the ruler and the distance the cup moves. Increasing the marble's release height on the ruler also increases its potential energy, this in turn produces an increase in its kinetic energy, speed, and momentum upon impact with the cup.

2. Have students discover the Law of Conservation of Momentum by exploring the results of two colliding objects. (See Student Activity #4).



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Momentum Bashing

STUDENT ACTIVITY 2

Crash test question(s)

- What determines if one car has more momentum than another in a two-car collision?
- Does increasing an object's mass increase its momentum?

Purpose

- To determine if increasing mass increases momentum
- To explain how vehicles of different size can achieve the same momentum

Materials needed

For each group:

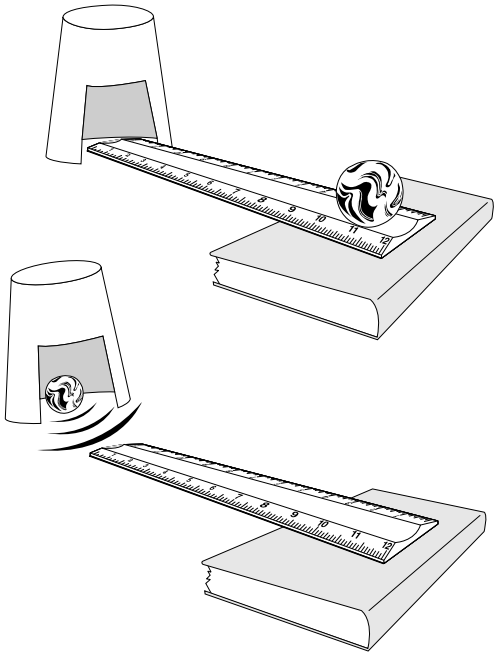
- ruler with center groove
- 4 marbles, same size
- 5-ounce (148 ml) paper cup
- scissors
- meter sticks (2)
- book to support track (3–4 cm height)

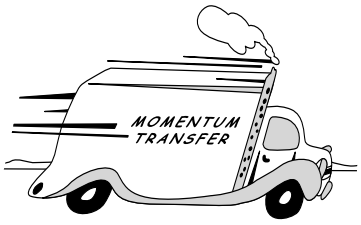
Discussion

To better understand what happens in a crash, it helps to see how force, inertia, and speed are related in a property called momentum. The amount of momentum an object has is often referred to as "oomph" or "bashing power." In this activity you will investigate how an object's mass affects its momentum or "bashing power!"

Procedure

1. Cut a 3.0 cm square section from the top of the paper cup.
2. Place the ruler with one end on a textbook (approximately 3.0 cm height) and the other end resting on the desk.
3. Place the 3.0 sq. cm opening of the cup over the end of the ruler resting on the desk.
4. Place a meter stick along side the cup to measure the distance it moves.
5. Position ONE (1) marble in the groove at the ruler's maximum height.





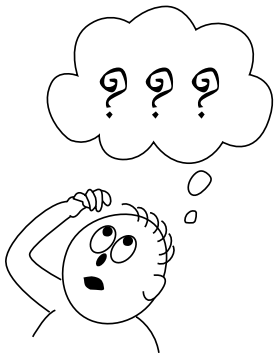
"CRASH COURSE" ACTIVITY

Momentum Bashing

STUDENT ACTIVITY 2

6. Release the marble and observe the cup.
7. Measure the **distance** the cup moved (to the nearest 0.1 cm).
8. Perform three (3) trials for 1, 2, 3, and 4 marbles and average the results. **Record** these measurements in the data table below.

number of marbles	measured distance cup moves (cm) trial 1	trial 2	trial 3	average distance cup moves (cm)
1				
2				
3				
4				



Analysis

1. Describe the relationship between the number of marbles hitting the cup and the distance the cup moves.

_____

2. As the marbles collided with cup, did you encounter any problems with the marbles staying in the cup? If yes, describe what happened.

_____

3. Explain how marbles escaping the cup during the collision affected your results. Can you find evidence of this in your data?

_____

4. How could you revise this investigation to increase the momentum of the overall collision using only ONE marble?

_____

_____

Crash question

1. Explain why an 80,000 pound big rig traveling 2 mph has the same momentum as a 4,000 pound sport utility vehicle (SUV) traveling 40 mph.

_____

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