STUDENT ACTIVITY

Name: _____ Class: _____ Date: _____

CRASH SCIENCE IN THE CLASSROOM

CONSERVATION: IT'S THE LAW!

MOMENTUM TRANSFER

MATERIALS NEEDED

For each pair of students

- Seven glass marbles, all the same size
- One 92-cm (3-foot) piece of dark gray "foam-type" pipe insulation (3/8" tubular polyethylene used to insulate 3/4" pipe), without adhesive
- 30-cm of masking tape
- One meter stick
- Three to five books to support the pipe insulation track
- One wooden pencil

Per Student

- One copy of the "Conservation: It's the Law!" Student Activity Sheet

Key Question(s)

- How do crash forces affect the motion of two colliding objects?
- How does the momentum of objects change before and after a collision?
- Where does the energy of moving objects "go" in a collision?

Purpose

- To apply Newton's third law of motion to collisions
- Use data to describe a collision in terms of changes and transfers in momentum
- To infer how the law of conservation of momentum is applied in collisions
- To explain how the law of conservation of energy is applied in collisions

Did You Know?

In the previous activities, you explored how engineers use Newton's Laws of Motion and the concepts of momentum and impulse to study the physics of car crashes. Engineers at the IIHS's Vehicle Research Center also rely on two other important laws of physics that have been called the most powerful tools for studying the field of mechanics, namely the Law of Conservation of Energy and the Law of Conservation of Momentum. In this activity you will study collisions between marbles to observe these two laws in action.

Procedure

Part A. Marble Collision Test Track Assembly

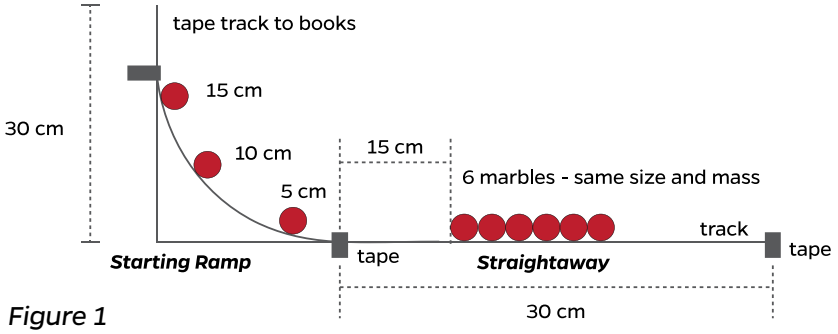


Figure 1

1. With books as a support, create an elevated "starting ramp" for the marble collision test track by using two small pieces of masking tape to secure the left and rights sides of one end of the track to the stack of books at a height of 25–30 cm. At the bottom of this elevated starting ramp, create a 60-cm long straightaway on a flat, hard surface (floor or table top) and use small pieces of tape on the left and ride sides at each end of the straightaway to secure it to the floor or table top. (See Figure 1 above).

Procedure (continued)

2. Using three more small pieces of tape and the meter stick, measure and mark the following three marble release heights on the outside of the starting ramp as indicated in Figure 1: 5.0 cm, 10.0 cm, 15.0 cm. Make measurements straight up from the surface of the table or floor and place the small tape pieces so that the top of each tape piece is 5.0, 10.0, and 15.0 cm above the table or floor.

Part B. Observing Newton's Third Law and the Transfer of Momentum

1. Place six marbles side by side in the groove of the track with the first marble about 15 cm away from the bottom of the starting ramp (See Figure 1).

2. Push the six marbles together and make sure they are all touching.

3. Hold the seventh marble at the top of the tape piece marking 5.0 cm on the starting ramp.

4. Release the marble and allow it to roll down the track and collide with the row of six marbles. Observe what happens and record how many marbles roll away from the row after the collision in Data Table #1.

5. Place the six marbles back in the starting position shown in Figure 1 and complete additional test collisions by releasing the seventh marble from the 10.0 and 15.0 centimeter marks on the starting ramp. Record the number of marbles that roll away from the row after collisions at each of these heights in Data Table 1.

6. Repeat steps 1 through 5 again with collisions using the following combinations of marbles:
- » Two moving marbles and five stationary marbles
- » Three moving marbles and four stationary marbles
- » Two moving marbles and one stationary marble

Data Table 1

NUMBER OF MARBLES RELEASED	HEIGHT OF RELEASE	NUMBER OF MARBLES IN ROW	NUMBER OF MARBLES KNOCKED AWAY FROM ROW
1	5.0 cm	6	
	10.0 cm	6	
	15.0 cm	6	
2	5.0 cm	5	
	10.0 cm	5	
	15.0 cm	5	
3	5.0 cm	4	
	10.0 cm	4	
	15.0 cm	4	
2	5.0 cm	1	
	10.0 cm	1	
	15.0 cm	1	

Part C. Observing the Law of Conservation of Momentum

1. Place six marbles side by side in the groove of the track with the first marble about 15 cm away from the bottom of the starting ramp again (See Figure 1).

2. Push the six marbles together and make sure they are all touching.

3. Hold the seventh marble at the top of the tape piece marking 5.0 cm on the starting ramp.

MOMENTUM TRANSFER

CONSERVATION: IT'S THE LAW!

MOMENTUM TRANSFER

Procedure (continued)

4. Release the marble and allow it to roll down the track and collide with the row of six marbles. Observe the speed of the released marble just before it collides with the row of six marbles as well as the speed of the marble knocked away from the row after the collision. Record these qualitative observations of the speed of the released marble and the marble knocked away (slow, medium, or fast speed) in Data Table #2.

Data Table 2

HEIGHT OF RELEASE OF ONE MARBLE	SPEED OF RELEASED MARBLE BEFORE IMPACT (SLOW, MEDIUM, FAST)	SPEED OF MARBLE KNOCKED AWAY (SLOW, MEDIUM, FAST)
5.0 cm		
10.0 cm		
15.0 cm		

5. Place the six marbles back in the starting position shown in Figure 1 and complete additional test collisions by releasing the seventh marble from the 10.0 and 15.0 centimeter marks on the starting ramp. Record qualitative observations of the speed of the released marble and the marble knocked away at these two release heights in Data Table 2.

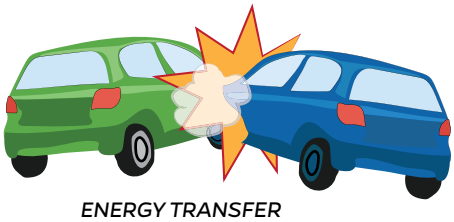
Analysis Questions

1. Based on your observations (e.g., sights and sounds of the collisions) and the results in **Data Table 1**, how does the number of marbles released and the height of release affect the impact forces between the moving marbles and the row of stationary marbles?

2. Based on your results in **Data Table 1**, what is the relationship between the number of marbles released and the number of marbles knocked away in each collision?

3. Based on your results in **Data Table 1**, how does the number of marbles released affect the total amount of momentum of the moving marbles in a collision?

4. Based on your results in **Data Table 2**, what is the relationship between the height of release of the marble and the speed of the marble before it collides with the row of stationary marbles?



ENERGY TRANSFER

Analysis Questions (continued)

5. Based on your results in **Data Table 2**, what is the relationship between the speed of the released marble and the speed of the marble knocked away?

6. Based on your results in **Data Table 2**, how does the height of release affect the momentum of a moving marble in a collision?

7. Recall that Newton's third law of motion involved the idea of forces always coming in pairs. With this thought in mind, explain why this statement in FALSE: "A 3000 kg truck collides with a 1500 kg stationary car. The car experiences the greater collision force."

8. Recall that momentum is the product of an object's mass and its velocity. The more massive an object, the more momentum it has. With this thought in mind, explain how your observations and data in Part B illustrate the Law of Conservation of Momentum in a collision.

9. Marbles moving at a greater speed have more kinetic energy (energy of motion). With this thought in mind, explain how your observations and data in Part C illustrate the Law of Conservation of Energy in a collision.