Determining the Effect of Mass on Kinetic Energy

Background Information

You wouldn't be afraid to stop a marble rolling down an incline, but if a bowling ball was rolling down the same incline, you'd probably move out of the way. Both objects are rolling because of Earth's gravity, yet the bowling ball has much more energy. The **potential energy** (PE) of an object being pulled by gravity is the product of its mass (m), the acceleration due to gravity (g), and its height (h).

$$\mathbf{PE} = mgh$$

Think of a marble and a bowling ball rolling down the same slope from the same starting point. In the absence of friction, they move at the same speed, but they have different amounts of energy. It is a lot easier to see this difference when the potential energy is converted to **kinetic energy** as the object begins to move. As the marble and the bowling ball accelerate to the same speed (v) under the force of gravity, the only difference in their kinetic energies (KE) is due to mass.

$$\mathbf{KE} = \frac{1}{2}mv^2$$

In this investigation, you will accelerate four different masses to the same speed. Then, you will compare their kinetic energies.

Problem

How is the energy of a moving object influenced by its mass?

Pre-Lab Discussion

Read the entire investigation. Then, work with a partner to answer the following questions.

1. **Controlling Variables** Identify the manipulated, responding, and controlled variables in this investigation.

   a. Manipulated variable

   _____

   _____

   b. Responding variable

   _____

   _____

   c. Controlled variables

   _____

   _____

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2. **Applying Concepts** How will the mass of the rolling bottle affect its speed when it collides with the plastic cup? (*Hint:* The bottle accelerates much like a falling body.)

3. **Predicting** How do you expect the mass of the bottle to affect the distance the cup moves?

4. **Applying Concepts** How is work related to the distance that the cup moves?

5. **Formulating Hypotheses** State a hypothesis about how the kinetic energy of the rolling bottle affects the amount of work done on the cup and the distance the cup moves.

Materials *(per group)*

2 textbooks
flat board
masking tape
250-mL beaker
balance
plastic bottle that holds about 500–600 mL, with screw cap
plastic cup or margarine container
paper towel
meter stick

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Safety

Put on safety goggles. Handle the board carefully to avoid splinters. Note all safety alert symbols next to the steps in the Procedure and review the meaning of each symbol by referring to the Safety Symbols on page xiii.

Procedure

1. Stack the two textbooks. Place one end of the board on the stack of books to form a ramp, as shown in Figure 1. Tape the ramp in place so it cannot move.
2. Attach a piece of masking tape across the ramp 15 cm from the bottom of the ramp. Use a pencil to mark the starting point on the masking tape. The bottle will be released from this point in each trial.

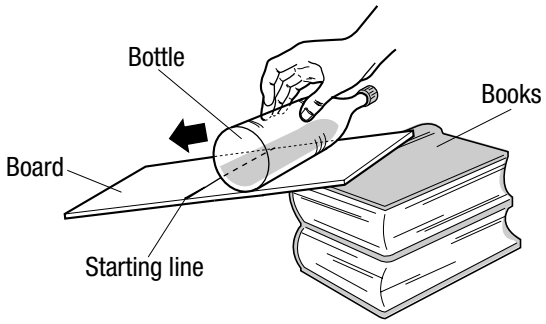

Figure 1

3. Using the beaker, carefully pour 100 mL of water into the bottle. Close the bottle tightly and dry the outside of the bottle with the paper towel. Wipe up any spills immediately.
4. Using the balance, measure the total mass of the bottle of water and record it in the data table.
5. Place a small piece of masking tape on the floor in line with the center of the ramp at a distance of 20 cm from the base of the ramp. This is the starting position for the cup in each trial.
6. Place the empty cup at its starting point, with its closest point to the ramp touching the piece of masking tape.
7. Hold the bottle of water lying across the ramp at the starting point, as shown in Figure 1. Allow it to roll down the ramp and collide with the cup. When both the bottle and the cup have stopped moving, use the meter stick to measure the distance the cup moved from its starting point. Record the result (to the nearest centimeter) in the appropriate place in the data table.
8. Repeat Steps 6 and 7 until you have made and recorded five measurements.
9. Using the beaker, add 100 mL of water to the bottle and close it tightly. Measure and record the new mass of the bottle.
10. Repeat Steps 6 and 7 to make five measurements using the new mass.
11. Again, add 100 mL of water to the bottle and close it tightly. Measure and record the new mass.
12. Repeat Steps 6 and 7 to make five additional measurements.

13. Add 100 mL of water to the bottle as before (for a total of 400 mL) and close it tightly. Measure and record the new mass.
14. Repeat Steps 6 and 7 to make five additional measurements.
15. Calculate the average distance that the cup moved for each bottle mass by adding the five distances and dividing by 5. Record your results to the nearest centimeter in the data table.
16. On the grid provided, construct a graph of your data with the mass of the bottle on the horizontal axis and the average distance the cup moved on the vertical axis. Draw a straight line as close as possible to the data points.

Observations

DATA TABLE

	Volume of Water			
	100 mL	200 mL	300 mL	400 mL
	Mass of Bottle and Water (g)			
Distance Moved by Cup (cm)				
Trial 1				
Trial 2				
Trial 3				
Trial 4				
Trial 5				
Total Distance (cm)				
Average Distance (cm)				

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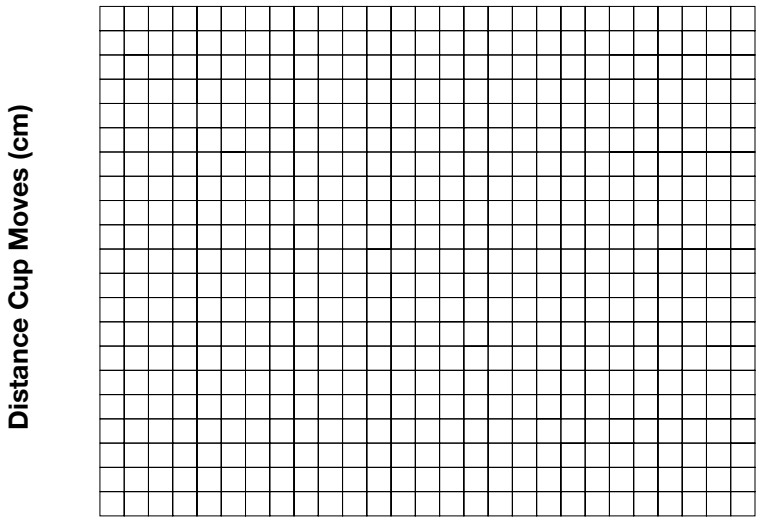

Analysis and Conclusions

1. **Controlling Variables** What procedure was followed to make sure that the bottle would be moving at the same speed each time it collided with the cup? Does this method work? Explain your answer.

2. **Inferring** Why is it important that the bottle have approximately the same speed each time it collides with the cup in order to measure the effect of mass on energy?

3. **Analyzing Data** As the mass of the bottle increased, what happened to the distance that the bottle moved the cup?

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4. **Relating Cause and Effect** Why did the cup eventually come to a complete stop?

5. **Forming Operational Definitions** How was the distance that the cup moved related to the bottle's kinetic energy?

6. **Evaluating and Revising** Did your experimental results agree with your hypothesis about how the kinetic energy of the bottle affects the amount of work done on the cup? Explain your answer.

7. **Applying Concepts** This investigation assumes that the rolling bottle experiences only a small frictional force. How accurate is this assumption? Could this assumption affect the results of the investigation? Explain your answer.

Go Further

In this investigation, you examined the relationship between the mass of a rolling bottle and its kinetic energy. Design a procedure to measure how the height of a ramp affects the kinetic energy of a bottle rolling down the ramp. Have your teacher approve your procedure before you carry out the investigation. Propose an explanation for what you find.