STAY ON TARGET! (1 Hour

In this activity, students will use a ramp to launch a ball and strike a target.

Topic: **Projectile motion**

Real-World Science Topics

- An exploration of projectile motion
- An exploration of forces and motion

Objective

Students will gain an understanding of how force affects an object's speed and will observe how a projectile travels through the air.

Materials Needed for Teacher Demonstration

- large, heavy object, such as a desk or box of books
- wooden board or kinetics track (2–3 feet long)
- Hall's carriage or toy car
- several books or other adjustable-height objects (to support the ramp)
- stopwatch
- masking tape or duct tape
- large, open area, such as a large table or tile floor

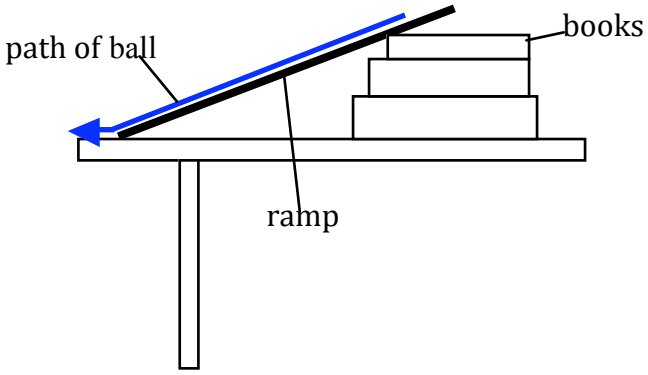
Materials Needed for Student Teams

- wooden board or kinetics track (2–3 feet long)
- golf ball, table tennis ball, or marble (must be able to roll down the board or track)
- several books or other adjustable-height objects (to support the ramp)
- paper or plastic cup (large enough to hold the ball or marble) or small, shallow basket
- meter stick or measuring tape
- masking tape
- stopwatch
- table or desk (large enough to hold the ramp)
- clear area of floor (at least 5–10 feet if possible)
- protractor (optional)

STAY ON TARGET!

Teacher Preparation

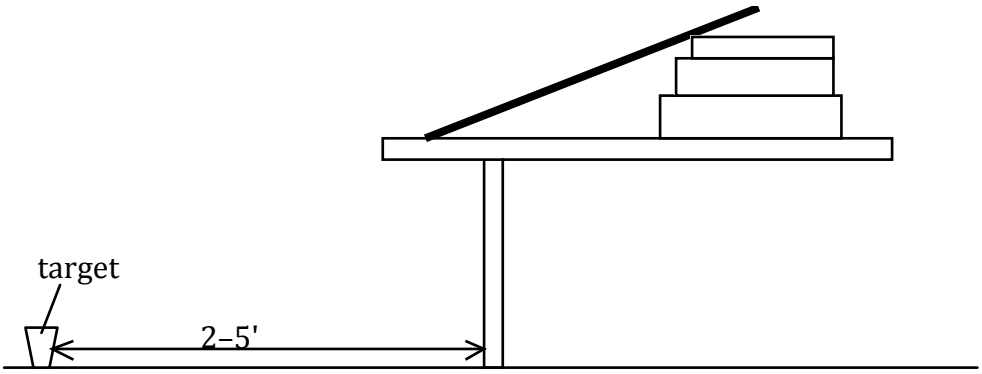
Depending on student ability, you may wish to construct the ramps for student teams ahead of time. It is important that the golf ball roll down the ramp in a straight line and then travel a short distance along the table before falling off the edge, as shown by the blue line below.



You should mark the end of each ramp on the table using tape. When students adjust the height of the ramp, the end of the ramp should remain at the same place. This will ensure the ball travels the same distance along the table during each trial.

If you are using a board for a ramp, you may wish to attach strips of cardboard to the board to form a chute for the ball to roll in. This will ensure the ball rolls straight down the board.

Place a target (cup or basket) on the floor, 2–5 feet away from the edge of the table, as shown below.



STAY ON TARGET!

You may wish to tape the target to the floor (or, at least, mark the target location on the floor with tape) so that it remains fixed even if a ball hits it. The distance between the table edge and the target should be different for the different groups.

Because students will be launching objects into the air during this activity, you should caution students to be very careful and alert during the experiment. Students should not launch their balls unless all members of the group are paying attention. If possible, set up the groups so that there is minimal chance that one group's ball will fly into another group's setup. Remind students to pick up their balls immediately to avoid tripping hazards.

STEPS FOR *STAY ON TARGET!*

1. **Warm-Up Activity:** Introduce the concept of the relationship between the magnitude of force applied to an object and the object's final speed. Point out a large, heavy object in the classroom and ask one student to try to move the object by pushing or pulling on it. (Ideally, the object should be heavy enough that one student cannot move it.) Ask students for ideas of ways to move the object. Students should suggest having additional people help the student. Have more students push or pull on the object until it begins to move. Ask students to explain why having more people push on the object allowed it to move. Encourage them to phrase their answers in terms of force. They should realize that each additional student applied more force to the object.

2. Set up the board or kinetics track as a ramp on the floor. Place the Hall's carriage or car at the top of the ramp, and then release it. Have a student time how long it takes the carriage to roll down the ramp. Mark the place where the carriage stops with tape. Point out to students that the carriage began rolling on the ramp because gravity was pulling it down the ramp. Explain that gravity pulls the carriage straight down, but the carriage cannot go straight down because the ramp is in the way. Ask them to predict what will happen to the speed of the car if you increase or decrease the height of the ramp. Then repeat the demonstration with a higher and a lower ramp. The car should roll more quickly down the ramp and travel farther along the floor as the ramp gets steeper. Have students think about why this is the case. Then, explain to students that as the ramp gets steeper, the carriage moves faster because more force acts on it. The closer the ramp gets to vertical, the more the gravity on the carriage pulls it along the ramp. Tell students that in this experiment they will use a ramp to launch a ball off the side of a table. They will adjust the height of the ramp so that the ball will land on a target.

3. Show students the experimental setup. Demonstrate for them how to adjust the height of the ramp. Point out the target (the cup or basket) and explain that their goal is to get the ball to land in the target. If necessary, demonstrate for them how to roll the ball down the ramp. Make sure they understand the following points:
   - The bottom end of the ramp should always remain at the same place on the table.
   - The ball should be released from the same point on the ramp during every test.
   - The ball should always be released from rest. It should never be pushed down the ramp.
   - For each test, students should measure and record the height of the ramp, the amount of time the ball was in the air (i.e., the time between when the ball left the table and when it landed), and the horizontal distance the ball traveled. If you wish, you may also have them use protractors to measure the angle between the ramp and the table.
   - When students measure time and travel distance, they should observe the first place the ball touched the floor (i.e., they should ignore bounces).

4. Divide students into groups. Assign each member of the group one of the following roles:

- Timer: uses the stopwatch to measure the flight time of the ball
- Marker: identifies and marks (with masking tape) the point at which the ball lands
- Measurer: measures the height of the ramp and the distance the ball travels
- Recorder: records all measurements

These roles can be rotated among the students at each trial if you wish. Have each group test their setup once and observe how long the ball is in the air and where the ball lands. They should mark the ball's landing spot with masking tape.

5. Once students have made their first observations, have them work together to decide how to adjust the ramp height to get the ball to land in (or on) the target. Remind them to give justifications for their predictions. If necessary, remind them of what they observed about the speed of the carriage in the warm-up activity. Ask them to consider how the speed of the ball when it leaves the table might affect the distance it travels.

6. Allow students to test their predictions. Remind them to record the height of the ramp, the flight time of the ball, and the horizontal distance the ball traveled.

7. Have students continue to adjust the height of the ramp and repeat their investigations. Make sure they are making justified predictions about how to change the height of the ramp, rather than just changing the height randomly. Students should continue to modify the ramp height until their ball lands in the target several times in a row.

8. Wrap-up Activity: Have each group demonstrate its successful setup to the rest of the class. Ask each group to state the height of the ramp they used and the distance between the edge of the table and the target. Record the data for each group on the board. Draw or project an empty graph of travel distance vs. ramp height. Ask students to predict what the graph will look like and explain their reasoning. Then, use the class data to generate the graph, and have students discuss any differences between their predictions and the actual shape of the graph. Depending on student ability, you may have students create this graph in groups before you complete it in front of the class. Ask students to share their experiences. Prompt discussion by asking some of the following questions:

- How does the distance the ball travels relate to the height of the ramp?
- How many times did you have to change the ramp height to get the ball to hit the target? What process did you use to decide what heights to test?
- What challenges did you encounter, and how did you resolve your challenges?

Stay on Target! Extension Activities

1. Have students experiment with releasing the ball from different points on the ramp (keeping the ramp height constant). Ask them to determine how the distance along the ramp that the ball travels is related to the travel distance of the ball through the air.

2. Have students explore the relationship between mass and travel distance by using different objects to roll down the ramp. (They should learn that mass has little to no effect on the path of the projectile.)

What makes objects move?

An object's motion can change only if a force acts on it. This is also known as Newton's first law of motion. Any time an object's motion is changing (that is, if it is speeding up, slowing down, or changing direction), a force must be acting on the object. The force acts in the same direction as the change in motion. For example, if an object is slowing down, then the force acting on the object must be acting in a direction opposite its direction of motion. If an object is turning right, the force on the object must be to the right.

Newton's second law of motion states that larger forces produce larger changes in motion if an object's mass does not change. In other words, to get an object to move more quickly, you should apply more force to it.

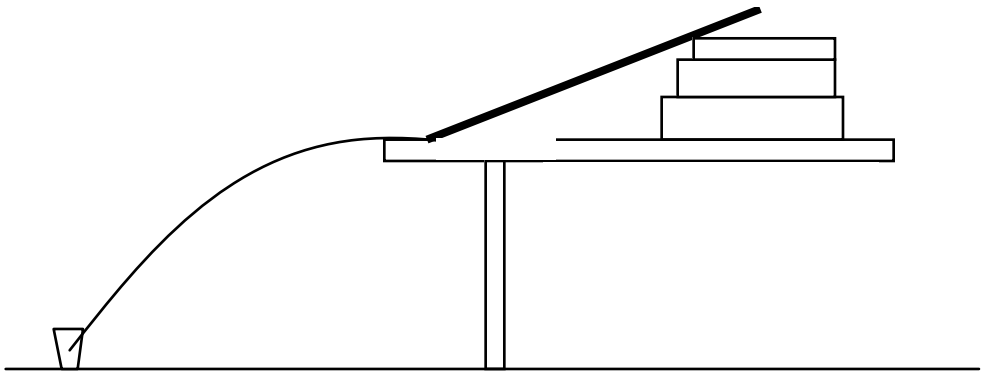
Why does the ball roll down the ramp?

A ball resting on a perfectly flat surface will not move (assuming no other unbalanced forces are acting on it). Gravity pulls the ball down toward Earth, but it cannot move downward because the surface it is sitting on keeps it from moving. (The surface produces an upward force on the ball that is the same size as the downward force of gravity. Because these two forces are the same size but act in opposite directions, they cancel each other out, and the ball does not move.)

If you rest the ball on a ramp, however, it begins to roll. This happens because now, as gravity pulls down on the ball, the ball can move downward. It cannot move straight down, because the ramp is in the way. Instead, it rolls down the ramp. A fraction of gravity's downward pull acts in the same direction as the ramp. As the ramp gets steeper, that fraction gets larger, so the ball reaches a higher speed as it rolls down the ramp. When the ramp is vertical, the entire gravitational pull acts on the ball, so it falls as quickly as the force of gravity will cause it to move.

What happens when the ball leaves the table?

When the ball leaves the table, it becomes a projectile. A projectile is an object that flies through the air. The instant the ball leaves the table, it is moving only horizontally. Once it is in the air, it also begins to fall downward because gravity pulls on it. However, the pull of gravity does not reduce the ball's horizontal speed. That is why the ball keeps moving away from the table. The combination of horizontal motion and vertical motion makes the ball follow a curved path, as shown below.



The horizontal and vertical motions of the ball do not affect each other. If you dropped a ball straight down from the edge of the table at the same instant that the rolling ball left the table, both balls would land at the same time.

Why does the height of the ramp affect the final position of the ball?

If the ramp is steeper, then the force of gravity acting on the ball is greater, and this causes the ball to achieve a higher speed when it leaves the table. The greater the horizontal speed, the farther from the table the ball can travel before it hits the ground. (Remember, the ball has the same downward vertical speed no matter how fast it is going when it leaves the table. It is the vertical speed that determines how long the ball is in the air. In other words, the ball is in the air for the same amount of time no matter how fast it is moving when it leaves the ramp.)

Key Vocabulary

force: a push or pull

projectile: an object that is flying through the air and experiences no forces except gravity

1. What do you think will happen to the ball as you make the ramp steeper?

[Sample answer: I think the ball will fall closer to the table if we make the ramp steeper.]

Complete the table below with the data you collected during your experiment.

Test Number	Height of ramp	Time ball was in the air	Distance ball traveled
1	[0.10 m]	[0.48 s]	[0.5 m]
2	[0.14 m]	[0.47 s]	[0.6 m]
3	[0.26 m]	[0.49 s]	[0.8 m]
4	[0.41 m]	[0.48 s]	[1.0 m]

2. How high did your ramp have to be to get the ball into the target?

[Answers will depend on the location of the cup.]

3. What was the relationship between the height of the ramp and the distance the ball traveled?

[As the ramp got steeper, the ball traveled farther.]

4. Did your observations agree with your prediction? Explain your answer.

[Sample answer: No, my observations did not agree with my prediction. I thought the ball would land closer to the table if the ramp was steeper.]

Name:

Date:

1. What do you think will happen to the ball as you make the ramp steeper?

Complete the table below with the data you collected during your experiment.

Test Number	Height of ramp	Time ball was in the air	Distance ball traveled
1			
2			
3			
4			

2. How high did your ramp have to be to get the ball into the target?

3. What was the relationship between the height of the ramp and the distance the ball traveled?

4. Did your observations agree with your prediction? Explain your answer.