Gizmos

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Student Exploration: Golf Range

Vocabulary: acceleration, air resistance, gravity, hang time, launch angle, projectile motion, trajectory, vector, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. You are in a contest with your friends to see who can drive a golf ball the farthest. Should you hit a "line drive" (low to the ground) or a shot with a very high angle? Explain.

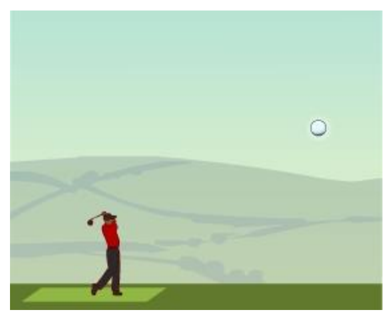
   If I had to choose between a shot that was very low to the ground and a shot with a very high angle, I would hit a line drive. The line drive will cover a greater horizontal distance than the high shot, which will reach a much greater vertical height but a smaller horizontal distance.

2. Golf drives travel much farther than Major League home runs. Why might this be?

   This might be because golf balls have less mass than baseballs. Given the same force, a golf ball will have a greater acceleration (F = ma) than a baseball. The golf ball, with a greater acceleration, should travel further than the baseball.

Gizmo Warm-up

Have you ever hit a hole-in-one? You will have a chance to do that in the *Golf Range* Gizmo, where you will see how a variety of factors affect the path of a golf ball. The movement of objects such as a ball through space is called **projectile motion**.



1. Press **Play** ( ). Did the ball go too far, the right distance,

   or not far enough? Not far enough

2. Click **Reset** ( ). Move the $\boldsymbol{v_{initial}}$ and $\boldsymbol{\theta}$ *sliders* to adjust the **velocity** and **launch angle** until you get a hole-in-one. (With the Gizmo sound on ( ) you will hear "Hole in one!")

   What were the velocity and launch angle values? V_initial(m/s) = 64.0 m/s, theta(deg) = 45.0 degrees to the horizontal

3. Can you get holes-in-one using other combinations of $\boldsymbol{v_{initial}}$ and $\boldsymbol{\theta}$? If so, give an example.

V_initial(m/s) = 68.0 m/s, theta(deg) = 54.0 degrees to the horizontal

Activity A: Maximum distance	Get the Gizmo ready: • Click **Reset** and check that **Atmosphere: Air** is selected. • Set $\boldsymbol{v_{initial}}$ to 75 m/s and $\boldsymbol{\theta}$ to 45.0 degrees.	

Question: What launch angle will produce the longest drive?

1. Form hypothesis: What launch angle do you think will yield the longest drive? [1]
   A launch angle of 45 degrees will yield the longest drive.

2. Experiment: Turn on the **Show grid** checkbox. With the velocity set to 75 m/s, experiment with a variety of launch angles until you find the one that yields the longest driving distance. [2]

   A. What launch angle produced the longest drive?
      A launch angle of 45 degrees to the horizontal produced the longest drive.

   B. How far did the ball travel?
      The ball traveled approximately 373.6 meters horizontally.

3. Observe: Click **Reset** and turn on **Show paths**. Click **Clear paths**. Take a swing with the optimum launch angle. The curved path the ball takes through the air is its **trajectory**. [1]

   Look closely at the trajectory. Does it appear symmetrical?
   No, the curve seems skewed towards the right.

   The curve is slightly steeper on the right than on the left as a result of **air resistance**.

4. Experiment: Click **Reset**, then select **Atmosphere: None**. As before, use trial and error until you find the launch angle that produces the longest drive. [4]

   A. What launch angle produced the longest drive?
      A launch angle of 45 degrees to the horizontal produced the longest drive.

   B. How far did the ball travel?
      The ball traveled approximately 575.5 meters.

   C. Why do you think the ball traveled farther in this situation?
      Air resistance exerts a force on the ball that slows the ball in the air. Since this simulation assumed that there was no atmosphere, there was no air resistance to slow the ball down and the ball traveled further. In the other simulation, air resistance slowed the ball through the air, making it fall

5. Extend your thinking: The Moon has much less gravity than Earth and has an extremely thin atmosphere. How would these factors affect the trajectory of a golf ball on the Moon? [2]
   The reduced gravity implies that a gravitational force with a **smaller** magnitude pulls the ball towards the center of the Moon, allowing the ball to reach a greater height and travel a greater horizontal distance.
   The reduced atmosphere implies that the air imparts a force with a **smaller** magnitude on the ball through the air than the force from air resistance on Earth. Thus, the trajectory of

the golf ball would be more like a parabola in comparison to the trajectory of a golf ball hit with similar initial conditions on Earth. Depending on the density of the Moon’s atmosphere, the effects of air resistance may be negligible, making the trajectory a parabola.