

# Gravity Pitch

## Answer Key

**Vocabulary:** escape velocity, gravity, orbit, orbital velocity, trajectory, velocity

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

*[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]*

On their summer vacation, a family is standing at a scenic overlook at the top of a tall cliff. Young Alice (age 2) tosses a rock over the edge and giggles as she watches it fall. Brother Darrell (age 8) thinks he can do better and hurls another rock over the edge. Papa Billy chuckles, picks up a nice round rock, and flings it off the cliff as hard as he can.

1. In the picture to the right, draw the **trajectory**, or path, that each rock would take. Label the three trajectories "Alice", "Darrell" and "Billy" (or just A, D and B).



*Answers will vary.*

*[Most drawings will show that Papa Billy's ball goes farthest.]*

2. What would happen if Billy could throw the rock as fast as a rocket?

*Answers will vary. [Students may consider the shape of Earth, and may even think of orbit.]*

### Gizmo Warm-up: Which way does gravity pull?

1. Use the slider to set the **Velocity** to 0.0 km/s (kilometers per second). **Velocity** is basically the same thing as speed, but has direction as well. In this case the pitcher is simply dropping the ball. Click **Play** (▶).

A. What direction does the ball go? *Straight down.*


B. Sketch the pitcher and the trajectory of the ball on the diagram. *All dropped balls should go toward Earth's surface.*



2. Click **Reset** (↺) and drag the pitcher to several new positions. Click **Play** and watch him drop the ball each time. Sketch the pitcher and the trajectory of each ball on the diagram.

A. What do you notice? *The ball lands at the pitcher's feet each time.*

B. The ball is pulled by a force called **gravity**. In what direction does gravity always pull the ball? *Gravity always pulls the ball toward the center of Earth.*

<b>Activity A:</b>  <b>How far does it go?</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>Click <b>Reset</b>.</li> <li>Drag the pitcher back to the top.</li> <li>Set the <b>Velocity</b> to 1.0 km/s (2,232 miles per hour).</li> </ul>	
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**Question: Why do objects go around, or orbit, other objects?**

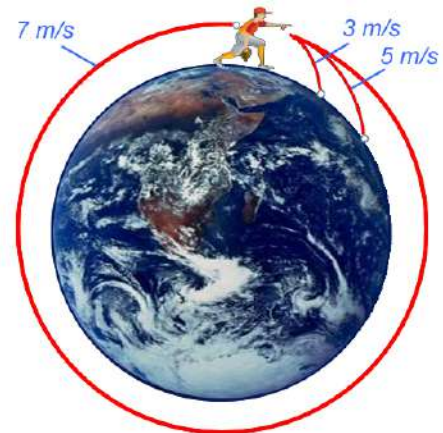
1. Observe: Click **Play** and observe the ball's trajectory. (Note: The pitcher is very tall – about 1500 km (930 miles) tall!)

2. Predict: How would the trajectory of the ball change as the pitcher throws it harder and harder? Explain below, and draw several predicted trajectories on the diagram.

*Predictions will vary. Check student work on the diagram.  
[Students may consider orbiting or near-orbiting balls.]*

3. Collect data: Throw the ball at velocities of 3, 5, and 7 km/s. If necessary, use the **Fast forward** button (▶▶) to speed things up and the “–” zoom control to see a larger area. For each throw, sketch and label the trajectory and record the **Distance traveled** in the table below.

Velocity	Distance traveled
3 km/s	2,784 km
5 km/s	5,001 km
7 km/s	46,247 km



4. Analyze: What happens?

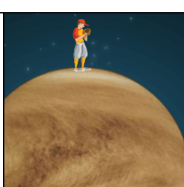
*As the velocity increases, the ball goes farther before it hits the Earth. At 7 km/s, the ball goes all the way around Earth, and then hits the pitcher!*

5. Draw conclusions: What force causes objects to stay in orbit?

*Gravity causes objects to stay in orbit. [Objects are “falling” toward Earth as they orbit Earth. If the orbit is circular, the rate of falling matches the curvature of Earth.]*

6. Run Gizmo: Test 8 km/s and 9 km/s. (If you have a lot of spare time, try 10 km/s as well.) Use the “–” zoom control. What happens?

*The orbit becomes oval-shaped [elliptical]. If the ball is thrown fast enough, it escapes, never to be seen again. [Escape velocity on Earth is 11.2 km/s.]*

<b>Activity B:</b>  <b>Comparing planets</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>Click <b>Reset</b>.</li> <li>On the <b>Planet</b> menu, choose <b>Venus</b>.</li> <li>Set the <b>Velocity</b> to 1 km/s.</li> </ul>	
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**Question: How would the gravity of other planets affect a pitched ball?**

1. Observe: Look at the **Planet mass** and **Planet radius** of Venus. The **mass** of a planet is how much matter it contains. The **radius** of a planet is the distance from the center to the surface. Compared to Earth, what are the mass and radius of Venus?

Venus mass:  $0.81 \times$  Earth's mass

Venus radius:  $0.95 \times$  Earth's radius

2. Predict: Will the pitcher have to throw the ball faster or not as fast to send a ball into orbit around Venus? *Predictions will vary.* Why? *Answers will vary.*

3. Run Gizmo: **Orbital velocity** is the velocity needed to make a circular orbit. Use the Gizmo to find the orbital velocity of the ball on Venus. Make the orbit as circular as you can.

A. What is the orbital velocity on Venus?  $6.6 \text{ km/s}$  [Accept within 0.2 km/s of this value.]

B. Do the same on Earth. What is the orbital velocity on Earth?  $7.1 \text{ km/s}$ .

C. Based on this, which planet do you think has stronger gravity, Venus or Earth?

Explain. *Earth's gravity is stronger. It requires a higher velocity to orbit Earth.*

4. Predict: Select **Mars**. Estimate what the orbital velocity will be on Mars: *Answers will vary.*  
Why did you choose that value? *Answers will vary.*

5. Run Gizmo: Adjust the **Velocity** until you create a circular orbit on Mars.


A. What is the orbital velocity on Mars? *Between 2.9 km/s and 3.0 km/s.*

B. How does gravity on Mars compare to Earth and Venus? *Much weaker on Mars.*

6. Extend your thinking: The **escape velocity** is the smallest velocity needed for the baseball to escape from the planet's gravity and fly off into space, never to return.

A. Which planet do you think has the lowest escape velocity? *Mars.*

B. Use the Gizmo to test your prediction. Were you correct? *Answers will vary.*

<b>Activity C:</b> <b>Design a planet</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>Click <b>Reset</b>.</li> <li>On the <b>Planet</b> menu, select <b>Custom</b>.</li> <li>Set the <b>Velocity</b> to 7.0 km/s.</li> </ul>	
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**Question: How does a planet's mass and radius affect a pitched ball?**

1. Observe: Using the sliders, try a variety of values for **Planet mass** and **Planet radius** for your custom planet. Observe the trajectory of the ball each time.

2. Form hypotheses: Fill in the blanks below:

*As its mass increases, the strength of a planet's gravity **Increases** (Hypotheses will vary.)*

*As its radius increases, the strength of a planet's gravity **Decreases** (Hypotheses will vary.)*

3. Run Gizmo: Set **Planet mass** to 0.0 of Earth (no mass), **Planet radius** to 1.0 of Earth (equal to Earth). Press **Play** and record results. Repeat for **masses** of 1.0 (equal to Earth) and 2.0.

Planet mass	Planet radius	Velocity	What happened?
0.0	1.0	7.0 km/s	<i>The ball went in a straight line to outer space.</i>
1.0	1.0	7.0 km/s	<i>The ball orbited the planet and hit the pitcher.</i>
2.0	1.0	7.0 km/s	<i>The ball hit the ground in front of the pitcher.</i>

4. Analyze: How does increasing the mass affect the gravity of the planet? How do you know?

*Increasing mass increases the strength of gravity. The greater the planet's mass, the more gravity pulled on the ball.*

5. Experiment: Do the same kind of experiment, but now keep the **Planet mass** at 1.0 and change the **Planet radius**. Record results in a notebook or on a separate sheet of paper.

A. What do you notice? *As the radius increases, the ball travels farther.*

B. How does changing the radius affect the strength of a planet's gravity?

*As radius increases, gravity gets weaker.*

6. Apply: Using what you have learned, create a planet with the strongest possible gravity. What are the mass and radius of this planet?

*Strongest gravity in Gizmo: Mass = 2.0 × Earth's mass, Radius = 0.3 × Earth's radius.*