Name: _____ Date: _____

Student Exploration: Free-Fall Laboratory

Vocabulary: acceleration, air resistance, free fall, terminal velocity, velocity, vacuum

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

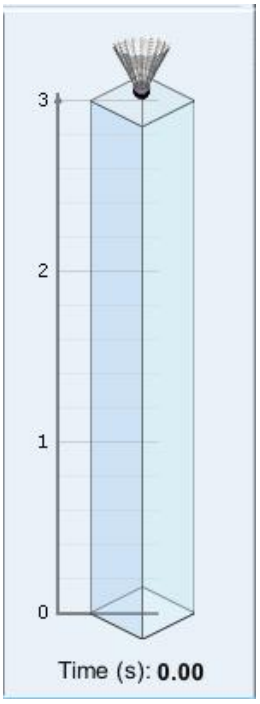
1. Suppose you dropped a feather and a hammer at the same time. Which would hit the ground first? _____

2. Imagine repeating the experiment in an airless tube (**vacuum**). Would this change the result? Explain. _____

   _____

Gizmo Warm-up

The *Free-Fall Laboratory* Gizmo™ allows you to measure the motion of an object in **free fall**. On the CONTROLS pane check that the **Shuttlecock** is selected, the **Initial height** is **3 meters**, and the **Atmosphere** is **Air**.



1. Click **Play** ( ) to release the shuttlecock. How long does it take to fall to the bottom? _____

2. Select the GRAPH tab. The box labeled ***h*** **(m)** should be checked, displaying a graph of height vs. time. What does this graph show?

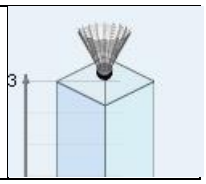
   _____

3. Turn on the ***v*** **(m/s)** box to see a graph of **velocity** vs. time. Velocity is the speed and direction of the object. Because the object is falling downward, its velocity is negative.

   Does the velocity stay constant as the object drops? _____

4. Turn on the ***a*** **(m/s/s)** box to see a graph of **acceleration** vs. time. Acceleration is the rate at which the velocity changes over time. What does this graph show?

   _____

Activity A: **Falling objects**	Get the Gizmo ready: • Click **Reset** ( ). • Select the CONTROLS tab.	

Question: What factors affect how quickly an object falls?

1. Observe: Drop each item through **Air** from a height of **3 meters**. Record how long it takes to fall below. For the tennis ball, try to click **Pause** ( ) when it hits the ground.

Shuttlecock	Cotton ball	Tennis ball	Rock	Pebble

2. Form a hypothesis: Why do some objects fall faster than others? _____

_____

3. Predict: A vacuum has no air. How do you think the results will change if the objects fall through a vacuum?

_____

4. Experiment: On the **Atmosphere** menu, select **None**. Drop each item again, and record the results below.

Shuttlecock	Cotton ball	Tennis ball	Rock	Pebble

5. Analyze: What happened when objects fell through a vacuum? _____

_____

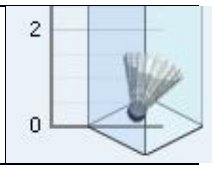
6. Draw conclusions: Objects falling through air are slowed by the force of **air resistance**. Which objects were slowed the most by air resistance? Why do you think this is so?

_____

_____

_____

_____

Activity B: **Terminal velocity**	Get the Gizmo ready: • Click **Reset**. • Set the **Initial height** to **12 meters**. • Set the **Atmosphere** to **Air**.	

Question: How does air resistance affect falling objects?

1. Observe: Select the **Shuttlecock**. Choose the BAR CHART tab, and click **Play**. What do you notice about the velocity and acceleration of the shuttlecock?

   _____

   _____

   When objects fall through air for a long time, they will eventually stop accelerating. Their velocity at this point is called **terminal velocity**.

2. Form hypothesis: How will an object's size and mass affect its terminal velocity?

   _____

3. Experiment: Click **Reset**. On the CONTROLS tab, select **Manual settings**. Set the **height** to 100 meters and the air density (***ρ***) to 1.3 kg/m^3, close to actual air density at sea level.

   For each combination of **mass** and **radius** in the charts below, find the terminal velocity ($v_{terminal}$) of the object. Use the BAR CHART tab to find the terminal velocity. (Hint: Turn on **Show numerical values**.)

Mass	Radius	$v_{terminal}$
1.0 g	3.0 cm	
10.0 g	3.0 cm	
50.0 g	3.0 cm	

Mass	Radius	$v_{terminal}$
10.0 g	2.0 cm	
10.0 g	5.0 cm	
10.0 g	10.0 cm	

4. Analyze: Your data show how mass and radius affect terminal velocity.

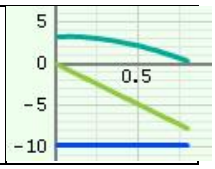
   A. What was the effect of increasing mass? _____

   B. What was the effect of increasing radius? _____

5. Apply: If you wanted to use a device to slow your fall, what properties should it have?

   _____

   _____

Activity C: **Acceleration, distance, and time**	Get the Gizmo ready: • Click **Reset**. • Select **Common objects**. • Set the **Atmosphere** to **None**.	

Question: How long does it take an object to fall from a given height?

1. Observe: Select the **Rock**, and set the **Initial height** to **3 meters**. Choose the GRAPH tab, and click **Play** to drop the rock through a vacuum. Turn on all three graphs.

   A. What is the shape of the graph of velocity vs. time? _____

   B. What is the shape of the graph of acceleration vs. time? _____

   C. What is the shape of the graph of height (displacement) vs. time?

   _____

   Draw a picture of the graph with the 3 lines (height, velocity & acceleration). Label the 3 lines (height, velocity & acceleration)