Lesson Title: Was Galileo Right? **Date:**_____

Subject: Forces and Motion **Topic:** Acceleration Due to Gravity

Grade: 8 or 9 **Designer:** Concord Consortium

Stage 1 - Desired Results

Lesson Overview

In this lesson, students will explore the effects of gravity on objects of different masses during free fall. Prior knowledge of position-time and velocity-time graphs, along with slope meaning and measurement is recommended.

Standards Addressed

- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph. (NSES p154, grades 5-8)
- Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F=ma, which is independent of the nature of the force. (NSES p 179, grades 9-12)
- Graphs can show a variety of possible relationships between two variables. (BSL 9B/M3, grades 6-8)
- Tables, graphs, and symbols are alternative ways of representing data and relationships that can be translated from one to another. (BSL 9B/H4, grades 9-12)
- Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. (PA 3.2.P.B1)

Enduring Understanding:	**Essential Question(s):** Do heavier objects fall at the same rate as lighter objects?
An object's acceleration can be determined by velocity-time data in a table or graph.	
Students will need to know: • **Key terms:** position, time, mass, meters, seconds, grams, velocity, constant, steady, changing, slow, fast, slope, interval, acceleration, gravity • How to measure the slope of a line segment	**Students will be able to:** • Predict the position-time and velocity-time graphs of falling balls with different masses. • Compare position-time and velocity-time graphs of light and heavy balls. • Describe an object's velocity qualitatively. • Find the acceleration of a falling object by analyzing its velocity-time graph.

Stage 2 - Assessment Evidence

Performance Tasks	**Other Evidence:**
In this activity, students: • Analyze position-time and velocity-time data to compare velocities of different falling balls. • Find accelerations of falling balls. • (other tasks to be filled in by teacher)	• *Was Galileo Right?* Check-In • (other assessments to be filled in by teacher)

(over)

Stage 3 - Learning Plan	
Learning Procedure **Many days before:** • Review lesson plan, practice activity, secure equipment, design additional teaching instruments as desired. **Day of:** • Set up groups, computers, projector. • Introduce lesson (method tbd by teacher). • Have students complete *Was Galileo Right?* • Conclude lesson (method tbd by teacher).	**Required Materials:** • PC or Macintosh Computers: 1 per group • Supported Internet browser with access to SmartGraphs portal • Projection device (LCD, SmartBoard, or large monitor) preferred but not required
Possible Discussion Questions for Students:	**Sample Answers to Discussion Questions:**
How can you tell which ball took less time to fall from a fixed height?	Time the motions directly or find the times from position-time data or velocity-time data.
How can you tell whether one ball fell at a faster **average rate** than the other?	Since both balls fell from the same height, you could find how long each took by using a stop watch or using position-time data. (The ball that took less time fell at a faster average rate.) Or, you could look find the slope of the position-time data to find the average velocity. If velocity was constant, you could find the average velocity from velocity-time data.
What does a straight line on a velocity-time graph indicate?	A straight line indicates that the change in velocity per change in time was constant. If the line is horizontal, the object's velocity was constant --- its change in velocity per change in time (acceleration) was 0. Positive velocity refers to forward motion; negative velocity refers to backward motion. If the line crosses the x axis, the object's direction changed. If the line does not cross the x axis, the object either sped up or slowed down at a constant rate.
What does an upward u-shaped curve on a velocity-time graph indicate?	An upward u-shaped curve on a velocity-time graph indicates that the object's velocity increased with time. Steeper portions indicate more dramatic changes in velocity than flatter portions.
What does the slope of a velocity-time graph indicate?	Here, the slope indicates how the object's velocity changed per unit of time (acceleration). To find the slope, divide the change in velocity by the change in time for a given interval. A larger slope (steeper line) indicates faster acceleration than a smaller slope (flatter line). If the line is horizontal, the acceleration is 0, which means the object's velocity did not change. The sign indicates acceleration (+) or deceleration (-).

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