TEACHWITHPORTALS™

Subject: Physics

Title: Gravity

Author: Cameron Pittman, Teacher

School / Organization, City and State / Province: Stratford STEM Magnet High School, Nashville, TN

Grade Level: 11-12 (or advanced conceptual physics students)

Standards Met:

Physics Standards

Gravity, Acceleration

Next Generation Science Standards

HS.PS-FM Forces and Motion, performance standards a) Plan and carry out investigations to show that the algebraic formulation of Newton's second law of motion accurately predicts the relationship between the net force on macroscopic objects, their mass, and acceleration and the resulting change in motion

Science and Engineering Practices: Planning and carrying out investigations, Analyzing and interpreting data, Using mathematics and computational thinking, Constructing explanations and designing solutions, Developing and using models

ACT Standards

Interpretation of Data – Translate information into a table, graph, or diagram (20-23), compare or combine data from a complex data presentation (24-27)

Scientific Investigation – Predict how modifying the design or methods of an experiment will affect results (33-36), Identify an alternate method for testing a hypothesis (28-32)

Evaluation of Models, etc – Determine whether given information supports or contradicts a complex hypothesis or conclusion, and why (33-36)

Time Needed: 60 minutes

Objective(s): Students will design a test that allows players to test the properties of gravity in *Portal 2*. Students will demonstrate proper experiment design.

Summary: Students will be building their own experiment to calculate acceleration due to gravity in the game world. Students will decide how to build an apparatus that allows them to calculate the time it takes for an object to fall a certain distance within the game.

Vocabulary: Gravity, Acceleration, Velocity, Displacement

Student Prerequisites: knowledge of gravity, decent algebra skills

Teacher Materials Needed: None

Student Materials Needed: Stopwatch, Microsoft Excel (optional, but recommended)

This lesson plan was developed with the idea that the educator understands physics and the basics of Portal 2. *The lesson itself should flow from an introduction, into a main lab activity, and then finish with follow up questions and a homework assignment. The* ***Introductory Activity*** *section starts with questions to ask students at the beginning of class or in the class prior. The* ***Implementation*** *section gives instructions to the instructor as to how to set up the main lab activity. The* ***Closing Activity*** *section lists questions for students after they complete the main lab activity. The* ***Homework*** *section suggests questions to assign as homework after the lab. The* ***Grading Advice*** *section gives answers to all of the questions in the* ***Introductory Activity***, ***Implementation***, ***Closing Activity***, *and* ***Homework*** *sections. I'm always looking for better lessons or ideas. If you have any questions or comments, please contact me at: cameron *dot* w *dot* pittman *at* gmail *dot* com.*

Introductory Activity:

Displacement due to gravity is found through the equation

$$\Delta x = v_i t + \frac{1}{2} g t^2 \qquad (1)$$

Let's assume that, in a given situation, the initial velocity of an object is 0. Solve equation 1 for g.

Implementation:

- Instruct students to build an experiment in the game that allows players to test the strength of gravity.
- Instruct students to build an experiment which easily allows them to reach three different heights repeatedly.
- It will be easiest to use heights of 1, 2, 3 units above the ground.
- For three trials at each height, students will need to use a stopwatch to calculate the time it takes them to fall to the ground (9 total measurements). Students will record their data on the attached worksheet.
- The class should share data by posting it on a blackboard/whiteboard.

Closing Activity:

1. What was the most difficult part of testing gravity? What variable was the most difficult to account for?
2. Does the class' data make sense? Why or why not?
3. Calculate gravity by taking the average of the class' data [probably a good time for Excel]. Assuming each wall panel is 2 meters tall, how does gravity in the game compare to gravity on earth?
4. Is there a limit to the distance an object can fall in the game being used to test the strength of gravity? Why?

Homework:

Chell is on a platform 15 units above the ground. Using your data from class, calculate the time it will take her to reach the ground if she falls off the platform. Assume that g = 4.7 u/s^2 and friction is negligible.

Grading Advice:

Introductory Activity:

$$\Delta x = \frac{1}{2} g t^2 \quad (2)$$

$$2\Delta x = g t^2 \quad (3)$$

$$\frac{2\Delta x}{t^2} = g \quad (4)$$

Implementation Grades:

To get an A: projects that easily allow students to easily and accurately measure both the time and distance of a fall.
To get a B: projects that are easy to perform but have high levels of uncertainty in measurements.
To get a C: projects that are not easy to perform and contain high levels of uncertainty.
To get a D: projects that do not allow players to test for either height or time.

The strength of gravity in *Portal 2* is: **$g \approx 4.7$ u/s²**.

Closing Activity:

1. Varies from student to student. Time will probably be the trickiest.
2. Everyone should get about 4.7 u/s².
3. g = 4.7 u/s² = 9.4 m/s².
4. Yes. Once players start falling about 5 units, air resistance comes into noticeable effect.

Homework:

Students should begin with equation 2. Rearranged, it easily becomes:

$$\sqrt{\frac{2\Delta x}{g}} = t \quad (5)$$

Plugging in, using Δx = 15 u and g = 4.7 u/s², we get t = 2.5 s.

Additional Activities:

- Students collect data using each other's puzzles.
- Students can build a puzzle around their gravity test.
- Calculate error on class measurements.

Data Collection (with lots of room for scratch work!)

Calculate the strength of gravity in Portal 2 using your answer from the introductory activity and data from your experiments.

Height (units)	Time (s)	Gravity (u/s^2)

Equation from the introductory activity: _____

Average strength of gravity: _____

Introductory Activity: (ASSIGN AS PREVIOUS NIGHT'S HOMEWORK OR EXPLAIN BEFORE BEGINNING LESSON) Displacement due to gravity is found through the equation

$$\Delta x = v_i t + \frac{1}{2} g t^2 \quad (1)$$

Let's assume that, in a given situation, the initial velocity of an object is 0. Solve equation 1 for g.

Implementation:

1. Instruct students to build an experiment in the game that allows players to test the strength of gravity.
2. Students will need to calculate the time it takes them to fall to the ground from five different distances. Students will record their data on the attached worksheet.
3. Instruct students to build an experiment which easily allows them to reach five different heights repeatedly.
4. Students need to record fall time from each of the five heights at least 3 times.
5. Hint: use the size of the wall panels to calculate the fall distance.

Closing Activity:

5. What was the most difficult part of testing gravity? What variable was the most difficult to account for?
6. Does the class' data make sense? Why or why not?
7. Calculate gravity using class data [in Excel, if possible, so that students can easily get an average for gravity using multiple data points]. Assuming each wall panel is 2 meters tall, how does gravity in the game compare to gravity on earth?
8. Is there a limit to the distance an object can fall in the game being used to test the strength of gravity? Why?

Homework:

Chell is on a platform 15 units above the ground. Using your data from class, calculate the time it will take her to reach the ground if she falls off the platform (i.e., her initial velocity is 0).

Grading Advice:

Introductory Activity:

$$\Delta x = \frac{1}{2} g t^2 \quad (2)$$

$$2\Delta x = g t^2 \quad (3)$$

$$\frac{2\Delta x}{t^2} = g \quad (4)$$

Implementation:

A. Projects that easily allow students to easily and accurately measure both the time and distance of a fall.
B. Projects that are easy to perform but have high levels of uncertainty in measurements.
C. Projects that are not easy to perform and contain high levels of uncertainty.
D. Projects that do not allow players to test for either height or time.

Homework:

Students should begin with equation 2. Rearranged, it easily becomes:

$$\sqrt{\frac{2\Delta x}{g}} = t \quad (5)$$

Then students need simply to plug in their calculation for gravity and solve using a height of 15 units.

Additional Activities:

- Students collect data using each other's puzzles.
- Students can build a puzzle around their gravity test.

Height (units)	Time (s)	Gravity (u/s²)

Calculate gravity using your answer from the introductory activity.

Average strength of gravity: _____