Subject: Physics

Title: Building an Oscillator

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Grade Level: 11-12

Standards Met:

Physics Standards

Oscillations, Data Collection and Analysis

Next Generation Science Standards

Science and Engineering Practices for grades 9-12: 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 – Identify and/or use a complex mathematical relationship between data (28-32), Translate information into a table, graph, or diagram (20-23), Determine how the value of one variable changes as the value of another variable changes in a complex data presentation (24-27)

Scientific Investigation – Identify an additional trial or experiment that could be performed to enhance or evaluate experimental 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: 90 minutes (this one might run long) (give it a good intro in the class prior to this one)

Objective(s): Determining the relationship between height of a fall, mass of an object, and periodicity of motion, data collection and analysis

Summary: Students will be building an analyzing an oscillator. In the process, students will study periodicity, friction, air resistance, and consider the implications of physical process on game design.

Vocabulary: Oscillator, Period

Student Prerequisites: None

Teacher Materials Needed: None

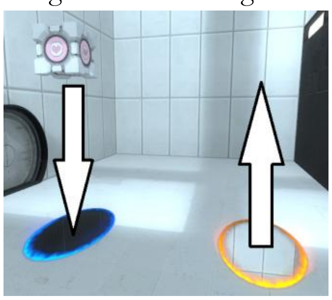
Student Materials Needed: Stopwatch, Microsoft Excel (for calculations)

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:

1. Harmonic motion describes any naturally repeating process. Pendulums and oscillating springs are most often used in class. Think outside of the box. Name three other naturally repeating processes that can be described using simple harmonic motion. For each, identify what qualifies as a period and, if possible, how the length of one period is determined.

2. Imagine the following scenario:



A cube is falling into and out of portals laid on a horizontal surface in a repeating, harmonic process. One period is the amount of time it takes for the cube to fall into the blue portal, come out the orange portal, and reach the height at which it started.

   a) How long does it take to complete **half** of a period? In other words, how long does it take a falling object to reach the ground? Assume no friction and no starting velocity. Start with:

$$h = \frac{1}{2}gt^2 \tag{1}$$

   b) So then, how long does it take an object to make a full period in the scenario above?
   c) Rearrange your equation from part (b) to solve for g.

Implementation:

- Instruct students to build a level where they can easily fall through portals or drop companion cubes into portals from **three** different heights (but no higher than 5 wall panel units). Both portals should be on a flat surface at the same level.
- Instruct students that they need to be able to easily watch and identify when either the player or a cube has made 1 period through their portals.
- To be clear, 1 period is the amount of time it takes to go from a height, fall into a portal, come out of the other portal, and reach the original height.
- Students will be using a stopwatch to calculate the amount of time it takes for a falling object to complete one period.
- Instruct students to fill out their data tables (see attached worksheets). They need to include the height (in wall units) of the fall, the time it takes to make 1 full periods (in seconds), and the type of

object (H for Human or C for Cube). They should repeat their experiment five times per height per object (see **Grading Advice**). To complete the second worksheet, students will need to calculate the average for each set of trials on the first page.

- Instruct students to answer the questions below their tables. The goal is to calculate an accurate value for g using equation 5.

Closing Activity:

1. Students calculate the average time for each object to make one period at each height. (see attached worksheets)
2. Students use their answer from opening activity #2 to solve for g using their data (equation 5).

Homework:

1. Finish the closing activity and answer questions on the attached worksheet.

Grading Advice:

Introductory Activity:

1. Planetary motion, turning wheels, wave motion, bouncing balls, etc.
2. a) $h = \frac{1}{2}gt^2$ (1)

   $\frac{2h}{g} = t^2$ (2)

   $t = \frac{T}{2} = \sqrt{\frac{2h}{g}}$ (3)

   b) $T = \sqrt{\frac{8h}{g}}$ (4)

   Just double the answer from part (a).

   c) $g = \frac{T^2}{8h}$ (5)

Main Activity and Closing Activity (including data collection worksheets):

- It's going to be much faster to do calculations in Excel.
- Students should calculate g using equation 5. Make sure they have it by the time they start their experiment

1. Students should notice that cube slow down but players do not. The period of cubes should be slightly smaller than that of players.
2. Height
3. As height increases, so does period.
4. Air resistance
5. Possibly that players think of themselves as heavier and less prone to air resistance, while a cube looks light and easily blown around by the wind. It probably makes more intuitive sense for game designers to make the cubes susceptible to air resistance at low speeds but not the player.
6. No, because the period of the oscillations decreases.
7. Collect data using as few oscillations as possible (potentially just 1 or 0.5 oscillations).
8. No. Periods should be proportional to $\sqrt{h}$ by equation **

9. See #8
10. Hopefully, they're consistent. So long as objects don't fall from great heights, friction shouldn't be too big of a factor for falling cubes.
11. Cubes are dampened, players aren't. There might be a small difference between cube oscillations and player oscillations.
12. Quirks in the game engine, etc.
13. Using some type of automated timer within the game, using more identical oscillations, etc.
14. Test using cubes of different frictions or masses, test using different in-game objects, alternate strength of gravity.
15. Hopefully similar.
16. They really shouldn't be different.
17. Height, gravity. In the real world, height is much more easily changed.

Additional Activities:

- Calculate uncertainty
- Display and use class data to get a class average for g.

Special thanks to avheuv on the beta teacher forum for the idea

For a video review of this lesson, go to http://www.youtube.com/watch?v=Wmc4GfTCiu8&

Data Collection – page 1

Height (units)	Three Periods Time (s)	Object

Height (units)	Three Periods Time (s)	Object

Height (units)	Three Periods Time (s)	Object

Height (units)	Three Periods Time (s)	Object

Height (units)	Three Periods Time (s)	Object

Height (units)	Three Periods Time (s)	Object

1. What do you notice about your data? Where do you find similarities in your data? Where do you find differences?
2. What appears to control the length of a period?
3. How do the periods of each height compare?
4. You should have noticed that the companion cube gradually slows down. What could cause the height of each oscillation for a companion cube to drop?
5. Why might the game makers decide to slow down companion cubes but not players?
6. Is your data using the companion cube still useful if it slows down? Why or why not?
7. If your answer to the previous question was no, suggest a method to collect useful data using the companion cube.

8. Does your data appear to scale linearly for oscillations where the player is falling? (in other words, does $T = mh$, where m is some arbitrary slope?)
9. If your answer to 4 was no, suggest some other relationship between period and height.

Data Collection – page 2

Height 1 – Player – Average Three Periods (s) (s)

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Height 1 – Player – Average Period (s)

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Height 1 – Player – gravity (u/s^2)

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Height 2 – Player – Average Three Periods (s) (s)

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Height 2 – Player – Average Period (s)

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Height 2 – Player – gravity (u/s^2)

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Height 3 – Player – Average Three Periods (s) (s)

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Height 3 – Player – Average Period (s)

____

Height 3 – Player – gravity (u/s^2)

____

Height 1 – Cube – Average Three Periods

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Height 1 – Cube – Average Period (s)

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Height 1 – Cube – gravity (u/s^2)

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Height 2 – Cube – Average Three Periods

____

Height 2 – Cube – Average Period (s)

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Height 2 – Cube – gravity (u/s^2)

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Height 3 – Cube – Average Three Periods

____

Height 3 – Cube – Average Period (s)

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Height 3 – Cube – gravity (u/s^2)

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10. How do your values for g compare? Do they vary wildly? Do they generally agree?
11. If you answered that g varies significantly for each experiment, suggest an explanation.
12. What factors outside of your control might have made this experiment inaccurate?
13. What could you have done to make your experiment more accurate?
14. What additional experiments follow this one? What next steps could you take?
15. Compare your values for g from this experiment to your value calculated earlier. Are they similar? Are they different?
16. If you answered different, why might they be different?

17. And, just to be clear, let's just go ahead and write down the two variables that affect the motion of a pendulum. Which one changes more easily?

Height 1 – Player – Average Three Periods (s)

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Height 1 – Player – Average Period (s)

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Height 1 – Player – gravity (u/s²)

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Height 2 – Player – Average Three Periods (s)

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Height 2 – Player – Average Period (s)

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Height 2 – Player – gravity (u/s²)

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Height 3 – Player – Average Three Periods (s)

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Height 3 – Player – Average Period (s)

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Height 3 – Player – gravity (u/s²)

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Height 1 – Cube – Average Three Periods (s)

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Height 1 – Cube – Average Period (s)

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Height 1 – Cube – gravity (u/s²)

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Height 2 – Cube – Average Three Periods (s)

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Height 2 – Cube – Average Period (s)

____

Height 2 – Cube – gravity (u/s²)

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Height 3 – Cube – Average Three Periods (s)

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Height 3 – Cube – Average Period (s)

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Height 3 – Cube – gravity (u/s²)

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18. How do your values for g compare? Do they vary wildly? Do they generally agree?
19. If you answered that g varies significantly for each experiment, suggest an explanation.
20. What factors outside of your control might have made this experiment inaccurate?
21. What could you have done to make your experiment more accurate?
22. What additional experiments follow this one? What next steps could you take?
23. Compare your values for g from this experiment to your value calculated earlier. Are they similar? Are they different?
24. If you answered different, why might they be different?
25. And, just to be clear, let's just go ahead and write down the two variables that affect the motion of a pendulum. Which one changes more easily?