TEACHWITHPORTALS™

Subject: Physics

Title: Getting Faster as You Fall

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Grade Level: 11-12

Standards Met:

Physics Standards

Projectile Motion (PM), Conservation of Energy

Next Generation Science Standards

HS.PS-E Energy, performance standard (a) Construct and defend models and mathematical representations that show that over time the total energy within an isolated system is constant, including the motion and interactions of matter and radiation within the system

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 – Determine how the value of one variable changes as the value of another variable changes in a simple data presentation (16-19)

Scientific Investigation – Understand a complex experimental design (24-27), Determine the experimental conditions that would produce specific results (24-27)

Evaluation of Models, etc – Use new information to make a prediction based on a model (28-32)

Time Needed: 60 minutes (allow extra time if students share problems with class)

Objective(s): Student demonstration of fall height vs horizontal distance covered

Summary: Students will have freedom in this lesson to build a puzzle that challenges players to acquire a specific velocity through conservation of energy.

Vocabulary: Gravity, Conservation of Energy, Projectile Motion, Kinetic Energy, Potential Energy, Velocity, Acceleration

Student Prerequisites: conservation of energy, projectile motion (knowledge of PM, not necessarily the math behind it), some knowledge of graphing in Microsoft Excel (or similar spreadsheet program)

Teacher Materials Needed: None

APERTURE LABORATORIES

Student Materials Needed: Microsoft Excel

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: (probably best done in class the day before or as homework)

1. As an object falls, its potential energy changes to kinetic. Without any friction present, all potential energy becomes kinetic during a fall. We can equate the amount of potential energy at the top of a fall to the kinetic energy at the bottom.
   $$\frac{1}{2}mv^2 = mgh \qquad (1)$$
   Solve for velocity.
2. Use Microsoft Excel to graph velocity vs. height fallen for heights between 0 and 10 meters.

Implementation:

- Instruct students to build a puzzle that challenges players to use gravity to acquire a specific velocity to cross a horizontal distance (aka, a momentum fling). Players need to use their knowledge of how kinetic energy changes as an object falls in order to solve it.
- Levels should present multiple possible solutions but can only be solved if a player understands how velocity changes as the potential energy of a fall changes.
- Hint that students might need pits with portalable floors at varying depths.
- Students test each other's levels.
- The creator of a puzzle needs to be able to quantitatively demonstrate why a particular solution works using conservation of energy. They need to show why a player achieves a certain velocity and why that velocity is necessary to cross a horizontal distance.

Closing Activities:

1. How does the height of a fall affect the velocity of the player?
2. Two players jump off a ledge at the same time. Player 1's horizontal velocity is 0, while player 2's horizontal velocity is greater than 0. Who hits the ground first? Why?
3. Some students might have dropped cubes through portals, while others may have used Chell. Does the mass of an object affect its velocity (ignoring air resistance)? Why or why not?
4. How does an object's potential energy at the height of a fall compare to its kinetic energy at ground level (ignore air resistance)?

Homework:

Diagram 1: 

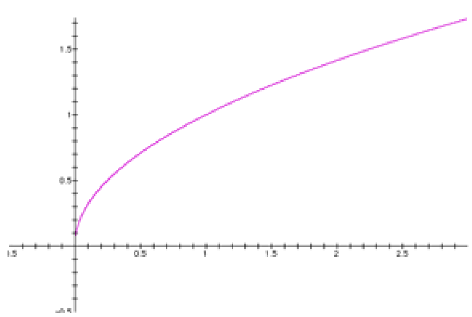
Chell has a dangerous job. She is standing on the ledge seen in diagram 1 and needs to fling herself with a velocity of at least 9 units/s in order to launch herself to a distant platform. If Chell puts her orange portal on the point labeled 'B' and her blue portal on the point labeled 'A,' will she gain enough energy falling from her ledge to make it to the platform? Assume no friction and gravity works at $4.7u/s^2$.

Grading Tips:

Introductory Activity

$$v = \sqrt{2gh} \tag{2}$$

The graph should look like:



Implementation

To get an A: Students create a level that explicitly allows a single solution requiring a player to make a choice that accelerates them to a specific velocity and can provide the math.

To get a B: Students create a level with one solution but cannot provide a complete explanation of the math.

To get a C: Students create a level with more than one solution, allowing variance in a player's velocity, but can provide the math.

To get a D: Students create a level with more than one correct solution and cannot provide the math.

Closing Activity

1. As height increases, so does velocity (see equation 2).
2. They hit the ground at the same time. Horizontal and vertical velocities are independent. Therefore, horizontal velocity can have no effect on who hits the ground first (ignoring friction).
3. No. The mass of an object has no effect on the rate at which it falls (see equation 2 where there is no mass). See the famous Apollo 15 hammer and feather drop on the moon.
4. As the object falls, its potential energy is converted to kinetic (ignoring friction). By the time it reaches the ground, all of the potential energy has been converted to kinetic energy by the law of conservation of energy. Therefore, PE at the top of a fall is the same as KE at the bottom of a fall.

Homework

Yes, she will be going fast enough. By equation 2, you find that $v = 9.7u/s$.

Additional Activities:

- Instruct students to build more complex levels.
- Instruct students to show the math behind the momentum fling in their level