How Objects Fall – Sam Hadden

This lesson will explore the way in which objects fall under the force of Earth's gravity and explore the kinematics of objects launched with different initial velocities. Students will also be exposed to how computers can be used to model the objects' motions.

Overview

The lesson is broken in to two parts: a hands-on experimentation section followed by a computational portion. For the experimentation section, students will be prompted to answer the question "How does the time it takes an object launched horizontally to reach the ground compare to the time it takes an object dropped from rest?" by designing and carrying out their own experiment. Students will spend time designing their own experiment to answer the prompt question and should reflect how their experimental design will influence their ability to gather reliable data. After the experiment, students will learn about the way gravity effects the motion of falling objects and will model the motion of objects under the force of Earth's gravity a simple program implemented in a spreadsheet. The computational component will introduce the concept of acceleration in analogy to speed and the students will learn to do simple calculations involving speed, acceleration, and time.

Student Outcomes

- Students will learn that the time it take an object to fall to the ground from a given height is independent of its initial horizontal velocity.
- Students will be introduced to the concepts of velocity and acceleration and be able to do simple calculations to determine a velocity/speed, given an acceleration and amount time, in analogy to computing a distance, given a speed and amount of time.
- Students will learn how to use a simple time-stepping routine in a spreadsheet program to model projectile motion. They will be able to plot and interpret the data they generate in the spreadsheet program.

Standards Addressed

CCSS.Math.Content.8.EE.B.5 Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. For example, compare a distance-time graph to a distance-time equation to determine which of two moving objects has greater speed.

CCSS.Math.Content.8.EE.C.7 Solve linear equations in one variable.

MS-PS2-2. **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object**

Time
4.5 – 5 hour long class periods:

- One hour-long class period for the introduction and discussion of the experimental question and designing experiments.
- One hour-long class period for carrying out experiments and organizing the data collected.
- Half of a class period for discussing the results of the experiments and the data collected.
- One class period for introducing acceleration / practice problems involving distance, velocity, acceleration and time.
- One class period for spreadsheet calculation of object motions.

Reach for the Stars is a GK-12 program supported by the National Science Foundation under grant DGE-0948017. However, any opinions, findings, conclusions, and/or recommendations are those of the investigators and do not necessarily reflect the views of the Foundation.

Level: 8th grade Physical Science

Materials and Tools

- The computational component of the lesson requires computers with access to spreadsheet software (e.g. Microsoft Excel or Google Docs Spreadsheets)
- The material required for the first half of the lesson will be contingent on the experiment designed by the students, but is likely to include timer mechanisms and some form of projectiles (e.g. tennis balls, soccer balls, etc.)

Preparation

- Depending on the experimental design decided on by the students, the teacher may need to secure access to an open space such as an auditorium or gymnasium for carrying out the student-designed experiments.
- For the computational lesson component, the teacher should ensure that the students will have access to computers. The students should also be able to access a spreadsheet that is partially filled out with columns for positions, velocities, time step, and acceleration.

Prerequisites

- Students will need to have some familiarity with using a spreadsheet program, therefore a lesson on using spreadsheet software may be necessary, depending on the students' level of experience.
- Calculations involving acceleration, speed, and time should be introduced to the students in analogy to speed/distance/time calculations. Some time should be devoted before the computational portion of the lesson to practicing calculations involving speed, distance and time as well as acceleration, speed, and time.

Background

Most people are familiar with the fact that gravity is the force responsible for keeping us anchored to the ground and causing objects to fall. We develop an intuitive sense of the notion 'what goes up must come down' and our intuition allows us to predict where and when things will reach the ground without doing pen-and-paper calculations. Consider an outfielder catching a fly ball-- he doesn't need to do any math to figure out where to stand and when to put his glove up.

However, carefully controlled experiments can often show us that our intuition about the physical world isn't always reliable. Intuitively, you might expect that a cannonball shot horizontally out of a cannon would stay aloft longer than one that was simply picked up and then dropped. The shot cannonball certainly travels much further but your sense of how long it spends traveling may be surprisingly deceptive. The best way to discover the true answer is to simply preform an experiment! A well-designed experiment should be able to give reliable and repeatable results that allow you not only support a conclusion, but also be confident in the conclusion you discover.

Teaching Notes

Experiment Section (Note: the experiment section or computational section could stand alone as a single lesson)

- The teacher should begin by introducing the prompting question "How does the time it take an object dropped from rest to fall to the ground compare to the time it takes an object launched horizontally?" and explain that they will be designing experiments to answer the question.
- Students should be asked to share their predictions and reasoning behind their predictions in a class discussion facilitated by the teacher.
- The students should design experiments in groups to attempt to answer the question. The only constraint on the experiments should be that they can be reasonably accomplished in the classroom or at school. Students should design the experiment to obtain as accurate results as possible and should consider sources of error.
    - Alternatively, the teacher may decide to carry out a single class-wide experiment and should facilitate the design of the experiment as a class discussion.
- After the groups have finished their experiments the teacher should gather the results from the students and make plots from the data.

Computational Section

- The teacher should begin by reviewing with the class how to solve "distance = speed * time" problems.
- After reviewing, the teacher should asks the students to consider the motion of an object who's speed is changing. This can be easily introduced through the example of a car trip: cars always start at rest, and in traffic you frequently slow down or speed up. The teacher can then introduce example problems with acceleration and speed, "speed = acceleration * time" in analogy with "distance = speed * time". Students should complete some practice problems involving acceleration. (These problems should only involve solving for velocity, restricting the calculations to a linear problem, identical to the distance/speed/time problems.)
- The teacher should point out that the practice problems only addressed the issue of how to compute velocities for an accelerating object and ask the students to consider how acceleration affects the distance an object travels. The problem of how to compute distance traveled while an object is accelerating is not obvious and the teacher should introduce the idea of approximating the motion using a 'time step' during which the speed of the object is treated as constant and used to compute a new position. After each time-step the object's speed is changed based on the objects acceleration. The class should fill out an example 'time-step' table together.

- The teacher will then have the students open a partially prepared spreadsheet on computers. The teacher may decide how much of the spreadsheet to fill out ahead of time and how many of the equations should be entered into the spreadsheets by the students themselves based on the level of the class. The students should follow instructions on how to make or complete a 'time-step' table in the spreadsheet program and how to plot the data that they compute. Students should be given time to experiment with different initial conditions.

Assessment

- Students should informally present the results of their experiment, state their conclusion and provide supporting evidence, and be able to identify possible sources of error in their measurements.
- Students should save plots from their spreadsheet simulations and describe the qualitative features of the projectile's behavior for different initial conditions

Reach for the Stars is a GK-12 program supported by the National Science Foundation under grant DGE-0948017. However, any opinions, findings, conclusions, and/or recommendations are those of the investigators and do not necessarily reflect the views of the Foundation.