Galileo's Investigation

Introduction

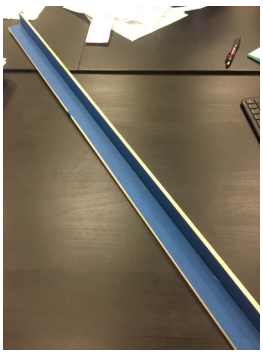
In our course reader: '*Infinite Powers*' (2019), mathematician Steve Strogatz describes an important moment in mathematical history, featuring one of the world's most important scientists: Galileo Galilei. Galileo, an Italian astronomer, physicist and engineer, who lived in the 1700's wanted to measure how fast objects fell, but there were no video cameras, or even accurate clocks to help this endeavor. Galileo was not deterred by these challenges and he set up an experiment. Instead of dropping a rock off a bridge he allowed a ball to roll slowly down a ramp. To measure the time passing he used a water clock. The "clock" allowed water to flow and when he wanted it to stop he closed a valve to stop the water flow. By weighing how much water had gathered he could quantify the time passed. Galileo made the ramp almost horizontal so that he could measure the speed of his falling object, measuring distance against time. This is when he found something incredible – the odd numbers 1,3,5,7 ... hide inside the falling of objects. Strogatz explains this saying: "Let's suppose the ball rolls a certain distance in the first unit of time. Then in the next unit of time it will roll three times as far, and in the next unit of time it will roll 5 times as far ... It's amazing; the odd numbers 1, 3, 5 and so on are somehow inherent in the way things roll downhill" (p67). Strogatz notes that he can "only imagine how pleased Galileo must have been when he discovered this rule." (p67).

In this activity we invite students to conduct their own version of Galileo's experiment, enabling them to use derivatives as rates and to consider the differences between average and instantaneous speed. ***The task illustrates the big idea of derivatives as a tool for understanding and describing movement in the universe.***

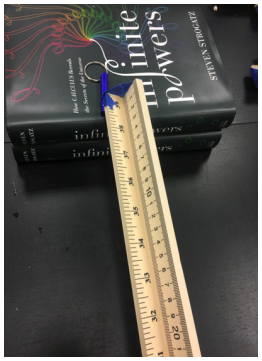
Materials

The ramp is constructed by taping two meter (or yard) sticks together. Depending on time constraints, the teacher can construct the ramps ahead of time or have students do so in class. For students to be able to compare results across groups, it is important to have them all use the same number (and size of) books to elevate their ramp.

- 1 ramp per group (two meter or yard sticks taped together, elevated by two books)
- 1-2 marbles per group
- If possible, access to a phone with a stopwatch and/or camera



Two meter sticks were taped together with blue painter's tape to construct the ramp (left), which was then elevated on two books (right).



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Agenda

Time	Task
5 min	**Launch** • Show students a picture of how to set up their ramp and pose the question: ◊ Find the exact speed that the marble is rolling when it is half-way down your ramp. • Distribute the following materials to each group: ramps (meter sticks taped together), one marble, and two books of the same size. • Share that they can use their phones if they find them to be useful for this task.
30 min	**Group work time** • About halfway through the work time, pose the following extension questions for groups that have already found the speed of the marble: ◊ Find the speed in the middle of the ramp in a different way. ◊ Where on the ramp is the marble at its average speed? ◊ What is the acceleration of the marble in the middle of the ramp? Is the acceleration constant throughout the marble's journey?
10 min	**Small group share-out & preparation for whole class discussion** • Combine two groups of four together to form a group of eight • Explain that each group of four will share their thinking with the other group of four, as they discuss the following questions: ◊ What speed did your group find? What method did you use? ◊ Discuss similarities and differences across your two groups' methods. ◊ Discuss any extension problems one or both groups did. • As the discussions are winding down, instruct each group of eight to decide on 1-2 interesting methods from their conversation to share with the whole class.
15 min	**Whole class discussion** • Have each group of eight share their method(s) with the class, sequencing the methods however makes sense • Open it up for a discussion around similarities and differences across the whole class, as well as any extension questions that came up.

References:

Strogatz, Steven. Infinite Powers: How Calculus Reveals the Secrets of the Universe. Houghton Mifflin Harcourt, 2019.