Lesson Title	Slow Motion: The Bouncing Water Drop
Length of Lesson	50 minutes
Created By	Emily Burtnett and Nathan DuFour
Subject	Advanced Geometry
Grade Level	10^{th}, 11^{th}, 12^{th}, High School Topics
State Standards	Geometry 2a
DOK Level	2
DOK Application	Represent data from geometric and real-world contexts with expressions, formulas, tables, charts, graphs, relations, and functions.
National Standards	Understand patterns, relations, and functions.
Graduate Research Element	Calculating diameter from spherical droplet volume, observation and analysis of experimental data, prediction of droplet behavior

Student Learning Goal:
Students will discover how calculating volume of a sphere can be applied to a real-world application. Using the diameters of the six different sized spheres, the students will calculate the volume of the spheres. Students will explore analytic techniques which can be used to define physical behavior, in this case, of the water droplet bouncing on the surface of water.

Materials Needed (supplies, hand-outs, resources):
Computers, Microsoft Excel, overhead projector, video, rulers, calculators
http://dsc.discovery.com/videos/time-warp-water-droplet.html

Lesson Performance Task/Assessment:
Students will use rules and an Excel Spreadsheet to measure and record diameters and time from the enlarged image of the video (using a projector). This activity will give them the opportunity to implement topics in the classroom on real world applications as well as another area such as science. Students will complete a worksheet to record measurements, consider units and answer questions. Instructor guided classroom discussion will also demonstrate an understanding through student participation. Students will have the opportunity to present and discuss their results prior to discussion. Using the analytic techniques will allow students to see the usefulness of geometry in real world scenarios.

Lesson Relevance to Performance Task and Students:
Students will explore analytic techniques which can be used to define physical behavior, in this case, of the water droplet bouncing on the surface of water. Students learn to utilize tools such as rules and Microsoft Excel. They will be able to recognize the correlations of radius, diameter to the volume of a sphere equation, and also the connection of volume with respect to time of the falling droplet. They will obtain relevant

experience using Excel graphing tools to see which equation type bests describes a graph (linear, exponential, etc.).

Anticipatory Set/Capture Interest:
Show video of bouncing water droplet. Spark interest by having the instructor ask questions:

- Given a spherical drop of water, what behavior is demonstrated when it impacts a pool of water?
- Is the volume of water lost consistent between each bounce?
- What kind of things do you think an engineer would do with this video?
    - What kind of data do you think an engineer would want to extract from the "slow motion" video of the falling water droplet? Why?

Guided Practice:
The instructor will give a brief demonstration of how students are to use a rule to measure the diameter of a droplet and enter the data into an Excel spreadsheet. The instructor will demonstrate an example of various potential trendlines and ask students to make predictions about the behavior of the water droplet just from watching the video. For example, does the water droplet loose a consistent amount of liquid volume after each drop or does it decrease in volume exponentially?

Example: the first drop has a volume of x… the second drop has a volume of x/2 … the third drop has a volume of x/4… the volumes decrease linearly, and this linear behavior can be modeled with a linear equation. Similar techniques can be applied to the area of the cross sectional area of each drop. Explore connections across all observations. Is there a math connection between the decreasing areas versus the decreasing volumes? Are there relationships between both volume and area with respect to changing radius or time? Are there other opportunities to explore?

The instructor will guide the students through understanding the characteristics of the trendlines and how it describes the data.

Independent Practice:
Students will be allowed to work in partners for efficient data collection of the droplet diameter. One student will measure and the other will record. The instructor will encourage both students to confirm the measurement for accuracy, however. Students will use their calculators and/or Excel to calculate the volume of the sphere (Eq. 1) and use the graphing tools in Excel to plot data and look at trendlines.

$$Vol = \frac{4}{3}\pi r^2 \qquad (1)$$

Where r is the radius or half the measured diameter of the sphere. Students will proceed to complete a worksheet which will draw their attention to details such a units, as well as the components of the trendlines.

Remediation and/or Enrichment:
For enrichment, the measurements and time data of the droplets will be provided to the students so they can take more time to focus on plotting and understanding the results. It will be beneficial to have students calculate the volume Individual IEPs will be supported. For remediation, the students will do the measuring of the diameter of the droplet. Knowing how to use and read a ruler or measuring device to obtain data is an essential skill for several real-world applications.

Check(s) for Understanding:

- Completing the worksheet, completing the calculating
- Recognizing correlations between data and participation in group discussions
- Given a spherical drop of water, what behavior is demonstrated when it impacts a pool of water?
- Is the volume of water lost consistent between each bounce?
- Which trendline best describes the data graphed? Why?

Closure:

- Re-ask the Anticipatory Set questions to see how students' answers change.
- Given a spherical drop of water, what behavior is demonstrated when it impacts a pool of water?
- Is the volume of water lost consistent between each bounce?
- What kind of things do you think an engineer would do with this video?
    - What kind of data do you think an engineer would want to extract from the "slow motion" video of the falling water droplet? Why?

Possible Alternate Subject Integrations:

Teacher Notes:
See Excel Spreadsheet attachment for example data and plots
Video