“The Sky’s The Limit”
Grade 9, Algebra

Common Core Standard	Standard(s) for Mathematical Practice
Grade 9, Algebra 1 • CCSS.Math.Content.A-CED.A.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. • CCSS.Math.Content. F-IF.B.611 Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph	• CCSS.Math.Practice.MP1 Make sense of problems and persevere in solving them. • CCSS.Math.Practice.MP Reason abstractly and quantitatively. • CCSS.Math.Practice.MP4 Model with mathematics. • CCSS.Math.Practice.MP6 Attend to precision.

Activity Description

Learning Objectives

Students will:

- Use real data to write a quadratic function to model objects in motion
- Find the initial velocity of the position function
- Find the maximum height the object is thrown

Students will use a quadratic function to calculate how high they can toss a bean bag. Using the height from which the bean bag is released, the time it takes for it to hit the ground, and the basic height function for a projectile, students will calculate the initial velocity, the height function for the data, and the maximum height.

After students have read the explanation on the website of the physics of free-falling objects in motion, discuss the variables and parameters used in the function to describe projectile motion on Earth.
Once you have assured that the students are able to work with the position or height function of a projectile, they are ready for the fun.

Divide students into groups of four or five. Each will be given a role: thrower, recorder and 3 timers. The object is to throw the bean bag or tennis ball as high as they can and the use the height function to compute how high. The thrower will be throwing a tennis ball or bean bag straight into the air as high as they can. Each group will throw each object 3 times. *If time is a factor you can suggest the same person throws every time so that initial position is calculated only once.*

TASKS:

1. **Measure initial position** by measuring the distance from your wrist to the ground in feet when your hand is extended straight up. Record this in your chart. ****Remember we are measuring distances in feet.

2. **Throw the object straight up** and have group members use timers to measure the time it takes for the object to hit the ground. Record all times in your chart.

3. **Calculate the average time** and use this as ***t*** to **calculate the initial velocity**. Record the initial velocity in your chart.

4. Use the initial velocity and initial position to **write the height function**.

5. **Calculate the maximum height** by finding the ***y*** value of the vertex of your function.

Assessing Questions (In case students cannot get started)	Advancing Questions (Extensions for those students who finish early)
Assessments 1. Discuss why more than one timer is used. 2. Where does the maximum/minimum vale of a quadratic occur? 3. Is there more than one way to find the maximum height? .	**Extensions** 1. Discuss the relationship between the initial velocity and the height reached by the object 2. Have students in each group create a table and graph each of their initial velocities and the height reached to help discover the relationship between them. 3. Would we use the same height function if we were throwing the object at an angle?
Quick Tips (Possible Mathematical Errors)	**Future Connection**
Questions for Students 1. How did you compute the initial velocity? 2. When the object hits the ground what is the value of the height function? **Teacher Reflection** • Were students enthusiastic about the activity • How well did the students demonstrate understanding of the materials presented? • Did you set clear expectations so that students knew what was expected of them? If not, how can you make them clearer?	
Reference:	**Materials:**
http://www.purplemath.com/modules/quadprob.htm	• Graphing calculators may be used but or not necessary. Non-graphing calculators are sufficient. • [Large graph paper] • Timers • Tennis Balls • Bean Bags • Data and Task Sheet (1 per group)

Group Members: Thrower: _______________________ Data Recorder: ___________________________

Timer: ______________________ Timer: ________________________ Timer: ______________________

Object Thrown: _______________________

Initial Position (feet)	Time 1 (sec)	Time 2 (sec)	Time 3 (sec)	Average Time = Total / 3 (sec)	Initial Velocity (ft/sec)	Height Function H(t) =	Max Height Reached (feet)

Calculations:

Object Thrown: _______________________

Initial Position (feet)	Time 1 (sec)	Time 2 (sec)	Time 3 (sec)	Average Time = Total / 3 (sec)	Initial Velocity (ft/sec)	Height Function H(t) =	Max Height Reached (feet)

Calculations:

TASKS:

1. **Measure initial position** by measuring the distance from your wrist to the ground in feet when your hand is extended straight up. Record this in your chart. ****Remember we are measuring distances in feet.

2. **Throw the object straight up** and have group members use timers to measure the time it takes for the object to hit the ground. Record all times in your chart.

3. **Calculate the average time** and use this as ***t*** to **calculate the initial velocity**. Record the initial velocity in your chart.

4. Use the initial velocity and initial position to **write the height function**.

5. **Calculate the maximum height** by finding the ***y*** value of the vertex of your function. ***remember the quadratic function $f(x) = ax^2 + bx + c$ has vertex $\left(\frac{-b}{2a}, f\left(\frac{-b}{2a}\right)\right)$

h(t) is Height in feet at time t seconds

$$h(t) = -16t^2 + v_0 t + s_0$$

v_0 is initial velocity in ft/sec s_0 is initial position(height) in ft

*** **$h(t) = 0$ when the object hits the ground**

Use time measured for when the object hits the ground to find the initial velocity. (Remember $h(t) = 0$ when the object hits the ground.) Then put back into general form to get the function for your projectile.