

NUMB3RS Activity: Clearing All Obstacles Episode: "Hot Shot"

Topic: Parabolic Equations

Grade Level: 10 - 12

Objective: Students will use the TI-Navigator™ system to explore changes of projectile motion due to initial angle of flight.

Time: 30 minutes

Materials: TI-83/84 Plus graphing calculators, TI-Navigator™ system, piece of paper made into a paper ball, plastic spoon, CBL 2™, Vernier Photogate sensor, DATAGATE Program, *PhotogateSetup.doc*, *ProjectileA.act*, *ProjectileB.act*

To download these files, go to <http://education.ti.com/exchange> and search for "6955."

Introduction

In "Hot Shot," Larry is in his office catapulting grapes with a spoon to practice for the Physics Department food fight. This catapulting action is similar to work that was done in the Middle Ages when Galileo Galilei found that the path of a projectile is parabolic in nature.

As a fun exercise, you are going to use a paper ball projectile to simulate a food fight. This activity allows students to review algebraic solutions of equations as well as practice curve fitting to determine a parabolic path of a projectile. Students will first use the CBL 2 and Vernier Photogate sensor to determine the initial velocity of a paper projectile being launch from a spoon.

Part I: Data Collection

1.
 - a. Students should work in groups during this part of the activity.
 - b. Students will use the CBL 2 and Vernier Photogate to determine the velocity v with which a paper projectile leaves a plastic spoon.
 - c. Students should follow the instructions on the *Photogate Setup Guide* to determine the velocity v .
 - d. Have students repeat the trial three times and find an average velocity for their group.

2.
 - a. Assign each group an angle at which their paper projectile has left the spoon.

Group 1:	15° angle
Group 2:	25° angle
Group 3:	35° angle
Group 4:	45° angle
Group 5:	55° angle
Group 6:	65° angle
Group 7:	75° angle

- b. Using this angle, students should find the vertical velocity V_v and horizontal velocity V_H of the projectile using the following equations:

$$\text{Horizontal Velocity: } V_H = v (\cos(\theta))$$

$$\text{Vertical Velocity: } V_v = v (\sin(\theta))$$

Example with a velocity of 10 m/s and an angle of launch of 70°:

$$\begin{aligned} \text{Horizontal Velocity: } & V_H = 10 (\cos(70^\circ)) \\ & V_H = 3.42 \text{ m/s} \end{aligned}$$

$$\begin{aligned} \text{Vertical Velocity: } & V_v = 10 (\sin(70^\circ)) \\ & V_v = 9.40 \text{ m/s} \end{aligned}$$

Note: Make sure your calculator is in degree mode.

- c. Once students determine the vertical and horizontal velocities, they must determine the vertical and horizontal displacement over time. Have students use the following formulas to calculate the vertical and horizontal displacement for the given time values in the table:

$$\text{Horizontal Displacement: } x = V_H(t)$$

$$\begin{aligned} \text{Vertical Displacement: } & y = -4.9(t^2) + V_v(t) + H_0 \\ & (H_0 = \text{Initial height of object}) \end{aligned}$$

Time (t)	Horizontal Velocity (V_H)	Horizontal Displacement (L_1)	Vertical Velocity (V_V)	Vertical Displacement (L_2)
0.0				
0.1				
0.2				
0.3				
0.4				
0.5				
0.6				
0.7				
0.8				
0.9				
1.0				
1.1				
1.2				
1.3				
1.4				
1.5				
1.6				
1.7				
1.8				
1.9				
2.0				

- d. Have students enter their horizontal displacement in list L_1 on their calculators and the vertical displacement in list L_2 on their calculators.
3.
 - a. Launch TI-Navigator on the computer and click **Begin Class** to start the session.
 - b. Have students log into NavNet on their calculators.
 - c. Open the Activity Center in TI-Navigator.
 - d. Load the **ProjectileA.act** activity setting file into Activity Center. This activity setting is configured to grab the lists from the students' calculators once the activity has been started.
 - e. Click **Start Activity**. Instruct students to enter the Activity Center. Once the lists appear on their calculator screens, have students press **Send**.
 - f. Click **Stop Activity**.

4. a. Discuss the results of the resultant parabolic paths. Include a discussion about how the angle at which the paper projectile left the spoon affects the vertical and horizontal displacement. Also, remember to discuss how the amount of time the projectile is in flight changes with the angle.
- b. Have students algebraically determine an equation that will match their plots. Remember that x is horizontal displacement and y is vertical displacement. This can be done by solving the horizontal displacement equation for t . Then substitute that solution for t in the vertical displacement equation.



$$x = V_H(t) \rightarrow t = \frac{x}{V_H}$$

$$y = -4.9\left(\frac{x}{V_H}\right)^2 + V_v\left(\frac{x}{V_H}\right) + H_0 \quad (H_0 = \text{Initial Height of object})$$

Example with a velocity of 10m/s and an angle of launch of 70° (using values found in example from 2b):

$$y = -4.9\left(\frac{x}{V_H}\right)^2 + V_v\left(\frac{x}{V_H}\right) + H_0$$

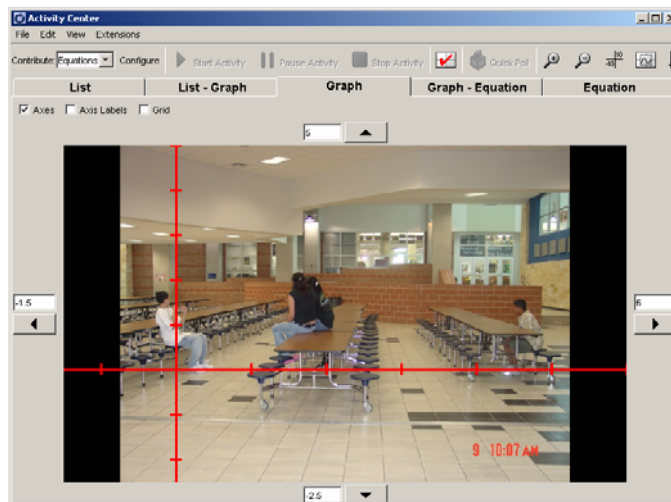
$$y = -4.9\left(\frac{x}{3.42}\right)^2 + 9.40\left(\frac{x}{3.42}\right) + H_0$$

5. a. Students should still be in the Activity Center. Go to the Contribute drop-down list, select **Equations**, and then click **Configure**. Reconfigure activity center so that students can submit one equation, students are allowed to resubmit equations, and send the current graph contents as background.
- b. Click  and have the students input their new equation for y into Y_1 and press **Send**.
- c. Discuss the differences and similarities found in students' equations.
- d. Click .

The goal of this activity is to give your students a short and simple snapshot into a very extensive math topic. TI and NCTM encourage you and your students to learn more about this topic using the extensions provided below and through your own independent research.

Extension: Clearing an Object

Josh (left, white shirt) is practicing for a food fight (not recommended for actual practice). He is trying to shot a piece of food over the obstacle (the girls) to hit Barry (right, brown shirt). At what angle must Josh launch the food in order to clear the girls and hit Barry?



ProjectileB.act screen shot

- In this part of the activity, students will work in groups to determine the angle at which an object must leave the spoon in order to hit a desired target.
 - Load the **ProjectileB.act** activity setting file into Activity Center. Go to **Edit > Clear Activity Data** and click **Yes**. This activity setting is configured to allow groups to submit an equation that will allow them to hit the desired target. Click **Start Activity**.
 - Have one student in each group log into NavNet and enter the Activity Center. This calculator will be used by the group to enter their equation(s) into activity center. All other calculators in the group should be used for the needed calculations to obtain the group's equation.
- Using the results from Part I, find the class' average velocity.
 - Have students choose an angle to begin. Repeat Part I Steps 2b and 4b from the activity using this angle and the average velocity. Determine an equation that will allow the projectile in the picture to hit the desired target. (Hint: Students may need to change the initial height.)
 - Have the groups enter their equations into Y_1 (on the calculator in the Activity Center) and press **Send**. Do their equations hit the target? (That is, did they choose the correct angle?)
 - If a group's equation is not correct, have them choose another angle and repeat Extension Steps 2b and 2c until they hit the desired target.
 - Once all equations have been submitted, click **Stop Activity** and discuss the results. Is there more than one angle that you could launch a projectile to hit the desired target?