

M103 Performance Task

Take Me Out to the Ball Game

Modeling with Functions of Quadratic Type
Teacher Version

Design Notes

In this task, students will create a quadratic model that simulates the flight of a t-shirt that is ejected from a t-shirt cannon at a ball game. The learning experience centers around the Common Core State Standards for Math (CCSSM) modeling cycle, as illustrated below:

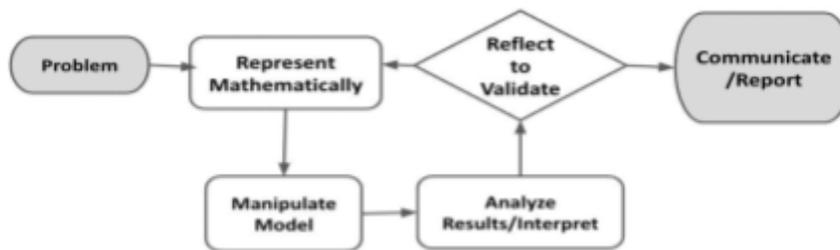


Figure 1. Diagram of Modeling Process. From "Progressions for the Common Core State Standards for Mathematics" [Draft manuscript], by Common Core Standards Writing Team, 2019, p. 6 (http://mathematicalpractices.org/wp-content/uploads/2022/05/modeling_02082019.pdf).

Connections to Learning Principles

Students will:

- employ Learning Principles 1 and 2 by collecting data from a short video and using their findings to develop a quadratic model (LP1);
- assist each other in data collection (LP2);
- think critically about the viability of their model and its accuracy (LP3);
- have a model that is specific to their ideal t-shirt launch scenario, their idea of how a perfect t-shirt cannon would behave, and have opportunities to engage further with the concept (and the modeling software) in other settings they might find interesting (LP4); and
- use technology as a tool to problem solve and deepen understanding (LP7).

The following pages provide teacher versions of this task with guidance, suggestions, and comments in **red** and sample student responses in *blue italics*.

Student Task

The Modeling Cycle

Sometimes at sporting events, parades, or other fun events, you might see t-shirts flying high into the air. Spectators throw their arms up in the air, hoping to be one of the lucky people to catch one of these flying prizes. So how far and how high can those t-shirt cannons actually shoot the balled-up shirts? Let's find out!

Mathematical models are used to make sense of ideas and phenomena in our world. As illustrated in the image below, the modeling cycle is a process of collecting data about an idea or problem, creating models of that data, analyzing the story told by those models, and reporting the results to the appropriate audience. In this task, you will be engaging with the mathematical modeling cycle to analyze the trajectories of flying t-shirts to understand how to create a path for an object traveling in a parabolic direction.

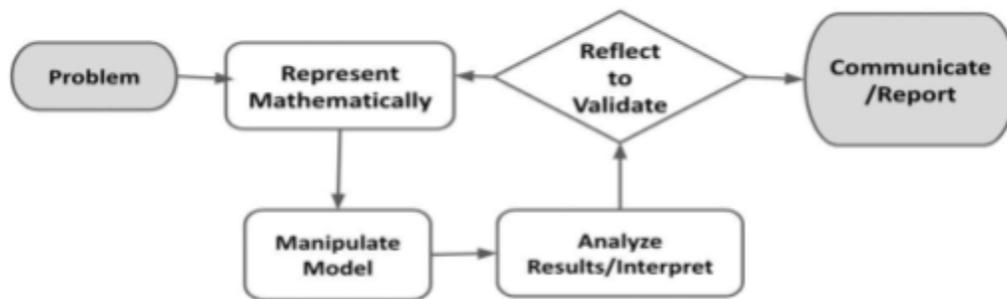


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Take Me Out to the Ball Game

Launch

QUESTION 1



Watch this [short video clip](#) about the t-shirt launcher the New York Mets use at their baseball games. What do you notice and wonder about this clip?

Answers will vary. Possible student responses:

- *What angle is the launcher at when the t-shirt is launched?*
- *How fast is it going? How does it go that fast?*
- *How high does it go?*

- *How can you get it to go farther and faster?*
- *How does the launch angle affect the flight path?*
- *What about wind resistance and drag?*

- If for some reason you cannot access the video, you can find any video with a projectile launch or you can simply have the class go outside, have one student throw a tennis ball in the air, and ask if students can figure out how high the projectile went. If going outside instead of watching a video, skip question 2.

QUESTION 2



Watch the launch one more time. What are some data or measurements that were included in the video? Why do you think the creator decided to include those measurements?

Answers will vary. Possible student responses:

- *T-shirt cannon weighs 10 pounds, cannon uses compressed carbon dioxide, 408 feet from home plate to back fence, 155 feet from home plate to second base, 335 feet from home plate to third base fence, 128 feet from homebase to third base*
 - *Distance test 1: home plate to center field: 165 feet*
 - *Distance test 2: home plate to left field: 230 feet*
 - *90 feet to upper deck*
 - *Test to stands: 100 feet vertical distance*
- Students might need you to pause the video to give them time to record measurements. Encourage students to note the numbers they see and give each one a context (for example, if a student writes “408 feet,” push them to write “408 feet from home plate to the back fence going over second base”). They will not use all of the measurements, but it is a good exercise for the students to be the ones who decide which of the measurements are important and which are not useful for the values they are trying to find.

Introduction: Projectiles

A projectile is something that is projected (which means launched into the air), and the only force acting on it is gravity. Examples of projectiles are footballs being thrown, a pencil falling off a desk, or water coming out of a hose at an angle, to name a few. The image below presents visuals of some of these projectile paths, the shape of which is often mathematically called a parabola, or a parabolic path.

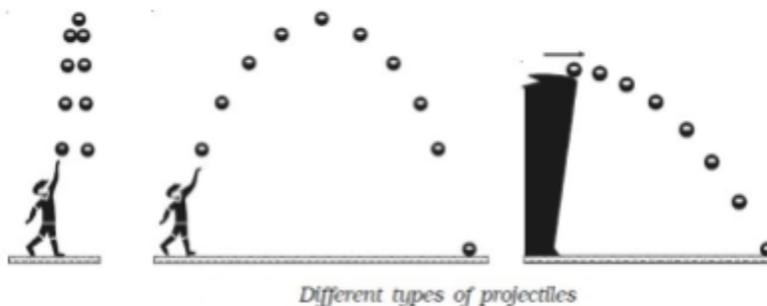


Image 1. Credit: from [Engineers Field](#) website.

Your Task: Imagine you had a job in which it was important to be able to precisely define the path of an object, such as a video game programmer or a scientist at NASA. In this task, you will explore how to create a mathematical model for the parabolic path of an object and consider ways to refine the mathematical model to make it more precise.

In the **Problem Formulation** sections, you will revisit the video clip of the t-shirt launcher and generate some specific measurements associated with each launch. The **Problem Formulation Checklist** can be used to ensure you have the necessary components before moving on to the remaining parts of the task.

Problem Formulation

QUESTION 1



Examine the three launches shown in the video clip [Science Behind the Mets T-Shirt Cannon](#) for each of the time intervals shown below. Record your responses in a Google document or on a sheet of paper.

Launch 1 (video clip from 1:38-1:50)

1. What is the approximate height from which the t-shirt is launched? How did you estimate this height?
2. How far from the initial launch point does the t-shirt land?
3. Do you have any other information about the location of the t-shirt between its initial launch and its landing on the ground? If so, describe it in detail.

Launch 2 (video clip from 1:50-2:03)

1. What is the approximate height from which the t-shirt is launched? How did you estimate this height?
2. How far from the initial launch point does the t-shirt land?

- Do you have any other information about the location of the t-shirt between its initial launch and its landing on the ground? If so, describe it in detail.

Launch 3 (video clip from 2:03-2:20)

- What is the approximate height from which the t-shirt is launched? How did you estimate this height?
- What other information do you have about this launch?

Problem and Formulate Checklist

Requirement	Teacher Notes
There is a reasonable estimated height for the initial launch for each video clip.	(Teachers, please add your notes here.)
Additional information, such as distance from initial launch or maximum vertical height, has been provided.	(Teachers, please add your notes here.)
(Teachers, please add your notes here.)	

In the **Represent Mathematically** and **Compute** sections, you will use some of your measurement data to generate one or more equations to represent the path of a t-shirt. The **Represent Mathematically & Compute Checklist** can be used to ensure you have the necessary components before moving on to the remaining parts of the task.

Represent Mathematically

QUESTION 2



Based on your information from the previous section, write the coordinates of two points that would be on the graph of the t-shirt's path for each launch. The coordinates will represent the horizontal distance of the t-shirt from its launch point and the height of the t-shirt in the air.

Launch	Point 1 Coordinates	Point 2 Coordinates
Launch 1 (center field)		
Launch 2 (left field)		
Launch 3 (upper deck)		

Consider providing this table as a scaffold for students who require it:

Coordinate Pair (x, y)	Verbal Description of What That Point Represents in the Flight Path
(__ , __)	
(__ , __)	
(__ , __)	

ACTION



Open the [Desmos Calculator](#) to begin to generate an equation for one of the launches. Choose the launch for which you think you have the best estimate for two of the points on the t-shirt's path.

Directions for generating a quadratic regression equation:

- Select the + sign and then choose table.
 
- Enter the x and y values for two points associated with the launch. Enter a third point if you have one.
- Create a generic form of a quadratic equation by typing $y_1 = ax_1^2 + bx_1 + c$ in a new cell
 

Which launch are you graphing?

Students can make accounts on Desmos and save their graphs if this is a multiple day activity. **Be careful! If students do not physically click "save" on their graph, it will not be automatically saved!**

QUESTION 3



Using the values of a, b, and c given, what equation does Desmos give for the current points you have plotted?

QUESTION 4



Do you think that the regression graph created in Desmos accurately depicts the path of the t-shirt launch? Why or why not?

Compute

QUESTION 5



What are the coordinates of two additional points on the graph that you currently have created in Desmos?

QUESTION 6



What do these points mean, if anything, in the context of the problem?

Represent Mathematically and Compute Checklist

Requirement	Teacher Notes
The Launch Coordinates table has been completed with at least one set of realistic coordinates for each t-shirt launch's projected points on a graph.	(Teachers, please add your notes here.)
An equation and related regression graph have been generated in Desmos.	(Teachers, please add your notes here.)
The Desmos regression graph has been evaluated for accuracy against the actual t-shirt launch path, and other graph points have been identified and explained within the context of the problem.	(Teachers, please add your notes here.)
(Teachers, please add your notes here.)	

In the **Analyze and Interpret** section, you will identify a potential additional t-shirt launch path point and evaluate its influence on your Desmos graph. The **Analyze and Interpret Checklist** can be used to ensure you have the necessary components before moving on to the remaining parts of the task.

Analyze and Interpret

QUESTION 7



Watch the [Science Behind the Mets T-Shirt Cannon](#) video again starting from 1:25. You can slow down and pause the video as much as needed.

Use the video to estimate at least one additional point that is on the path of the t-shirt for the launch you currently have graphed in Desmos. What are the coordinates of this point?

QUESTION 8



How did you estimate this point?

QUESTION 9



Add this point to your table in Desmos. How does this additional point change the graph and the equation?

Analyze and Interpret Checklist

Requirement	Teacher Notes
An additional t-shirt launch path point has been estimated, the coordinates have been identified, and the estimation has been explained mathematically.	(Teachers, please add your notes here.)
The estimated coordinates have been added to the original Desmos table, and any resulting changes to the Desmos graph have been identified/described.	(Teachers, please add your notes here.)
(Teachers, please add your notes here.)	

In the **Reflect to Validate** and **Report** sections, you will analyze, evaluate, and refine your graph, and you will create an informational product to guide others in examining similar parabolic paths traveled by objects. The **Reflect to Validate and Report Checklist** can be used to ensure you have the necessary components before moving on to the remaining parts of the task.

Validate and Report

QUESTION 10



Watch the video again from 1:25. Are there methods you could use to improve the accuracy of your current graph? If so, explain what they are. If not, explain why you don't think so.

Guiding Questions

- What are some points on the current graph that you have in Desmos? Do any of them seem unreasonable?
- How high is the upper deck? Did the t-shirt go above that? How far above?
- If you are unable to use the video to refine the graph, explain what you would want to do to feel more confident in your estimated equation.
- Describe whether you decided to refine your graph further or whether you decided it was already pretty accurate. What information did you use to decide? If you refined the graph, what is the new equation?

QUESTION 11



It's fun to think about the paths created by t-shirts launched from a cannon. The stakes are pretty low if you're hoping to get it into the upper deck but only manage to shoot it into the middle section. However, there are other scenarios in the world where the stakes are a bit higher. For people designing "jumps" in video games, they will need greater precision about how players take off and land. Scientists mapping out the paths of rocket ships or other projectiles from take off to landing need even greater precision.

Create an informational video, pamphlet or other output to explain how somebody might plan the path of an object that travels in a parabolic direction. Include specific examples from your work here to help your viewers or readers understand why each step you are giving them matters.

Reflect to Validate and Report Checklist

Requirement	Teacher Notes
An informational product has been created that comprehensively and accurately provides guidance on how to illustrate parabolic travel by objects.	(Teachers, please add your notes here.)
The guidance in the product is mathematically sound, and the product includes illustrative examples from the study of t-shirt cannon launch paths.	(Teachers, please add your notes here.)
(Teachers, please add your notes here.)	

Extension

YouTuber Mark Rober built the world's largest t-shirt cannon. Watch this [16-minute video](#) to see how t-shirt cannons work.

References

Graphing Calculator. (n.d.). Desmos. <https://www.desmos.com/calculator>

Projectile motion. (n.d.). Engineersfield. <https://engineersfield.com/projectile-motion/>

Science Behind The Mets T-Shirt Cannon. (2015, July 5). YouTube.

<https://www.youtube.com/watch?v=qaXvobsI7Ss>

World's Largest T-Shirt Cannon (breaks the roof). (2021, December 20). YouTube.

<https://www.youtube.com/watch?v=QikZYt9070U>