# Properties of Quadratic Functions

## Lesson Overview

In this lesson, students identify key features of parabolic curves by first brainstorming questions that might be asked about the kick of a football. Students work in groups to determine the key characteristics that are important in describing a parabola and connect these characteristics to the mathematical terminology and their questions about the kick of the football. Then, they develop their mathematical vocabulary about the key features of quadratic functions. This two-day lesson is the third mathematics lesson in the unit One Dimensional Kinematics—Modeling Motion.

## Alignment

### Science and Engineering Practices

**H.P.1A.5** Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.

### Crosscutting Concepts (from the SDE instructional unit resources document)

3. **Scale, proportion, and quantity**: The National Research Council (2012) states that "in considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance" (p. 84). The ideas of ratio and proportionality are important here along with being able to predict the effect of a change in one variable on another. For example, how will the speed of an object change if the time traveled is increased but the distance remains the same?

### Math Standards

FIF.4    Interpret key features of a function that models the relationship between two quantities when given in graphical or tabular form. Sketch the graph of a function from a verbal description showing key features. Key features include intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior.

FIF.5    Relate the domain and range of a function to its graph and, where applicable, to the quantitative relationship it describes.

## Standards for Mathematical Practice

SMP.2  Reason abstractly and quantitatively.

SMP.3  Construct viable arguments and critique the reasoning of others.

SMP.6  Attend to Precision.

## ELA Writing

Standard 6:  Write independently, legibly, and routinely for a variety of tasks, purposes, and audiences over short and extended time frames.
>  6.1      Write routinely and persevere in writing tasks over short and extended time frames, for a range of domain-specific tasks, and for a variety of purposes and audiences.

## ELA Communication

Standard 1      Interact with others to explore ideas and concepts, communicate meaning, and develop logical interpretation through collaborative conversations; build upon the ideas of others to clearly express one's own views while respecting diverse perspectives.
>  1.2      Initiate and participate effectively in a range of collaborative discussions with diverse partners; build on the ideas of others and express own ideas clearly and persuasively.
>  1.4      Engage in dialogue with peers and adults to explore meaning and interaction of ideas, concepts, and elements of text, reflecting, constructing, and articulating new understandings.
>  1.5      Synthesize areas of agreement and disagreement including justification for personal perspective; revise conclusions based on new evidence.

## Connections

### Content Area (2 or more) Connections
- Science (Physics)
- Mathematics (Algebra 2)

### Content Connections
The understanding of multiple representations of quadratic functions, as well as the modeling of quadratic relationships graphically and algebraically is a cornerstone skill used in physics to analyze one dimensional kinematics.  Motion data collected for objects with a changing velocity at constant acceleration is represented with a quadratic model.

**Active Learning Strategies (for Purposeful Reading, Meaningful Writing, and Productive Dialogue)**
Brainstorm
Focused Listing
Graphic Organizer


**Computational Thinking**
In this lesson, students will be developing computational thinking by logically organizing and analyzing data and representing data through abstractions such as models and simulations (during the group activity).  In addition, the dispositions of "ability to deal with open ended problems" and "ability to communicate and work with others to achieve a common goal or solution" will be necessary for successful completion of the lesson tasks.


## Lesson Plan:  Properties of Quadratic Functions


*Time Required* – Two 55-minute classes

*Disciplinary Vocabulary* – parabola, intercepts, interval, increasing, decreasing, relative maximum, relative minimum, axis of symmetry, vertex, end behavior, domain, range,

*Materials Needed:*

- Computer with speakers
- Video:  https://youtu.be/HB4ws7RoA3M
- Sets of "Sorting Parabolas" cards, 2 sets per group of 3-4 students, printed on two different colors cardstock
- Chart Paper and Markers, 1 set per group of 3-4 students
- Key Features of Quadratic Function Graphic Organizer, 1 per student
- Key Features of Quadratic Functions Task, 1 per student

*Formative Assessment Strategies:* Focused Listing, Graphic Organizer

*Misconceptions:*

- Since this is a vocabulary development lesson, students may continue to use informal vocabulary to describe parabolas instead of the mathematical vocabulary.  For example, "turning point" or "turn" for "vertex".
- For parabolas that are concave up, students may confuse the endpoints shown on the graph as the "maxima" of the graph.  Remind students that parabolic curves have a

domain of all real numbers unless otherwise noted and the graph continues for values not seen on the paper. Similarly, for parabolas that are concave down, students may confuse the endpoints shown on the graph as the "minima" of the graph.

## Day One

### Engage

- Show video "Projectile Motion & Parabolas—Science of NFL Football" (https://youtu.be/HB4ws7RoA3M ) . Stop video at 2:08 to show sketch of parabolic path of the punted football.
- **Strategy: Brainstorm**—As a class, brainstorm questions we might ask about the path of the football. Teacher should guide brainstorming to ensure questions will lead to key features of parabolas. Record questions on a class chart.
    - Example Questions:
        - How high is the football at the highest point? (i.e. vertex)
        - When does the football stop rising and begin descending towards the ground? (i.e. vertex)
        - How high off the ground was the football when it was kicked? (i.e. x-intercept, if kicker's position is considered the y-axis)
        - When will the football hit the ground? (i.e. y-intercept, if ground is considered the x-axis)
        - How fast is the football going? (If this question is asked, list it on the chart but it is beyond the scope of this lesson.)
- Say: "Today we are going to learn the mathematical language that describes many of these features of parabolic motion."

### Explore

- Student groups of 3-4 complete the activity "Sorting Parabolas". Each group will need two sets of the activity cards, separated and printed on two colors of card stock (i.e. pink and blue).

### Explain

- **Strategy: Focused Listing**--Student groups identify the characteristics that were most important in identifying the correct parabola. Groups create a list of characteristics on chart paper.
- Display all groups' charts side by side and ask students to identify commonalities. Teacher facilitates the creation of a class list of characteristics (or key features) of parabolas. As characteristics are identified, the teacher should offer the formal

mathematical language to represent any informal language that is used.  The teacher should connect vocabulary to the list of questions about football from the engage video.

- o Key Features of Parabolas (terms to list):
  - Vertex
  - Axis of Symmetry (this concept may need to be introduced by the teacher, students may not informally consider the axis of symmetry as an important characteristic)
  - X-intercept
  - Y-intercepts
  - Concave Up
  - Concave Down
  - Maximum
  - Minimum
  - Domain
  - Range
- After the group discussion and development of a consensus list, students should edit their **VVWA** definition card for quadratics to add any characteristics or information they did not include when it was created in Lesson 2 (Comparing Function Families).
- If time allows, show the end of the video "Projectile Motion & Parabolas—The Science of NFL Football" (https://youtu.be/HB4ws7RoA3M )

## Day Two

## Extend

- Student pairs will use the **Key Features of Quadratic Functions Graphic Organizer** to summarize their learning from the previous day. Students label the graph of the parabola with each key feature, then complete the vocabulary chart for each key feature.
- Pairs will square to compare their summary graphic organizer and provide feedback to each other.

## Evaluate

- Students will complete the **Key Features of Quadratic Functions Task**.  Teacher may choose to allow them to use their graphic organizer to assist with completion and/or work in pairs to complete the task.

**Group Activity:  Sorting Parabolas**

| Group Members: |
| --- |
|  |
|  |

1. Select one group member to be the "viewer".  The viewer will sit across from the remaining group members.  The viewer will describe a parabola for the other group members to identify.  A study corral may be used to prevent the two groups from seeing one another's cards.
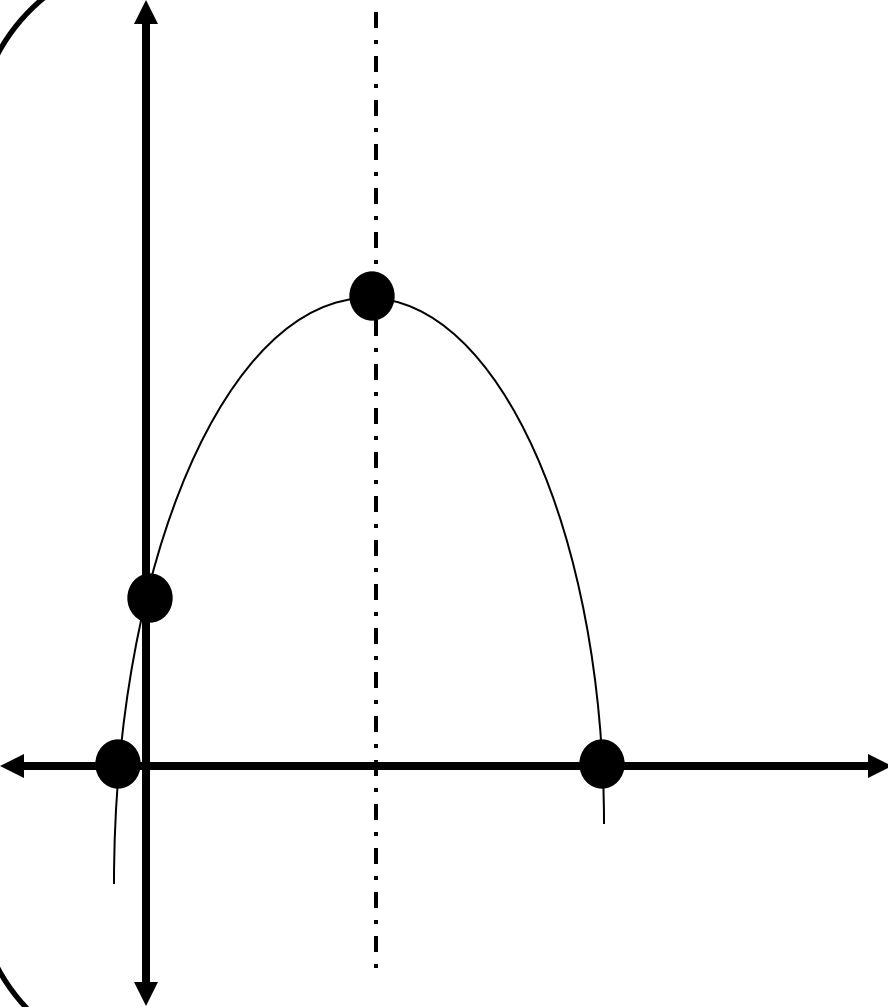
   Seating Arrangement:
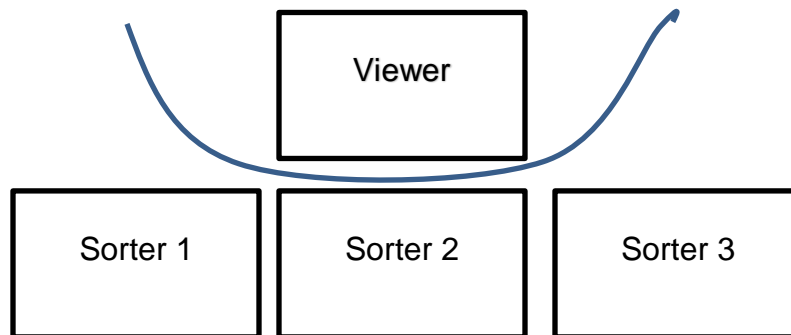
   

2.  The "sorters" will spread one set of cards on the table where all three can see them.  Cards should be face up.
3. The "viewer" will select one card from the second set of cards.  Without showing the card to the sorters, the viewer will describe the parabola on the selected card.
4. As the viewer describes the selected parabola, sorters will choose cards that meet the characteristics given until they have determined which ONE parabola matches the one described.
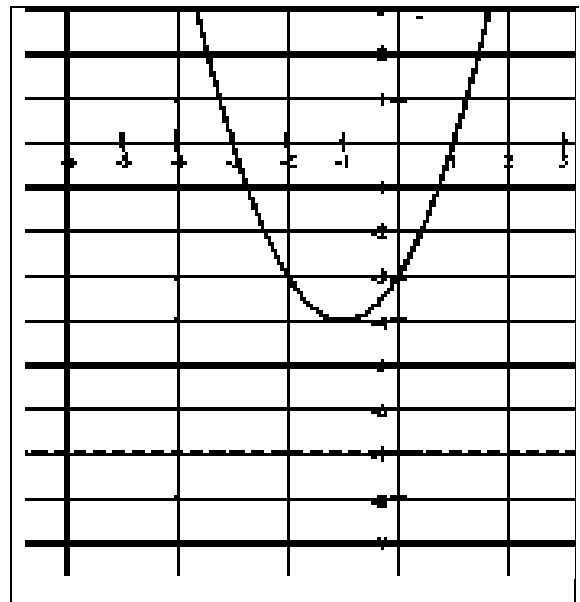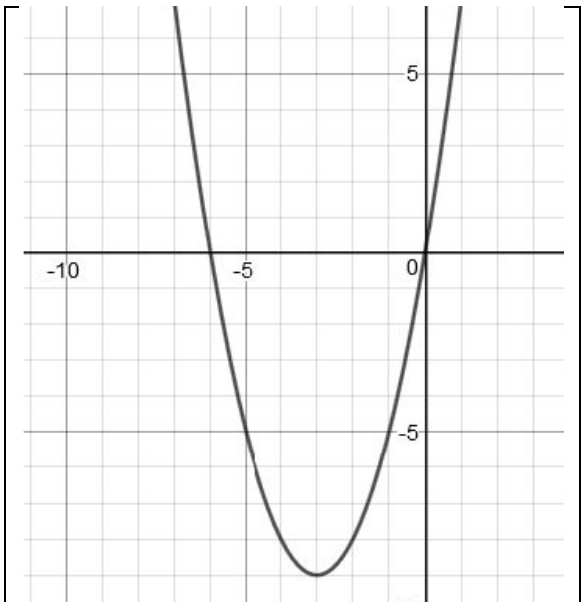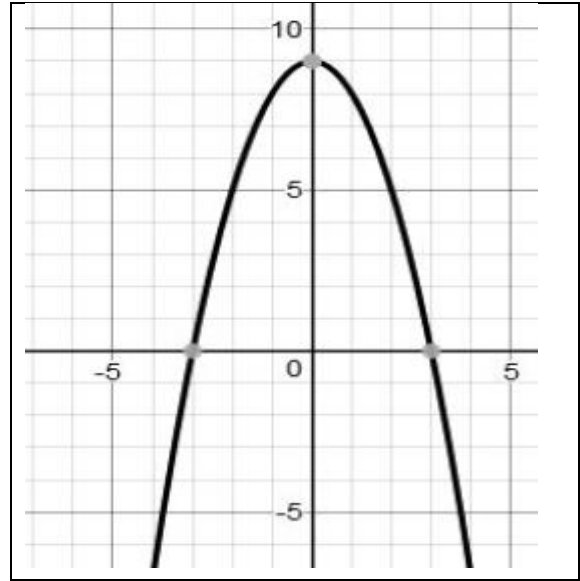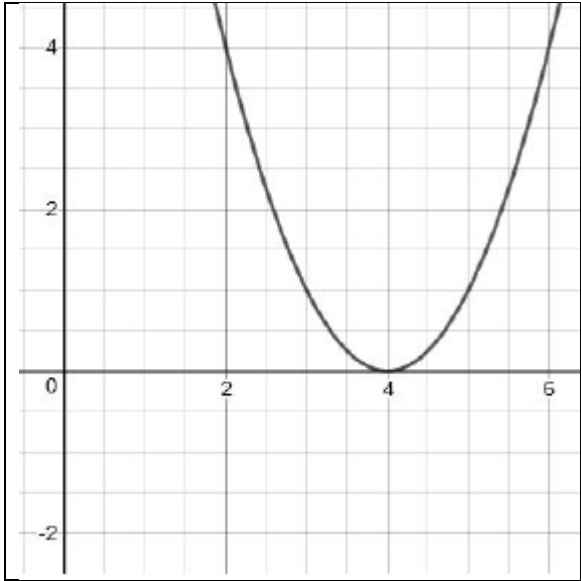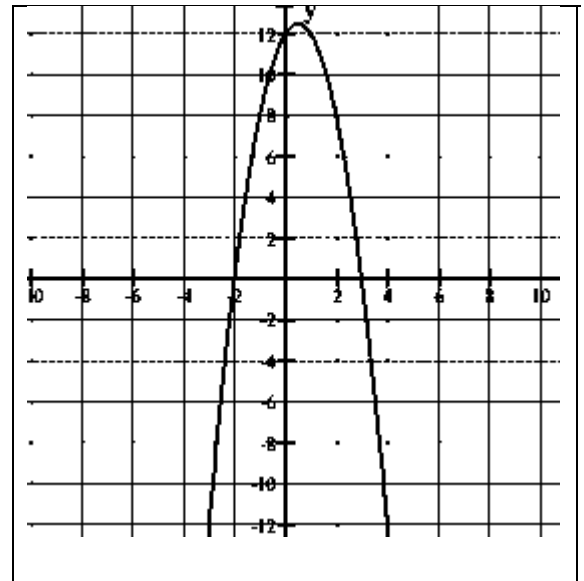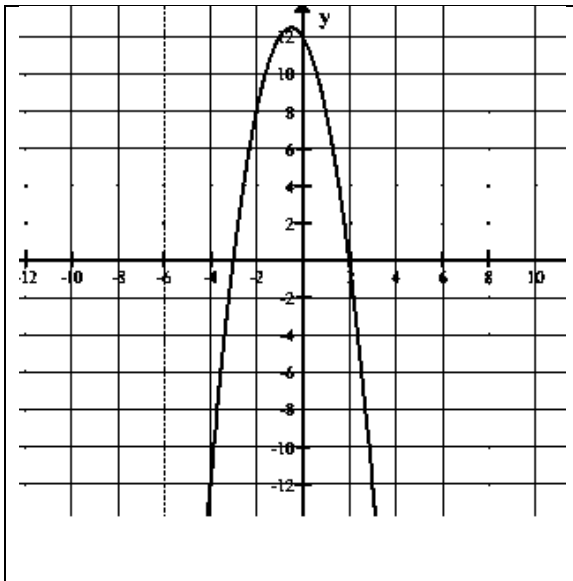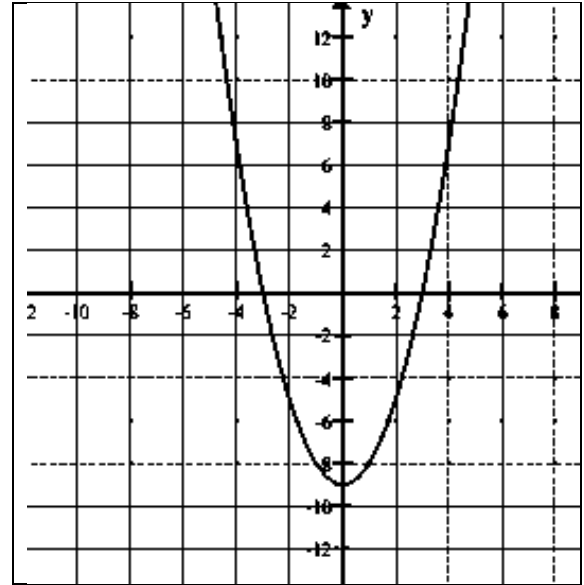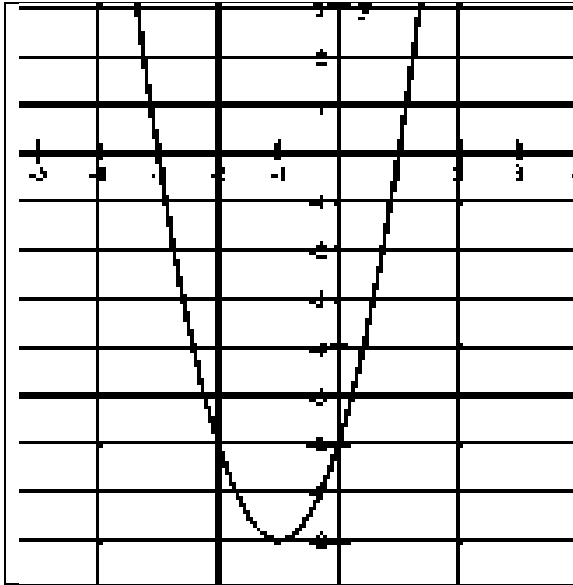
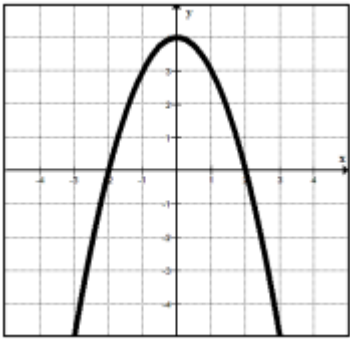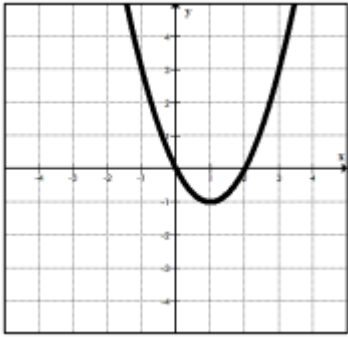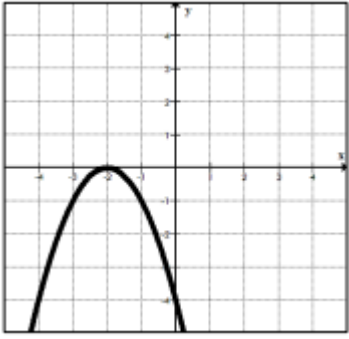**Key Features of Quadratic Functions Graphic Organizer**



| Key Feature | Description | Memory Clue |
|---|---|---|
| Vertex | | |
| Axis of Symmetry | | |
| x-intercept | | |
| y-intercepts | | |
| Maximum or Minimum | | |
| Domain | | |
| Range | | |

**Key Features of Quadratic Functions Task**          **Name: _____**

**Use the graph of each function to complete the table of key features.**

| Key Feature | Graph 1 | Graph 2 | Graph 3 |
|---|---|---|---|
| *Vertex* | | | |
| *Axis of Symmetry* | | | |
| *x-intercept* | | | |
| *y-intercepts* | | | |
| *Maximum or Minimum* | | | |
| *Domain* | | | |
| *Range* | | | |