Algebra 2

MATH NATION
BY ACCELERATE LEARNING

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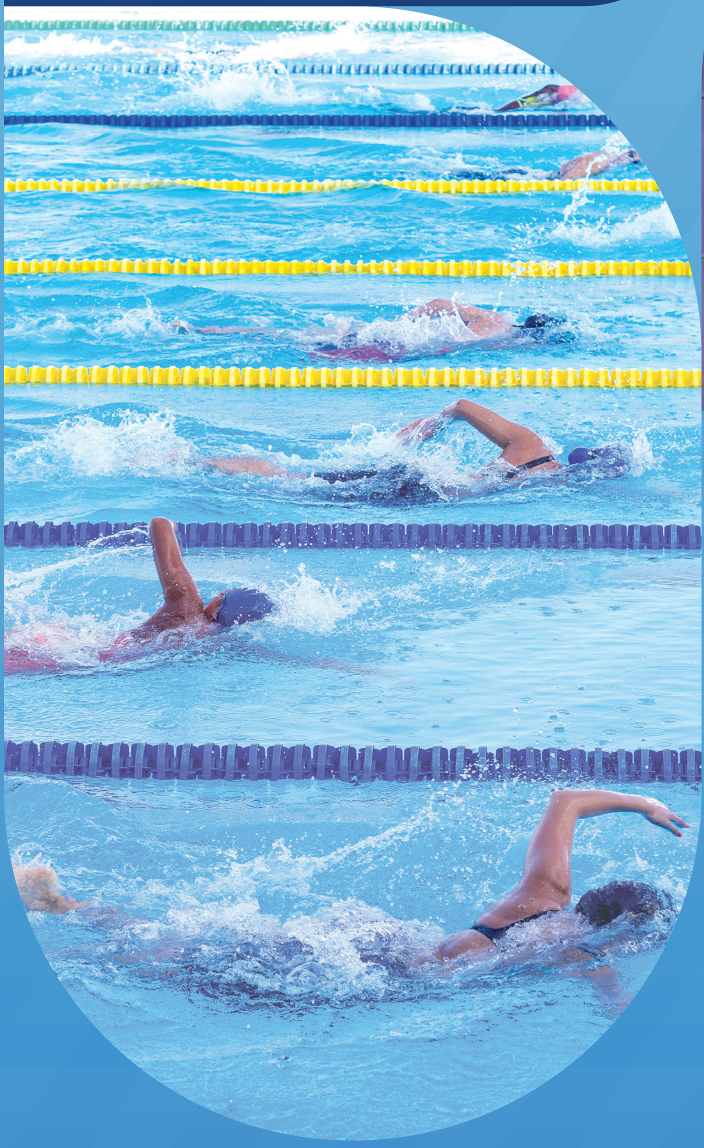

Accelerate LEARNING
THE LEADER in STEM EDUCATION

What's Inside This Sample Lesson?

- A fully guided lesson written to meet rigorous state and national standards
- **Teacher Edition** pages, **Student Workbook** pages, and other **helpful resources** to fully experience a Math Nation lesson
- Warm-ups, exploration tasks, instructional routines, and teacher prompts
- Support for English learners and students with disabilities
- Integrated reflection, synthesis, and cool-down opportunities

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Algebra 2, Unit 5, Lesson 1 - Matching Up to Data

Go Online!
Explore the digital resources for this lesson.

LESSON 1
MATCHING UP TO DATA

LEARNING GOALS

- *Describe informally (orally and in writing) transformations of graphs.*
- *Describe (in writing) how to transform a given function to fit a data set.*

ALIGNMENT

Building On

- **HSF-IF.B.4** For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.

Addressing

- **HSF-BF.B.3** Identify the effect on the graph of replacing $f(x)$ by $f(x) + k$, $kf(x)$, $f(kx)$, and $f(x + k)$ for specific values of k (both positive and negative); find the value of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. Include recognizing even and odd functions from their graphs and algebraic expressions for them.

Building Toward

- **HSF-BF.B.3** Identify the effect on the graph of replacing $f(x)$ by $f(x) + k$, $kf(x)$, $f(kx)$, and $f(x + k)$ for specific values of k (both positive and negative); find the value of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. Include recognizing even and odd functions from their graphs and algebraic expressions for them.
- **HSS-ID.B.6.a** Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.

LESSON PREPARATION

Required Materials

- Pre-printed slips, cut from copies of the blackline master

Required Preparation

- Devices are required for the digital version of the activity, “Which Function?”.
- Be prepared to display data points and graphs using the embedded Desmos applet (recommended) or other graphing technology.

LESSON INFORMATION

Student Learning Goals

- Let’s describe how to transform graphs.

Student Learning Targets

- I can describe how a graph is transformed.

Lesson Narrative

The purpose of this lesson is to introduce students to one of the big ideas of the unit: we can transform functions to model sets of data. The main focus of this lesson is to elicit ideas and language around transforming graphs that will be refined throughout the unit. Later in the unit, students will make connections between graphical and algebraic transformations and directly manipulate equations to transform graphs.

The two functions in Which Function? are both good fits for the data, providing students with the opportunity to make an argument about why a particular function is a better fit (MP3). Students continue to critique each other's arguments as they make adjustments to the functions to get a better fit. In the next activity students take turns describing transformations between pairs of graphs, giving an opportunity for students to refine their language and connect back to transformation vocabulary from geometry (MP6).

One of the activities in this lesson works best when each student has access to devices that can run the digital applet because students will benefit from seeing the graph in a dynamic way.

WARM-UP | NOTICE AND WONDER: COOLING DOWN *5 minutes*

Instructional Routines

- Notice and Wonder

The purpose of this warm-up is to allow students to consider a graph of data and the units in preparation for informally fitting functions to sets of data, which is a focus of the lesson. This warm-up prompts students to make sense of a problem before solving it by familiarizing themselves with a context and the mathematics that might be involved (MP1).

The specific data shown here is used in the following activity, where students decide which of two given functions best fits the data, and in a future lesson, where students transform a given equation so that the corresponding graph fits the data.

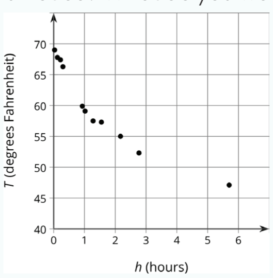
While students may notice and wonder many things about the graph, the shape of the data in the context is the important discussion point, making use of the structure of the graph and relating it to the graphs of functions they have seen in previous lessons (MP7).

LAUNCH

Display the graph for all to see. Ask students to think of at least one thing they notice and at least one thing they wonder. Give students 1 minute of quiet think time, and then 1 minute to discuss the things they notice and wonder with their partner, followed by a whole-class discussion.

STUDENT-FACING TASK STATEMENT

What do you notice? What do you wonder?



Possible Responses

Things students may notice:

- The data is decreasing.
- Something is cooling down from about $70°$ to about $45°$.
- The temperature is decreasing as time goes on, but it's decreasing faster at the start.

Things students may wonder:

- What is the value when $h = 0$?
- What sort of a function would model the data?
- Why is there an almost 3 hour gap in the data?
- Will the points ever intersect the horizontal axis?

Activity Synthesis

Ask students to share the things they noticed and wondered. Record and display their responses for all to see. If possible, record the relevant reasoning on or near the graph. After all responses have been recorded without commentary or editing, ask students, "Is there anything on this list that you are wondering about?" Encourage students to respectfully disagree, ask for clarification, or point out contradicting information.

If the general shape of the data or a possible situation that the data represents does not come up during the conversation, ask students to discuss these ideas.

EXPLORATION ACTIVITY | WHICH FUNCTION? *15 minutes*

Instructional Routines

- MLR1: Stronger and Clearer Each Time

Building on the work in the warm-up, the purpose of this activity is for students to determine which of the given functions is a better fit for the data. For this activity, students should use any language that makes sense to them to describe why a function is or is not a good fit and how they would change the function to be a better fit for the data. Since both functions offer reasonably good fits for the data, students have the opportunity to make an argument about why they think a particular function is a better fit (MP3).

Monitor for students using different explanations of what makes a function fit the data, such as by focusing on the general shape, the accuracy for individual points, or the average error for all the points.

This activity works best when each student has access to devices that can run the Desmos applet because students will benefit from seeing the relationship in a dynamic way. If students don't have individual access, projecting the applet will be helpful during the synthesis.

Support for English Language Learners

Writing, Conversing: MLR1 Stronger and Clearer Each Time.
Use this routine to help students improve their writing by providing them with multiple opportunities to clarify their explanations through conversation. Give students time to meet with 2–3 partners to share their response to the question "Which function better fits the shape of the data? Explain your reasoning." Students should first check to see if they agree with each other about which function fits the data better. Provide listeners with prompts for feedback that will help their partner add detail to strengthen and clarify their ideas. For example, students can ask their partner, "What did you look at in the graph to make your decision?" or "Can you say more about what ________ means?" Next, provide students with 3–4 minutes to revise their initial draft based on feedback from their peers. This will help students produce justifications for determining what makes a function a good fit for data.

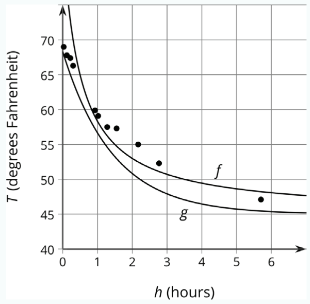
Design Principle(s): Support sense-making; Optimize output (for explanation)

STUDENT-FACING TASK STATEMENT

A bottle of soda water is left outside on a cold day. The scatter plot shows the temperature T, in degrees Fahrenheit, of the bottle h hours after it was left outside. Here are 2 functions you can use to model the temperature as a function of time:

$$f(h) = 45 + \frac{20}{h + 0.5}$$

$$g(h) = 45 + 33(0.5)^{h+0.5}$$



1. Which function better fits the shape of the data? Explain your reasoning.
2. Where do you see the 45 in the expression for each function on the graph?
3. For the function you thought didn't fit the shape of the data as well, how would you change it to fit better?

Possible Responses

1. Sample responses: f fits better because it stays closer to the data points. g fits better because its shape is a better fit and the vertical intercept is closer to what the data shows.
2. Sample response: Adding the 45 raises the T value, the output, of each function by 45 degrees, so the graph is 45 degrees higher at each point.
3. Sample response: g would fit better if the curve was moved up higher about 3 degrees.

Anticipated misconceptions

In order to show the temperature trend better, the first tick mark on the temperature axis represents 45 degrees, even though each successive tick mark only represents an additional 5 degrees. If students are confused that the first tick mark does not represent 5 degrees, remind them that since the range of this function does not include any numbers less than 45, it is convenient to start the range values at 45.

Activity Synthesis

Use graphing technology, such as the applet in the digital version of this activity, to project the data given here along with S the two functions $f(h) = 45 + \frac{20}{h + 0.5}$ and $g(h) = 45 + (0.5)^{h+0.5}$.

h (Hours)	T (°F)
0.03	69
0.12	67.8
0.22	67.4
0.3	66.3
0.93	59.9
1.02	59.1
1.28	57.5
1.55	57.3
2.17	55
2.77	52.3
5.7	47.1

Invite previously identified students to share which function they think fits better and why. Since there is no single correct answer, attend to students' explanations and ensure the reasons given are correct. Ask 2–3 students for ideas on how they would adjust either f or g to be a better fit.

Conclude the discussion by showing how the graphs of f and g change when the 45 is removed from the equation. If students called the 45 the vertical intercept, note that this is true for some equations, such as the b in $y = mx + b$, but the constant term is not always the vertical intercept, as shown by the equations for f and g. Tell students that a goal of this unit is to understand how to transform the graphs of functions in different ways and what different transformations mean for the corresponding expressions.

EXPLORATION EXTENSION | ARE YOU READY FOR MORE?

STUDENT-FACING TASK STATEMENT

Consider the function a given by $a(h) = \frac{2}{3}(h - 6)^2 + 46$.

1. Explain how the equation defining a is related to the temperature data.
2. How well does a model the data compared to f or g? Explain your reasoning.

Student Response

1. Sample response: The minimum of a is at $h = 6$ reflecting the decreasing temperature of the soda water. The T-intercept is close the beginning of the data, at 70.
2. Sample response: The function a is a good choice in that it decreases between $h = 0$ and $h = 6$, and the rate of decrease slows down as h grows. It is not a good choice in that once $h > 6$, the output of a starts to grow which will not model what happens to the temperature of the soda water.

EXPLORATION ACTIVITY | WHAT HAPPENED TO THE GRAPH? *15 minutes*

Instructional Routines

- MLR2: Collect and Display
- Take Turns

In this partner activity, students take turns describing transformations of a graph and sketching the transformed graph from the description. As students trade roles explaining their thinking and listening, they have opportunities to refine and use more precise language when describing transformations (MP6).

Encourage students to attend to details such as direction, distance, and shape. While students work, record words you notice students using in their descriptions, such as vertex, intercept, or maximum, for all to see to provide ideas for other students and to reference during the whole-class discussion.

LAUNCH

Arrange students in groups of 2. Tell students that they are going to take turns. One partner will describe the transformation of graph a to graph b that they see on their handout, the other will draw the transformation based on the description. Each partner will draw 3 graphs and describe 3 transformations.

Ask students to be specific in their descriptions but note that the goal is for their partner to draw the transformation correctly without needing to name specific points.

Distribute 2 half sheets to each group from the blackline master, 1 to each student. Remind students to keep their sheet hidden from their partner.

Support for English Language Learners

Conversing: MLR2 Collect and Display.
Listen for and collect language students use to describe the transformations. Record informal student language alongside the mathematical terms (translate up or down, translate right or left, reflect, stretched, “squashed”) on a visual display and update it throughout the remainder of the lesson. Remind students to borrow language from the display as needed. This will provide students with a resource to draw language from during small-group and whole-group discussions.

Design Principle(s): Maximize meta-awareness; Support sense-making

Support for Students with Disabilities

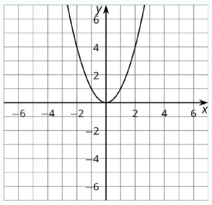
Representation: Internalize Comprehension.
Chunk this task into more manageable parts to differentiate the degree of difficulty or complexity by beginning with fewer cards. For example, give students a subset of the cards to start with and introduce remaining cards if time allows.

Supports accessibility for: Conceptual processing; Organization

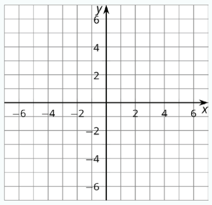
STUDENT-FACING TASK STATEMENT

Your teacher will give you a card. Take turns describing the transformation of the graph on your card for your partner to draw and drawing the transformed graph from your partner's description.

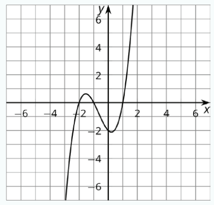
1. A.



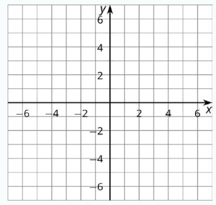
1. B.



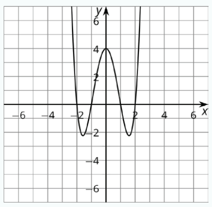
2. A.



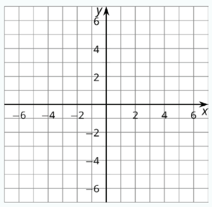
2. B.



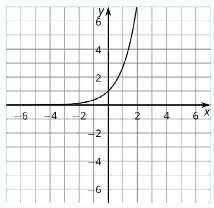
3. A.



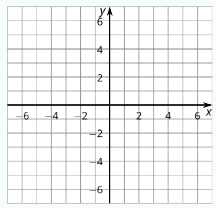
3. B.



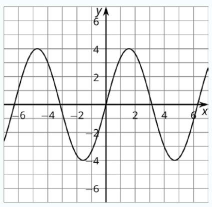
4. A.



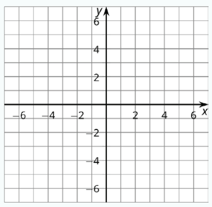
4. B.



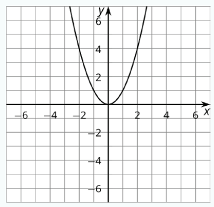
5. A.



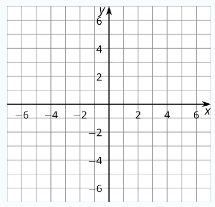
5. B.



6. A.



6. B.



Possible Responses

Sample responses:

1. translated up by 3 units
2. translated right by 1 unit
3. translated left by 1 unit and down by 2 units
4. reflected across the y-axis
5. squashed horizontally by a factor of $\frac{1}{2}$
6. stretched horizontally by a factor of 2 or squashed vertically by a factor of $\frac{1}{4}$

Anticipated misconceptions

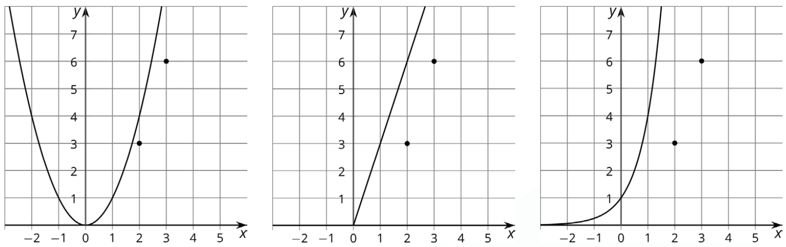
Some students may describe the transformations without enough detail, making it difficult for their partner to sketch the correct transformation. Emphasize that the goal is for their partner to draw the transformed graph with precision so that it matches what they see exactly.

Activity Synthesis

The purpose of this discussion is for students to describe the transformations they saw when graphing. Encourage students to use precise language such as translate, reflect, and stretch. Students will continue to refine their language around graphical transformations throughout the unit, so it is okay for students to use more informal language at this time.

Begin the discussion by inviting students to share what types of transformations they saw, displaying the graphs for all to see to help illustrate student descriptions and connecting back to the list of words recorded during the activity. Connect any words students used back to geometry vocabulary (translate and reflect). Ask, "Are any of these transformations dilations?" (No, they are only stretching in one direction.)

LESSON SYNTHESIS



Display the three graphs. Invite students to describe how to transform each graph to fit the points.

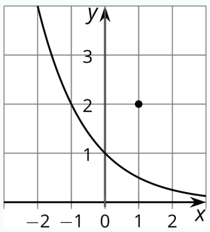
Here are some questions for discussion:

- "Which graph fits the data the best?" (All three can fit perfectly, for example, by translating the parabola up 2 and right 1.)
- "Imagine a situation where each graph—linear, quadratic, and exponential—would be the best choice to model the relationship." (Any explanation works so long as the rate of change in the scenario matches the graph chosen. For example: The exponential would be best if the situation was population growth over time. The line would be best if the situation was price per pound.)
- "When we fit a curve to data points, will the curve always go precisely through all of the points?" (Not always, but the shape of the curve should fit the general shape of the data.)

COOL DOWN | TRANSLATING TWO WAYS *5 minutes*

STUDENT-FACING TASK STATEMENT

There are many ways to translate the graph so that it goes through the point $(1, 2)$. Describe two.

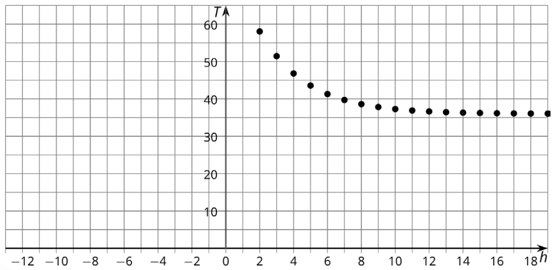


Possible Responses

Sample responses: Translate the graph right 1 unit and up 1 unit. Translate the graph right 2 units. Translate the graph right 3 units and down 2 units. Stretch the graph vertically by a scale factor of about 4.

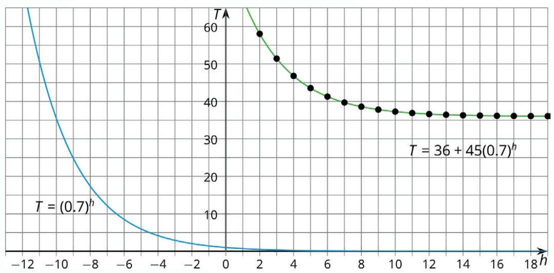
STUDENT LESSON SUMMARY

The data in the graph show the temperature T, in degrees Fahrenheit, of a can of soda h hours after it was put into the refrigerator.



What if we want to build a function that fits this data set? One way to find a function that fits the data well is to start with a simpler function that has the same general shape as the data when graphed and transform it. What shape does this data form?

Let's try an exponential decay function. We can get the right shape using a simpler equation like $T = (0.7)^h$, but the graph doesn't fit where the data is. The graph of the function given by $T = 36 + 45(0.7)^h$ isn't represented by a simple equation, but it does fit the data.

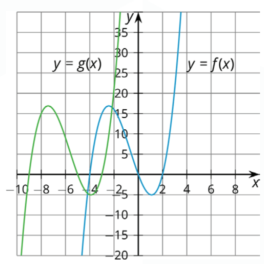


PRACTICE PROBLEMS

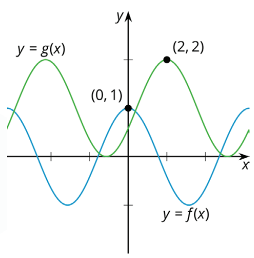
PROBLEM 1

Describe a transformation that gives the graph representing g from the graph representing f.

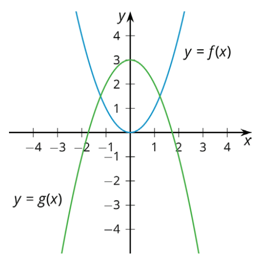
A.



B.



C.



Possible Solutions

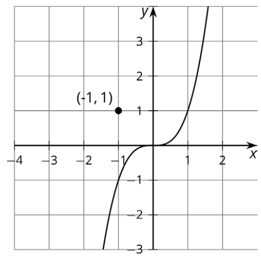
Sample response:

- **A.** Shift left 5 units.
- **B.** Shift right 2 units and up 1 unit.
- **C.** Reflect over the x-axis and shift up 3 units.

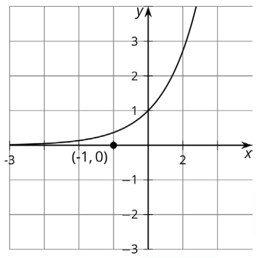
PROBLEM 2

Describe a way to transform each graph so that it goes through the labeled points.

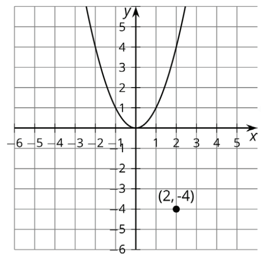
A.



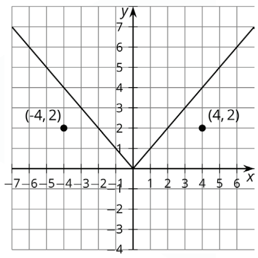
B.



C.



D.



Possible Solutions

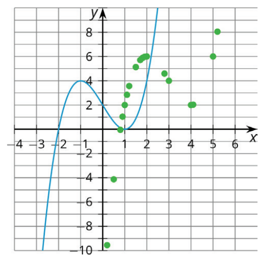
Sample responses:

- **A.** Reflect over the y-axis, or reflect over x-axis, or shift left 1 unit and up 1 unit.
- **B.** Shift down 1 unit and left 1 unit.
- **C.** Reflect over the x-axis, or shift right 2 units and down 4 units.
- **D** Shift down 2 units.

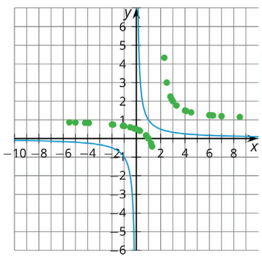
PROBLEM 3

Describe a way to transform each graph so that it better matches the data.

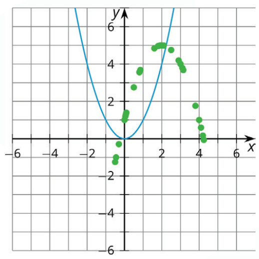
A.



B.



C.



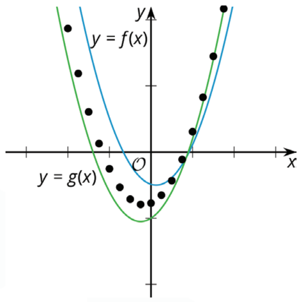
Possible Solutions

Sample responses:

- **A.** Shift 3 units right and 2 units up.
- **B.** Shift 2 units right and 1 unit up.
- **C.** Reflect across the x-axis and shift 2 units right and 5 units up.

PROBLEM 4

Does the function f or the function g fit the data better? Explain your reasoning.



Possible Solutions

Sample response: Both functions show the overall trend of the data, but g matches the data better because the points are closer in general to the graph of g than they are to the graph of f.

PROBLEM 5

(From Unit 2, Lesson 13)

For the polynomial function $A(x) = 2x^3 + 5x^2 - 28x - 15$ we know $(x + 5)$ is a factor. Rewrite $A(x)$ as a product of linear factors.

Possible Solutions

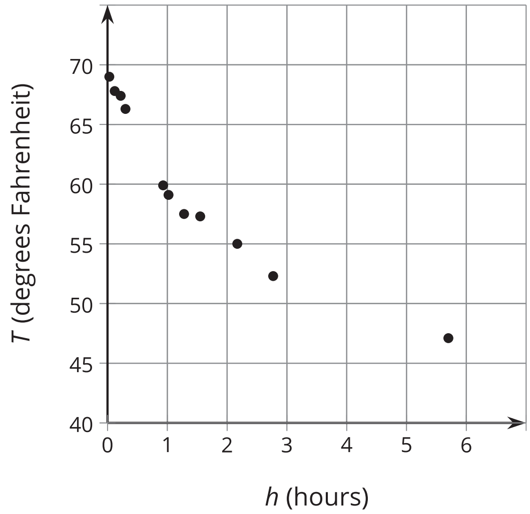
$A(x) = (x + 5)(x - 3)(2x + 1)$

REFLECTION AND NOTES

Unit 5, Lesson 1: Matching up to Data

Notice and Wonder: Cooling Down

What do you notice? What do you wonder?



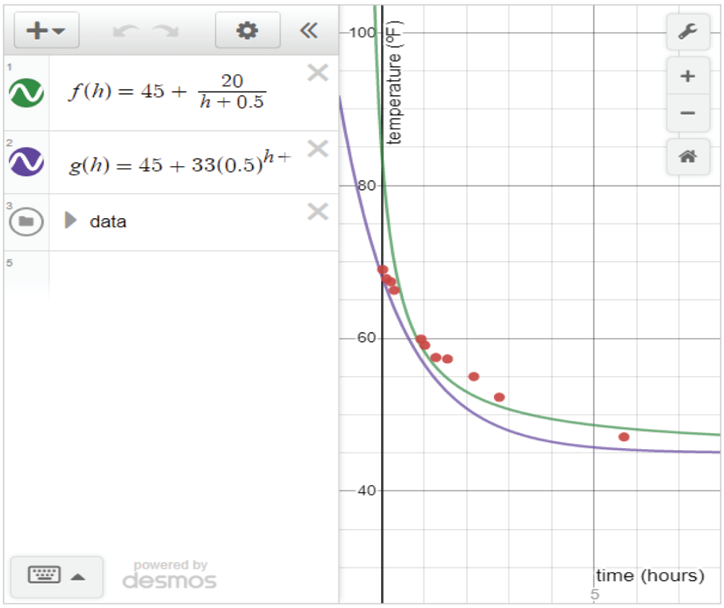
Which Function?

These activities require the use of an applet, so please make your way over to the digital platform to find the link.

A bottle of soda water is left outside on a cold day. The scatter plot shows the temperature T, in degrees Fahrenheit, of the bottle h hours after it was left outside. Here are 2 functions you can use to model the temperature as a function of time:

$$f(h) = 45 + \frac{20}{h + 0.5}$$

$$g(h) = 45 + 33(0.5)^{h+0.5}$$



1. Which function better fits the shape of the data? Explain your reasoning.

Use the applet to zoom out on the graphs.

2. Does this change your opinion about which function fits better?

3. Where do you see the 45 in the expression for each function on the graph?

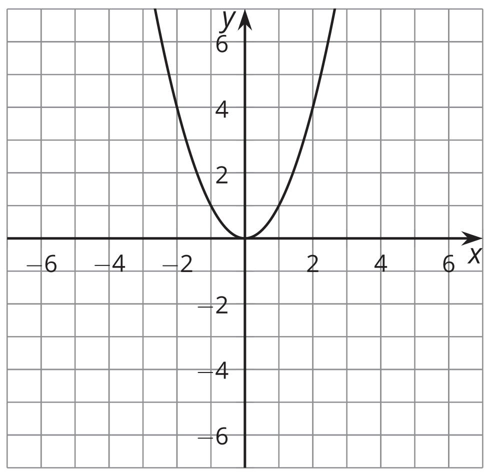
4. For the function you thought didn't fit the shape of the data as well, how would you change it to fit better?

What Happened to the Graph?

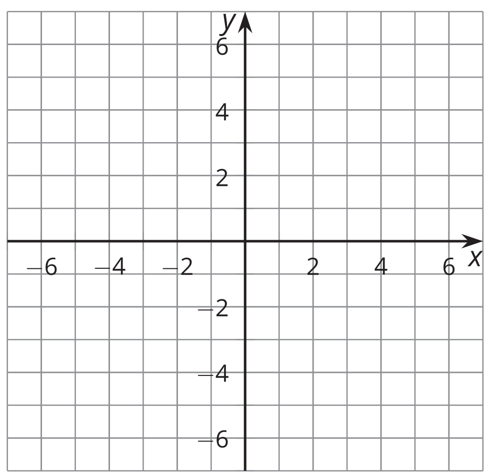
Your teacher will give you a card. Take turns describing the transformation of the graph on your card for your partner to draw and drawing the transformed graph from your partner's description.

1.

A.

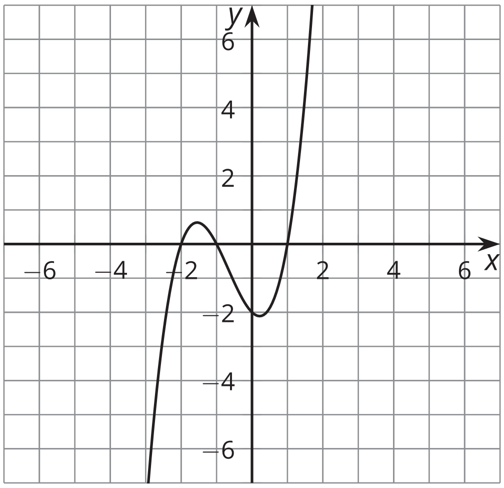


B.



2.

A.



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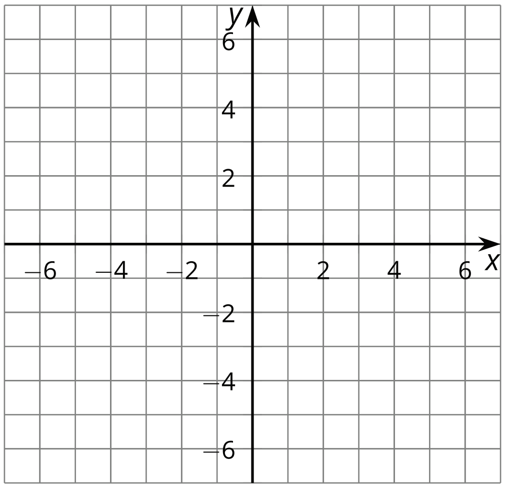
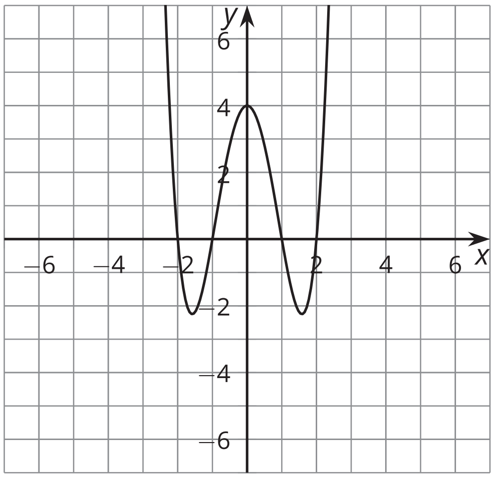


3.

A.



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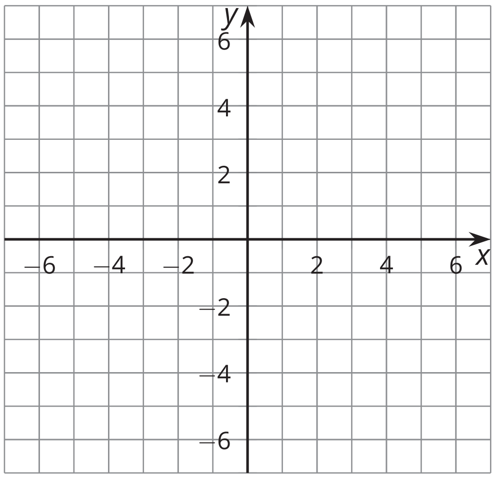
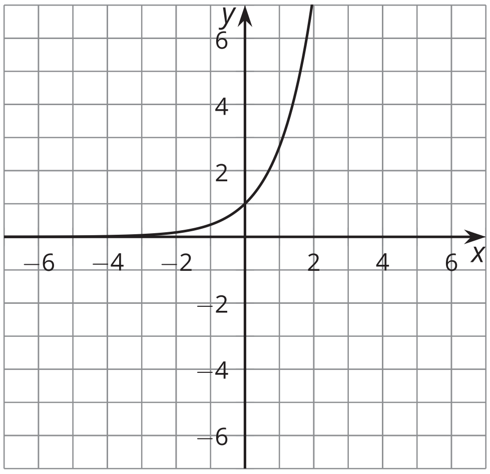


4.

A.



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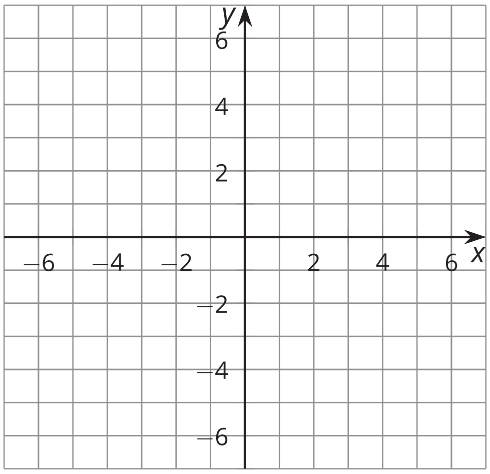
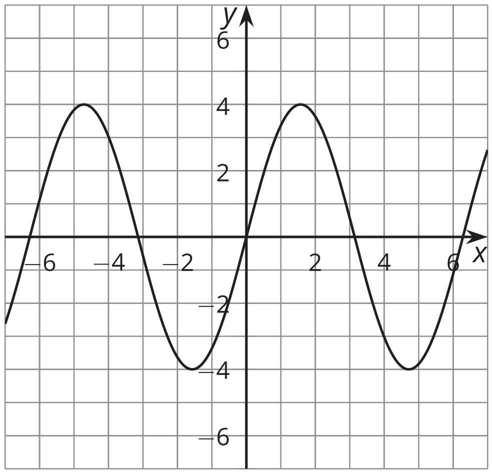
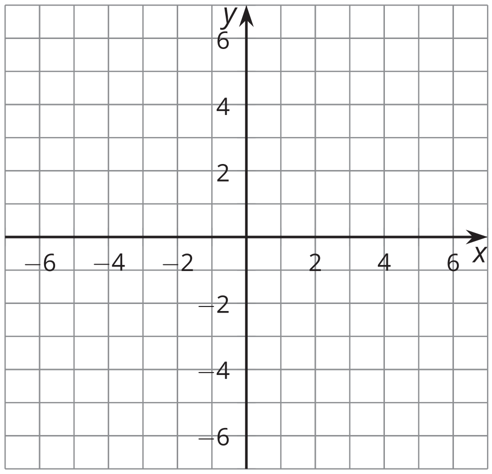


5.

A.

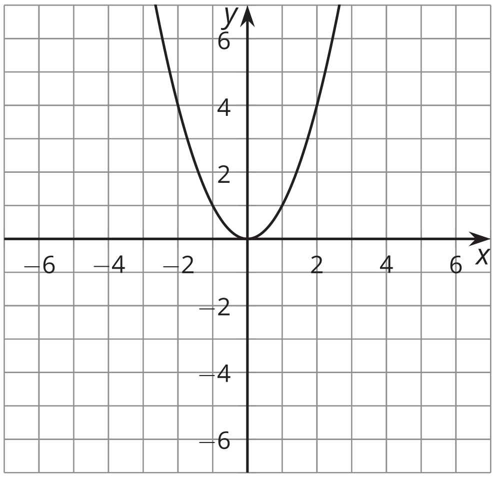


B.



6.

A.



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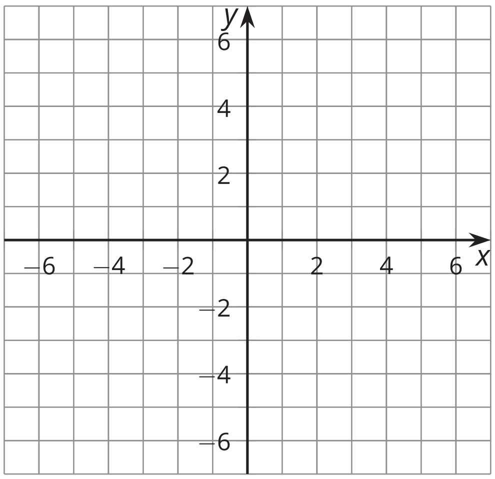
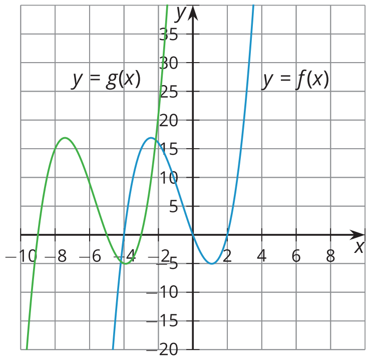


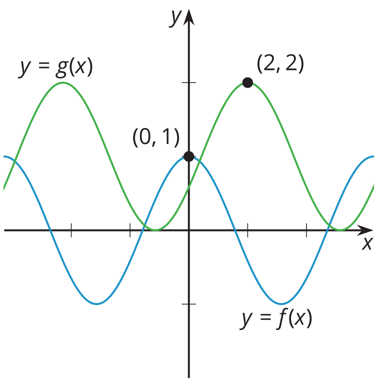
Practice Problems

1. Describe a transformation that gives the graph representing g from the graph representing f.

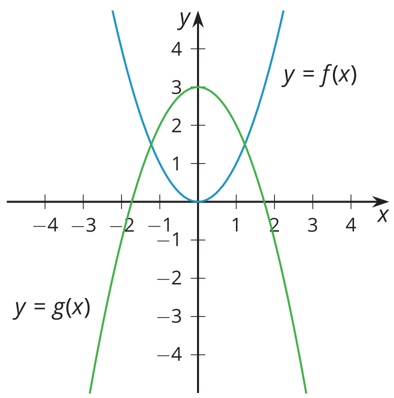
A.



B.

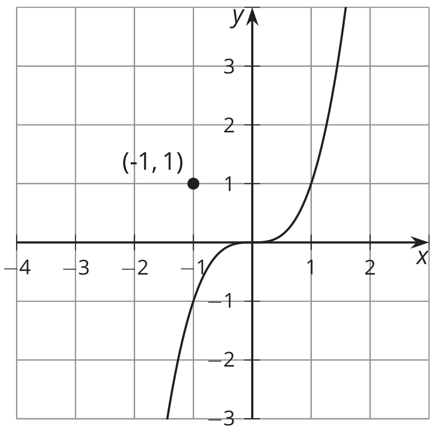


C.



2. Describe a way to transform each graph so that it goes through the labeled points.

A.



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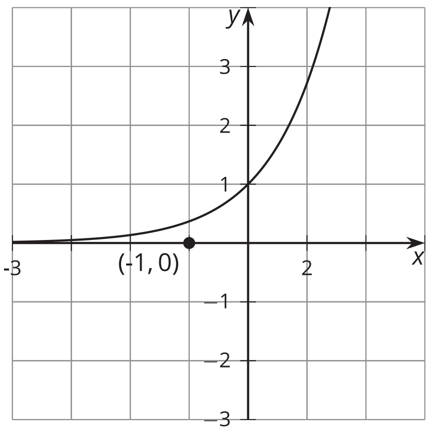
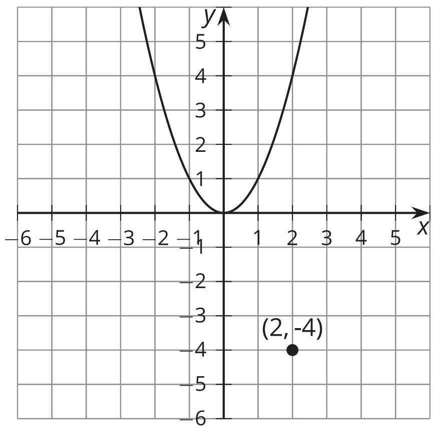
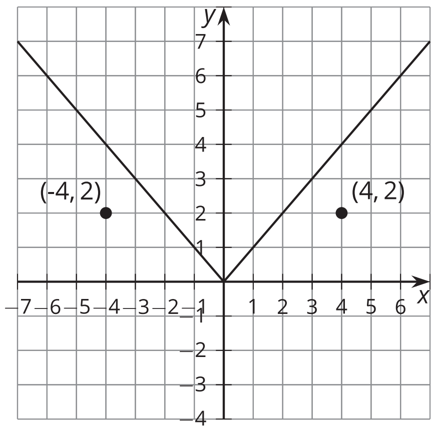


C.

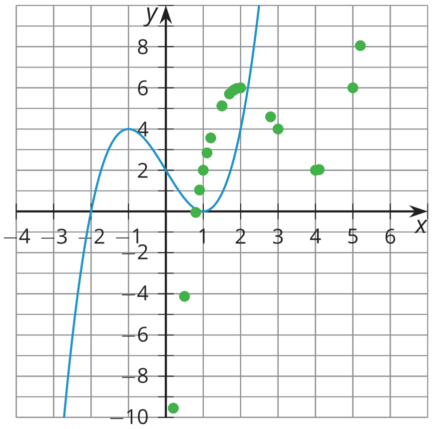


D.

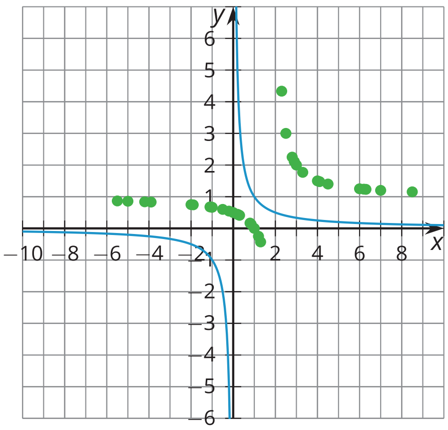


3. Describe a way to transform each graph so that it better matches the data.

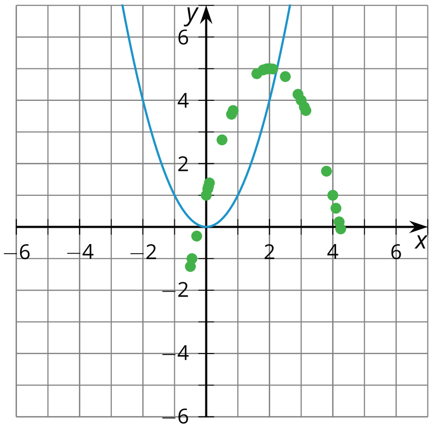
A.



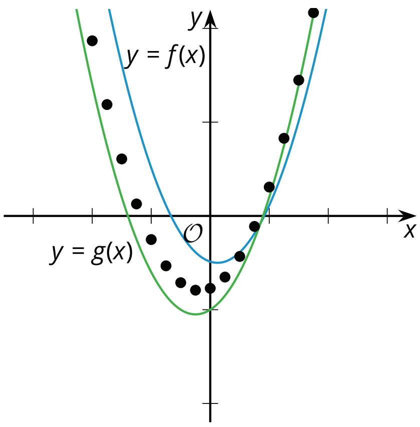
B.



C.



4. Does the function f or the function g fit the data better? Explain your reasoning.

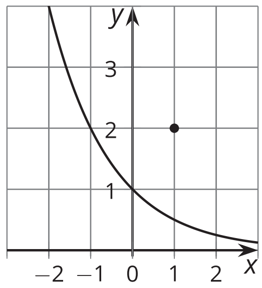


5. For the polynomial function $A(x) = 2x^3 + 5x^2 - 28x - 15$ we know $(x + 5)$ is a factor. Rewrite $A(x)$ as a product of linear factors.

Lesson 1: Matching up to Data

Cool Down: Translating Two Ways

There are many ways to translate the graph so that it goes through the point $(1, 2)$. Describe two.

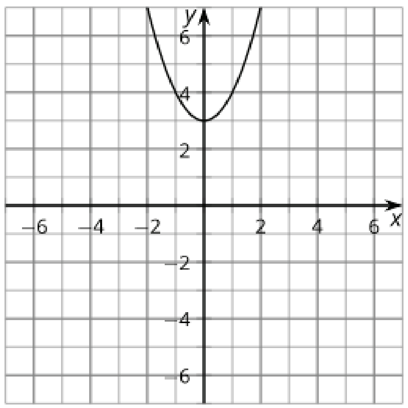


Alg2.5.1.3 What Happened to the Graph?.

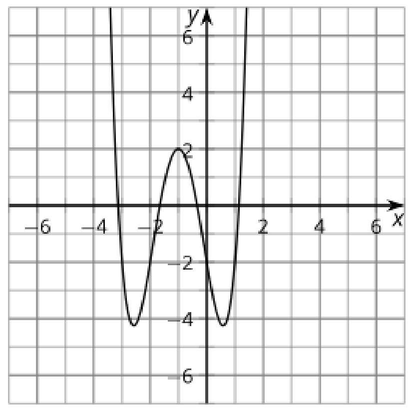
What Happened to the Graph?

Card 1

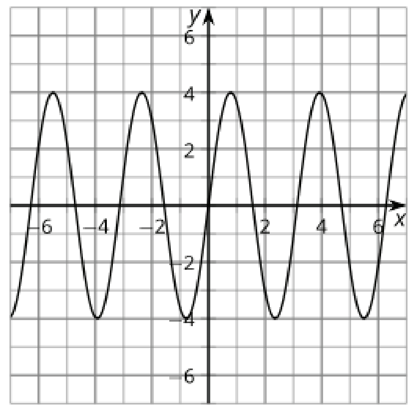
1. b.



3. b.



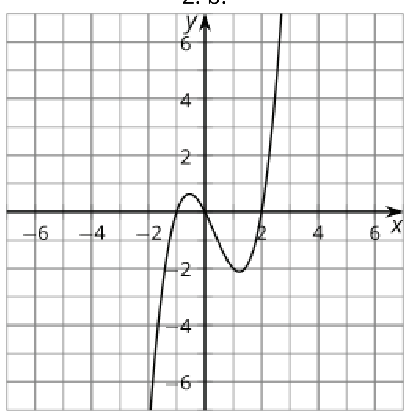
5. b.



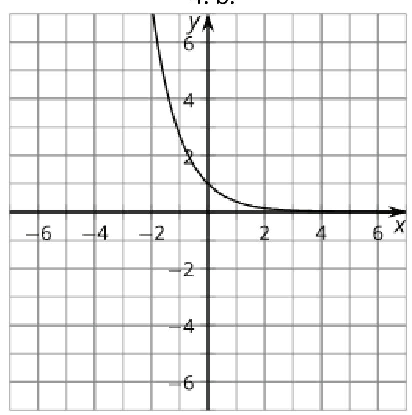
What Happened to the Graph?

Card 2

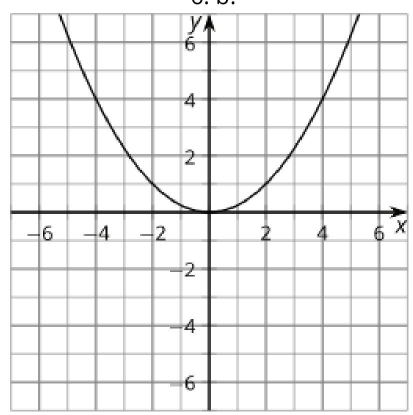
2. b.



4. b.



6. b.



Notes

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