



TOPICS 1–4

Integrate Data Science
Investigate Roller Coasters

Purpose

Students will investigate roller coaster data and make general observations about the design to create a mathematical model represent it. They will research, analyze, and interpret data findings and use the math they have learned to answer questions posed or questions of particular interest to them. They will use the data to drive decisions and to make predictions.

Students have the opportunity to apply all or a subset of the concepts and skills they have learned in Topics 1–4.

Pacing

Allow 3–4 days for students to complete the investigation and optional extension.

Invite Student Questions and Conjectures

To engage students in the context, you might show students some photos or videos of roller coasters. To encourage students to bring their own unique experiences and ideas to the situation, consider these prompts:

- Q: In your opinion, are roller coasters exciting or terrifying?
- Q: Are all roller coasters the same? How are they alike and different?
- Q: Why do people enjoy roller coasters? Can engineers influence how thrilling a ride is?

 Interactive version is available at SavvasRealize.com.

Integrate
Data Science
Investigate
Roller
Coasters



Do you find roller coasters exciting or intimidating? Roller coasters like the one above are made from steel and are carefully engineered to safely deliver a rush of adrenaline. With sharp turns, loops, steep lifts, and sudden drops, riders are in for an exhilarating ride! What design features make roller coasters so thrilling — or terrifying?

English Language Development

MLR2 Collect and Display



Activity

Notice and Wonder **WHOLE CLASS**



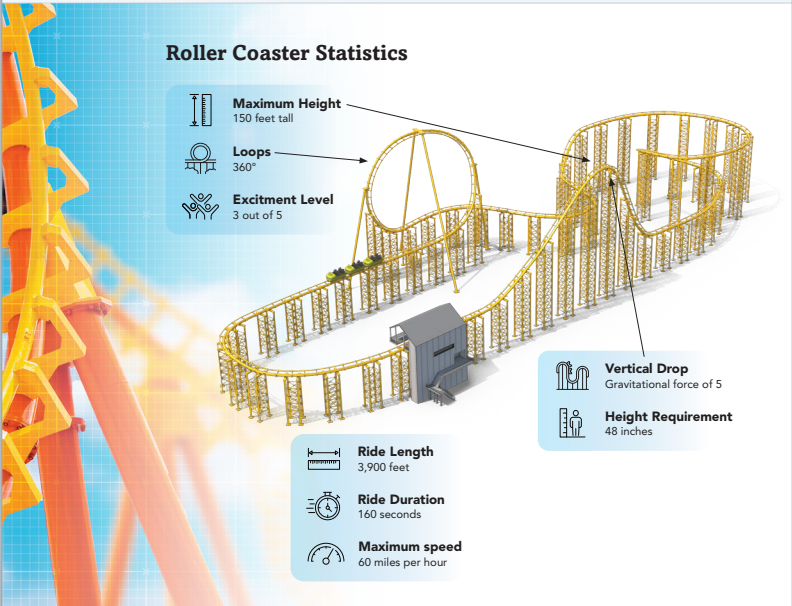
Engage students in classroom discourse as they notice and wonder about the roller coaster design features.

MLR2 Collect and Display

Record what students notice and wonder, and revisit the lists during the investigation. While recording, listen for informal words students may use, and revise what you record as students refine their terminology.

Notice	Wonder
• The roller coaster design starts with a vertical lift then a drop. • The highest point is either on the loop or at the top of the first lift. • The maximum speed is 60 mph. • The maximum speed is about as fast as a car on the highway.	• Do all roller coasters start with a lift then a drop? • Does the roller coaster stay at the same speed the entire ride? • How do engineers make sure the ride is safe?

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Roller Coaster Statistics

- Maximum Height**
150 feet tall
- Loops**
360°
- Excitement Level**
3 out of 5
- Ride Length**
3,900 feet
- Ride Duration**
160 seconds
- Maximum speed**
60 miles per hour
- Vertical Drop**
Gravitational force of 5
- Height Requirement**
48 inches

What do you notice?

What do you wonder?

If you make a claim based on your observations, where can you find the evidence to support it?

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Activity

Promote Mathematical Discourse

Before answering questions, have students work in small groups to discuss what roller coaster design features and variables they notice from the information on the page. Add to the class notice and wonder display as students share their observations. **MLR2**

Q: What are some design features of roller coasters that you notice that we may not have considered yet? [Sample response: top speed, shape, maximum height, duration, car style (seated or standing), etc.]

Q: What variables in the data table might you want to investigate further? [Sample response: I want to explore if maximum height and speed are related.]

Launch the Investigation SMALL GROUP

You may choose to complete parts 1–4 as a class or in small groups. Facilitate classroom discussion at pause points between each part.

1. Sample response: Functions that could model these shapes are linear, quadratic, and exponential functions.
2. Sample response: (70,47). I think feet makes sense.
3. Sample response: A drop from a high point probably gives the roller coaster more speed to complete the ride without using much power from electric. I think that is why many roller coasters start with a climb and then a drop.
4. Sample response:

x1	y1
85	245
57	150
73	202
78	218
38	120
76	175
62	115
128	456

Linear Regression

EQUATION

$y = 3.95409x - 83.17347$

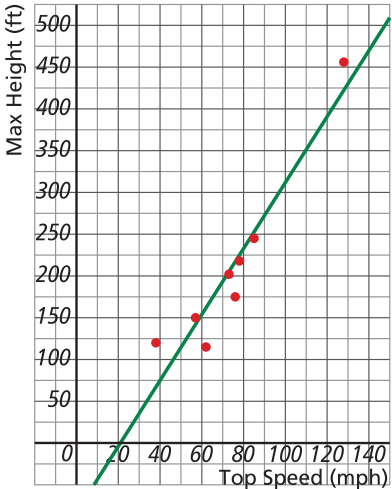
STATISTICS

$R^2 = 0.9015$

$r = 0.9495$

RESIDUALS

e_1



There is a positive linear association between max height and top speed. The linear equation $y = 3.95x - 83.17$ models the relationship. I could also explore the relationship between speed and duration.

Interactive version is available at SavvasRealize.com.

SOME ROLLERCOASTERS REACH SPEEDS FASTER THAN MOST CARS ON HIGHWAYS.

Mathematical modeling plays a crucial role in roller coaster design, ensuring the structure is safe, functional, and thrilling. Engineers use mathematical functions to represent the shape and motion of the tracks, taking into account factors such as speed, acceleration, and gravity.

X2 Roller coaster
Six Flags Magic Mountain
California



- 1 What function types do you see in the shape of the roller coaster?
- 2 The quadratic equation $f(x) = -0.01x^2 + 1.34x + 2.11$ models the shape of the hill on the X2 roller coaster at Six Flags Magic Mountain. In this model, x represents the horizontal distance from the start of the hill. How could you use the model to find the maximum height of the hill? What units make sense?
- 3 Many roller coasters start with a climb followed by a drop. Why might this be an important design feature?
- 4 How are the height of a roller coaster and its top speed related? What other relationships between the variables could you explore?

Coaster	State	Top Speed (mph)	Max Height (ft)	Duration (sec)
Batman The Ride™	TX	38	120	120
Hangtime™	CA	57	150	75
Kingda Ka™	NJ	128	456	50
Raging Bull™	IL	73	202	150
Son Of Beast™	OH	78	218	140
Titan™	TX	85	245	210
X2™	CA	76	175	120
Zonga™	CA	62	115	120

What else do you wonder about other variables related to roller coasters?



DRIVE YOUR INVESTIGATION

Anticipate

As you plan, anticipate ways that students will ...

- choose which roller coaster(s) they will investigate
- use tools to design their own roller coaster path
- analyze data from official websites
- determine whether and how the variables are related

Also anticipate errors that may occur like:

- failing to identify the correct association of the data
- misinterpreting data when doing research
- misinterpreting the variables
- drawing conclusions without mathematical evidence to back it up

Monitor

Questions for Students Before Starting the Investigation

- Q:** What functions could model the shape of a roller coaster?
[Sample response: Quadratic, linear, exponential.]
- Q:** Which variables do you think are related? How could you use modeling to represent relationships between the variables?
[Sample response: I think max speed and height are related. I could use regression to determine how variables are associated.]

Questions for You As You Observe

As you monitor students working, ask yourself the following questions:

- **Which students need support with researching the information they need?** Refer students to the data from the guided activity, or data from official websites.
- **Which students need help creating models that represent the data?** Encourage students to use technology tools such as Desmos Tool(s), graphing calculators, or spreadsheet applications. Note: If the students are modeling shape of a roller coaster, they can import the photo using Desmos Tool(s).

Questions for Students During the Investigation

- Q:** Which representation, a table or graph, is best for analyzing the data from official websites? Guide students to discuss a strategy for their selection. Help them to see the advantages of comparing two variables graphically.
- Q:** If part of the path is parabolic in shape, what points on the parabola do you know? How can you build a quadratic equation to go through these points? Help students see that they can build a quadratic equation using the zeros or using the vertex of the parabola.



Interactive version is available at SavvasRealize.com.

DRIVE YOUR INVESTIGATION	REFLECT ON MATH PRACTICES AND PROCESSES
Choose another roller coaster that you are interested in researching more. To drive your investigation, search for data about the roller coaster on official websites. 1. Make Sense of the World Investigate roller coasters in your state or in an area of interest to you. Create a mathematical model to represent the roller coaster(s) you investigated, or design your own.	Choose two of the following questions to reflect on how you engaged the math practices and processes during the investigation. 1. Model with Mathematics How did you use mathematical models to represent the roller coaster?
2. Predict How can you use your model to make predictions about the roller coaster?	2. Use Appropriate Tools What tools use in your investigation? How did your choice of tools help you answer the questions?
3. Make an Impact When designing roller coasters, what factors do you think engineers need to consider? How could the materials and design be used to minimize environmental impact?	3. Reason How does your mathematical model represent the physical and design features of the roller coaster?
	4. Look for Relationships What patterns did you notice in the roller coaster data? How did these patterns help you to create your model?

EXTENSION

Investigate innovative amusement park designs that are better for the environment.

- What measures are in place to help amusement parks minimize environmental impact?
- Given your research, suggest ways a local amusement park could make their roller coasters more environmentally friendly.
- How could you support your recommendations using data?

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Questions to Assess Student Understanding (Assessing Questions)

- Q:** If you created a model to show the shape of the coaster, what do your variables mean?
- Q:** How are the variables you chose to investigate related? How do you know?

Questions for Students Who Need Help (Assessing Questions)

- Q:** Would a linear or exponential model best fit the relationship between the variables? Why?
- Q:** How can you use technology to help you develop or analyze a model?

Questions to Help Students Think More Deeply (Assessing Questions)

- Q:** What mathematical evidence do you have to support your conclusions and predictions?



Select and Sequence Solutions

The following is a possible sequence for the presentation of sample student work with suggested questions. This sequence of solutions does not have a particular coherence and can be reordered in any way. You should select and sequence responses from your own students, using the sample responses provided only as needed.

It is recommended that this part of the lesson take place after the Investigation.

1. **A student who used Desmos Graphing Calculator to fit a model to the path of a roller coaster.** (Student Work A)
 - Q:** How can you tell if your model is a good fit?
 - Q:** How can you adjust your model?
2. **A student uses linear and exponential models to describe the relationship between top speed and max height data from an official website for all roller coasters.** (Student Work B)
 - Q:** Which tools did you use to analyze the data? How did the tools help you to develop a model?
 - Q:** How does the data support your conclusion?
3. **A student uses quadratic equations to create their own roller coaster.** (Student Work C)
 - Q:** How did you determine the domain for each part of the roller coaster?
 - Q:** What considerations might an engineer need to make when designing a roller coaster?
4. **A student uses x -intercepts to build the factored form of a quadratic equation, modeling the path of their roller coaster.** (Student Work D)
 - Q:** How did you build your equation to match your design?

Connect to the Goals of the Investigation

After allowing students to finish the questions for the lesson, return to an all-class discussion to solidify the connection to the goals of the lesson.

- Q:** How did you use a model that could be used to describe the roller coaster(s) you investigated? Or, how did you model your own design?
- Q:** What trends did you notice and how does the data support your observations?
- Q:** Now that you know more about roller coasters shape and variables, what conclusions can you make about future roller coaster designs? Will current models be a good fit?
- Q:** How is student A's strategy different from student D's? How is it similar?
- Q:** Could student B use their equations to make a prediction about the maximum height given the speed? How confident would you be in that prediction?
- Q:** What additional considerations might Student C need to ensure their design is safe?

REFLECT ON MATH PRACTICES AND PROCESSES

Ask students to choose two of the math practices and processes questions that reflect the ways that they engaged with math practices during the investigation.

You may also assign questions to facilitate discussion about how students demonstrated proficiency with the math practices and processes.

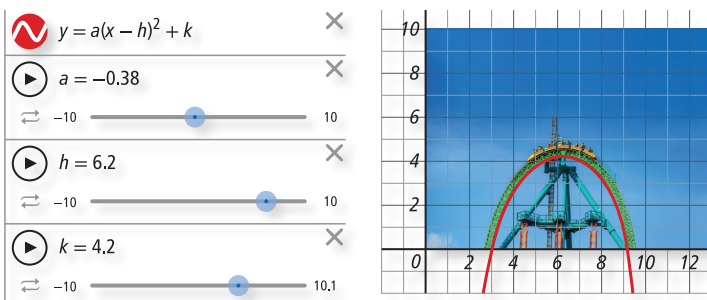
EXTENSION

- Q:** How will you identify ways which amusement parks minimize environmental impact?

ANALYZE STUDENT WORK

Project these individually or together from SavvasRealize.com.

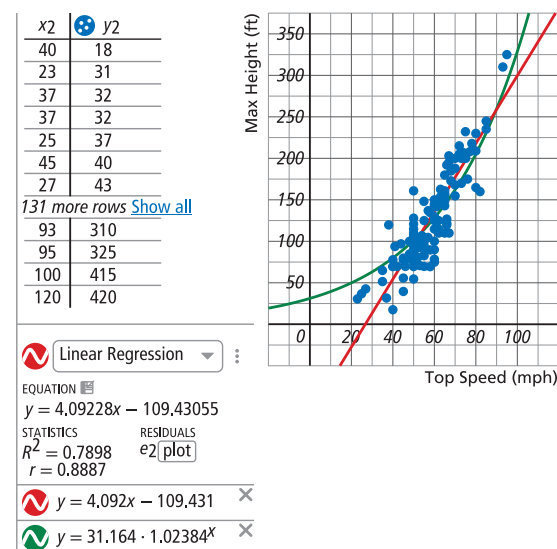
Student Work A



I choose Kingda Ka because it was the tallest roller coaster in the world with a maximum height at 456 feet. I used Desmos Graphing Calculator to fit the quadratic model to the largest loop in Kingda Ka. Building a mathematical model helps predict the behavior of a roller coaster. It can then be used to examine the forces, speeds, and motion to ensure safety and enhance performance. Engineers designing roller coasters need to consider factors like safety, structural integrity, rider experience, speed and acceleration. They can also consider the impact on the environment.

To review content, refer students to Topic 3, Lessons 1 to 4.

Student Work B



I used data from an official website to investigate the relationship between top speed and max height. I compared the first and second differences between the top speed and max height, but I did not see a clear relationship since the differences were inconsistent. So, I analyzed a scatter plot of the data which shows there is a positive association between the top speed and max height of the coasters. I used Desmos Graphing Calculator to compare models to fit the data. The linear and exponential models $f(x) = 4.092x - 109.431$ and $g(x) = 31.164 \cdot 1.02384^x$ seemed to best fit the data. I think the linear model is a better fit for the data over the entire range $23 < x < 95$. As I predicted, these variables are related and as the top speed increases, so does the max height of the coaster. I could use the models to predict the max height given the speed.

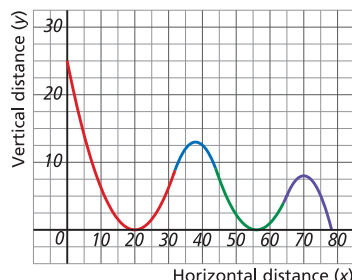
To review content, refer students to Topic 1, Lesson 4 and Topic 3, Lessons 4 and 5.



ANALYZE STUDENT WORK Project these individually or together from SavvasRealize.com.

Student Work C

$$\begin{aligned} f(x) &= \frac{1}{16}(x-20)^2 \quad \{0 < x < 32\} \\ g(x) &= 13 - \frac{13}{116}(x-38)^2 \quad \{32 < x < 44\} \\ h(x) &= \frac{1}{16}(x-56)^2 \quad \{44 < x < 64\} \\ i(x) &= 8 - \frac{2}{17}(x-70)^2 \quad \{64 < x < 78\} \end{aligned}$$

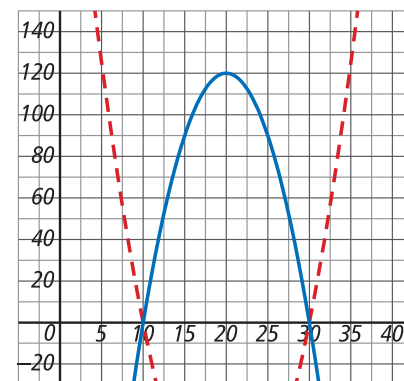


I designed my own roller coaster using Desmos Graphing Calculator with four quadratic functions. The graph shows the distance from the ground in meters over time. To make sure the ride was smooth, I connected the four parabolas in this way:
 from 0 to 32 is $f(x) = \frac{1}{16}(x-20)^2$;
 from 32 to 44 is $g(x) = 13 - \frac{13}{116}(x-38)^2$;
 from 44 to 64 is $h(x) = \frac{1}{16}(x-56)^2$;
 from 64 to 78 is $i(x) = 8 - \frac{2}{17}(x-70)^2$.

To review content, refer students to Topic 3, Lessons 3 and 4.

Student Work D

$$\begin{aligned} f(x) &= (x-10)(x-30) \\ g(x) &= -1.2(x-10)(x-30) \end{aligned}$$



I designed a roller coaster hill using a quadratic function. I started with zeroes at 10 and 30 and created the function $f(x) = (x-10)(x-30)$ and then explored more. I added a negative leading coefficient so the parabola would make a hill shape then I made the coaster steeper by changing the coefficient to 1.1. My final design is $f(x) = -1.1(x-10)(x-30)$ with domain $10 \leq x \leq 30$. I think engineers would need to consider how steep to make the hills so that the ride is safe. The roller coaster could be built using recycled materials to make it better for the environment.

To review content, refer students to Topic 2, Lesson 5 and 6 and Topic 4, Lesson 2.

You can use the space below to reflect on the Integrate Data Science. The questions can be used as a guide, or you can write freely as you reflect on the investigation.

Integrate Data Science Teacher Reflection

Instructional Strategies	Resources and Tools
- Which instructional strategies were most effective? - Which instructional strategies were less effective?	- Which resources and/or tools best supported learning and/or data analysis? - Are there additional resources and/or tools that could be utilized next time?

Key Moments	Review
- What were some memorable insights or unique approaches to the investigation? - Were there any surprising outcomes or shifts in students' thinking?	What skills or concepts need to be reviewed?

Investigate Roller Coasters: Key Takeaways