Collaborative Learning
This investigation is Exploros-enabled for tablets. See page xiii for details.

B2 Making Predictions Using a Graph

Key Question: *Can you predict the speed of the car at any point on the ramp?*

In this investigation, students use a photogate to determine the speed of a car at various points along a ramp. The data is used to make a graph of speed versus position. They then use the graph to predict the speed at a point where they had not placed the photogate. Data is collected to compare the predicted and actual speeds, and students find the percent error and percent correct.

Learning Goals

✔ Determine the speed of the car at various points along the ramp and graph the results.

✔ Use the graph to predict the speed at a chosen point on the ramp.

✔ Measure the actual speed at the chosen point and calculate percent error and percent correct.

GETTING STARTED

Time 50 minutes

Setup and Materials

1. Make copies of investigation sheets for students.
2. Watch the equipment videos.
3. You will need access to AC outlets for the timer.
4. Review all safety procedures with students.

Materials for each group

- Car and Ramp
- Physics Stand
- Timer and photogates
- DataCollector
- Metric tape measure
- Calculator
- Pencils
- Ruler or straightedge
- Graph paper

Online Resources

Available at curiosityplace.com

- Equipment Videos: Car and Ramp, Timer
- Skill and Practice Sheets
- Whiteboard Resources
- Animation: Average and Instantaneous Speed
- Science Content Video: Speed vs. Time Graphs 1
- Student Reading: Graphing Motion

NGSS Connection

This investigation builds conceptual understanding and skills for the following performance expectation.

HS-PS2-1. *Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data	PS2.A: Forces and Motion PS2.B: Types of Interactions	Cause and Effect

Vocabulary

dependent variable – the variable that may change as a result of changes in the independent variable

distance – the amount of space between two positions

independent variable – the variable that is purposely manipulated in an experiment

origin – a fixed reference point from which position is measured

position – the location of an object relative to an origin

speed – the distance an object travels divided by the time it takes

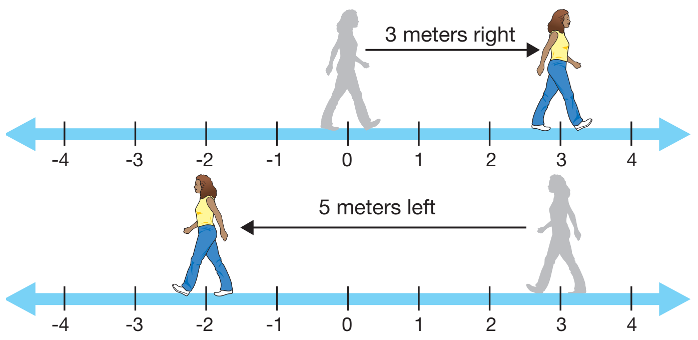
velocity – the speed of an object in a certain direction

BACKGROUND

An object's **position** is its location at one instant in time. A position is always given compared to an **origin**. The origin is a fixed reference point. If you were doing an experiment with a car on a track, you would define the origin as the position where the car starts.

Both positive and negative numbers are used to describe position. A positive position usually means in front of, to the right of, or above the origin. A negative position usually means behind, to the left of, or below the origin. It is important to define positive and negative directions if you are doing an experiment.

Distance is the amount of space between two positions. A number line can be used to think about distance in a straight line. The origin is at zero. If you start at the origin and move a distance 3 meters to the right, your position is +3 meters. If you then move 5 meters to the left, your position is –2 meters.



Speed is the rate at which an object's position changes. Speed is calculated by dividing the distance an object travels by the time taken. The letter *d* stands for "distance traveled" and the letter *t* stands for "time taken." The letter *v* is used to represent "speed" because it refers to the word **velocity**. You follow the same steps whether you are calculating speed or velocity. The only difference is that when giving an object's velocity, you must include the direction of its motion in addition to the speed.

SPEED

Speed (m/s) $v = \dfrac{d}{t}$ ***Distance traveled*** (m) / ***Time taken*** (s)

Graphs are an important tool used to show the motion of an object or the relationship between any two variables in an experiment. It is often easier to see patterns in data on a graph than in a data table. Typically, a graph plots two variables from an experiment, one on the *x*-axis and the other on the *y*-axis. The variable that is purposely changed in an experiment is the **independent variable**. The variable that changes as a result is the **dependent variable**. When making a graph, the independent variable is plotted on the *x*-axis. The dependent variable is plotted on the *y*-axis.

As with many rules, there are important exceptions. Time is an exception to the rule about which variable goes on each axis. When time is one of the variables on a graph, it always goes on the *x*-axis. This is true even if time is not the independent variable.

5E LESSON PLAN

Engage

Try this simple graphing activity to ensure that students understand how to make graphs using experimental data. Students often find it challenging to choose a proper scale. Their first inclination is to use the data values to label the axis without considering whether it makes sense to do so. Provide numerous opportunities for students to practice making graphs to remedy this issue.

A student conducted an experiment to determine how the temperature of a pot of water changed over time when it was on a hot plate. His data is represented in the table. Have students identify the independent and dependent variables, create the graph using an appropriate scale, and explain the relationship, if any, between variables.

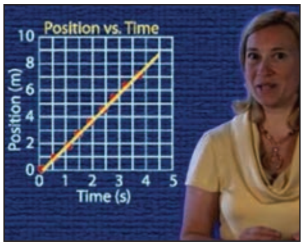
Time (min)	Temperature (°C)
0	21
2	24
4	38
6	54
8	66
10	64
12	61
14	59

Explore

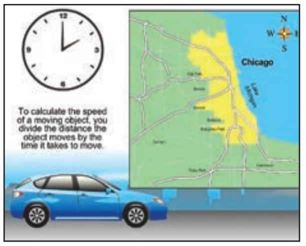
Students complete Investigation B2, *Making Predictions Using a Graph*. In this investigation, students use a photogate to determine the speed of a car at various points along a ramp. The data is used to make a graph of speed versus position. They then use the graph to predict the speed at a point where they had not placed the photogate. Data is collected to compare the predicted and actual speeds, and students find the percent error and percent correct.

Explain

Revisit the Key Question to give students an opportunity to reflect on their learning experience and verbalize understandings about the science concepts explored in the investigation. Curiosityplace.com resources, including student readings, videos, animations, and whiteboard resources, as well as readings from your current science textbook, are other tools to facilitate student communication about new ideas.



Science Content Video
Speed vs. Time Graphs 1



Animation
Average and Instantaneous Speed

Elaborate

During the investigation, students perform the same calculation eight times when finding the car's speed. Instruct students on how they could have done this much more quickly using a computer spreadsheet. You may want to work with your school's computer specialist to develop a lesson on using spreadsheets.

Once students learn how to use a spreadsheet, have them use the computer to make a graph of their data. They can then use the graph to make a new estimate of the car's speed at their chosen position on the ramp. The percent error and percent correct can be calculated.

Evaluate

- During the investigation, use the checkpoint ✓ questions as opportunities for ongoing assessment.
- After completing the investigation, have students answer the assessment questions on the *Evaluate* student sheet to check understanding of the concepts presented.

Explore INVESTIGATION **B2**

Name ______________________ Date ____________

B2 Making Predictions Using a Graph

Can you predict the speed of the car at any point on the ramp?

What happens to the **speed** of the car as it rolls down the ramp? You can answer this question by measuring its speed at different points. By making a graph of the car's speed according to its **position**, you can see a pattern in how speed changes. A graph not only shows the relationship between variables, but also shows how much one variable affects another. A graph that shows a steady relationship between variables helps us identify relationships that exist in nature. In this investigation, you will use a graph to predict the car's speed at any point on the ramp.

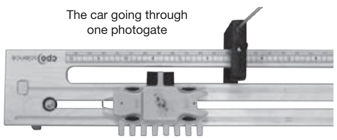
Materials:

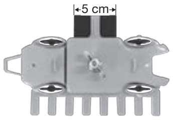
- ✔ Timer with one photogate
- ✔ Car and Ramp set
- ✔ Metric tape measure
- ✔ At least one calculator
- ✔ Graph paper
- ✔ Pencils
- ✔ Ruler or straightedge
- ✔ Physics Stand

❶ Finding the speed of the car

Using two photogates far apart allows you to measure the average speed of the car between the photogates. The car could be going faster at the lower photogate and slower at the upper one. But to get a true picture of how the speed of the car changes, you will need to measure the instantaneous speed at one photogate.

The car going through one photogate





$$\text{Speed} = \frac{5\text{ cm}}{\text{Time through photogate}}$$

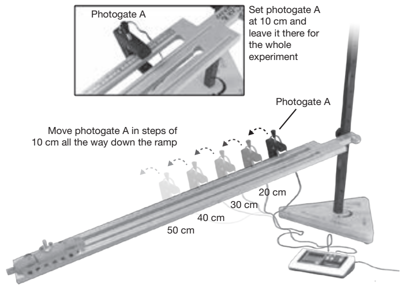
Remember, with one photogate, the timer measures the time that the beam is broken. As the car passes through the photogate, the light beam is broken for the width of the wing. The speed of the car is the width of the wing (**distance** traveled) divided by the time it takes to pass through the light beam (time taken). The advantage to this technique is that it is easy to move a single photogate up and down the ramp to make measurements of the instantaneous speed at many places.

After taking eight measurements and calculating the speed of the car at eight locations on the ramp, you will be asked to estimate the speed of your car between two of those locations. How accurately do you think you can estimate the actual speed of the car at a chosen spot in between two of your eight locations?

Explore INVESTIGATION **B2**

❷ Setting Up

1. Set up the ramp and physics stand at an angle given by your teacher.
2. Put photogate A at the 10 cm position. Record this position in Table 1.
3. Move photogate A to different positions 10 cm apart along the ramp. Record each position in Table 1.
4. For every position of photogate A, record the time through the beam in Table 1.
5. Take at least eight data points along the ramp. Start the car the same way every time.



6. Calculate the speed of the car using the car wing length (5.00 cm) and the time measurement. Record this value in Table 1.

Table 1: Position versus time data

Position of photogate A (cm)	Time through photogate A (s)	Distance traveled by car (cm)	Speed of the car at photogate A (cm/s)
10	0.0878	5.00	56.9
20	0.0611	5.00	81.8
30	0.0498	5.00	100.4
40	0.0435	5.00	114.9
50	0.0390	5.00	128.2
60	0.0358	5.00	139.7
70	0.0332	5.00	150.6
80	0.0312	5.00	160.3

Guiding the INVESTIGATION

❷ Setting up

You may wish to have every group use the same hole to connect the ramp to the stand, or you can have different groups use different holes and compare results. Holes 6 through 12 work well for the experiment.

Review how to calculate speed. This investigation uses the 1 cm wing on the car to get more accurate instantaneous speed values along the track. Students often make the mistake of dividing the time by 1 centimeter rather than dividing 1 centimeter by the time. Encourage students to look at their results and think about whether they are reasonable. If they divide the wrong way, they will get a speed of much less than 1 cm/s, and they should be able to see that this does not make sense.

Explore — INVESTIGATION B2

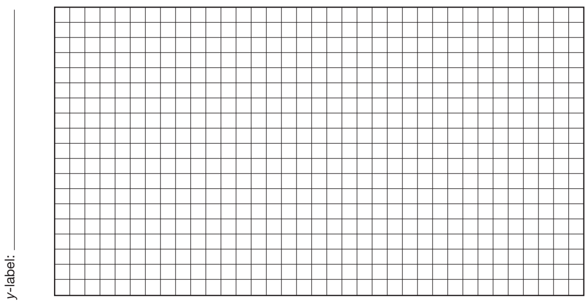
3 Graphing and analyzing your results

a. Do you notice a trend in your measurements? How does the speed of the car change as it moves down the ramp?

Yes, the speed increases as the car moves down the ramp.

b. Graph the speed of the car versus position. Place speed of the car on the *y*-axis and position of photogate A on the *x*-axis. Add labels to each axis and title the graph.

Title: ______



x-label: ______

See 3b sample graph.

c. What does the graph show about the speed of the car?

The speed increases smoothly, but the line is not straight. It's increasing a little less each 10 cm.

Explore — INVESTIGATION B2

4 Using your graph to predict the speed of the car

Answers will vary. Sample answers below.

a. Choose a spot on the ramp where you did not measure the speed of the car.

We chose 55 cm.

✓**b.** Use your graph to find the estimated speed of the car at that distance. Record your estimated speed. What percent correct do you think your estimated speed will be?

From the graph, we predict a speed of 135 cm/s at 55 cm. We predict a 10% difference between our estimated speed and the actual speed.

c. Place the photogate at the distance you selected in Step a. and record the time it takes for the car to pass through the photogate.

The car takes 0.0373 seconds to pass through the photogate.

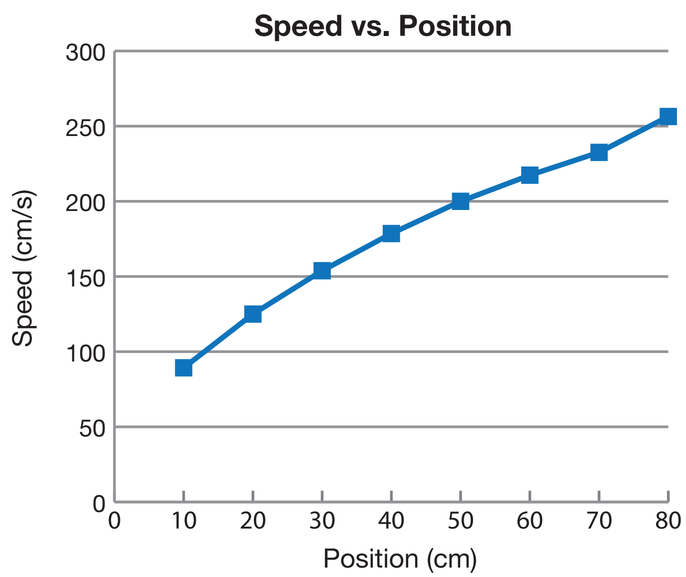
d. Use the wing length (5.00 cm) and the time to calculate the speed.

The actual speed at 55 cm is 5.0 cm/ 0.0373 s = 134 cm/s.

✓**e.** How does your estimated speed compare with the actual measured speed? What does this tell you about your experiment and measurements?

The prediction was pretty close, so our measurements and graph can be used to predict speeds with accuracy.

3b sample graph

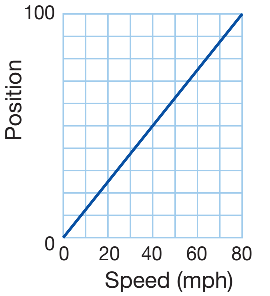


STEM CONNECTION

Stock Market Predictions Graphs are useful far beyond the walls of a science classroom. The stock market is a great example of graphs in action. After the prediction exercise, ask students what would happen if they could predict the stock market as well as they predicted the car's speed. Students will likely answer "I'd be rich." Ask students to think about why we can't predict the fluctuations in the stock market. The answer is that we have no control over the variables. In fact, if you did try to control the variables (and some people do), you would be arrested for securities violations. Science is much more predictable than human behavior, and among the sciences, physics experiments are the easiest for teaching students how to identify and control variables.

TEACHING TIP

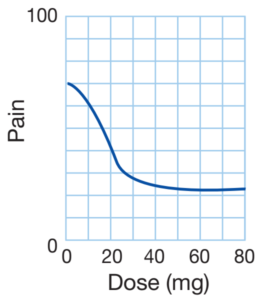
Speed vs. Position



Many students are used to seeing graphs that go up and to the right. The graph of speed vs. position will be a nice, predictable up-and-to-the-right sort of graph. It shows that the speed of the car increases as the car moves down the ramp.

The graph below does not follow this predictable pattern. Suppose you are testing a new kind of aspirin. You might do an experiment where you gave 100 people with headaches different amounts of aspirin and measured their pain before and after taking it. The results of your experiment could be put on a graph like the one below (sketch on the board). The vertical axis shows the amount of pain, with 0 being no pain, and 100 representing a lot of pain.

Aspirin Test



This graph is called a dose-response curve. Medical researchers use this type of graph to evaluate the effectiveness of new medicines. In this example, the best dose is about 40 milligrams; this is the smallest dose that produces the maximum decrease in pain. Another variable often tracked in dose-response diagrams is the pain sufferer's weight, so that exact dosing can be determined, such as 1 mg of aspirin per 4 pounds of body weight.

Explore INVESTIGATION **B2**

❺ Calculating percent error and percent correct

a. Find the difference between the estimated speed and the actual, calculated speed.

Estimated speed – Actual speed = Difference

135 cm/s – 134 cm/s = 1 cm/s

b. Take this difference and divide it by the estimated speed, then multiply by 100.

Difference ÷ (Estimated speed) × 100 = Percent error

1 ÷ 135 cm/s × 100 = 0.74% error

c. Use the percent error to calculate percent correct.

100 – Percent error = Percent correct

100% – 0.74% = 99.26%

d. How did your prediction compare to your percent correct? Did you do better or worse than you predicted?

We predicted that we would be within 10% of the actual speed, which we thought at the time would be pretty good. We were actually better than 1%, in fact we were only 0.7% off, which makes us 99.3% correct!

e. How well did your prediction compare to the predictions of the other groups in your class?

Most of the groups in our class did better than their predictions. We were one of the groups that did far better than we predicted.

f. What would you suggest to make your prediction even more accurate?

Being more consistent with release technique or creating a larger graph with more detail.

5 of 5
B2 Making Predictions Using a Graph
Car and Ramp

Guiding the INVESTIGATION

❺ Calculating percent error and percent correct

Discuss how to find the difference between two values. You can give an example of one person having $5 in her wallet, and another person having $20. What is the difference between the amount of money they have? Students will answer $15. Ask how they got the answer and why they didn't answer -$15.

When calculating percent difference, we need to use a positive value. Students should have learned about absolute value in math class; use that term to refer to how to calculate the difference between their predicted and actual speeds.

Evaluate

INVESTIGATION **B2**

Name ______________________ Date ____________

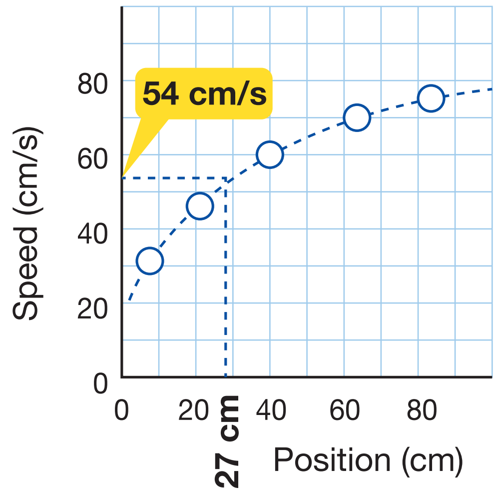
1. Calculate the speed of the car if it takes 0.04 second to pass through the photogate and the 5 cm wing is used to block the photogate beam.
   125 cm/s
2. Explain what it means to have a high percent error in an experiment.
   Percent error is a measure of how far apart two values are. A high percent error means the predicted and actual values are far apart, and the experiment or the prediction was not accurate.
3. Your predicted speed in an experiment is 110 cm/s, and the actual speed is 117 cm/s. Find the percent error and percent correct.
   The percent error is 6%. The percent correct is 94%.
4. Suppose you do an experiment to study the motion of skydivers. You make a scale model of a parachute, attach action figures of different masses to it, and measure the speed of each action figure as it hits the ground. Your data is shown below. Make a graph of the data, and use it to estimate the speed of a skydiver with a mass of 50 grams.

Mass (g)	Speed (m/s)
20.0	1.2
32.5	1.5
41.9	1.8
55.2	2.3
68.4	3.2

   2.2 m/s
5. Explain how a graph can be helpful when looking at data from an experiment.
   A graph can help you see the relationship between two variables. It can also help you make estimations for values for which you didn't collect data.

TEACHING TIP

When students need to make a prediction using their graphs, they will begin by finding the location on the ramp where they want to predict the speed. In the sample below, students are going to make an estimate of the speed of the car on the ramp at the 27 cm mark.



Once students find the location on the x-axis, they draw a straight, vertical line upwards until that straight line intersects the curve of the graph. Students will then make a point on the curve at this location. Using this new point, they will then draw a straight horizontal line over to the y-axis. The value given on the y-axis where the horizontal line intersects with it is the predicted speed of the car. In the example graph, the students' prediction will be 54 cm/s It may be helpful to draw a sample graph with your students and review this process with them.

WRAPPING UP

Have your students reflect on what they learned from the investigation by answering the following questions:

1. How can a graph be a useful tool?
2. Compare and contrast the meanings of the terms *percent error* and *percent correct*.

Notes and Reflections