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Elementary Science with Vernier

4th Edition

By
Marti Moore
David Carter
Barbara Andersen
Tara Windle

Vernier

EWV

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Vernier Software & Technology
13979 SW Millikan Way • Beaverton, OR 97005-2886
Toll Free (888) 837-6437 • (503) 277-2299 • Fax (503) 277-2440
info@vernier.com • www.vernier.com

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About the Authors

Juanita M. “Marti” Moore received her BAE in Curriculum and Instruction, an EdM in Curriculum and Instruction with an emphasis in Elementary Mathematics and Science, and her EdD in Elementary Education at the University of Mississippi. She has taught every grade from 1st to 8th in public and private schools in Mississippi and Tennessee. She currently teaches 1st grade English Language Learners at Charlotte Park Elementary School, Nashville, TN. She has also taught undergraduate teacher education courses at the University of Mississippi as a graduate assistant. She served as an Assistant Professor of Curriculum and Instruction at Mississippi Valley State, where she taught undergraduate and graduate courses and served as the Coordinator of the graduate program in Education. She has written science materials for the University of Mississippi and for mathematics textbooks. She has been a co-leader of the Delta Area Physics, Physical Science and Applied Mathematics program where she worked with middle school science and math teachers.

David Carter received a BA in Physics from Rhodes College, in Memphis, Tennessee, and EdM in K–12 Educational Leadership from the University of Mississippi, with additional graduate work in physics and education. He served as Laboratory Physicist at the University of Mississippi where he coordinated undergraduate physics laboratories. He taught middle school science and algebra 1 at the Westminster School in Nashville, Tennessee. He has conducted numerous teacher workshops as Field Coordinator and later as Project Director for the Delta Area Physics, Physical Science and Applied Mathematics Eisenhower Program in Mississippi. He served as the Director for the Institute for Effective Teaching Practices at Mississippi Valley State University. The Institute provided professional development opportunities for K–16 teachers in the Mississippi Delta region. He currently serves as STEM Training Director for Vernier Software & Technology, traveling all over the United States conducting teacher training sessions and workshops.

Barbara Andersen has a BS in Elementary Education from the University of Montana and an MS in Technology Integration from Lesley University in Massachusetts. All of her 16 years of teaching have been at Peterson Elementary in Kalispell, Montana. Barb is an instructor with Teachers Teaching with Technology, T^3, a professional development program for teachers sponsored by Texas Instruments. She assisted in the curriculum development of T^3’s Elementary Science workshop and their Environmental Science workshop. She is currently working on reviving the Electronic Field Trip (EFT) to Glacier National Park, where she enjoys sharing the wonders of her part of the world with classes around the globe. Two highlights of Barb's career are her selection as the Elementary Science Teacher of the Year in 2003 for Montana and the Presidential Award for Excellence in Science in 2004. In addition to assisting with this book, Barb has authored several novel unit guides for Kendall Hunt Publishing's Literature-based reading program, including one on oceans.

Tara Windle has been a classroom teacher in South-Western City Schools near Columbus, Ohio since 1978. She received a BA from Bowling Green State University in Elementary Education with a minor in Math Education. She taught all subjects in 7th and 8th grades for 17 years, but math and science were her loves. During that time she received a MA in Math Education from The Ohio State University. In 1995, she moved to Franklin Heights High School to teach algebra and geometry and was introduced to graphing calculator technology. As her sons began school, she experimented (quite successfully) with their kindergarten teacher using graphing calculator technology with five-year-old students. Tara was asked by Texas Instruments to be part of a writing team for elementary science lessons using graphing calculators and Vernier sensors. Tara has been a T3 instructor since 1998, and has done professional development for elementary and middle school teachers around the country. After eight years at the high school level, she is currently teaching at the intermediate level and using data collection technology with 5th and 6th graders.

Contributing Editors

Alexandria Plank received her BA in Geology from Pomona College in Claremont, California, an MA in Geography from University of Oregon in Eugene, and an MS in Education from Portland State University in Portland, Oregon. Alex has been employed by Vernier since 1994 and is Senior Publications Specialist in the Publications Department. She is co-author of *Investigating Solar Energy*, *Investigating Wind Energy*, and *Renewable Energy with Vernier* lab books.

Marianne Sweeney received her BS in Elementary Education with a Music minor, from College Misericordia in Dallas, Pennsylvania. She received her MS in Philosophy and Education from Teacher's College, Columbia University, New York. She taught in Jefferson County Colorado for two years and then at Riverdale Grade School in Portland, Oregon for 30 years. She has written materials used by the Classroom Law Project and Oregon Children's Theater.

Robyn L. Gastineau received her BS in Integrated Science Education from George Fox College in Newberg, Oregon, and her MST in Chemistry from Portland State University (Oregon). She taught science in Vancouver, Washington for 11 years before coming to work at Vernier in 1998. She is a co-author of *Water Quality with Vernier* and *Earth Science with Vernier* lab books.

Proper safety precautions must be taken to protect teachers and students during experiments described herein. Neither the authors nor the publisher assumes responsibility or liability for the use of material described in this publication. It cannot be assumed that all safety warnings and precautions are included.

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Preface

Probeware is an integral and indispensable component of a science activities in the classroom. This book contains experiments that make use of Vernier data-collection technology for data collection and analysis. We hope this book will make it easier for you to bring meaningful, hands-on science into your classroom.

It is important that your students understand that science involves hypothesizing, collecting data, then analyzing that data to determine whether the hypothesis was correct. Young students may worry about whether their hypothesis is correct or not. In order for students to enjoy science and learn from it, they need to feel comfortable with their hypothesis being incorrect. Assure them that this is all part of the scientific process and that their grade will depend on careful thought and complete answers, not necessarily a correct hypotheses.

The materials needed for the activities in this book are, for the most part, everyday items. Cups are often listed, but if you have beakers available, you can use them instead. You might want to buy some mugs with handles for use in the activities. These can be used over and over again. Clearly label them for science use only so they are not used for drinking. Other items can easily be substituted throughout this book. See Appendix B for a complete list of equipment and supplies.

Several of these activities involve water. In these cases, we suggest that you have the students conduct their work on trays such as those that are found in a cafeteria or fast food restaurant. If a spill should occur, the water will be confined to the tray. Additional safety information can be found in Appendix C.

Electronic Resources

Rather than acting as stand-alone curriculum, the purpose of this book is to supplement the science-teaching materials adopted for use in your school. To that end, this book comes with Electronic Resources that include word-processing files and PDFs of the student experiments, in addition to other supporting files. Log into you account at **vernier.com/account** to download the Electronic Resources. If you don't have an account, you can create one on that same web page.

The site license that accompanies this book allows you to share the files in the Electronic Resources with others at your school. You can upload the files to a password protected intranet site, but please do not make the files available on the Internet or other sites that can be accessed by people outside of your school.

Student Activities

The activities in this book are a mixture of guided activities, student inquiry, and class activities based on teacher demonstration. If you only have one Chromebook, computer, or mobile device available, most of the activities can be done as a teacher demonstration.

PDFs and word-processing files of the student activitys are provided in the Electronic Resources, so you can print and modify the activitys to best match your equipment and teaching preferences:

- **PDF files**: Print the PDF version of the student activity and have students follow the procedures as they are written. This format is also ideal for viewing activitys on mobile devices or other platforms.
- **Word-processing files**: Edit the word-processing files to fit your teaching style. Some instructors update the materials list to match the specific equipment in their classroom. Teachers who prefer inquiry-style activitys often remove data tables and reduce the amount of detail in the procedures.

Teacher Information

The Teacher Information section for each experiment has sample results, answers to questions, directions for preparing solutions, and other helpful hints regarding the planning and implementation of the activity.

Appendices

The appendices include valuable information:

Appendix A: Electronic Resources

There are multiple versions of each student activity—one for each supported data-collection software (e.g., Graphical Analysis). Appendix A includes detail about which Vernier data-collection programs are supported in this book as well as any other supplemental materials that may be available.

Appendix B: Equipment and Supplies

A complete list of equipment and supplies needed for performing the activitys in this book can be found in Appendix B.

Appendix C: Safety Information

See Appendix C for important safety information regarding the use of chemicals. More detailed and comprehensive safety information can be found within each Teacher Information section and in the SDS that accompanied the chemicals at time of purchase.

Name: ________________________________

Graphical Analysis **1**

Learning to Use a Temperature Probe

You can use a Temperature Probe to measure the temperature of many things, like water, air, or your hand. In this activity, you will learn how to use a Temperature Probe and Graphical Analysis.

OBJECTIVES

- Measure the temperature of your hand.
- Explore graphs produced by moving a Temperature Probe between cups holding water with different temperatures.
- Learn to write detailed steps to be able to create the shape of an **M** or **W** on the graph using the Temperature Probe.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
cup of warm water
cup of cold water
paper towels or rags to clean up spills
tray

PROCEDURE

Part I Learn about the Temperature Probe

1. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.
2. Follow these steps to get the materials ready to do this part of the activity:
   a. Put the Temperature Probe on the table and don't touch it again until you're told to do so later on.
   b. Get a cup and fill it about half full with cold water.
   c. Get another cup and fill it about half full with warm water.
   d. Put the cups on the tray and be careful not to tip them over. If the cups spill, get a towel to clean up and tell your teacher right away.

3. Now you will collect data with the Temperature Probe by following these steps. After, you will write down what you observe during data collection, so carefully watch what happens. You may want to look at the Observations Sheet in the next step to know what observations you will make.
   a. Look at the screen and click or tap Collect to start data collection.
   b. Pick up the Temperature Probe and put the tip of the metal part in your hand:

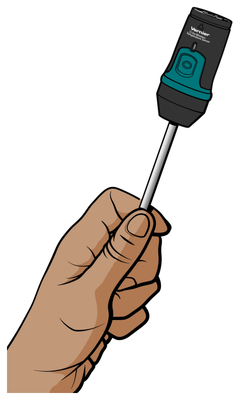

Figure 1

   c. Watch how the temperature of the probe changes on the screen.
   d. After a little while, the temperature will stop changing so much. When this happens, put the metal part of the probe into the cup with the warm water. Be careful not to tip over the cup.
   e. Again, watch how the temperature of the probe changes.
   f. After a little while, the temperature will stop changing so much. When this happens, put the metal part of the probe into the cup with the cold water. Be careful not to tip over the cup.
   g. Again, watch how the temperature of the probe changes.
   h. Click or tap Stop to stop data collection.

4. Answer the questions on the Observations Sheet based on your observations during data collection. You can add drawings to help describe what you saw.

Observations Sheet
1. When I put the Temperature Probe in my hand, the temperature reading
2. When I put the Temperature Probe into the warm water, the temperature reading
3. When I put the Temperature Probe into the cold water, the temperature reading

Part II Making letters with the Temperature Probe

5. Click or tap Mode to open Data Collection Settings. Set End Collection to 60 s. Click or tap Done.

6. In this part of the activity, you will complete writing the steps necessary to create the letter **M** using a Temperature Probe. An example of what this might look like is shown in Figure 2. Think about how you would make a similar M shape and fill in the blanks. Read and fill in all the blanks before starting data collection.
   a. Start with the Temperature Probe in the air.
   b. Click or tap Collect to start data collection.
   c. Keep the Temperature Probe in the air for 5 seconds.
   d. Put the Temperature Probe in _____________ (warm or cold) water.
   e. When the temperature stops changing a lot, move the Temperature Probe into the _____________ (warm or cold) water.
   f. When the temperature is close to the starting temperature, move the Temperature Probe into the _____________ (warm or cold) water.
   g. When the temperature stops changing a lot, move the Temperature Probe into the _____________ (warm or cold) water.
   h. When the temperature is close to the starting temperature, click or tap Stop to stop data collection.

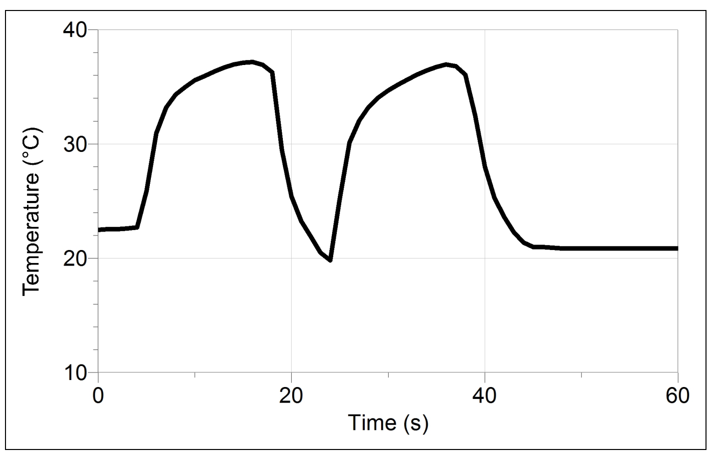

Figure 2

7. Do the following to get the materials ready to make the letter **M**.
   a. Put the Temperature Probe on the table.
   b. Refill your cups with warm and cold water, if needed.

8. Follow the steps you wrote in Step 6 to make a graph that looks like an **M**. When prompted, discard your earlier data.

9. If the graph looks like an **M**, congratulations! You can move on to the next step. If you want to try to make the **M** again, try again.

10. After you've made the letter **M**, you will try to make the letter **W**. Write down the steps you would take to make a letter **W**. Use the words in Step 6 as a pattern. **Hint**: You don't need to start with the probe in the air.

11. Do the following to get the materials ready to make the letter **W**:
    a. Put the Temperature Probe on the table.
    b. Refill your cups with warm and cold water, if needed.

12. Follow the steps you wrote in Step 10.

13. If the graph looks like a **W**, congratulations! If your teacher says it is okay, you can try making other letters or shapes. If you want to try to make a **W** again, try again.

Learning to Use a Temperature Probe

BACKGROUND INFORMATION

This activity serves as an introduction to using a Temperature Probe and a data-collection program to collect and analyze temperature data.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Crosscutting Concepts	Science and Engineering Practices
Cause and effect	Planning and carrying out investigations

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. Prior to doing the activity with students, it would be a good idea to read through the student version to look for terms that your students may not be familiar with such as "collect data." You could introduce these words to students as an introduction to the activity.

3. To set stage for a successful activity, you may also show students how to connect the probes and demonstrate some of the steps of the Procedure.

4. We suggest that you provide each group with a tray such as those found in the cafeteria or fast-food restaurant. If students work with the liquids on a tray, it can help protect the electronic equipment from potential damage caused by spills. See the preface for more safety information.

5. You have a variety of options for the types of cups that you use in this and other activities in this book. An inexpensive option would be to buy a set of plastic party-type cups. One concern with using these of cups is the possibility of spilling because they aren't very stable. If you do use plastic cups, remind your students throughout the activity to keep their hands on the probe in order to reduce the likelihood of spilling. A good alternate is to get a set of mugs with handles. These can be bought inexpensively at a thrift store or dollar store. The mugs are more stable and the handles will make it easier for the students to carry them around. Try to get mugs

with a large diameter that will hold a soda-pop size bottle. During Activity 18, "Under Pressure," it is helpful for students to place their bottles in a mug.

6. The warm water used by students should not be boiling. Hot water out of the tap should work well, as long as it is above about 30–32°C. If your students fill up their own cups, tell them to let the water run until it is hot. If you do not have easy access to a sink, try maintaining the temperature of the water on a hot plate, or put heated water in an insulated thermos.
7. The cold water can come from the tap. Ensure that the temperature is different enough from the warm temperature bath to make it possible for students to make the letters. If you do not have easy access to a sink, try making a cold-water bath by adding ice to cold water and keeping it in a thermos.
8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.
9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Part I

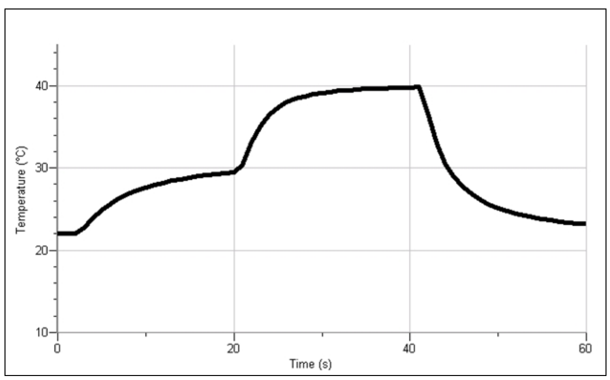

Figure 1 Temperature data from a hand, warm water, and cold water.

Part II

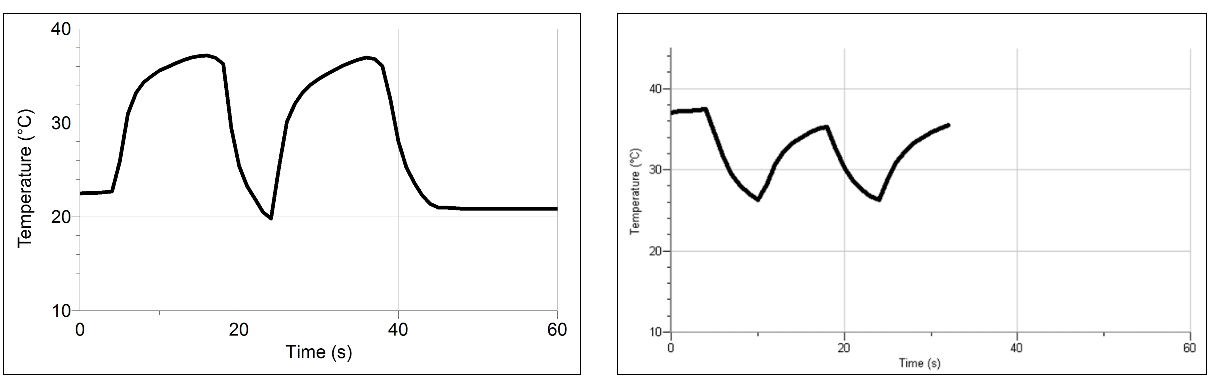

*Figure 2 Sample **M** and **W** shapes made with a Temperature Probe and water.*

ASSESSMENT

1. Ask students when they might want to use a Temperature Probe during their day or why their family members may want to use one.

2. Ask students what other letters could be made and how they would do it.

EXTENSIONS

1. Have students draw letters and try to match them. You could suggest that they draw very wide, narrow, or tall M or W shapes.

2. Encourage students to look at the digital meter (all data-collection programs) or thermometer (Logger Lite only). Ask them if they can pick a temperature and make the probe stay at that temperature.

3. If you have enough temperature probes, try making the letter X or the letter A. (Students could either use two Temperature Probes simultaneously or collect data with one probe, store a run, and collect a second run with the same probe.)

Name: ______________________________

Graphical Analysis **2**

How Do Mittens Keep You Warm?

Do you have a favorite pair of mittens or gloves? Even if you do not live in a cold place, it is possible that you have been somewhere cold or will go to a cold place when you are older. When you wear mittens or gloves to keep you warm, where do you think the warmth comes from? In this experiment, you are going to find the source of the heat.

OBJECTIVES

- Find the temperature of the classroom and the temperature of your hand.
- Try to predict temperature changes that happen when the Temperature Probe is placed in various locations.
- Test how warm mittens help your hands stay warm.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
mitten

KEY QUESTION

Do mittens make heat or hold heat in?

HYPOTHESIS

Choose one of the following by checking the box in front of the statement that you think is right.

□ 1. Mittens make their own heat.

□ 2. Mittens hold heat in.

Why do you think so?

____

____

____

PROCEDURE

1. Get the equipment ready for data collection:
   a. Launch Graphical Analysis.
   b. Connect the Temperature Probe to your Chromebook, computer, or mobile device.
   c. Put the Temperature Probe on the desk and don't touch it until you are told to do so later on.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 60 s. Click or tap Done.

3. Do the following to find the temperature of the classroom:
   a. Make sure the Temperature Probe is lying on the desk and hasn't been touched by anyone. If it has been lying there for a few minutes, it will be the temperature of the room.
   b. Look at the meter and write down the temperature as the Room temperature in the Data Table.

Data Table		Room temperature ____________ °C	
	Prediction (°C)	Maximum temperature (°C)	Was your prediction high or low?
Open hand			
Empty mitten			
Open hand in mitten			

4. Make a prediction:
   a. Think about what will happen to the temperature on the screen if you hold the probe across the palm of your open hand during data collection. Think about your body temperature compared to the room temperature.
   b. Guess how high the temperature will be at the end of data collection and write down your prediction in the Data Table.

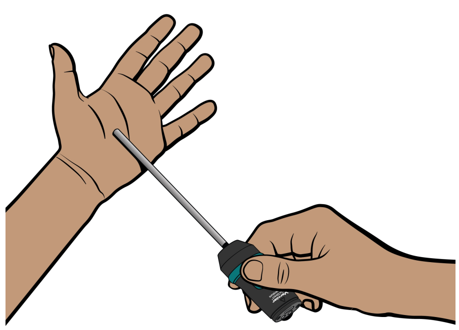

Figure 1

5. Now, collect data for the temperature of your open palm:
   a. Make sure the temperature values on the meter are very close to the value you recorded as the room temperature in your Data Table in Step 3.
   b. Click or tap Collect to start data collection.
   c. Place the tip of the metal part of the probe in the middle of your open palm, holding it by the black end with your other hand. **Important**: The tip of the probe should be gently touching your palm. Don't close your fingers over the metal part.
   d. Hold the probe in the correct position during data collection.

6. Do the following to find the maximum temperature of your open palm:
   a. Click or tap View, , and choose Graph and Table.
   b. Look through the data table on the screen and find the maximum (largest) temperature value.
   c. Record this value in the correct place on the Data Table.

7. After you have finished finding the temperature of your open palm, place the Temperature Probe on your table and allow it to sit there without being touched. This way, the probe will cool down to the temperature of the room. While it cools, continue with the next step.

8. During this part of the experiment, you will place the Temperature Probe inside the mitten so you can measure the temperature inside the mitten. You will not have a hand inside the mitten, just the Temperature Probe.
   a. Think about what will happen to the temperature inside a mitten while it is sitting on the desk. The Temperature Probe will be inside the mitten but your hand will not be.
   b. Now, guess how high the temperature will be at the end of data collection and write down your prediction in the Data Table.
   c. Without touching the Temperature Probe, look at the temperature values in the digital meter on the screen. Make sure the temperature is very close to the value you recorded as the room temperature in your Data Table. If the temperature is not very close, wait until it is.
   d. Place the mitten on the table and slip the Temperature Probe into the mitten. Make sure you do not touch the metal part of the probe.
   e. Click or tap Collect to start data collection. **Note**: The first data set is automatically saved.
   f. When data collection is done, look through the data table on the screen.
   g. Find the maximum (largest) temperature value for the Latest data. Record this value in the correct place on the Data Table.
   h. Place the Temperature Probe on the table and allow it to sit there without being touched.

9. During this part of the experiment, you will measure the temperature of your hand inside the mitten.
   a. Think about what will happen to the temperature of your hand inside the mitten.
   b. Now, make a prediction about how high the temperature will be at the end of data collection and write down your prediction in the Data Table.
   c. Without touching the Temperature Probe, look at the temperature values in the digital meter on the screen. Make sure the temperature is very close to the value you recorded as the room temperature in your Data Table in Step 3.
   d. Place the mitten on your hand and slip the Temperature Probe into the mitten (see Figure 2). Position the tip of the probe in the middle of your palm. Leave your hand open during data collection, do not close your fist.

e. Start data collection.
f. When data collection is done, look through the data table on the screen.
g. Find the maximum (largest) temperature value for the Latest data. Record this value in the correct place on the Data Table.

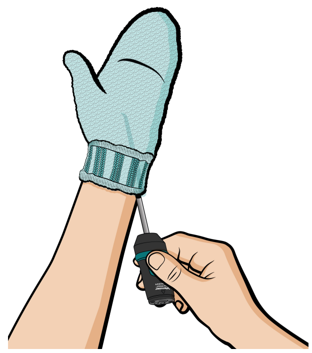

Figure 2

ANALYZE YOUR DATA

1. What is the source of heat in this experiment?

____

____

2. If the mitten does not produce heat on its own, then how do mittens keep your hands warm?

____

____

3. Thinking about the previous question, explain the difference between heat production and heat retention.

____

____

How Do Mittens Keep You Warm?

BACKGROUND INFORMATION

The goal of this activity is for students to discover that mittens are warm because they help hold in heat from the body and minimize its loss into the air. In other words, mittens act as insulators. Humans are warm-blooded animals. We typically maintain a body temperature of 37°C (98.6°F). On cold days, we lose some of our body heat to the air and our surroundings. This is because heat flows from materials with higher temperatures to materials with lower ones. One of the purposes of clothing is to hold in our body heat and minimize this heat loss. This is the reason we change the amount and kind of clothes we wear depending on weather.

The first several temperatures are taken to allow students to discover that (a) air temperature is usually less than body temperature and (b) the temperature of the surface of a hand is typically below normal body temperature because heat is lost to the cooler surrounding air.

The final steps of the activity are done to show the insulating ability of the mitten. By itself, the empty mitten should have the same temperature as the air temperature. With your hand in the mitten, the temperature is higher because your hand is providing heat to warm the Temperature Probe. This temperature is also greater than the previously recorded temperature of the palm without the mitten. The mitten prevents the cold air from the outside from making contact with your hand; the mitten insulates your hand from the cold surroundings. Thus, our hands are warmer when we have mittens on.

Even if you live in a warm climate, you can do this activity. Many students will have been to colder places and can share their experiences with the rest of the class. You can also relate this activity to holding a cold drink or ice cream. Tell students that if they do go to a cold place in the future, they'll be able to help their family buy the things that they need by sharing the information they learn in this activity.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Language Arts – *The Mitten*, by Jan Brett, is a wonderful picture book to read. Discuss why the animals might want to snuggle in the mitten. A class discussion of the story and of appropriate clothing for different weather will lead students to a hypothesis of how mittens keep hands warm. If you choose to read this book to your students, you may want to use the following introduction in addition to what is already in the student version of the activity: Listen to your teacher read *The Mitten* by Jan Brett. Why do you think all the animals wanted to snuggle in Nicki's mitten?

Math – comparisons, graph analysis

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting temperature data with Vernier equipment, we recommend that you start with Activity 1.

3. You can introduce the activity by reading the story, *The Mitten*, by Jan Brett. A discussion of the story and of appropriate clothing for different weather will lead the students to a prediction of how mittens keep hands warm.

4. Discuss the Key Questions as a large group. You can have students write their hypothesis and then share with the class.

5. If you do not have sufficient mittens, but you do have wool or synthetic, hiking-type socks, you may do the activity with those instead.

6. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

	Maximum temperature (°C)
Open hand	28.1
Empty mitten	26.4
Open hand in mitten	33.5

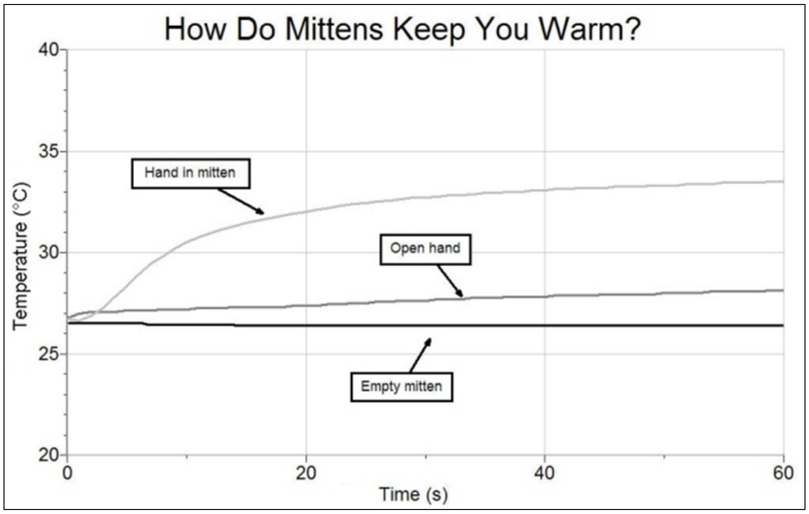

Figure 1

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. The source of heat in this experiment is the student's hand, not the mitten.
2. Your hands produce the heat and the mittens keep the heat concentrated around your hands.
3. Answers will vary, but should include the facts that heat retention is the ability to keep the heat from leaving the mittens, and that without a source of heat the mittens will eventually cool to room temperature.

ASSESSMENT

Have students transfer what they have learned by writing about how heat is produced in their own homes and how this heat is retained. Asking them to write about how their homes are kept cool in the hot season can be a nice extension.

EXTENSIONS

1. Students can bring in their own mittens or gloves to compare how well they insulate their hands.
2. Invite in a community member, such as a rescue worker, who can discuss how heat is lost in air and how heat is lost in water. Have students make a Venn diagram while they listen to the talk to compare and contrast heat retention and loss. Another idea for a speaker would be someone who works with a greenhouse to discuss what they do for heat production and heat retention.

Name: ______________________________

Baggie Mittens

Humans create their own body heat by eating and then converting food, water, and body fat into other forms of energy, including heat energy. Our bodies are also affected by the temperature of our surroundings. In a process called *conduction*, heat always travels from a warmer area to a cooler area. Sometimes our body is the warmer area; sometimes it is the cooler area.

This effect of the external temperature explains why we wear different types and amounts of clothing in different seasons. To minimize the loss of heat from our bodies during the winter, we wear warm clothes and lots of layers. To help us eliminate heat from our bodies in hot weather, we wear clothes made of light, thin material.

Insulators minimize the flow of heat from warmer areas to cooler ones. The better the insulator, the less the temperature will change over a certain time period because it takes longer for the heat to be conducted through the insulator.

OBJECTIVES

- Compare mittens made of plastic baggies containing different types of insulation.
- Determine how long would it take for a person's hand to get cold wearing different kinds of mittens.
- Use graphs to get information about the different materials' performance.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
2 different baggie mittens
ice pack
paper towels or rags to clean up spills

PRE-LAB PREDICTION

Look at the kinds of insulation your teacher has provided and choose two baggie mittens made out of different materials. Predict which material will best hold in the heat, or, in other words, will be the best insulator. Write down the name of the material in the first space of the Insulator column. Write down the type of material of the other baggie mitten in the second space in the Insulator column.

Data Table			Room temperature: ____________°C		
Prediction rank	Insulator	Minimum temperature (°C)	Maximum temperature (°C)	Change in temperature (°C)	Actual rank
1					
2					

PROCEDURE

1. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device. Don't touch the Temperature Probe until you are told to do so in a later step.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 120 s. Click or tap Done.

3. Do the following to find the temperature of the room:
   a. Make sure the Temperature Probe is still on the table and hasn't been touched.
   b. Look at the temperature displayed in the meter on the screen.
   c. The temperature readings should be *constant*. That is, the readings should stay just about the same. This temperature is important because the Temperature Probe must be at room temperature before each test you do with the baggie mitten.
   d. Record the temperature as the room temperature in the Data Table.

4. Now you will follow these steps to collect data for your first baggie mitten:
   a. Get one of the baggie mittens and place your left hand inside it.
   b. Now, put the Temperature Probe in the bag so the tip of the probe is touching your palm.
   c. Watch the temperature on the screen and keep the probe in the same position until the temperature is constant (stays about the same). This will take about 1 minute.

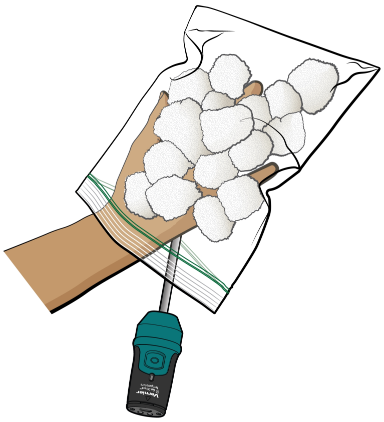

Figure 1

Figure 2

5. When the temperature of the probe is constant (stays the same), collect data by doing the following:
   a. Get an ice pack from your teacher and place it on the table.
   b. Have a teammate click or tap Collect to start data collection.
   c. With your hand still in the baggie mitten and the tip of the Temperature Probe touching your palm, put your hand, palm down, on the ice pack.
   d. During data collection, keep your hand in the same place, with the tip of the probe touching your palm.

6. When data collection ends, do the following to find the change in temperature during data collection:
   a. Click or tap Graph Tools, , and choose View Statistics.
   b. Find the Minimum (Min) temperature and the Maximum (Max) temperature of your data and record these values in the Data Table, on the line for the type of baggie mitten you were using.
   c. Subtract the Minimum value from the Maximum value to find the change in temperature. Dismiss the Statistics Box.

7. Now follow these steps to collect data for your other baggie mitten:
   a. Look at the temperature readings on the screen to make sure that the Temperature Probe is at the temperature of the room.
   b. Get the next baggie mitten and place your right hand inside it. You are changing hands so that when you collect data this time, your beginning hand temperature will be the same temperature as it was in the first run.
   c. Now, put the Temperature Probe in the bag so the tip of it is touching your palm.
   d. Keep your hand in the bag until the temperature in the meter stops changing very much.

e. Click or tap Collect to start data collection.
f. Put your hand, palm down, on the ice pack.

8. When data collection ends, do the following to find the change in temperature during data collection:
   a. Click or tap Graph Tools, 📈, and choose View Statistics.
   b. Find the Minimum (Min) temperature and the Maximum (Max) temperature of your data and record these values in the Data Table, on the line for the type of baggie you were using.
   c. Subtract the Minimum value from the Maximum value to find the change in temperature. Dismiss the Statistics box.

ANALYZE YOUR DATA

1. Which insulation material did you predict would be the one that would hold the heat the longest and why did you choose it?

___

___

___

2. Which insulation material actually did retain the heat the longest? Explain why you think this happened.

___

___

3. Which of the materials that you tested surprised you the most? Why?

___

___

Baggie Mittens

BACKGROUND INFORMATION

Humans create their own body heat by converting food and body fat into other forms of energy. Our bodies are also affected by the temperature of our surroundings. In a process called *conduction*, heat always travels from a warmer area to a cooler area. Sometimes our body is the warmer area, sometimes it is the cooler area.

This effect of external temperature explains why we wear different types and amounts of clothing in different seasons. To minimize the loss of heat from our bodies during the winter, we wear warm clothes and lots of layers. To help us eliminate heat from our bodies in hot weather, we wear clothes made of light, thin material.

Insulators minimize the flow of heat from warmer areas to cooler ones. The better the insulator, the less the temperature will change over a certain time period because it takes longer for the heat to be conducted through the insulator.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Language Arts – *The Mitten*, by Jan Brett, is a great read-aloud book for kids of all ages.

Math – graphs, ranking

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting temperature data with Vernier equipment, we recommend that you start with Activity 1.

3. In this activity, students will compare different materials to determine which are better insulators. Each group will need access to each of three types of baggie mittens. To make these mittens, follow these instructions.
   a. Turn one quart-sized zipper-type plastic bag inside out.
   b. Insert it inside a second bag that is still right side-out. If you do this correctly, you will be able to seal the two bags together.
   c. Before zipping them together though, insert the insulation materials between them.
   d. Label each bag with the name of the insulation it contains.

4. You can change the material you place inside the baggie mittens to accommodate what you have available. Make at least two types of baggie mittens. If you have eight groups and make four sets of two, the student groups can rotate through them. If you have sufficient materials, you may want to make a few extras to keep faster groups occupied.

5. The materials list in the student version of the activity calls for an ice pack. If you do not have a sufficient number of ice packs, you can place ice cubes in a sandwich-size, zipper-style baggie. The ice packs are preferable because they tend to leak less.

6. You may want to model how to do this activity. Tell students that the same person needs to be the subject for two data-collection runs. Also, remind them that they need to switch hands between the two data collection runs. While this isn't ideal scientific methodology, it will help to ensure that the initial temperatures are the same for the two runs.

7. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Note: As the student version of the activity is written, students collect data for two types of baggie mittens. Several examples are shown here so that you can choose materials that may produce varied results.

Insulator	Final temperature (°C)
Feathers	22–24
Styrofoam	20–23
Foil	20–23
Cotton balls	22–24
Denim	17–20
Fleece	22–25

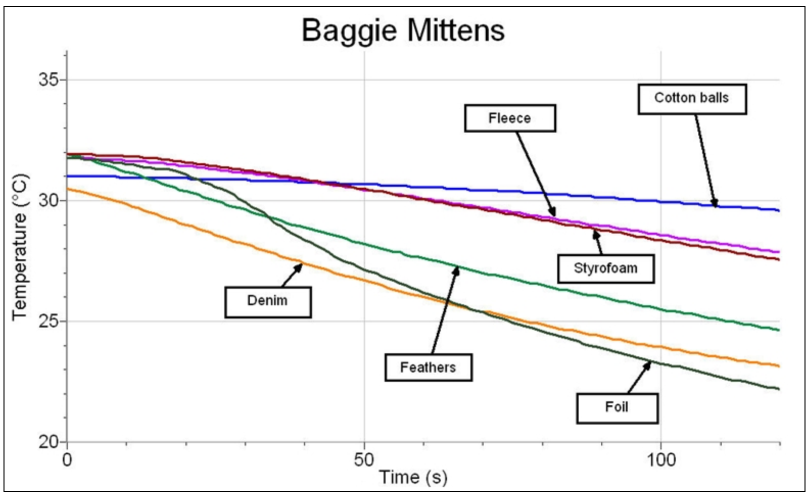

Figure 1 Temperature over time for six different insulation materials

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers will vary.
2. Answers will vary.
3. Answers will vary, but based on the sample data, the student should choose the insulation that was farthest from their prediction.

ASSESSMENT

Have the students write a short paper on what features they will look for in their next purchase of gloves or mittens.

EXTENSIONS

1. Students can try this activity with their own mittens or gloves.

2. Bring in a building contractor as a guest speaker. Have the speaker discuss what features they look at when they are bidding and then insulating new homes. Other guest speakers could be ski patrollers who could discuss hypothermia signs and how insulation can help or hinder this danger.

3. Have students brainstorm other materials they could use and have them make their own baggie mittens at home. They could then bring in their mittens to test.

4. Test to see how wetness affects the ability of a material to insulate. You could make up some cotton and wool baggie mittens and test to see which is a better insulator when it is wet.

Name: ______________________________

The Sole Purpose!

Have you ever wondered how shoe companies decide what kind of sole to put on the bottom of their shoes? This activity explores the heat produced by friction on different sole materials. You will rub a Temperature Probe back and forth across several different shoe soles to collect temperature data. Then you will compare and analyze your results to decide why different shoes have soles made from different materials.

OBJECTIVES

- Predict which shoe sole will get the hottest and which will stay the coolest.
- Compare the temperatures of different line graphs and analyze your data.
- Discuss the purpose of each type of shoe, and why the sole is made from that material.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
4 shoes with different types of soles

KEY QUESTION

Does the type of sole on a shoe affect the amount of friction (heat) you can produce by rubbing a Temperature Probe on it for 20 seconds?

HYPOTHESIS

I think that the ________ shoe with the ___________ sole will get the hottest because

____

I think that the ________ shoe with the __________ sole will stay the coolest because

____

PROCEDURE

1. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device. Put the Temperature Probe on the table and don't touch it until you are told to do so later on.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 120 s. Click or tap Done.

3. Choose four shoes with different types of soles.

4. Fill in the first two empty columns in the Data Table.

Data Table		Room temperature: ________________ °C	
Shoe	Description of shoe and sole	Main use of shoe	Final room temperature (°C)
1			
2			
3			
4			

5. Do the following to find the temperature of the classroom:
   a. Make sure the Temperature Probe is still on the table and has not been touched.
   b. Look at the temperature displayed on the screen.
   c. The temperature readings should be constant; that is, they should stay just about the same as you read the meter. This temperature is important because the Temperature Probe must be at room temperature before each test you do.
   d. Record the room temperature in the Data Table.

6. Collect data while you rub a Temperature Probe on the sole of a shoe by following these steps:
   a. Pick up Shoe 1.
   b. Click or tap Collect to start data collection. Rub the Temperature Probe back and forth across the sole of the shoe during the whole data-collection period.
   c. When you are done, put the Temperature Probe on the table and don't touch it until you are told to do so later.

Figure 1

7. Determine the final temperature of the run:
   a. Click or tap View, ⊞, and choose Graph and Table. Scroll down through the data of this run to find the final temperature.
   b. Write down the final temperature in the Data Table.

8. Repeat Steps 6–7 for each of the other shoes. Each time, be sure to
   - Make sure the Temperature Probe is at room temperature before you start.
   - Rub the Temperature Probe at the same speed that you rubbed the first shoe.

   Note: The previous data set is automatically saved each time you click or tap Collect.

ANALYZE YOUR DATA

1. Click or tap the word Temperature on the Temperature axis. Select all three sets of data so all three are checked. Dismiss the box to see a graph with all your data. What did you notice about the beginning temperatures of each set of data? Were they the same? Why or why not?

   ____

   ____

2. What did you notice about the ending temperatures of each graph? Were they the same? Why or why not?

   ____

   ____

3. How close was your hypothesis? Which shoe got the hottest and which shoe was the coolest?

   ____

   ____

4. Which shoe would be the easiest to slide around on (and so has the lowest friction)?

   ____

5. How does the temperature increase relate to the friction on the sole of the shoe?

   ____

   ____

6. For what kind of activity would you want shoes with high-friction soles? For what kind of activity would you want low-friction soles? Explain your answers.

   ____

   ____

   ____

The Sole Purpose!

BACKGROUND INFORMATION

In this activity, students compare the different materials used to make the soles of four types of shoes. Basketball shoes need to create a lot of friction to minimize sliding while bowling shoes have smooth soles to allow for maximum sliding. Students will predict the amount of friction each sole will produce, use the Temperature Probe to create friction on the soles of different shoes, and finally analyze the results.

TIME FRAME FOR ACTIVITY

This activity takes about 50 minutes. If you would like to break up the activity over two days, a good stopping point is after collecting data for two shoes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – the scientific process, friction, thermal energy

Math – graphic analysis; statistics including minimum, maximum, and mean; line graphs

HELPFUL HINTS

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2. If this is the first time your students will be collecting temperature data with Vernier equipment, we recommend that you start with Activity 1.

3. Gather shoes with soles that have a variety of textures and materials: smooth leather soles, rubber soles, bumpy soles, and/or wood or cork soles. More variety in style, material, and design will provide a wider variation in the students' results. Be careful, however, as very bumpy or lugged soles can offer a challenge and their results may be difficult to explain in comparison to data from other types of soles. A trip to your local thrift store might help provide the variety to produce varied results.

4. It is important that students return the probe to room temperature before beginning each run. To make this happen more quickly, you can give each group a cup of room-temperature water. The students can place the probe in the water for about 10 seconds and then dry it off with a paper towel or rag. Warn them not to rub the probe vigorously to dry it off or the heat they produce through friction will cause the probe to heat up.

5. It is also important that the students rub the sole of each shoe at approximately the same rate for each run. Rubbing much more quickly causes increased friction, and as a result, a relatively high level of temperature change.

6. Bumpiness is not the only factor that will affect the final temperature during each run. Shoes with smooth, soft rubber soles may reach a higher temperature because the softer rubber will cause increased friction while hard, bumpy rubber soles may not cause as much friction.

7. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Data Table		Room temperature: 24.8°C	
Shoe	Description of shoe & sole	Main use of shoe	Final temperature (°C)
1	Red canvas high top sneaker with smooth rubber sole	Basketball	32.3
2	Black leather boot with bumpy rubber sole	Hiking, walking in snow	40.2
3	Tan leather dress shoe with smooth leather sole	Dressing up, weddings	27.4
4	Blue plastic sandal with thin vinyl sole	Pool, beach	29.0

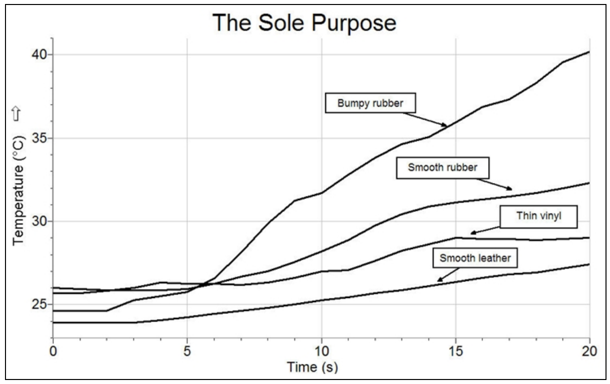


Figure 1 Change in temperature for different soles

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. The temperatures should all be very close to room temperature.
2. Answers will vary, but the ending temperatures are different. Differences in the amount of friction between the probe and the sole resulted in different temperatures.
3. Answers will vary, depending on the student's hypothesis and shoe samples. But using the sample data, shoe number 2 got the hottest and shoe number 3 was the coolest.
4. Answers will vary, but using the sample data, shoe number 3 would be the easiest to slide around on and so have the lowest friction.
5. Answers will vary. More friction causes the temperature to go higher.
6. Answers will vary, but the you would want to wear shoes with high-friction soles in situations where it is important to have good traction (e.g., playing basketball, rock climbing) You would want low friction soles when you want to be able to glide (e.g., dancing, bowling, ice skating).

ASSESSMENT

Choose an additional sole material. Based on the previous activity, what are your predictions?

EXTENSIONS

1. A research project could involve writing to a shoe company to gather information on the considerations that go into choosing the type of sole for a given shoe. The information could then be used to confirm the findings of the original activity.
2. Depending on the number of students, use one or more shoes and have students compete to get the highest temperature during a set amount of time. You could do this as a whole class, as an activity for students who finish early, as a competition between different groups.

Name: ______________________________

Cool Reaction! The Reaction of Baking Soda and Vinegar

Have you ever mixed vinegar and baking soda? It's fun to watch, but did you know that the reaction between the two is actually a chemical reaction that produces gas and changes temperature, too? The gas it produces is carbon dioxide, CO_2, and the temperature changes. Does the temperature go up or down? We will soon find out!

OBJECTIVES

- Produce a reaction between baking soda and vinegar.
- Measure the changing temperature of a reaction.
- Make observations.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
goggles
cup with fill-level marking
plastic spoon
baking soda
vinegar
paper towels or rags to clean up spills
tray

Figure 1

PROCEDURE

1. Get goggles and wear them.
2. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.
3. Click or tap Mode to open Data Collection Settings. Set End Collection to 40 s. Click or tap Done.
4. Fill your cup to the line with vinegar.

5. Place the Temperature Probe into the cup of vinegar. Hold onto the cup so it does not tip over.

6. Look at the temperature displayed on the screen. The value tells you the temperature of the solution that the Temperature Probe is in. Record the temperature of the vinegar in the Data Table as the "Starting temperature." Be sure that the probe is actually in the vinegar before you start data collection.

Data Table		
Starting temperature (°C)	Ending temperature (°C)	Change in temperature (°C)

7. Use your spoon to get a leveled-off, plastic spoonful of baking soda. **Important**: Do not put the baking soda in the cup with the vinegar until the next step.

8. When everything is ready, click or tap Collect to start collecting data. Wait 5 seconds, then add the baking soda.

Figure 2

9. Data collection will last 40 seconds. During this time, you should make observations about the temperature changes displayed on the screen and about what is happening in the cup.

10. On the Observations Sheet, record your observations on the about the change in temperature and what happened in the cup during the reaction.

Observations Sheet
Write observations about the reaction and change in temperature of the mixture.

11. What was the temperature of the vinegar after it had reacted with the baking soda? Record this value in the Data Table as the ending temperature. Remember, you can click or tap any data point to find exact values of the data points.
12. Subtract the starting and ending temperatures to find out how much the temperature changed during the reaction. Write your answer in the last column of the Data Table.
13. Dispose of your materials as directed by your teacher.

ANALYZE YOUR DATA

1. What happened to the temperature of the vinegar after you added the baking soda? Why do you think this happened?

____

____

____

2. What do you think would happen if you added more baking soda?

____

____

____

Cool Reaction! The Reaction of Baking Soda and Vinegar

BACKGROUND INFORMATION

This activity can be used to explore temperature changes that result from a chemical reaction. The chemical reaction between vinegar and baking soda is summarized as

$HC_2H_3O_2$	+	$NaHCO_3$	→	CO_2	+	$NaC_2H_3O_2$	+	H_2O
vinegar (acetic acid)		baking soda (sodium bicarbonate)		carbon dioxide gas		sodium acetate		water

The actual reaction takes place in several steps. The initial neutralization reaction gives off heat, but other factors such as the rapidly expanding CO_2 gas and evaporation cool the solution to create the observed temperature decrease.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS1.B Chemical Reactions PS3.A: Definitions of Energy PS3.D: Energy in Chemical Processes and Everyday Life	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – temperature, measurement

Math – graphic analysis; statistics including minimum, maximum, and range

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or

LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting temperature data with Vernier equipment, we recommend that you start with Activity 1.

3. We suggest that you provide each group with a tray such as those found in the cafeteria or fast-food restaurant. If students work with the liquids on a tray, it can help protect the electronic equipment from potential damage caused by spills. See Appendix C for more safety information.

4. In this activity, students make observations about the reaction between baking soda and vinegar. It is important that they wear goggles during the activity. The reaction will produce white bubbles, and the temperature of the liquid will drop several degrees.

5. To save time and reduce mess, students are directed to collect one set of data in the Procedure. Ideally, students learn that it is good scientific practice to collect multiple trials when conducting an experiment. As such, we encourage you to gather the data from each group and compare the different values as a class.

6. The volume of vinegar and the amount of baking soda that you use could vary. In order to reduce potential messiness with this lab, it is important that you use amounts that will not cause the reaction to flow over the top of the cups that you are using (although the students will think this is great fun!). When testing this lab, we used a plastic cup with a volume of 500 mL (approximately 2 cups). We used 50 mL of vinegar (approximately 1/4 cup) and 4 g of baking soda (approximately 1/2 teaspoon or 1 leveled-off plastic spoon.)

7. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Starting temperature (°C)	Ending temperature (°C)	Change in temperature (°C)
23.7	19.5	4.2

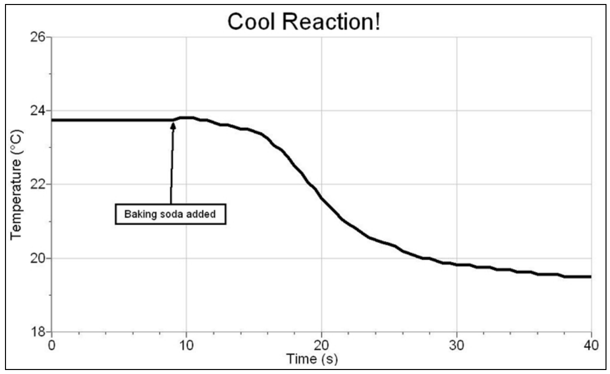


Figure 1 Temperature drop as baking soda reacts with vinegar.

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. The mixture got colder. This happened because there was a chemical reaction.
2. Answers will vary. If you add more baking soda, you might get more of a reaction and more cooling, but at some point, you have used up all the vinegar and more baking soda won't make a difference.

ASSESSMENT

Discuss the students' responses to the Analyze Your Data question: What do you think would happen if you added more baking soda?

EXTENSIONS

1. If you have the ability to measure different volumes precisely (using graduated cylinders and a balance, or using cup measures and measuring spoons), it would be interesting to perform this activity several times, using different amounts of baking soda and vinegar. The addition of 1 g of baking soda to 50 mL of vinegar produces a much smaller temperature change (although still visible on the screen), and a smaller amount of bubbles. Even if you are measuring with a plastic spoon and do not have access to standard measuring devices, you could do a qualitative analysis with the students, and show how smaller amounts of baking soda in equal volumes of vinegar produces a smaller temperature change.
2. Try the activity with other types of vinegar to see if they produce the same degree of temperature change.

Name: ______________________________

Cold as Ice

Ice water can be pretty cold. Is it always the same temperature? Is there anything you can do to make it even colder?

OBJECTIVES

- See how salt affects the temperature of freezing water.
- See how low you can decrease the temperature of liquid water.

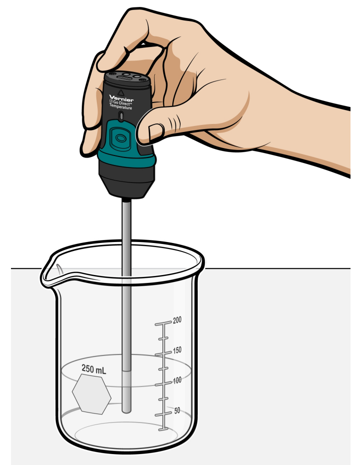


Figure 1

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
cup or beaker
tap water
ice cubes
plastic spoon
2 spoonfuls of table salt
paper towels or rags to clean up spills
tray (if available)

KEY QUESTION

How low can you drop the temperature of water while still keeping it liquid?

PRE-LAB PREDICTION

I predict I can drop the temperature of water to _____________˚C by adding

____ to the water.

PROCEDURE

1. Connect the Temperature Probe to your Chromebook, computer, or mobile device. Launch Graphical Analysis.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 120 s. Click or tap Done.

3. Fill your cup 1/3 full with water.

4. Do the following to find the temperature of water:
   a. Place the Temperature Probe into the cup and stir carefully. Be careful not to spill the water!
   b. Click or tap Collect to start data collection.
   c. When data collection is complete, click or tap Graph Tools, , and choose View Statistics.
   d. Record the Mean temperature in the Data Table in the space under the heading: Water temperature.

Data Table		
Water temperature (°C)	Ice water temperature (°C)	Ice water with salt temperature (°C)

Figure 2

5. Collect data with ice in the water by doing the following:
   a. Place enough ice in the cup to bring the water level up to about 2/3 full.
   b. Place the Temperature Probe into the cup and stir carefully.
   c. Click or tap Collect to start data collection. **Note**: The previous data set is automatically saved.
   d. When data collection is complete, click or tap Graph Tools, , and choose View Statistics.
   e. Record the Minimum (Min) temperature in the Data Table in the space under the heading: Ice water temperature.

6. Collect data with salt and ice in the water by doing the following:
   a. Add 2 spoonfuls of salt to the ice water.
   b. Repeat Step 5 to collect data for the ice water with salt. When you write down the temperature, write it under the heading: Ice water with salt temperature.

ANALYZE YOUR DATA

1. What happened to the temperature of the water as you added ice?

2. What do you think would happen if you continued to add ice cubes to the water? Could you ever drop the temperature below zero degrees Celsius?

3. When salt was added, what did you notice about the temperature of the ice water? Why do you think this happened?

4. What could you do to drop the temperature even more?

Cold as Ice

BACKGROUND INFORMATION

Water can be a solid or a liquid at 0°C. This is called the melting temperature or freezing temperature of water. Above 0°C, water will be liquid, and below 0°C, it will be solid (ice). Ice in your freezer may be at a temperature of less than 0°C, but will quickly warm to 0°C to once it has been removed. It will then begin to melt if left out of the freezer.

When you add salt to the water, it dissolves and forms a salt solution. This causes the freezing temperature to be lowered by a few degrees, depending on the amount of salt added. The temperature of salt water must be lowered to below 0°C in order to freeze.

Any substance (e.g., salt or sugar) that dissolves in water will lower the freezing temperature. Salt has a particularly large effect. This is why it is more difficult to freeze the salt water in oceans, compared to fresh water in lakes. It is also why rock salt is used to de-ice roads in some parts of the country. You can have your students try this by taking a piece of ice at 0°C and sprinkling salt on it. Have them watch closely as the ice melts.

TIME FRAME FOR ACTIVITY

This activity requires about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS1.B Chemical Reactions PS3.A: Definitions of Energy PS3.D: Energy in Chemical Processes and Everyday Life	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Language Arts – *Brrr!*, by James Stevenson (Greenwillow Books), is a wonderful picture book to read. If you choose to do the ice cream extension with your students, a good book to read is *Ice Cream Soup*, by Frank Modell (Greenwillow Books). Students will be able to understand what the characters are doing wrong as they make ice cream.

Math – comparisons, graph analysis

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting temperature data with Vernier equipment, we recommend that you start with Activity 1.

3. We suggest that you provide each group with a tray such as those found in the cafeteria or fast-food restaurant. If students work with the liquids on a tray, it can help protect the electronic equipment from potential damage caused by spills. See Appendix C for more safety information.

4. Water from the tap probably won't be at room temperature. You may want to fill a large container with water the day before so that it can be at room temperature for this activity.

5. You can introduce the activity by reading the story *Brrr!*, by James Stevenson. A discussion of the story and how cold can always be thought of as even colder by a cute story that has Grandpa telling about the frigid winter of 1908 to his complaining grandchildren fits in even with older elementary students.

6. You can discuss the Key Question with your class as a large group. You may want to have students write their hypotheses and then share with the class.

7. If you live in a place where there is ice on the roads during the year, you may want to introduce this idea by discussing what the city or county does to make the roads more safe. If you don't experience icy roads, you can tell your students about the practice of using salt to help make the roads easier to drive on.

8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Water temperature (°C)	Ice water temperature (°C)	Salty ice water temperature (°C)
22	0	–5

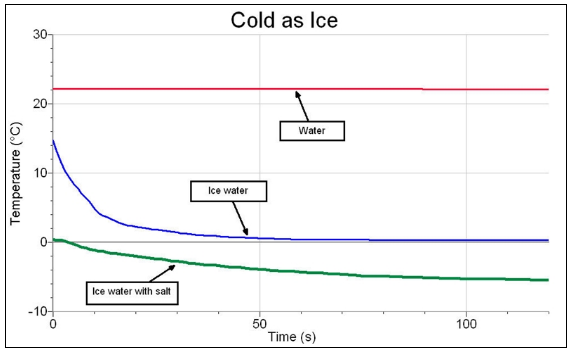


Figure 1 Temperature of room temperature water, ice water, and salty ice water

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. The temperature decreased as we added ice to the water.
2. Using enough ice, the water could decrease to 0°C.
3. Answers will vary, but should include the fact that the addition of salt lowered the temperature of the water because the water molecules have difficult time bonding together.
4. Answers will vary, but should include either adding more ice or salt.

ASSESSMENT

Have students set up their own experiments and come up with other things to add to ice water to check on the temperature changes. Sugar, lemon juice, or other safe kitchen items could be used.

EXTENSIONS

1. Invite a guest speaker in who works for the Highway Department in your area. Have the speaker discuss what is actually done in your area on the roads in winter. Have your students contrast the salt put on roads to lower the freezing temperature and the sand put on roads for friction.
2. If local and state regulations allow, bring in an ice cream maker and demonstrate how ice cream is made. *Ice Cream Soup*, by Frank Modell, is a funny way to finish up this extension. Two boys decide to throw a birthday party for the entire town. They want to make their own cake and ice cream. Your students will understand what the boys are doing wrong after your students have made their own in class.

Name: ______________________________

Are We Cool or What?

Is your hand always cool? Is it always warm? What makes it change? The temperature of your own hand is just one of many things you will be able to measure with a Temperature Probe.

OBJECTIVES

- Measure the changing temperature of your hand under different conditions.
- Create a hypothesis.
- Create a plan to test your hypothesis and carry out your plan.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature

PROCEDURE

Part I Measure the temperature of our hands

1. Fill in the names of your group members in the Part I Data Table.

Part I Data Table		
Group member number	Group member name	Maximum hand temperature (°C)
1		
2		
3		
4		

2. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.

3. Click or tap Mode to open Data Collection Settings. Set End Collection to 60 s. Click or tap Done.

4. Give the Temperature Probe to the first group member. They should be ready to hold the tip of the probe as soon as data collection is started. For now, hold onto the plastic part of the probe, so the temperature of the probe does not start to adjust to the temperature of your hand.

5. When everything is ready, click or tap Collect to start data collection.

6. The first group member should now hold the tip of the probe. Watch the temperature on the meter.

7. Data collection will last 60 seconds. It is important to hold the tip of the probe for the entire 60 seconds so that it has enough time to adjust to the temperature of your hand.

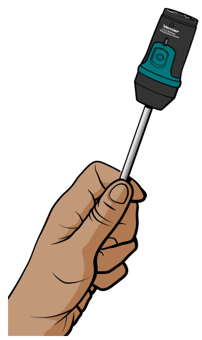


Figure 1

8. How hot was your hand? You can probably tell from the graph, but to find out exactly, examine the graph. To examine the data pairs on the displayed graph, tap any data point. As you tap each data point, the temperature and time values are displayed to the right of the graph.

9. Repeat Steps 4–8 for each group member. Make sure the temperature probe has cooled back down to room temperature between runs. **Note**: The previous data set is automatically stored each time you click or tap Collect.

Part II Change the temperature of our hands

Think of some ways that you could change the temperature of the palm of your hand. How would the temperature change if you rubbed your hands together? What if you placed your hand on the window and held it there for five seconds? What if you placed it near a heater? Each person in your group will try a different way of changing the temperature of his or her hand.

10. Choose the way you will try to change the temperature of your hand.

11. Write your hypothesis about what will happen. For example, a hypothesis about soup would be: "If I put my bowl of hot soup on the porch for five minutes, and then measure the temperature of the soup, I think the temperature will go down a lot."

Hypothesis

If I ____

____

and then measure the temperature of the palm of my hand, I think the temperature will

____

12. Write the names of the members of your group and the action each plans to take.

Part II Data Table				
Group member name	Action taken	Starting temperature (from Part I) (°C)	Ending temperature (°C)	Increase or decrease? (+ or -) (°C)

13. Write the starting temperatures of the members of your group in the column marked "Starting temperature." These temperatures can be found in the Part I Data Table.

14. The first group member should now do the following:
    a. Do the action you have planned to change the temperature of your hand.
    b. Grab the tip of the Temperature Probe and click or tap Collect to start data collection.
    c. When the data collection is finished, tap anywhere on the graph.
    d. If you were trying to cool down your hand, use the cursor to find the coldest temperature. If you were trying to heat up your hand, use the cursor to find the warmest temperature. Record this temperature in the "Ending temperature" column of the Part II Data Table.

15. Each group member should repeat Step 14.

ANALYZE YOUR DATA

1. Subtract the starting and ending temperatures to find out how much the temperature increased or decreased. Write your answer in the last column of the Part II Data Table. If the temperature increased, write a "+" in front of the number. If it decreased, write a "–" in front of the number.

2. Were you able to change the temperature of the palm of your hand? ____________________

3. Was your hypothesis correct? __________ Why or Why not? ________________________

   ____

4. Which action caused the greatest temperature change? ______________________________

   ____

5. If you had a chance to try this experiment again, what action would you take to get an even greater temperature change?

   ____

6. Why couldn't you hold the probe for just 10 seconds instead of 60 seconds?

   ____

Are We Cool or What?

BACKGROUND INFORMATION

Friction is an important concept in this activity. Whether an object's surface is smooth or rough, atoms are stacked at various levels. When the surfaces come into contact, friction occurs. The amount of friction depends on the "roughness" of the objects' surfaces. The greater the amount of friction, the potential exists to produce more heat. To reduce friction, introducing a "slippery" substance, such as oil, to reduce the contact of surface atoms, thus reducing wear and tear as well as heat generation.

Heat transfer is also central to this activity. When an object's atoms and molecules become hotter, they become excited and jiggle. Hot atoms and molecules that come into contact with cold atoms make the cold atom and molecules jiggle more. When you place your hand on a cold object, such as a window in the winter, it feels cold. The heat from your hand moves toward the window surface. Thus, the surface of your hand feels colder. Conversely, this works the opposite way, too. If you place your hand on the hood of a car on a 40°C (104°F) day, you will quickly feel the heat from the car hood transfer to your hand. Ouch!

TIME FRAME FOR ACTIVITY

This activity requires about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Language Arts – measurement, temperature

Math – comparisons, graph analysis, minimum, maximum, subtraction

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting temperature data with Vernier equipment, we recommend that you start with Activity 1.

3. Each student should fill out a table for the whole group so comparisons can be made and so they can practice keeping track of their data.

4. In the second part of the activity, the students are asked to try to change the temperature of their hands. Rubbing hands together, placing them against a cold window or under hot or cold water, sitting on them, and holding an ice cube, a cold cup, or a hot cup, are all different options that work well. If they can't come up with enough different activities for each member of the group, they can try to vary the time they spend rubbing their hands or holding their hands in the cold water.

5. You might have the groups share the procedures that worked best at raising or lowering the temperature of their palms. Have them share ideas of what they might try if they have had the opportunity to redo the activity. Encourage students to ask questions of each other to stimulate discussion and to question their own assumptions.

6. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Part I Data Table		
Group member number	Group member name	Maximum hand temperature (°C)
1	Rose F.	32.2
2	Beth Q.	31.1
3	Sean B.	29.8

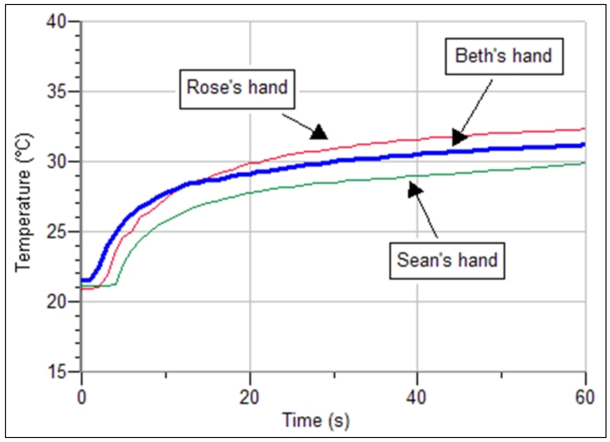


Figure 1 Students' hand temperatures recorded during Part I

ANSWERS TO QUESTIONS

1. Answers will vary.
2. Answers will vary.
3. Answers will vary depending on their hypothesis.
4. Answers will vary.
5. Answers will vary.
6. In 10 seconds, the probe would not yet have warmed up to the hand temperature.

ASSESSMENT

Provide friction and heat transfer scenarios for students to determine whether the objects' temperatures would increase or decrease. Examples include: a car's tires rolling on the highway, a hot bucket of water left outside on a cold day, and a chainsaw cutting through a tree trunk.

EXTENSIONS

Have students generate experiments in a similar manner, but with a goal of creating more friction or reducing friction.

Name: ________________________________

Why Do We Need Thermometers?

Do you ever feel really cold in your classroom while everyone else is hot? Do you sometimes feel really warm outside, even though you are told that you need to wear a coat because it's cold? The temperature your body senses does not always match the temperature that would be recorded by a thermometer. It is possible that on the day you felt warm outside, even though it was cold, you had been running around and were already warm. When you do this activity, you will see if previous conditions affect the ability of your hands to measure temperature.

Figure 1

OBJECTIVES

- Determine if touch is adequate to determine temperature.
- Explain the need for a thermometer.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
3 cups
warm water, cold water, room-temperature water
paper towels

PROCEDURE

1. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.

2. Line up the cups of water in front of you on the desk so the room-temperature water is in the middle and the warm and cold are at either end.

3. Each group member will have a chance to do the experiment. Decide who will go first. Have that person place two fingers of one hand in the warm water and two fingers of their other hand in the cold water. Hold them there for about 30 seconds. It is important to leave your fingers in the water baths for the whole 30 seconds.

4. The person with his or her fingers in the water should estimate (make a best guess at) the temperature of the water in the two cups, in °C. Record these values in the Data Table.

Data Table			
	Estimated temperature (°C)	Measured temperature (°C)	Temperature difference (°C)
Cold water			
Room-temperature water			
Warm water			

5. The person with his or her fingers in the water should now put their fingers in the room-temperature water (the one in the middle). Record the estimated temperature of the room-temperature water in the Data Table.

6. Record your observations about what your fingers were feeling when they were placed in the room-temperature water.

Observations

7. While the person who tested the water first records their observations, dispose of the water as directed by your teacher, and then obtain new amounts of all three types of water.

8. Repeat Steps 2–7 for each person in the group.

9. You will now measure the temperatures of the water baths using the Temperature Probe.
   a. Place the probe in the cool water. Hold onto the probe so you do not tip the cup over.
   b. Watch the temperature in the meter. When the temperature readings are the same for several seconds (stop increasing or decreasing for each reading), record the temperature value in your Data Table.

10. Repeat Step 9 two times. The first time, place the Temperature Probe in the room-temperature water, and the second time, place the probe in the warm water.

ANALYZE YOUR DATA

1. Subtract to find the difference between the estimated and measured temperatures for each of the water baths. Record these values in the Data Table.

2. How close were your estimates of the different baths? ________________________________

   ____

3. Based on the observations you made earlier and the calculations you just performed, do you think that your hands are good at measuring the temperature of water? Why or why not?

   ____

   ____

   ____

   Do you need to use a thermometer to accurately measure temperature? _________________

   Why or why not? ____

   ____

Why Do We Need Thermometers?

BACKGROUND INFORMATION

In 1593, Galileo developed a device called a thermoscope. A thermoscope can monitor the temperature of a liquid, but can only show a difference in temperature. For example, it can show that a liquid is getting hotter. However, because a thermoscope does not have markings, you cannot tell how much hotter the liquid is.

The first mercury thermometer was developed by Daniel Fahrenheit, a German physicist, in 1714. Fahrenheit also developed a temperature scale, the Fahrenheit scale, which is used in the United States.

In 1742, Anders Celsius, a Swedish astronomer, developed a different temperature scale, the Celsius scale (also known as the Centigrade scale). Celsius is the SI unit of temperature and the scale used in the majority of countries in the world.

TIME FRAME FOR ACTIVITY

This activity requires about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – measurement, temperature

Math – comparison, graphical analysis, minimum, maximum, subtraction

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or

LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting temperature data with Vernier equipment, we recommend that you start with Activity 1.

3. By default, all of our data-collection programs display and record temperature in degrees Celsius. If you want your students to work in Fahrenheit degrees, you will need to direct student to change units:
   - Graphical Analysis 4: Click or tap the Temperature meter and select the Units you want to display.
   - Logger Lite: Click the Switch button, .
   - LabQuest App: On the Meter tab, choose Change Units from the Sensors menu. Select the units you want to display.

   Activity 9 in this book can be a good way for students explore the differences between the Celsius and Fahrenheit scales.

4. This activity has been written so that each of the students have the opportunity to feel the temperature of the different water baths. The first student to perform the activity will place a finger in each of the hot and cold water cups and will predict what the temperature is in each of the two bowls. After 30 seconds, the student places both fingers in the room-temperature cup. Both hands should feel something different—the hot hand will feel colder and the cold hand will feel warmer—so both hands will feel like they are in different cups! After one student has does this, the students switch roles. If there are time constraints, you can have fewer students test the water. This is not preferred, however, as it can be hard for students to understand what happens if they don't actually test the water themselves.

5. Each group will need three cups of different temperature water—cold water, hot tap water, and room temperature water. Stability of the cups is a factor to consider when choosing cups. Because cups are used with such frequency in these activities, we recommend investing in some reusable plastic cups. While size is not important for this activity, for Activity 10, we recommend using cups that can hold a volume of approximately 500 mL or 18 oz. Purchase clear cups, if possible, as students will need to make observations about what is going on inside the cup.

6. In order to maintain constant temperatures for the water baths, it would be helpful if the water could be held in insulated containers. It would be helpful to put some ice in the cold water, is not essential. Fresh water should be used each time a different student does the procedure to ensure that the temperatures of the cold and warm water are very different from the temperature of the room-temperature water. Use the warmest water you feel comfortable having your students work with. Best results can be achieved using very cold and very warm water, but you must balance this with safety considerations. You do not want your students to scald themselves when they put their fingers in the water. For this activity, warm tap water will work just fine.

7. When everyone is finished, engage the class in a discussion of their last question—is there a need for a thermometer. You may ask if everyone estimated the same temperature of the water

just by touch. Ask why there were differences. Ask how close using the sense of touch was to using the temperature probe for an actual temperature. When is it important that we know the actual temperature (baking cookies, worrying about water pipes freezing, knowing if it will rain or snow)? These types of questions should get them to share reasons for why we use thermometers instead of just relying on our senses.

8. Students do not collect data in this activity, so there is no need to print a copy of the graphs or data tables. Remind your students to write down the temperatures or they will have a difficult time answering the questions.
9. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.
10. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

	Estimated temperature (°C)	Measured temperature (°C)	Temperature difference (°C)
Cold water	6	15.4	4.6
Room temperature water	23	22.6	0.4
Warm water	30	25.1	4.9

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. See the Sample Results.
2. Answers will vary. You should direct students as to whether you want qualitative (e.g., close, far, or near) or quantitative (e.g, 68–53=15) responses.
3. Answers will vary.
4. Answers will vary. We do need thermometers to be accurate and to compare temperatures between different people.

ASSESSMENT

Have students share other examples of when your body senses do not always match the temperature that would be recorded by a thermometer such as wind chill, sitting still on a cold day, and jumping into a pool on a hot day.

EXTENSION

Have students conduct the experiment with other liquids such as salt water or vegetable oil.

Name: ________________________________

Celsius or Fahrenheit, What's the Difference?

In the United States, people usually measure temperature using the Fahrenheit scale. If it is a cold day, the temperature on the Fahrenheit scale might be about 35°F. However, in science and in most other parts of the world, people use a different temperature scale, called the Celsius scale. If you told a person who was used to the Celsius scale that it was 35 degrees outside, they would think that it was really hot!

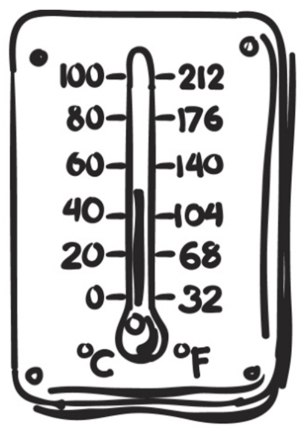


Figure 1

OBJECTIVES

- Take the temperature of a variety of items using two different temperature scales.
- Compare the Celsius and Fahrenheit scales.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
cold water
warm water
cup or beaker

PROCEDURE

1. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 60 s. Click or tap Done.

3. Get a cup or beaker half full of cold water, and place it in front of you on the table.

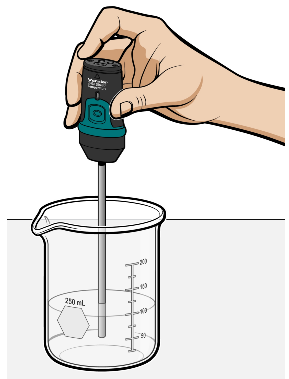


Figure 2

4. Place the Temperature Probe in the cup or beaker.

5. When everything is ready, click or tap Collect to start data collection. Data will be collected for 60 seconds.

6. Watch the temperature on the screen. What was the coldest temperature recorded during the data collection period? You can probably tell from the graph, but to find out exactly, examine the graph.
   a. Click or tap the graph to examine the data pairs on the displayed graph. **Note**: You can also adjust the Examine line by dragging the line.
   b. Drag the Examine line around the graph until you find the lowest temperature.
   c. Record this temperature in the Data Table. Be sure to record it in the correct column.

Data Table		
Item	Temperature in degrees Celsius (°C)	Temperature in degrees Fahrenheit (°F)
Cold water		
Warm water		
Hand		

7. Now determine the temperature of the bath according to the Fahrenheit scale.
   a. Click or tap View, ⊞, and select Graph and Table.
   b. Click or tap the Temperature meter and change Units from °C to °F. The temperature displayed in the table will now display the temperature values in Fahrenheit.
   c. Examine the table until you find the lowest temperature.
   d. Record this temperature in the Fahrenheit column of the Data Table.

8. Change the units back to °C, so that the temperature values are displayed in degrees Celsius again.
   a. Click or tap the Temperature meter.
   b. Change Units from °F to °C.

9. Dispose of the water as directed by your teacher and repeat Steps 3–8 using warm water.

10. Dispose of the water as directed and repeat Steps 5–7 to determine the temperature of your hand on the two scales.

ANALYZE YOUR DATA

1. Is the cold water the same temperature on the different scales? ______________________

2. Is the warm water the same temperature on the different scales? _____________________

3. Is your hand temperature the same temperature on the different scales? ________________

4. If water freezes at 0°C and the temperature outside is 30°F, could it snow? Why or why not? (**Hint**: Look at a thermometer that has both °C and °F on it.)

   ____

   ____

5. If water boils at 100°C and your body temperature is 98°F, is your blood close to boiling? Why or why not?

   ____

   ____

Celsius or Fahrenheit, What's the Difference?

BACKGROUND INFORMATION

Students should be made aware that there are a number of different scales used to measure temperature. In science, the Celsius scale is the standard unit for temperature measurement. In the United States, most students in the United States are familiar with the Fahrenheit scale. To convert from degrees Fahrenheit to degrees Celsius, use the following conversion:

$$(°F–32)(5/9) = °C$$

Another temperature scale, known as the Kelvin scale, is also sometimes used in science. Kelvin is similar to Celsius in that a 1°C change in temperature is equal to a 1 K change in temperature.

	Celsius (°C)	Fahrenheit (°F)	Kelvin (K)
Water freezes	0	32	273
Water boils	100	212	373
Absolute zero	–273.15	–459.67	0

One good way to make the students more comfortable with the different scales is to ask them at what temperatures they might do different things. For example, at what temperature do we usually wear shorts (in °F and then in °C), when do we put on our sweaters, what is a comfortable room temperature?

You might start off with a discussion of the different kinds of thermometers they have seen (body temperature, oven thermometer, outdoor thermometer, one they might have used in science class, candy thermometer).

TIME FRAME FOR ACTIVITY

This activity requires about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – measurement, temperature

Math – comparison, graphical analysis, minimum, maximum, subtraction

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. When you talk about the different temperature scales, you might tie this into measurement. People who grow up in the United States don't usually use the metric system in their everyday lives (yet!), but in science, the metric system is the customary system.

3. In order to maintain different temperatures of the water that students will use, it would be helpful if the water could be held in insulated containers. It would be helpful to add some ice, but not essential. **Important**: The water the students use should not have ice in it.

4. Use the warmest water you feel comfortable having your students work with. Best results can be achieved using very cold and very warm water, but you must balance this with safety considerations. You do not want your students to scald themselves if they have a spill.

5. When students are making measurements, remind them to wait until the temperature remains steady before recording the temperature on the data table. Stirring the water with the temperature probe will help to ensure constant temperatures.

6. Have the students share their responses to the two last questions. Make sure they realize that because the two temperature scales are different, regular body temperature is not the same as boiling even though the numbers are similar!

7. Students do not collect data in this activity, so there is no need to print a copy of the graphs or data tables. Remind your students to write down the temperatures or they will have a difficult time analyzing their data.

8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Item	Temperature in degrees Celsius (°C)	Temperature in degrees Fahrenheit (°F)
Ice water	5.6	42.1
Warm water	31.4	88.5
Hand	29.8	85.6

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. No, ice water is not the same temperature on the different scales.
2. No, warm water is not the same temperature on the different scales.
3. The hand temperature is not the same on the different scales, either.
4. Yes, if water freezes at 0°C and the temperature outside is 30°F, it could it snow.
5. No, if water boils at 100°C and my body temperature is 98°F, my blood is not close to boiling.

ASSESSMENT

Have students create illustrations or a slideshow depicting examples of what would commonly occur or be seen at various Celsius and Fahrenheit temperatures.

EXTENSION

Have students research the Kelvin temperature scale and absolute zero.

Name: ______________________________

Getting it *Just* Right!
Adjusting Water Temperature

Have you ever gotten into a bathtub that was either too hot or too cold? It's not very comfortable, is it? You can get just the right temperature for your bath by combining hot and cold water in the right amounts. In this activity, you will combine different amounts of warm and cold water, and predict what temperature the resulting mixture will be.

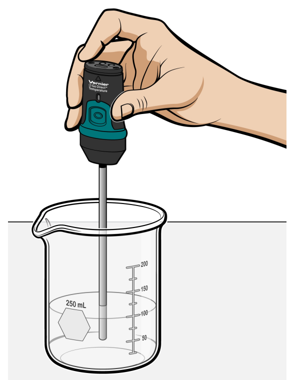


Figure 1

OBJECTIVES

- Record what happens to temperature as different amounts of warm water and cold water are mixed together.
- Try to predict the temperature of a mixture of certain amounts of warm water and cold water.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
warm water
cold water
3 cups

PROCEDURE

Part I Mixing warm water and cold water

1. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 100 s. Click or tap Done.

3. In this part of the activity, you will mix specific volumes of warm and cold water with known temperatures, and then use the temperature probe to measure the temperature of the resulting mixture. The Part I Data Table will help you keep track of the volumes you should measure. You will also record the temperature values in the Part I Data Table.

Part I Data Table					
Run	Volume of cold water (mL)	Volume of warm water (mL)	Temperature of cold water (°C)	Temperature of warm water (°C)	Temperature of the mixture (°C)
1	25	75			
2	50	50			
3	75	25			

4. Obtain a cup with 25 mL of cold water in it and another cup with 75 mL of warm water in it. Be sure there is no ice in your cold water!

5. Place an empty cup near the other two cups. You will mix the cold and warm water in this cup after you measure the temperature of both, separately.

6. You will now measure the temperature of the cold water, the warm water, and the mixture. You will need to make several measurements within the 100 second data collection period, but you will have enough time if you keep working.
   a. Identify one person to move the Temperature Probe and another person to mix the cold and warm water in the empty cup. **Important**: Do not mix the water until told to do so later on in this step.
   b. Place the Temperature Probe in the cold water and click or tap Collect to start data collection. Hold on to the cup to keep it from tipping.
   c. Watch the temperature on the screen. It will take a few seconds for the probe to adjust to the temperature of the water.
   d. When the readings are the same for several seconds, take the probe out of the cold water and place it in the warm water.
   e. Watch the temperature values. When the readings are the same for several seconds, take the probe out of the warm water. Place the probe into the empty cup in which you will mix the water.
   f. Now mix the cold and the warm water in the cup. Watch the temperature value. Data collection will end after a total of 100 seconds.

7. Determine the temperatures of the cold water, the warm water, and the mixture.
   a. Click or tap the graph to examine the temperature and time values. **Note**: You can also adjust the Examine line by dragging the line.
   b. Drag the Examine line to the area of the graph where the probe was in the cold water and the readings were the same for several seconds.
   c. Record this temperature as the "Temperature of cold water" for Run 1 in the Part I Data Table.
   d. Drag the Examine line to the flat area where the probe was in the warm water. Record this value as the "Temperature of warm water" for Run 1.
   e. Drag the Examine line to the flat area where the probe was in the mixture of cold and warm water. Record this temperature as the "Temperature of the mixture."

8. Prepare to collect data for Run 2.
   a. Empty the mixture of water as directed by your teacher.
   b. Get 50 mL of cold water and 50 mL of warm water in separate cups and place the cups in front of you on the table. Put the empty cup on the table, too.
   c. Repeat Steps 6–7. **Note**: The previous data set is automatically saved. For this run, you will record the temperature values in the Run 2 row.

9. Prepare to collect data for Run 3.
   a. Empty the mixture of water as directed by your teacher.
   b. Get 75 mL of cold water and 25 mL of warm water in separate cups and place the cups in front of you on the table. Put the empty cup on the table, as well.
   c. Repeat Steps 6–7. For this run, you will record the temperature values in the Run 3 row.
   d. When you are done, empty the mixture of water as directed.

Part II Estimating the temperature of a mixture

You have now mixed specific amounts of water with different temperatures, and then used a Temperature Probe to determine the temperature of the mixture. Now, you will estimate the temperature of a mixture of 70 mL of cold water and 30 mL of warm water. You will then determine the actual temperature.

10. Write a hypothesis about what will happen when you mix 70 mL of cold water and 30 mL of warm water. For example, a hypothesis about putting ice in a drink would be: "If I put one cube of ice in my drink, I think the temperature of my drink will go down by 3°C." When you are trying to make your hypothesis, think about the temperatures of the mixtures of cold and warm water that you measured in Part I.

    Hypothesis

    If I mix 70 mL of cold water and 30 mL of warm water, I think the temperature of the

    mixture will be ____.

11. Prepare to measure the temperature of the mixture of cold water and warm water.
    a. Ask your teacher for 70 mL of cold water and 30 mL of warm water.
    b. Mix them in your empty cup and place the probe in the mixture of water.

12. You will now determine the temperature of the mixture of cold water and warm water.
    a. Click or tap Collect to start data collection.
    b. Watch the temperature displayed on the screen. It will take a few seconds for the probe to adjust to the temperature of the water.
    c. When the temperature values stay the same for several seconds, click or tap Stop to stop data collection.
    d. Record the temperature of the mixture in the Part II Data Table. Remember, you can click or tap the graph if you want to examine the data in more detail.

Part II Data Table		
Volume of cold water (mL)	Volume of warm water (mL)	Temperature of the mixture (°C)
70	30	

ANALYZE YOUR DATA

1. What did you notice about the temperatures of warm tap water? Were they always the same? Why or why not?

____

____

2. What did you notice about the temperatures of cold water? Were they always the same? Why or why not?

____

____

3. Describe any pattern you noticed as you changed the amounts of warm water and cold water in the mixture.

____

____

4. How did you decide on your prediction for the temperature that resulted from mixing 30 mL of warm tap water with 70 mL of cold water?

____

____

5. How close was your prediction of the resultant temperature when mixing 30 mL of warm water with 70 mL of cold water? What might help you make a better prediction?

____

____

Getting it Just Right!
Adjusting Water Temperature

BACKGROUND INFORMATION

In this activity, students mix different amounts of warm tap water and cold water, taking the temperature before and after. Before collecting data, students make a prediction of the resulting temperature when mixing certain amounts of water together.

Heat transfer is a central concept in this activity. When water is warmer, its atoms and molecules become excited and jiggle. Conversely, the atoms and molecules of cooler water become sluggish and move less. When hot and cold water are mixed, atoms and molecules will either slow down or speed up, depending on which temperature of water is more prevalent in the mixture.

TIME FRAME FOR ACTIVITY

This activity requires about 60–75 minutes. If you would like to do the activity in two sessions, we recommend doing Part I on the first day and Part II on the following day.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – measurement, temperature

Math – comparison, graphical analysis, minimum, maximum, subtraction

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware

they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. Each group needs three containers to hold water; one is used for warm water, another for cold water, and the third for mixing the water. Beakers, mugs, or cups work well. Each container must be able to hold at least 100 mL of liquid.

3. In the Procedure, students are directed to obtain water in volumes of 25, 30, 50, 70, and 75 mL. If you do not have enough beakers, or if you are concerned that students will not be able to measure out the volumes themselves, you have several options. If your students can measure volumes themselves, you can mark a set of cups with the appropriate lines and make them available at the water stations. If there is concern that students will be unable to accurately measure, you can measure the water and distribute it to students. This may also be a good solution if there is a concern that students will spill the water while walking between their desks and the water stations. Finally, if you have the resources, and your students can accurately measure, you can give each student group their own water containers.

4. If you do not have access to graduated cylinders or beakers, you can estimate the volumes for the activity and make marks on cups that students can use for measuring volumes of water. A 1-cup measuring cup holds 237 mL; therefore a 1/4-cup measuring cup holds approximately 60 mL. Using these values, mark cups with the different volumes that students should use. We recommend marking the cups with volumes in milliliters (mL), even though they will not be exact, to help students become familiar with the metric system. This also makes it easier for the students to follow the Procedure.

5. Student groups need both warm water and cold water. For the warm water, use the warmest water you feel comfortable giving to your students. For the cold water, crushed ice in a beaker of refrigerator water works well. Best results can be achieved using very cold and very warm water, but you must balance this with safety considerations based on the age and maturity of your students. Good results can be achieved when the warm water has a temperature that is well below boiling (see Sample Results).

6. Pitchers with lids can be a great way to provide cold water to students. Pitchers often have a spout that is designed to keep the ice in the pitcher (and consequently out of the water used by students during the activity). The lid can also help maintain a more constant temperature.

7. During the activity, when students mix the water in the third container, tell them to pour the water from the warm and cold water cups at the same time. This will ensure smooth lines on their graphs. If they pour into one cup and then into the other, the temperature values will spike and may make it difficult to determine the temperature. Tell them not to worry if their graphs are not clean. They will still be able to determine the temperatures of the water baths using the data.

8. Because of the possibility for water being spilled, direct your students to be extra cautious. We suggest that you provide each group with a tray such as those found in the cafeteria or fast-food restaurant. If students work with the liquids on a tray, it can help protect the electronic equipment from potential damage caused by spills. See Appendix C for more safety information.

9. Students should be able to realize that as the amount of cold water in the mixture is increased, the temperature of the mixture decreases.

10. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

11. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Part I Data Table					
Run	Volume of cold water (°C)	Volume of warm water (°C)	Temperature of cold water (°C)	Temperature of warm water (°C)	Temperature of the mixture (°C)
1	25	75	3.7	36.4	26.9
2	50	50	3.7	36.4	18.6
3	75	25	3.7	36.5	13.1

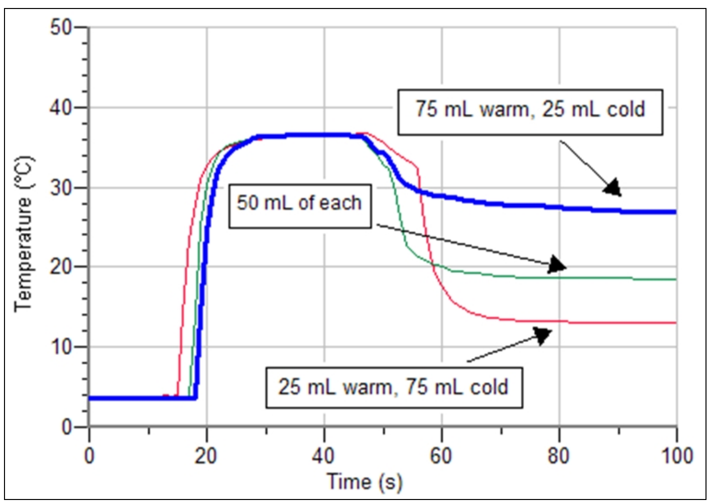


Figure 1 Sample graph showing the temperatures of cold water, warm water, and the various mixtures of cold and warm water

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Depending on the source of their water, the students may get cooler temperature values for each of their runs.

2. Depending on the source of their water, the students may get warmer temperature values for each of their runs.

3. Students should notice that as they mix more cold water with less warm water, the temperature of the mixed bath gets cooler.

4. Answers will vary.

5. Answers will vary.

Name: ________________________________

The Temperature Probe Spends the Night

To preserve resources and save money, schools, businesses, and individuals stop heating or cooling their homes during the nighttime. How much does this affect the temperature of a room at night? Can you tell what time the heat or air conditioning is turned off or on by measuring the temperature in a room overnight? By completing this activity, you will attempt to answer these questions.

OBJECTIVES

- Set up Graphical Analysis 4 to collect data overnight.
- Make estimates based on the data you collected.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature

PROCEDURE

Day 1 Prepare for data collection

1. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.
2. Click or tap Mode to open Data Collection Settings. Change Time Units to **h** for hours and set End Collection to 24 h. Click or tap Done.
3. Set the Temperature Probe near your Chromebook, computer, or mobile device.

4. When everything is ready, click or tap Collect to start data collection. Data collection will continue for 24 hours. **Important**: Make sure your Chromebook, computer, or mobile device is plugged in to AC power!

5. Record the time that you started data collection in the Data Table.

6. Write a hypothesis about what will happen to the temperature of the room during the 24-hour data collection period. For example, a hypothesis about soup would be: "If I put my bowl of hot soup on the porch for 5 minutes and then measure the temperature of the soup, I think the temperature will go down a lot."

   Hypothesis

   If the _______________ turns off at night, I think the temperature will ___________________.

   If the _______________ turns back on in the morning, I think the temperature will

   ____

Day 2 Examine your data

7. Check to be sure data collection is done. If it is, you will see the Collect button at the top of the screen. If data collection is not done you will see the Stop button. Record the time that data collection ended in the Data Table.

8. Click or tap the graph to examine your data. Record the following values in the Data Table. **Reminder**: The time values displayed next to the Examine line not the actual times that data was recorded. You must figure out the actual time based on the time that data collection was started (the value you recorded on Day 1).
   - The highest temperature and the time at which it was recorded
   - The lowest temperature and the time at which it was recorded
   - The temperature at the beginning of the data collection (on Day 1)
   - The temperature at the end of data collection (Day 2)

Data Table		
	Time (example: 1:00 pm)	Temperature (°C)
Start of data collection		
End of data collection		
Warmest temperature		
Coldest temperature		
Estimated time air conditioning or heat was turned off at night		
Estimated time air conditioning or heat was turned on in the morning		

ANALYZE YOUR DATA

1. Did the temperature increase or decrease during the night? ________________________

   Why did this happen? ____

2. Was your hypothesis correct? ____

   Why or Why not?

   ____

   ____

3. How much colder or warmer did it get during the night? __________________________

4. How much did it cool down or heat up in the morning? __________________________

5. Estimate the time at which the heat or air conditioning was turned off during the night. Record this value in the Data Table. How did you make your estimate?

   ____

   ____

   ____

6. Estimate the time at which the heat or air conditioning was turned back on in the morning? How did you come up with your estimate?

   ____

   ____

   ____

7. In many buildings, there is a person who is in charge of turning the heat and air conditioning on and off. Can you find out who this person is and ask them if they know exactly when the heat or air conditioning was turned off and on? They may be interested in the data you collect. Write down the information that they give you and compare the value to your estimates. How close was your estimate?

   Actual time air conditioning or heat was turned off: __________________________________

   Actual time air conditioning or heat was turned on: __________________________________

   ____

   ____

The Temperature Probe Spends the Night

BACKGROUND INFORMATION

This activity takes two days to complete. On the first day, not much time is needed. Students simply set up their stations for overnight data collection. You may want to have the equipment set up in a location where it will not get disturbed. On the second day, students analyze the data.

Long-term data collection is useful in many ways. One application is cost analysis for energy efficiency. Schools and businesses may analyze temperature data to control costs for budgetary purposes. Temperature cost analysis of existing buildings also could be applied to the design and construction of new structures. Asking students to generate reasons why school a might be interested in overnight data collection could be a good launch point for this activity.

In large buildings, do not be surprised if the temperatures do not change very much overnight. Bigger buildings take a long time to warm up and cool down. You may want to take equipment home and do this activity in your own living space to see what happens. You can show your data to your students and discuss possible reasons for any observed differences.

TIME FRAME FOR ACTIVITY

This activity requires overnight data collection and 30 minutes for analyzing data.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – measurement, temperature, cycles

Math – comparison, graphical analysis, minimum, maximum, patterns

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. In the Procedure, students are directed to set up the equipment to collect data for 24 hours. However, the analysis questions do not require students to have information from the daytime. You can set up the equipment at the end of the first day and then return to the activity at the beginning of the next day. Simply have the students stop data collection early.

3. Vernier data-collection programs, including Graphical Analysis 4 and LabQuest App, do not collect data based on a 12- or 24-hour clock. Because of this, it may be easiest for your students to correlate the time of day to their data if you start data collection at 12:00 noon. If you are unable to do this, you will need to work with your students to correlate their data to actual times of the day.

4. If you want students to analyze the daytime data, you could ask them to determine the hottest part of the day and compare that to the morning and nighttime temperature values. You could compare these values to the high and low temperature values published in the paper or on the internet to see how inside and outside temperatures compare. If done over a several-day period, numerous questions could be asked regarding how weather affects the temperature of our living spaces and our use of energy.

5. It is okay if the screen on your computer, Chromebook, or mobile device goes to sleep; data collection will continue. However, you will want to be sure that other people who use the area are aware that the equipment needs to be left on and that the setups should not be disturbed. You may want to leave a note telling people what is going on. Devices that run on batteries (e.g., laptops or phones) should be connected to AC power.

6. One of the questions at the end of the activity asks students to find out who controls the air conditioning or heating system in the building. This may be an interesting extension for students to perform. The person in charge of these systems may also be interested in the data you collect. If possible, you could print out one of the graphs for the students to give to the person as a thank you.

7. There are many ways this activity could become an integral part of a unit on weather. Have students make observations about the conditions outside and the temperatures recorded during the activity. If security is not an issue, you could even hang a temperature probe out a window during the 24-hour data collection period and compare the outside temperature values to the inside temperature values. If it is wet outside, stick only the metal part of the probe out the window. If you have computers or Chromebooks with more than one USB port or are using Go Direct sensors, you may want to have fewer stations, each with multiple Temperature Probes connected. One probe could record the outside temperature and the other could record the inside temperature.

8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

	Time (example – 1:00 pm)	Temperature (°C)
Start of data collection	8:30 am	22.2
End of data collection	8:30 am	22.1
Warmest temperature	7:30 am	22.6
Coldest temperature	5:20 am	19.6
Estimated time air conditioning or heat was turned off at night	4:30 pm	
Estimated time air conditioning or heat was turned on in the morning	5:15 am	

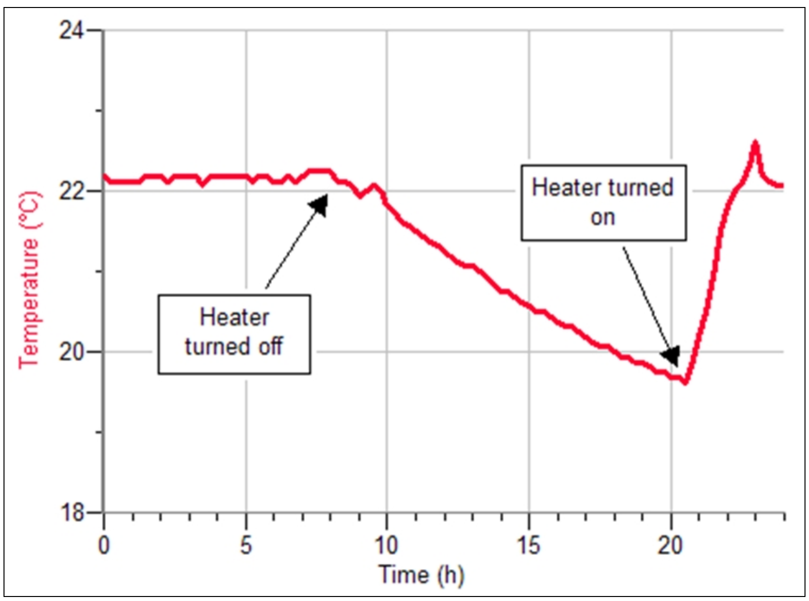


Figure 1 Indoor temperature over a 24-hour period.
Data collection was started at 8:30 am.

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers will vary. If it is very hot outdoors, it may get warmer in the evening after the air conditioning is turned off. If it is cool outdoors, it will most likely cool off in the evening.

2. Answers will vary.

3. Answers will vary. See the Sample Results.
4. Answers will vary. See the Sample Results.
5. Answers will vary.
6. Answers will vary.
7. Answers will vary.

ASSESSMENT

Provide students with building temperature data of a warm school day with air conditioning being used. Have students analyze the graph to explain the data.

EXTENSION

Have students collect and analyze overnight data of other spaces in the school building such as the gym or cafeteria.

Name: ______________________________

Hold Everything!
Comparing Insulators

Do you ever put a hot drink in a mug to keep your drink warm? When it is cold outside, do you put on a hat to keep warm? We do these types of things because mugs and hats are *insulators*, materials that keep heat in. Other materials, such as metal, are good *conductors*, materials that transfer heat from the source very well. You may have experienced the conductivity of metal if you've touched a spoon that had been in a very hot bowl of soup, or sat on a metal seat belt that had been in the sun.

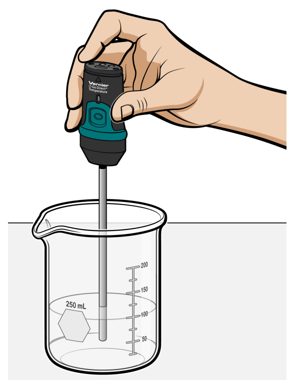


Figure 1

OBJECTIVES

- Compare temperature readings from two different cups when hot or cold water is added to them.
- Determine which material is a better conductor and which is a better insulator.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
2 cups made of different materials
masking tape and a waterproof marker

PROCEDURE

1. Predict which cup will be the best insulator and label it Cup 1. Label the cup that will be a better conductor as Cup 2.

2. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.

3. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Time Units to min and Rate to 10 samples/min.
   c. Set End Collection to 10 min. Click or tap Done.

4. Write a hypothesis about what will happen to the water in each of your cups. For example, a hypothesis about soup would be: “If I put my soup in a bowl that is a good conductor, I think the temperature will go down a lot. If I put my soup in a bowl that is a good insulator, I think the temperature will stay the same.”

   Hypothesis

   If I put cold water in a cup that is a good insulator, I think the temperature will

   ____

   If I put cold water in a cup that is a good conductor, I think the temperature will

   ____

5. Fill Cup 1 half full of water and place the cup in front of you on the table.

6. Place the temperature probe in the water in Cup 1. Hold onto the probe to ensure that it doesn’t tip the cup over.

7. When everything is ready, click or tap Collect to start data collection. Data will be collected for 10 minutes.

8. Click or tap the graph to examine the temperature and time values. **Note**: You can also adjust the Examine line by dragging the line.
   a. Drag the Examine line to the beginning of the graph. The first few readings may represent the period when the Temperature Probe was adjusting to the temperature of the water. After this short period, the actual temperature of the water was recorded.
   b. Record the temperature of the water before it started to warm up in the Data Table.
   c. Now drag the Examine line to the end of the graph. Record the ending temperature in the Data Table.

9. Repeat Steps 5–8 for Cup 2. **Note**: The previous data set is automatically saved.

Data Table				
Cup	Type of material	Starting temperature (°C)	Ending temperature (°C)	Change in temperature (°C)
1				
2				

ANALYZE YOUR DATA

1. Subtract the starting and ending temperatures to find out how much the temperature increased or decreased. Write your answer in the Data Table.
2. Was your hypothesis about the temperature changes of the water correct? _______________
3. In this activity, which cup was the better insulator? What material was this cup made out of? Write your answer in the Data Table.
4. In this activity, which cup was the better conductor? What material was this cup made out of? Write your answer in the Data Table.
5. If you wanted a cup of hot chocolate to stay hot, which of the two cups would you use?

   __________________________ Why? ____

   ____

   ____

6. If you had a cold drink and you wanted it to stay cold, which of the two cups would you use?

   __________________________ Why? ____

   ____

   ____

Hold Everything! Comparing Insulators

BACKGROUND INFORMATION

In this activity, students compare different materials to determine which is a better insulator and which is a better conductor. Prior to the activity, you may wish to provide the students with a background in heat transfer:

- *Conduction* is heat moving because of direct contact—this is the main type of heat transfer occurring in these activities. Most students are familiar with touching a hot object or heating a metal spoon by leaving it in a cup or bowl of hot liquid.
- *Convection* is the transfer of heat by movement of a gas or liquid—for example, steam rising from a cup of boiling water or heated air from a fireplace or wood stove.
- *Radiation* is the transfer of heat through space—such as heat energy from the sun warming us up.

This would also be a good time to introduce the concepts of insulator and conductor—an insulator does not allow heat to flow through it easily while a conductor does.

TIME FRAME FOR ACTIVITY

This activity requires about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – measurement, temperature, conduction, insulation, radiation

Math – comparison, graphical analysis, minimum, maximum

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. Each group will need two cups made out of different materials. Styrofoam® cups, plastic cups, coffee mugs, and metal cups (or tin cans) work well.

3. In the Procedure, students are instructed to use cold water. Adding ice to the water to make the water more cold can create more dramatic results, but this is not essential; cold tap water can work. In order to maintain constant temperatures of the water baths, it is also helpful if the water can be held in insulated containers. **Important**: If you add ice to the water, ensure that water used by students does not contain ice.

4. Students do not need to stir the baths during the data-collection period.

5. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

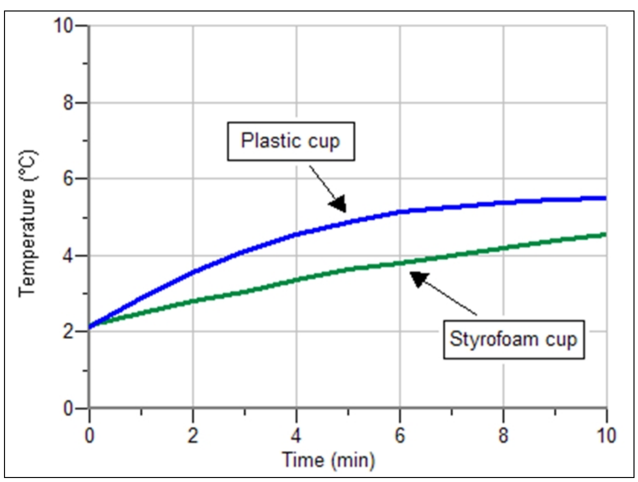


Figure 1 Warming of ice water in two different cups

Cup	Type of material	Starting temperature (°C)	Ending temperature (°C)	Change in temperature (°C)
1	Polystyrene foam cup	2.2	4.6	2.2
2	Plastic cup	2.1	5.5	3.4

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. See Sample Results.
2. Answers will vary.
3. Answers will vary, but for the sample data, Cup 1, the polystyrene foam cup, was a better insulator.
4. Answers will vary, but for the sample data, Cup 2, the plastic cup, was a better conductor.
5. Answers will vary. Based on the sample data, students should choose Cup 1 (polystyrene foam) because they want to keep the water warm.
6. Answers will vary. Based on the sample data, students should choose the polystyrene foam cup because they want to keep the water cold.

ASSESSMENT

Provide students with images of beverage containers. Have students rank the containers for their insulating ability.

EXTENSION

As an extension, have students try the activity with hot water instead of cold water. This will help students to understand that insulators keep hot things hot and cold things cold, not just one or the other. Use the warmest water you feel comfortable having your students work with. Best results can be achieved using very warm water, but you must balance this with safety considerations. You do not want your students to scald themselves if they have a spill. Warm tap water will work just fine.

Name: ______________________________

Keepin' it Cool!
Design Your Own Thermos

How does a thermos keep hot drinks hot and cold drinks cold? This activity will give you a chance to use some of the things you have learned about heat to design your own thermos.

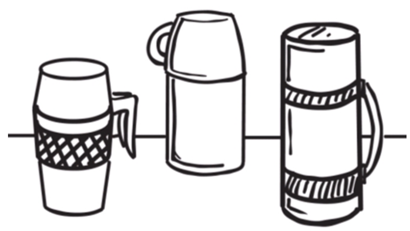


Figure 1

OBJECTIVES

- Use what you learned about heat to design a thermos that will keep cold water cold for as long as possible.
- Measure the changing temperature of the water in the thermos.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
cold water
a variety of materials provided by your teacher (you get to choose from these)
shoebox

PROCEDURE

Part I Design and make a thermos

1. Develop a design for your thermos. In the Thermos Design Sheet, write down your design plan and make a sketch of your design. Here are some questions to consider when working on your design.
   - What materials are available to me?
   - How will I insulate my thermos?

   Reminder: You will need a hole in the thermos to put the Temperature Probe in it.

Thermos Design Sheet
Design Plan ____ ____ ____
Design Sketch (Remember to label all parts and materials.)

2. Based on your design and the materials you have available, build your thermos.
3. Write your hypothesis about what will happen. For example, a hypothesis about a table would be: "I think the table that I made is very strong and will be able to hold 50 pounds of bricks. However, one of the legs is weak and, therefore, it might break after 30 pounds of bricks are placed on it."

Hypothesis

I think my thermos design is very ________________ and will maintain the temperature of the cool water for about __________________. However, ______________________________ ________________ and, therefore, it might lose heat more quickly.

Part II Testing the thermos

4. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.
5. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Time Units to min and Rate to 10 samples/min.
   c. Set End Collection to 20 min. Click or tap Done.
6. Place your thermos on your table.
7. Get the correct amount of cold water. Ask your teacher how much you should use if they have not already told you. Make sure there is no ice in the water.
8. Place the Temperature Probe in the thermos.
9. When everything is ready, click or tap Collect to start data collection. Data will be collected for 20 minutes.
10. How many degrees did the temperature change? You can probably tell from the graph, but to find out exactly, do the following:
    a. Click or tap the graph to examine the data. Drag the Examine line to the beginning of the graph. The first few data points may represent the time during which the probe adjusted to the temperature of the water.
    b. Identify and record the temperature of the water before it started to change in the Data Table.
    c. Record the ending temperature on the graph in the Data Table.

Data Table	
Starting temperature (°C)	
Ending temperature (°C)	
Change in temperature (+ or –) (°C)	

ANALYZE YOUR DATA

1. Look at your starting temperature and ending temperature to see which one is greater. Subtract the lower temperature from the higher temperature to find out how much the temperature changed. Write your answer in the last column of the Part II Data Table. If the temperature increased, write a "+" in front of the number. If it decreased, write a "–" in front of the number.
2. Was your hypothesis correct? __________________ Why or Why not?

   ____

   ____

3. Explain the design of your thermos.

4. Why did you choose to build your thermos as you did?

5. How successful was your design? Why do you say this?

6. If you could design another thermos, what would you do differently?

Keepin' it Cool!
Design Your Own Thermos

BACKGROUND INFORMATION

This activity ties together change of state, conduction, insulation, convection, and conduction. Students will take all they have learned and put it together to build a thermos that will keep ice water from warming up.

Prior to the activity, you may wish to provide the students with a general history of the thermos:

> The thermos was invented by Sir James Dewar, a Scottish scientist. He knew heat was transferred by conduction and convection. To prevent heat loss from convection, he put a cork in the top of the flask. To prevent heat loss from conduction, he put a glass in a glass and removed all the air out between the two layers. He minimized heat loss due to radiation by coat the inner glass with silver. Finally, he placed a steel or plastic case around the outer glass to keep it from breaking.

Technology has improved since the time of Sir James and we now use different insulating materials and seldom use glass when making an insulated container.

TIME FRAME FOR ACTIVITY

This activity requires at least three 45-minute sessions. We recommend the following structure:

> Session 1: Students individually design an insulated container. Then, they collaborate in small groups to develop a group design.
>
> Session 2: Students construct their insulated containers.
>
> Session 3: Students collect and analyze their data.

In the analysis questions, students are asked how they would change their design. If you would like to expand upon the activity, you could give students a chance to create a new container and collect additional data. This would require two or three additional sessions.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer ETS1.A: Defining and Delimiting Engineering Problems ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – measurement, temperature, conduction, insulation, radiation

Math – comparison, graphical analysis, minimum, maximum

Engineering – Engineering Design Process

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. You may have the students check their design with you before they begin construction, to be sure they have thought it out fully. Once students have designed their thermos and checked the design with you, have them build the thermos, and fill the container 3/4 full of ice water. Try to give each group the same amount of water so they can compare their data.

3. Make the following materials available to the students, if possible:
   - shoe boxes (for outer containers)
   - plastic or polystyrene foam cups
   - hot cup lids
   - aluminum foil
   - construction paper
   - tape
   - scissors
   - polystyrene foam peanuts or pieces for insulation
   - plastic bubble wrap
   - different sizes of jars with lids (punch holes in the lids with a hammer and nail so the temperature probe will fit into the "thermos")

- newspaper
- paper towels
- plastic containers with lids with holes in them
- waxed paper
- whatever else you think students may want or that you have handy to act as insulation (wool, scrap fabric, batting, etc.).

4. Depending on the interest level of the students, you may want to actually let them redesign and reconstruct their thermos based on the findings from their preliminary designs.

5. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Starting temperature (°C)	3.2
Ending temperature (°C)	3.9
Change in temperature (+ or -) (°C)	+0.7

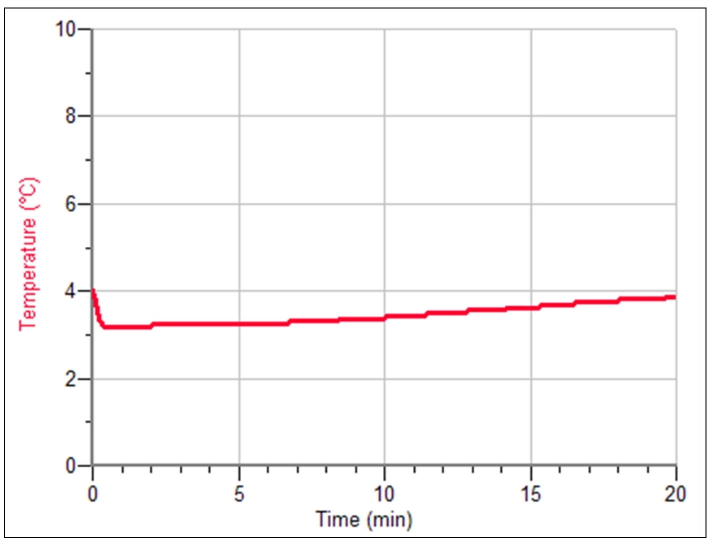


Figure 1 Temperature change in a student-made thermos. Note: In order to record the lowest temperature, data collection was started before the Temperature Probe had fully adjusted to the temperature of the water.

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers will vary. See the Sample Results.
2. Answers will vary.
3. Answers will vary.
4. Answers will vary.
5. Answers will vary.
6. Answers will vary.

ASSESSMENT

The last two questions in the Analyze Your Data section provide students with the opportunity to demonstrate their understanding. You might initiate a class discussion to share student results prior to assigning these questions.

EXTENSIONS

1. As part of the Engineering Design Process, students to test their innovations and then make revisions to improve them. Have students use their first experience to design and create a new prototype.
2. Transform this activity into a STEAM project. Introduce design elements such as product naming, logos, label design, slogan, and aesthetic container design.

Name: ________________________________

I'm Melting!
Water Changes States

As you probably know, if you put ice in a drink, the ice cools down the drink. At the same time that the ice is cooling down the drink, it is being melted by the liquid it is in. Do you think that if you put an ice cube in hot water, it will melt at a different rate than if you put it in colder water? During this activity, you will investigate how ice melts in water.

OBJECTIVES

- Observe the melting of ice cubes over a period of time.
- Learn about the properties of solid water and liquid water.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Temperature
2 cups or beakers
ice
room-temperature water

PROCEDURE

1. Write a hypothesis about what will happen to the ice and the temperature of the water when you put an ice cube in room temperature water.

   Hypothesis

   If I put an ice cube in room temperature water, it will ______________________________

   ____

   and the temperature of the water will ____

   ____

2. Connect the Temperature Probe to your Chromebook, computer, or mobile device. Launch Graphical Analysis.

3. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Time Units to min and Rate to 50 samples/min.
   c. Set End Collection to 10 min. Click or tap Done.

4. Fill one of your cups about half full with room-temperature water provided by your teacher and place it in front of you on the table.

5. Put two whole ice cubes in your other cup.

6. Place the Temperature Probe in the water. Make sure it won't tip over the cup.

7. You will now collect data and make observations about the melting ice and the temperature of the water. You may want have one person be in charge of adding ice cubes and another to write down your observations. Someone should also be responsible for stirring the water with the temperature probe for the entire time that data are being collected.

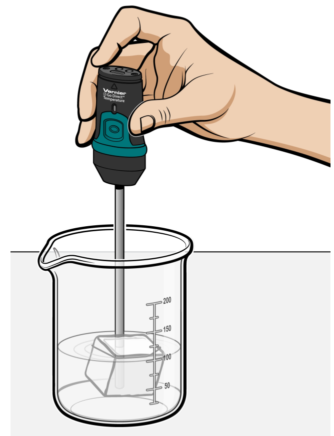


Figure 1

8. When everything is ready, collect data and make observations.
   a. Click or tap Collect to start data collection.
   b. Add one ice cube to the water. Gently stir the water with the temperature probe.
   c. Watch the temperature on the screen. In the space provided on the Observations Sheet, write a few observations about the ice cube and the temperature of the water.
   d. When the ice cube has melted completely, immediately add another ice cube, and continue stirring with the temperature probe. Write down your observations.
   e. When the second ice cube has melted completely, stop data collection.

9. Dispose of your materials as directed by your teacher.

Observations Sheet
When I put the first ice cube in the water, it melted in __________ minutes. The temperature of the water ______________________________ ______________________________ ______________________________

ANALYZE YOUR DATA

1. Was your hypothesis correct? Why or why not?
2. What temperature was the water when you put in the first ice cube? Record this value in the Data Table as the "Starting temperature" for ice cube number 1. Remember, you can click or tap the graph to find exact values of the data points.
3. What was the temperature of the water when the first ice cube had melted completely? Record this value in the Data Table as the "Ending temperature" for ice cube number 1.
4. Record the values of the starting and ending temperatures for ice cube number 2.
5. Subtract the starting and ending temperatures for the two ice cubes to find out how much the temperature decreased while each ice cube melted. Write your answers in the last column of the Data Table.

Data Table			
Ice cube number	Starting temperature (°C)	Ending temperature (°C)	Change in temperature (°C)
1			
2			

6. Look at the graph that was made during data collection. Which ice cube melted the fastest?

____

____

7. Explain why it took longer for one of the ice cubes to melt.

____

____

I’m Melting!
Water Changes States

BACKGROUND INFORMATION

During this activity, students watch two ice cubes melt. They make observations about the melting of the ice cubes and the effect of melting ice on the temperature of water that is initially at room temperature.

Since this activity has students observe ice cubes melting and their effect on water temperature, this may be a good opportunity to discuss the effects of melting polar ice on ocean temperatures, ecosystems, and climate.

TIME FRAME FOR ACTIVITY

This activity requires about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – measurement, temperature

Math – comparison, graphical analysis, subtraction

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and

the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. Remind students to stir the water for the entire data-collection period.

3. The temperature changes that your students observe will be affected by the size of the ice cube they use. For comparison between students, it is best if they all have similar sized ice cubes. However, you may want to use different sized ice cubes between groups and lead the students in a discussion about why different groups got different values. If different kinds of cups are used, this could also be brought up in a discussion before or after the activity.

4. The data in the Sample Results was collected by melting large ice cubes from a refrigerator ice-making machine in about 1 measuring cup or 300 mL of water. The volume of each of the ice cubes used was approximately 9 mL. If your students use smaller ice cubes, the overall time of data collection will be shorter, and students will see a smaller change in temperature. If you are using very small ice cubes, you will want to make sure that students will see enough of a temperature change.

5. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Ice cube number	Starting temperature (°C)	Ending temperature (°C)	Change in temperature (°C)
1	21.6	12.4	9.2
2	12.4	5.4	7.0

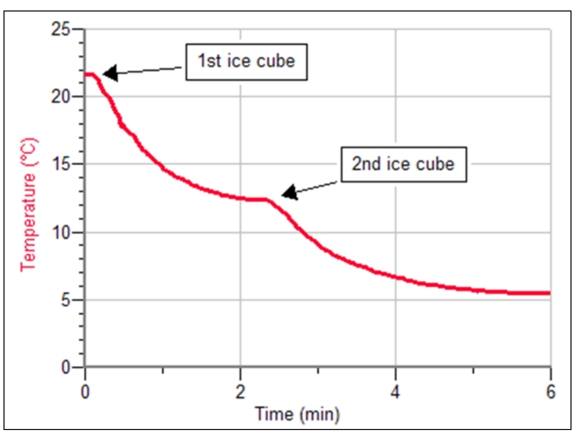


Figure 1 Decrease in water temperature as ice cubes are added

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers will vary.
2. Answers will vary. See the Sample Results.
3. Answers will vary. See the Sample Results.
4. Answers will vary. See the Sample Results.
5. Answers will vary. See the Sample Results.
6. Answers may vary. For the Sample Results, the first ice cube melted the fastest.
7. Answers may vary. If students are unable to answer this question on their own, you may want to discuss the fact that there is a smaller temperature difference between the temperature of the second ice cube and the water and, therefore, it melts at a slower rate.

ASSESSMENT

Ask students to predict what they would observe with the water temperature if a third ice cube and fourth ice cube were added to the water using the same process as was done in the Procedure.

EXTENSION

Have students conduct the activity using a salt water mixture and compare with the original fresh water version of the activity.

Name: ______________________________

Solid, Liquid, Gas: Water Can Do It All

As you have learned, materials can exist in three different states: solid, liquid, and gas. Water is a substance that we often see in all three states. You put solid water (ice) in your drinks to cool them down. You drink liquid water when you are thirsty. You breathe gaseous water when you take a breath. During this activity, you will watch your teacher melt and boil water, and make observations about what you see happening.

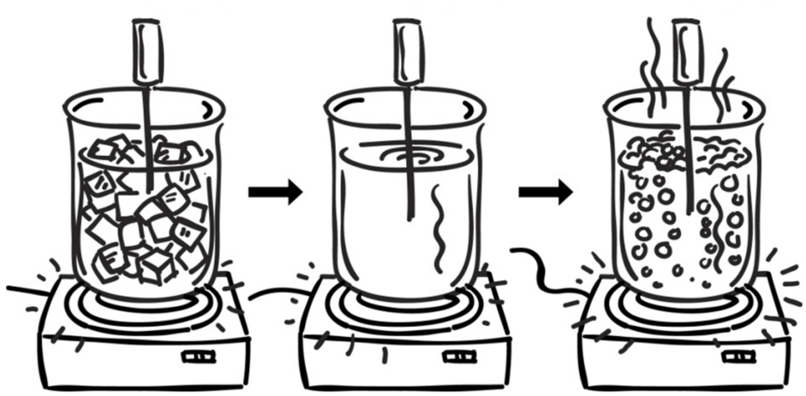
OBJECTIVES

- Determine the temperature at which ice melts.
- Determine the temperature at which water boils.
- Make observations about water as it goes from a solid to a liquid, and then to a gas.

MATERIALS

paper and a pencil

PROCEDURE



Your teacher will perform a demonstration using heat. Your job is to make observations about changes in the temperature and the object being heated. Record your Observations on the Observations Sheet. Be sure to answer all of the questions on the Observations Sheet.

Observations Sheet

1. What happens to the ice as heat is added?

2. What happens to the temperature as heat is added to the ice?

3. What happens to the temperature when the ice is completely melted?

4. What happens to water as heat is added?

5. What happens to the temperature as heat is added to water?

6. What happens to boiling water as heat is added?

7. What happens to the temperature as heat is added to boiling water?

ANALYZE YOUR DATA

1. At what temperature does ice melt? ___________________________
2. At what temperature does water boil? __________________________
3. What do you need to do to turn steam back into water?

   ____

   ____

4. What do you need to do to turn water back into ice?

   ____

   ____

Solid, Liquid, Gas: Water Can Do It All

BACKGROUND INFORMATION

This activity is best done as a demonstration because it involves heating and boiling water. If you feel your students are old enough to work with hot plates and boiling water, you can tell them how to carry out the Procedure that is included here.

TIME FRAME FOR ACTIVITY

This activity requires about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS1.A: Structure and Properties of Matter PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – measurement, temperature, states of matter

Math – comparison, graphical analysis

MATERIALS

data-collection program (e.g., Graphical Analysis 4 or Logger Lite)
data-collection interface (if necessary for your equipment)
Temperature Probe (e.g., Stainless Steel Temperature Probe or Go Direct Temperature Probe)
large beaker or other heat-safe, clear container
water
ice
hot plate
goggles

PROCEDURE

1. Set up the data-collection equipment.

   Graphical Analysis 4

   a. If you are using a Stainless Steel Temperature Probe (TMP-BTA), connect the Temperature Probe to the data-collection interface, and then connect the interface to your Chromebook, computer, or mobile device. Then, launch Graphical Analysis. If you are using a Go Direct Temperature Probe (GDX-TMP), first launch Graphical Analysis. Then, connect the Temperature Probe to your Chromebook, computer, or mobile device.
   b. Click or tap Mode to open Data Collection Settings. Change Time Units to **min** for minutes and set End Collection to 30 min. Click or tap Done.

   Logger Lite

   a. If you are using Go!Temp, connect the probe to your computer. If you are using a Stainless Steel Temperature Probe, connect the probe to the interface and then connect the interface to your computer.
   b. Start Logger Lite on your computer.
   c. Click Open, .
   d. Open the folder called "Elementary Science".
   e. Open the file called "Act 15 Solid Liquid Gas."

   LabQuest App

   a. Connect the Temperature Probe to LabQuest.
   b. Choose New from the File menu.
   c. On the Meter screen, tap Length. Change the data-collection unit to Minutes and the data-collection length to 30 minutes. Select OK.

2. Collect data.
   a. Fill the beaker half-full with ice. Add water so it just covers the ice.
   b. Start data collection.
   c. Place the beaker on a hot plate and heat to boiling.

HELPFUL HINTS

1. The student version of this activity was designed as a space to record observations of the teacher demonstration. As with all the other activities in this book, you will find word-processing and PDF files of the student pages in the Electronic Resources. If necessary, edit the word-processing file to create a handout that works well for your context. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information.

2. The graph in the Sample Results was made by boiling 300 mL (just over one measuring cup) of ice filled with enough water to just cover the ice. We performed the activity using a beaker.

We recommend using something clear, so that students will be able to make observations. **Important**: Be sure you are using a Pyrex or Kymax container that is guaranteed to handle temperatures in excess of 100°C. You should also wear goggles.

3. It is important to continuously stir the water while the ice melts, and eventually boils, in order to maintain a constant temperature throughout the bath. It is also important for the temperature probe not to rest on the bottom of the container in which you are boiling the water, because it will be sensing the temperature of the container rather than the water.

4. Bubbles started to form on the bottom of the container at a temperature of about 43°C. While stirring, these bubbles were released and may appear to students as if the water had begun boiling. A small amount of steam was observed at about 80°C and actual boiling began just under 100°C.

5. Review the questions on the Observations Sheet with your students. Be sure they understand that heat is needed to change states from solid to liquid to gas. As heat is removed, substances will change from gases to liquids to solids. Think about water vapor on a cold window or your glasses, or, putting water in the freezer. The cold takes away the heat (that's why we put ice on burns!). As the heat energy is taken away, the particles in the matter move more slowly, the temperature drops, and the state may change.

6. Students may have a difficult time understanding why the temperature of the ice water does not go up very much until the ice is mostly melted. Students will probably predict that the temperature will go up gradually. Try to get them to understand that during a change in state, the temperature will not change very much. All of the energy is going toward melting the ice, not increasing the water temperature. Once all the ice is melted, the temperature will increase at a faster rate.

7. You may want your students to sketch a copy of the graph to use when answering the questions in the Analyze Your Data section.

8. As an extension, you could compare the length of time that it takes for water to boil with and without a lid. This could tie into your lessons about insulators. In this extension, you may not want to stir the water when boiling in order to more accurately compare the boiling of the water with a lid on. You should attempt to find a way to keep the probe from resting on the bottom of the container.

9. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

10. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

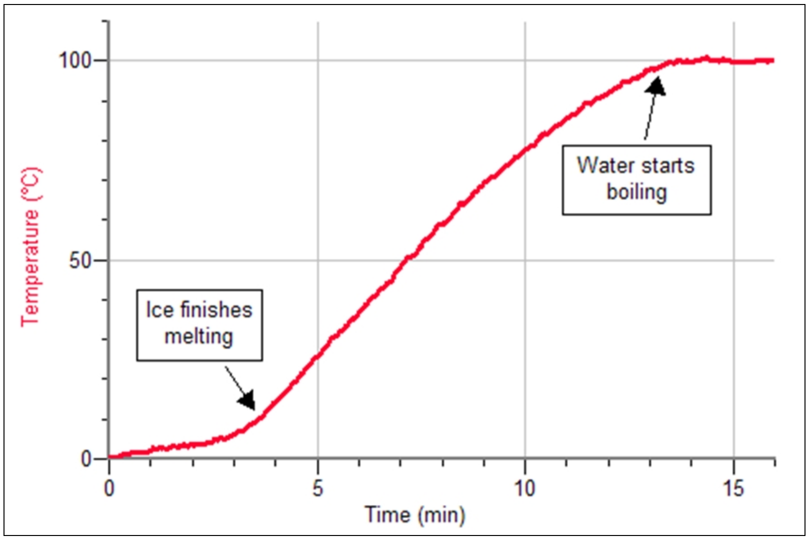


Figure 1 Temperature of ice water as it is heated to boiling

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. For the Sample Results, the ice melted between 0°C and 10°C.
2. For the Sample Results, the water boiled at 98.8°C.
3. You need to cool the steam to turn it back into water.
4. You need to cool the water to turn in back into ice.

Name: ______________________________

Learning to Use a Pressure Sensor

You can use the Pressure Sensor to measure changes in pressure in a closed system (a container that does not allow any air to move in or out). In this activity, you will work with a Pressure Sensor to learn how it behaves.

OBJECTIVES

- Learn to use the Gas Pressure Sensor.
- Measure the changing pressure as you move the plunger on a syringe.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Gas Pressure Sensor
plastic syringe

PROCEDURE

Part I Learn about the Pressure Sensor

1. Launch Graphical Analysis. Connect the Pressure Sensor to your Chromebook, computer, or mobile device.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 120 s. Click or tap Done.

3. Do the following to get the equipment ready. If your teacher has set up the equipment for you, you can skip this step.
   a. Position the plunger so the front edge of the plunger is at the 10 cc (mL) mark on the syringe.

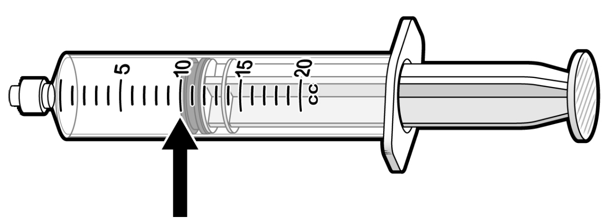


Figure 1

b. Gently twist the syringe onto the pressure sensor. **Caution**: Do not twist too far, it only takes about 1/2 turn.

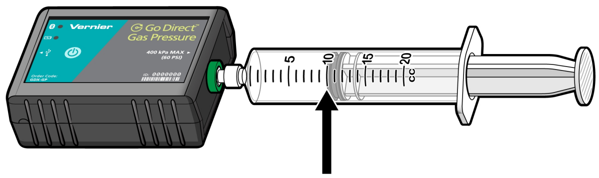


Figure 2

4. Now, by performing the following steps, collect data using the Pressure Sensor. After you collect data, you will make observations about what happens when you use the Pressure Sensor, so pay attention to what happens!
   a. Look at the screen and click or tap Collect to start data collection.
   b. Push in the plunger and watch how the pressure changes. How high can you make the pressure go? **Caution**: The connection point between the syringe and the sensor is delicate. Don't bend at the connection.
   c. Hold the syringe in the same place for about 5 seconds.
   d. Now pull the plunger out past the 10 mL mark. How low can you make the pressure go without pulling the plunger all the way out?

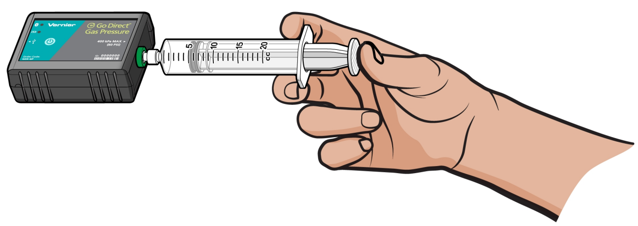


Figure 3

5. Answer the questions on the Observations Sheet:

Observations Sheet
1. When I pushed the plunger in, the pressure _______________________________________
2. The highest pressure I got was ______________ kPa.
3. When I held the plunger steady, the pressure _______________________________________
4. When I pulled the plunger out past the 10 mL mark, the pressure _______________________________________
5. The lowest pressure I got was _______________ kPa.

Part II Making letters with the Pressure Sensor

6. In this part of the activity, you will make a graph shaped like the letter **M** (see Figure 4). Think about what you will need to do with the plunger in the syringe. Then, fill in the blanks with your plan.
   a. Start with the plunger at the 10 mL mark.
   b. Click or tap Collect to start data collection.
   c. Keep the plunger at 10 mL for _______ seconds.
   d. ___________ (Push or Pull) on the plunger.
   e. ___________ (Push or Pull) on the plunger.
   f. ___________ (Push or Pull) on the plunger.
   g. ___________ (Push or Pull) on the plunger.
   h. Move the plunger to the _______ mL mark and hold it there until data collection ends.

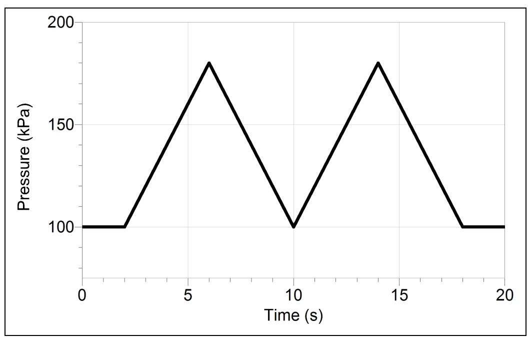


Figure 4

7. Follow the steps you wrote in Step 6.

8. If the graph looks like an **M**, congratulations! You can move on to the next step. If you want to make the **M** again, repeat Step 6.

9. After you have made the letter **M**, you will make the letter **W**. Write down the steps you would take to make a letter **W**. Use the words in Step 6 as a pattern.

____

____

____

____

____

____

10. Follow the steps you wrote in Step 9.

11. If the graph looks like the **W**, congratulations! If you want to make a **W** again, repeat the steps you wrote.

Learning to Use a Pressure Sensor

BACKGROUND INFORMATION

This activity serves as an introduction to the use of a Gas Pressure Sensor. The Gas Pressure Sensor can be used to measure changes in pressure of gas (usually air). A set of accessories comes with the Gas Pressure Sensor. In this activity, students will work with the plastic syringe. The plastic tubing and the stoppers are used in other activities. Should you need to replace items, you can purchase additional accessory kits (product name: Gas Pressure Sensor Replacement Parts, order code: PS-ACC).

Pressure can be measured in many different units. The equivalent values of 1 atmosphere in other units are

1 atm = 101.3 kPa (kilopascals, used by much of the world and the scientific community)

= 760 mmHg (millimeters of mercury, often used by meteorologists to measure barometric or atmospheric pressure)

= 14.7 psi (pounds per square inch, often used in measuring tire pressure, pressure of basket balls, etc.)

TIME FRAME FOR ACTIVITY

This activity takes about 30 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Crosscutting Concepts	Science and Engineering Practices
Cause and effect	Planning and carrying out investigations

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. Work with students to show them how to use the Pressure Sensor without damaging the connection between the sensor box and the syringe.
   - Syringes only need be turned about 1/2 of a turn to connect them to the Gas Pressure Sensor. Tightening them any further can damage the plastic. If students won't be able to follow this direction, you may want to set up the equipment beforehand.
   - A good way to hold the sensor/syringe is illustrated in Figure 1. This orientation protects the connection between the sensor and the syringe through bending or twisting.

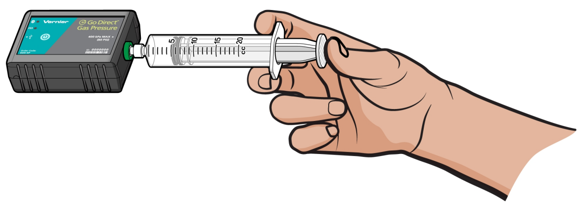


Figure 1

3. If you have not covered closed and open systems with your students, you may want to discuss them as part of this activity. The Gas Pressure Sensor with the syringe attached is a *closed* system. That is, no air can move in or out when you move the plunger. The sensor measures how much the volume of air in the system is compressed or expanded. The volume changes, but the amount of air in the system does not.

4. When students fill in the Observations Sheet, they are asked to record the highest and lowest pressures they produced during data collection. You can remind them about scrolling through the data table or using the Statistics feature of the data-collection software:
   - Graphical Analysis 4: Click or tap Graph Tools, , and choose View Statistics.
   - Logger Lite: Click Statistics, .
   - LabQuest App: Choose Statistics from the Analyze menu.

5. You can change units the displayed units for the Pressure Sensor in the Vernier data-collection program:
   - Graphical Analysis 4: Click or tap the Pressure meter and select the Units you want to display.
   - Logger Lite: Choose Change Units from the Experiment menu.
   - LabQuest App: On the Meter tab, choose Change Units from the Sensors menu. Select the units you want to display.

6. The plastic syringes needed for this activity come with the Pressure Sensors. Should you need to replace the syringes, you can purchase additional accessory kits (product name: Gas Pressure Sensor Replacement Parts, order code: PS-ACC).

7. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

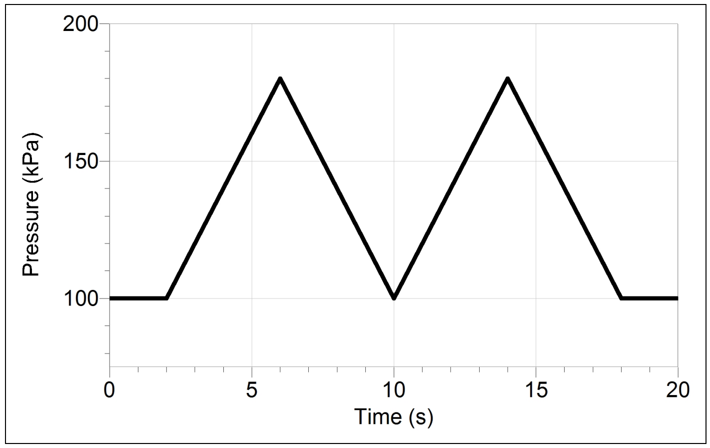


Figure 2 Data collected while doing Part II of this activity

ASSESSMENT

1. Ask students if they can think of reasons it would be helpful to use a Pressure Sensor. They may need help with this idea and you could discuss how pressure is related to weather.
2. Ask students what other letters could be made.

EXTENSIONS

1. Have the students draw predictions and try to match them themselves.
2. You could draw other shapes or letters and have the students try to match them. See who can match them the best after only one try.

Name: ________________________________

Get a Grip!

In this experiment, you will measure your grip strength. You will see if your grip strength changes as you grip an object for a longer time. You will also compare your grip strength with your classmates.

OBJECTIVES

- Use a computer and a Pressure Sensor to measure your grip strength.
- See which of your hands has the greater grip strength.
- Learn what happens to your grip strength as time goes by.
- Compare your grip strength with your classmates.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Gas Pressure Sensor
equipment for your setup:
  plastic tubing and bulb assembly
  or
  plastic bottle and plastic tubing with stopper assembly

PROCEDURE

1. Assemble your equipment as shown (bulb setup in Figure 1, bottle setup in see Figure 2). If you are using a bottle, make sure the valve is in the closed position.

Figure 1

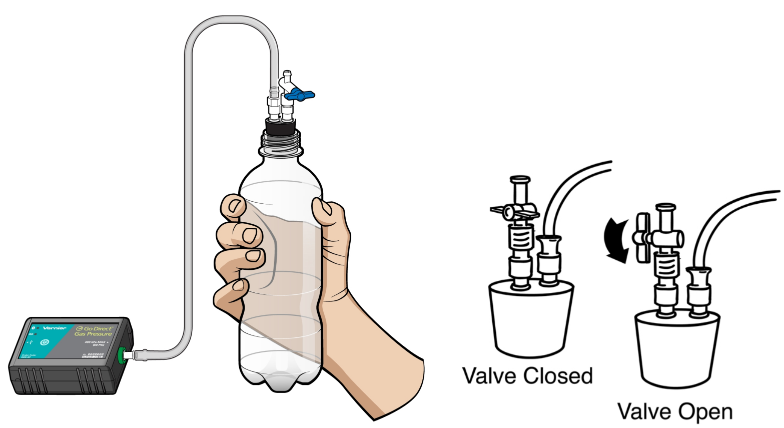


Figure 2

2. Launch Graphical Analysis. Connect the Pressure Sensor to your Chromebook, computer, or mobile device.

3. Click or tap Mode to open Data Collection Settings. Set End Collection to 60 s. Click or tap Done.

4. Each person in the group will have a chance to test their grip strength. Decide who will go first.

5. When it is your turn, collect data for your right hand first:
   a. Pick up the bulb or bottle with your right hand and begin squeezing as hard as you can.
   b. Have a teammate click or tap Collect to start data collection.
   c. Keep gripping as hard as you can until data collection stops. Do not lean your hand or arm on anything!

6. To find out your average pressure for the time period that you were gripping, do the following:
   a. Click or tap Graph Tools, , and choose View Statistics.
   b. If this was your turn to grip, record the average (mean) pressure for the 60-second period in Table 1.

Table 1	
	0–60 s average pressure (kPa)
My right hand	
My left hand	

7. Now collect data on your left hand by doing the following:
   a. Pick up the bulb or bottle with your left hand and begin squeezing as hard as you can.
   b. Have a teammate start data collection.
   c. Keep gripping as hard as you can, but do not lean your hand or arm on anything!

8. Do the following to find out the average pressure for your data:
   a. Click or tap Graph Tools, , and choose View Statistics.
   b. If this was your turn to grip, record the average (mean) pressure for the 60-second period in Table 1.

9. Repeat Steps 5–8 for each person in your group. **Note**: The previous data set is automatically saved each time you click or tap Collect.

ANALYZE YOUR DATA

1. What happened to your gripping strength during the 60 seconds that data were collected?

2. Which of your hands is stronger? Use your data to explain your decision.

____

____

3. Do you use your stronger hand to write or do other things? Give examples of what you think you could do to make your weaker hand as strong as your strong hand.

____

____

4. What did you learn about your strength in this experiment? Were you surprised?

____

____

5. In Table 2, record the 0–60 s results for the strong hand of the other students in your group. Calculate and record your group average. Calculate and record the class average for 0–60 s.

Table 2: Group and Class Results	
Name	Strong hand average for 0–60 seconds (kPa)
Group average (Group mean sum ÷ number of group members)	
Class average	

6. How does your grip compare with the class average?

____

____

____

TEACHER INFORMATION

Activity **17**

Get a Grip!

BACKGROUND INFORMATION

The harder the students grip the bottle, the higher the pressure inside the bottle will be. As their muscles fatigue, their grip will loosen and the pressure will decrease.

TIME FRAME FOR ACTIVITY

This activity requires about 45–60 minutes depending on the number of group members.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Physiology – difference between right- and left-handedness, ambidextrousness

History/Cultural Difference – difference in how people of different cultures have been, and possibly are, treated if they display a tendency toward being left-handed

Math – mean, subtraction, statistics

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. This should probably not be the first Pressure Sensor activity your students do. Begin with 16, "Learning to Use the Pressure Sensor."

3. Either plastic water bottles or Gas Pressure Sensor Bulbs can be used for this experiment. However, the plastic in modern water bottles is very thin and tends to crack after only a few trials. In addition, it may be difficult to find bottles that fit the rubber stoppers that come with the sensor. For these reasons, the Gas Pressure Sensor Bulb is recommended (order code: GPS-BULB1 for a single bulb or GPS-BULB4: for a pack of 4 bulbs).

4. If a water bottle and a two-hole stopper are used for this activity, you may wish to assemble them beforehand. Make sure the valve is in the closed position. When the handle is perpendicular to the valve (making a plus sign), the valve is closed (see Figure 1). When the handle is lined up with the tube, the valve is open.

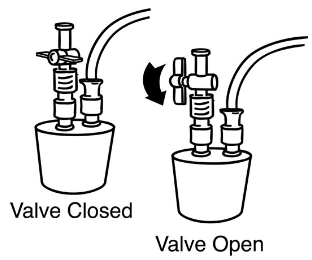


Figure 1

5. If a water bottle is used for this activity, it can be used in 18, "Under Pressure," and/or 19, "Bubbles in Your Bread."

6. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

	0–60 s average pressure (kPa)
Right hand	114.3
Left hand	112.6

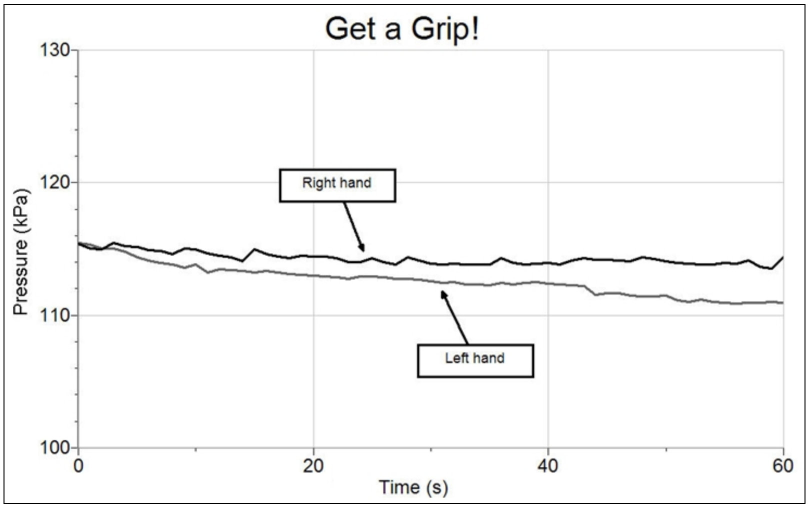


Figure 2 Change in gripping pressure over time for a student

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Gripping strength generally decreases during the 60 s period because of fatigue.
2. Answers will vary. Generally, the dominant hand will be stronger.
3. Answers will vary. Generally, students will write with the hand that is stronger. They may suggest doing exercises or other activities to strengthen their weaker hands.
4. Answers will vary. Some students will be surprised at how quickly they fatigue.
5. Students will fill in the table.
6. Answers will vary.

ASSESSMENT

Engage in a discussion with the students about why their dominant hands are stronger than their non-dominant hand.

EXTENSIONS

1. Challenge students to see if they can increase their grip strength over time. Ask them what they might do to achieve such a goal.
2. Have students research how left-handedness is viewed in different cultures as well as how/if attitudes have changed over time.

Name: ______________________________

Graphical Analysis **18**

Under Pressure

Do you ever wonder why you can only blow so much air into a balloon before the balloon bursts? Or why a volcano erupts and shoots gases, dust, and molten rock high up into the air? This activity will allow you to explore pressure changes similar to these in the safety of your own classroom! Be sure to wear your safety goggles whenever you work with chemical reactions — this activity is a BLAST!

OBJECTIVES

- Record what happens to the air pressure when you combine vinegar and baking soda in a plastic water bottle.
- Find out what happens when you mix different amounts of vinegar and baking soda together.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Gas Pressure Sensor
plastic tubing and stopper assembly
50 mL vinegar
3 spoonfuls baking soda
cup with marking on side
plastic spoon
plastic bottle
water
goggles
paper towels or rags to clean up spills
tray

PROCEDURE

1. Get a pair of goggles and put them on. Make sure each person in your group is wearing a pair of goggles during this activity.

2. Launch Graphical Analysis. Connect the Pressure Sensor to your Chromebook, computer, or mobile device.

3. Click or tap Mode to open Data Collection Settings. Set End Collection to 120 s. Click or tap Done.

4. Place one leveled-off, plastic spoonful of baking soda in the plastic bottle.

5. Twist the stopper into the mouth of the bottle so it fits tightly. **Important**: The stopper must be twisted in tightly or it may pop out during the reaction.

6. Close the system by rotating the handle on the valve so it is sideways to the valve (like the "Valve Closed" drawing in Figure 1). Remember, in this position, the system is closed and nothing can move in or out. **Note**: During this activity you will rotate the handle, opening and closing the system when you need to, so make sure you understand the drawings.

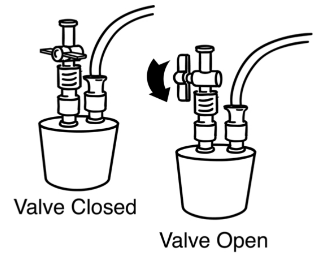


Figure 1

7. Now, get vinegar in the syringe by following these steps:
   a. Get about 50 mL of vinegar in your cup.
   b. Pick up the syringe and push the plunger all the way into the syringe.
   c. Place the tip of the syringe into the vinegar in your cup.
   d. Draw 5 mL of vinegar up into the syringe by pulling up on the plunger until the front edge of the plunger is at the 5 mL mark.

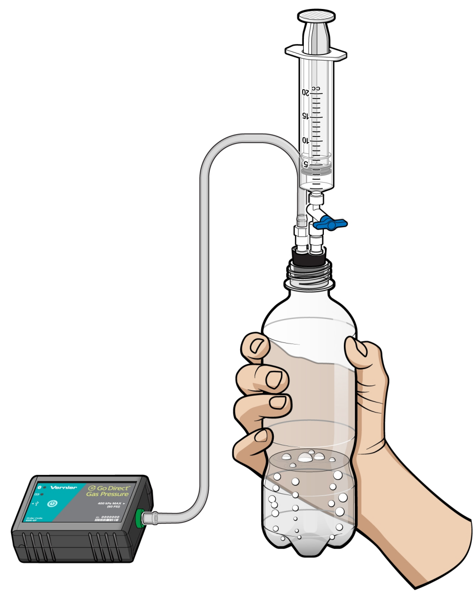


Figure 2

8. Attach the syringe to the stopper by doing the following:
   a. Make sure the handle on the stopper is in the closed position.
   b. Gently twist the syringe onto the handle valve. **Caution**: Do not twist too far; it only takes about 1/2 turn.

9. You will now collect data. **Important**: This step needs to be done quickly, so read through the directions once before you do anything. When you have read and understood the directions, you can collect data.
   a. Twist the handle on the valve so that it is in the open position.
   b. Click or tap Collect to start data collection.
   c. Press and hold the plunger down to add the vinegar.
   d. Once all the vinegar is in the bottle, quickly twist the handle on the valve to close the system (making a plus sign).
   e. Gently swirl the bottle so all the vinegar reacts with the baking soda. Have one person hold the stopper and syringe plunger in place so they do not pop up or out. **Caution**: Do not shake the bottle!

10. Fill out the Data Table for this run by following these steps:
    a. Click or tap View, ⊞, and choose Table. Find the pressure at the beginning of the run (the Pressure value at Time = 0 sec).
    b. Write down this value as the beginning pressure in the Data Table.
    c. Now, scroll down through the data to find the final pressure (the pressure value at time = 40 seconds).
    d. Write down this value as the final pressure for this run.

Data Table					
Run	Amount of baking soda	Volume of vinegar (mL)	Beginning pressure (kPa)	Final pressure (kPa)	Change in pressure (kPa)
1	1 spoon	5			
2	1 spoon	10			
3	1 spoon	15			

11. Empty the bottle as instructed by your teacher, then rinse it with water.
12. Repeat Steps 4–11, but this time, use 10 mL of vinegar. **Note**: The previous data set is automatically saved.
13. Repeat Steps 4–11, but this time, use 15 mL of vinegar.
14. Help clean up any messes that were made during the activity. After you have cleaned your bottle, ask your teacher where it should go.

ANALYZE YOUR DATA

1. How did the pressure in the bottle change during the reaction? What do you think caused this change?

____

____

____

2. To create a graph showing all of your data, click or tap the y-axis label (Pressure) and select all the data sets. Describe any pattern you noticed as you changed the amount of vinegar you added to the baking soda inside the bottle.

____

____

____

Under Pressure

BACKGROUND INFORMATION

In this activity, students compare pressure changes as they mix vinegar and baking soda together in a plastic bottle. This chemical reaction can be summarized as

$HC_2H_3O_2$	+	$NaHCO_3$	→	CO_2	+	$NaC_2H_3O_2$	+	H_2O
vinegar (acetic acid)		baking soda (sodium bicarbonate)		carbon dioxide gas		sodium acetate		water

Students will observe the pressure increase caused by the production of carbon dioxide gas, CO_2.

The quantity of vinegar used is then varied while the quantity of baking soda remains constant. As long as there is ample baking soda, an increased volume of vinegar will produce a greater amount of CO_2, thereby increasing the pressure.

TIME FRAME FOR ACTIVITY

This activity takes about 1 hour. If you would like to divide it into two sessions, a good stopping point is after either Run 2 or Run 3.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions PS3.A: Definitions of Energy PS3.D: Energy in Chemical Processes and Everyday Life	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – the scientific process, air pressure, measurement

Literacy – compare, contrast

Math – graphic analysis and statistics including minimum, maximum, range

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting pressure data with Vernier equipment, we recommend that you start with Activity 16.

3. We suggest that you provide each group with a tray such as those found in the cafeteria or fast-food restaurant. If students work with the liquids on a tray, it can help protect the electronic equipment from potential damage caused by spills. See Appendix C for more safety information.

4. Plastic soda bottles (0.591 L or 20 oz) work well for this experiment. You may use the same bottle for the Activity 17, "Get a Grip", and Activity 19, “Bubbles in Your Bread.” The mouth is a tight fit for the stopper, but will work. Have one student hold the stopper in place during the experiments. Runs with high pressure will make the stopper prone to popping off the bottle.

5. If you do a dry run of this activity with your students, it will help it go more smoothly. If you have not yet discussed open and closed systems with your students, you may want to prior to starting the activity. Make sure they understand the role of the handle on the valve in the stopper. When it is perpendicular to the valve (making a plus sign), it is closed; when it is lined up with the valve, it is open. Remind your students that they do not need to twist the syringe on too tightly. It only takes about one half of a turn to secure it.

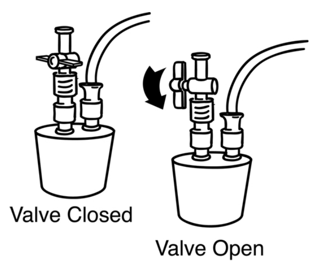


Figure 1

6. Show your students how to draw the vinegar up into the syringe. They need to depress the plunger fully (push it all the way in) before they start drawing up the vinegar. The front edge of the plunger (the part that touches the front of the syringe when it is pushed all the way in) should be lined up with the 5, 10, or 15 mL mark to measure the correct amount of vinegar.

7. Close attention should be paid while students are collecting data. The system needs to be closed when they attach the vinegar-filled syringe and start data collection. Then, students need to open the system, depress the plunger, and hold it down while they re-close the system. If they do not hold down the plunger, the plunger will begin to rise because of the increase in pressure in the bottle and it could eventually pop out. After the system is closed, students are

instructed to swirl the bottle to ensure that all the vinegar reacts with the baking soda. Remind them not to shake too hard or the stopper could pop out.

8. When the students begin to work with the bottle, they may have trouble getting the baking soda into the bottle. A paper funnel can help ensure that all the baking soda gets into the bottle.
9. If you have a set of mugs that will accommodate the width of the bottle, give each group a mug that they can place their bottle in during the activity.
10. If the students are not getting significant changes in pressure, or the pressure drops dramatically during the activity, it is likely that the stopper or the valves have become dislodged. Make sure all the connections are secure. Another thing to check is the pressure scale on the graph on the screen.
11. During the activity, students record their beginning and final pressure values for each run. If, during one of the runs, the plunger comes out before data collection is over, but the maximum pressure for the run has been reached (pressure values have stabilized), they can record this value as the final pressure.
12. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.
13. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Run	Volume of baking soda	Volume of vinegar (mL)	Beginning pressure (kPa)	Final pressure (kPa)	Change in pressure (kPa)
1	1 spoonful	5	101.4	116.8	15.4
2	1 spoonful	10	100.1	131.0	30.9
3	1 spoonful	15	100.6	147.7	47.1

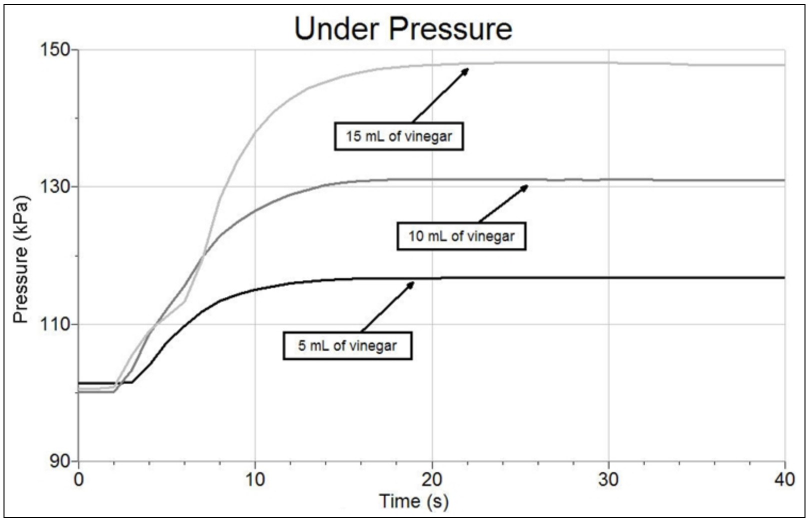


Figure 2 Change in pressure over time for the reaction between 1 spoonful of baking soda and increasing volumes of vinegar

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. The pressure inside the bottle increased during each data-collection run. Adding more vinegar caused the higher pressures.

2. Students should find that adding more vinegar resulted in an increase in pressure.

ASSESSMENT

1. Have the students think of other containers they could use that would allow the pressure to remain relatively constant and then check them.

2. Have the students think of other containers they could use that would allow the pressure to increase to the maximum allowed by the sensor and then check to see if they work.

EXTENSIONS

1. Do this activity in conjunction with Activity 5, "Cool Reaction!" Students will learn how the reaction between vinegar and baking soda produces a gas as well as a temperature change.

2. Learn about other reactions that can be conducted safely using common household materials. Test to see if they produce temperature changes or a gas.

Name: ______________________________

Bubbles in Your Bread

All over the world, every day, people bake bread. Some people make a type of flat bread by mixing flour, salt, and water. In some places, it is common to include yeast when making bread. Have you ever baked bread using yeast? Did you know that yeast are living organisms? In a water environment, yeast use sugar and oxygen to produce a gas called carbon dioxide, CO_2. The carbon dioxide makes the dough rise and creates the bubbles or air pockets that you can see in the bread.

OBJECTIVES

- Use a Pressure Sensor to measure the pressure caused by the production of CO_2.
- Make observations about how temperature affects rising dough.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Gas Pressure Sensor
plastic tubing and stopper assembly
large bowl
warm water (approximately 30–35°C)
cold water (approximately 5–10°C)
bread dough
plastic bottle
paper towels or rags to clean up spills
tray (if available)

KEY QUESTION

Does temperature make a difference in the amount of time it takes for bread to rise?

HYPOTHESIS

I think that the _________ (warm or cold) bread dough will rise faster because ______________

____

PROCEDURE

Part I Pressure change for dough in cold water

1. Do the following to get the Pressure Sensor ready to collect data.
   a. Launch Graphical Analysis. Connect the Pressure Sensor to your Chromebook, computer, or mobile device.

b. Close the valve on the stopper. The handle should be sideways to the valve. Look at Figure 1 to see what the valve looks like when it is closed and open.

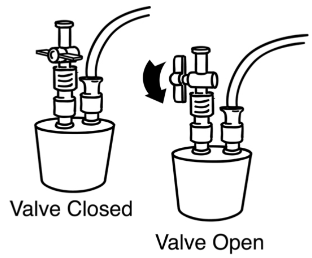


Figure 1

2. Set up the data-collection mode
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Time Units to min for minutes and Rate to 10 samples/min.
   c. Set End Collection to 10 min. Click or tap Done.

3. Draw a prediction of how the pressure will change during data collection.
   a. Click or tap Graph Tools, ⟋, and choose Add Prediction.
   b. Draw a line that shows your prediction for how the pressure will change when the dough is in cold water. Click or tap Save.

4. To prepare the dough for data collection, follow these steps:
   a. Get a ball of dough from your teacher.
   b. Put the dough in the bottle. Rolling the dough into a snake shape may help you get it in the bottle.
   c. Lightly tap the bottle on a table to help the dough settle to the bottom.

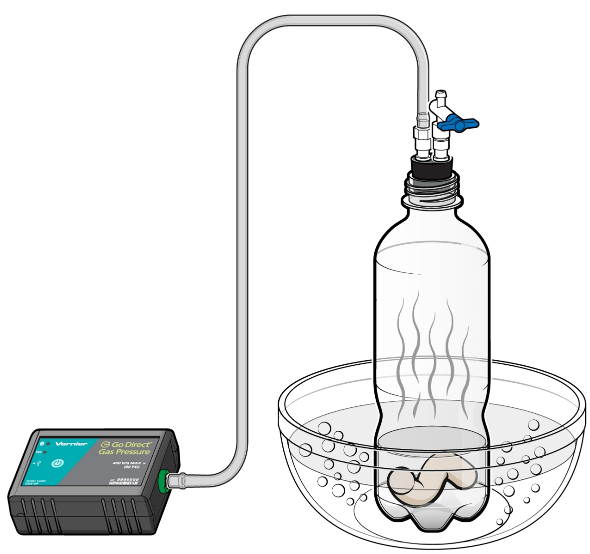


Figure 2

5. Follow these steps to get ready to collect data:
   a. Twist the stopper into the mouth of the bottle so it fits tightly. **Important**: The stopper must be twisted in tightly or it may pop out.
   b. Put the bottle in the bowl.
   c. Have one student hold the bottle down in the bowl, or use masking tape to tape the bottle down.
   d. Carefully pour the cold water into the bowl.

6. Click or tap Collect to start data collection.

7. Data collection will last 10 minutes. During this time, watch the data and the dough to observe the changes taking place. Record your observations about the pressure and what happened in the bottle during the reaction in the Part I Observations Sheet.

Part I Observations Sheet

8. Click or tap the graph to examine the data. **Note**: You can also adjust the Examine line by dragging the line. Use the graph to find the pressure at each minute of the experiment. Record each value in its place in the Data Table in the Analyze Your Data section.

9. Open the valve on the stopper and watch what happens to the pressure. Record what you see on the Part I Observations Sheet.

Part II Pressure change for dough in warm water

10. In this part you will measure the pressure change while the dough is warming up. Think about how you think the pressure will change and make a prediction:

    Prediction

    To draw another prediction, click or tap Graph Tools, , and choose Add Prediction. Draw a line that shows your prediction for how the pressure will change as the dough is warmed up and then click or tap Save. Your first prediction will be automatically removed.

11. Do the following to get the materials ready for data collection.
    a. Empty the cold water as directed by your teacher.
    b. Close the valve on the stopper by turning it sideways to the valve, making a plus sign (see the “Valve Closed” drawing in Figure 1).
    c. Put the bottle back in the bowl.
    d. Carefully pour warm water into the bowl.

12. Click or tap Collect to start data collection. During data collection, record your observations about the pressure changes and what happens in the bottle on the Observations Sheet:

Part II Observations Sheet

13. Open the valve on the stopper and watch what happens to the dough. Record what you see on the Part II Observations Sheet.

14. Dispose of your materials as directed by your teacher.

ANALYZE YOUR DATA

1. Click or tap the graph to examine the data pairs on the graph. Use the graph to find the pressure at each minute of data collection with the dough in warm water. Record each value in its place in the Data Table.

Data Table		
Time (minutes)	Cold Water Pressure (kPa)	Warm Water Pressure (kPa)
0 (beginning pressure)		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

2. Look at each of the columns in the Data Table. Do you see a pattern in the values for the warm-water dough? Is there a pattern in the values on the cold-water dough column?

   ____

   ____

   ____

3. What do you think would happen to the warm-water dough if you allowed the experiment to run much longer? How about the cold-water dough?

   ____

   ____

   ____

4. What effect does temperature have on the reaction? Do you think it would be easier to bake bread on a hot day or a cold day? Why do you think so?

   ____

   ____

   ____

Bubbles in Your Bread

BACKGROUND INFORMATION

In this activity, students observe the pressure caused by gases that are the result of the digestive processes of yeast in the dough. Yeast are single-cell fungi. We tend to think of their work in bread as biological, but it is also a chemical process. These little organisms digest the sugar in the dough and create carbon dioxide gas, which makes the little bubbles in bread. Creating a gas is one indication that a chemical reaction has taken place. In addition to gas, alcohol is produced, giving bread dough its characteristic smell.

As the bread dough rises, the gases created by the yeast's digestion increase the pressure. If the temperature is too cold, however, the yeast are not as active and will not create the gas needed for the dough to rise.

TIME FRAME FOR ACTIVITY

This activity can be completed in about 60 minutes after an initial 10–15 minutes to prepare the dough.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions PS3.A: Definitions of Energy PS3.D: Energy in Chemical Processes and Everyday Life	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Social Studies – breads from different cultures, basic needs of humans

Math – comparisons, graph analysis, volume measurements

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware

they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting pressure data with Vernier equipment, we recommend that you start with Activity 16.
3. As a precursor to this activity, you may want to have students examine a piece of bread to find the little bubbles that are the result of the yeast.
4. Prior to giving the equipment to the students, attach the plastic tubing to the stopper prior.
5. You will need to provide students with warm water and cold water. The warm water should be about 30–35°C. You can usually obtain water of this temperature from the tap. The cold water should be about 5–10°C. If your tap water is not this cold, add a little ice.
6. Prepare the dough in front of the students or, if you prefer to do it beforehand, make the dough ahead of time and store it in the refrigerator. Allow time for the dough to return to room temperature before you give it to your students. A recipe can be found at the end of this Teacher Information.

   Another option is to buy pre-made dough, such as self-rising biscuits. Take dough out of the freezer about 2 hours before starting the activity. If the dough is out for a shorter period of time, it might not show much change. If the dough is out for too long, it may have finished rising before you give it to the students. If you use self-rising biscuits, place them individually on a flat surface so they don't all stick together. Give three rolls to each group.
7. Rolling dough into small "snakes" makes it easier to put the dough in the bottles.
8. In order to compare data between student groups, give each group approximately the same amount of dough. If you have a class discussion and compare the results, it can be a great time to discuss variables in the experiment. Work with students to generate a list of factors such as differences in the amount of dough, variations in bottle size, and variability in the temperature of the water baths.
9. If you have sufficient materials, you can do both parts of this activity simultaneously.
10. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.
11. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

The amount of dough in your bottle and the temperature of your water will greatly affect the change in pressure during data collection. It is possible that you will not have as much pressure change as can be seen in the sample data.

Time (minutes)	Cold water Pressure (kPa)	Warm water Pressure (kPa)
0 (beginning pressure)	100.0	101.6
1	99.4	105.3
2	99.7	107.3
3	100.1	109.1
4	100.6	111.2
5	101.0	113.2
6	101.4	115.5
7	102.0	117.3
8	102.2	119.3
9	102.6	121.2
10	102.9	123.3

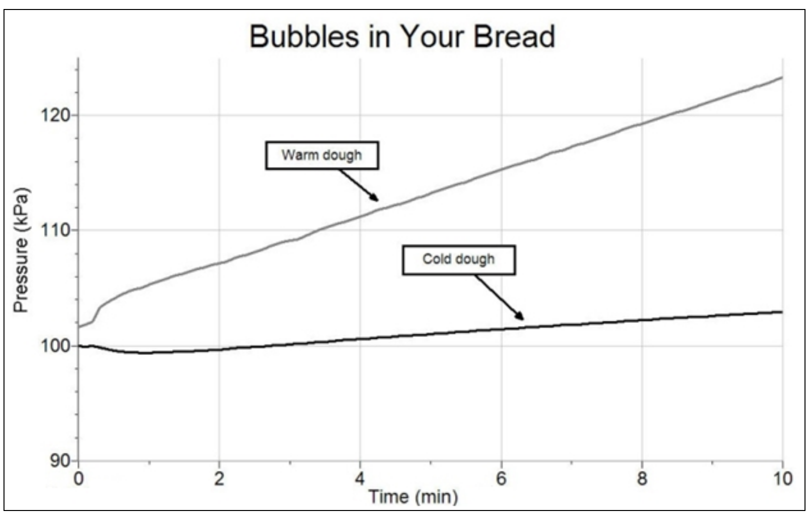


Figure 1 Pressure change caused by the rising of dough in a bottle in warm and cold water baths

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers are based on each individual graph. Values from the sample data are displayed in the table above.

2. Answers are based on student graphs, but there should be a pattern that is evident in the numbers as well as the graph. For example, the cold water dough drops in pressure, then increases by about 0.4 kPa each minute. The warm water dough increased almost 4 kPa at the beginning, and it continued to increase about 2 kPa each minute after that.

3. If the experiment were allowed to continue, the pressure in the warm dough bottle would pop the stopper out of the bottle, and the pressure would immediately drop. The cold water dough would continue to rise very slowly, but as the water warmed, the pressure in the bottle would rise more like the warm dough.

4. Yeast are not as active in cold temperatures. Therefore, if a cold day means a cold kitchen, you might not have bread in time for dinner!

ASSESSMENT

1. Have students write a statement about the effect of temperature on the reaction of the bread dough and relate it explicitly to the data on their graph.

2. Provide students with a description of an experiment and a graph of pressure *vs*. time that is different than the warm water/cold water dough comparison. Have them write a description of the data shown on the graph.

EXTENSIONS

1. Determine other factors the might affect the way bread rises. Design an experiment to explore those ideas.

2. Use a yeast-sugar mixture alone (instead of dough) and perform the same experiment.

3. Discuss what happens when you open the valve after you take data. Why does the dough suddenly expand? (When the valve is opened, the compressed air escapes. This allows the gas in the dough to expand into the space left by the escaping air.)

4. Research types of bread from different cultures.

5. Find a bread recipe that does not use yeast and use it to perform this activity.

6. If local regulations allow, make extra bread for the entire class to eat.

Simple Yeast Bread Recipe

450 mL (2 cups) warm water (water too hot to keep your finger in is too hot)
10 g (2 teaspoons) sugar
7 g (1 package) fast acting active dry yeast
900 g (3 ½ cups) all purpose flour
14 g (1 tablespoon) salt

Add the sugar and yeast to about 100 g (1/2 cup) of warm water and dissolve. After a few minutes, the mixture should have small bubbles forming around the edge. This means the yeast is active.

Meanwhile, put the flour and salt in a large mixing bowl. Mix well and then add about 100 g (½ cup) of warm water. Stir, then add the yeast mixture and blend to make soft dough. Add as much water and flour as needed to make dough that is not sticky. This makes it easier for the “bread snakes” to fit through the mouth of the bottle without sticking.

At this point the dough is ready for the experiment. This makes enough dough for about six groups. Keep the dough cold before giving it to the students or it may begin to rise.

If you make a batch of dough for eating, at this point you would allow the dough to rise for about 20 minutes, and then bake it in small loaves or rolls on a cookie sheet at 200°C (400°F) for 30 to 45 minutes, depending on the size you choose to make.

Name: ______________________________

Learning to Use a Motion Detector

You can use a Motion Detector to measure the position of objects as they move. In this activity, you will learn how to use a Motion Detector.

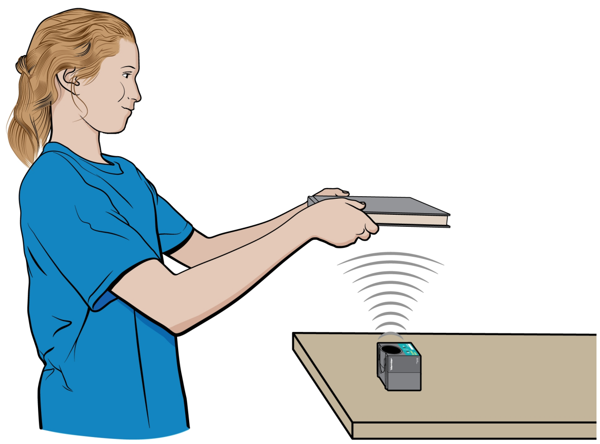


Figure 1

OBJECTIVES

- Learn to use a Motion Detector.
- Measure the distance between a book and the Motion Detector.
- Match a shape by moving a book up and down above a Motion Detector.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Motion Detector
book

PROCEDURE

Part I Learn about the Motion Detector

1. Do the following to set up the Motion Detector for data collection:
   a. Launch Graphical Analysis.
   b. Connect the Motion Detector to your Chromebook, computer, or mobile device. The detector is located in the circular hole on the front of the Motion Detector.
   c. Click or tap View, ⊞, and choose 1 Graph. This will display a graph of position *vs*. time.

2. Collect data:
   a. Put the Motion Detector on a table or chair with the detector facing up towards the ceiling. Make sure there is nothing in the path of the signal coming out of the detector. **Note**: When you are done collecting data, you will record your observation by answering a few questions. You can look at the Observations Sheet in the next step to see the questions you will answer.
   b. Have one person stand holding a book about 0.5 meters above the Motion Detector.
   c. Look at the screen and click or tap Collect to start data collection.
   d. Slowly move the book straight upwards and watch what happens on the graph on the screen.
   e. Now slowly move the book down toward the sensor, but don't get closer than about 15 cm. Watch to see what happens when you move closer to the Motion Detector.
   f. Now, move the book upwards very quickly and watch what happens.
   g. Data collection will stop after 5 seconds.
   h. You can try it again by starting data collection again.

3. Use your experiences in Step 2 to complete the statements in the Observations Sheet.

Observations Sheet
1. When I slowly move the book up and away from Motion Detector, ____ ____
2. When I slowly move the book down and towards the Motion Detector, ____ ____
3. When I lift the book up very quickly the graph is different than when I move it slowly because ____ ____

Part II Make a snake with the Motion Detector

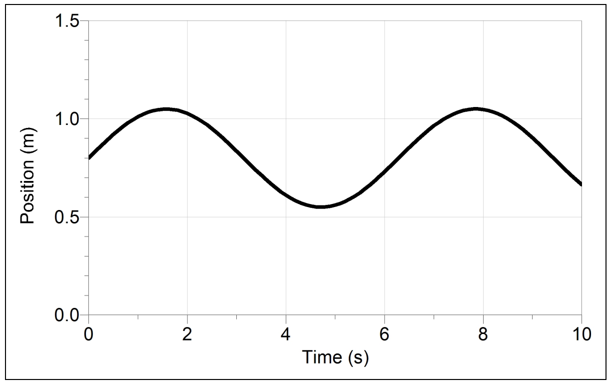


Figure 2

4. In this part of the activity, you will match the shape of the snake. An example of what this might look like is shown in Figure 2. Before you start, think about what happened when you moved the book in front of the Motion Detector. Fill in the blanks as a plan for matching the shape on the Graph.
   a. Start with the book _______ meters above the Motion Detector.
   b. Move the book ___________ (up or down) so that the book is about _________ meters above the Motion Detector.
   c. Move the book ___________ (up or down) until it is about ___________ meters above the Motion Detector.
   d. Move the book ___________ (up or down) until it is about ___________ meters above the Motion Detector.
   e. Move the book ____________ (up or down) until it is about ___________ meters above the Motion Detector.
5. Click or tap Collect to start data collection, then follow the plan you wrote in Step 4, trying to match the snake.
6. If the data you collected matches the snake shape on the screen, congratulations! If you want to try to match the snake again, just start data collection and repeat the plan you wrote.

Learning to Use a Motion Detector

BACKGROUND INFORMATION

The motion detectors sold by Vernier work by sending out sonic waves from the detector, measuring how long it takes for the waves to return, and then calculating a distance based on that duration of time. The signal widens as it gets further from the detector, making a conical shape. Because of this, the detector can receive up reflections from objects, such as chairs or tables, that are not directly in front of it.

Our motion detectors have a range of 0.15 meters to 6 meters. If you are closer to or further away from the sensor, it will "peg out" or give constant readings.

If you are using Go! Motion (order code: GO-MOT) or Motion Detectors (MD-BTD), you will find a switch that affects sensitivity. The Ball/Walk setting (see Figure 1) works well for all the activities in this book. The Cart/Track setting is designed for collecting data along a very focused path. **Note**: If you are using Go Direct Motion Detectors (GDX-MOT), there is not sensitivity switch; the range adjusts automatically.

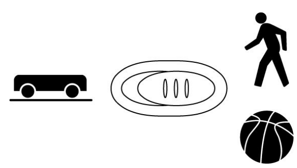


Figure 1

TIME FRAME FOR ACTIVITY

This activity takes about 30 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS4.A: Wave Properties	Patterns Cause and effect Scale, proportion, and quantity	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. Prior to doing the activity with students it would be a good idea to read through the student version to look for terms that your students may not be familiar with, such as "collect data" and concepts about wave properties.

3. The purpose of using books during this activity is to create a good reflector for the motion detector. The books can be standard textbooks or something a bit smaller. If it is too small, the readings will be erratic.

4. Warn your students not to drop anything on the motion detectors. They should be especially careful about poking or spilling things into the round, metal part of the sensor.

5. If the data-collection software records a large spike in the data, the graph may autoscale to fit all data. If this happens, either adjust the axes or zoom in on the data.

6. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

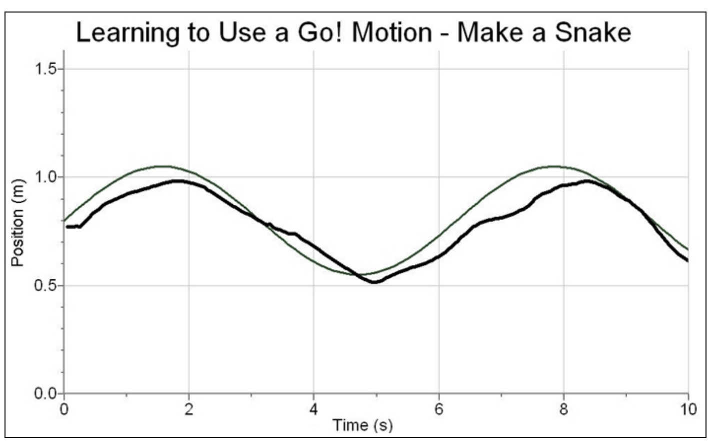


Figure 2 Matching the shape of a snake

ASSESSMENT

1. Ask students about when they might want to use a motion detector during their day or why their family members or others may find them useful.
2. Ask students what other shapes could be made and how they would do it.

EXTENSIONS

1. Have students draw letters and try to match them. You could suggest that they draw really wide, narrow, or tall M or W shapes.
2. Try making the letter X or the letter A by storing and displaying multiple trials.

Name: ______________________________

e-Motion

Have you ever wondered how automatic doors at grocery stores know when to open? There is a sensor over the door that detects objects, such as a person walking up to the door.

The Motion Detector that you will use in this activity can also do this. The Motion Detector works by sending out a signal and then measuring how long it takes for reflections to return to the sensor. Based on the amount of time it takes the signal to bounce back, the data-collection software is able to calculate the position of the object.

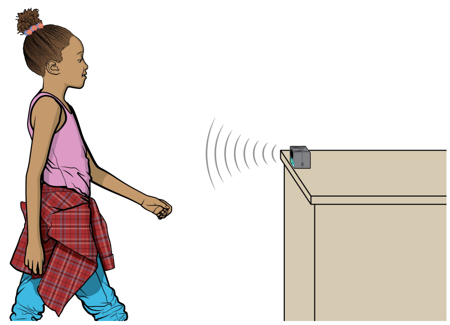


Figure 1

OBJECTIVES

- Explore the different lines and curves produced by moving in front of the Motion Detector.
- Learn to write detailed steps for creating an M or W shape on the graph.
- Match different letter and designs drawn on the graph.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Motion Detector

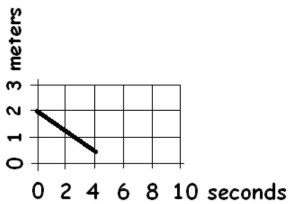
PROCEDURE

Part I Creating straight-line letters such as M and W

1. Set up the equipment for data collection:
   a. Launch Graphical Analysis.
   b. Connect the Motion Detector to your Chromebook, computer, or mobile device.
   c. Click or tap Mode to open Data Collection Settings. Set End Collection to 10 s. Click or tap Done.
   d. Click or tap View, ⊞, and choose 1 Graph. This will display a graph of position *vs*. time.

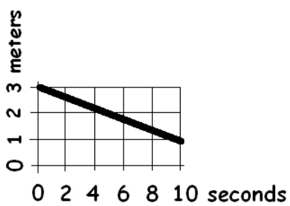
2. Set the Motion Detector on a table so that there is an open path at least 2 meters wide and 3 meters long in front of it. You should face the sensor and must also be able to see the screen of your Chromebook, computer, or mobile device.

3. Before you begin, review the different lines you can make using the Motion Detector. Draw lines to connect each graph to the directions that you would follow to make the line.



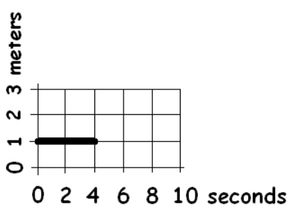
(A)

(1) Start 3 meters from the Motion Detector and move forward for 10 seconds moving slowly.



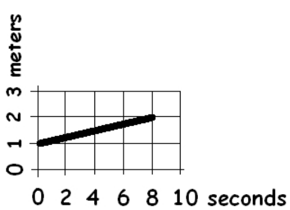
(B)

(2) Start 0.5 meters from the Motion Detector and move backward for 6 seconds moving quickly.



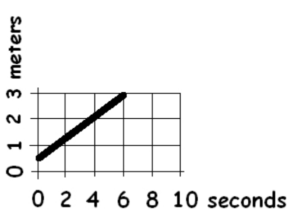
(C)

(3) Start 1 meter from the Motion Detector and move backward for 8 seconds moving slowly.



(D)

(4) Start 2 meters from the Motion Detector and move forward for 4 seconds moving quickly.



(E)

(5) Start 1 meter from the Motion Detector and stand still for 4 seconds.

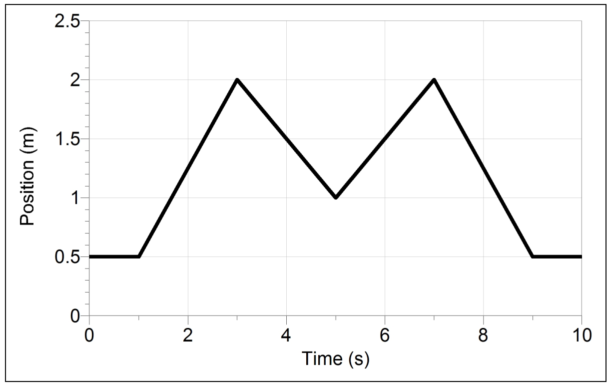


Figure 2

4. In this part of the activity, you will write the steps that you will follow to create the letter **M** using a Motion Detector. An example of what the **M** might look like is shown in Figure 2. Think about how you would make a similar **M** shape and fill in the blanks below. You will have a total of 10 seconds.
   a. Start _______ meters from the Motion Detector.
   b. Stand still for _______ second(s).
   c. Move ______________ (forward or backward) for _______ seconds moving __________ (quickly or slowly).
   d. Move ______________ (forward or backward) for _______ seconds moving __________ (quickly or slowly).
   e. Move ______________ (forward or backward) for _______ seconds moving __________ (quickly or slowly).
   f. Move ______________ (forward or backward) for _______ seconds moving __________ (quickly or slowly).
   g. Stand still for the last _______ second(s).
5. Estimate the distance from the sensor needed to begin the **M** and then stand in front of the Motion Detector, facing it at that position.
6. Have another person click or tap Collect to start data collection, and follow the directions you wrote in Step 4. **Note**: Be sure to keep your hands at your sides and as still as possible.
7. If the graph of the **M** looks like the example, congratulations! If you want to try to make the **M** again, just start data collection, and follow the directions you filled out.

8. You will now make the letter **N**. Think about how you would move to make the **N**:

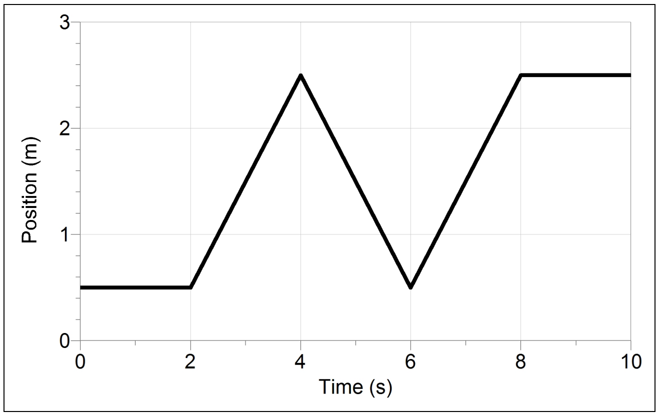


Figure 3

9. Write down the steps you would take to match the letter **N**. Use the words in Step 4 as a pattern.

____

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10. Have one student stand in the right place in front of the Motion Detector. Have another student click or tap Collect to start data collection, and then follow the directions you wrote in Step 9 for making the letter **N**.

11. If the graph of the **N** looks like the example, congratulations! If you want to try to make the **N** again, just start data collection, and follow the directions you wrote.

12. You will now make the letter **W**. Think about how you will move to make the **W**.

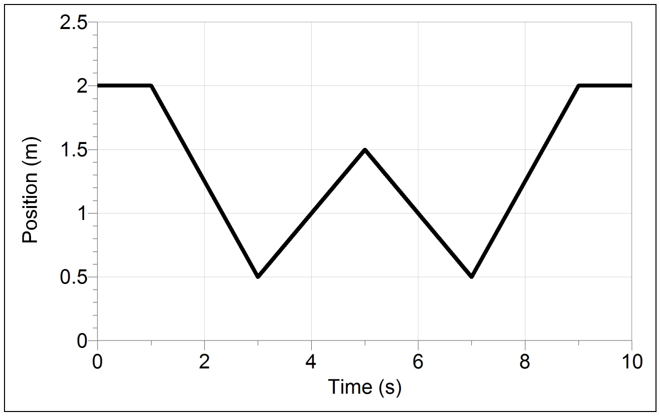

Figure 4

13. Write down the steps you would take to match the letter **W**. Use the words in Steps 4 and 9 as a pattern.

____

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____

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14. Have one person stand in the right place in front of the Motion Detector. Have another student click or tap Collect to start data collection, and then follow the directions you wrote in Step 13 for making the letter **W**.

15. If the graph of the **W** looks like the example, congratulations! If you want to try the **W** again, just click or tap Collect to start data collection, and follow the directions you wrote.

Part II "e-motion-al" graphs

You have now made three letters with straight-line segments. Now let's try expressing our "e-motions" by making a happy face and a sad face on the graph!

16. You will now make a happy face. To get started, do the following things:
    a. Choose New from the File menu.
    b. On the Meter screen, tap Duration. Change the data-collection duration to 10 seconds.
    c. Click or tap the Graph tab. Choose Show Graph from the Graph menu and select Graph 1. This will display a graph of position *vs*. time.

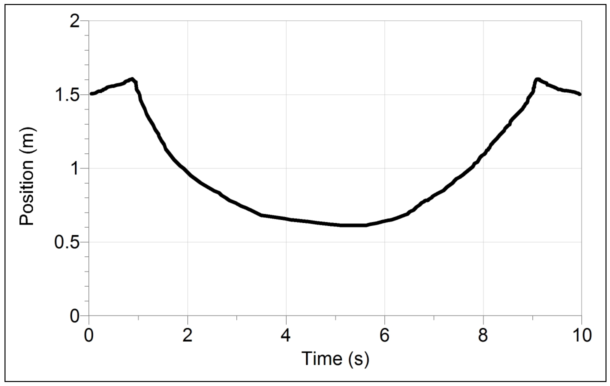

Figure 5 Happy face

17. Write the steps you should follow to match the happy face graph shown in the example. Use the directions you wrote as a guide for what to write.

____

____

____

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18. Have one person stand in the right place in front of the Motion Detector, then have another student click or tap Collect to start data collection. Then, follow the directions you wrote in Step 17 for making the happy face.

19. If the graph of the happy face matches the example, congratulations! If you want to try to make the happy face again, just click or tap Collect to start data collection and follow the directions you wrote.

20. You will now make a sad face. To get started, do the following things:
    a. Choose New from the File menu.
    b. On the Meter screen, tap Duration. Change the data-collection duration to 10 seconds.
    c. Tap the Graph tab. Choose Show Graph from the Graph menu and select Graph 1. This will display a graph of position *vs*. time.

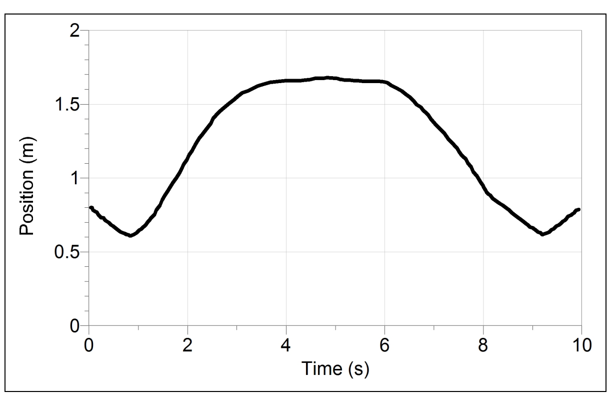

Figure 6 Sad face

21. Write down what you need to do to match the sad face.

____

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22. Have one person stand in the right place in front of the Motion Detector, then have another student click or tap Collect to start data collection. When you hear fast clicking, follow the directions you wrote in Step 21 for making the sad face.

23. If the graph of the sad face matches the sad face example, congratulations! If you want to try to make the sad face again, just start data collection, and follow the directions you wrote.

e-Motion

BACKGROUND INFORMATION

In this activity, students create and analyze graphs using a motion detector. They move in front of the sensor to create line graphs that look like the letters M, N, and W, then a smile ∪ and a frown ∩. They will also write the steps needed to create these graphs.

TIME FRAME FOR ACTIVITY

This activity takes about 50 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS4.A: Wave Properties	Patterns Cause and effect Scale, proportion, and quantity	Asking questions and defining problems Developing and using models Planning and carrying out investigations Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – motion, rate, writing instructions

Math – line graphs, slope, measurement, estimation

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

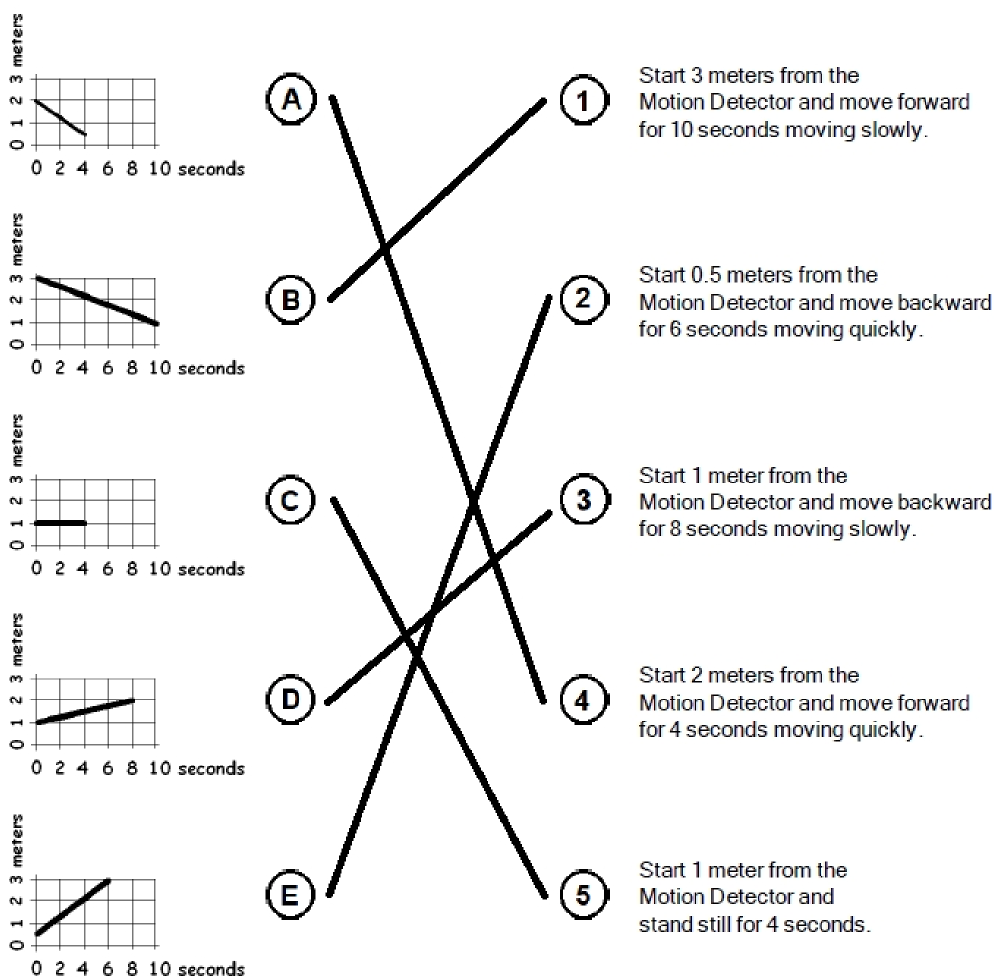
2. If this is the first time your students will be collecting motion data with Vernier equipment, we recommend that you start with Activity 20.

3. At the beginning of the activity, students review the types of lines they will need to use for the letters. They may walk in front of the motion detector to help them review. In the Segment column of the Line Segment Table (see the student Procedure or the Sample Results), there is a

time scale for all graphs along the bottom of the column. Students may not understand that each cell in the Segment column is a miniature graph. Have them imagine that on the bottom of each cell is an x-axis, scaled from 0 to 10 seconds, and that the left side of each cell is a y-axis, scaled from 0 to 3 meters.

4. In the rest of the activity, students practice drawing and matching letters and shapes. If they are having a difficult time with this part of the activity, you may want to work through making one of the letters as a group. It may be challenging for them to get used to moving away from the motion detector to make the line of the graph go up and toward the motion detector to make the line go down. Remind them that the line represents how far away they are from the motion detector. If they move away from the motion detector, the distance is greater and therefore the line of the graph will move upwards.
5. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.
6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS



ANSWERS TO THE "WRITING THE STEPS" SECTION

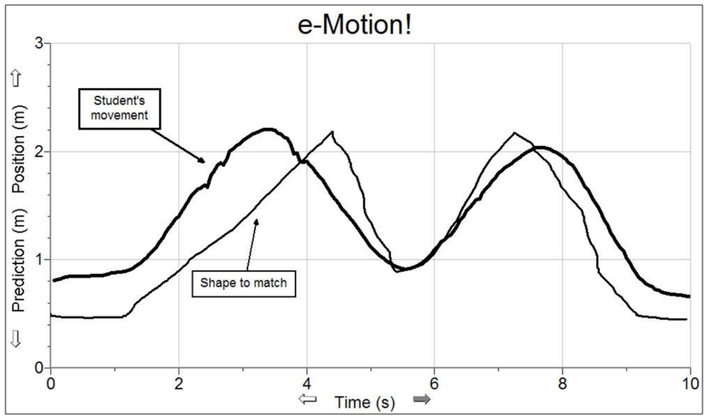


Figure 1 Attempting to match the predicted shape

Answers will vary. Example steps for making letters:

M graph (based on the graph in Figure 1)

a. Start 0.5 meters from the motion detector and stand still for 1 second.
b. Move backward for 3.5 seconds moving fast.
c. Move forward for 1.5 seconds moving fast.
d. Move backward for 2 seconds moving fast.
e. Move forward for 2 seconds moving fast.
f. Stand still for 1 second.

N graph

a. Start 0.5 meters from motion detector.
b. Walk backward for 4 seconds moving at a medium speed.
c. Walk forward for 3 seconds moving fast.
d. Walk backward for 4 seconds moving at a medium speed.

W graph

a. Start 2.5 meters from motion detector and stand still for 1 second.
b. Walk forward for 2 seconds moving fast.
c. Walk backward for 2 seconds moving fast.
d. Walk forward for 2 seconds moving fast.
e. Walk backward for 2 seconds moving fast.
f. Stand still for 1 second.

Happy face

a. Start at 1.5 meters and walk backward slowly for 1 second.
b. Walk forward for 3 seconds, slowly at first and then more quickly.
c. Stand still for 2 seconds.

d. Walk backward for 3 seconds, quickly at first and then slowly.
e. Walk forward slowly for 1 second.

Sad face

a. Start at 1.5 meters and walk forward slowly for 1 second.
b. Walk backward for 3 seconds, quickly at first and then slowly.
c. Stand still for 2 seconds.
d. Walk forward for 3 seconds, slowly at first and then more quickly.
e. Walk backward slowly for 1 second.

ASSESSMENT

1. Ask students how it is different to make graphs with straight lines versus curved lines.
2. Give the students a series of lines to create on the graph. Be sure to have them write the steps needed in the correct order. For younger students, you could give them the steps out of order and have them rearrange in the correct order. Finally, have them walk in front of the motion detector to create the graph.
3. Give the students a combination of straight lines and curves. Have them write the steps needed, then walk in front of the motion detector for authentic assessment.
4. Ask students to cite examples of real-world uses of motion sensors (e.g., doors and lights that are activated when someone walks by).

EXTENSION

Have the students come up with letters or designs to make using the motion detector. These can include both straight lines and/or curves.

Name: ________________________________

Batty About Science

Bats are not blind, but for most bats, their sense of hearing is better than their sense of sight. Bats use echolocation (a type of sonar that allows them to emit a very loud, high-pitched sound and then interpret the echoes) to locate their prey and capture it.

Bats are not "mice with wings." They belong to their own group, called chiroptera, which means *hand-wing*. They are the only mammals that really fly! (Flying squirrels don't fly; they glide.)

Bats are not our enemies. Of the 900+ species of bats, only three species are vampire bats, and they are limited to Latin America. Vampire bats do not like the taste of human blood. They prefer the blood of cattle and other livestock.

Bats are important to humans. They contribute to a healthy ecosystem. In areas where bats have been wiped out, insects increase rapidly and cause agricultural problems. Bats are also important as pollinators and seed distributors.

OBJECTIVES

- You will lean how bats sense their prey by pretending that the Motion Detector is a bat and that you are its prey.
- Discover how this movement is graphically represented.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Motion Detector

PROCEDURE

Part I You as an insect

1. Do the following to set up the Motion Detector for data collection:
   a. Launch Graphical Analysis.
   b. Connect the Motion Detector to your Chromebook, computer, or mobile device.

2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Set End Collection to 15 seconds. Click or tap Done.

3. Click or tap View, ⊞, and choose 1 Graph. This will display a graph of position *vs*. time.

4. Lift up the head of the Motion Detector and rotate it so it is open at a right angle. Set it on the edge of your desk, just like in Figure 1. Make sure there is an open path at least 1 meter wide and 4 meters long in front of the Motion Detector. When you are in front of the Motion Detector, you should be able to see the gold circle of the sensor.

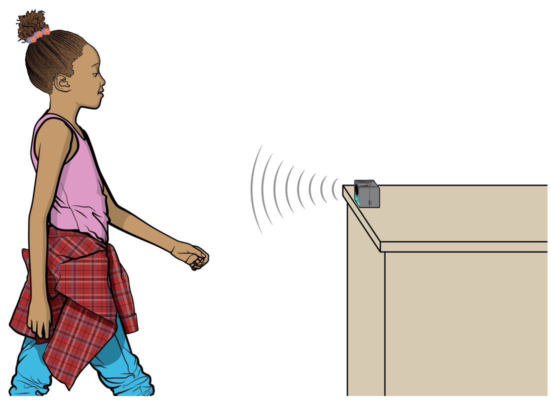


Figure 1

5. Pretend that the Motion Detector is a bat hanging from a branch and that you are an insect, something the bat wants to eat. You will collect several runs of data to learn what the bat sees when you (the insect) do different things. Each time you will carefully copy the graph from the screen onto one of the blank graphs.
   a. For the first graph, you will stand in front of the Motion Detector without moving. Stand 0.5 meters from the Motion Detector and don't move. Have another student start data collection.
   b. Draw the data on the blank graph in Figure 2.
   c. Stand at 2 meters in front of the Motion Detector and have your teammate click or tap Collect to start data collection.
   d. Draw the data on the same graph.

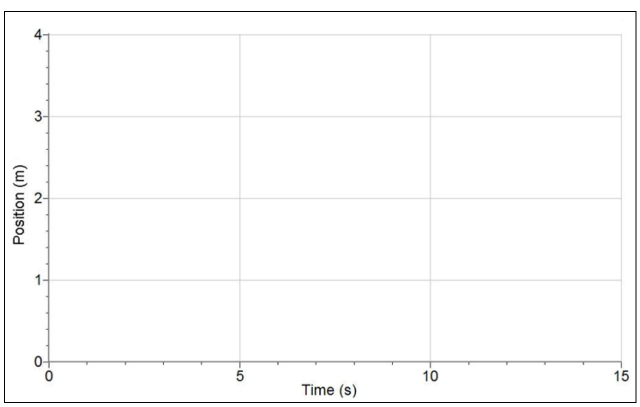


Figure 2 Standing still 0.5 and 2 meters in front of the bat (Motion Detector)

6. Now, follow these steps to graph what the bat (Motion Detector) senses as you move away from it at different speeds. Be sure to keep your hands at your sides and as still as possible.
   a. For this graph, you will stand facing the Motion Detector and slowly walk backwards away from it. Stand still 0.5 meters in front of the Motion Detector.

b. Have another student click or tap Collect to start data collection. Then, *slowly* back away from the Motion Detector.

c. Draw the data on the blank graph in Figure 3.

d. Now, you will quickly move away from the Motion Detector. Again, stand 0.5 meters in front of the Motion Detector and have another student start data collection. Then, *quickly* walk away from the Motion Detector.

e. Draw this data on the same graph. The graph will now have data from when you were walking away slowly and when you were walking away quickly.

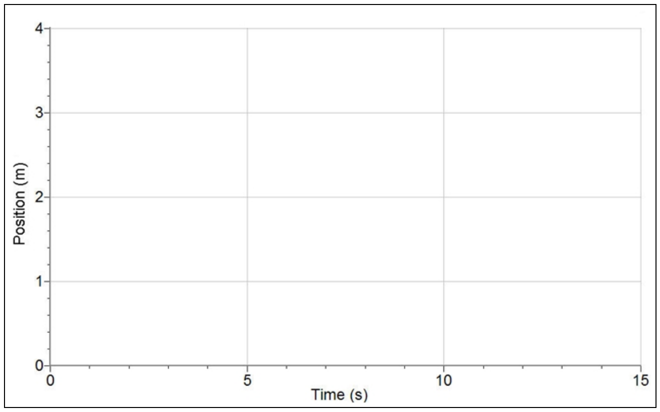


Figure 3 Walking slowly and quickly away from the bat (Motion Detector)

7. Now, follow these steps to graph what the bat sees when you move towards it at different speeds.

   a. First, you will slowly move towards the Motion Detector. Stand 3 meters in front of the Motion Detector.

   b. Have another student click or tap Collect to start data collection. Then, slowly walk towards the Motion Detector.

   c. Draw the data on the blank graph in Figure 4.

   d. Now, you will quickly move towards the Motion Detector. Again, stand 3 meters in front of the Motion Detector and have another student click or tap Collect to start data collection. Then, walk quickly toward the Motion Detector.

   e. Draw this data on the same graph. The graph will now have data from when you were walking toward it slowly and when you were walking toward it quickly.

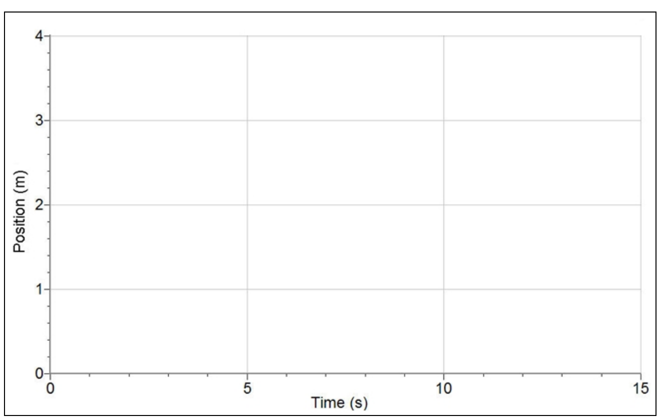


Figure 4 Walking slowly and quickly toward the bat (Motion Detector)

8. Now you will collect data one more time.
   a. For this graph, you will jump up and down in front of the Motion Detector. Stand 2 meters in front of the Motion Detector and have another student click or tap Collect to start data collection.
   b. Then, jump up and down, trying to land at the 2-meter mark each time you jump. Remember, hands at your sides!
   c. Draw the data on the blank graph in Figure 5.

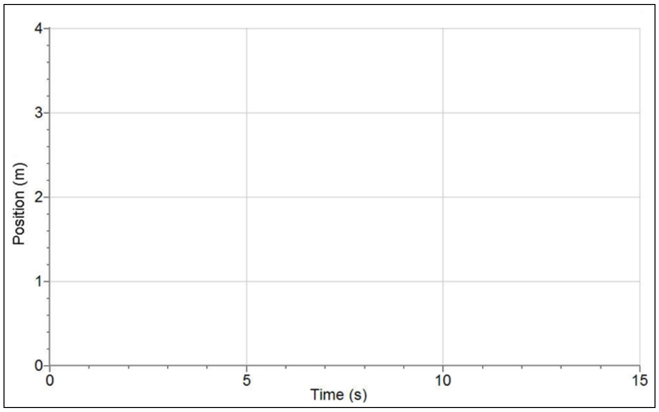


Figure 5 Jumping up and down in front of the bat (Motion Detector)

9. Answer the Part I questions in the Analyze Your Data section at the end of this activity.

Part II Following the path of other insects

In this part of the activity, you will examine the path of other insects that flew in front of the bat and were able to escape. Because you also want to stay away from the bat, you will try to follow the path of the insects!

10. Look at Figure 6 to see the flight path of the first insect. Think about what you did in Part I to make similar lines and then fill in the blanks in the next step.

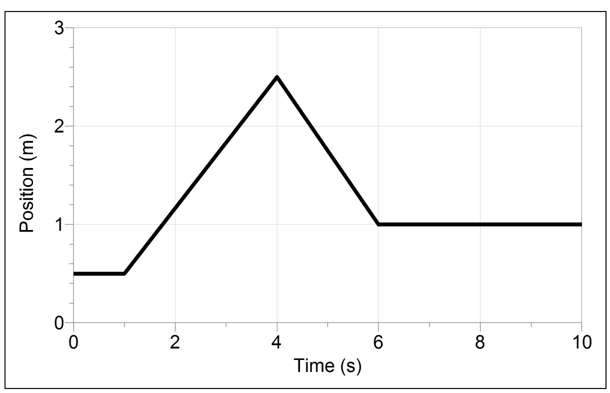


Figure 6

11. Fill in the blanks based on what you think you need to do to match the flight path.
    a. Stand _______ meters in front of the bat (Motion Detector).

    b. Stand still for _______ seconds.

    c. Then, for _______ seconds, move _____________ (towards or away from) the bat _____________ (quickly or slowly).

    d. Then, for _______ seconds, move _____________ (towards or away from) the bat _____________ (quickly or slowly).

    e. Stand still for _______ seconds _______ meters from the bat.

12. Now, get ready to try to follow the path. Stand where you want to and have your teammate click or tap Collect to start data collection. Then, follow the steps you wrote.

13. Were you able to follow the path of the other insect? What would you do differently next time?

____

____

____

14. Now, try to match the flight path of the second insect by following these steps:
    a. Look at the flight path of the second insect and think about what you would do to match the flight path.

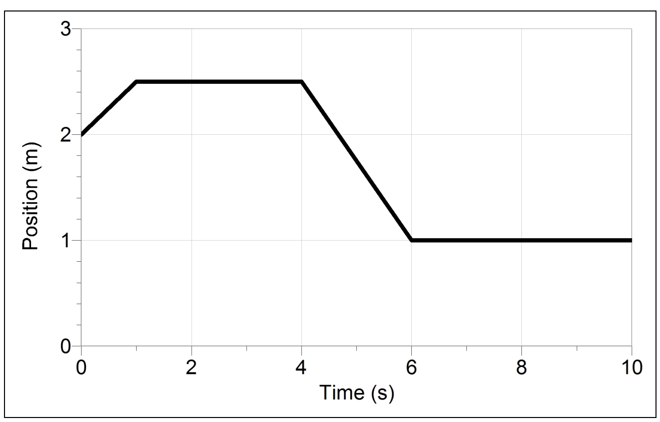


Figure 7

b. Write down what you will do to match the flight path. Use the directions you filled out in Step 13 as a pattern.

____

____

____

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____

15. Now, get ready to try to follow the path. Stand where you want to and have your teammate click or tap Collect to start data collection. Then, follow the steps you wrote.
16. How did you do? If you want to try again, click or tap Collect to start data collection and follow the steps you wrote.
17. Answer the Part II questions in the Analyze Your Data section.

ANALYZE YOUR DATA

Part I You as an Insect

1. What does the graph line look like when you, the insect, do not move?

____

____

2. When the insect moves farther away from the bat, Motion Detector, which way does the line on your graph go?

____

____

3. When the insect moves closer to the bat, which way does the line on your graph go?

____

____

4. Describe the slope of your graph line when the insect moves quickly towards the bat. (Is it sloping upwards or downwards? Is it a steep or gentle slope?)

____

____

5. Describe the slope of your graph when the insect moves very slowly away from the bat.

____

____

6. When you stand in front of the bat in one place and jump up and down, what does the graph do? Why doesn't the graph line go up and down like you?

____

____

Part II Following the Path of Other Insects

7. Imagine a graph where the path of an insect slopes downward gently for 5 seconds, then stays flat. Describe what the insect was doing when this graph was made.

____

____

____

8. Imagine a graph where the path of an insect stays flat for 7 seconds, and then slopes steeply upward. Describe what the insect was doing when this graph was made.

____

____

Batty About Science

BACKGROUND INFORMATION

In this activity, students apply what they learned in the previous two activities to a real-world, predator-prey interaction. The background science for this activity is found in the introduction to the student section.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS4.A: Wave Properties	Patterns	Asking questions and defining problems
LS1.A: Structure and Foundation	Cause and effect	Developing and using models
LS1.C: Information Processing	Scale, proportion, and quantity	Planning and carrying out investigations
		Analyzing and interpreting data
		Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Language Arts – *Stellaluna*, by Janell Cannon, is an excellent picture book for kids of all ages. It tells of a baby bat that has lost her mother and must find her way, and can lead into an excellent discussion of echolocation.

Math – comparisons, graph analysis

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting motion data with Vernier equipment, we recommend that you start with Activity 20.

3. In this activity, students move around in front of the motion detector. Because of this, you will need to make marks at 1, 2, 3, and if possible, 4 meters in front of where the motion detector will be located. If there is not enough room, the students will still be able to do the activity, but their data may not fill the graphs. If that is the case, you can autoscale or adjust the end points of the axes.

4. If you want to, you may introduce the activity by reading the story, *Stellaluna*, by Janell Cannon. A great way to start this unit is with a discussion of how the bat was able to find her way home using echolocation.

5. Another good way to introduce the activity is with a discussion of how sometimes scientists simply explore things to get a better understanding of how something works in nature.

6. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Part I You as an insect

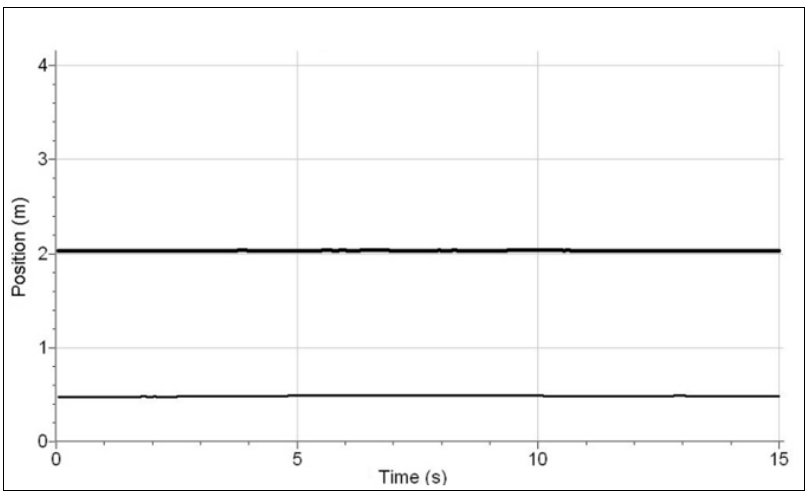

Figure 1 Example of data drawn on graph in student Step 5

See the following figures for sample data. Notice that when collecting the sample data, we had only 2.3 m of space in which to work. The difference in walking speed is still clearly identified on the graphs.

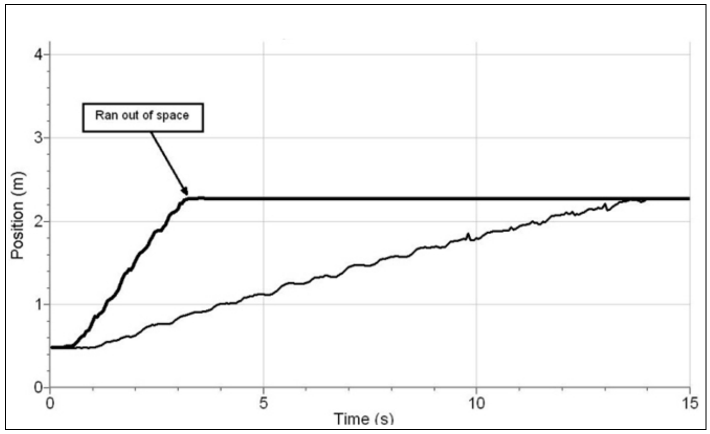

Figure 2

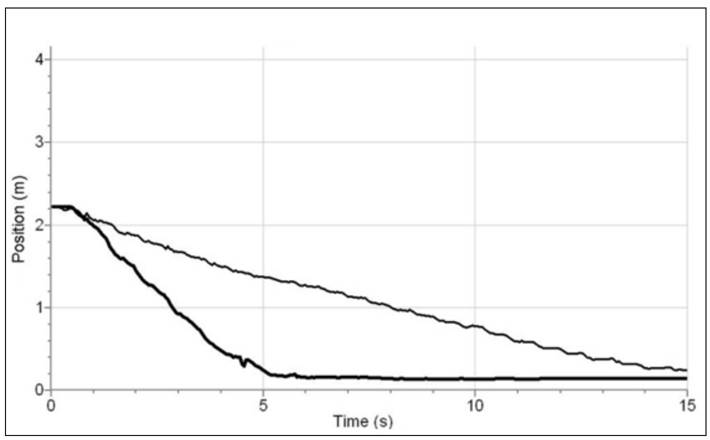

Figure 3

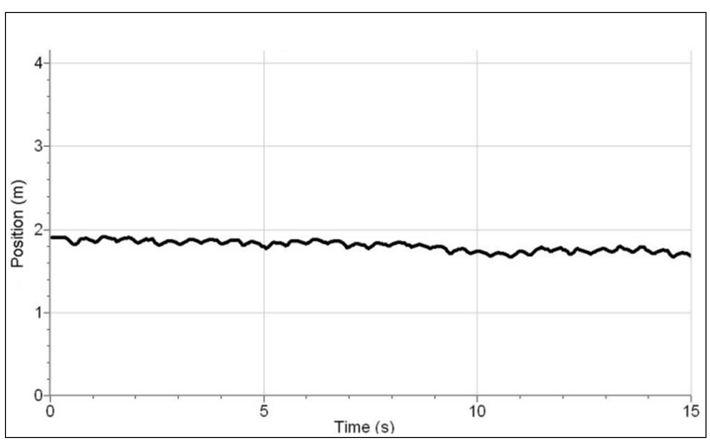

Figure 4

Part II Following the path of other Insects

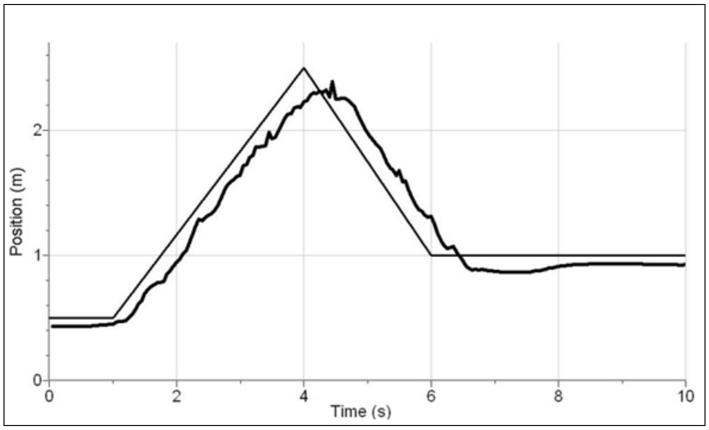

Figure 5 Matching the path of Insect 1

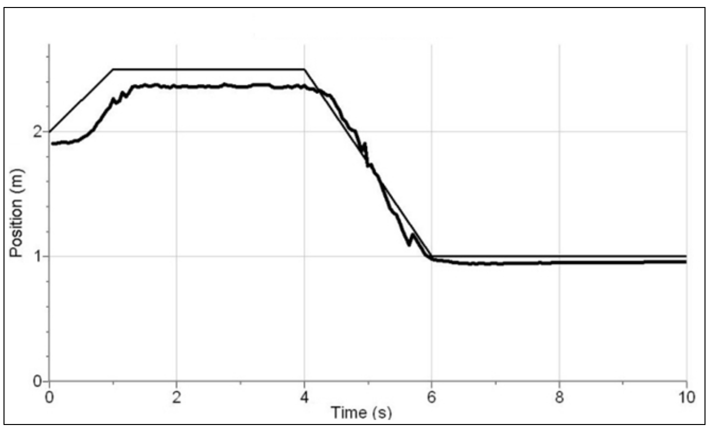

Figure 6 Matching the path of Insect 2

ANSWERS TO THE ANALYZE YOUR DATA SECTION

Part I You as an insect

1. The graph line should be a flat line since no distance is changing over time.
2. As the insect moves farther away from the bat, the distance increases. Therefore, the line should move upwards on the graph.
3. As the insect moves closer to the bat, the distance decreases. This is represented by a line moving down on the graph.
4. When the insect is moving quickly towards the bat, the slope is very steep and downwards.
5. When the prey is moving slowly away from the bat, the slope should be gradual or gentle and should slope upwards.

6. When the students stands in front of the motion detector in one place and jumps up and down, the graph should be almost flat. The shape of your body and the fact that it is impossible to jump straight up and down, will cause some up and down movement of the line. Emphasize that the motion detector is measuring distance of the student from the detector, not of the student from the floor.

Part II Following the path of other insects

7. Answers will vary. Students may make up a story about what the insect is doing, but generally, they should say that the insect was slowly moving towards the bat for 5 seconds and then stopped moving and stayed in the same place (maybe resting on a branch).

8. Answers will vary. Again, students may make up a story about the path of the insect, but they should understand that the bat was the same distance from the bat for 7 seconds and then moved away quickly.

ASSESSMENT

Discuss the way bats use echolocation to catch insects.

EXTENSION

Find the range of the motion detector. Find out how far away students can stand and still register, and also how close they can stand without disrupting the graph. Similarly, map out how far side to side the wave is extending.

Name: ______________________________

Spring into Action

Remember the last time you played on a swing set? Scientists call this type of back and forth motion *simple harmonic motion*. Besides describing back and forth, or *horizontal*, movement, simple harmonic motion can also be a movement that is up and down, or *vertical*, like a bungee jumper bouncing after the jump. The time it takes for one complete cycle of these up-and-down movements is called a *period*. In this activity, we will study the up-and-down motion of a ball at the end of a Slinky® using a Motion Detector.

OBJECTIVES

- Graph vertical simple harmonic motion.
- Find how long it takes to make one complete cycle, or period.
- Find out how the period is affected by pulling the spring further down.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Motion Detector
meter stick with Slinky and ball attached
heavy books

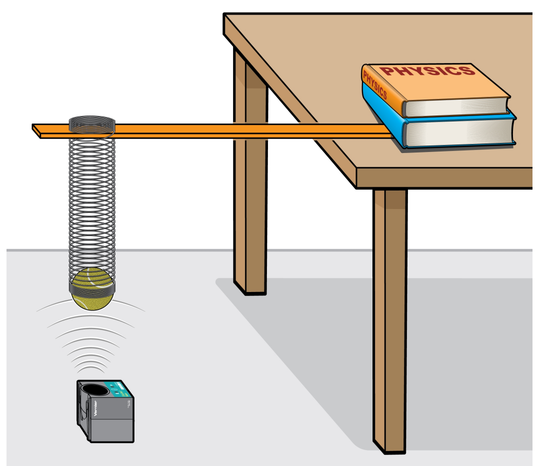

Figure 1

KEY QUESTION

What is the relationship between the distance a spring is pulled down, or *displaced*, and its period?

HYPOTHESIS

When a spring is displaced further, the period will be _______________ (shorter, longer, or the same).

PROCEDURE

1. Do the following to set up the Motion Detector for data collection:
   a. Launch Graphical Analysis.
   b. Connect the Motion Detector to your Chromebook, computer, or mobile device.
2. Assemble the equipment as shown in Figure 1. Put the meter stick on a table or desk so the Slinky is hanging freely. Place the books on the meter stick to keep it on the table. Carefully place the Motion Detector so it is directly underneath the ball. Let the ball come to rest.
3. Collect data for the 10 cm displacement:
   a. Have one student pull the ball down about 10 cm from its resting height. Make sure you pull the ball straight down, or it will swing around when you let go.
   b. Release the ball, then click or tap Collect to start data collection.
   c. When data collection is done, look at graph. The high points in the wave are called peaks and the low points are called troughs. Was the ball closer to the Motion Detector during a peak or a trough? Discuss this with your teammates and make sure you all agree.
   d. If there are sharp spikes on your graph, it probably means the ball swung out of range of the detector. If this happened, collect data again by starting data collection again.
4. Find the period of the Slinky.
   a. Click or tap the graph to examine the position and time values. **Note**: You can also adjust the Examine line by dragging the line.
   b. Find the time of the first peak and write it in the Data Table.
   c. Find the time of the second peak and write it in the Data Table.
   d. Subtract the time of the first peak from the time of the second peak. This gives you the length of the period. Record this time in the Data Table.

Data Table				
Run	Spring displacement	Time of 1st peak (s)	Time of 2nd peak (s)	Length of one period (s)
1	10 cm			
2	20 cm			

5. You will now repeat the data collection, but this time the displacement will be larger. Repeat Steps 3–4, pulling the ball down 20 cm instead of 10 cm.

ANALYZE YOUR DATA

1. What did you learn about the relationship between a spring's displacement and its period? Was your hypothesis correct?

   ____

   ____

   ____

2. Were the peaks and troughs larger when the displacement was 10 cm or 20 cm?

   ____

   ____

   ____

Spring into Action

BACKGROUND INFORMATION

Objects that oscillate up and down or back and forth in a repetitive manner are said to have simple harmonic motion. Simple harmonic motion occurs in many places, such as the pendulum of a clock, a person bouncing after a bungee jump, metronome hands, or a child on a swing. This kind of motion can be represented by a graph where the highest part of the wave is called the peak, the lowest is called the trough, and the time interval from one peak to another is the period.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion PS2.B: Types of Interactions PS3.C: Relationship Between Energy and Forces PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces PS4.A: Wave Properties	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Music – Bring in a metronome and play it for the kids. Discuss musical periods or cycles.

Math – graph analysis and comparisons, negative numbers, waves

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students collect motion data with Vernier equipment, we recommend that you start with Activity 20.

3. Prepare the Slinkys and the meter sticks ahead of time. It may help to affix each Slinky with only a portion of its length hanging down so that when the Slinky is fully extended during data collection, the bottom of the Slinky doesn't get too close to the motion detector. (Note that objects must be at least 15 cm from the motion detector in order to be detected.) As long as each group uses the same setup for both data-collection runs, it is not necessary for all the Slinkys to be the same length.

4. The motion detector can only detect solid surfaces; therefore, the motion detector cannot "see" the Slinky. Create a solid surface on the bottom of the Slinky by taping a ball or a circular piece of cardboard to the end of the Slinky that will be closest to the motion detector. If your Slinky is very tight (doesn’t extend easily), you may add a heavier ball or similar object. Make sure the object is very well attached if it is small enough to fit into the detector of the motion detector (the round, gold foil) and/or protect the detector with something such as an upside down "in box" tray.

5. The concepts covered in this activity can be difficult to understand, especially for younger students. As a group, discuss the Key Question “What is the relationship between the distance a spring is pulled down, or *displaced*, and its period?” By the end of the experiment, students see that the period stays the same while displacement increases. In other words, the end of the Slinky travels further when there is greater displacement (the peaks and troughs are larger), but because the end of the Slinking is also moving faster, each period is still the same duration.

6. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Run	Spring displacement (cm)	Time of 1st peak (s)	Time of 2nd peak (s)	Length of 1 period (s)
1	15	2.10	2.75	0.65
2	25	1.00	1.65	0.65

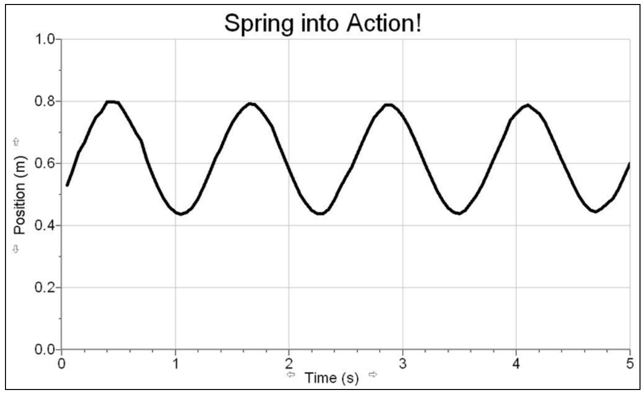

Figure 1 Position data for spring with 20 cm displacement

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. The periods should be the same, or very close, for both displacements.
2. The peaks and troughs were larger for the 20 cm displacement.

ASSESSMENT

Ask students what the effects would be if the displacement was increased even more. How would the length of the period be affected? What would happen to the size of the peaks and troughs?

EXTENSIONS

1. These concepts and terms used in this activity can transfer to pendulum experiments. Have students make simple pendulums with objects such as yo-yo's. Ask them to identify what one period is. Have students predict whether or not the period length will be affected by pulling the yo-yo out further before letting it swing. Then ask them if the period length will change if you change the length of the string, making it longer or shorter.
2. Take a visit to a local science museum that may have a swinging pendulum. Some pendulums can be used to demonstrate the rotation of the earth.
3. Give each child a Slinky and let them experiment with the different kinds of wave motion they can make, such as transverse or compressional waves.

Name: ______________________________

Graphical Analysis **24**

Air Ball!

Do you ever wonder how the National Basketball Association (NBA) decides how much air should be in the basketballs used during a game? The NBA measures the pressure inside the ball in units of pounds per square inch, or psi. In this activity, you will experiment with the amount of air in a basketball, but you will use the units scientists use to measure pressure called kilopascals, or kPa. You will vary the amount of pressure in the ball, then use the Motion Detector to measure how high the ball bounces.

OBJECTIVES

- Record what happens to the bounce height of a basketball as you vary the pressure of the air inside it.
- Graph your data.
- Draw conclusions based on your data.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Motion Detector
Go Direct Gas Pressure
basketball
stopper with needle, stopper stem, and tubing attached
meter stick
large rubber bands or masking tape

KEY QUESTION

How does the amount of air in a basketball affect how high it bounces?

HYPOTHESIS

As I let air out of the ball, the ball will bounce ____________ (higher or lower).

PROCEDURE

1. Do the following to set up the sensors for data collection:
   a. Launch Graphical Analysis.
   b. Connect the Pressure Sensor and Motion Detector to your Chromebook, computer, or mobile device.

2. Set up the data-collection mode:
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Rate to 20 samples/second.
   c. Set End Collection to 4 s. Click or tap Done.

3. You will now get everything ready to do this activity.
   a. Obtain your basketball.
   b. Wet the needle attached to the Pressure Sensor and insert the needle into the ball.
   c. Look at the pressure reading on the screen and record it in the first row in the Actual pressure column in the Data Table.
   d. Remove the needle from the ball.

4. Click or tap View, ⊞, and choose 1 Graph. This will display a graph of either position *vs*. time or pressure *vs*. time. If it is pressure *vs*. time, click or tap the y-axis label. Select Position and deselect Pressure. Click the graph to dismiss the box.

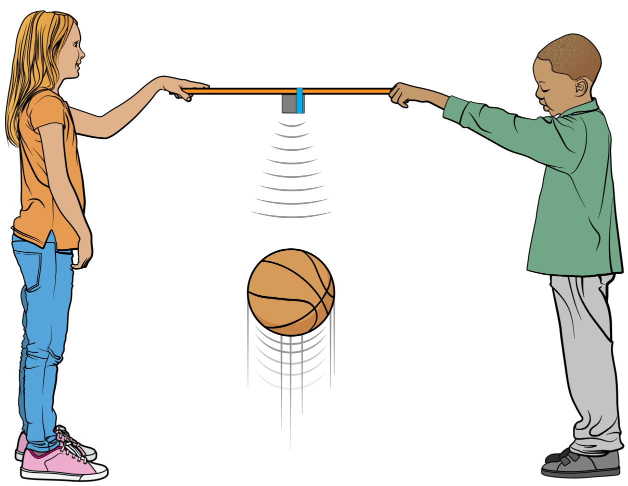

Figure 1

5. Use masking tape or large rubber bands to attach the Motion Detector to the middle of a meter stick with the sensor facing away from the stick. **Caution**: Do not cover the detector (gold circle) of the Motion Detector!

6. Have two students hold the ends of the meter stick approximately 1.5 meters above the floor with the sensor facing down. Hold it still during data collection.

7. Do the following to collect data:
   a. Hold the ball directly below the sensor with about 15 cm of space between the ball and the sensor.
   b. Click or tap Collect to start data collection. When data collection begins, let the ball drop and bounce on the floor. Do not throw it down!
   c. If your graph does not look something like the graph in Figure 2, line up the ball and start data collection again.

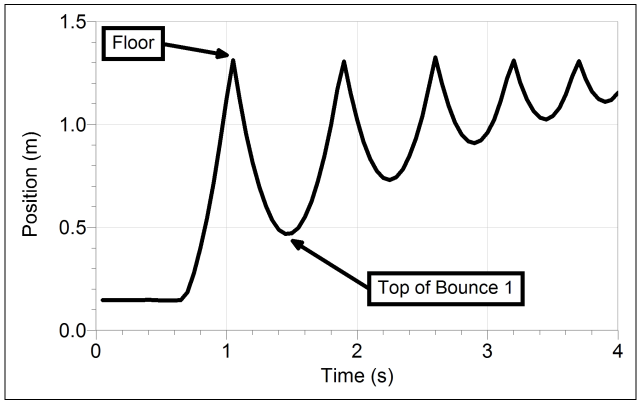

Figure 2

8. Click or tap the graph to examine the position and time values. Find the position of the floor, relative to the Motion Detector, and the position of the ball at the top of Bounce 1. Record these values in the Data Table. **Note**: You can also adjust the Examine line by dragging the line.

Data Table				
Target pressure (kPa)	Actual pressure (kPa)	Floor (m)	Top of Bounce 1 (m)	Height of Bounce 1 = Floor – Bounce 1 (m)
170				
160				
150				
140				
130				
120				
110				
100				

9. Decrease the pressure in the ball by doing the following:
   a. Wet the needle attached to the Pressure Sensor and insert it into the ball.
   b. Look at the pressure readings in the meter on the screen.
   c. Very slightly, loosen the connector on the plastic valve sticking into the stopper. You do not want to disconnect the tubing, you simply want to slowly release a little air.
   d. Continue watching the pressure on the screen until the pressure has decreased by 10 kPa (the first time you do this, the pressure will go from 170 kPa to 160 kPa).
   e. When the pressure has decreased by 10 kPa, tighten the connector so no more air escapes. **Note**: It is okay if the pressure goes down by a bit more than 10 kPa, but try to get as close as you can. If you accidentally lose a lot of air, tell your teacher.
   f. Record the pressure in the data table in the next row of the Actual pressure column.

10. Repeat Steps 7–9 for 160 kPa, 150 kPa, and so forth, until you have completed the 100 kPa trial.

11. Disconnect the Pressure Sensor and the Motion Detector from your Chromebook, computer, or mobile device.

12. Fill in the Height of Bounce 1 column in the Data Table, using the following equation:

    Height of Bounce 1 = Floor – Top of Bounce 1

ANALYZE YOUR DATA

1. You will now graph your results. First, set up the data table for data entry:
   a. Click or tap File, 🗋, and choose New Experiment. Click or tap Manual Entry..
   b. In the table, click or tap more, ⋯, in the X column header. Choose Column Options.
   c. Enter **Pressure** as the Name and **kPa** as the Units. Click or tap Apply.
   d. In the table, click or tap more, ⋯, in the Y column header. Choose Column Options.
   e. Enter **Height** as the Name and **m** as the Units. Click or tap Apply.
   f. Select the first cell in the Pressure column and enter the first pressure value you wrote down in the Data Table.
   g. Move to the first cell in the height column and enter the height of the first bounce that you calculated in your Data Table.
   h. Continue in this manner to enter data for the remaining data.

2. Describe any pattern you noticed about the heights of the bounces as the pressure in the ball was decreased. Was the first decrease the same size as the last decrease?

   ____

   ____

   ____

3. Based on your graph, how high do you think the basketball would bounce if its pressure was 180 kPa? How about 190 kPa?

   ____

   ____

4. What would be the lowest pressure in the ball you would want to use for playing basketball? Explain your answer using the data you collected.

   ____

   ____

   ____

Air Ball!

BACKGROUND INFORMATION

In this activity, students work in groups to explore how air pressure affects the height of the first bounce of a basketball (or some similar type of ball) after it has been dropped. Students will use a Gas Pressure Sensor to measure the pressure in the ball in kilopascals (kPa), the SI unit for measuring pressure.

According to the regulations on the National Basketball Association's website (www.nba.com), a basketball should be inflated to 7.5–8.5 pounds per square inch (psi). If using a pressure sensor that measures in units of kPa, use the following equations to convert values between units of kPa and psi if you would like to help your students make the connection between kPa and psi (a unit they, if living in the United States, are more likely to be familiar with):

$$\text{pressure in kPa} = (\text{pressure in psi}) \times 6.89\ \frac{\text{kPa}}{\text{psi}}$$

$$\text{pressure in psi} = (\text{pressure in kPa}) \times 0.145\ \frac{\text{psi}}{\text{kPa}}$$

Note: This activity is written with the assumption that students will collect data with a motion detector and a pressure sensor. If you do not have pressure sensors, see the Helpful Hints for possible modifications.

TIME FRAME FOR ACTIVITY

This activity takes about two 60-minute class periods since the activity may take more teacher introduction than others in this book. You may wish to instruct students determine a good stopping place on the first day of the activity. If you do the activity over multiple days and are using Vernier gas pressure sensors, you will need to zero the sensors each day.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion PS2.B: Types of Interactions PS3.C: Relationship Between Energy and Forces PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces PS4.A: Wave Properties	Patterns Cause and effect Scale, proportion, and quantity Energy and matter Stability and change	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – the scientific process, air pressure

Math – graphic analysis and statistics, line graphs, measurement, differences

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting motion data with Vernier equipment, we recommend that you start with Activity 20.

3. In this activity, students should work in groups of four or five: two hold the meter stick with the Motion Detector taped to it, one drops the ball, one starts data collect collection, and one records data.

4. This activity is written to use a Motion Detector and a Gas Pressure Sensor at the same time. If you are using sensors that must be connected via USB and do not have two USB ports, you have several options:
   - Use a USB hub. A USB hub plugs into the USB port of your computer or Chromebook and has several ports into which you can plug additional USB devices.
   - Instead of using the Gas Pressure Sensor, you can you a pressure gauge to measure the pressure in the ball. Pressure sensors for measuring air pressure in a ball are available at most places where sports equipment is sold.
   - If no Gas Pressure Sensor or gauge is available, you can do a qualitative study in regards to the air pressure in the ball (you will still be collecting quantitative data with the Motion Detector). Start with a ball that seems fully inflated. For each trial, use the needle to let air out of the ball for a given period of time. For a standard-size ball, 3 seconds works well.

5. If you are using Vernier pressure sensors, assemble the equipment ahead of time. In order to use the sensor to measure the pressure in the ball, you will need to insert a pump needle into one of the stoppers that comes with the sensor. Ideally, use the smaller, 1-hole stopper found in the Pressure Sensor Accessories Kit (included with the Pressure Sensor), and leave it set up for when you do this activity in the future. This stopper should already have a plastic valve extender inserted in the hole. Use pliers to hold the pump needle, and insert the threaded end into the other end of the stopper. The hole is quite a tight fit for the needle, but this ensures that it stays in. Remind students that when they pull the needle out of the ball, they should reach around the stopper and grab hold of the needle, rather than pulling only on the stopper. If you need to replace the stopper, you can purchase addition kits (order code: PS-ACC).

6. If you are using Vernier pressure sensors, inflate the balls so the pressure is at 170 kPa (Graphical Analysis 4) or 80 kPa (with the sensor zeroed in Logger Lite and LabQuest app) before giving the balls to students. During the activity, students will decrease the pressure in

the ball, incrementally, by 10 kPa. To do this, they should slightly untwist connection between the tubing and the plastic valve extender, allowing air to escape while watching the pressure readings on the screen. When the pressure has dropped by 10 kPa, the students should tighten the connection. It is okay if the students release a little too much air. In the student version of the activity, students are told to record the exact pressure in their data table. When they enter their data to create a graph, students will enter the actual values they recorded during data collection.

7. Be sure that the students start with the ball at least 15 cm from the motion detector. If they start with it touching the detector, they could get faulty data. Instruct your students to drop (not throw) the ball straight down so that it bounces directly below the motion detector. If their graph does not look similar to the sample on their worksheet, have them restart data collection to repeat data collection.

8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

SAMPLE RESULTS

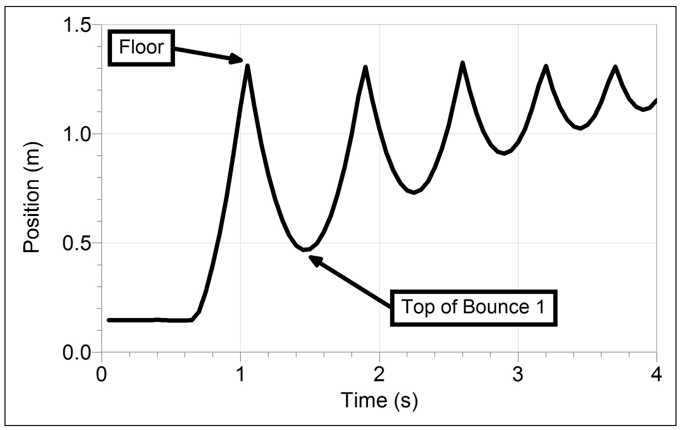

Figure 1 Graph of ball bouncing under a Motion Detector.

The sample data were collected in Graphical Analysis 4. If students are using Logger Lite or LabQuest app, the initial target pressure is 80 kPa.

Target pressure (kPa)	Actual pressure (kPa)	Floor (m)	Top of Bounce 1 (m)	Height of Bounce 1 = Floor – Bounce 1 (m)
170	170.3	1.29	0.56	0.73
160	159.9	1.30	0.58	0.72
150	150.1	1.29	0.61	0.68
140	140.0	1.30	0.65	0.65
130	129.2	1.29	0.59	0.60
120	120.1	1.31	0.76	0.55
110	111.9	1.28	0.79	0.49
100	100.3	1.29	0.99	0.30

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Students fill in the last column of their Data Table and then enter their data in the data-collection program:
   - Graphical Analysis 4: Open a new file and start a Manual Entry file.
   - Logger Lite: Enter data on Page 2 of the experiment file.
   - LabQuest App: Enter data into the table on Table tab.

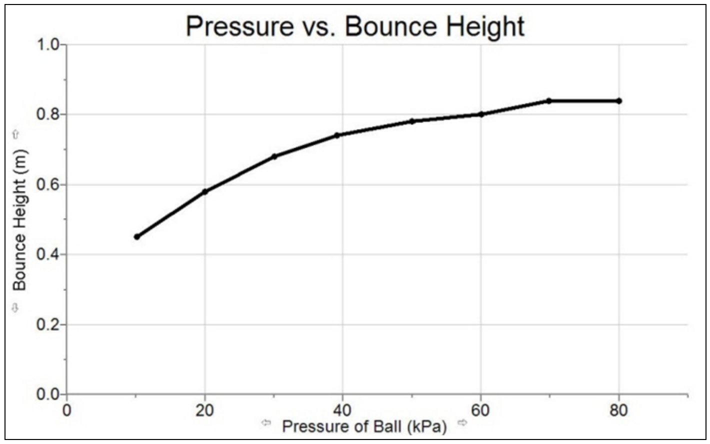

Figure 2 Graph of pressure versus bounce height

2. Answers will vary, but students should identify that the bounce height decreases more at lower pressures and less at higher pressures.

3. Answers will vary.

4. Answers will vary, but it should be the lowest pressure before the bounce height began to drop off.

ASSESSMENT

Lead a discussion about how the amount of pressure in a ball affects how high the ball bounces.

EXTENSIONS

1. Students could test the bounce heights on volleyballs, soccer balls, or playground balls.

2. Have students learn about the regulation ball pressure for game play of different sports. Why might the pressure in a soccer ball differ from that of a basket ball?

Name: ______________________________

Graphical Analysis **25**

Driving with Energy

People get energy from the food they eat. Energy also comes in other forms, like the electricity that allows us to turn on lights and heat water. Energy comes from different sources, but did you know that most energy, no matter what it is used for or where it comes from, can be classified as either potential energy or kinetic energy? Let's take a look at these two types of energy.

Energy waiting to be released is called *potential* energy. Objects with only potential energy aren't in motion, but could be soon. Objects in motion have energy called *kinetic* energy. Energy can change from potential to kinetic and back again. For example, when you are at the top of a roller-coaster ride, the car is barely moving, but it is so high off the ground it has a lot of potential energy. That means it has the potential to gain speed when it goes down the hill. As it descends, potential energy is converted to kinetic energy. At the bottom, when the roller coaster is moving the fastest, the potential energy has been converted into kinetic energy. Kinetic energy is then converted back to potential energy as it climbs back up the hill. When the ride ends and stops moving at the bottom, it contains neither potential nor kinetic energy.

In this activity, a toy car will be pulled back a certain distance, giving it a certain amount of potential energy. The distance your toy car travels will be an indicator of how much kinetic energy it has.

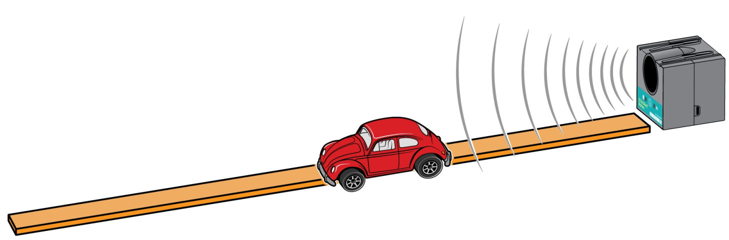

Figure 1

OBJECTIVES

- Vary the amount of potential energy in a toy car.
- Use a Motion Detector to measure the movement of a toy car.
- Define kinetic and potential energy.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Motion Detector
pull-back toy car (friction car)
meter stick

KEY QUESTION

Does greater potential energy convert into greater kinetic energy?

HYPOTHESIS

The more potential energy a toy car has, the ________________ (more or less) kinetic energy it will have.

PROCEDURE

1. Set up the Motion Detector for data collection.
   a. Launch Graphical Analysis.
   b. Connect the Motion Detector to your Chromebook, computer, or mobile device.
2. Click or tap View, ⊞, and choose 1 Graph. This will display a graph of position *vs*. time.
3. Put the meter stick in front of the Motion Detector with the 0 cm end close to it (see Figure 1). Tape the stick to the table so it doesn't move. Make sure the Motion Detector is no closer than about 15 cm from the end of the meter stick.
4. Follow these steps to collect data:
   a. Straddle the car over the meter stick and position the front wheels at the 25 cm mark.
   b. Pull the car 10 cm backwards to the 15 cm mark.
   c. Think about what kind of energy the car has now as it is held in place and write it in the blank:

      ____

   d. Have one person in your group click or tap Collect. Then, have the person holding the car release it.
   e. Think about what kind of energy the car has while it is moving and write it in the blank:

      ____

5. Find how far the car moved from the Motion Detector by doing the following:
   a. Click or tap View, ⊞, and choose Table. Look in the Position column of the table.
   b. Find the biggest value in the Position column and record it in the right place in the Distance traveled column in the Data Table.

Data Table		
Run	Pullback distance	Distance traveled (m)
1	10 cm	
2	15 cm	
3	20 cm	

6. Now, do the following to collect and analyze data for a 15 cm pullback:
   a. Straddle the car over the meter stick. Position the front wheels at the 30 cm mark.
   b. Pull the car 15 cm backwards to the 15 cm mark.
   c. Have one person in your group start click or tap Collect to start data collection. After data collection begins, have the person holding the car release it.
   d. Repeat Step 5 to examine your data.
7. Collect and analyze data for a 20 cm pullback:
   a. Straddle the car over the meter stick and position the front wheels at the 35 cm mark.
   b. Pull the car 20 cm backwards to the 15 cm mark.
   c. Have one person in your group click or tap Collect and then have the person holding the car release it.
   d. Repeat Step 5 to examine your data.

ANALYZE YOUR DATA

1. What did you do to your car in this activity to give it more potential energy?

   ____

   ____

2. Which of your three trials showed more kinetic energy?

   ____

3. At the beginning of this activity, you wrote a hypothesis that answered the following question: Does greater potential energy convert into greater kinetic energy? Was your hypothesis correct? Explain using the data you collected.

   ____

   ____

Driving with Energy

BACKGROUND INFORMATION

The introduction to the student section of this activity contains background information.

TIME FRAME FOR ACTIVITY

This activity takes about 60 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion PS2.B: Types of Interactions PS3.C: Relationship Between Energy and Forces PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Literature – *The Little Engine that Could*, by Wally Piper, is a great read-aloud for kids of all ages. It is not only a tie-in with simple machines and energy, it is also a motivational story that showcases the power of positive thinking. Another book that would go along with this theme would be *Mike Mulligan and his Steam Shovel*, by Virginia Lee Burton.

Science – potential and kinetic energy, changing forms of energy, heat from friction as another form of energy

Math – graph analysis, comparison of different graphs

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting motion data with Vernier equipment, we recommend that you start with Activity 20.

3. You may want to demonstrate the following things to your class to show them different examples of potential and kinetic energy.
   - Ball suspended in air (potential)
   - Ball falling (kinetic)
   - Stretched rubber band (potential)
   - Rubber band released (kinetic)
   - Have students stand on a step (potential)
   - Have students jump off step (kinetic)

4. Discuss the Key Question "Does greater potential energy convert into greater kinetic energy?" as a group. Have students write their hypothesis and then share with the class.

5. You may want to model how to set up the meter stick and the motion detector. If the cars you have are too small to be detected by motion detector, tape an index card to them.

6. If you have small cars, or cars that go very far when pulled by 20 cm, you may need to alter this activity. Smaller cars can be pulled back next to, rather than straddling, the meter stick. If cars go too far, you can have students pull them back 10, 13, and 16 cm (or some similar set of distances) rather than the prescribed 10, 15, and 20 cm.

7. LEGO® kits are an excellent tool that allows students to design, construct, and test a pull-back car that uses a rubber band for power.

8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Trial	Pullback distance	Distance traveled (m)
1	10 cm	0.68
2	15 cm	0.90
3	20 cm	1.09

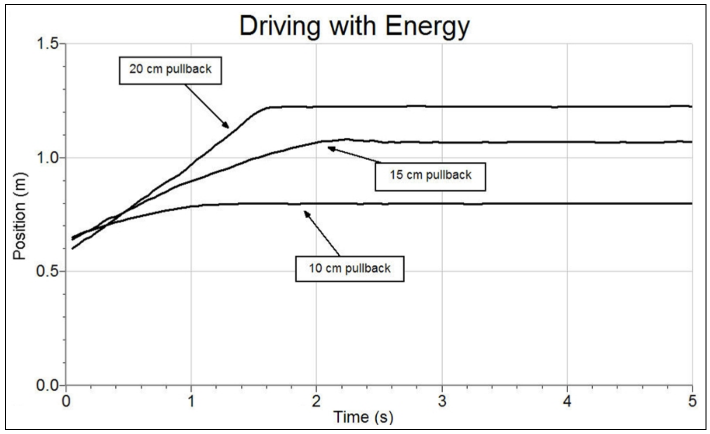

Figure 1 Comparing change in position for a windup car being pulled back different distances

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. I gave the car potential energy by pulling it back.
2. The trial that had the farthest pullback showed the most kinetic energy.
3. Answers will vary, but the data should suggest that the farther the car was pulled back (more potential energy), the farther it went (more kinetic energy).

ASSESSMENT

Have each team describe various situations portraying potential and kinetic energy. Examples could include a sibling at the top of a slide, or on the way down; someone skateboarding; a stretched rubber band; and so on. If students have access to a digital camera, have them take pictures of situations portraying potential and kinetic energy, and then give them time to present to the class.

EXTENSION

Repeat the activity on various surfaces. Investigate whether differences in surface texture affect the distance traveled.

Name: ________________________________

Graphical Analysis **26**

Weigh Station – All Trucks Stop!

Do you ever wonder if trucks would roll down a hill faster when they have a full load or when they are empty? This activity will help you test a truck on a downhill ramp. You will discover whether the truck goes faster when it is lighter or as you add weight to its load.

OBJECTIVES

- Use a Motion Detector to measure the time it takes a truck to go down a ramp.
- Predict what will happen as you add weight to the truck.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Motion Detector
ramp
piece of paper
several text books
masking tape
plastic toy truck
3 rolls of pennies
calculator

KEY QUESTION

Does adding weight to a truck cause it to go faster when it rolls down a ramp?

HYPOTHESIS

The truck will go ______________ (faster or slower) as I add weight to its load.

This means it will take ______________ (more or less) time to roll down the ramp.

PROCEDURE

1. Set up the Motion Detector for data collection.
   a. Launch Graphical Analysis.
   b. Connect the Motion Detector to your Chromebook, computer, or mobile device.
2. Click or tap Mode to open Data Collection Settings. Set End Collection to 3 s. Click or tap Done.

3. Click or tap View, ⊞, and choose 1 Graph. This will display a graph of position *vs*. time.

4. Draw a prediction of how the motion will change during data collection.
   a. Click or tap Graph Tools, 📈, and choose Add Prediction.
   b. Draw your prediction of the truck's movement down the ramp. Click or tap Save.

5. Follow these steps to set up a ramp at an 11° angle:
   a. Fold a piece of paper at the corner to form a 45° angle.
   b. Fold it again to make a 22.5° angle, then a third time to get an 11.25° angle.
   c. Use this paper to adjust the ramp to approximately an 11° angle.

6. Place another heavy book against the low end of the board (see Figure 1). This book will stop the truck.

7. Put a piece of masking tape approximately 0.25 meters from the high end of the board.

8. Position the Motion Detector so that the back of the Motion Detector is lined up with the back of the high end of the ramp. The detector (gold circle) should be pointing downhill (see Figure 1).

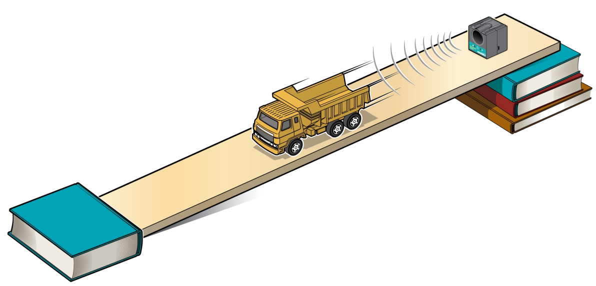

Figure 1

9. Collect data by doing the following:
   a. Place the rear wheels of the truck on the masking tape as a starting position.
   b. Click or tap Collect to start data collection, and release the car.
   c. If the truck runs off the ramp or goes past the book, put the truck at the starting point and start data collection again.

10. Click or tap the graph to examine the position and time values. Find the time of start and time of stop for the truck's movement down the hill. Record the data in the Data Table.

Data Table					
Run	Total mass added	Time of start (s)	Time of stop (s)	Total run time = stop – start time (s)	Average time for Runs A & B (s)
1A	0 penny rolls				
1B					
2A	1 penny roll				
2B					
3A	2 penny rolls				
3B					
4A	3 penny rolls				
4B					

11. Subtract the start time from the stop time. This is the amount of time it took the truck to get down the ramp. Record this value in the Total run time column.
12. Repeat Steps 9–11 for Run B.
13. Calculate the average time it took for the truck to get down the ramp. To calculate this value, add together the two values in the Total run time column and then divide by 2 to get the average time.
14. Add one roll of pennies to the truck's load and repeat Steps 9–13.
15. Add another roll of pennies so that there are two rolls of pennies on the truck and repeat Steps 9–13 again.
16. Add another roll of pennies so that there are three rolls of pennies on the truck and repeat Steps 9–13 for a last time.

ANALYZE YOUR DATA

1. Were the values in the Time of start column the same or different for every run? Why do you think this is the case?

____

____

2. Describe any pattern you noticed about the time it took the truck to get down the ramp as you changed the amount of weight the truck was carrying. Does this mean the truck went faster or slower when you added more weight?

3. Was your hypothesis correct? Explain using the data you collected.

Weigh Station – All Trucks Stop!

BACKGROUND INFORMATION

In this activity, students investigate how adding weight to a truck's load affects the time it takes for a toy truck to roll down a ramp. In a frictionless environment, the weight of the truck and its load would make no difference; the speed of a heavy truck would be the same as the speed of a lighter truck. Friction exists, however, between the tires and the road, as well as within the mechanism of the wheels and axle. Rotational inertia also plays a role. Because of these factors, the heavier truck will generally go down the ramp faster.

TIME FRAME FOR ACTIVITY

This activity takes 60–75 minutes. If you prefer to divide the activity into two sessions, we suggests you collect runs 1A–2B in the first session and runs 3A–4B in the second session.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS4.A: Wave Properties PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Science – measurement, friction, motion, rate

Math – graph analysis; statistics: minimum, maximum, range; slope

Literacy – compare and contrast

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting motion data with Vernier equipment, we recommend that you start with Activity 20.

3. In this activity, students roll a small truck down a ramp. Use a 1.5–2 m (4–6 foot) board that is at about 2.5 cm (1 inch) thick and at least 20 cm (8 inches) wide.

4. Find a plastic or metal truck with a flat tailgate, bed, or top. You may be able to find them at a local dollar or thrift store. You could also try making simple trucks of your own. Using LEGO® kit pieces to construct vehicles is a great way to combine engineering skills with this activity. Whatever you do, make sure the trucks can hold three rolls of pennies and still be able to roll down the ramp. If the truck cannot be detected by the Motion Detector, tape an index card or folded piece of paper on the back to act as a reflector.

5. If using penny rolls is inconvenient, you may wish to substitute penny rolls for D batteries. They are nearly the same weight.

6. Be sure that the ramp is stable. You can put duct tape at each end to hold it in place.

7. You will probably want to set up the equipment ahead of time and make adjustment until you get a graph that looks something like the one shown in the Sample Results. If students set up their own equipment, you may want them to do a few trial runs to ensure the axes are set for the data they will get during the experiment. If the data-collection software records a large spike in the data, the graph may autoscale to fit all data. The experiment data can then be difficult to see. Either adjust the axes or zoom in on the experiment data if this happens.

8. Your results will vary with the length of the ramp, the initial weight of the vehicle, and the surface of the ramp. Generally, the truck will go down the ramp faster as you add more weight.

9. Remind students to clear their data only after they have recorded the value of the time is takes for the truck to get down the ramp. If they delete the data too early, they will have to do the run again.

10. The truck needs to get down to the end of the ramp and run into the book. If it goes past the book, the student should do the run again.

11. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

12. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Data Table					
Run	Total mass added	Time of start (s)	Time of stop (s)	Total run time = stop – start time (s)	Average time for Runs A & B (s)
1A	0 penny rolls	0.90	1.80	0.90	0.85
1B		0/75	1.60	0.80	
2A	1 penny roll	0.85	1.70	0.85	0.80
2B		0.95	1.60	0.75	
3A	2 penny rolls	0.70	1.50	0.75	0.75
3B		0.70	1.50	0.75	
4A	3 penny rolls	0.80	1.40	0.60	0.63
4B		0.75	1.30	0.65	

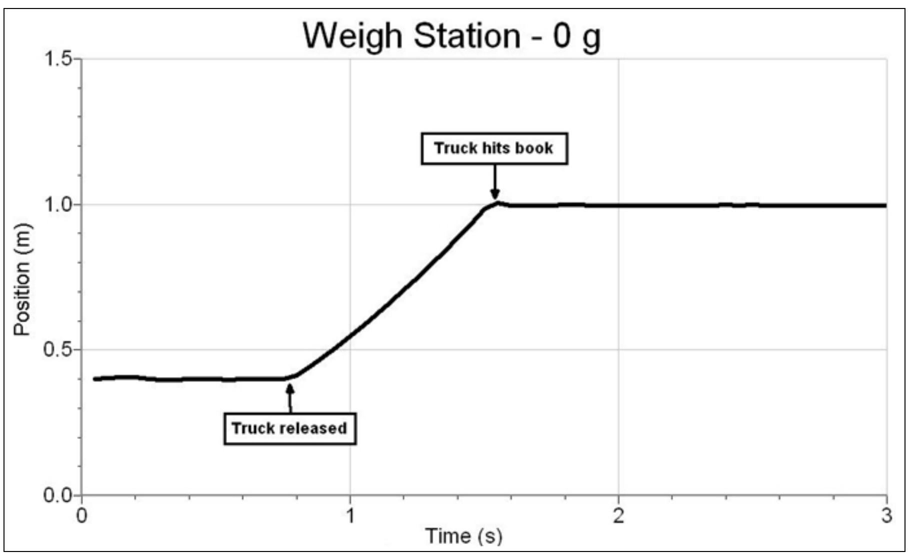

Figure 1 Distance from a Motion Detector as an empty truck rolls down a ramp

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. See the sample data table. Starting times will vary with student reflexes.
2. Answers will vary, but generally, more weight means faster times down the ramp.
3. Answers will vary depending on students' data and hypothesis.

ASSESSMENT

1. Give students a graph and ask them to identify the three parts of the graph (starting, rolling, stopped) and label where the truck is moving.
2. Conduct a class discussion based on the questions in the Analyze Your Data section.

EXTENSIONS

1. Ask the students to design another activity using the Motion Detector, a ramp, and the truck. They should write a procedure for others in the class to follow along with a few analysis questions.
2. Have the students contact trucking companies to get data about how the weight of the load in a truck affects the way it reacts to hills and how the driver adjusts on hills.
3. Test a truck as the angle of the ramp gets steeper. Do not change the weight of the truck's load, but add one more thick book for each run. Compare and contrast these results to those of the original activity.

Name: ______________________________

Graphical Analysis 27

Learning to Use a Force Sensor

You can use a Force Sensor to measure the strength of a push or pull. In this activity, you will work with a Force Sensor to learn how it works.

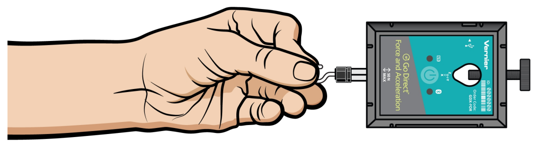

Figure 1

OBJECTIVES

- Learn to use the Force Sensor.
- Measure the changing forces as you pull and push on the Force Sensor.
- Match shapes using what you have learned about the Force Sensor.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Force and Acceleration Sensor

PROCEDURE

Part I Learn about the Force Sensor

1. Launch Graphical Analysis. Connect the Force Sensor to your Chromebook, computer, or mobile device.
2. Click or tap Mode to open Data Collection Settings. Set End Collection to 60 s. Click or tap Done.
3. Do the following to collect data using the Force Sensor:
   a. Look at the screen and click or tap Collect to start data collection.
   b. Push very softly on the hook of the Force Sensor and watch what happens on the graph.
   c. Now, push more forcefully on the hook. Watch how the force changes when you push with more force.
   d. Try pulling very gently on the hook, and then try pulling more forcefully. Watch how the force changes when you pull on the hook.
   e. Click or tap Stop to stop data collection if data collection has not ended.

4. In the Observations Sheet, write what happened to the force when you pushed gently on the hook, when you pushed more forcefully on the hook, and when you pulled on it.

Observations Sheet
1. When I pushed gently on the hook, the force reading ____ ____
2. When I pushed more forcefully on the hook, the force reading ____ ____
3. When I pulled on the hook, the force reading ____ ____

Part II Making faces with the Force Sensor

In this part of the activity, you will make a smile on the graph. You want your graph to look something like the one in Figure 2.

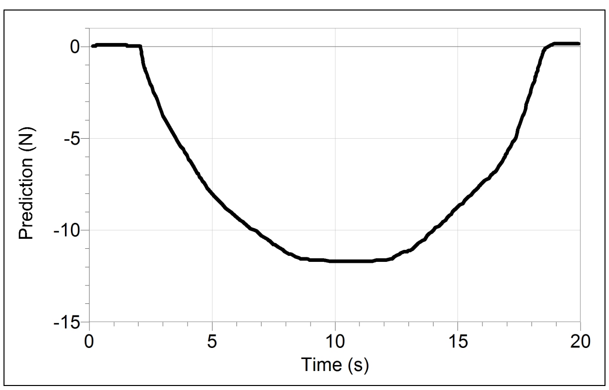

Figure 2

5. Before you start, think about what happened when you pushed and pulled on the hook of the Force Sensor. Fill in the blanks as a plan for matching the smile on the graph.
   a. To get ready, there should be force on the hook (no pushing or pulling).
   b. Start data collection and wait for _________ seconds.
   c. Then, ___________ (push or pull) the hook until the bottom of the smile is reached.
      At this point, the force will be about _________ N.
   d. At the bottom, ____________________________ to make the force return to about 0 N.
6. Follow the plan you wrote in Step 5, trying to match the smile.
7. If the data you collected matches the smile, congratulations! You can move on to the next step. If you want to try match the smile again, start data collection and repeat the plan you wrote.
8. After you've made the smile, you will make a frown. You want your graph to look something like the one in Figure 3.

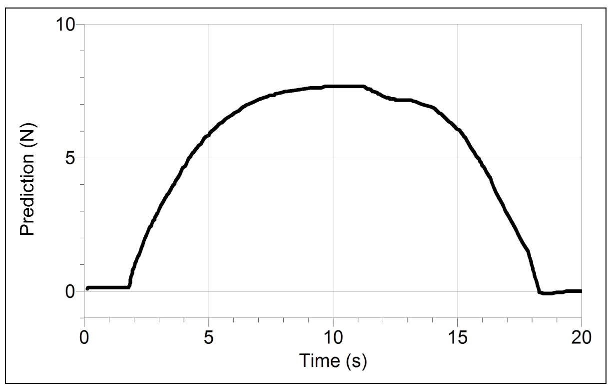

Figure 3

9. Write down the plan for matching the frown shape. Use the words in Step 5 as a pattern.

____

____

____

____

10. Click or tap Collect to start data collection, then follow the plan you wrote in Step 9.
11. If the graph looks like a frown, congratulations! If you want to try to make the frown again, just start data collection and repeat the steps you wrote.

Learning to Use a Force Sensor

BACKGROUND INFORMATION

The purpose of this activity is to allow students a chance to learn about the force sensor and how it works so they will be more comfortable with it later.

Both the Dual-Range Force Sensor (order code: DFS-BTA) and the Go Direct Force and Acceleration Sensor (GDX-FOR) measure the force of both pulls and pushes in a range of ±50 newtons (N). Beyond these values, the sensor will "peg out" or give constant readings.

Newtons are a measure of weight, similar to pounds. One pound (lb) of force is approximately equal to 4.4 newton (N). Our data-collection programs default to measuring in Newtons because it is the SI unit for measuring force.

When the hook on the sensor is pulled, the readings will be above zero. When the sensor hook is pushed, the readings will be below zero. This may be a bit confusing to your students at first.

There is a switch on the Dual-Range Force Sensor that affects its sensitivity. If you are measuring forces less than 10 N, the sensor should be set to the ±10 N setting. If you are measuring forces less than 50 N but you expect peaks of more than 10 N, the sensor should be set to the ±50 N setting. In this activity, the ±50 N setting is used. **Note**: Go Direct Force and Acceleration does not have a switch; the range adjusts automatically.

TIME FRAME FOR ACTIVITY

This activity takes about 30 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion PS2.B: Types of Interactions PS3.C: Relationship Between Energy and Forces PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or

LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. Prior to doing the activity with students, it is a good idea to read through the student version to look for terms that your students may not be familiar with. You could introduce these words to students as an introduction to the activity. It may also be helpful review with the students how to read an x,y coordinate graph.

3. Starting the activity with a demonstration can be an effective way to introduce students to the force sensor. Show students how to push and pull on the hook of the force sensor. In order to protect the internal sensor, students should always push or pull in line with the hook rather than pressing sideways on the hook. In the Procedure, students are told to push or pull "more forcefully" on the hook; you may want to give students guidance about how hard they can push or pull.

4. It can also be useful to have discussion with students about positive and negative numbers before they get started. Positive and negative numbers are important concept when working with force sensors because when the hook of the Force Sensor is pushed in, the force values in the data-collection software are negative; when the hook is pulled out, the force values are positive. If students are aware that they might see negative numbers, they are less likely to be concerned that they are doing something incorrectly.

5. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

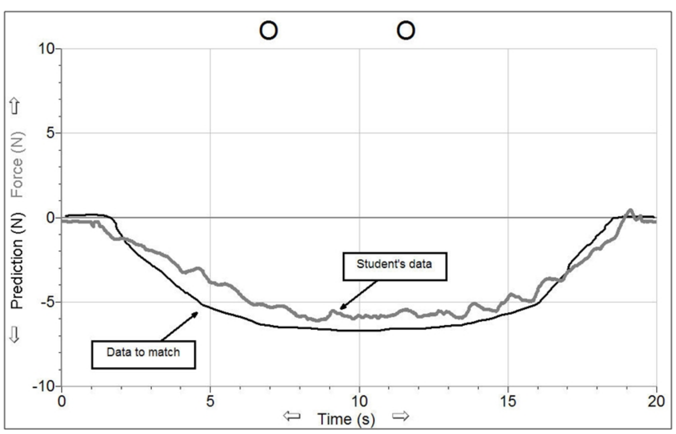

Figure 1 Sample data collected while matching a shape

ASSESSMENT

Ask students what other shapes could be made and how they would do it.

EXTENSIONS

1. Have students draw letters or shapes and try to match them.
2. Have students make the letter X or the letter A. They can use two Force Sensors or store one run and collect a second run on the same graph.

Name: ______________________________

Graphical Analysis **28**

Lift the Load!

The Greek philosopher Archimedes said, "Give me a lever long enough and a place to stand, and I can move the world." What did he mean by this? In this activity, you will get a chance to investigate how levers work.

OBJECTIVES

- Make a lever.
- Measure the amount of force needed to lift up a book when applying a force at different positions on the lever.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Force and Acceleration Sensor
meter stick
heavy book
fulcrum
tape
loop of string

PROCEDURE

Part I Lever with fulcrum at 20 cm

1. Get the Force Sensor ready to collect data.
   a. Launch Graphical Analysis.
   b. Connect the Force Sensor to your Chromebook, computer, or mobile device.
2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Enter **Length** as the Event Name and **cm** as the Units. Click or tap Done.

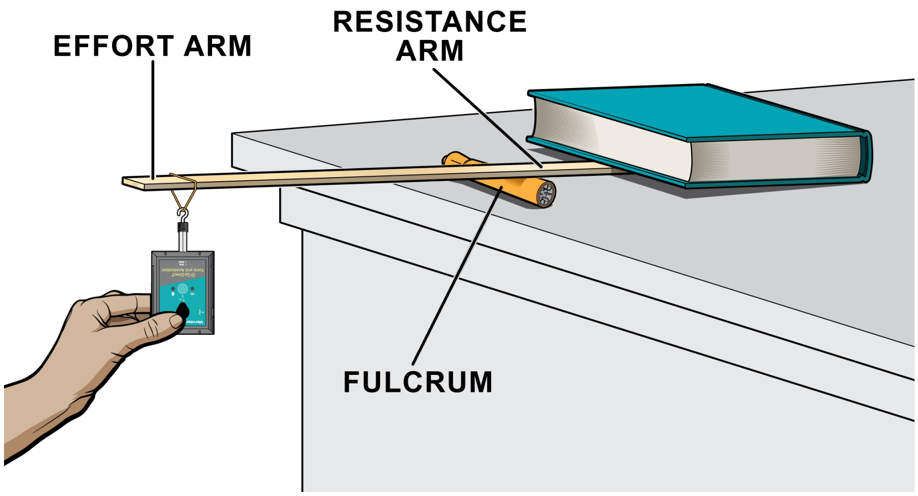

Figure 1

3. Set up the first lever. Look at Figure 1 to help you set everything up in the right way.
   a. Tape your fulcrum near the edge of the table or desk so that it cannot move.
   b. Place the lever so that the 20 cm mark is on the fulcrum, leaving the longer end sticking out over the side of the table.
   c. Put the book you are going to lift at the 5 cm mark so that just the edge of the book rests on the meter stick and the rest of the book is on the table.

4. Zero the sensor:
   a. Hold the Force Sensor so that the hook on the end points upward. Hold it very still.
   b. Click or tap the Force meter and choose Zero.

5. To finish setting up the lever system, complete these steps:
   a. Slide the loop of string up the meter stick from the end overhanging the table until it reaches the 30 cm mark.
   b. Hook the Force Sensor on the loop of string, as shown in Figure 1.

6. Different parts of a lever system have different names. Read the following steps to learn about the different parts of the lever.
   a. The side of the lever where the book is placed is called the resistance arm. For lever you have built, the resistance arm is 20 cm.
   b. The side of the lever where the push or pull happens is called the effort arm. To find the length of the effort arm, find the difference between where the Force Sensor is attached and the fulcrum. Since the loop of string is holding the Force Sensor at 30 cm and the fulcrum is at 20 cm, the length of the effort arm is 10 cm.

7. Collect data by doing the following:
   a. Click or tap Collect to start data collection.
   b. Holding the Force Sensor, slowly pull down until the lever is horizontal.
   c. While holding the lever steady, have someone in the group click or tap Keep. This will record the force you applied to lift the book.
   d. Enter **10** to indicate the 10 cm effort arm and click or tap Keep Point.

e. The person pulling on the sensor should notice how it feels to pull down. Write this observation on the Observations Sheet:

Observations Sheet Fulcrum at 20 cm
10 cm effort arm
20 cm effort arm
30 cm effort arm
40 cm effort arm
50 cm effort arm

8. Collect more data.
   a. Reposition the book so the edge is at the 5 cm mark and make sure the fulcrum is in the right place.
   b. Move the string out to the 40 cm mark.
   c. Now pull down on the Force Sensor to lift the book. When the lever is horizontal, click or tap Keep, and enter **20** for the length of the effort arm. Click or tap Keep Point.
   d. Record the observations about how much effort it took to pull down the lever.
9. Repeat Step 8, moving the string 10 cm each time, until you reach the 70 cm mark. Each time you move the string, enter the new effort arm length and record your observations.
10. When you are done collecting data, click or tap Stop to stop data collection. Click or tap the graph to examine the length and force values. Record the applied force for each of the effort arm distances in Table 1. **Note**: You can also adjust the Examine line by dragging the line.

Table 1 Fulcrum at 20 cm		
Position of Force Sensor (cm)	Effort arm length (cm)	Applied force (N)
30	10	
40	20	
50	30	
60	40	
70	50	

Part II Lever with fulcrum at 30 cm

11. Move the meter stick so the fulcrum is at the 30 cm point. In this position, the resistance arm is 30 cm. Keep the book in the same position as before. Now, read the Key Question and make a prediction.

    Key Question

    How will having a longer resistance arm affect how hard you must pull to pick up the book?

    Prediction

    Click or tap Graph Tools, , and choose Add Prediction. Draw what you think will happen now that the fulcrum is at 30 cm. Click or tap Save.

12. Collect data.
    a. Click or tap Collect to start data collection. **Note**: The previous data set is automatically saved.
    b. Move the string and Force Sensor to the 40 cm mark.
    c. Holding the Force Sensor, slowly pull down on the sensor until the lever is horizontal.
    d. While holding the lever steady, click or tap Keep. This will record the force.
    e. Enter **10** to indicate the 10 cm effort arm and click or tap Keep Point.

13. Collect more data.
    a. Make sure the edge of the book is at 5 cm and that the fulcrum hasn't moved.
    b. Move the string out to the 50 cm mark.
    c. Now pull down on the Force Sensor to move the lever. When the lever is horizontal, click or tap Keep, and enter **20** for the length of the effort arm. Click or tap Keep Point.
    d. Record the observations about how much effort it took to pull down the lever.

14. Repeat Step 13, moving the string 10 cm each time, until you reach the 80 cm mark. Each time you move the string, enter the new effort arm length and write down your observations.

15. When you are done collecting data, click or tap Stop to stop data collection.

16. Record the applied force for each of the effort arm lengths in Table 2.

Table 2 Fulcrum at 30 cm		
Position of Force Sensor (cm)	Effort arm length (cm)	Applied force (N)
40	10	
50	20	
60	30	
70	40	
80	50	

ANALYZE YOUR DATA

1. What did you notice about how hard you had to pull as the effort arm became longer and longer?

   ____

   ____

2. How did your prediction match what happened when the resistance arm moved from the 20 cm mark to 30 cm?

   ____

   ____

3. Do you think it would be possible to make a lever that would allow you to be able to pick up a car? Describe the effort arm and resistance arm you might need to do it.

   ____

   ____

4. Go back to the introduction and look at the quote by Archimedes. How did Archimedes feel about the amount of help this simple machine could offer humans?

   ____

   ____

Lift the Load!

BACKGROUND INFORMATION

Levers are simple machines that consist of an object pivoting around a single point called the fulcrum. We use simple machines, such as levers, every day. This exercise gives the students an opportunity to measure how levers work, particularly in terms of having lever arms of different lengths.

TIME FRAME FOR ACTIVITY

This activity takes about 75–90 minutes. You may wish to divide this activity into two class sessions (between Part I and Part II).

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion PS2.B: Types of Interactions PS3.C: Relationship Between Energy and Forces PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Social Studies – Look at how simple machines have affected human history.

Math – measurement

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting force data with Vernier equipment, we recommend that you start with Activity 27.
3. A good way to introduce this activity is to have a discussion about different kinds of simple machines. Many students have experienced simple machines before, but have never had an opportunity to investigate how simple machines actually help us accomplish tasks.
4. A magic marker or AA battery makes a good fulcrum for this activity.
5. The meter stick used in this activity must be a very sturdy one. If you do not have strong meter sticks available, use a piece of wood instead. Mark off 10 cm intervals on the piece of wood.
6. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.
7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Table 1 Fulcrum at 20 cm		
Position of force sensor (cm)	Effort arm length (cm)	Applied force (N)
30	10	14.7
40	20	6.0
50	30	3.3
60	40	2.5
70	50	1.8

Table 2 Fulcrum at 30 cm		
Position of force sensor (cm)	Effort arm length (cm)	Applied force (N)
40	10	19.2
50	20	10.2
60	30	7.0
70	40	4.9
80	50	4.0

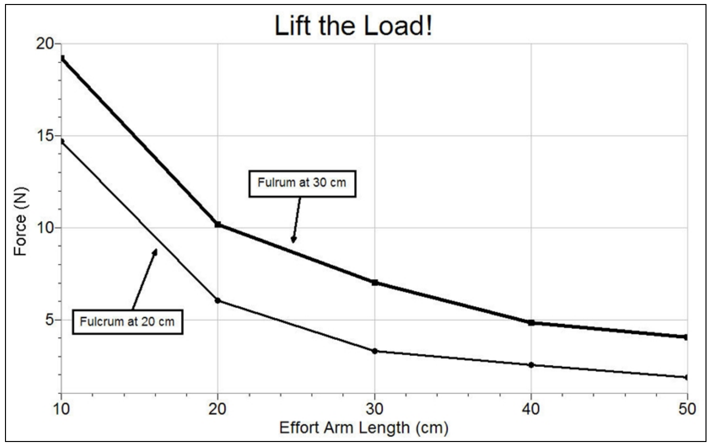

Figure 1 Change in force necessary to lift an object as effort arm length increases in two lever systems

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. The second pull on the force sensor was much easier than the first—the data show that the second pull required about half the force of the first one. After that, each pull required less force, but did not decrease by as much.
2. Answers will vary. One possibility would be that since the effort arm was easier when it got longer, I thought the resistance arm getting longer would make it easier, but it was the opposite.
3. Yes. If you took a very long, strong board and placed it on a rock or other large object so that the effort arm was very long compared to the resistance arm, you could pick up a car.
4. Archimedes said he could lift the world with a long enough lever and a place to stand. Archimedes was probably trying to make a point about how much levers help us in our everyday tasks as well as very heavy and difficult lifts.

ASSESSMENT

1. Give the students different drawings of levers with varying effort arm lengths and have them identify and explain which one would be the easiest to use.
2. Have the students write a story about someone using a lever to pick up something very heavy. In the story they explain how the lever works.

EXTENSIONS

1. An alternate way to do this experiment involves the use of two force sensors. Instead of lifting a book, attach a force sensor to the end of the lever on the resistance side. This force sensor needs to be rigidly attached to the table using a clamp or duct tape. On the effort side, the experiment is the same as in the original activity. This extension allows the students to quantify both the resistance and the effort forces.
2. Have the students test different classes of levers to test how they give mechanical advantage.
3. Have the students multiply the effort arm distance by the applied force. The product is referred to as the torque. The amount of torque should be the same (or very close) for every trial.

Name: ______________________________

Graphical Analysis **29**

What a Drag!

Why do you have to wear tennis shoes to your physical education class? Have you ever worn slippery-soled dress shoes? In this activity, you will observe the differences between the slickness of the bottom of different shoes. When the shoes are dragged across a surface, a frictional force opposes the motion. If the bottom of shoe is slick, you will need less force to pull it across the table because there is less friction. The opposite is also true—if the bottom of the shoe is very sticky or bumpy, there is more friction, and you will need more force to pull the shoe.

OBJECTIVES

- Make observations and predictions about shoes.
- Measure the force needed to pull different shoes across a surface.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Force and Acceleration Sensor
3 shoes with different soles
3 loops of string

KEY QUESTION

Does the material on the bottom of the shoe affect the amount of force it takes to move it across the ground? Feel the bottom of each of the shoes. Which one feels the slickest? Which one feels the bumpiest? Based on what you feel, complete the hypothesis.

HYPOTHESIS

The _______________________ shoe will have the most friction, and the

_______________________ shoe will have the least friction.

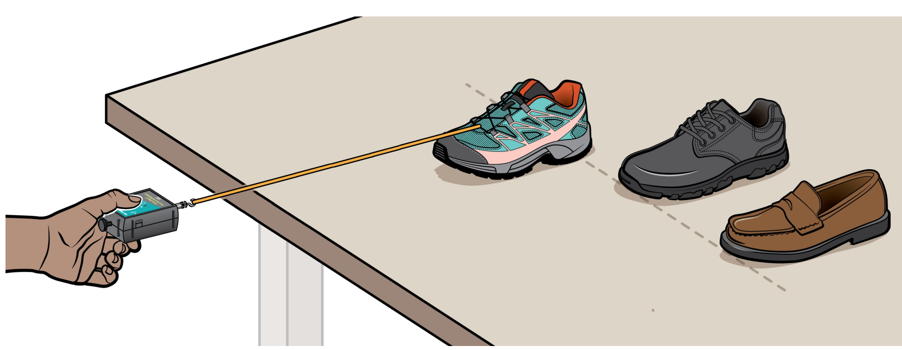

Figure 1

PROCEDURE

1. Get the Force Sensor ready to collect data.
   a. Launch Graphical Analysis.
   b. Connect the Force Sensor to your Chromebook, computer, or mobile device.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 4 s. Click or tap done.

3. Get the Force Sensor ready to collect data by doing the following:
   a. Hold the Force Sensor, with the hook pointing towards the ground.
   b. Look at the force value on the screen.
   c. When the value stabilizes (stays the same), click or tap the Force meter and choose Zero. The reading should be very close to zero.

4. Attach a loop of string to the shoes in a way that will allow you to drag it across the table.

5. Measure the weight of each of the shoes by hanging them from the Force Sensor and record their weights in the Data Table. Describe the type of shoe in the table also.

Data Table		
Type of shoe	Weight of shoe (N)	Average force (N)

6. Hook the Force Sensor to the string attached to the shoe and practice using the Force Sensor to drag the shoe across the table. When you drag the shoe, be sure to pull so the Force Sensor remains horizontal to the table top. Practice a few runs to make sure you can pull the shoe slowly and steadily.

7. Collect data:
   a. Begin slowly and steadily pulling the shoe across the table.
   b. Once the shoe is moving steadily, have another person in the team click or tap Collect to start data collection.
   c. If you reach the end of the table before data collection is over, repeat the run. You want to have a relatively steady force value for the four-second run.

8. When you have successfully collected data, click or tap Graph Tools, , and choose View Statistics. Record the mean (average) force in the Data Table.

9. Repeat Steps 7–8 for each of the remaining shoes.

ANALYZE YOUR DATA

1. Was your hypothesis about the shoes correct? Tell what you observed about the shoes that made you think this hypothesis would be true.

   ____

   ____

2. Write about the shoes that you used for this activity. What are they used for? Why do they need less or more friction?

   ____

   ____

3. Use your data to draw some conclusions about what activities might require shoes with more or less friction than the ones you tested. For example, what kinds of shoes do golfers or ballet dancers wear?

   ____

   ____

What a Drag!

BACKGROUND INFORMATION

Some people believe that friction is inherently “bad,” but without friction we would not be able to walk. Most everyone has had the experience of trying to walk on a surface with little friction (ice for example). It is the frictional force between the bottom of your shoe and the floor that propels you forward. Whenever two objects are rubbed against each other, there is friction between them. The amount of friction depends on two factors. One is the makeup of the surfaces, such as soft rubber, which can be very sticky, or ice, which is very slippery. The second factor is the amount of force pressing the surfaces together. For example, it is possible to slide a block of soft rubber if there is very little force pressing it against the other surface.

There are also two types of friction. *Static friction* is the friction that keeps objects from sliding past one another, such as what you have between your foot and the ground when you walk without slipping. *Kinetic friction* is the friction between two surfaces that are sliding past each other, such as the friction that happens when you rub your hands together.

In this activity, students explore the surfaces and control for the forces pressing down on them.

TIME FRAME FOR ACTIVITY

This activity takes about 40 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion PS2.B: Types of Interactions PS3.C: Relationship Between Energy and Forces PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Math – statistics: mean

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting force data with Vernier equipment, we recommend that you start with Activity 27.

3. Provide shoes that have soles with significant differences in their slickness. Most children's shoes have soles that are not very slick. A good choice for slick shoes would be adult dress shoes with leather soles. Bowling shoes are even slicker, but may be harder to find. Thrift stores may be a good source of shoes for this activity. Comparing adult dress shoes and a tennis shoe of approximately the same size and weight should provide good results.

4. The surface area of the sole and the weight of the shoe will affect the amount of friction. Therefore students should compare shoes of the same approximate weight and size. If this is not possible, put a water bottle in one of the shoes to make them approximately the same weight.

5. You may want to attach loops of string to each shoe prior to beginning the activity. If so, instruct students to ignore this step in the student version of this activity. Students will have more success keeping the soles flat on the surface if the string is attached as close to the toe as possible.

6. It is very important that the students pull the shoes across the surfaces without lifting the shoes. One way of doing this is to put the force sensor on the surface and pull it. Another way is to keep it just above the surface and pull it parallel to the surface.

7. If students gets surprising results during this activity (for example, a bumpy sole slides more easily than a slick sole), consider the following factors with your students: The reduced amount of area that touches the smooth table top caused by the bumpiness of a sole may result in less friction, even if the shoe is designed to help increase friction when on rough surfaces. The relative softness or hardness of the shoe will affect how the shoe slides; soft rubber will slide less easily than hard rubber. Also remind your students that friction is cause by the weight of the person using the shoe. Try attaching bottles of water to the shoes to see if it affects the outcomes.

8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Type of shoe	Weight of shoe	Mean force
Tennis shoe	4.0 N	5.8 N
Brown loafer	6.5 N	4.2 N
Dress shoe	4.9 N	3.9 N

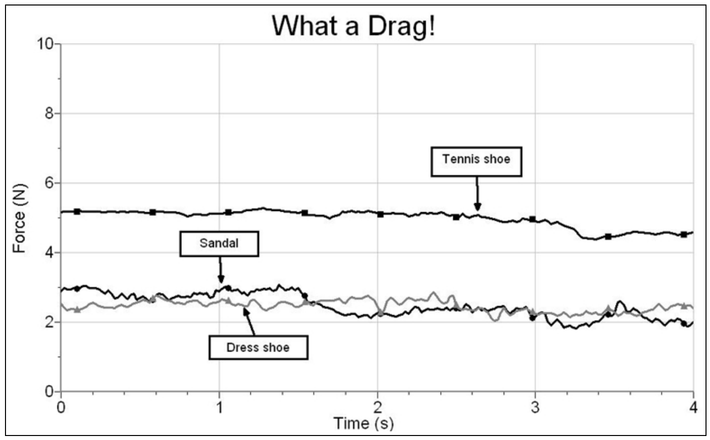

Figure 1 Change in force measured by a force sensor while being used to drag different types of shoes across a tabletop.

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers will vary based the student's hypothesis and data. Their answer should include the idea that the higher the friction, the greater the force.

2. Answers will depend on the kinds of shoes used in your activity. For the sample data, the Nike shoe is used to play sports and run, which requires friction. The dress shoes are not for running. The child's dress shoe allows the most slipping, and the woman's shoe is not as slippery.

3. Answers will vary, as there are comparisons to the data taken in the activity. For the sample data, people usually like to slide to the line when they are bowling, so a bowling shoe might have even less friction than a women's dress shoe. Golfers wear spiked shoes, which helps them keep from slipping when they swing.

ASSESSMENT

1. Pose a question such as, "Your friend is planning on going to soccer practice wearing dress shoes. Explain to the friend that other shoes would be better for soccer, using information from your data."

2. Pose a question such as, "Your friend is going to ballet wearing tennis shoes. Help your friend make a better choice in shoes using information from your data."

EXTENSIONS

1. Explore special shoes or boots that are used for different purposes. Some examples: Rock climbing, baseball, construction, or work in food processing. Rain boots, snow boots, or water shoes may also provide interesting comparisons. Students might also explore times when people prefer to go barefoot in their activities (such as martial arts or yoga).
2. Placing bottles of water inside the shoes, consider if additional weight in the shoes (as would occur if someone were wearing them) affects how much force it takes to move them.
3. Try the experiment under different surface conditions, such as on a wet or gravel surface, or a tennis, basketball, or beach volleyball court. Use a shallow tray to make a mini ice rink to test the shoes on ice.
4. Test to see if pulling the shoes up a ramp *vs*. over a horizontal plane gives different results. Try different angles and different types of soles.

Name: ______________________________

Oh! My Aching Back!
How Ramps Make Lifting Easier

Is your backpack heavy? Have you ever tried to find ways to help you move it around more easily? Force is a measure of how hard you have to work to move something. In this activity, you will compare the force needed to lift your backpack straight off the ground to the force needed to pull the backpack up a ramp.

Figure 1

OBJECTIVES

- Lift your backpack to a chair in two different ways.
- Measure the force needed for each way of lifting.
- Make observations.
- Think of ways ramps are used to help people move things more easily.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Force and Acceleration Sensor
student backpack with 2 text books inside
student's chair
ramp
piece of rope about 1 meter long

KEY QUESTION

What difference do ramps make in moving heavy things to a higher level?

PRE-LAB PREDICTION

A ramp will make it _______________ (easier or harder) to lift heavy things.

PROCEDURE

1. Launch Graphical Analysis. Connect the Force Sensor to your Chromebook, computer, or mobile device.

2. Put the rope through the top loop of the backpack, and tie the two ends of the rope in a knot to make a large circle.

3. Put the Force Sensor hook into the knot and make sure it is secure.

4. Watch the meter on the screen as you lift the backpack a few times by pulling up on the Force Sensor. What do you notice as you pull? The numbers in the live reading tell how much force (push or pull) you are exerting. Notice how the numbers change as you lift the backpack and then slowly set it on the floor.

5. Stand next to a chair with the backpack. Click or tap Collect to start data collection, wait about two seconds, then slowly and smoothly lift the backpack straight up and set it on the chair.

6. Find the highest typical force value.
   a. Click or tap the graph to examine force and time values. **Note**: You can also adjust the Examine line by dragging the line.
   b. Drag the line along the graph to find the highest typical force value. Write the value in the Data Table.

Data Table		
Highest force without ramp (N)	Highest force with ramp (N)	Difference (N)

7. Record your observations about the direct lift on the Observations Sheet:

Observations Sheet
Direct Lift
Ramp Lift

8. Think about how the force will be different when you use a ramp to help lift the backpack. Then, make a prediction:

   Prediction

   Click or tap Graph Tools, [icon], and choose Add Prediction. Draw on the graph to show how the force will change when you use the ramp to lift the backpack. Click or tap Save.

9. Using a board, build a ramp on the same chair. Place the backpack on the lower end of the ramp. Start data collection, wait about 2 seconds, then slowly and smoothly pull the backpack up the ramp until it is on the chair.

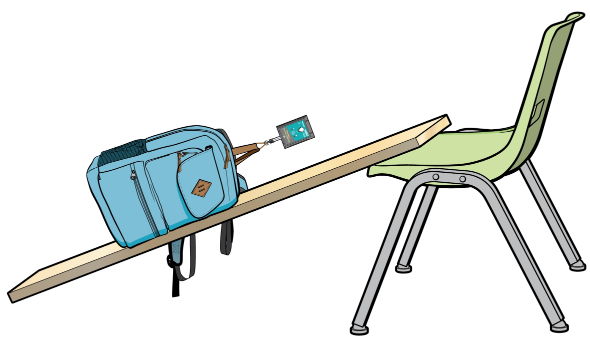

Figure 2

10. Find the highest typical force value.
    a. Click or tap the graph to examine force and time values. **Note**: You can also adjust the Examine line by dragging the line.
    b. Drag the line along the graph to find the highest typical force value. Write the value in the Data Table.

11. Record your observations about the ramp lift on the Observations Sheet. Describe the difference between the two lifts.

ANALYZE YOUR DATA

1. How did it feel to lift the backpack directly? Use your experience and the data to describe how it felt to lift it without the ramp.

   ____

   ____

2. How did it feel to pull the backpack up the ramp? Use your experience and the data from the graph to describe that part of the activity.

   ____

   ____

3. Are the highest force values for the two runs different? If so, which one is greater? Find the difference between the two values and record the difference in the Data Table.

   ____

   ____

4. Write about where you see ramps in your everyday life. Can you think of places where ramps are needed? Can you think of other situations in which you would need a ramp?

   ____

   ____

   ____

Oh! My Aching Back!
How Ramps Make Lifting Easier

BACKGROUND INFORMATION

In this activity, students use an object they are very familiar with to explore how a simple machine, in this case an inclined plane, or ramp, helps us move heavy objects with less force. By using a force sensor, students can measure how much force must be applied to raise the backpack onto a chair using a ramp versus simply lifting the backpack onto the chair.

TIME FRAME FOR ACTIVITY

This activity takes about 30 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion PS2.B: Types of Interactions PS3.C: Relationship Between Energy and Forces PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Social Studies – jobs, rights for persons with movement disabilities

Math – angles, distance, measurement

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting force data with Vernier equipment, we recommend that you start with Activity 27.

3. The board used to make the ramp should be smooth and about 2.5 cm (1 inch) thick, 20 cm (8 inches) wide, and 1.5–2 m (4–6 feet) long. Bracing the board against the wall and resting the higher end on the edge of a chair makes a sturdy ramp. If the board isn't smooth, it can actually take more force to slide the backpack up the ramp. Should your students see these results, simply talk to them about the effect of friction.

4. Using a backpack containing books for this activity is intended to help students relate to the idea of lifting something heavy. If the force reaches 50 N, remove one of the books to lighten the bag.

5. The rope or string used to hang the backpack from the hook of the force sensor must be strong enough to withstand the weight of the backpack, yet thin enough to fit into the hook.

6. Since the activity has the students identify the peak force, it is possible that the ramp trial will show the larger force, contrary to expectation. This will happen if the ramp has a rough surface or if the student jerks the pack up the ramp. Instruct students to pull the pack up the ramp gently.

7. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Highest force without ramp (N)	Highest force with ramp (N)	Difference (N)
28.5	15.6	12.8

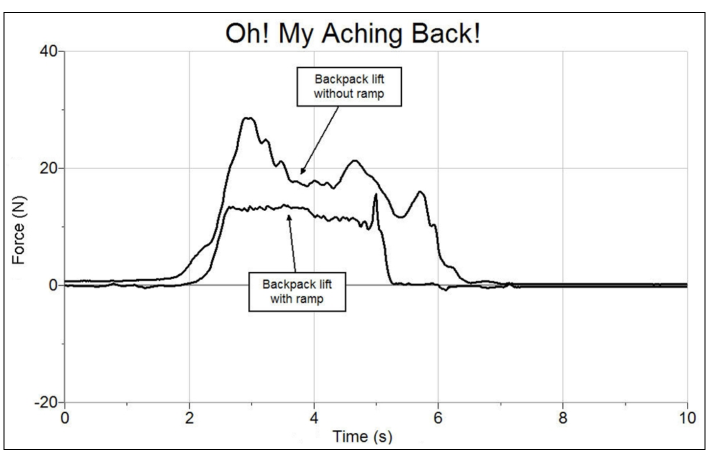

Figure 1

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. It felt like I had to pull especially hard at first to lift the bag. The graph shows that because the highest peak was at the beginning of the lift.
2. When I pulled the backpack up the ramp, it felt easy until I had to lift a little more to pull it off the end of the ramp. On the graph, there is a little peak at the end of the lift.
3. The highest values on the two lifts are quite different. The direct lift required a greater force to lift than the ramp lift.
4. Possible answers: People in wheelchairs need ramps to move from the street to the sidewalk or up to the door of a building. When people are loading trucks, they use ramps to pull boxes into or out of the truck. At the airport, conveyer belts that are tilted like ramps carry bags into and out of the cargo area of the planes. It might help students if the steps into the school were changed to ramps, because their backpacks are so heavy!!

ASSESSMENT

Have the students write a letter to an imaginary construction company explaining how ramps could help them move their equipment more easily from one floor to another.

EXTENSIONS

1. Write an essay about the history of the Americans with Disabilities Act (ADA).
2. Learn about how ramps may have been used to build the pyramids in Egypt.
3. Try lifting different masses in the backpack. Compare both the straight lift and the ramp lift. Is the ramp more helpful with heavier masses? Lighter masses? No difference?

Name: ________________________________

Learning to Use a Light Sensor

Is it sunny outside or cloudy? Are the lights on in your room? How bright is it where you are sitting? Is it brighter if you are close to a light bulb or next to the window? You can use a Light and Color Sensor to measure the brightness of light around you.

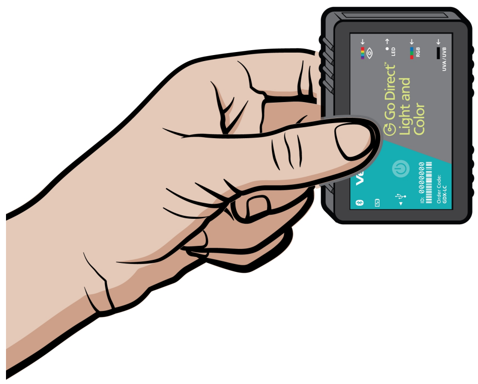

Figure 1

OBJECTIVES

- Learn to use the Light and Color Sensor.
- Measure different light levels in your room.
- Make letters on a graph using the Light Sensor.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Light and Color
light source

PROCEDURE

Part I Learn about the Light Sensor

1. Launch Graphical Analysis. Connect the Light Sensor to your Chromebook, computer, or mobile device.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 30 s. Click or tap done.

3. Now, collect data using the Light and Color Sensor. In the next step, you will record your observations about what happens, so pay close attention to what happens when you do different things.
   a. Look at the screen and click or tap Collect to start data collection.
   b. Point the tip of the Light and Color Sensor directly at the light source and hold it still for a few seconds. Pay attention to what happens to the light values.
   c. Slowly rotate the Light and Color Sensor away from the Light and Color Sensor and point it at the ground. Try to make the light level change very slowly.
   d. Finally, cover the tip of it with your hand.
   e. Click Stop to stop data collection, if it has not ended already.

4. On the Observations Sheet, write down what happened when you did different things to the Light and Color Sensor. **Tip**: Tap any data point on the graph to see the exact light levels.

Observations Sheet
1. When I pointed the sensor at the light source, the light level ____ ____
2. When I rotated the sensor toward the ground, ____ ____
3. When I covered the tip with my hand, the light level ____ ____
4. The lowest light level was ________________. The highest was ________________.

Part II Making letters with the Light and Color Sensor

5. In this part of the activity, you will complete writing the steps necessary to create the letter **W** on the graph. Think about how you would do this and fill in the blanks.
   a. Start with the Light and Color Sensor pointing ___________________ (toward or away from) the light source.
   b. Keep pointing in the same direction for a few seconds.
   c. Slowly, move the Light and Color Sensor ___________________ (toward or away from) the light source.
   d. Slowly, move the Light and Color Sensor ___________________ (toward or away from) the light source.
   e. Slowly, move the Light and Color Sensor ___________________ (toward or away from) the light source.
   f. Slowly, move the Light and Color Sensor ___________________ (toward or away from) the light source.
   g. Hold the probe still for a few seconds and then stop data collection.
6. Click or tap Collect to start data collection and follow the steps you wrote in Step 5.
7. If the graph looks like a **W**, congratulations! You can move on to the next step. If you want to try to **W** again, click or tap Collect to start data collection and repeat the steps you wrote.
8. After you've made the letter **W**, you will try to make the letter **M**. Write down the steps you would take to make a letter **M**. Use the words in Step 5 as a pattern.

   ____

   ____

   ____

   ____

   ____

   ____

   ____

9. Follow the steps you wrote in Step 8.
10. If the graph looks like the **M**, congratulations! If you want to try to make a **M** again, start data collection and do the steps you wrote.

Learning to Use a Light Sensor

BACKGROUND INFORMATION

The purpose of this activity is to allow students a chance to learn about the light sensor and how it works so they will be more comfortable with it later.

The Vernier Light Sensor (order code: LS-BTA) and the Go Direct Light and Color Sensor (GDX-LC) measure in units of lux by default. The TI Light Probe (TILT) measures the light level on a scale of 0 to 1; there are no units.

TIME FRAME FOR ACTIVITY

This activity takes about 30 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS4.A: Wave Properties	Patterns Cause and effect Scale, proportion, and quantity	Asking questions and defining problems Developing and using models Planning and carrying out investigations Constructing explanations and designing solutions

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. Bright classroom lights or table lamps work best for this activity. If it is a sunny day, pointing the light sensor at a window could also work. If the reading is at the top end of the sensor's ability to measure, however, the sensor is "pegged out" and you will need to find an alternate, dimmer light source.

3. In Part I of this activity, students move the sensor in different directions and then cover it with their hand to see what happens to the light level. If students run out of time, they can simply start data collection again. **Note**: In Graphical Analysis 4, the data sets are automatically saved every time you click or tap Collect. Oppositely, when data collection starts in Logger Lite and

LabQuest App, the current data is overwritten if it hasn't been stored. Have students write down their observations after each run rather than waiting till the end.

4. It may be a challenge for students to make the diagonal lines to make letters in Part II. Encourage them to try to move the sensor slowly in order to make the shape they want.

5. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

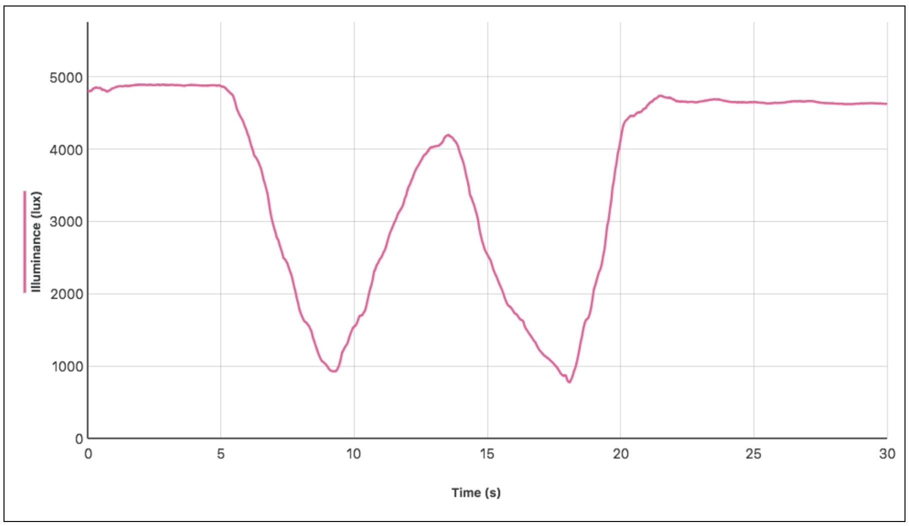

Figure 1 Example of the letter W during Part II of the student activity

ASSESSMENT

1. Ask students what other letters could be made.

2. Lead a discussion about what kinds of things you could do or study using a light sensor.

EXTENSIONS

1. Have the students draw shapes or other letters and try to match them.

2. You could draw particular letters or shapes and have the students try to match them.

Name: ______________________________

Graphical Analysis **32**

Distance From the Sun

Have you ever thought about what it would be like if you were on another planet looking back at the sun? In this activity, you will use a Light and Color Sensor to get an idea of how much light the planets would receive.

OBJECTIVES

- Make a simulation of the planets of our solar system to scale.
- Measure the amount of light from a light source at different distances.
- Draw conclusions about conditions on other planets.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Light and Color
meter stick
table or floor lamp with 60 watt bulb
tape and marking pen

PROCEDURE

Part I Marking the distances of the planets

1. Launch Graphical Analysis. Connect the Light and Color Sensor to your Chromebook, computer, or mobile device.

2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Enter **Length** as the Event Name and cm as the Units. Click or tap Done.

3. Now you will use the meter stick and tape to make a scale model that shows the relative distances of the planets from the sun by following the steps:
   a. Put the 0 cm end of the meter stick at the light.
   b. Measure 10 cm from the light and mark the place with a piece of tape labeled “Mercury”. In this model, 25 cm is one Astronomical Unit, or AU. One AU is the distance from the Sun to the Earth. All of the other planet distances are compared to this distance between Earth and the Sun.
   c. Measure 18 cm from the light. Mark this place with a piece of tape labeled “Venus.”
   d. Continue marking the distances from the sun to the planets, using the Table of Distances.

Table of Distances			
Planet	Distance (cm)	Distance (m)	Distance (AU)
Mercury	10	0.10	0.4
Venus	18	0.18	0.7
Earth	25	0.25	1.0
Mars	38	0.38	1.5
Jupiter	125	1.25	5.0

Part II How much light would each planet get from the sun?

4. In this part, you will measure how much light from the sun reaches each planet. To get started, read the key question and make a prediction.

Key Question

How does the light level change when you get farther away from the sun?

Prediction

a. Click or tap Graph Tools, , and choose Add Prediction.

b. Draw how you think the light level will change as you increase the distance between the Light and Color Sensor and the light bulb. Click or tap Save.

5. Turn the lamp on, and then darken the room as much as possible.

6. Collect data by following the steps:

a. Decide who will hold the Light and Color Sensor and who will enter the data.

b. Click or tap Collect to start data collection.

c. Put the sensor at the position where Mercury is located in the model so the sensor is pointing towards the lamp.

d. Look at the live readings in the meter on the screen, showing what light level is reaching the sensor. Move the tip around a bit to get the highest reading you can. **Careful**: Make sure you are still pointing towards the lamp!

e. Click or tap Keep to save this data point.

f. Enter in the value for the planet location in AU from the Table of Distances (for Mercury this value is 0.4). Click or tap Keep Point.

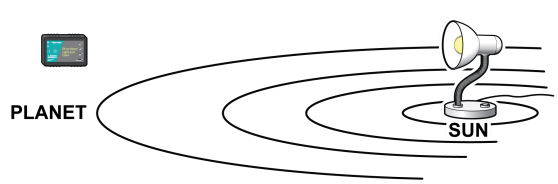

Figure 1

7. Repeat Step 6 for each of the planets in the model.
8. When you have collected all your data, click or tap Stop to stop data collection.
9. Write your observations on the Observations Sheet.

Observations Sheet
Write observations about how the light level changes as you move away from the sun.

ANALYZE YOUR DATA

1. Use the data from your graph to describe the light levels of the first five planets. Did your prediction match your data?

   ____

   ____

2. Write about two ways that we on Earth depend on the sun.

   ____

   ____

3. Imagine you have traveled to one of the outermost planets. Write a sentence that describes what the sunlight on the planet might be like and how the sun would look from that planet.

   ____

   ____

4. Imagine that we are going to try to begin a colony on another planet. Using what you know about how we on Earth depend on the Sun, and your data from this activity, describe what you would need to make the colony a place where humans could survive.

   ____

   ____

Distance From the Sun

BACKGROUND INFORMATION

In this activity, students use a light sensor to explore how light levels from the sun might differ on the planets in the solar system. When comparing the distances of the planets in our solar system, scientists use Astronomical Units (AU) as the unit of measurement. One AU is the average distance from the Earth to the Sun. To make the scale model of the solar system, students will use 0.25 meters (25 cm) to represent one AU. The distances given in this activity are rounded to make them easier to measure, but they are roughly to scale.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes. There is an extension that allows you to measure the light level at the outermost planets. If you have sufficient space to do this extension, it will take more time.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS4.A: Wave Properties PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer ESS1.A: The Universe and Its Stars	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Literature – fiction and nonfiction stories about space exploration

Math – measurement, scale models

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting light data with Vernier equipment, we recommend that you start with Activity 31.

3. Students need to understand that this is a simulation. The light used in this activity is not to scale! Emphasize that the levels they record in their data are simply to give us an idea of how much sunlight there would be on other planets.

4. If you wish to obtain the classic inverse square relationship of light level to distance, the light source should be a fully exposed light bulb. It should not have a shade or reflector. An inexpensive source would be an old table lamp from a thrift store.

5. Part I of this activity directs students to set up the model for data collection. To save time, you may want to do this beforehand. One solution for reducing the number of lamps necessary for this activity would be to put the lamp on the floor and have several (3, 4, or 5) stations around the lamp (like spokes of a wheel).

6. Test the light sensor reading of the light bulb at 10 cm and verify that the light level is not causing the sensor to "peg out" at its top reading. (If you are using a TI Light Probe, it “pegs out” at a value of 1.) If the light level for Mercury is reading is above the top reading for the sensor, you will need to use a bulb that is not as bright or increase the distance.

7. There is an extension at the end of this teacher section that involves collecting data in a model of the entire solar system. This extension takes a lot of space (see Table 1) and also requires that the room be quite dark in order to get viable results for the outermost planets. If you are unable to achieve these conditions, it could still be interesting for your students to see a model that includes the outer planets. It could be feasible to make a complete model in the playground or down a long hallway.

8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

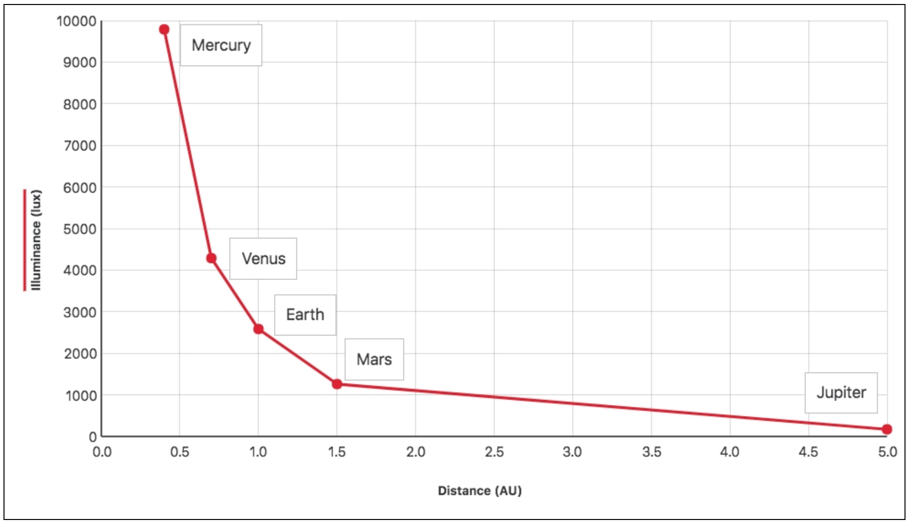

Figure 1 Simulated levels of light received by the first five planets in the solar system

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Mercury's light level is very high. The next three planets' light levels drop off very quickly. Jupiter has very low light levels.
2. We depend on the sun for our light and heat, including light to grow crops we use for food.
3. Possible answer: On one of the outermost planets, it would seem very dark all the time because there is very little light shining from the sun. If you looked toward the sun, it would look more like a regular star, only a little spot of light.
4. Possible answer: To live on a planet far from the sun would require an energy source to provide artificial light and heat.

ASSESSMENT

Give students three different values for light levels of planets, then have students use their data to identify the possible planets. Have them justify their guesses by interpreting the data from their graph and then explaining the characteristics of that planet based upon its light level compared to other planets.

EXTENSIONS

1. Use the light simulation data and research about atmospheric conditions on other planets to broaden understanding of characteristics that may be hospitable to life on other planets and their satellites. For example, atmospheric conditions on one of Saturn's moons might make it one of the most likely to support life even though it is so far from the sun.

2. Continue this project by researching scale models of the solar system that include the sizes of the planets to scale as well. One example in entitled “The Earth as a Peppercorn,” first developed by Guy Ottewell. It is available on several websites on the Internet. This particular scale model uses readily available items to simulate the relative sizes of the planets and the sun. For example, if the Earth is the size of a peppercorn, the sun is about the size of a soccer ball, and Jupiter would be a chestnut or pecan. The distances are also remarkable, and require a trip outside to get enough room.

3. Provide the students with a list of the average surface temperatures of each of the planets. Have them relate this data to the data they obtained from the experiment. Keep in mind that the atmospheric conditions on a planet have a profound effect on the surface temperatures.

4. If you have enough space and control over light levels, you could make a model of the outer planets as well as the inner planets (see Table 1 for the amount of space necessary). It is often difficult to see a difference in the graph of the outer planets because the light levels get very near zero. While this is thought-provoking, the measurements for Jupiter and Saturn are also low enough to be pretty remarkable.

   If you are using a desktop computer, you will need to put the sensor and computer on a rolling cart to collect the data. If you have a laptop or mobile device, you may not need the rolling cart. You may need to adjust the axes to view the data for the outer planets.

Table 1: Table of Distances

Planet	Distance (m)	Distance (AU)
Mercury	0.1	0.4
Venus	0.18	0.7
Earth	0.25	1.0
Mars	0.38	1.5
Jupiter	1.25	5.0
Saturn	2.5	10
Uranus	5.0	20
Neptune	7.5	30
Pluto	10	40

Name: ______________________________

Summer and Winter

Do you know why it is warmer in the summer than in the winter where you live? The Earth travels around the sun once every year and repeats the cycles of the seasons. You can use a Light and Color Sensor to see how differently sunlight shines on the Earth in each season.

OBJECTIVES

- Observe the differences in the light level during summer and winter.
- Draw conclusions about what effect light has on weather and temperature.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Light and Color
globe
foam ball with an axis (skewer) and a hole cut out for the sensor
lamp
meter stick

KEY QUESTION

What causes the seasons?

PRE-LAB HYPOTHESIS

When it is summer where I live, we receive ______________ (more or less) sunlight.

When it is winter where I live, we receive ______________ (more or less) sunlight.

PROCEDURE

1. Launch Graphical Analysis. Connect the Light and Color Sensor to your Chromebook, computer, or mobile device.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 20 s. Click or tap done.

3. Place the lamp on a table and turn it on.

4. Collect data for summer:
   a. Compare the foam ball to the globe. Hold the ball so that the top of the skewer is tilted toward the light at an angle of 23°. This matches the angle of the tilt of the Earth. The tip of the Light and Color Sensor should be pointing between the North Pole and the equator.
   b. Practice spinning the ball slowly around the skewer. Practice counting while you spin so that you make two complete rotations in about 20 seconds.
   c. Hold the ball over the meter stick so it is about 50 cm from the light.
   d. Turn the lights down in the room.
   e. Click or tap Collect to start data collection and slowly rotate the ball twice around the skewer in the 20-second data-collection period.

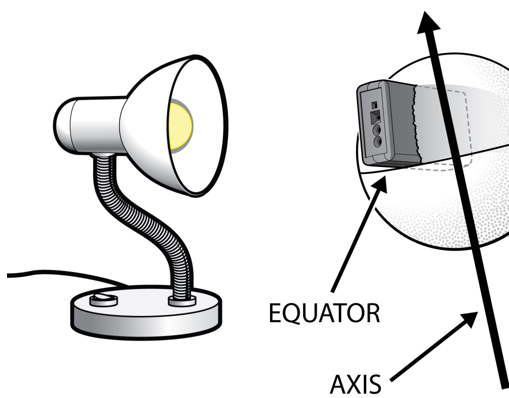

Figure 1 Summer set up

5. Determine the light levels for daytime and nighttime during summer.
   a. Click or tap the graph to examine the light and time values. **Note**: You can also adjust the Examine line by dragging the line.
   b. Drag the Examine line to the highest point of the graph.
   c. Record the value as the Summer Light Level – Day in your Data Table.
   d. Drag the Examine line to the lowest point of the graph.
   e. Record the value as the Summer Light Level – Night in your Data Table.

6. Now, do the following to collect data for winter:
   a. Hold the ball so that the top of the skewer is tilted away from the light at an angle of 23°.
   b. Hold the ball over the meter stick so it is about 50 cm from the light.
   c. Click or tap Collect to start data collection and slowly rotate the ball twice around the skewer in the 20-second data collection period. **Note**: The previous data set is automatically saved.

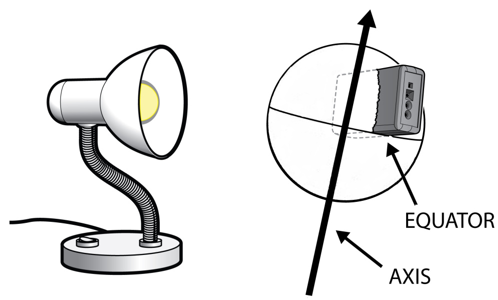

Figure 2 Winter set up

7. Determine the light levels for daytime and nighttime during winter.
   a. Click or tap the graph to examine the light and time values.
   b. Drag the Examine line to the highest point of the graph.
   c. Record the value as the Winter Light Level – Day in your Data Table.
   d. Drag the Examine line to the lowest point of the graph.
   e. Record the value as the Winter Light Level – Night in your Data Table.

8. Record your observations about the amount of light that reaches the surface during the summer and winter.

Observations Sheet

ANALYZE YOUR DATA

1. Use your graph to fill in the Data Table. Record the highest (day) and lowest (night) light levels for the summer and winter. Then, subtract the low values from the high values to find the differences.

Data Table			
	Summer Light Level	Winter Light Level	Difference in Light Levels
Day			
Night			

2. Look at your data for summer. Describe the amount of sunlight during the day. How do you think the amount of light affects the weather, specifically the temperature?

____

____

3. Describe the amount of light in winter shown on your graph. How is it different from the summer data? What do you think its effect would be on the weather?

____

____

4. Compare the difference in the brightness of the summer night and the winter night. Do you think the amount of light gives an accurate picture of the difference between winter and summer nights? How do you think light could affect how different summer and winter nights are where you live? (**Hint**: Think about how light or heat during the day could affect the night.)

____

____

Summer and Winter

BACKGROUND INFORMATION

Many people have misconceptions about why summer is warmer than winter and why the northern and southern hemispheres have opposite seasons. Many people believe the reason it is warmer in the summer in the Northern hemisphere is because the Earth is closer to the sun. This is not true. The Earth is actually a little closer to the sun in January than it is in July. It is the tilt of the Earth's rotational axis that leads to the seasons. In July, the Earth is tilted such that the northern hemisphere is receiving the sun's rays more directly and for a longer period of time each day. Using a light sensor and a foam ball to represent the Earth, students explore how the angle at which the light strikes their location on Earth affects the light level. From concepts explored in this activity, students can draw conclusions about how the sun and the tilt of the Earth create our seasons.

TIME FRAME FOR ACTIVITY

This activity takes about 1 hour.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
ESS1.A: The Universe and Its Stars	Patterns	Asking questions and defining problems
ESS1.B: Earth and the Solar System	Cause and effect	Developing and using models
PS4.A: Wave Properties	Scale, proportion, and quantity	Planning and carrying out investigations
PS3.A: Definitions of Energy	Systems and system models	Analyzing and interpreting data
PS3.B: Conservation of Energy and Energy Transfer	Energy and matter	Using mathematics and computational thinking
		Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Geography – tilt and spin of the Earth, effect of tilt on weather/seasons

Social Studies – cultural effects of different seasons, weather, celebrations

Math – angles, characteristics of a ball

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting light data with Vernier equipment, we recommend that you start with Activity 31.

3. Creating the ball for use in this activity takes a little time, but the results are worth it.
   - A polystyrene foam ball with a diameter of about 15 cm (6 in) works well; there is no need to go larger.
   - If using a Vernier Light Sensor (order code: LS-BTA) or TI Light Probe (TILT), make a hole by twisting a table knife back and forth into the ball so that it goes all the way through, passing as closely to the center of the ball as possible. If using Go Direct Light and Color (GDX-LC), you can dig out a rectangular-shaped hole into which you can position the sensor; we recommend covering the mini-USB port with tape so it doesn't get foam inside.
   - The body should fit snugly with the tip protruding slightly beyond the surface of the ball.
   - Once the hole is made, use a permanent marker to draw the equator on your ball.
   - To make the axis, push the dulled skewer into the ball perpendicular to the equator.
   - After the hole has been made and the axis inserted, push the sensor gently into the hole.

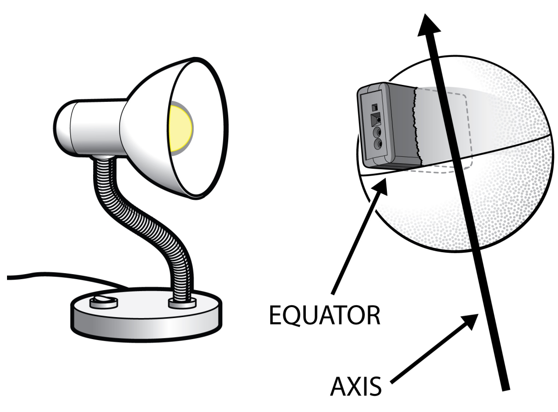

Figure 1

4. This activity assumes that you live in the northern hemisphere. If you live in the southern hemisphere, we apologize! You may wish to alter the words using the word-processing files in the Electronic Resources.

5. The student activity assumes that each student group has a directional light source (with a shade). If you are using lamps without shades and have a large enough desk for the students to gather around, you could place the lamp on a table in a position that allows students to access it from different sides.

6. Demonstrate how to hold the ball at an angle while spinning it. Students will need to practice. This spinning will mimic the Earth's rotation. To ensure that students hold the model Earth at the same height each time, it is helpful if the students hold the model with two hands. One hand, with elbow resting on the table, should hold the bottom of the skewer (the south pole). The other hand should hold the top of the skewer (the north pole).
7. It is helpful to compare the ball to the globe in order to tilt the ball so that the hole corresponds to a position about halfway between the equator and the north pole.
8. You will need to turn the lights down in your room before students actually collect data. However, it will be helpful for students to practice rotating the model Earth in the light. Students are directed to turn down the lights in the step where they collect data, but it will be important to make sure all the students are ready for data collection before this is done.
9. With younger students, rather than comparing changes in light level during the seasons, you may just want to compare the light levels of daytime and nighttime.
10. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.
11. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

	Northern hemisphere summer: light level (lux)	Northern hemisphere winter: light level (lux)	Difference
Day	4160.9	0	4160.9
Night	353.6	0	353.6

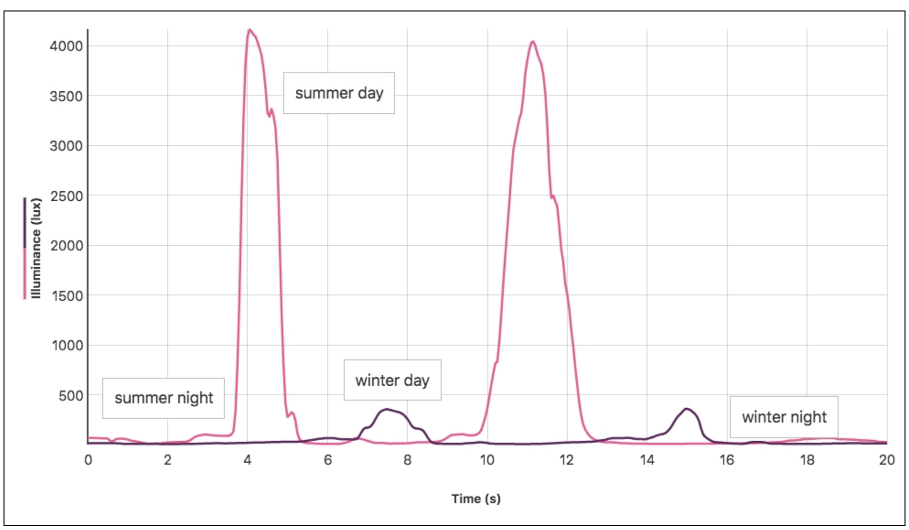

Figure 1 Change in light level during 20 seconds as a model Earth is rotated on its axis

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Students will fill in their data table. See Sample Results.
2. Possible Answer: The amount of light in the summer is really high. There is so much light from the sun that it makes the temperature hot.
3. Possible Answer: Winter light levels are low. The summer light in the daytime is much higher than the winter. That could be why it is colder here in the winter.
4. Summer and winter nights are not different in terms of how much light there is, because there is not much light at night in summer or winter. Having so much light during the day could make things really hot in the summer, and that is why summer nights can be so much warmer than winter nights.

ASSESSMENT

Have students write a paragraph, based on their data, explaining why it is warmer in the summer than in the winter.

EXTENSIONS

1. Position the sensor so the tip is in the southern hemisphere and compare seasons and light levels (southern hemisphere data for winter should look like northern hemisphere data for summer).
2. Have students write a story that describes what their year would be like if they lived in the other hemisphere. Ask them to include at least three specific days or holidays in their story and describe in detail how different they would be.

Name: ________________________________

Graphical Analysis **34**

Sunshine on My Shoulders

You have been asked by the ACME shirt company to design a shirt that will block the most light for the company's new "Sunblocker" line of shirts. They have given you several fabrics to test. Use Go Direct Light and Color to measure how much light is blocked by layers of the different materials.

OBJECTIVES

- Measure the light intensity as it passes through layers of different kinds of fabrics.
- Predict which fabric will block the most light.
- Draw conclusions about which fabric would be best for a shirt.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Light and Color
3 strips of different kinds of fabric
several books to hold Go Direct Light and Color
meter stick
tape
lamp with light bulb

KEY QUESTION

What makes a material good at keeping light from reaching your skin?

PRE-LAB HYPOTHESIS

The ________________ fabric will block the most amount of light and the ________________

fabric will block the least amount of light because ____________________________________

____

____

____

PROCEDURE

1. Do the following to get the Light and Color Sensor ready to collect data:
   a. Launch Graphical Analysis.
   b. Connect the Light and Color Sensor to your Chromebook, computer, or mobile device.
   c. Get a stack of books that will raise the Light and Color Sensor to the level of the light source.
   d. Place the edge of the probe just sticks out over the edge of the book.
   e. Tape down the probe so it doesn't move during data collection.
   f. Position the tip of the Light and Color Sensor 20 cm from the light source, with the sensor pointing directly at the bulb.

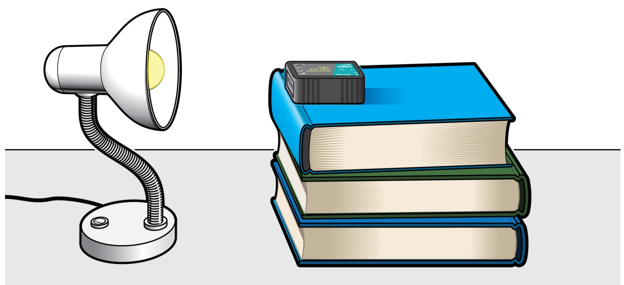

Figure 1

2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Enter Layers as the Event Name and leave the Units field blank. Click or tap Done.

3. Turn on the lamp.

4. Now, by doing the following, you will collect data for 3 layers of the same fabric. **Careful**: Make sure that the book and the Light and Color Sensor stay in the same place while you collect data!
   a. Click or tap Collect to start data collection.
   b. Tap Keep and enter **0** for the number of layers. Click or tap Keep Point.
   c. Place one layer of fabric "A" over the tip of the Light and Color Sensor. Be careful not to put your fingers between the probe and the light.
   d. Tap Keep, then enter **1** for the number of layers of fabric. Select OK.
   e. Fold the fabric so that two layers cover the tip of the Light and Color Sensor. Click or tap Keep and enter **2** for the layers of fabric. Click or tap Keep Point.
   f. Fold the fabric so that three layers cover the tip of the Light and Color Sensor. Click or tap Keep and enter **3** for the layers of fabric. Click or tap Keep Point.
   g. Click or tap Stop to stop data collection.

5. Repeat Step 4 for the other two fabrics. **Note**: The previous data set is automatically saved.

ANALYZE YOUR DATA

1. Compare the three sets of data on a single graph. What similarities and differences do you notice? **Note**: To display all sets of data, click or tap the y-axis label and select the data you want to display.

 ____

 ____

2. Which fabric did the best job of blocking out light? Use your data to explain your answer.

 ____

 ____

3. Did your hypothesis match your results? Use your data to explain your answer.

 ____

 ____

4. If you were given three other fabrics, describe the characteristics you might look for to help determine which one would be the best at blocking the light.

 ____

 ____

5. Write a formal letter to the ACME shirt company reporting your research and advising them on which material will make a shirt that will block the most light.

 ____

 ____

Sunshine on My Shoulders

BACKGROUND INFORMATION

The light sensor used in the activities in this book measures the intensity of the light striking the photocell at the end of the sensor. If the sensor is covered up with your thumb, the reading should be zero (or very close to zero). If the tip of the sensor is covered by something that does not completely block the light, such as the cloth used in this experiment, the sensor reading will be less than when it is uncovered. As the thickness of the fabric increases, the more the light is blocked. Students use this information to decide which fabric would make the best shirt for blocking sunlight.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS4.A: Wave Properties PS4.B: Electromagnetic Radiation PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Social Studies – look at the clothing, or fabrics, worn around the world

Math – algebraic thinking, looking for patterns in data

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting light data with Vernier equipment, we recommend that you start with Activity 31.

3. The strips of fabric should vary in the amount of spacing between the threads so that there is a difference in the amount of light blocked. It is probably best to have at least one gauzy fabric, one medium density, and one tightly woven fabric.

4. The fabric strips should be 4–5 cm wide and 20 to 25 cm long. This makes it easy for the students to fold the fabric over on itself to make layers.

5. Label the fabrics "A," "B," and "C" before giving them to students. To facilitate comparison between groups, label all samples of one type of fabric with the same letter.

6. It is very important that the students keep their light sensors aimed at the same light source without moving it around. In the student version of the activity, students are told to tape their sensor to stack of books. Position the tip of the sensor at the same height as the light bulb.

7. Before students start data collection, ask them to verify that the light level is not causing their sensor to "peg out" at its top reading. Students can increase the distance between the light and their sensor if necessary.

8. This is a good activity in which to discuss the concepts of variables and controls. The only thing that should vary is the type of fabric used. Each piece of fabric should be folded and held in the same way so that it is possible to observe patterns in the data. Because of this, you may want to model to your students how to hold the fabric over the tip of the probe. The fabric should be taut in order to keep folds from affecting the light level readings. However, the students do not want to pull them too tightly or the readings will be distorted.

9. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

10. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

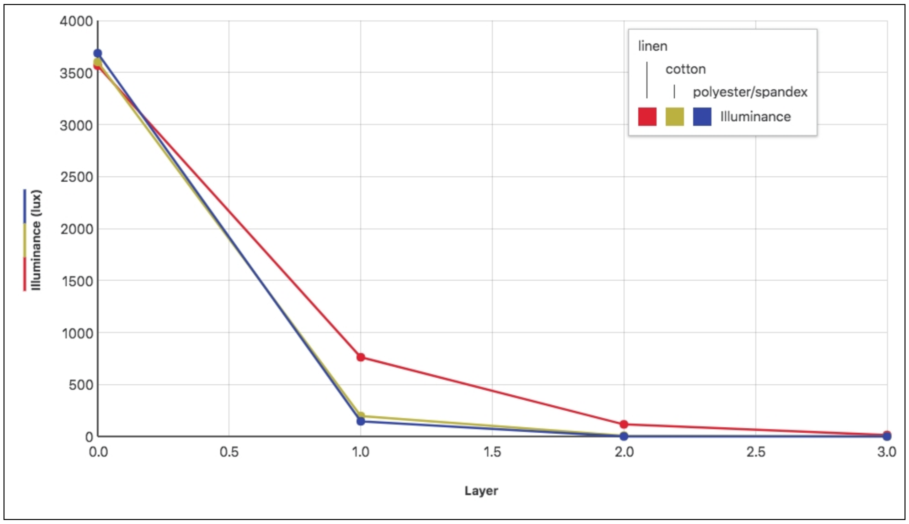

Figure 1 Change in the level of light getting through increasing layers of different types of fabric

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers will vary depending on fabric types. Students may notice may notice similar patterns of diminishing light levels with an increase in fabric layers.
2. For the sample data, the linen fabric did the best job of blocking light. Heavier, tighter woven fabrics will generally block out light waves better than lightweight fabrics.
3. Answers will vary depending on students' hypotheses and data.
4. Answers will vary. Students might answer that they could look at the looseness of the weave, the thickness of the fabric, the type of material (cotton, polyester, etc.).
5. Students should write a business letter explaining which fabric fulfills the company's objective. Answers will vary depending on the fabrics used.

ASSESSMENT

Tell students that the company has found that they can no longer get the fabric the students identified as best. Have the students write a paragraph that tells ACME how the next best fabric compares to the first choice using specific information from their data.

EXTENSIONS

1. Use a Vernier UVB or UVA Sensor to measure the amount of ultraviolet light that passes through each fabric and compare it to the amount of visible light measured with the light sensor.

2. Introduce the costs of each fabric and have students include this information in the decision-making process.
3. After looking at the different amounts of light that passes through fabrics, have students bring in their favorite "play clothes." Next, they could research recommendations for the use of sunscreen along with the clothing they wear.

Name: ______________________________

Graphical Analysis **35**

Reflectivity of Light

Light is reflected from surfaces based on their texture and color. The amount of light reflected is called the *reflectivity* of the surface. Reflectivity is important in determining our climate on Earth. Things like oceans, trees, ice, and deserts greatly affect how much of the sun's light energy is reflected and how much heats the Earth.

OBJECTIVES

- Use a Light Sensor to measure reflected light.
- Make conclusions based on your data.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Light and Color
piece of white paper
piece of black paper
2 more pieces of paper of different colors
pencil, pen, or ruler
tape
ruler

KEY QUESTION

How reflective are different colors of paper?

PRE-LAB PREDICTION

Predict the order of the reflectivity of your pieces of paper from lowest to highest:

Lowest Reflectivity   Highest Reflectivity

__________________ __________________ __________________ __________________

PROCEDURE

1. Get the Light Sensor ready to collect data:
   a. Launch Graphical Analysis. Connect the Light Sensor to your Chromebook, computer, or mobile device.
   b. Tape the Light Sensor to the ruler, pen, or pencil so that the tip of the Light Sensor is 5 cm beyond the eraser end of the sensor. When you hold the ruler up and down, the tip of the Light Sensor will be 5 cm from the surface of the table (see Figure 1).

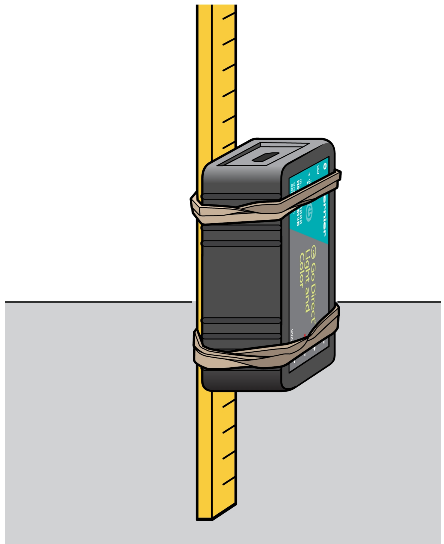

Figure 1

2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Choose Selected Event as the Event Mode.
   c. Check the box next to Average sensor reading over 10 seconds.
   d. Enter Color as the Event Name and leave the Units field blank. Click or tap Done.

3. Click or tap Collect to start data collection.

4. Follow these steps to collect data.
   a. Put the white paper on the table.
   b. Pick up the Light Sensor and put the tip of the ruler in the center of the piece of paper.
   c. Make sure there are no shadows under the tip of the sensor. If there are, move your hand around so that the shadow doesn't fall over the sensor (look for the highest reading you can get).
   d. When the light level readings are constant (stay the same), click or tap Keep. Hold the Light Sensor in place for 10 seconds while data are collected.

5. Repeat Step 4 for the piece of black paper and the other two pieces from your teacher.

6. Click or tap Stop to stop data collection.

7. Fill in the data table by doing the following:
   a. Click or tap the graph to examine the light level values. **Note**: You can also adjust the Examine line by dragging the line.
   b. Find the light level values for the four pieces of paper and write them in the Data Table. Be sure to write down the name of the color in the spaces provided.

Data Table				
Color	White	Black	______________	______________
Light level				

ANALYZE YOUR DATA

1. Which color has the highest reflectivity?

   ____

2. Which color has the lowest reflectivity?

   ____

3. What surfaces might give a planet a high reflectivity? Explain.

   ____

   ____

   ____

4. Do you think that the planet Earth has a high reflectivity? Why or why not?

   ____

   ____

   ____

Reflectivity of Light

BACKGROUND INFORMATION

In this activity, students measure the reflection values of different colors of paper, including black, white, and two other colors. The Analyze Your Data questions guide students to think about the reflectivity of the earth based on their data. Because of this, you may want to connect this activity to a lesson on snow cover or the seasons.

TIME FRAME FOR ACTIVITY

This activity takes about 30 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS4.A: Wave Properties PS4.B: Electromagnetic Radiation PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions

CURRICULAR CONNECTIONS

Social Studies – global climate change, typical style and color of clothing in various parts of the world

Math – compare reflectivity values, bar graphs

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting light data with Vernier equipment, we recommend that you start with Activity 31.

3. Equal-size pieces of construction paper should be used and can be saved for reuse.

4. If you have ring stands, it may be easier to hold the light sensor with a clamp. This way the student's hand will not create a shadow and affect the reflectivity readings.

5. If your classroom is not very bright, you may want to provide each student group with a lamp. Have them place the lamp so that it is pointing directly at the paper.

6. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Color	White	Black	Purple	Orange
Light level (lux)	1297.8	194.6	519.7	832.2

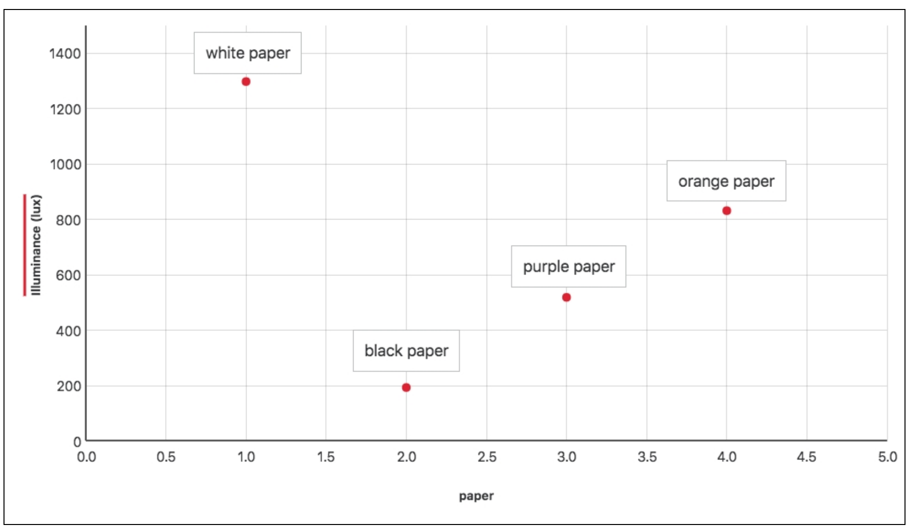

Figure 1 Example light levels collected using a lamp

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. White.

2. Answers will vary. The answer will most likely be black, but other colors could be close.

3. Snow, ice, sand, clouds, and water would be expected to give a planet high reflectivity.

4. Planet Earth has high reflectivity because much of it is covered by snow, ice, sand, clouds, and water. The results of this experiment suggest that dark-colored parts of the earth, such as forests and green cropland, would have lower reflectivity.

ASSESSMENT

Ask students to think about the temperature of the ground outside during the summertime. Do you have concrete sidewalk and roads or a playground made out of asphalt in your area? Usually concrete is cooler than asphalt because the concrete is usually a lighter color. Do your students notice this difference?

EXTENSIONS

1. Try doing the activity with other colors of paper or other materials such as aluminum or different colors of sand.

2. Try collecting temperature data with a Temperature Probe under the piece of paper to see if higher reflectivity equates to lower temperature under the piece of paper. **Caution**: You will need a high wattage light bulb to create significant temperature changes. Monitor your students closely or do this as a teacher demonstration.

Name: ______________________________

Graphical Analysis 36

Learning to Use a Magnetic Field Sensor

Have you ever played with magnets? One reason why they are fun and interesting is that they can have an effect on objects around them. This is because magnets are surrounded by a *magnetic field*. You may have seen the ends of magnets labeled as a *north pole* or *south pole*, just like the Earth. The Magnetic Field Sensor will help you find the north and south poles of a magnet.

OBJECTIVES

- Learn how to use a Magnetic Field Sensor.
- Measure the magnetic field of a bar magnet.
- Identify the north and south poles of a bar magnet.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct 3-Axis Magnetic Field Sensor
bar magnet
pen
tape

PROCEDURE

Part I Learn about the Magnetic Field Sensor

1. Set up the Magnetic Field Sensor for data collection.
   a. Launch Graphical Analysis.
   b. Connect the Magnetic Field Sensor to your Chromebook, computer, or mobile device.
   c. Find the dots near the end of the Magnetic Field Sensor. This is the part of the sensor that senses the magnetic field.
2. Set up the data-collection program.
   a. Click or tap Mode to open Data Collection Settings. Set End Collection to 30 seconds. Click or tap Done.
   b. Click or tap View, ⊞, and choose Meter.

3. Find out which end of the magnet is the north pole and which is the south pole:
   a. Place the Magnetic Field Sensor on the table and tape the sensor in place.
   b. Pick up the magnet and look at the meter on the screen while you move one end of the magnet towards the Magnetic Field Sensor.
      - A **positive number** means the **south pole** of the magnet is close to the sensor.
      - A **negative number** means the **north pole** of the magnet is close to the sensor. (If a number is negative, it will have a minus sign (–) in front of it.)
   c. Label the south pole with an "S" and the north pole with an "N."

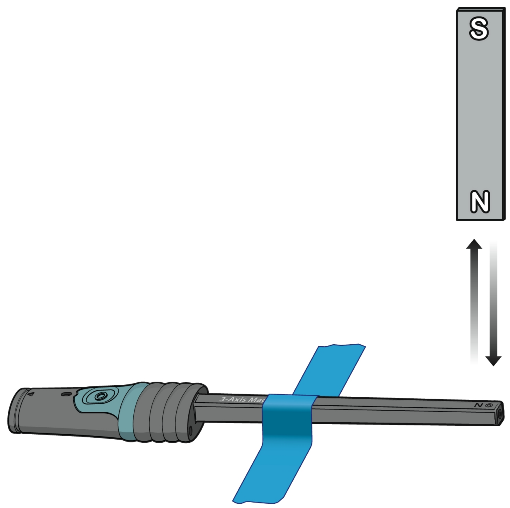

Figure 1

4. Do the following to collect data. Later, you will record your observations about what happens, so pay close attention to what happens.
   a. Click or tap View, ⊞, and choose 1 Graph.
   b. Pick up the magnet and locate the north pole. Hold the magnet vertically, with the north pole of the magnet pointing directly at the end of the sensor (see Figure 1).
   c. Click or tap Collect to start data collection.
   d. Slowly move the magnet towards and away from the tip of the sensor. What happens to the values of the strength of the magnetic field when you do this?
   e. Now, turn the magnet around so the south pole faces the sensor. Move the magnet towards and away from the sensor. What happens?
   f. Click or tap stop to Stop data collection if it is not already over.

5. On the Observations Sheet, write down what happened to the strength of the magnetic field as you moved the magnet around.

Observations Sheet
1. When I moved closer to the north pole of the magnet, the strength of the magnetic field ______________________________ ______________________________
2. When I moved away from the north pole, the magnetic field strength ______________________________ ______________________________
3. When I moved towards the south pole of the magnet, the strength of the magnetic field ______________________________ ______________________________
4. When I moved away from the south pole of the magnet, the strength of the magnetic field ______________________________ ______________________________
5. What surprised you about the strength of the magnetic field around a magnet during this activity? ______________________________ ______________________________

Part II Making letters with the Magnetic Field Sensor

6. In this part of the activity, you will complete writing the steps necessary to create the letter **M** on the graph. Think about how you would do this and fill in the blanks:
   a. Start with the ____________________ (north or south) pole of the magnet

      _______________________ (close to or far from) the white dot on the sensor.

   b. Move the magnet _______________________ (closer to or further from) the sensor.

   c. Move the magnet _______________________ (closer to or further from) the sensor.

   d. Move the magnet _______________________ (closer to or further from) the sensor.

   e. Move the magnet _______________________ (closer to or further from) the sensor.

   f. Hold the magnet still and click ■ Stop to end data collection.

7. Click or tap Collect to start data collection and follow the steps you wrote in Step 6.

8. If the graph looks like an **M**, congratulations! You can move on to the next step. If you want to try to make the **M** again, start data collection and follow the steps in Step 6.

9. After you've made the letter **M**, you will try to make the letter **W**. Write down the steps you would take to make a letter **W**. Use the words in Step 6 as a pattern.

   ____

   ____

   ____

   ____

   ____

   ____

   ____

10. Click or tap Collect to start data collection and then follow the steps you wrote in Step 9.

11. If the graph looks like a **W**, congratulations! If you want to try to make the **W** again, start data collection and repeat the steps you wrote.

Learning to Use a Magnetic Field Sensor

BACKGROUND INFORMATION

The Magnetic Field Sensor (order code: MG-BTA) and the Go Direct 3-Axis Magnetic Field Sensor (GDX-3MG) measure the magnetic fields that exist around magnetic objects such as permanent magnets. They are also sensitive enough to measure the magnetic field of the earth.

The sensor measures the strength of a magnetic field in millaTesla (mT). A milliTesla is a unit that measures the strength of a magnetic field, and is named for scientist Nicolai Tesla.

Magnetic Field Sensor (MG-BTA)

The magnetic field readings are based on the strength of the magnetic field that is perpendicular to the sensor at pivoting tip of the Magnetic Field Sensor (the white dot at the tip indicates the location of the sensor). The maximum positive reading will be reached when the white dot is facing up toward the ceiling and is directly over a magnetic north pole. The maximum negative reading will be reached when the white dot is facing up toward the ceiling and is directly over a magnetic south pole.

There is a switch on the box of the Magnetic Field Sensor that affects the amplification of its readings. When measuring strong magnetic fields, such as those in permanent magnets and electromagnets, the sensor should be on the 6.4 mT or low setting, depending on your sensor. The switch should be set to the 0.3 mT or high setting when measuring a weak magnetic field, such as that of the Earth.

Go Direct 3-Axis Magnetic Field Sensor (GDX-3MG)

When using the x-direction magnetic field channel (the default channel) of Go Direct 3-Axis Magnetic Field, magnetic fields that point in the same direction the wand is pointing are recorded as positive and fields that point in the opposite direction are recorded as negative. Thus, the magnetic field of the Earth will register as a positive field when the wand is pointed toward the magnetic pole in the Earth’s northern hemisphere, which is a South magnetic pole. When the wand is aligned with a permanent magnet and pointed toward the South pole of a magnet it will also record a positive field.

TIME FRAME FOR ACTIVITY

This activity takes about 30 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion PS2.B: Types of Interactions	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions Using mathematics and computational thinking

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. It is possible that the stickers your students place on their magnets will not match the manufacturer's original labels. This is because magnetic north and south poles are often confused. The needle on a compass that points north is called the north-seeking pole, or north pole for short. Therefore, the magnetic pole in the Earth's northern hemisphere is a south magnetic pole. Because this is so often misunderstood, many magnet manufacturers have chosen to label the poles of their magnets incorrectly.

3. If students are using the Magnetic Field Sensor (MG-BTA), it is important that they pay close attention to the orientation of the white dot at the tip of the sensor. This area is very sensitive to small changes in the strength of the magnetic field. Before collecting data, students should tape the Magnetic Field Sensor to the desk white dot facing directly up toward the ceiling. Keep an eye on the sensors to make sure they aren't moving around or students will get readings that are difficult to interpret.

4. Before you give the bar magnet to each group, put masking tape over each end. During the activity, the students will identify the north and south poles and then use this information to create letters.

5. If you do not have enough bar magnets, you can use other magnets. However, the student version of the activity assumes the students have a bar magnet and so you may need to provide a bit of clarification.

6. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

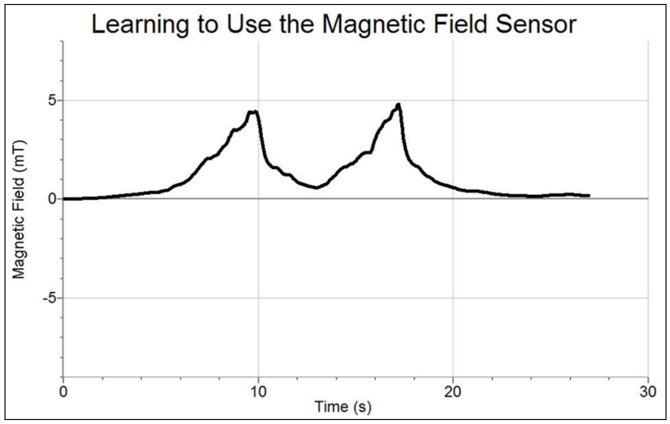

Figure 1 Sample data collected while trying to make an M shape

ASSESSMENT

Have students draw letters or shapes and try to match them.

EXTENSIONS

1. Research why the units used to measure magnetic field strength are named after Nicolai Tesla with your students.
2. If you have enough magnetic field sensors, try making the letter X or the letter A. You could also do this by collecting two sets of data.

Name: ______________________________

Graphical Analysis **37**

Exploring the Poles (Without Leaving Your Classroom!)

Magnets have north and south poles. Do you think that the poles of differently shaped magnets are in different places? In this activity, you will use the Magnetic Field Sensor to find the poles of various magnets, make diagrams of them, and then see how the poles of one magnet make it behave with the poles of another magnet.

OBJECTIVES

- Make observations about the poles of differently shaped magnets.
- Diagram the position of the poles of differently shaped magnets.
- Draw conclusions about the poles of magnets.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct 3-Axis Magnetic Field Sensor
several differently shaped magnets (bar, disk, horseshoe, cow magnet, etc.)
paper and markers or crayons
small stickers

PROCEDURE

Part I Make a map of your magnets

1. Set up the Magnetic Field Sensor for data collection:
   a. Launch Graphical Analysis.
   b. Connect the Magnetic Field Sensor to your Chromebook, computer, or mobile device.
   c. Find the dots near the end of the Magnetic Field Sensor. This is the part of the sensor that senses the magnetic field.
   d. Place the Magnetic Field Sensor on the table and tape the sensor in place.

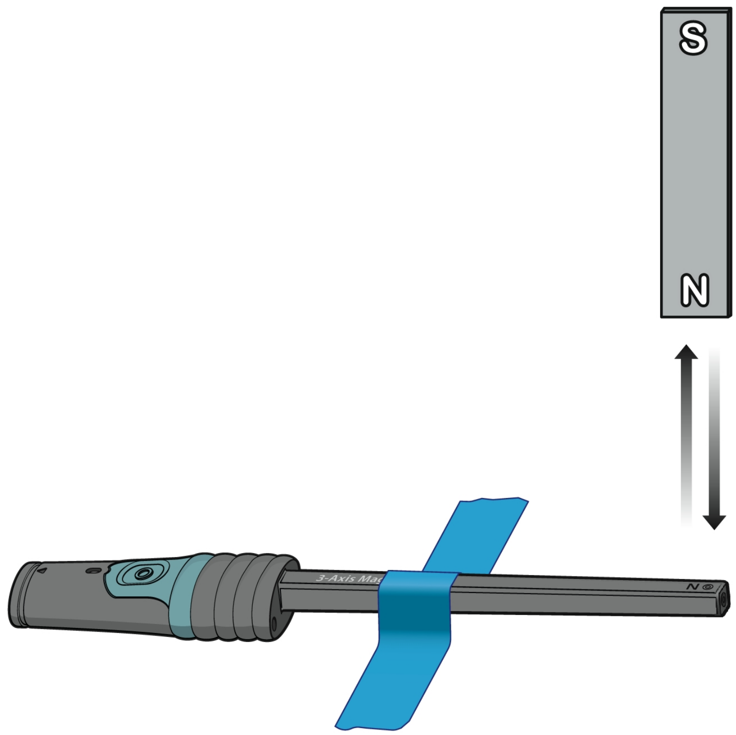

Figure 1

2. Find the north and south poles of the magnet:
   a. Choose one of the magnets and trace its outline on a piece of paper.
   b. Pick up the magnet and look at the meter on the screen while you move one end of the magnet towards the Magnetic Field Sensor.
      - A **positive number** means the **south pole** of the magnet is close to the sensor.
      - A **negative number** means the **north pole** of the magnet is close to the sensor. (If a number is negative, it will have a minus sign (–) in front of it.)
   c. Label the south pole of the magnet with an "S" and the north pole of the magnet with an "N."

3. Repeat Step 2 to find the north and south poles on your other magnets.

4. Record your observations on the Observations Sheet.

Observations Sheet

Part II Find how the poles interact

5. Find out how the poles of the different magnets interact with each other.
   a. Choose two of your magnets. Find the north pole of one magnet, and put it right next to the south pole of the other magnet. Write down what happens in the Data Table.
   b. Now put the north pole of the first magnet near the north pole of the other magnet. Write down what happens in the Data Table.

Data Table	
Position of the magnets	What happens
North near South	
North near North	
South near South	

6. Make a prediction about what will happen if you put the south pole of one magnet near the south pole of another magnet:

   Prediction

   I think the south poles of the two magnets will

   ____

   ____

7. Now test your prediction. Write down what happens in the Data Table.

ANALYZE YOUR DATA

1. Write down what you have learned about magnets.

2. Look at the different tracings you made. Choose two of your magnets and tell about their shapes and where their poles are.

____

____

____

3. Write a sentence that tells how the poles of magnets behave when the same (or like) poles are pushed together and when opposite (or different) poles are pushed together.

____

____

____

Exploring the Poles

BACKGROUND INFORMATION

In this activity, students use the magnetic field sensor to find and compare the poles of differently shaped magnets. Every magnet has a north and south pole, regardless of its shape. Flexible refrigerator magnets often have multiple stripes of alternating polarities. See the Teacher's Information of Activity 36, "Learning to Use a Magnetic Field Sensor," for more information about magnets and their poles.

After students find the poles of their magnets, they will use choose two of the magnets and explore how the poles interact.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion	Patterns	Asking questions and defining problems
PS2.B: Types of Interactions	Cause and effect	Developing and using models
	Scale, proportion, and quantity	Planning and carrying out investigations
	Energy and matter	Analyzing and interpreting data
		Constructing explanations and designing solutions
		Using mathematics and computational thinking

CURRICULAR CONNECTIONS

Geography/Social Studies – Earth's poles

Math – positive and negative numbers

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting magnetic field data with Vernier equipment, we recommend that you start with Activity 36.

3. In this activity, students will use magnets of different shapes, such as horseshoe, bar, disk, etc. Cow magnets (the magnets used in cow's stomachs to trap metal objects that they may accidentally eat) work well. They can be purchased from most scientific supply companies.

4. Demonstrate tracing the shape of each magnet on the recording sheet. You may want to have them trace the shape slightly larger to make labeling easier.

5. If students are using a Magnetic Field Sensor (MG-BTA), it is important that they pay attention to the location of the white dot at the tip of the sensor. This area is very sensitive to small changes in the strength of the magnetic field. Before collecting data, students should tape the Magnetic Field Sensor to the desk white dot facing directly up toward the ceiling. Keep an eye on the sensors throughout the activity because if the sensor is in any other orientation, the readings will not correspond to the students' instructions.

6. If you do not have stickers that will stick to the magnets, you or the students can wrap tape around the end of the magnets.

7. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Position of the magnets	What happens
North near South	They pull together.
North near North	They push apart.
South near South	They push apart.

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers will vary.

2. Answers will vary. Possible answer: I chose a horseshoe magnet that is shaped like a letter u. It has a north pole on one end and a south pole on the other. I had a circle magnet that was north, south, north, south, as I moved it over the sensor.

3. When like poles are pushed together, they push away from each other. When different poles are pushed together, they stick together.

ASSESSMENT

If possible, assess students individually with the magnets. Give the student two magnets, and have them tell you about how they behave when you put two ends together.

EXTENSIONS

1. Set up an area for exploration of magnets of different strengths, sizes and shapes.
2. Research how magnets are used in different objects. For example, magnets are used in speakers, tape recorders, and door latches. Have students record the shapes of magnets used in each case and determine why that shape may have been used in that particular situation.
3. Research the magnetic field of Earth and discuss as a class how it benefits life on the planet.

Name: ______________________________

Graphical Analysis **38**

Making Magnets

Have you ever wondered how a magnet is made? In this activity, you will turn an ordinary nail into a temporary magnet. You will then use the Magnetic Field Sensor to compare the temporary magnet that you made with the permanent magnet you used to make it. After you are done, you will use the temporary magnet to pick up a paper clip.

OBJECTIVES

- Make observations about the magnetic fields of objects.
- Use a permanent magnet to make a temporary magnet.
- Use a Magnetic Field Sensor to measure the magnetic field of magnets.
- Look for relationships between the permanent magnet and temporary magnet.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct 3-Axis Magnetic Field
nail
magnet
2 other metal objects
metal paper clip
tape

KEY QUESTION

Is the magnetic field of a temporary magnet similar to the magnetic field of a permanent magnet?

PRE-LAB HYPOTHESIS

The magnetic field of a temporary magnet and the magnetic field of a permanent

magnet will be ____

PROCEDURE

1. Set up the Magnetic Field Sensor for data collection:
   a. Launch Graphical Analysis.
   b. Connect the Magnetic Field Sensor to your Chromebook, computer, or mobile device.
   c. Place the Magnetic Field Sensor on the table and tape the sensor in this position.

2. Practice moving the magnet past the Magnetic Field Sensor.
   a. Place the magnet flat on the table as shown in Figure 1.
   b. Move the magnet slowly past the tip of the sensor along the length of the magnet to the count of 10 seconds. You should reach the middle of the magnet at about 5 seconds.

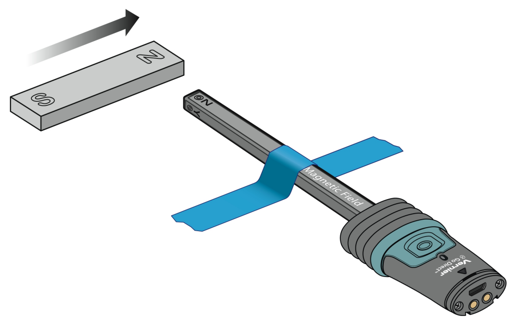

Figure 1

3. Collect data.
   a. Move the magnet far away from the sensor. Click or tap the Magnetic Field meter and choose Zero.
   b. Now, click or tap Collect to start data collection and slowly move the magnet past the Magnetic Field Sensor along the length of the magnet. Remember to move the magnet slowly and try to be at the middle of the magnet when you are at the 5-second mark on the graph.
   c. If you did not have enough time to take data for the entire magnet or if you moved the magnet too quickly, click or tap Stop to stop data collection. Click or tap Collect to start data collection and try again. **Note**: The previous data set is automatically saved.

4. Now, you will get to use your magnet.
   a. Get a metal paper clip from your teacher and put it on your desk.
   b. Pick up your magnet and use it to pick up the paper clip.

5. Measure the magnetic field of a nail before it has been magnetized:
   a. Get a nail from your teacher. During data collection you will move the nail past the tip of sensor from the flat end to the pointed end.
   b. Place the nail on the table so the flat end of the nail is close to the tip of the sensor.
   c. When you are ready, click or tap Collect to start data collection and slowly (to the count of 10 seconds, as above) move the nail from the flat end to the pointed end past the tip of Magnetic Field Sensor. Attempt to reach the middle of the nail at about 5 seconds.

6. Use the magnet to stroke the nail from the flat end to the pointed end 10 times (see Figure 2).

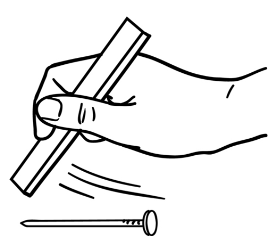

Figure 2

7. Make a prediction about the level of magnetism of the nail:

Prediction

Click or tap Graph Tools, , and choose Add Prediction. Draw on the graph on the screen to show what you think will happen when you move the magnetized nail past the tip of the sensor during data collection. Click or tap Save. (Note that the previous data is automatically saved.)

8. To measure the nail after you have stroked it with the magnet, place the nail on the table so the flat end of the nail is close to the tip of the sensor. Click or tap Collect to start data collection again, and slowly move the nail past the Magnetic Field Sensor to a count of 10 seconds. Start at the flat end and move to the pointed end, and attempt to reach the middle at 5 seconds.

9. Now, you will get to use your temporary magnet!
   a. Get a metal paper clip from your teacher and put it on your desk.
   b. Pick up your nail and use it to pick up the paper clip.

10. Record your observations about the magnetic field of the temporary magnet and your ability to use it to pick up the paper clip on the Observations Sheet.

Observations Sheet

ANALYZE YOUR DATA

1. Describe the line made by the data for each of the three runs.

Run	Description of line
Permanent magnet	
Nail *before* it was magnetized	
Nail *after* it was magnetized	

2. Do you see any relationship between the data from the permanent magnet and the nail after it was magnetized? Tell how they are alike and different.

3. What do you think would happen if you used the magnet to stroke the nail ten more times? Write your prediction.

   Now, test your prediction and tell what happened.

4. What are some reasons you might need to make a magnet? (For example, why might it be helpful if a screwdriver were magnetized?)

5. Choose two objects to magnetize. Describe the objects and what you will do to magnetize them. Try your experiment, and describe the results in the table:

Object	What I Tried	Results

Making Magnets

BACKGROUND INFORMATION

Making a temporary magnet is a fun way to explore some interesting properties of magnets. Certain materials, including iron, nickel and cobalt, can be magnetized. These materials are called ferromagnetic metals. Permanent magnets can be created by placing ferromagnetic materials in a strong magnetic field. Temporary magnets can be made by stroking a ferromagnetic material with a permanent magnet. For example, if you repeatedly stroke an iron nail with a permanent magnet, the nail will become weakly magnetized. Heating the nail, or striking it very hard, will cause it to be demagnetized.

Young people often generalize their experiences with magnets, concluding that all metals can become magnets, which is not true. If you take a permanent magnet and stroke it across an aluminum can, the can will not become magnetic. They will explore this at the end of the activity.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion	Patterns	Asking questions and defining problems
PS2.B: Types of Interactions	Cause and effect	Developing and using models
	Scale, proportion, and quantity	Planning and carrying out investigations
	Energy and matter	Analyzing and interpreting data
		Constructing explanations and designing solutions
		Using mathematics and computational thinking

CURRICULAR CONNECTIONS

Math – positive and negative numbers

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and

the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting magnetic field data with Vernier equipment, we recommend that you start with Activity 36.

3. The nails you give to the students should be at least 7.5 cm (3 inches) long. When you go to find nails for this experiment, try to find nails with as much iron in them as possible. This will make a stronger temporary magnet.

4. In this activity, students make a temporary magnet, but it will be quite weak. Encourage the students to look at the change in the nail, and not to be discouraged if the nail does not have as strong a magnetic field as the permanent magnet.

5. Collect other metal objects such as nails made of other metals such as food cans, drink cans, and flatware. In the Analyze Your Data section, students will pick two objects and try to magnetize them.

6. It is possible to use a permanent magnet in a shape other than a bar magnet, but having a magnet that is a similar shape to the object you are making into a temporary magnet makes comparison much easier.

7. When students compare the permanent magnet to the magnetized nail, the two graphs may be opposite. Just turn the magnet around and collect another run of data.

8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

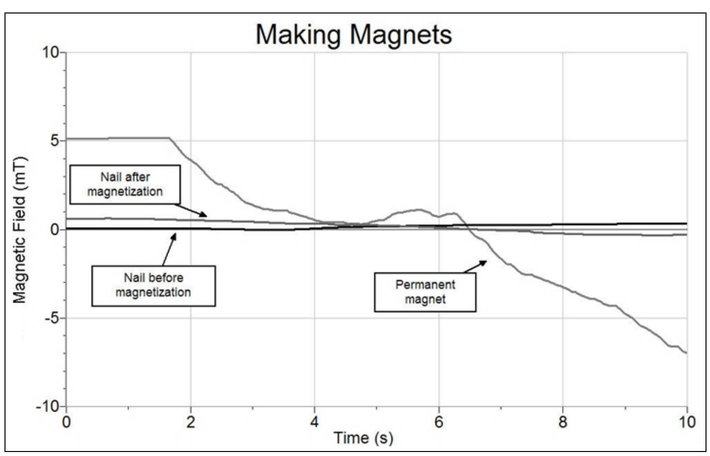

Figure 1 Magnetic field data for a permanent magnet, a nail, and the same nail after magnetization.

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. The permanent magnet's line went from above the zero line to below the zero line. It started close to 5 mT and went down to –7 mT.
   a. Before I magnetized the nail, it was a straight line.
   b. After I magnetized the nail, its line went from almost 1 mT above the zero line to about 0.5 mT below the zero line.

2. The magnetic field of the nail has changed to be more like the magnet, with definite poles.

3. Answers will vary. Possible answer: I think the nail will be a stronger magnet. After I tested my prediction the nail was not any stronger.

4. Answers will vary. Magnets can be used to help pick things up. A screwdriver is a shape that can be reached into small spaces to pick up small metal objects like nails or screws.

5. Answers will vary. Possible answers:

Object	What I Tried	Results
Spoon	I touched it with a magnet at each end.	It didn't become a magnet.
Horseshoe	I moved the magnet along the outside of the horseshoe.	It became a magnet.

ASSESSMENT

Give students a graph of the magnetic field of a magnet, a nail, and a magnetized nail that does not have any labels. Have them identify each data line and tell how they know which is which.

EXTENSIONS

1. Encourage students to continue to collect objects or materials that they think might become magnetized if they were stroked by a permanent magnet. You might want to collect the items and place them in a center for testing periodically.

2. Have students look for ways that magnets are used in our daily life. The refrigerator magnet is the first that comes to mind, but students might be surprised to find that there are magnets in speakers and recording devices. They may be interested in researching why the magnets are there.

Name: ______________________________

Electromagnets

Have you ever made a magnet with a nail, some wire, and a battery? This kind of magnet is called an electromagnet because it uses an electric current traveling through a wire to make the magnet. To make the electromagnet in this activity, a wire will be wrapped around the nail and then the wire will be connected to the ends of the battery.

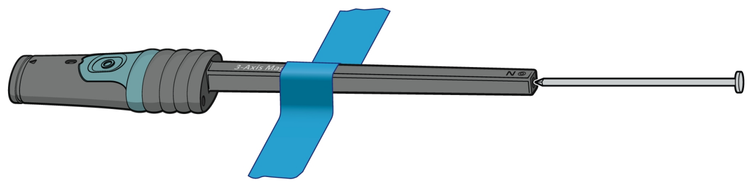

Figure 1

OBJECTIVES

- Make an electromagnet using a steel nail, a wire, and a D battery.
- Measure the strength of the magnet as you wrap more wire around the nail.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct 3-Axis Magnetic Field Sensor
nail
piece of insulated wire 1 meter long
D battery
masking tape

KEY QUESTION

What will happen to the magnetic field of a nail if you wind more and more wire connected to a battery around it?

PRE-LAB HYPOTHESIS

When you wind a wire connected to a battery around a nail, the magnetic field will

____

PROCEDURE

1. Do the following to get the Magnetic Field Sensor ready for data collection:
   a. Launch Graphical Analysis.
   b. Connect the Magnetic Field Sensor to your Chromebook, computer, or mobile device.
   c. Find the dots near the end of the Magnetic Field Sensor. This is the part of the sensor that senses the magnetic field.
   d. Tape the sensor to the tabletop with the tip pointing to the side.

2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Enter **Winds** as the Event Name and leave the Units field blank. Click or tap Done.

3. Follow these steps to collect data:
   a. Hold the pointed tip of the nail at the end of the Magnetic Field Sensor with the pointed end of the nail touching the end (see Figure 1).
   b. Click or tap the Magnetic Field meter and choose Zero. After zeroing is done, the live values on the screen should be very close to zero.
   c. Click or tap Collect to start data collection, then click or tap Keep.
   d. Enter **0**, for 0 winds of wire, then click or tap Keep Point.

4. Leaving about 10 cm of wire free to connect to the battery, wrap the wire around the nail 5 times. See Figures 2 and 3 for how to wrap the wire.

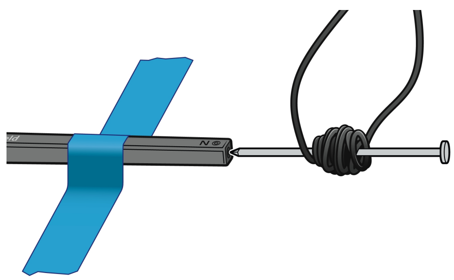

Figure 2 Correct

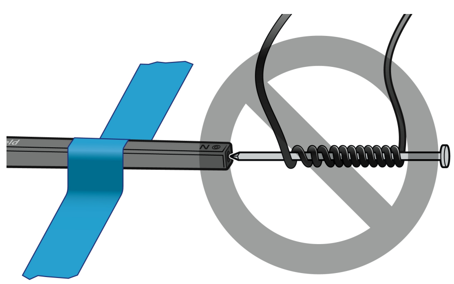

Figure 3 Incorrect

5. Now, do the following to make and test your circuit:
   a. Hold the ends of the wires so they touch the ends of the battery, making a circuit.
   b. Hold the tip of the nail at the end of the sensor.
      - If the values are positive (such as "0.02 m"), the wires are touching correctly. Tape the correct end of the wire to the negative end of the battery (see Figure 4).
      - If the values are negative (such as "–0.02 mT"), switch the wires around. Then tape the correct end of the wire to the negative end of the battery.
   c. After you tape the wire to the battery, testing the circuit by touching the free end of the wire to the positive end of the battery and checking that the values are positive.

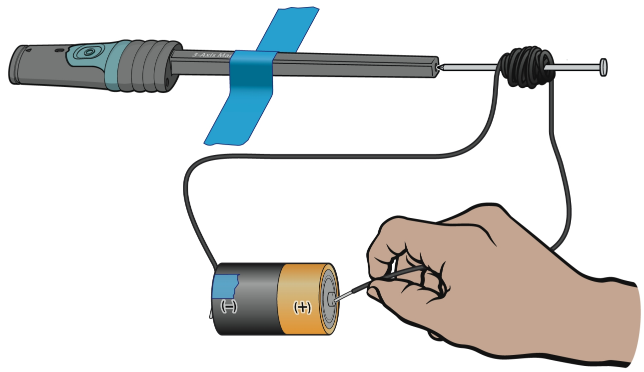

Figure 4

6. Collect data with 5 winds of wire around the nail.
   a. Hold the nail tip at the end of the sensor. Each time you take a measurement, it is important to hold the nail with the point touching the end of the sensor.
   b. Touch the positive end of the wire to the negative end of the battery.
   c. Look at the magnetic field strength values on the screen. When they are constant (stay the same for a few seconds), click or tap Keep. **Tip**: If the values are at 0, or very close to 0, check the connection between the wire and the battery. It is likely that they are not touching completely.
   d. After you have clicked or tapped Keep, disconnect the wire from the positive end of the battery. If you leave it attached, the wire can get very hot and the battery will drain.
   e. Enter **5** for the number of winds of wire. Click or tap Keep Point.

7. Wrap the wire around the nail 5 more times, for a total of 10 winds. Place the nail tip at the end of the sensor, touch the positive end of the wire to the positive end of the battery, and click or tap Keep when the values are constant (stay the same for a few seconds). Disconnect the positive end of the wire. Enter **10** for the number of winds of wire and click or tap Keep Point.

8. Repeat Step 7 for 15 turns, 20 turns, and 25 turns. When you finish 25 turns, stop data collection.

9. When you are done collecting data, click or tap the graph to examine your data. Record the magnetic field strength values in the Data Table. **Note**: You can also adjust the Examine line by dragging the line.

DATA TABLE

Number of winds	Magnetic field strength (mT)
0	
5	
10	
15	
20	
25	

ANALYZE YOUR DATA

1. Was you hypothesis correct? Use your data to explain.

____

____

2. Why is it important to keep the nail in the same position each time when making measurements of the magnet's strength?

____

____

Electromagnets

BACKGROUND INFORMATION

Magnets can be made by wrapping an iron nail with an insulated wire and letting a current flow through the wire. This kind of magnet is referred to as an electromagnet. The strength of the magnetic field in an *electromagnet* depends on two factors: the amount of current flowing through the wire and the number of times the wire is wrapped around the nail. Under ideal conditions, the magnetic field strength is directly proportional to the number of turns around the nail. If you double the number of wire turns around the nail, you double the magnetic field strength. If you double the amount of current flowing through the wire, the magnetic field will also double. In this lab, the students are asked to change the number of turns around the nail and measure the field strength.

TIME FRAME FOR ACTIVITY

This activity takes about 60 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS2.A: Forces and Motion	Patterns	Asking questions and defining problems
PS2.B: Types of Interactions	Cause and effect	Developing and using models
PS3.A: Definitions of Energy	Scale, proportion, and quantity	Planning and carrying out investigations
PS3.B: Conservation of Energy and Energy Trasfer	Energy and matter	Analyzing and interpreting data
PS3.D: Energy in Chemical Processes and Everyday Life		Constructing explanations and designing solutions
		Using mathematics and computational thinking

CURRICULAR CONNECTIONS

History – electromagnets in items such as the telegraph

Math – proportions, ratios

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting magnetic field data with Vernier equipment, we recommend that you start with Activity 36.

3. The nail for this activity should be at least 7.5 cm (3 inches) long and should contain as much iron as possible. Uncoated steel nails, such as a 16d or 20d (read "20 penny") nails work well.

4. Make sure to cut the wire and strip the ends before the activity. The wire should be about 22 gauge insulated wire. You should be able to get it at a local hardware store. The color of the wire is not important. Each end of the wire needs to be stripped so that it can make electrical contact with the battery.

5. During data collection, check to make sure the wire remains coiled around the nail. Sometimes the wire springs loose after coiling.

6. The ends of the wire can become quite warm if they both stay connected to the battery for several seconds. In the student version of the activity, students are directed to tape the negative end of the wire to the negative end of the battery and then to connect the positive ends only when they are collecting data. Remind them to disconnect the positive ends when they are not collecting data.

7. If using a Magnetic Field Sensor (order code: MG-BTA), it is very important that the students tape the sensor to the table top with the white dot pointing along the surface. It is also very important that the students hold the nail horizontally with the sharp end touching the white dot at the end of the probe. This helps ensure that the only variable in the experiment is the number of turns of wire. It also provides a good example of controls and variables in scientific experiments.

8. It is okay if the students overlap the wire as they wrap it around the nail.

9. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

10. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Number of winds	Magnetic field strength (mT)
0	0.005
5	0.098
10	0.261
15	0.546
20	0.712
25	1.144

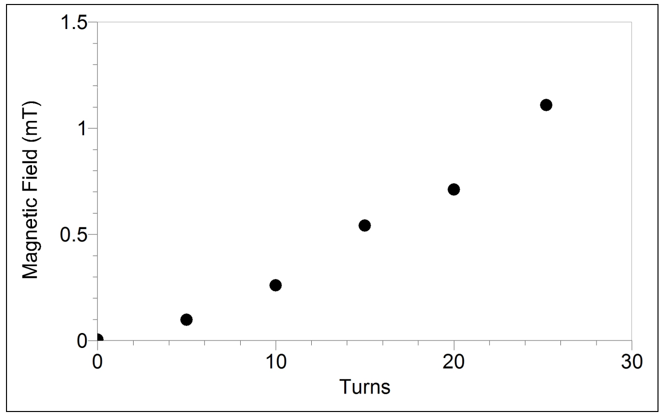

Figure 1 Increase in magnetic field as additional winds of wire are added to a nail

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers will vary depending on hypothesis and data. The data should show that as more wire was wrapped around the nail, the magnetic field got stronger.

2. It is important to keep the nail's position constant to avoid making it another variable in the experiment.

ASSESSMENT

Have students construct an electromagnet with the purpose of picking up a certain number of small metal (uncoated) paperclips, such as five or ten clips. This could be put in the context of the uses of electromagnets in industry.

EXTENSIONS

1. Examine the uses of electromagnets in history, for example, the importance of the telegraph.

2. Try using different materials in place of the nail, such as a wooden dowel or pencil, and iron rod, or an aluminum rod. They can also remove the nail and test how the coils themselves behave as an electromagnet.

3. Have students try using more than one battery to construct their electromagnets. They could hook batteries in series (end-to-end) or in parallel (side-by-side). For series, the batteries can be taped together so that the "+" contacts the "–" of the other battery. For parallel, cut two pieces of aluminum foil that are approximately 5 cm by 10 cm. Fold the aluminum foil on itself so that they form strips that are 10 cm long and about 1 cm wide. Place two batteries side-by-side and tape the aluminum foil strips across the top and bottom of the battery. The wires for the electromagnets are then attached to the aluminum strips.

Name: ______________________________

Learning to Use a Voltage Probe

A Voltage Probe can measure the voltage of a battery. This is one way of checking whether a battery is good. In this activity, you will learn about the Voltage Probe by working with a battery.

OBJECTIVES

- Learn to use the Voltage Probe.
- Measure the voltage of a battery.
- Match patterns on a graph using the Voltage Probe

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Voltage Probe
battery
ruler with center groove

PROCEDURE

Part I Learn about the Voltage Probe

1. Launch Graphical Analysis. Connect the Voltage Probe to your Chromebook, computer, or mobile device.

2. Click or tap Mode to open Data Collection Settings. Set End Collection to 20 seconds. Click or tap Done.

3. Look at the materials you will be using in this activity.
   a. Pick up the battery. Do you know which end is the positive end and which is the negative? Make sure everyone in your group agrees upon which is positive and which is negative and put the battery in the groove in the ruler.
   b. Now, look at the clips of the Voltage Probe. You will be touching the metal tips of these clips to the ends of the batteries later on.

4. Zero the Voltage Probe.
   a. Clip together the ends of the red and black wires coming from the Voltage Probe.
   b. Click or tap the Potential meter and choose Zero to zero the Voltage Probe. The voltage readings should be at or near 0 V.
   c. Disconnect the clips.

5. Collect data using the Voltage Probe. You will record your observations after you collect data, so pay careful attention.
   a. Look at the screen and click or tap Collect to start data collection.
   b. Touch the two Voltage Probe clips together. Notice if anything happens to the voltage.
   c. Now, touch the black clip to the positive end of the battery (the side with the bump) and the red clip to the other end, and hold them for a few seconds. Are the voltage values negative?
   d. Finally, switch the clips around so the red clip touches the positive end of the battery and the black clip touches the negative end. Are the voltage values negative now?
   e. Click or tap Stop to stop data collection if it has not stopped already.

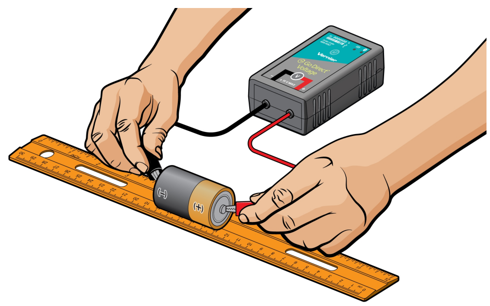

Figure 1

6. Use your observations about what happened during data collection to finish the sentences on the Observation Sheet:

Observations Sheet
1. When I touched the two clips together, the voltage ____ ____
2. When I touched the black clip to the positive end of the battery and the red clip to the negative end of the battery, the voltage ____ ____
3. When I touched the red clip to the positive end of the battery and the back clip to the negative end of the battery, the voltage ____ ____

Part II Match patterns using the Voltage Probe

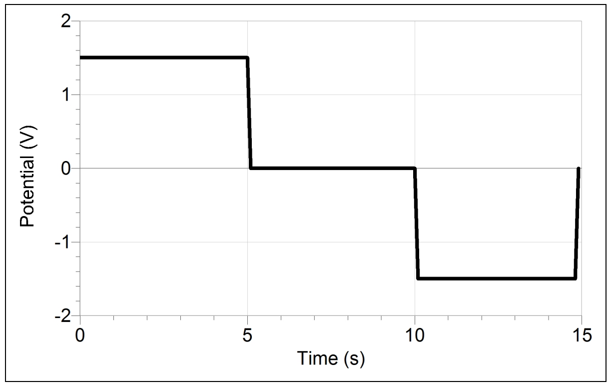

Figure 2

7. In this part of the activity, you will complete writing the steps necessary to match the pattern on the graph in Figure 2. Think about how you would do this and fill in the blanks. **Note**: Your voltage readings might not match the pattern, exactly. It is most important to make the pattern similar to that on the graph, rather than reach the same voltages.
   a. Start with the red clip touching the _________________ (positive or negative) end and the black clip touching the _________________ (positive or negative) end of the battery.
   b. Keep the clips in this position for _________________ seconds.
   c. Quickly, touch the clips together and hold them there for ________________ seconds.
   d. Quickly, touch the red clip to the _________________ (positive or negative) end and the black clip to the other end and hold them there for _________________ seconds.
   e. Quickly, touch the clips together and hold them there for _________________ seconds until data collection ends.
8. Click or tap Collect to start data collection and follow the steps you wrote in Step 7.
9. If your data matches the original pattern, congratulations! If you want to try again, repeat the steps you wrote in Step 7.

Learning to Use a Voltage Probe

BACKGROUND INFORMATION

The Differential Voltage Probe (order code: DVP-BTA) and the Go Direct Voltage Probe (order code: GDX-VP) are both designed for doing activities that explore electricity, including learning about how batteries provide power to objects.

Vernier voltage probes measure electrical potential in units of volts (V). The range of the Differential Voltage Probe is ±6 V and of the Go Direct Voltage Probe is ±15 V, both of which work very well for the activities in this book.

TIME FRAME FOR ACTIVITY

This activity takes about 30 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.D: Energy in Chemical Processes and Everyday Life	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. Prior to doing the activity with students, it would be a good idea to read through the student version to look for terms that your students may not be familiar with. You could introduce these words to students as an introduction to the activity.

3. The type of battery (e.g., AA, D, etc.) is not important; you can use a mix if that is what you have available. However, for this activity, all the batteries should be close to full power.

4. In Part II, students match a pattern. If they are using Logger Lite, they will match a pattern that is stored in the experiment file. If they are using Graphical Analysis 4 or LabQuest App, they will match a pattern that they draw on the screen. Regardless of the data-collection program, it is possible that the voltages of students' batteries will not match exactly with the pattern on the screen. Tell your students that the purpose is not to exactly match the data, but rather to try to match the pattern. Their data should be positive when the line on the screen is positive, negative when the line is negative, and zero when the line is zero.

5. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

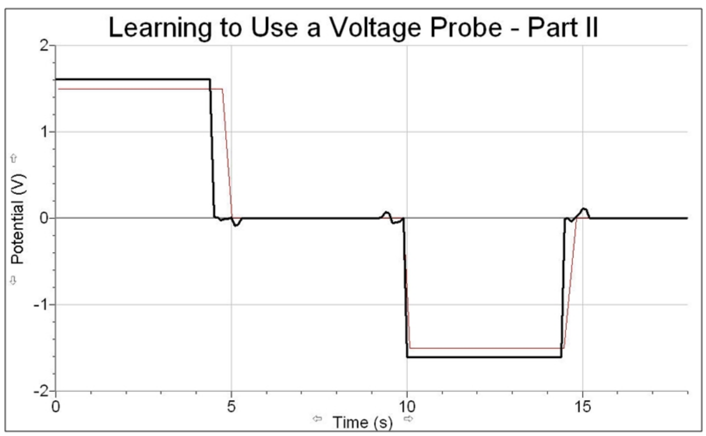

Figure 1 Sample data collected while trying to match a pattern with a Voltage Probe and battery

ASSESSMENT

1. Ask students if they think a voltage probe would be a good tool to have at home. Are there other applications for a device that measures voltage?

2. Ask students what other shapes could be made on the graph and how they would do it.

EXTENSIONS

1. Have students draw shapes and try to match them or have them draw patterns for others to match.

2. See who can best match the patterns in the fewest tries.

Name: ________________________________

Graphical Analysis **41**

Are All Batteries the Same?

Why are there so many kinds and sizes of batteries? Does the size of the battery determine the voltage of the battery? In this activity, you will set up an electrical circuit and investigate some of the properties of batteries.

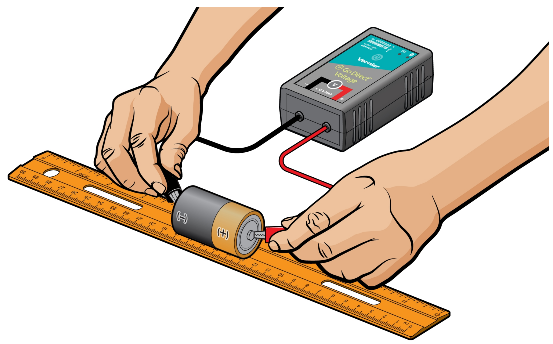

Figure 1

OBJECTIVES

- Make observations about the size of different batteries.
- Use a probe to measure the voltage of various batteries.
- Make simple circuits with batteries and bulbs.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Voltage
Go Direct Light and Color
1 AAA battery
2 AA batteries
1 C battery
2 D batteries
small light bulb in socket
ruler with groove for holding batteries
2 jumper wires with alligator clips on each end
masking tape

PROCEDURE

Part I Looking at batteries and measuring

1. Your teacher is going to hold up different batteries, starting with a AAA battery. The voltage of the AAA battery is 1.5 V.

   Prediction

   Predict the voltages of the other batteries and record your predictions in the Predicted voltage column of the Part I Data Table. The value for the AAA battery has been filled in for you.

Part I Data Table			
Battery type (V)	Predicted voltage (V)	Measured voltage (V)	Voltage printed on battery (V)
AAA battery	1.5		
AA battery			
C battery			
D battery			

2. Launch Graphical Analysis. Connect the Voltage Probe to your Chromebook, computer, or mobile device.
3. Zero the Voltage Probe:
   a. Clip together the ends of the red and black wires coming from the Voltage Probe.
   b. Click or tap the Potential meter and choose Zero. The voltage reading should be at or near 0 V.
4. Measure the voltage of each battery:
   a. Place the red clip of the Voltage Probe on the positive (+) end of the battery and the black clip on the negative (–) end of the battery.
   b. Look at the voltage displayed on the screen.
   c. Record the value in the Part I Data Table in the Measured voltage column.
5. Repeat Step 4 for each of the batteries. Do not forget to record your values in the Part I Data Table.
6. Now, read the voltage listed on the side of each battery (you may need a magnifying glass for some batteries). Record the voltage values in the Part I Data Table under Voltage printed on battery.

Part II Using batteries to light up a light bulb

7. Do the following to get the sensor ready for this part of the activity.
   a. Disconnect the Voltage Probe and connect the Light Probe.
   b. Choose New from the File menu.

c. Lay the Light Probe on the table and tape it down.

d. Put a piece of tape on the table, with one edge right under the tip of the probe.

8. Set up the circuit pictured here using the AAA battery, wires, and the light bulb. Place the tip of the light bulb on the edge of the tape so it is pointing straight at the Light Probe. Someone in your group should hold the socket of the bulb in place during data collection. **Careful**: Do not put your finger between the Light Probe and the bulb when you are collecting data!

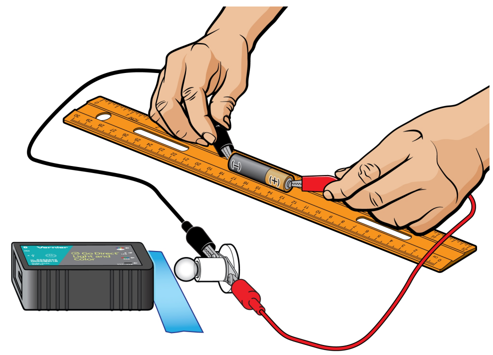

Figure 2

9. Now follow these steps to find out how bright the light bulb is:
   a. Touch one of the jumper wire cables to the positive end of the battery.
   b. Touch the other jumper wire cable to the negative end of the battery.
   c. Look at the light level values in the Illumination meter. When the number stays the same for a few seconds, record the value in the Part II Data Table.

Part II Data Table	
Type of battery in circuit	Light level
AAA battery	
AA battery	
C battery	
D battery	

10. Repeat Step 9 using a different battery in the circuit each time. Make sure the light bulb is in the right place and don't forget to record the Light Level in the Part II Data Table!

ANALYZE YOUR DATA

1. Look at the values for the voltages for the different batteries in the Part I Data Table. How do the voltages you measured compare to your predictions? Why did you make your prediction as you did?

2. What did you notice about the brightness of the bulbs when using the different batteries to light them in Part II? Did the size of the battery seem to make a difference in how bright the bulb was? Look at your data to help you answer these questions.

Are All Batteries the Same?

BACKGROUND INFORMATION

In this activity, students are asked to look at the voltages of various size batteries. It is surprising to most people that the voltage of a AAA battery is the same as a D battery. The voltage output of the cell is determined by the substances inside the battery. These substances create a voltage when a chemical reaction occurs. We use this effect to power devices such as radios and flashlights. The only difference between a AAA battery and the D battery (assuming they are the same type, such as "alkaline cells") is the amount of chemical reagents available for the reaction. If you took a small light bulb designed to operate at 1.5 volts and hooked it up to a new AAA battery, it would light up just fine, but would get dimmer much more quickly than if it were connected to a new D battery.

Some rechargeable batteries, such as nickel cadmium (NiCd) have a slightly different voltage reading, usually around 1.2 volts. This is because they are composed of different materials that generate a different voltage when they react. It is also important to note that the voltage of a "dead" battery is not zero. As a battery discharges, the internal resistance to current flow increases. The voltage will decrease somewhat (maybe to 1.2 volts for an alkaline cell), but will not go to zero.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.D: Energy in Chemical Processes and Everyday Life	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions Using mathematics and computational thinking

CURRICULAR CONNECTIONS

Math – decimals, addition, subtraction

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting voltage data with Vernier equipment, we recommend that you start with Activity 40.

3. At the beginning of Part I, students are asked to look at batteries that you, the teacher, are showing to the class. Start with a AAA battery and tell the students that the voltage of this battery is approximately 1.5 V. Then hold up a AA battery, and ask students to predict the voltage. Repeat for the C and D batteries. It is important not to hand out the batteries ahead of time so the students do not look at the voltage values on the batteries. Most students are inclined to believe that the bigger batteries have a higher voltage because they are physically bigger.

4. Students need to pay attention to the contact between the alligator clips and the batteries. If the connection isn't complete, the values on the screen will flicker between zero and the voltage and light levels.

5. The materials for this and the other battery-based activities can be purchased at a hardware store or internet retailers.
   - ≤3V light bulb and socket: Each group needs a 3 V or less light bulb (2.7 V or 2.3 V will work fine) as well as a light bulb socket. If you are doing an internet search, these small bulbs are sometimes called "lamps" or "miniature light bulbs."
   - Test leads: Each group will need two test leads (two wires with a total of four clips). A search on the internet for "alligator test leads" will yield many examples. The color of the wires does not matter; they can be mixed and matched. Lengths of about 50 cm (about 19 in) work well for this activity and are easily found.

6. For Part II, make it as dark as possible in your classroom. The light produced is very low when only one battery is in the circuit.

7. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Part I Data Table			
Battery type	Predicted voltage (V)	Voltage printed on battery (V)	Measured voltage (V)
AAA battery	1.5 V	1.5	1.52
AA battery	2 V	1.5	1.61
C battery	3 V	1.5	1.58
D battery	4 V	1.5	1.55

Part II Data Table	
Type of battery in circuit	Light level (lux)
D battery	0.6
C battery	0.4
AA battery	0.6
AAA battery	0.8

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answer will vary, depending on the predictions that students made.
2. A typical answer might be, "The bulb was about the same brightness for each kind of battery."

ASSESSMENT

1. Have students compose a statement that tells what they have learned about the different sizes of batteries compared to their voltages. You might give them a prompt such as:

   At first I thought larger batteries ____, but they

   are really alike because ____.

   Possible answer: At first I thought larger batteries would have higher voltage than the little ones, but they are really alike because when we measured them I found out that they have the same voltage.

2. Ask students to look at two different electronic devices, one using one battery, one using two of the same size battery. (Small flashlights would work particularly well. If it is not possible to find two things that use the same size batteries, just pose the question.) Have students tell how the batteries in them could make them different in how they perform.

EXTENSION

Have the students predict what the voltage reading would be for a “dead” battery, then measure the voltage using the probes.

Name: ________________________________

Stacked Batteries

Did you ever wonder why it takes two batteries stacked together to run a flashlight or why your video game player takes four batteries? Why do batteries need to be put into these devices a certain way? This activity will allow you to explore how all this works by measuring the voltages across different numbers of batteries stacked together.

OBJECTIVES

- Measure the voltages of batteries as they are stacked together.
- Compare the voltages of different types of stacked batteries.
- Draw conclusions about batteries in electronic devices.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Voltage
4 D batteries
4 AA batteries
ruler with groove for holding batteries

KEY QUESTION

What do you think will happen to the voltage as you stack more D batteries together and measure the voltages from the end of the first battery to the opposite end of the last battery?

PRE-LAB HYPOTHESIS

The voltage will ___________ by ___________ volts every time an additional D battery is added to the stack.

PROCEDURE

Part I Measure the voltage of stacked D batteries

1. Launch Graphical Analysis. Connect the Voltage Probe to your Chromebook, computer, or mobile device.

2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Enter **Batteries** as the Event Name and leave the Units field blank. Click or tap Done.

3. Zero the sensor and begin data collection by doing the following:
   a. Clip together the ends of the red and black wires coming from the Voltage Probe.
   b. Click or tap the Potential meter and choose Zero. The voltage reading on the screen should be at or near 0 V.

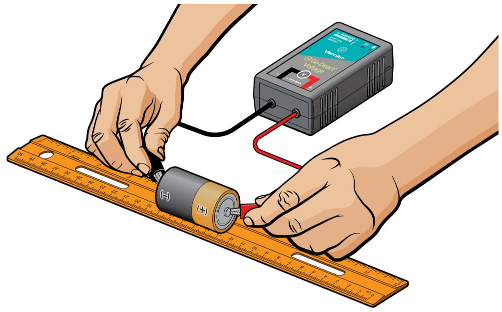

Figure 1

4. Collect data by following these steps:
   a. Click or tap Collect to start data collection.
   b. Click or tap Keep and enter **0** for 0 batteries. Click or tap Keep Point.
   c. Put the ruler on the table and put one D battery in the groove of the ruler.
   d. Now press the red clip to the positive end of the battery, and press the black clip to the negative end of the battery.
   e. When the voltage reading stays the same for a few seconds, click or tap Keep.
   f. Enter **1** for 1 battery, then click or tap Keep Point.

5. Collect data for two stacked batteries.
   a. Place a second battery on the ruler with the negative end of this battery touching the positive end of the first battery.
   b. Hold the red clip against the positive end of the first battery and the black clip against the negative end of the second battery.
   c. When the readings are the same for a few seconds, click or tap Keep.
   d. Enter **2** for 2 stacked batteries and then click or tap Keep Point.

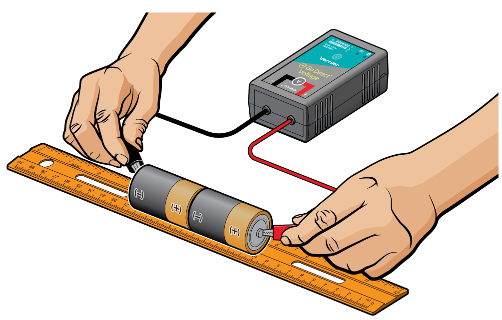

Figure 2

6. Collect data for the 3rd and 4th batteries by doing the following:
   a. Place another battery on the ruler with the negative end of this battery touching the positive end of the battery before it.
   b. Hold the red clip against the positive end of the first battery in the row and the black clip against the negative end of the last battery in the row.
   c. When the readings are the same for a few seconds, click or tap Keep.
   d. Enter **3** for 3 stacked batteries and then click or tap Keep Point.
   e. Repeat this step with four batteries in the stack.

7. When you have collected data for four batteries, click or tap Stop to stop data collection.

8. Click or tap View, ⊞, and choose Table. Look at the voltage values in the Potential column and record the voltages in the Part I Data Table.

Part I Data Table	
Number of D batteries	Potential (V)
1	
2	
3	
4	

Part II How do AA batteries stack up?

9. In this part, you will stack together more batteries and measure the voltage with each new battery. Read the key question, write a hypothesis, and then draw a prediction.

   Key Question

   What do you think will happen to the voltage as you add AA batteries together and measure the voltage? Will the voltage of AA batteries change the same amount as the voltage changed when you stacked D batteries? Why or why not?

   Hypothesis

   The voltage will _____________ by __________ volts every time another AA battery is added to the stack.

   Prediction

   Click or tap Graph Tools, 📈, and choose Add Prediction. Draw what you think will happen to the voltages as you add more AA batteries. Click or tap Save.

10. Repeat Steps 4–8 using the AA batteries. This time, write down your data in the Part II Data Table. **Note**: The previous data set is automatically saved.

Part II Data Table	
Number of AA batteries	Potential (V)
1	
2	
3	
4	

ANALYZE YOUR DATA

1. How did your prediction from Part II match your data?

___

___

___

2. What do you think the voltage would be if you stacked together 10 batteries? Why?

___

___

___

3. Compare your data from Parts I and II of this activity. Describe how they are the same and different. Do the similarities and differences surprise you?

___

___

___

___

Stacked Batteries

BACKGROUND INFORMATION

We use so many electronic devices that most children are familiar with replacing batteries and probably notice the different sizes and numbers needed for different devices. In this activity, students will explore the different sizes of batteries and draw conclusions about why remote controls, games, and flashlights might need different numbers and sizes of batteries.

In this activity, students investigate how batteries behave when stacked in series with each other. A typical voltage value across a new battery (whether AA, D-cell or any size in between) is somewhere near 1.5 volts. The voltage is not dependent on the size of the battery, but on the chemical make-up inside. The only difference between a D-cell and a AA battery is the quantity of chemicals available for the reaction. If you wired D-cells into a flashlight that required AA batteries, the larger batteries would not damage the device, but it would make it shine for a longer length of time. So why use different sizes of batteries? Since physical size is a consideration when making electronic devices, the physical size of the battery used is very important. Just imagine a handheld game that used four D-cells!

When the batteries are stacked together in the same orientation, the voltages add together serially. If one battery is 1.5 volts, then two would produce around 3.0 volts, three batteries around 4.5 volts, and so on.

When students begin to explore how many batteries electronic devices use, it may be necessary to take the time to point out how the batteries can be added up when they are turned in different directions—make sure the students understand that metal strips make the connections between the batteries to let them use space more efficiently.

TIME FRAME FOR ACTIVITY

This activity takes about 45 minutes.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.D: Energy in Chemical Processes and Everyday Life	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions Using mathematics and computational thinking

CURRICULAR CONNECTIONS

Math – comparisons, graph analysis, decimals, addition

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting voltage data with Vernier equipment, we recommend that you start with Activity 40.

3. As written, students are directed to use a ruler with a groove in it; the groove works well for lining up the batteries keeping them from rolling away. If you do not have access to this type of ruler, a battery holder can be made of a piece of foam pipe insulation from a hardware store. It generally comes in 2.4 m (8 ft) lengths. Cut the foam into pieces approximately 20 cm long and open the slit along the side of the insulation. The batteries can be pressed into the slit running down the side. Alternatively an empty paper towel tube can be cut in half lengthwise to form a trough in which the batteries can rest.

4. When measuring the voltage, it is important to press the leads on the voltage probes firmly against the ends of the batteries. This will help keep the batteries together so a complete circuit is formed.

5. We recommend that you use new batteries for this activity so that they are at approximately the same charge state. New batteries, such as those used to produce the data in the Sample Results, will often have a voltage that is grater than 1.5 volts. As a battery discharges, the voltage will be slightly less than the voltage printed on the side.

6. If your students have a difficult time keeping track of the positive and negative ends of the batteries, wrap two pieces of tape around the batteries and write the + and – signs on the correct ends.

7. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Part I Data Table	
Number of D batteries	Potential (V)
1	1.59
2	3.18
3	4.67
4	6.19

Part II Data Table	
Number of AA batteries	Potential (V)
1	1.61
2	3.21
3	4.82
4	6.23

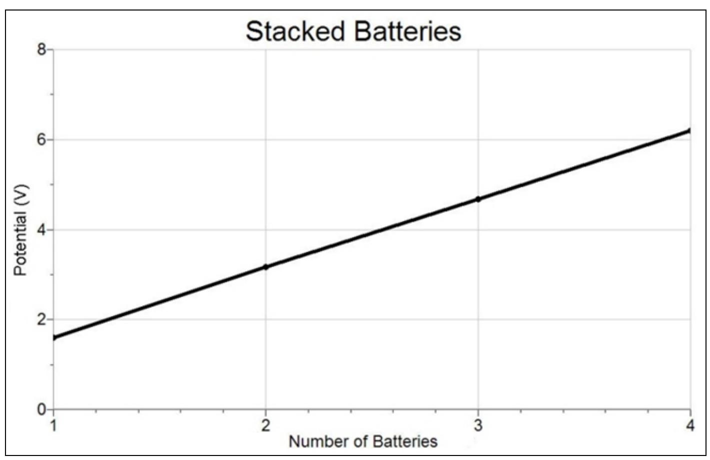

Figure 1 Sample graph for Part I showing voltage change as D batteries are added to the stack

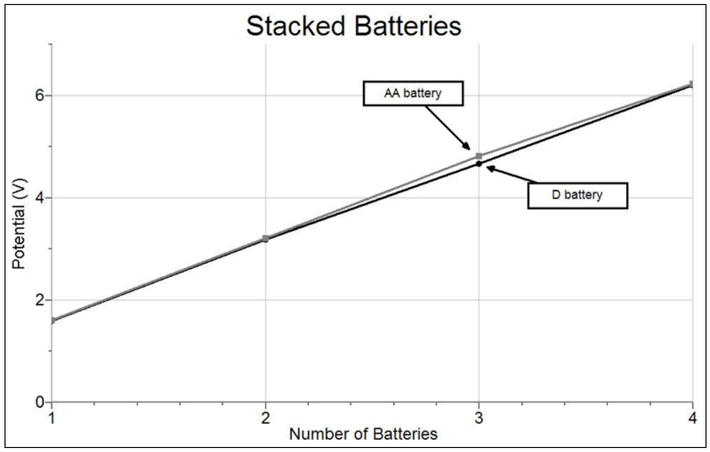

Figure 2 Sample graph for Part II showing voltage change as AA batteries are added to a stack, compared to the data collected in Part I

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. Answers will vary depending on the student's prediction.
2. Ten 1.5 V batteries would make a total of 15 V.
3. Answer will vary depending on what the students predicted. You should expect the voltages to be similar, assuming the batteries are new.

ASSESSMENT

Bring in (or have students bring in) several electronic devices that use various sizes and numbers of batteries. Have them calculate how much voltage each requires.

EXTENSIONS

1. Have the students repeat the experiment using other batteries (such as AAA or C batteries) to see if they get results comparable to those from their earlier activities.
2. Have the students experiment with reversing the polarity of the batteries in the stack. If the positive end "+", of one battery is connected to the negative end "–" of the other, the voltage across the two in combination will read close to zero.
3. Have students survey their electronic devices at home to see if there are patterns of the types and numbers of batteries that certain item use. For example, television remote controls often use one or two AA or AAA batteries, while boom boxes may use six or eight D cell batteries. They may wish to compare items that receive signals, produce light, or tell time.

Name: ________________________________

All Worn Out!

Have you ever wondered why some flashlights use small batteries and some use big ones? What difference does it make? Do larger batteries make the light brighter? Will the size of the battery make a difference in how long the flashlight will stay bright or is the battery chosen for some other reason?

OBJECTIVES

- Measure the voltage of batteries as they discharge.
- Predict how different size batteries will behave when being discharged.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Voltage Probe
new D battery
new AA battery
small light bulb and socket
2 jumper wires with alligator clip on each end
2 paperclips without plastic coating
masking tape
ruler with a groove for holding batteries

PROCEDURE

Part I Discharging the D battery

1. Connect the Voltage Probe to your Chromebook, computer, or mobile device. Launch Graphical Analysis.
2. Click or tap Mode to open Data Collection Settings. Change Time Units to min and End Collection to 60 min. Click or tap Done.
3. Obtain the materials you need for this activity:
   - 1 D battery with paperclips attached to each end
   - 1 light bulb and socket
   - 2 jumper wires
4. Zero the Voltage Probe.
   a. Clip together the ends of the red and black wires coming from the Voltage Probe.
   b. Click or tap the Potential meter and choose Zero. The voltage reading on the screen should be at or near 0 V.

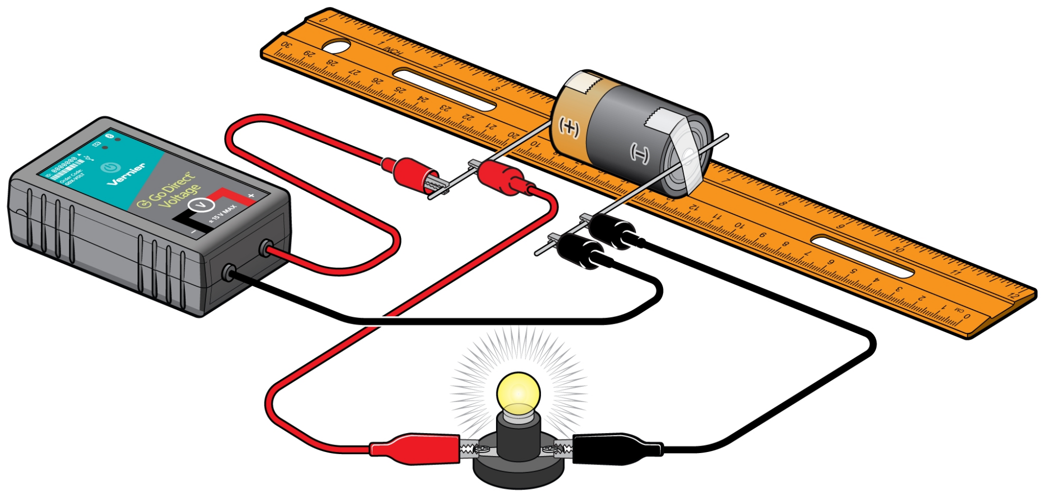

Figure 1

5. Use the jumper wires to connect the battery to the light socket. Each jumper wire should connect to one of the paperclips attached to the battery and to one of the terminals (the small metal tabs) of the light bulb socket. The bulb should light up when the final connection is made. If it does not, ask your teacher for help.

6. Hook the red clip of the Voltage Probe to the paperclip attached to the positive end of the battery and the black clip to the negative end of the battery (each paperclip will have a jumper wire clip and a Voltage Probe clip on it). At this point, the reading on the screen should be close to 1.5 volts.

7. You are going to measure the voltage of the battery as it discharges or wears out. Before starting to collect data, you need to do a couple of things.
   a. Tap the Graph tab.
   b. Click or tap Graph Tools, , and choose Add Prediction. Draw what you think will happen to the voltage over the time of data collection. Click or tap Save.
   c. Record any observations about the brightness of the bulb and the beginning voltage on the Observations Sheet for the D battery.

8. Click or tap Collect to start data collection. Data collection will take one hour.

Observations Sheet – D Battery

Part II Discharging the AA battery

9. During this part of the experiment, you are going to repeat data collection using a AA battery. First, read the key questions and write your hypothesis.

   Key Question

   Will there be a difference in the voltages of the D battery and the AA battery? What might make a difference?

   Hypothesis

   The AA battery voltage will discharge ________________ than the D battery because

   ____

10. Repeat Steps 6–8 using a AA battery. Record your observations for the AA battery. **Note**: The previous data set is automatically saved.

Observations Sheet – AA Battery

ANALYZE YOUR DATA

1. What did you notice about the brightness of the bulb when the circuit was first made for each battery? Was there a difference or were they about equally bright? Why do you think this happened?

   ____

   ____

   ____

2. Compare the brightness of the bulbs at the end of each run. Was there a difference or were they about equally bright? Explain why you think this happened.

   ____

   ____

3. How well did your predictions match your results?

   ____

   ____

4. What do you think would be the result of this experiment if a AAA battery (even smaller than a AA) was used?

____

____

5. Using what you have learned about batteries, tell why you think different flashlights use different sizes of batteries.

____

____

All Worn Out!

BACKGROUND INFORMATION

If you already completed Activity 41, "Are All Batteries the Same?", your students might have wondered what difference there is between different sizes of batteries. In this activity, students measure how much a battery discharges over time when they are being used to light a light bulb.

The basic difference between a AA battery and a D battery is the quantity of chemical reagents available to react, producing an electric current. An analogy could be the size of a gas tank in a car. The gasoline inside is the same, but the bigger tank contains more chemical potential energy because it contains more gasoline.

TIME FRAME FOR ACTIVITY

The data-collection duration for this activity is several hours. Actual hands-on time is two sessions of about 20 minutes for setup, followed by another two sessions of 20 minutes each for data analysis. As can be seen in the Sample Results, a change in voltage can be seen in 30 minutes. To do this activity in less time, you can shorten the data-collection duration. Note that the voltage changes will not be as significant, particularly for the D battery.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.D: Energy in Chemical Processes and Everyday Life	Patterns Cause and effect Scale, proportion, and quantity Energy and matter	Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions Using mathematics and computational thinking

CURRICULAR CONNECTIONS

Math – making comparisons, estimating

HELPFUL HINTS

1. In the Electronic Resources you will find multiple versions of the student experiment—one for each supported data-collection software or app (Graphical Analysis 4, Logger Lite, or LabQuest App). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic

Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Graphical Analysis versions (using Go Direct sensors) of the experiments.

2. If this is the first time your students will be collecting voltage data with Vernier equipment, we recommend that you start with Activity 40.
3. It is very important that the batteries used in this activity are new.
4. This activity was designed with incandescent bulbs. LED bulbs do not work well for this particular activity because of their energy-efficient nature.
5. Each student group will test a D battery and a AA battery. You can use fewer batteries if you have some groups do Part I first (using a D battery) and other groups do Part II first (AA battery). The groups can then trade after they have finished their first test.
6. The batteries will be worn down at the end of this activity. If you plan to do the other battery-based activities, you may want to do this one last.

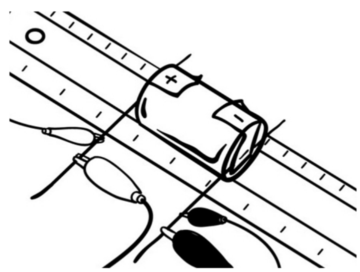

Figure 1

7. You will need to tape paperclips to each end of the batteries prior to giving the them to the students. This way, you will ensure that there is a good connection between the end of the battery and the paperclip. For each battery,
   a. Unbend each paperclip.
   b. Place one paperclip against the negative end of the battery and attach it with a piece of tape. Do not use such a long piece that it covers the other end of the battery. Keep track of which end is which, and if necessary, mark the ends so your students will know where to attach the clips.
   c. Place the second paperclip against the positive end of the battery. It may help to bend out the paperclip a bit in order to go around the bump on the positive end and make contact with the flat part of the battery end. Use tape to attach the paperclip. Make sure the paperclips are securely attached.
   d. To make sure the connections are good, start the connect the Voltage Probe and start the data-collection program. Attach one of the Voltage Probe clips to each of the paperclips. If the voltage in the meter reads about 1.5 V the setup is good (the value may be positive or negative depending on the way you have attached the clips). If the voltage is near 0 V, you need to reattach the paperclips.
8. The light bulb will not burn brighter for one battery, but will have a higher voltage at the end of data collection with the D battery when compared to the AA battery. This is because, while the initial voltage of each battery is the same, there is a larger amount of reactive material in the D battery, so it lasts a longer period of time.

9. The materials for this activity may be purchased from an online or local hardware store. See the Teacher Information section for Activity 41 for details about the light bulbs and test leads that are needed for this activity.

10. The data-collection duration for Part I is 60 minutes. But for Part II, you will want a longer data-collection duration. To collect data for a longer period of time, for example until the battery is completely discharged (the voltage will not go down to 0 V, but the light bulb will go out), follow the directions for your data-collection program:
    - Graphical Analysis 4: Set up data collection for a long time period, such as 5 hours.
    - Logger Lite: After data collection has begun, choose Extend Collection from the Experiment menu. You can choose Extend Collection several times, if you wish. Each time, data collection will expand to 1.5 times the current data collection length (e.g., if data collection is 60 minutes, Extend Collection will extend it to 90 minutes).
    - LabQuest App: Set up data collection for a long time period, such as 5 hours. After data collection has begun, choose Autoscale Once from the Graph menu to display the current data. As data collection continues, the x-axis will expand to include all data.

11. If you are able to collect data from two probes simultaneously, you can do several variations on the activity.
    - You could to do both parts of this activity at the same time.
    - You may set up one Light Probe and one Voltage Probe, placing the Light Probe next to the light bulb to quantify its change in brightness over time. A good way to do this is to place the battery, bulb, voltage probe and light sensor inside a closed box. This will keep ambient light from reaching the Light Probe.

12. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect to your sensor.

13. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

SAMPLE RESULTS

Note: Sample data were collected in units of hours; students may collect data in units of minutes.

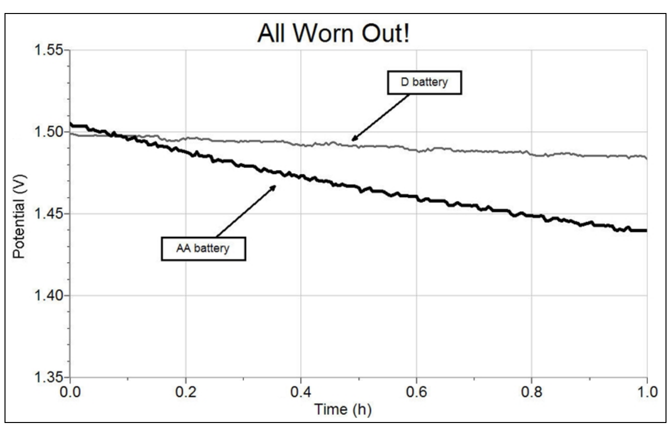

Figure 2 Change in voltage over a one-hour period of time for AA and D batteries

ANSWERS TO THE ANALYZE YOUR DATA SECTION

1. The batteries made the light burn at about the same brightness.
2. At the end of the run, the AA battery was only lighting the bulb a little, but the D battery was still lighting the light almost as bright as at the beginning.
3. Answers will vary.
4. Possible answer: I think the light would stop burning because the battery would die much more quickly.
5. Possible answer: Flashlights that are used for emergencies are usually really big and use D-cells, probably so that the bulb will burn for a longer time. Small flashlights that use small batteries might be more like toys and need to be lighter for a kid to carry, but they don't really have to stay on very long for safety.

ASSESSMENT

Have students make a summation statement telling what they found out about the difference between batteries.

EXTENSIONS

1. Explore electronic devices, paying particular attention to the light that the batteries have to power. Survey the kinds and sizes of batteries the different devices use.
2. Compare different brands of batteries of the same type (e.g., 2 or 3 brands of D batteries) to see if one particular brand last longer. Keep track of the cost of each battery to see if more expensive batteries are actually better. If you do this, be sure to keep in mind the initial voltage of each battery and calculate and compare the total change in voltage rather than the ending voltages.
3. Compare rechargeable and non-rechargeable batteries.
4. Use a Light Sensor to collect quantified data about the change in light level during data collection. See note in the Helpful Hints section above for more information.

Electronic Resources

The Electronic Resources for this book contain the following files. To download the Electronic Resources, create an account or log in at **vernier.com/account**

Elementary Science with Vernier.pdf–A searchable PDF of the entire book.

_Intro and Appendices

Appendices–Contains a file for each of the Appendices in this book.

Intro.pdf–Includes the Table of Contents and the Vernier Equipment chart for this book. Use the Vernier Equipment chart to identify which experiments can be done with a particular sensor.

Teacher–Contains a PDF of each of the Teacher Information files for this book.

Student Experiments–In the folder for each data-collection program you will find folders containing the PDF and Word files of each of the activitys.

Graphical Analysis–Supports Graphical Analysis 4 app on Chrome, Windows, macOS, and iOS and Android devices.

Go Direct Sensors–Use these files when collecting data with Go Direct sensors connected via Bluetooth or USB.

LabQuest Sensors–Use these files when collecting data with sensors that connect to an interface from the LabQuest family of interfaces (e.g., LabQuest 2 or LabQuest Mini).

LabQuest App–Supports LabQuest App version 2.2.1 or newer.

Logger Lite–Supports Logger Lite version 1.9.2 or newer.

Equipment and Supplies

A list of equipment and supplies for all experiments is included in this appendix. The amounts listed are for eight groups of students. The materials have been divided into nonconsumables, consumables, and chemicals. Most consumables and chemicals will need to be replaced each year. Most nonconsumable materials may be used many years without replacement. Note that this appendix does not include the Vernier products that are used in this book.

Item	Amount	Experiment
backpack (a student's backpack works well)	8	30
baking soda	1 box	5, 18
ball (approx. same diameter as Slinky, see below)	8	23
ball (foam, 4–6 inches in diameter)	8	33
basketball	8	24
batteries, size does not matter	8	40
battery, AAA	various	41, 42
battery, AA	8	41, 43
battery, C	various	41
battery, D	various	39, 41–43
beakers, 500 mL (if unavailable: pyrex measuring cup, 2 cups)	8	15
beakers, cups, or mugs	8–24	1, 5, 6, 8–10, 12–14, 18
board, about 2.5 cm (1") thick, 16 cm (8") wide, 1.5–2 m (4–6') long	8	26, 30
books (student textbooks work well)	various	20, 26, 28, 31, 34
bowl (medium size mixing bowl works well)	8	19
bread dough (see Teacher Info for recipe)		19
calculator (okay to use the calculator program on your computer or LabQuest)	8	17, 26
chair	8	30

Item	Amount	Experiment
fabric (3 different types, ~4–5 cm (2") wide, and 20–25 cm (10") long)	24 pieces	34
friction car (pull back, wind-up variety)	8	25
fulcrum (magic marker or AA battery)	8	28
globe	1	33
goggles, safety	24	5, 18
graduated cylinder, 100 mL (if unavailable: beaker or measuring cup)	8	10
hot plate	1	15
ice cubes (bagged from an ice tray or from an ice machine)	many	6, 8–10, 12–15
ice pack (if unavailable: ice cubes in zipper-style bag)	8	3
insulating materials cotton balls tin foil cotton material fleece feathers, etc.	various amounts	3, 13
jumper wires with alligator clips on each end	16	41, 43
lamp	8	31, 32, 33
light bulb and socket (1.5 V or higher)	8	31, 43
magnet (various shapes, see Teacher Info)	8	36, 37, 38
magnifying glass	8	41
measuring spoon, 1/2 teaspoon (if unavailable: plastic spoon)	8	16
metal objects (example: a spoon or a tin can)	10–12	38
meter stick	8	23, 25, 28, 32–34
mittens	8	2
nail, steel (7.5 cm (3 inches) in length)	8	38, 39
needle for air pump (used to blow up sports balls)	8	24

Item	Amount	Experiment
paper (various colors)		
color does not matter	8	26
black	8	35
white	8	35
other colors (two in addition to black and white)	16 (8 of each)	35
paper clips (without plastic coating)	16	38, 43
paper towels (for spills)	a lot	1, 3, 5, 6, 18, 19
pencil or pen	8	35
pencil or pen, waterproof	1	6, 13, 15
plastic bags, Ziploc style	16	3
plastic bottle [600 mL (20 fl. oz.) soda bottle]	8	17, 18, 19
plastic spoon	8	5, 6, 18
Pressure Sensor Accessories Kit (comes with Pressure Sensor)	8	16–19, 24
rolls of pennies	24	26
rope	8 meters	30
ruler with groove	8	35, 40–43
safety goggles	24	5, 18
salt (table salt is fine)	16 spoonfuls	6
shoe box	8	13
shoes with different soles (need four different types of soles)	8	4, 29
skewer, wooden	8	33
Slinky (smaller sizes, about 5 cm (2") diameter, works well)	8	23
stickers (small and blank, for writing on)	16	37
string	6 meters	28, 29
tape, masking	1 roll	23, 26, 28, 32, 34–39, 41, 43
toy truck with flat top, tail gate, or back	8	26
tray, cafeteria or fast food restaurant	8	1, 5, 6, 8–10, 12–14, 18, 28

Item	Amount	Experiment
vinegar	1 L bottle	5, 18
water (tap water is fine)	as necessary	1, 6, 18, 19
wire, insulated, approximately 1 m long	8 pieces	39

Safety Information

Adequate measures should be taken to ensure the safety of you and your students at all times. While this information attempts to cover most issues that may arise while performing the activities in this book, you should always use common sense to avoid accidents.

Many of the activities in this book require the students to use water in the vicinity of a computer or some other electronic device. If a spill should occur, the devices can be damaged and electrical shock could occur. To avoid this, we recommend that you obtain cafeteria trays for each group. Students should keep all liquids on the tray when they are working. That way, f any water is spilled, it will be confined to the tray. If you have no cafeteria, or if they cannot spare any trays, fast food restaurants will sometimes donate them to a good cause. An alternative would be to keep the devices on some type of raised platform.

Safety goggles should be worn any time the students are using chemicals other than water. They should also be worn when heating water. Student-sized goggles can be purchased from science education suppliers such as Flinn Scientific, **www.flinnsci.com**, 1.800.452.1261.

When heating water, use only glassware made from borosilicate glass (Kimax or Pyrex).

Warn the students that they should never eat or drink while doing science activities. You may be using ordinary drinking glasses in some of these activities, but be sure to label them clearly so that they are not used for drinking.

An excellent source for more information is the publication, *Safety in the Elementary Science Classroom*, published by the Committee on Chemical Safety of the American Chemical Society (ACS). It can be downloaded from the ACS website, **www.acs.org**, or ordered from the American Chemical Society by calling 800-227-5558 (US and Canada) or 202-872-4600 (worldwide).

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(By Experiment Number)