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# Middle School Science with Vernier

**4th Edition**

By  
Donald Volz  
Sandy Sapatka



MSV

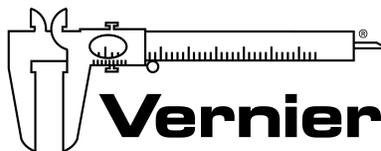




# Middle School Science with Vernier

**Donald L. Volz**

**Sandy Sapatka**



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# **Middle School Science with Vernier**

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## About the Authors

Donald L. Volz received his BS in Chemistry and Mathematics and his MS in Chemistry Teaching from Purdue University. He taught at Fontana High School in California before taking his first teaching position with the Department of Defense Dependents Schools in Japan. He subsequently transferred within DoDDS to Mannheim, Germany, where he served as a chemistry and general science teacher and as science department chairperson at Mannheim High School. He has taught several graduate-level courses and conducted numerous teacher workshops on the use of computers and calculators in science teaching. He is a Dreyfus Master Teacher and a 1991 Presidential Awardee for Excellence in Science Teaching. In addition to this book, he is co-author of *Chemistry with Vernier*, *Physical Science with Vernier*, and *Investigating Environmental Science through Inquiry*.

Sandy Sapatka received her BS in Science and Mathematics Education from Concordia Teachers College, her MA in Physical Science Education from Ohio State University, and an AAS in Electronics from The College of DuPage. She has taught in Illinois, in Hawaii, and for the Department of Defense Dependents Schools. Her DoDDS teaching assignments have been in Korea and Germany. She presently teaches physics, general science, astronomy, and Science, Technology, and Society (STS) at Mannheim American High School. She served on the Department of Defense Dependents Schools' STS writing team. She has taught several graduate-level courses and she has conducted numerous workshops on the subjects of using computers and calculators in the science lab, STS, and Project Physics. She is a 1989 Presidential Awardee for Excellence in Science Teaching. In addition to this book, she is co-author of *Physical Science with Vernier*.

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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# Equipment Used in Experiments

		Temperature	Motion	Force	Conductivity	Gas Pressure	Heart Rate	Light	Magnetic Field	pH	Voltage
1	A Hot Hand	1									
2	Heating of Land and Water	2									
3	The Greenhouse Effect	2									
4	Relative Humidity	2									
5	Soil Study									1	
6	Absorption of Radiant Energy	2									
7	Reflectivity of Light							1			
8	Schoolyard Study	1						1			
9	A Good Sock	2									
10	What Causes Seasons?	1									
11	Solar Homes	2									
12	Ocean Floor Mapping		1								
13	Boiling Temperature of Water	1									
14	Freezing Temperature of Water	1									
15	How Low Can You Go?	1									
16	A Good Cold Pack	1									
17	Lemon "Juice"										1
18	Get a Grip!					1					
19	Fun with Pressure					1					
20	Water Hardness Study				1						
21	Diffusion: How Fast?				1						
22	A Water Field Study	1			1					1	
23	Cooling Rates: Shaq vs. Susie	2									
24	Yeast Beasts in Action					1					
25	Heart Rate and Body Position						1				
26	Heart Rate and Exercise						1				
27	Mapping a Magnetic Field								1		
28	Electromagnets								1		
29	Friction			1							
30	First Class Levers			1							
31	Pulleys			1							
32	Buoyancy			1							
33	Graphing Your Motion		1								
34	Speeding Up		1								
35	The Indy 100		1								
36	Crash Dummies		1								
37	Falling Objects		1								
38	A Speedy Slide		1								



# Preface

Probeware is an integral and indispensable component of a science classroom. This book contains experiments that make use of Vernier data-collection technology to collect and analyze data.

## 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 or department. 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. Download the Electronic Resources from your account on the Vernier website, [vernier.com/account](http://vernier.com/account). 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 or college department. 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 or college department.

## Student Experiments

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

- **PDF files:** Print the PDF version of the student experiment and have students follow the procedures as they are written. This format is also ideal for viewing experiments 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 experiments often remove data tables and reduce the amount of detail in the procedures.

**Note:** Experiments written for Logger *Pro* software can also be conducted using our free Logger Lite software.

## 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 experiment.

## Appendices

The appendices include valuable information:

### Appendix A: Electronic Resources

There are multiple versions of each student experiment—one for each supported data-collection software (e.g., *Logger Pro*). 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 experiments in this book can be found in Appendix B.

### Appendix C: Chemical 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.

### Appendix D: Transferring Data

Appendix D contains instructions on how to transfer data collected using supported software (e.g., LabQuest App) into *Logger Pro 3* computer software for further analysis.

## Acknowledgments

Since the initial publication of this book, multiple people have contributed valuable updates, including many teachers who have taken time to provide us with suggestions and tips. For the 4th edition, we especially wish to thank Keith Clay, Thomas M. Smith, Frances J. Poodry, Joshua Ence, Joel Matykowski, and Colleen McDaniel.

# A Hot Hand

You will measure the temperature of the palm of your hand and the palm temperatures of your teammates in this experiment. In the process, you will learn how to use the data-collection equipment you will be using throughout the school year. You will also get to know your teammates better.

## OBJECTIVES

- Use a temperature probe to measure temperature.
- Calculate temperature averages.
- Compare results.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Temperature Probe  
beaker  
water  
paper towel

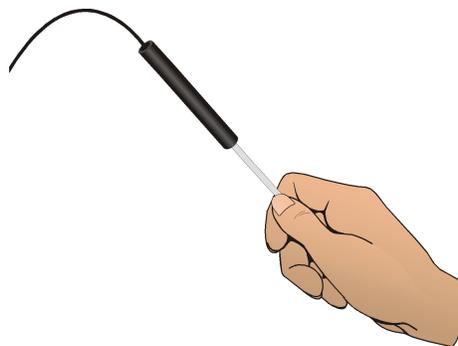


Figure 1

## PROCEDURE

1. Connect the Temperature Probe. Start the Vernier data-collection program and open the file “01 A Hot Hand” from the *Middle School Science with Vernier* folder.
2. Measure the temperature of the palm of your hand.
  - a. Click **Collect** to begin data collection.
  - b. Pick up the Temperature Probe and hold its tip in the palm of your hand as shown in Figure 1. Data collection will end when 60 seconds have gone by.
3. Record your maximum temperature.
  - a. Click Statistics, . The statistics box will appear on the graph, displaying several statistical values for the data, including the minimum and maximum temperatures recorded during the collection period.
  - b. In your data table, record the maximum temperature.
  - c. Close the Statistics box.
  - d. Choose Store Latest Run from the Experiment menu to store your data.
4. Prepare the Temperature Probe for the next run.
  - a. Cool the Temperature Probe by placing it into a beaker of room-temperature water until its temperature reaches the temperature of the water. The temperature of the probe is displayed

## Experiment 1

---

in the meter.

- b. Use a paper towel to dry the probe. Be careful not to warm the probe as you dry it.
5. Repeat Steps 2–4 for each person in your group. However, when you repeat the steps, after clicking Statistics, , choose Latest: Temperature as the run for which you want the statistics. Then, click  to view the statistics for the latest run. Do not choose Store Latest Run after the last run.
6. Print copies of the graph as directed by your teacher.

### DATA

Student name	Maximum temperature (°C)
Group average	

### PROCESSING THE DATA

1. Calculate the group average for the highest temperatures. Record the result in the data table.
2. How did the maximum temperature for each person compare?
3. Who had the “hottest hand”?

### EXTENSION

Determine the class average for maximum temperature.



## A Hot Hand

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., Logger *Pro* and Graphical Analysis). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 Logger *Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources. The Graphical Analysis Pro file for this experiment includes video of the first trial showing a single subject. Data from the other three trials, with different subjects, can be found in the data table in the Graphical Analysis file; videos of these trials are not included.

The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in Graphical Analysis Pro, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.

2. This experiment can be used at the beginning of the school year to introduce the use of data-collection tools; it also works well in a life-science setting.
3. If you are using Logger *Pro* or Graphical Analysis, consider having your students to add annotations to the graphs to identify the different data sets.
4. Any Vernier temperature probe can be used in this experiment. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
5. If you are using Go Direct sensors, see [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect your sensor.

### ESTIMATED TIME

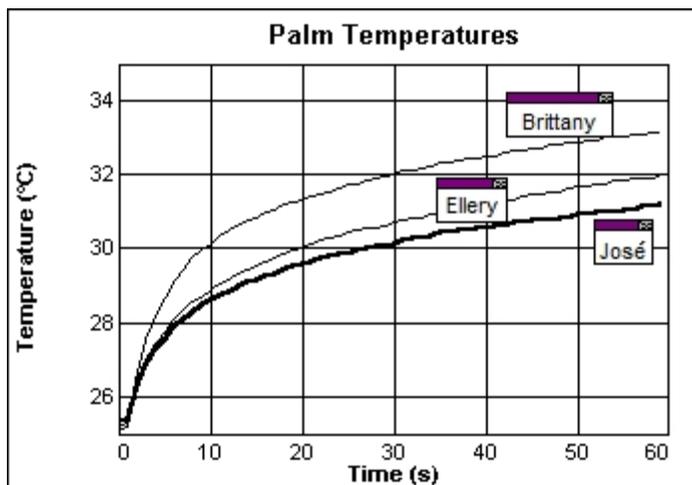
We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS3.A Definitions of Energy	Cause and effect Scale, proportion, and quantity Energy and matter Stability and change

## SAMPLE RESULTS

Student name	Maximum temperature (°C)
Ellery F.	32.0
Brittany M.	33.2
José R.	31.2
Group average	32.1



## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. Answers will vary.
3. Answers will vary.

# Heating of Land and Water

How fast land and water heat and cool influence our weather. In Part I of this experiment, you will heat sand and water. You will use two Temperature Probes to see which heats faster. In Part II, you will allow hot sand and hot water to cool. This time you will use two Temperature Probes to see which cools faster. You will then apply your results.

## OBJECTIVES

- Measure temperature.
- Calculate temperature changes.
- Apply your results.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
2 Temperature Probes  
2 pans  
sand  
water  
ruler  
lamp with 100 W equivalent bulb  
2 test tubes  
2 one-hole stoppers  
beaker  
hot water  
test-tube rack  
ring stand  
utility clamp

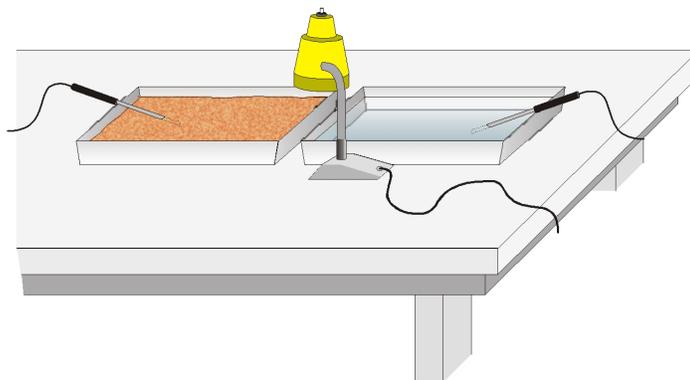


Figure 1

## PROCEDURE

### Part I Heating Sand and Water

1. Fill one pan with sand 1.0 cm deep. Fill another pan with water 1.0 cm deep.
2. Lean Probe 1 in the pan with sand as shown in Figure 1. Lean Probe 2 in the pan with water. The probe tips should be at the centers of the pans.
3. Position a light bulb directly over the boundary between the two pans and about 10 cm above the pans as shown in Figure 1. The bulb should be the same distance from both probe tips.
4. Connect the Temperature Probes. Start the Vernier data-collection program and open the file “02 Heat Land and Water” from the *Middle School Science with Vernier* folder.
5. Click  to begin data collection, then switch on the light bulb. Record the initial temperature measured by each probe in the data table. **Note:** Do Steps 9 and 10 of Part II while waiting for your Part I data to be collected.
6. When data collection is complete after 20 minutes, record the final temperature measured by each probe. Turn off the light bulb.
7. To confirm your minimum and maximum values, click Statistics, , then click  to display a Statistics box for each probe. Close the Statistics box by clicking on the upper-left corner of the box.
8. Print copies of the graph as directed by your teacher.

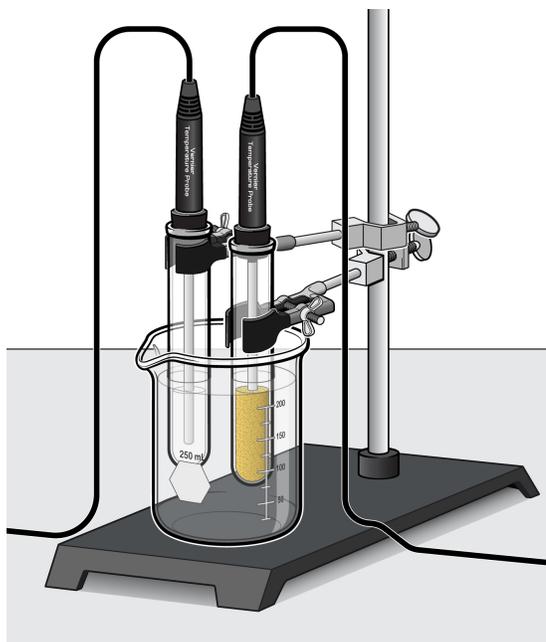


Figure 2

**Part II Sand and Water Cooling**

9. Fill one test tube 2/3 full with sand. Fill another test tube 2/3 full with water.
10. Place both test tubes in a beaker of warm water for several minutes.
11. Place a one-hole stopper onto each Temperature Probe. Carefully place Probe 1 in the sand. Tilt the test tube to loosen the sand and prevent damage to the probe. Suspend Probe 2 at the same depth in the water.
12. Begin data collection.
  - a. Note the temperature readings displayed in the meters. When the temperatures stop rising and are nearly the same, click  to begin data collection.
  - b. Record the initial temperature measured by each probe.
  - c. Remove the test tubes from the warm water and stand them in a test-tube rack to cool.
13. When data collection is complete after 20 minutes, record the final temperature measured by each probe.
14. To confirm your minimum and maximum values, click Statistics, , then click  to display a Statistics box for each probe.
15. Print copies of the graph as directed by your teacher.

**DATA**

**Part I Heating Sand and Water**

	Probe 1 Sand	Probe 2 Water
Final temperature (°C)		
Beginning temperature (°C)		
Temperature change (°C)		

**Part II Sand and Water Cooling**

	Probe 1 Sand	Probe 2 Water
Beginning temperature (°C)		
Final temperature (°C)		
Temperature change (°C)		

**PROCESSING THE DATA**

1. In the space provided in the data table, subtract to find the temperature changes.
2. Discuss how the sand and water temperatures changed in Part I.

## *Experiment 2*

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3. Discuss how the sand and water temperatures changed in Part II.
4. San Diego, California, is located on the Pacific Ocean while Barstow, California, is located in the Mojave Desert. Use the results of Part I to predict which city is warmer on summer afternoons. Explain.
5. Which city, San Diego or Barstow, cools more during summer nights? Explain.

### **EXTENSIONS**

1. Read about sea breezes. Use the results of this experiment to explain the directions of daytime and nighttime ocean-shore breezes.
2. Compare the heating rates of different-colored sands.
3. Compare the heating (cooling) rates of dry and wet sand.

## Heating of Land and Water

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources. The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in *Graphical Analysis Pro*, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.
2. In the Electronic Resources you will find a PDF of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. This is copyrighted material, so please do not post the content on a page that is accessible to the public. Sign in to your account at **vernier.com/account** to access the Electronic Resources.
3. This experiment was adapted from *Middle School Science with Vernier*, Experiment 02. Learn more at **vernier.com/msv**
4. In both parts of the experiment, it is best if the water and sand are at nearly the same initial temperatures.
5. If you are using calculators for data collection, this activity can be performed with calculators from the TI-83 Plus or TI-84 Plus families (except the TI-84 Plus CE) and a multi-channel interface. It cannot be performed with Easy products because both runs of data must be collected at the same time under similar conditions.
6. As the Sample Results would indicate, good results for Part II are obtained when the sand and water are initially at around 50°C. It is neither necessary nor desirable to use hotter water. If hot tap water is available, it can be used for the hot-water bath. Alternatively, a hot plate, maintained at a low setting, can be used to heat the water.
7. The data in the Sample Results were collected using a 100 W incandescent bulb positioned above the beakers, pointing downward. Incandescent bulbs can be difficult to find, but the amount of heat given off by an LED bulb may not be enough to obtain meaningful data.

## Experiment 2

---

- In Part II, 18 × 150 mm test tubes work well.
- In Part II, use one-hole stoppers to suspend the temperature probes in the test tubes. Stoppers with small-end diameters greater than the internal diameter of the test tubes should be used.
- Charcoal can be added to sand to make a darker sand and charcoal mixture for Extension 2.
- You might want to have your students print or sketch and label their graphs.
- For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
- If you are using Go Direct sensors, see [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect your sensor.

### ESTIMATED TIME

We estimate that this experiment can be completed in two 45–60 minute class periods.

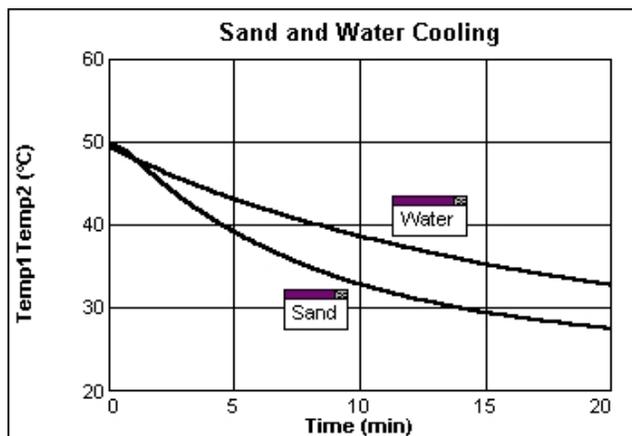
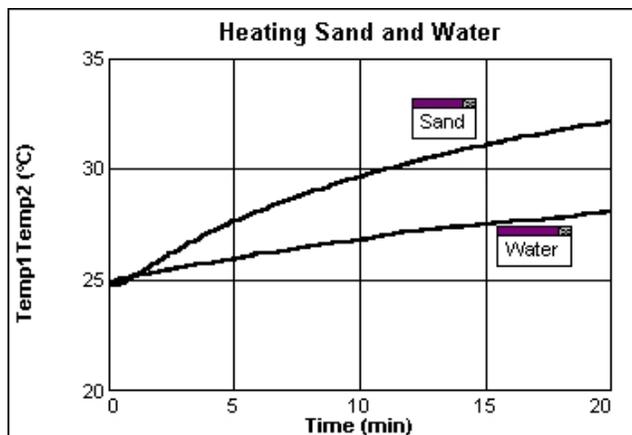
### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	ESS2.C The Roles of Water in Earth's Surface Processes ESS2.D Weather and Climate	Cause and effect Systems and system models Energy and matter Stability and change

### SAMPLE RESULTS

	Part I		Part II	
	Probe 1 Sand	Probe 2 Water	Probe 1 Sand	Probe 2 Water
Maximum temperature (°C)	32.2	28.1	49.8	49.6
Minimum temperature (°C)	24.9	24.9	27.8	33.0
Temperature change (°C)	7.3	3.2	22.0	16.6





## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. In Part I, the sand and water temperatures both increased. The temperature of the sand increased more; 4.8°C versus 2.0°C in the Sample Results.
3. In Part II, the sand and water temperatures both decreased. The temperature of the sand decreased more; 16.8°C versus 10.8°C in the Sample Results.
4. Because Barstow is located in a desert and far from the temperature-moderating influences of a large body of water, Barstow can be expected to be warmer than San Diego—which is located near a very large body of water. Barstow routinely has high temperatures greater than 38°C (100°F) in the summer. In contrast, 24°C (75°F) is a typical summertime high for San Diego.
5. Because Barstow is surrounded by land and is far from a large body of water, Barstow cools much more during the nighttime, when the sun is not heating it, than does San Diego.



# The Greenhouse Effect

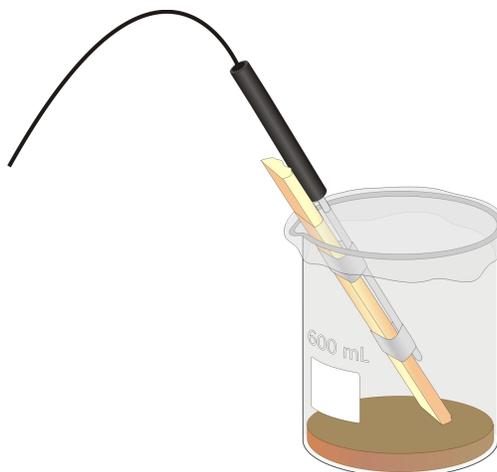
Greenhouses allow gardeners to grow plants in cold weather. This is because a greenhouse stays warmer than the outside air. You can feel this effect in a car parked in the sun. On a larger scale, the greenhouse effect helps keep our planet warm. It makes Venus one of the hottest planets in our solar system. In this experiment, you will use Temperature Probes to measure temperatures in a model greenhouse and in a control as they are heated. You will then calculate the resulting temperature changes.

## OBJECTIVES

- Measure temperatures as a model greenhouse and a control are heated.
- Determine the temperature changes for the two containers.
- Use the results to make conclusions about the greenhouse effect.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
2 Temperature Probes  
lamp with 100 W equivalent bulb  
2 rulers  
tape  
two 600 mL beakers  
soil  
plastic wrap



*Figure 1*

## PROCEDURE

1. Tape Probe 1 and Probe 2 each to a ruler as shown in Figure 1. The probe tips should be 3 cm from the ruler ends and the tape should not cover the probe tips.
2. Connect the Temperature Probes. Start the Vernier data-collection program and open the file “03 The Greenhouse Effect” from the *Middle School Science with Vernier* folder.
3. Obtain two beakers and prepare them for data collection.
  - a. Place a layer of soil 1 cm deep in each beaker.
  - b. Place the Temperature Probes into the beakers as shown in Figure 1.
  - c. Cover the beaker containing Probe 1 tightly with plastic wrap. Beaker 1 is your model greenhouse and Beaker 2 is the control.
  - d. Position a lamp bulb near the two beakers. It should be the same distance from both beakers and from the two probe tips. **Note:** Do not place the bulb so close that it might melt the plastic wrap.
4. Click  to begin data collection. Turn on the lamp. Data collection will stop after 15 minutes.
5. When data collection stops, turn the lamp off. Click Statistics, , then click  to display statistics for each probe. Record the min and max temperature for each probe.
6. Print copies of the graph as directed by your teacher.

## DATA

	Probe 1 Model greenhouse	Probe 2 Control
Final temperature (°C)		
Beginning temperature (°C)		
Temperature change (°C)		

## PROCESSING THE DATA

1. In the space provided in the data table, subtract to find the temperature changes.
2. Describe your graph.
3. Did the model greenhouse warm faster or slower than the control? What do you think caused the difference?
4. Explain why a closed automobile heats up in the sun.
5. Describe one advantage of using a greenhouse for growing plants.
6. Why might the greenhouse effect be a problem for our earth?

## **EXTENSIONS**

1. Repeat the experiment using the sun as the light source.
2. Run the experiment for two hours. How are the results different than your results for the 15 minute data-collection period? Explain the differences.
3. Study three successive “days” of day and night. Collect data for 30 minutes, while turning the light on at 0, 10, and 20 minutes. Turn the light off at 5, 15, and 25 minutes. Explain the results.
4. Repeat the experiment using plastic containers instead of glass ones. Discuss any differences that result.



## The Greenhouse Effect

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. If you are using calculators for data collection, this activity can be performed with calculators from the TI-83 Plus or TI-84 Plus families (except the TI-84 Plus CE) and a multi-channel interface. It cannot be performed with Easy products because both runs of data must be collected at the same time under similar conditions.
3. Matched 250 mL, 400 mL, 600 mL, and 1 L beakers and various wide-mouth jars work well in this experiment.
4. Black paper can be substituted for the soil.
5. The data in the Sample Results were collected using a 100 W incandescent bulb positioned above the beakers, pointing downward. Incandescent bulbs can be difficult to find, but the amount of heat given off by an LED bulb may not be enough to obtain meaningful data.
6. The opportunities for students to design their own extensions to this experiment are numerous. We encourage you to take advantage of them.
7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
8. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

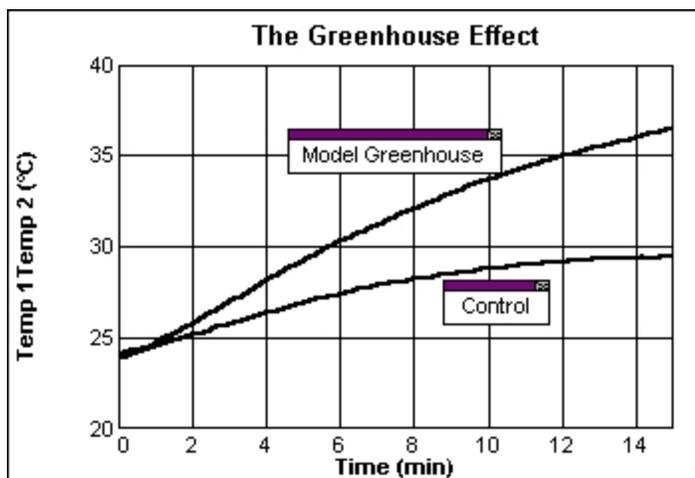
### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	ESS2.D Weather and Climate ESS3.D Global Climate Change	Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change

## SAMPLE RESULTS



	Model greenhouse	Control
Maximum temperature (°C)	36.6	29.6
Minimum temperature (°C)	24.0	24.2
Temperature change (°C)	12.6	5.4

## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. Answers will vary.
3. The model greenhouse warmed faster than the control. The glass walls of both the model greenhouse and the control allowed visible light to enter and be absorbed by soil. In turn, the glass walls of both the model greenhouse and the control trapped the heat radiated from the soil inside. The roof of the model greenhouse kept warm air inside from escaping. As a result, the model greenhouse warmed faster.



4. When a car is in the sun, its windows allow light in. Much of the light is absorbed and radiated as heat. The heat cannot easily escape and the car heats up.
5. Advantages in using a greenhouse include being able to start plants growing early for later planting, the ability to control the conditions in the growth of a plant, and the ability to grow tropical plants in areas where they could not normally grow.
6. If the earth heats up too much, ice caps could melt. Weather could change, causing living things to die because of the resulting changes in balance of the ecosystem.



# Relative Humidity

*Relative humidity* is a measure of the amount of water vapor in the air at a particular temperature compared with the total amount of water the air can hold at the same temperature. In this experiment, you will determine relative humidity at several places inside and outside your school.

## OBJECTIVES

- Measure temperature.
- Determine relative humidity.
- Explain your results.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
2 Temperature Probes  
piece of shoelace, 5 cm long  
masking tape  
beaker  
water



Figure 1

## PROCEDURE

1. Slip Probe 2 into a 5 cm piece of shoelace until the probe tip is at the middle of the shoelace piece as shown in Figure 1. Fasten the shoelace to the probe with masking tape.
2. Connect the Temperature Probes. Start the Vernier data-collection program and open the file “04 Relative Humidity” from the *Middle School Science with Vernier* folder.
3. Wet the shoelace on Probe 2 by placing it into a beaker of water that is at or above room temperature. Probe 1 is to stay dry.
4. Click  to begin data collection. Take a probe in each hand and gently wave the probes in the air.

## Experiment 4

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- Continue waving the probes until the temperatures measured by both probes stop changing, and then click  to end data collection. Record both final temperatures.
- Choose Store Latest Run from the Experiment menu to store your data.
- Repeat Steps 3–6 at another location inside your school. Be sure to re-soak the shoelace on Probe 2 when you are at the new location. Allow approximately one minute for the Temperature Probes to adjust to the temperature at the new location before beginning data collection.
- Repeat Step 3–5 outside your school at a third location. Use water that is at or above the air temperature at the outside location. (For example, if the outside air temperature is 22°C, the water temperature must be 22°C or higher.)

## DATA

	Site 1	Site 2	Site 3
	Classroom	_____	_____
Dry-probe temperature (Probe 1) (°C)			
Wet-probe temperature (Probe 2) (°C)			
Temperature difference (°C)			
Relative humidity (%)			

## PROCESSING THE DATA

- In the space provided in the data table, subtract to find the difference between the dry-probe (Probe 1) and wet-probe (Probe 2) temperatures at each site.
- Determine the relative humidity at each site using the Relative Humidity table above.
  - Find the temperature difference you calculated in Step 1 at the top of the table. Keep one finger on this number.
  - Find the dry-probe (Probe 1) temperature in the first column of the table.
  - Look across the row until you find the column marked with your finger. This is the relative humidity.
  - Record this number in your data table.
- How did the wet-probe temperature compare with the dry-probe temperature at each site? Explain.
- Which site had the highest relative humidity? Why?
- Which site had the lowest relative humidity? Explain.

**RELATIVE HUMIDITY TABLE**

Dry-probe temperature	Dry-probe temperature minus wet-probe temperature (°C)									
	1	2	3	4	5	6	7	8	9	10
10°C	88	77	66	55	44	34	24	15	6	
11°C	89	78	67	56	46	36	27	18	9	
12°C	89	78	68	58	48	39	29	21	12	
13°C	89	79	69	59	50	41	32	22	15	7
14°C	90	79	70	60	51	42	34	26	18	10
15°C	90	80	71	61	53	44	36	27	20	13
16°C	90	81	71	63	54	46	38	30	23	15
17°C	90	81	72	64	55	47	40	32	25	18
18°C	91	82	73	65	57	49	41	34	27	20
19°C	91	82	74	65	58	50	43	36	29	22
20°C	91	83	74	67	59	53	46	39	32	26
21°C	91	83	75	67	60	53	46	39	32	26
22°C	92	83	76	68	61	54	47	40	34	28
23°C	92	84	76	69	62	55	48	42	36	30
24°C	92	84	77	69	62	56	49	43	37	31
25°C	92	84	77	70	63	57	50	44	39	33
26°C	92	85	78	71	64	58	51	46	40	34
27°C	92	85	78	71	65	58	51	46	40	34
28°C	93	85	78	72	65	59	53	48	42	37
29°C	93	86	79	72	66	60	54	49	43	38
30°C	93	86	79	73	67	61	55	50	44	39

**EXTENSIONS**

1. Compare relative humidity values at sunny and shaded sites outdoors.
2. Compare relative humidity values at breezy and protected sites outdoors.



## Relative Humidity

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. In this activity, students take the data-collection equipment outside in order to collect data. The preferred data-collection method is to use an interface, such as a LabQuest, that can function as a standalone device. If your interface must be connected to a computer (e.g., LabQuest Mini or LabQuest Stream), each group will need a laptop or Chromebook.
3. The EasyData (calculator) student version of this activity contains two methods. Use Method 1 if you are collecting data with an EasyTemp or a Temperature Probe connected to an EasyLink. Use Method 2 if you are collecting data with two Temperature Probes and multi-channel interface.
4. Cotton gauze can be substituted for the shoelace piece in this experiment.
5. Have your students test areas that are likely to have relative humidity and/or temperature values different from your classroom. Some possible sites are the kitchen, the gym, and the furnace room.
6. Consider having your students test shady areas, such as under bushes or trees, as well as sunny areas outside the classroom.
7. Relative humidity tables with dry-bulb temperature ranges greater than the 10–30°C range of Table 1 can be found by doing a web search for “relative humidity table.” Relative humidity calculators can be found by doing a web search for “relative humidity calculator.”
8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
9. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

## Experiment 4

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### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	ESS2.D Weather and Climate	Cause and effect Scale, proportion, and quantity Energy and matter

### SAMPLE RESULTS

	Site 1	Site 2	Site 3
	Classroom	Hallway	Outdoors
Dry-probe temperature (Probe 1) (°C)	24.8	18.9	21.5
We- probe temperature (Probe 2) (°C)	18.0	17.3	17.7
Temperature difference (°C)	6.8	1.6	3.8
Relative humidity (%)	5	8	68

### ANSWERS TO QUESTIONS

1. See the Sample Results.
2. See the Sample Results.
3. The wet-probe temperatures are usually lower than the corresponding dry-probe temperatures because evaporating water absorbs energy and cools the wet probe.
4. Answers will vary. The Sample Results were collected on a bright, sunny morning. The shaded hallway, with the highest relative humidity, had not warmed to the extent that the classroom had.
5. Answers will vary. In the Sample Results, the sun-heated classroom had the lowest relative humidity because it had been heated to a higher temperature while the windows were closed.



# Soil Study

Soil is made up of tiny particles of rock, plant, and animal matter. Soil acidity can be expressed using the *pH* scale. The pH scale ranges from 0 to 14. Soils with pH above 7 are basic. Soils with pH below 7 are acidic. A soil with a pH of 7 is neither acidic nor basic, but is *neutral*. The pH and water absorption of soil help to determine which plants will grow well in it. The pH of soil helps to decide which minerals are available for plants. Most plants grow best in soil with a pH of 6.5. Erosion is controlled by how well the soil retains water. In this activity, you will measure the pH of soil and measure how well soil samples absorb water.

## OBJECTIVES

- Measure the pH of soil samples.
- Determine the amount of water retained by soil samples.
- Compare soil samples.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
pH Sensor  
distilled water  
3 or more soil samples  
3 or more jars with lids  
filter paper  
2 containers (one with holes in bottom)  
100 mL graduated cylinder  
beaker  
rinse bottle with distilled water

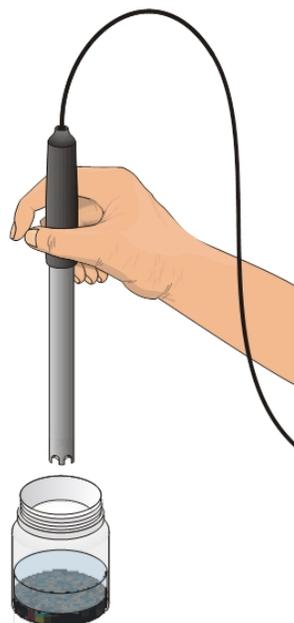


Figure 1

## PROCEDURE

### Part I Soil pH

1. Obtain soil samples as directed by your teacher.
  - a. Write a description of each soil sample in your data table.
  - b. Put three tablespoons of soil and 100 mL of distilled water into a jar with a lid.
  - c. Repeat Step b for your other soil samples.
  - d. Close each jar and shake each one vigorously 50 times.
  - e. Let the soil samples settle for 5 minutes.
  - f. Repeat Steps d and e.

## Experiment 5

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2. Connect the sensor to the computer interface. Start the Vernier data-collection program and open the file “05 Soil Study” from the *Middle School Science with Vernier* folder. The meter will display live pH readings.
3. Remove the pH Sensor from its protective container and store the container safely.
4. Measure the pH.
  - a. Rinse the pH Sensor with distilled water.
  - b. Place the pH Sensor in the liquid part of the soil and water mixture and briefly swirl the mixture. Note the pH reading in the meter.
  - c. When the reading stabilizes, record the pH value in your data table.
5. Repeat Step 4 for each of your other soil samples.
6. Rinse the pH Sensor with distilled water. Return it to its protective container.

### Part II Water Absorption

7. Determine water absorption.
  - a. Place 60 mL (4 tablespoons) of soil on a piece of filter paper.
  - b. Place the filter paper and soil into a container with holes in the bottom.
  - c. Have your lab partner hold this container over a container without holes.
  - d. Pour 100 mL of water through the soil, collecting the water in the bottom container.
  - e. Let the sample drip for 60 seconds.
  - f. Use the 100 mL graduated cylinder to measure the amount of water in the bottom container. Record this value in your data table.
8. Repeat Step 7 for each of your soil samples.

## DATA

Sample	Description	pH	Water volume before (mL)	Water in bottom container (mL)	Water absorbed (mL)
1			100		
2			100		
3			100		

## PROCESSING THE DATA

### Part I Soil pH

1. Which samples were acidic?
2. Which samples were basic?

**Part II Water Absorption**

3. Calculate the amount of water absorbed by each soil sample. Do this by subtracting the volume of water in the bottom container from 100 mL. Record your answers in the data table.
4. Which samples held the most water?
5. How does a soil's ability to hold water relate to soil erosion?
6. What are the characteristics of a good soil?

**EXTENSIONS**

1. Prepare one or more bar graphs from your data.
2. Test soil samples from your backyard or another environment and compare to your first results. Are the results the same or different? Try to explain why.



## Soil Study

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources.
2. Soils provide an anchor for plants and chemical elements necessary for growth. The major elements plants obtain from soil are nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. Some other elements that plants obtain from soil, such as iron and molybdenum, are present in much smaller quantities and are called trace elements. The availability of these elements depends not only on the amount but also on the form that is present, on the rate they are released from the soil, and on the pH of the soil. The pH of soil can range from 4.5 to 9.5. Most plants do well in soil with a pH of 6.5. Above 8.5, soil is too alkaline for most plants, and soil with pH less than 3.5 is too acidic. A more alkaline soil can reduce the availability of iron and manganese. A lower pH can cause molybdenum deficiency. Soils are mixtures of particles classified as gravel, sand, silt, and loam.
3. You can provide the soil samples, students can bring samples from home, or they can get samples from the schoolyard. You may desire to test an array of sandy, silty, and clay loams. All samples should be dry.
4. Show your students how to wash a pH Sensor using a rinse bottle filled with distilled water.
5. Paper towels or coffee filters can be substituted for filter paper.
6. Students can do Part II (water absorption) while their Part I samples settle.
7. Some suggestions for containers with holes in the bottom are small plastic flowerpots, cans with holes punched in the bottom, or milk cartons with holes punched in the bottom. If you use a quart-size milk carton with holes, a half-gallon size container could be used for the collector. A funnel does not work well because the drip rate is too slow.

Students are instructed to allow 60 seconds for the sample to drip through the filter. The actual time needed may vary depending on the container and filter material used. Adjust the time if necessary to match your situation.

## Experiment 5

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- For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
- If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	ESS2.A Earth Materials and Systems ESS2.C The Roles of Water in Earth's Surface Processes	Energy and matter Structure and function

### SAMPLE RESULTS

Sample number	Description	pH	Water volume before (mL)	Water in bottom container (mL)	Water absorbed (mL)
1	Potting soil, very dark in color, small lumps, soft	6.7	100	82	18
2	Garden soil, dried grass, lumps harder and larger	6.3	100	72	28
3	Soil from next to house, very hard, light in color	7.3	100	84	16

### ANSWERS TO QUESTIONS

- Answers will vary.
- Answers will vary.
- See Sample Results.
- Answers will vary.

5. Erosion can be prevented if soil can retain water. It will then not wash away and be lost as readily. The more water a soil can retain, the greater the chance that it will stay where it is.
6. Some factors making a good soil would be ability to retain water, pH, and minerals and nutrients in the soil.





# Absorption of Radiant Energy

Color affects the absorption of radiant energy. You can use the results of this experiment to better dress for the season—to keep cooler in the summer and warmer in the winter.

## OBJECTIVES

- Monitor temperature change due to radiant energy absorption.
- Calculate temperature changes.
- Interpret your results.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
2 Temperature Probes  
lamp and 100 W equivalent bulb  
piece of white paper  
piece of black paper  
tape

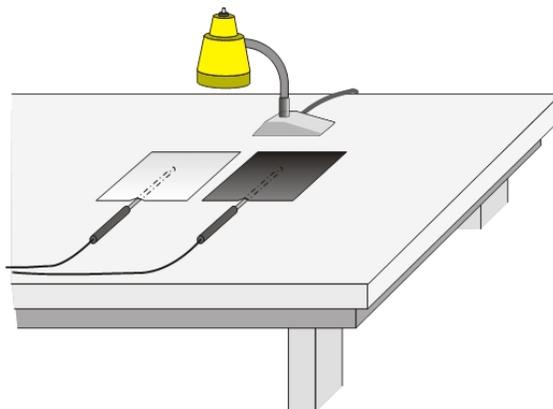


Figure 1

## PROCEDURE

1. Tape two Temperature Probes to the table surface in the arrangement shown in Figure 1.
2. Place a piece of white paper over Probe 1 and a piece of black paper over Probe 2 as shown in Figure 1.
3. Connect the Temperature Probes. Start the Vernier data-collection program and open the file “06 Absorption of Energy” from the *Middle School Science with Vernier* folder.

## Experiment 6

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4. Position a light bulb directly over the boundary between the two pieces of paper and about 10 cm above the paper pieces. The bulb should be the same distance from both probe tips.
5. Click  to begin data collection, then switch on the light bulb. Record the initial temperature measured by each probe.
6. When data collection is complete after 10 minutes, record the final temperature measured by each probe. Turn the light bulb off and return all materials to the places directed by your teacher.
7. To confirm your data, click Statistics,  to display a Statistics box for each probe.
8. Print copies of the graph as directed by your teacher.

## DATA

	Probe 1 White	Probe 2 Black
Final temperature (°C)		
Beginning temperature (°C)		
Temperature change (°C)		

## PROCESSING THE DATA

1. In the space provided in the data table, subtract to find the temperature changes.
2. Which color had the larger temperature increase?
3. Which color had the smaller temperature increase?
4. Why is it better to wear light-colored clothing in the summertime?
5. Solar collectors can be used to absorb the sun's radiation and change it to heat. What color would work best for solar collectors? Explain.

## EXTENSION

Design an experiment to compare the radiant heat absorption of different colors. Perform the experiment you designed.

## Absorption of Radiant Energy

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources. The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in *Graphical Analysis Pro*, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.
2. Construction paper works well in this experiment. Try to obtain pieces with the same texture and thickness. Rectangular 10 cm × 20 cm pieces work well.
3. We suggest the use of 100 W or 150 W bulbs. Remind your students not to touch a hot bulb.
4. The EasyData (calculator) student version of this activity contains two methods. Use Method 1 if you are collecting data with an EasyTemp or a Temperature Probe connected to an EasyLink. Use Method 2 if you are collecting data with two Temperature Probes and multi-channel interface.
5. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
6. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

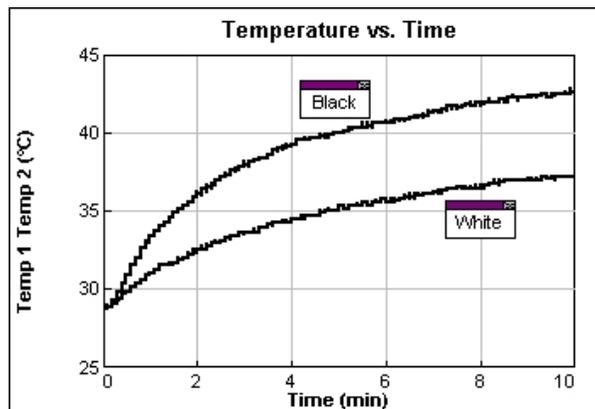
We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	ESS2.D Weather and Climate PS3.B Conservation of Energy and Energy Transfer PS4.B Electromagnetic Radiation	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change

## SAMPLE RESULTS

	Probe 1 White	Probe 2 Black
Maximum temperature	37.4°C	42.9°C
Minimum temperature	28.8°C	28.8°C
Temperature change	8.6°C	14.1°C



## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. Black had the larger temperature increase.
3. The temperature under the white paper increased less.
4. It is better to wear light-colored clothing in the summertime because it absorbs less radiant

energy from the sun and keeps you cooler than dark clothing does.

5. Black works best for use with solar collectors because black absorbs radiant energy best.



# Reflectivity of Light

Light is reflected differently from various surfaces and colors. In this experiment, you will be measuring the percent reflectivity of various colors. You will measure reflection values from paper of the various colors using a Light Sensor and then compare these values to the reflection value of aluminum foil. You will then calculate percent reflectivity using the relationship

$$\% \text{ reflectivity} = \frac{\text{value for paper}}{\text{value for aluminum}} \times 100$$

## OBJECTIVES

- Use a Light Sensor to measure reflected light.
- Calculate percent reflectivity of various colors.
- Make conclusions using the results of the experiment.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Light Sensor  
white paper  
black paper  
aluminum foil  
2 other pieces of colored paper  
ring stand  
utility clamp

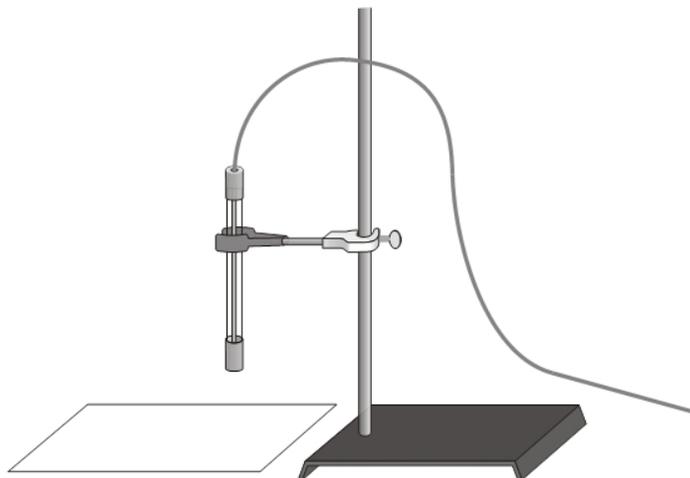


Figure 1

## PROCEDURE

1. If your Light Sensor has a switch, set it to the 0–6000 lux position. Connect the Light Sensor to the computer interface. Open the file “23 Reflectivity of Light” from the *Physical Science w Vernier* folder.
2. Use a utility clamp and ring stand to fasten a Light Sensor 5 cm from and perpendicular to the surface of the table (see Figure 1). The classroom lights should be on.
3. Position a piece of aluminum foil under the Light Sensor.
4. When the reading stabilizes, record the reflected light value (in lux). Lux is the SI unit for brightness of light (which is called illuminance).
5. Obtain pieces of white paper and black paper. Repeat Steps 3–4.
6. Obtain two other pieces of paper of other colors. Repeat Steps 3–4. When you record light values, record the color of the paper as well.
7. Before closing *Logger Pro*, continue to the Processing the Data section.

## DATA

Color	Reflection value	Percent reflectivity
Aluminum		100%
Black		
White		
_____		
_____		

## PROCESSING THE DATA

1. Calculate the percent reflectivity of each color using the formula given in the introduction. Show your work in the data table.
2. Which color, other than aluminum, has the highest reflectivity?
3. Which color has the lowest reflectivity?
4. What surfaces might give a planet a high reflectivity? Explain.
5. Does the planet Earth have high reflectivity? Why or why not?



## **EXTENSIONS**

1. Design an experiment to test the reflectivity of sand, soil, water, and other materials. Perform the experiment you designed.
2. Design an experiment to determine if there is a relationship between reflected light and heat absorbed by various colors or materials. Perform the experiment you designed.



## Reflectivity of Light

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources. In the *Graphical Analysis Pro* file for this experiment, data are included in the video. Students record the data directly into their data table found in the student handout.

The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in *Graphical Analysis Pro*, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.

2. Equal-size pieces of construction paper and aluminum foil can be used and saved for reuse.
3. This experiment can be performed with a Vernier Light Sensor, a Vernier Go Direct Light and Color Sensor, or a TI Light Sensor. The Vernier sensors and the TI Light Sensor do not measure the same quantity, but for the purposes of this experiment the units are not important. A Vernier Light Sensor has three ranges; students are instructed to set its range switch to the 0–6000 lux position. The range of the Vernier Go Direct Light and Color Sensor automatically adjusts; there is no switch to set. Light is the default channel that is active when you connect this sensor. The TI Light Sensor has only one range, so there is no need to set a range.
4. The *Logger Pro*/*Logger Lite* procedure directs students to record reflectivity data from the meter (without clicking **▶ Collect**). Another possibility is to have them use the Selected Events mode in *Logger Pro* or Events with Entry in *Logger Lite*. The *Logger Pro* file for this experiment is already set up for this Selected Events option. Simply have your students click **▶ Collect** and then click **⊗ Keep** when the reading is stable. This saves the reading along with its trial number in the table. The *Logger Lite* file for this experiment is already set up for Events with Entry mode. Simply have your students click **▶ Collect** and then click **⊗ Keep** when the reading is stable. They will need to enter a sample number when prompted.

## Experiment 7

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5. If you are using Go Direct Light and Color, you may want students to turn on the white LED on the sensor to provide a consistent light source. You can also see [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect your sensor. You may want students to turn on the white LED on the Go Direct Light and Color Sensor to provide a consistent light source.
6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS3.B Conservation of Energy and Energy Transfer PS4.B Electromagnetic Radiation ESS2.D Weather and Climate ESS3.D Global Climate Change	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function

### SAMPLE RESULTS

**Note:** The sample data were collected with a Vernier Light Sensor.

Color	Reflection value	Percent reflectivity
Aluminum	737.7 lux	100%
Black	231.2 lux	31.3%
White	582.2 lux	78.9%
Purple	326.9 lux	44.3%
Green	425.1 lux	57.6%

### ANSWERS TO QUESTIONS

1. See the Sample Results.
2. White has the highest reflectivity.
3. Black has the lowest reflectivity.

4. Snow, ice, sand, clouds, and water would be expected to give a planet high reflectivity.
5. 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.



# Schoolyard Study

Our environment is important to all of us. In this activity you will investigate your schoolyard as an environment. Scientists study large areas by looking at samples. One way to sample an environment is to look at data along a straight line called a *transect*. In this experiment, you will gather data along a transect in your schoolyard.

## OBJECTIVES

- Measure ground and air temperatures at various locations along a transect.
- Measure the light intensity at the same locations.
- Observe and classify the living organisms at those locations.
- Determine if there are temperature differences between the ground and air above it.
- Organize and present your results.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Temperature Probe  
Light Sensor  
10 meters of string  
meter stick  
ruler  
2 rubber bands

## PROCEDURE

### Part I Making a Transect

1. Make your transect.
  - a. Stretch 10 meters of string in a straight line across an area of your schoolyard. You will collect data along this line called a transect. Choose a stretch with as many different conditions as possible.
  - b. In the data table, write a description of each location you choose to study along the transect.
  - c. Record observations of any living things you see at the chosen locations.
  - d. Measure and record the distance (in m) from the beginning of your string to each location.
2. In the Sketch of Transect section after the Procedure, make a sketch of your transect. Label each location on the sketch.

## Experiment 8

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### Part II Measuring Temperature and Reflected Light Intensity

3. Connect the Temperature Probe and Light Sensor. If your Light Sensor has a switch, set it to the 0–150,000 lux position.
4. Start the Vernier data-collection program and open the file “08 Schoolyard Study” that matches the type of Light Sensor you are using from the *Middle School Science with Vernier* folder.
5. Measure the surface temperature at one end of your string. Place the tip of the Temperature Probe on the ground. Wait for the temperature reading to stabilize before recording it. **Note:** If there is direct sunlight on the probe tip during data collection, the readings will be too high. To prevent this, use your hand to shade the tip of the probe.
6. Have one person cover the tip of the Light Sensor with his or her hand so that the ground-level light intensity values will be zero.
7. Record the temperature for this location in your data table.
8. Repeat Steps 5–7 for each location along the transect you chose in Step 1.
9. Return to your first location. Fasten the Light Sensor to a ruler using two rubber bands. Slide the Temperature Probe under the rubber bands on the other side of the ruler as shown in Figure 1. Both probe tips should be at the 5 cm mark on the ruler. Uncover the tip of the Light Sensor.

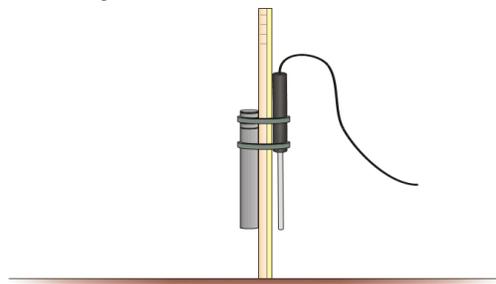


Figure 1

10. Measure the temperature and light intensity 5 cm above the surface at the same locations along your transect. **Note:** If it is a sunny day, hold the ruler so that the Temperature Probe is on the shady side. Record the temperature and light intensity readings in your data table.



## SKETCH OF TRANSECT

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0 m 10 m

## DATA

Distance (m)	Description	Temperature (at surface) (°C)	Temperature (at 5 cm) (°C)	Temperature difference (°C)	Light intensity (lux)

## PROCESSING THE DATA

1. In the space provided in your data table, subtract to find the difference between the temperature on the surface and the temperature above the surface at each location.

## ***Experiment 8***

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2. Which location had the greatest difference between its two temperatures? The smallest difference?
3. Give possible reasons for the results in Question 2.
4. Which location had the highest reflectivity? The lowest?
5. Give possible reasons for the results in Question 4.
6. Look at your reflectivity and temperature data. Do your results follow a pattern? Explain.

### **EXTENSIONS**

1. Prepare one or more bar graphs from your data.
2. Do additional transects in different areas and compare results.
3. Include a pH study of the soils along your transect.

## Schoolyard Study

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and Graphical Analysis). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. In this activity, students take the data-collection equipment outside in order to collect data. The preferred data-collection method is to use an interface, such as a LabQuest, that can function as a standalone device. If your interface must be connected to a computer (e.g., LabQuest Mini or LabQuest Stream) If you usually use computers in the classroom, each group will need a laptop, mobile device, or Chromebook.
3. This experiment can be performed with a Vernier Light Sensor, Vernier Go Direct Light and Color Sensor, or a TI Light Sensor. The Vernier sensors and the TI Light Sensor do not measure the same quantity, but for the purposes of this experiment the units are not important. A Vernier Light Sensor has three ranges; students are instructed to set its range switch to the 0–6000 lux position. The range of the Vernier Go Direct Light and Color Sensor automatically adjusts; there is no switch to set. The TI Light Sensor has only one range, so there is no need to set a range.
4. Help your students pick diverse areas for their transects. If the schoolyard does not present much variety, use a convenient backyard or park area.
5. This activity can be done in any weather. The results will vary depending on the time of day, time of year, weather, and presence of drifting clouds. Each different set of conditions will provide new learning opportunities. You may wish to have your students look at the same transect on different days or in different seasons and do a comparison.
6. You may wish to have your students collect samples. They could collect leaves or twigs that have fallen to the ground, rocks, or soil samples. Provide baggies for the samples.
7. The *Logger Pro*/*Logger Lite* procedure directs students to record data from the meter (without clicking ). Another possibility is to have them use the Selected Events mode in *Logger Pro* or Events with Entry in *Logger Lite*. In *Logger Pro* experiment file for this experiment, have your students click  and then click  when the reading is stable. This saves the reading along with its trial number in the table. In the *Logger Lite* experiment

## Experiment 8

file, have your students click **Collect** and then click **Keep** when the reading is stable. They will need to enter a site number when prompted.

- For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
- If you are using Go Direct sensors, see [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

## ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking questions and defining problems	PS3.B Conservation of Energy and Energy Transfer	Patterns
Planning and carrying out investigations	ESS3.C Human Impacts on Earth Systems	Cause and effect
Analyzing and interpreting data	PS4.B Electromagnetic Radiation	Scale, proportion, and quantity
Using mathematics and computational thinking		Energy and matter
Constructing explanations and designing solutions		Structure and function
Engaging in argument from evidence		

## SAMPLE RESULTS

Description	Temperature (at surface) (°C)	Temperature (at 5 cm) (°C)	Temperature difference (°C)	Light intensity (lux)
Asphalt in the sun	31.4	28.6	2.8	23,600
Asphalt in the shade	20.8	23.0	2.2	1,290
Concrete in the sun	28.2	27.9	0.3	26,900
Concrete in the shade	20.8	21.4	0.6	3,030
Grass in the sun	23.6	27.6	4.0	18,500
Grass in the shade	19.2	20.2	1.0	1,960
Soil in the sun	36.0	30.1	5.9	16,300
Soil in the shade	20.8	22.0	1.2	1,400
Under a bush	17.7	22.3	4.6	373

## **ANSWERS TO QUESTIONS**

1. See the Sample Results.
2. Student answers will vary depending on the temperature and light conditions. The Sample Results are from a sunny day.
3. Answers will vary.
4. Student answers will vary depending on the temperature and light conditions.
5. Answers will vary.
6. Answers will vary.



# A Good Sock

Insulation slows the flow of heat. Cotton, down, nylon, polypropylene, silk, and wool are some of the many insulating materials used in clothing. In this experiment, you will compare the insulating properties of cotton and wool using socks. You will also study the effect of moisture on the insulating properties of cotton.

## OBJECTIVES

- Use two Temperature Probes to measure temperature.
- Calculate temperature changes.
- Make a bar graph.
- Compare the insulating properties of cotton and wool.
- Investigate the effect of water on insulation.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
2 Temperature Probes  
2 plastic bottles  
2 modified lids for bottles  
2 cotton socks  
wool sock  
hot water  
room-temperature water

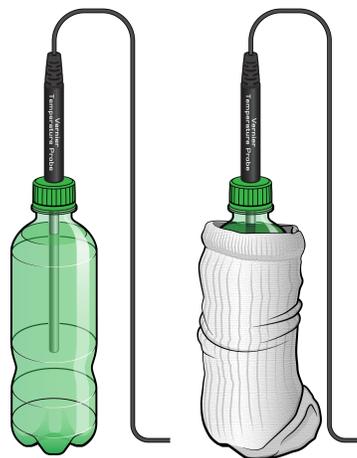


Figure 1

## PROCEDURE

1. Obtain and wear goggles.
2. Connect the Temperature Probes. Start the Vernier data-collection program and open the file “09 A Good Sock” from the *Middle School Science with Vernier* folder.
3. Get two identical bottles and two modified lids that properly fit the bottles.
4. **Note:** Steps 4, 5, and 6 must be done quickly for good results! Carefully fill the bottles with hot water so the water level is just below the neck of the bottle. Screw on the lids, and insert the probes into the bottles. Use a paper towel to dry the bottles.
5. Carefully cover one bottle with a wool sock. Leave the other bottle uncovered.
6. Click  to begin collecting data.

## Experiment 9

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- When data collection has ended, click Statistics, , then click . Record the minimum and maximum temperatures for each bottle.
- Repeat Steps 4–7 using two more identical bottles. Wrap the third bottle with a dry cotton sock, and the fourth bottle with a cotton sock soaked in room-temperature water. **Note:** It is important to begin with the hot water temperatures close to those previously measured in Step 4.

### DATA

	Minimum temperature (°C)	Maximum temperature (°C)	Temperature change (°C)
Uncovered			
Wool sock			
Cotton sock			
Wet cotton sock			

### PROCESSING THE DATA

- In the space provided in the data table, subtract to find the temperature changes.
- Make a bar graph of the results. Plot Material (none, wool, cotton, and wet cotton) on the horizontal axis and Temperature Change (in °C) on the vertical axis.
- Compare the insulation abilities of wool and cotton.
- Discuss how wool slows the transfer of heat.
- What happened to the temperature of the water in the bottle covered with the wet sock? Explain this effect.
- What do the results of this experiment suggest about wet clothing in cold weather?
- What was the purpose of the uncovered bottle in this experiment?

### EXTENSIONS

- Repeat the experiment using cold water instead of warm water.
- Repeat the experiment using wet wool.
- Study the insulating properties of other materials. You might use materials worn by skiers, campers, and mountain climbers.



## A Good Sock

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. The EasyData (calculator) student version of this activity contains two methods. Use Method 1 if you are collecting data with an EasyTemp or a Temperature Probe connected to an EasyLink. Use Method 2 if you are collecting data with two Temperature Probes and multi-channel interface.
3. Small bottles, such as 12 or 16 oz soda or water bottles, work well.
4. Holes in the bottle lids can easily be made by an adult using a hot nail or a knife in plastic bottle lids. A Size-2 or Size-3 one-hole stopper can also be used. Slit the stopper so the Temperature Probe can be removed without being damaged.
5. We use hot tap water for the experiment. A hot plate can be used to heat water, if necessary or desired. It is unnecessary to use water that is uncomfortably hot.
6. Remind your students to focus on the temperature changes. Because of the difficulty of getting uniform beginning temperatures, the relative values of the final temperatures are less significant.
7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
8. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

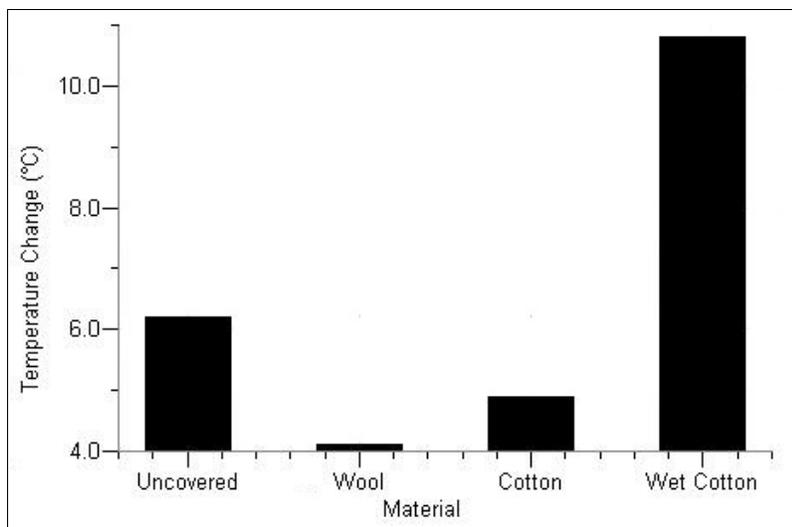
We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	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 Structure and function Stability and change

## SAMPLE RESULTS

	Maximum temperature (°C)	Minimum temperature (°C)	Temperature change (°C)
Uncovered	42.8	36.6	6.2
Wool	42.3	38.2	4.1
Cotton	42.7	37.8	4.9
Wet cotton	42.8	32.0	10.8



## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. See the Sample Results.

3. Wool insulates better than cotton.
4. Wool contains many air spaces. Neither wool nor air conducts heat well. The air spaces are too small for heat to be transferred through the air by convection.
5. The temperature of the water in the bottle covered by the wet sock drops dramatically. The evaporation of water from the sock is an endothermic process. Much of the energy absorbed by the evaporation comes from the warm water in the bottle, causing its temperature to drop.
6. Because the evaporation of water from wet clothing removes heat and lowers temperature, wet clothing can dangerously cool a person during cold weather.
7. In this experiment, the unwrapped bottle serves as a control.



# What Causes the Seasons?

Have you ever wondered why temperatures are cooler in the winter and warmer in the summer? This happens because the Earth's axis is tilted. The Earth remains tilted as it revolves around the sun. Because of this tilt, different locations on the Earth receive different amounts of solar radiation at different times of the year. The amount of solar radiation received by the Earth or another planet is called *insolation*. The *angle of insolation* is the angle at which the sun's rays strike a particular location on Earth. When the north end of the Earth's axis points toward the sun, the Northern Hemisphere experiences summer. At the same time, the south end of the axis points away from the sun and the Southern Hemisphere experiences winter.

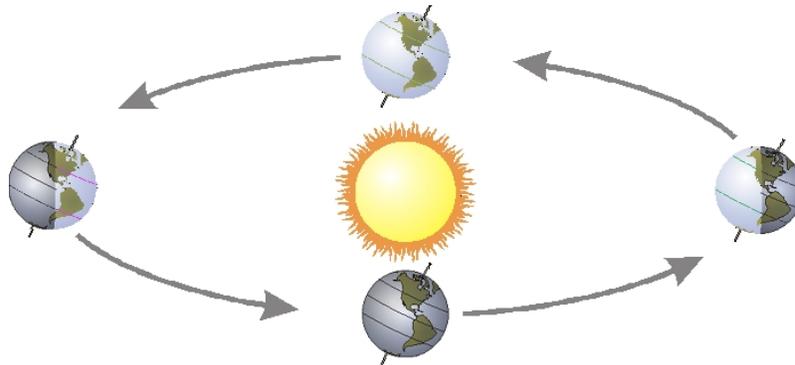


Figure 1

In this experiment you will investigate the relationship between angle of insolation and temperature change due to energy absorption from a simulated sun—a light bulb.

## OBJECTIVES

- Monitor simulated warming of your city by the sun in the winter.
- Monitor simulated warming of your city by the sun in the summer.
- Interpret your results.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Temperature Probe  
ring stand  
utility clamp  
globe of the Earth  
masking tape  
metric ruler  
lamp with 100 W equivalent bulb  
20 cm length of string

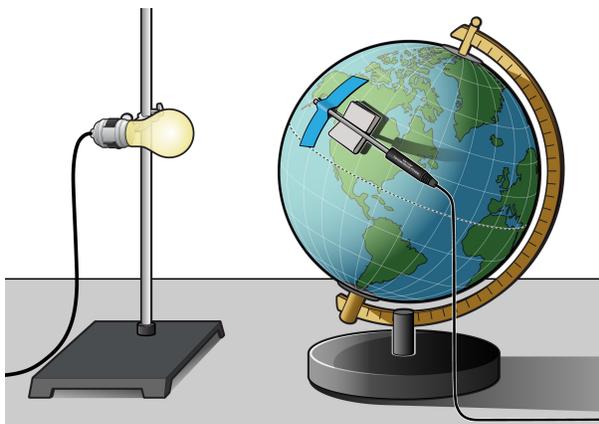


Figure 2

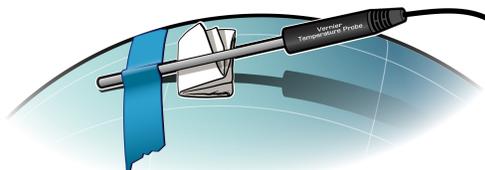


Figure 3

## PROCEDURE

1. Ready the light bulb (simulated sun).
  - a. Fasten the lamp to a ring stand as shown in Figure 2.
  - b. Stand the ring stand and lamp in the center of your work area.
  - c. Position the globe with the North Pole tilted away from the lamp as shown in Figure 2.
  - d. Position the bulb at the same height as the Tropic of Capricorn. **Note:** The sun is directly over the Tropic of Capricorn on December 21, the first day of winter.
2. Tape the Temperature Probe to the globe.
  - a. Find your city or location on the globe.
  - b. Tape the Temperature Probe to the globe with the tip of the probe at your location. Tape the probe parallel to the equator. Place the tape about 1 cm from the tip of the probe.
  - c. Fold a piece of paper and wedge it under the Temperature Probe to keep the tip of the Temperature Probe in contact with the surface of the globe as shown in Figure 3.
3. Position the globe for winter (in the Northern Hemisphere) data collection.
  - a. Turn the globe to position the North Pole (still tilting away from the lamp), your location, and the bulb in a straight line.
  - b. Cut a piece of string 20 cm long.
  - c. Use the string to position your location on the globe 20 cm from the bulb.
  - d. Do not turn on the lamp until directed in Step 5.
4. Connect the Temperature Probe. Start the Vernier data-collection program and open the file “10 What Causes Seasons” from the *Middle School Science with Vernier* folder.
5. Collect winter data.
  - a. Note and record the temperature displayed in the meter.
  - b. Click  to begin data collection.
  - c. After the first temperature reading has been taken, turn on the lamp.

- d. When data collection stops after 5 minutes, turn the lamp off.
  - e. Choose Store Latest Run from the Experiment menu.
6. Position the globe for summer data collection.
    - a. Move the globe to the opposite side of the lamp.
    - b. Position the globe with the North Pole tilted toward the lamp. **Note:** This represents the position of the Northern Hemisphere on June 21, the first day of summer.
    - c. Turn the globe to position the North Pole, your location, and the bulb in a straight line.
    - d. Use the string to position your location on the globe 20 cm from the bulb.
    - e. Do not turn on the lamp until directed in Step 7.
  7. Collect summer data.
    - a. Let the globe and probe cool to the temperature that you recorded in Step 5.
    - b. Click  to begin data collection.
    - c. After the first temperature reading has been taken, turn on the lamp.
    - d. When data collection stops after 5 minutes, turn the lamp off.
    - e. Click Statistics,  , then click  to display Statistics boxes for both runs. Record the minimum and maximum temperature for each run.
  8. Print copies of the graph as directed by your teacher.

## DATA

Beginning temperature (°C)		
	Winter	Summer
Maximum temperature (°C)		
Minimum temperature (°C)		
Temperature change (°C)		

## PROCESSING THE DATA

1. In the space provided in the data table, subtract to find the temperature change for each season.
2. How does the temperature change for summer compare to the temperature change for winter?
3. During which season is the sunlight more direct? Explain.
4. What would happen to the temperature changes if the Earth were tilted more than 23.5 degrees?
5. As you move the globe from its winter position to its summer position, the part of the globe closest to the bulb changes. Describe how it changes.
6. What other factors affect the weather in a region?

**EXTENSION**

Repeat the experiment for other locations in the Northern and Southern Hemispheres.



## What Causes the Seasons?

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. If you use globes with adjustable tilt, make sure the tilt is 23.5 degrees.
3. You may wish to use a fan to cool the globe and probe between runs.
4. If you have 150 watt bulbs available, you may wish to use them to obtain larger temperature changes.
5. Longer data-collection periods can be used.
6. Encourage your students to collect data for other cities and locations as suggested in the extension.
7. The Surface Temperature Sensor also works well for this experiment.
8. If you are collecting data with EasyData (calculators), the following procedure can be used to display graphs of 2 (or 3) successive runs:
  - a. After the first run, select **(File)** from the Main screen, and then select **STORE RUN**.
  - b. Select **(OK)** to store your latest data and overwrite the data in Lists 3 and 4 (L3 and L4).
  - c. Collect data for another run. **Note:** Do not save your last run.
  - d. From the Graph screen, select **(Adv)** and then select **L2 AND L3 VS L1** (or **L2, L3 AND L4 VS L1** if you have 3 runs).
9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
10. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models	ESS1.B: Earth and the Solar System	Patterns
Planning and carrying out investigations	ESS2.D Weather and Climate	Cause and effect
Analyzing and interpreting data	PS3.B Conservation of Energy and Energy Transfer	Scale, proportion, and quantity
Using mathematics and computational thinking	PS4.B Electromagnetic Radiation	Systems and system models
Constructing explanations and designing solutions		Energy and matter
		Stability and change

## SAMPLE RESULTS

	Winter	Summer
Final temperature (°C)	19.4	21.8
Beginning temperature (°C)	17.8	17.9
Temperature change (°C)	1.6	3.9

## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. Answers will vary. In the Sample Results, the summer temperature change is 2.3°C greater than the winter temperature change.
3. In the Northern Hemisphere, the sunlight is more direct in the summer because the earth is tipped toward the sun. A greater amount of solar radiation is directed at a smaller area.
4. If the Earth were tilted at a greater angle, summers would be warmer and winters would be colder.
5. When the globe is rotated from its winter position to its summer position, the lamp goes from a position directly above the Tropic of Capricorn in the Southern Hemisphere to a position directly above the Tropic of Cancer in the Northern Hemisphere.
6. Other factors that affect weather in an area include proximity to water, movement of air masses, and geographic features.

# Solar Homes

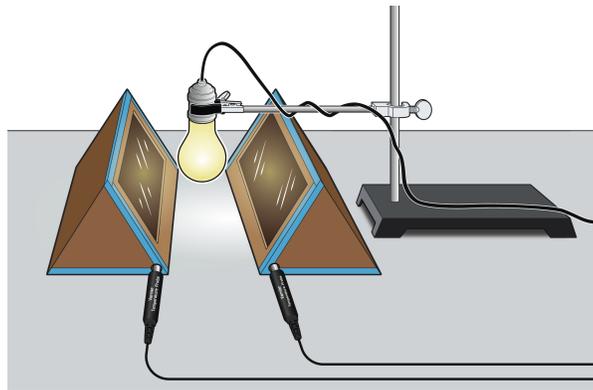
Renewable or alternative energy sources are energy sources other than nonrenewable fossil fuels—coal, oil, and natural gas. Solar energy, or energy from the sun, is one renewable energy source. One type of solar energy is known as passive solar. A passive solar heating system uses no pumps, fans, or mechanical devices. Insulation and heat storage are important factors in such a system. Heat can be stored using thermal masses, also called heat sinks. Thermal masses can keep a home from heating or cooling too fast. In this experiment, you will examine the effectiveness of a heat sink. You will then use what you learn to design and build a model solar home.

## OBJECTIVES

- Measure temperature.
- Find the relationship between thermal mass and the ability of a solar home to retain heat.
- Design, build, and test a model solar home.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
2 Temperature Probes  
2 model solar homes  
ruler  
tape  
plastic bottle with cap  
room-temperature water  
lamp with bulb



*Figure 1*

## PROCEDURE

### Part I

1. Place two model solar homes 20 cm apart with the window sides facing each other.
2. Fill a bottle with room-temperature water. Firmly tighten the bottle cap and place the filled bottle inside one of the model solar homes. This will be the thermal mass.
3. Tape both model homes shut.
4. Position a lamp to shine down between the model solar homes as shown in Figure 1. The lamp bulb should be 10 cm above the table top and equidistant from the two model homes. Do not turn the lamp on yet.
5. Place a Temperature Probe through the hole in each model solar home. Position each probe so that only the metal part is inside the home. Also, make sure the probe is not in direct light from the lamp.
6. Connect the Temperature Probes. Start the Vernier data-collection program and open the file “11 Solar Homes” from the *Middle School Science with Vernier* folder.
7. Click  to start data collection. Turn the light on after the first set of temperature readings appears in the table.
8. After 15 minutes, turn the light off and cover the window of each model solar home with a piece of cardboard. Data collection will end when a total of 30 minutes has passed.
9. Determine the maximum temperature reached in each of the model solar homes:
  - a. Click Examine, .
  - b. Move the cursor to the maximum temperature on the curve for the home with no heat sink. Record this value in the data table.
  - c. Move the cursor to the maximum temperature on the curve for the home with a heat sink and record this value in the data table.
10. Move the cursor to the last data point. Record the two final temperatures in the data table.
11. (optional) Print copies of the graph.

## DATA

	Maximum temperature (°C)	Final temperature (°C)	$\Delta t$ (°C)
No heat sink			
Heat sink			

## **PROCESSING THE DATA (PART I)**

1. In the space provided in the data table, subtract to find the temperature changes. Which model solar home cooled more?
2. How are the “no heat sink” and the “heat sink” curves similar? How are they different?
3. Which model solar home heated more slowly?
4. Which model solar home cooled more slowly?
5. What effect does the thermal mass have on the heating and cooling of a model solar home?
6. What are some advantages of heating a home with solar energy?
7. What is a disadvantage of heating a home with solar energy?

### **Part II Design Problem**

1. Design and build a model solar home that cools more slowly than the one you tested in the experiment. Follow these criteria:
  - Your design should be similar in size and shape to the ones you testing in the experiment so you can compare your results.
  - You may add no more than 3 cm to the thickness of the walls.
  - You may use no more than 500 mL of thermal mass.
  - Your home must have a window with an area of at least 150 cm<sup>2</sup>.
2. When testing your model, first use a lamp to raise the inside temperature to equal the maximum temperature inside the “with thermal mass” model in Part I. Then turn off the lamp, cover the window, and monitor temperature for 15 minutes as in Part I.
3. Compare the results with your Part I results and the Part II results of your classmates.
4. Explain why you chose the materials you did.

## **EXTENSIONS**

1. Run the experiment for two or more consecutive “daily” cycles of four hours or longer.
2. Design an experiment to test other types of thermal mass, such as stones or phase-change materials.
3. Design an experiment to test other variables affecting a solar home, such as color, window material, window size, and insulation type.



## Solar Homes

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. If you are using calculators for data collection, this activity can be performed with calculators from the TI-83 Plus or TI-84 Plus families (except the TI-84 Plus CE) and a multi-channel interface. It cannot be performed with Easy products because both runs of data must be collected at the same time under similar conditions.
3. The model solar homes can be made from cardboard. Cut three  $15 \times 25$  cm rectangular pieces for the sides and two equilateral triangles with 15 cm sides for the ends. In one of the rectangular pieces, cut a window, leaving a 3 cm "window frame" to which you can attach a transparent window. Make a hole for the Temperature Probe on the lower front corner of one of the triangular sides and place black construction paper on the floor. To reduce heat loss, tape all edges of the model home. **Note:** Leave one side open so that students can insert the heat sink before they start data collection. Provide tape so students can seal the side.
4. Another option is to make the model solar homes out of available boxes such as shoe boxes. Each group needs two identical boxes.
5. The transparent windows can be made of plastic wrap, Plexiglass, or any clear plastic material.
6. Give your students some class time for design and test purposes in preparation for the Part II competition.
7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
8. If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

## Experiment 11

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### ESTIMATED TIME

We estimate that Part I of this experiment can be completed in one 45–60 minute class period. Part II directs students to design and test their own model solar home; this can take an additional one or two periods depending on how much structure you provide.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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	ESS3.C Human Impacts on Earth Systems PS4.B Electromagnetic Radiation ETS1.A Defining Engineering Problems ETS1.B Developing Possible Solutions	Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change

### SAMPLE RESULTS

	Maximum temperature (°C)	Final temperature (°C)	$\Delta t$ (°C)
No heat sink	27.2	23.1	4.1
Heat sink	25.5	23.9	1.6

### ANSWERS TO QUESTIONS

1. See the Sample Result. The model solar home with no heat sink cooled more.
2. Answers will vary.
3. The “heat sink” model solar home heated more slowly, and its maximum temperature was lower than that of the “no heat sink” model.
4. The “heat sink” model solar home cooled more slowly, and its final temperature was higher than that of the “no heat sink” model.
5. Thermal mass causes a model solar home to heat and cool more slowly.
6. Solar energy is renewable and non-polluting.
7. Weather dependency is a disadvantage of solar heating.



# Ocean Floor Mapping

Oceanographers, marine geologists, and archeologists use sound to investigate objects below the surfaces of bodies of water. A signal is sent out and bounces back from a submerged surface. Scientists use the speed of sound in water and the time it takes for the signal to bounce back to calculate the depth of the object. *Sonar* is the name given to this system. The Motion Detector works in a similar manner. In this activity, you will use a Motion Detector to map objects on a simulated ocean floor.

## OBJECTIVES

- Use a Motion Detector to measure distances.
- Map simulated ocean floors.
- Analyze graphs to find the heights of objects on a simulated ocean floor.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Motion Detector  
1 m board  
masking tape or wide rubber bands  
2 or more boxes

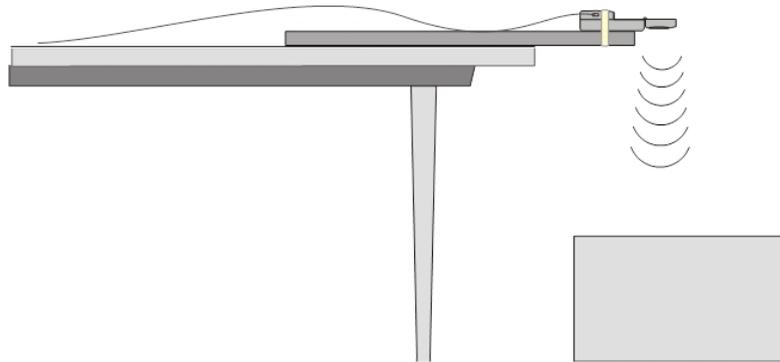


Figure 1

## PROCEDURE

### Part I Ocean Floor 1

1. Prepare the Motion Detector for data collection.
  - a. Get the board that will act as the support for your Motion Detector.
  - b. Tape or clamp the Motion Detector to one end of the board. Make sure that the round screen of the Motion Detector is not covered and is pointing downward.
  - c. Place the board with the Motion Detector flat on your table as shown in Figure 1.
  - d. Connect the Motion Detector. If the Motion Detector has a sensitivity switch, set it to Ball/Walk.



2. Prepare the ocean floor for data collection.
  - a. Place the box on the floor underneath the Motion Detector. **Note:** The Motion Detector must be at least 15 cm from the top of the box.
  - b. Line up the Motion Detector so that when it is moved along the table edge it will pass over the box.
3. Start the Vernier data-collection program and open the file “12 Ocean Floor Mapping” from the *Middle School Science with Vernier* folder.
4. To zero the sensor, click  with the Motion Detector in place.
5. Collect data.
  - a. Move the board to position the Motion Detector to the left of the box.
  - b. Click  to begin data collection.
  - c. When you hear clicking, slowly slide the board across the tabletop so that the Motion Detector passes over and past the box.
6. Record the measured distances.
  - a. Select a flat portion of the graph that represents the box.
  - b. Click Statistics, . Record the Mean (average) height of the box in meters.
7. Sketch and label your graph.

### Part II Ocean Floor 2

8. Prepare Ocean Floor 2.
  - a. Set up two boxes in the shape of steps. The tallest box must be at least 15 cm from the Motion Detector.
  - b. Repeat Steps 4–6. Be sure to record all both heights.

### Part III Hidden Ocean Floor

9. Your teacher will have a hidden ocean floor for you to measure. Repeat Steps 4–6 for the concealed object or objects. **Note:** If the table is a different height than the one you were using previously, zero your sensor before collecting data.

**DATA**

	Box height (m)
Ocean floor 1: single box	
Ocean floor 2: box 1	
Ocean floor 2: box 2	
Hidden ocean floor: box 1	
Hidden ocean floor: box 2	
Hidden ocean floor: box 3	

**GRAPH SKETCHES**

Ocean Floor 1

Ocean Floor 2

Hidden Ocean Floor

**PROCESSING THE DATA**

1. In the space provided in the data table above, find the height of each box. Do this by clicking Examine, , and moving the cursor across the line that represents each of the boxes.
2. Which was your best result? Why do you think it was better than your other results?
3. How did the shape of your graph compare to the actual object(s) in each case? Explain.
4. What factors might affect the accuracy of real ocean-floor mapping?

**EXTENSIONS**

1. Try other hidden ocean-floor arrangements.
2. Research the sonar process and compare it to what you did in this activity.



## Ocean Floor Mapping

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. There are several motion detectors that can be used for this activity. See [www.vernier.com/motion-detectors](http://www.vernier.com/motion-detectors) for options.
3. The boxes should be at least 10 cm wide and 10 cm tall.
4. Best results are obtained when the boxes are positioned so they are either touching each other or at least 50 cm apart.
5. The tabletops should be smooth and flat.
6. Boards longer than 1 m can be used. They should provide rigid support for the motion detector.
7. The hidden arrangement can be located behind a counter or demonstration table.
8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
9. If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	ESS2.A Earth Materials and Systems PS4.A: Wave Properties	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter

## SAMPLE RESULTS

	Box height (m)
Ocean floor 1: single box	0.14
Ocean floor 2: box 1	0.50
Ocean floor 2: box 2	0.75
Hidden ocean floor: box 1	0.18
Hidden ocean floor: box 2	0.45
Hidden ocean floor: box 3	0.28

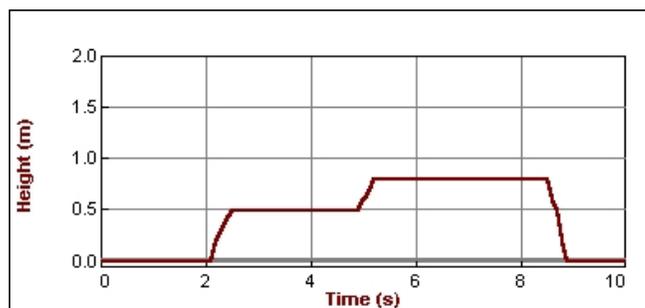


Figure 1 A two-box simulated ocean floor

## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. Answers will vary.
3. The shape of the graph is similar to the shape of the objects.

4. Real ocean-floor mapping is affected by the water, water temperature, ocean currents, weather, and interfering objects.





# Boiling Temperature of Water

The *physical properties* of a pure substance can be used to identify the substance and distinguish it from other pure substances. *Boiling temperature* is one such physical property. This is the temperature at which a substance changes rapidly from its liquid state into a gas. Rapid formation of bubbles is evidence that the liquid is at its boiling temperature. In this experiment, you will study the boiling of water.

## OBJECTIVES

- Observe the boiling of water.
- Measure temperature.
- Analyze data.
- Use your data and graph to make conclusions about boiling.
- Determine the boiling temperature of water.
- Apply the concepts studied in a new situation.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Temperature Probe  
ring stand  
utility clamp  
250 mL beaker  
hot plate  
water  
goggles

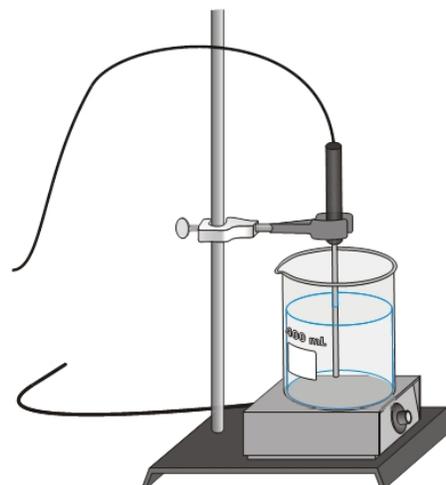


Figure 1

## PROCEDURE

1. Obtain and wear goggles. **Caution:** Handle hot water and hot equipment with care throughout the experiment.
2. Prepare the water sample.
  - a. Arrange a hot plate next to the base of a ring stand as shown in Figure 1.
  - b. Fill a 250 mL beaker 2/3 full with hot tap water.
  - c. Place the 250 mL beaker on the hot plate. Turn the hot plate to the temperature setting suggested by your teacher.
  - d. Use a utility clamp to suspend a Temperature Probe on the ring stand as shown in Figure 1. The tip of the probe should be 1–2 cm above the bottom of the beaker. **Caution:** Do not burn yourself or melt a probe wire with the hot plate!

## Experiment 13

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3. Connect the Temperature Probe. Start the Vernier data-collection program and open the file “13 Boiling Water” from the *Middle School Science with Vernier* folder.
4. Click  to begin data collection.
5. Record your observations as the water is heated to its boiling temperature and boils.
6. When the water has boiled with noticeable bubbling for six minutes, click  to end data collection. Turn off the hot plate and remove the Temperature Probe from the boiling water. Allow the beaker, water, and hot plate to cool before handling them.
7. On the displayed graph, analyze the flat part of the curve to determine the boiling temperature of water.
  - a. Move the mouse pointer to the beginning of the graph’s flat part. Click and drag across the flat part to select it.
  - b. Click Statistics, . The mean temperature value for the selected data is listed in the statistics box on the graph. Record this value as the boiling temperature in your data table.
8. Sketch or print the graph as directed by your teacher. Label the boiling temperature on your graph.

## OBSERVATIONS

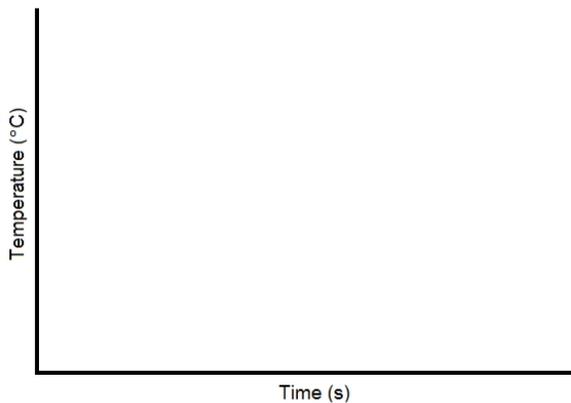
### DATA

Boiling temperature of water: \_\_\_\_\_ °C

### PROCESSING THE DATA

1. Describe your temperature vs. time graph.
2. What happened to the temperature of the water as it was heated prior to boiling?
3. What happened to the temperature of the water as it boiled?
4. The boiling temperature of isopropyl alcohol is 82°C. In the space to the right, sketch and label a graph for the boiling of isopropyl alcohol. Use a starting temperature of 20°C. Identify the

boiling temperature on the graph.



### **EXTENSION**

Determine the boiling temperatures of other liquids.



## Boiling Temperature of Water

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources. The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in *Graphical Analysis Pro*, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.
2. This experiment can be done using burners, but we recommend the use of hot plates. Modify the procedure to fit your equipment.
3. Boiling temperature is pressure dependent and is affected by altitude. Varying weather conditions cause the boiling temperature of water to vary at any one location.
4. As it is written, this experiment directs students to print graphs. If you prefer to have your students graph by hand, instruct them to record data from the table at half-minute intervals for this purpose.
5. Consult the *Science Catalog Reference Manual*, available from Flinn Scientific, Inc., [www.flinnsci.com](http://www.flinnsci.com), concerning safety when selecting liquids for the Extension.
6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
7. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS1.A Structure and Properties of Matter PS3.A Definitions of Energy	Cause and effect Systems and system models Energy and matter Structure and function Stability and change

## SAMPLE RESULTS

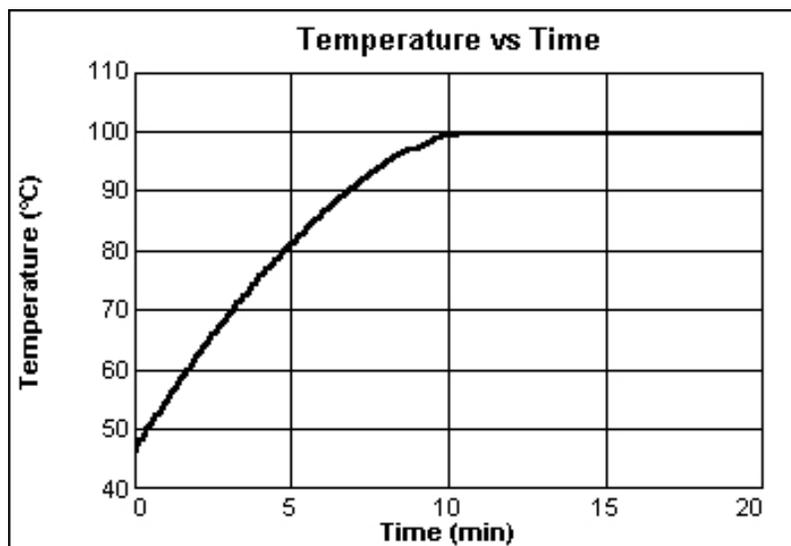


Figure 1 Boiling temperature of water

## ANSWERS TO QUESTIONS

- Answers will vary.
- The temperature increases as the water is heated prior to boiling.
- The temperature stays relatively constant at about 100°C during boiling. **Note:** Although the ideal boiling temperature of water is 100°C, factors such as water hardness and atmospheric pressure can cause deviation from this value.
- The graph should have the same shape as the water-boiling curve. The plateau should be at 82°C instead of 100°C.

# Freezing Temperature of Water

*Freezing temperature* is the temperature at which a substance turns from a liquid to a solid. In this experiment, you will study the freezing of water and find its freezing temperature.

## OBJECTIVES

- Observe the freezing of water.
- Measure temperature.
- Analyze data.
- Use your data and graph to make conclusions about freezing.
- Determine the freezing temperature of water.
- Apply the concepts studied in a new situation.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Temperature Probe  
ring stand  
utility clamp  
test tube  
400 mL beaker  
10 mL graduated cylinder  
distilled water  
tap water  
ice  
salt  
spoon

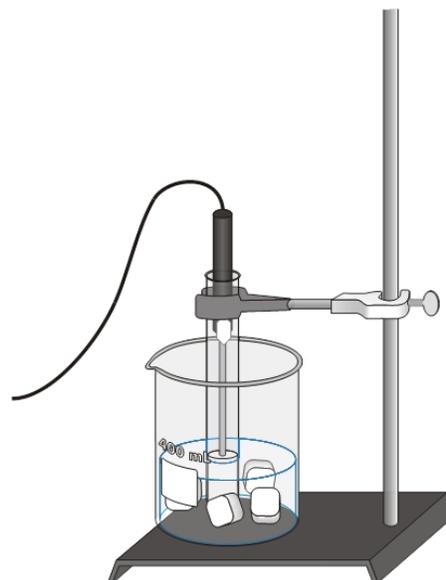


Figure 1

## PROCEDURE

1. Fill a 400 mL beaker 1/3 full with ice, then add 100 mL of water.
2. Put 5 mL of water into a test tube and use a utility clamp to fasten the test tube to a ring stand. The test tube should be clamped above the water bath. Place the Temperature Probe into the water inside the test tube as shown in Figure 1.
3. Connect the Temperature Probe. Start the Vernier data-collection program and open the file “14 Freezing Water” from the *Middle School Science with Vernier* folder.
4. When everything is ready, click  to begin data collection. Then lower the test tube into the ice-water bath.

## Experiment 14

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5. After lowering the test tube, add five spoons of salt to the beaker and stir with a spoon. Continue to stir the ice-water bath.
6. Slightly, but continuously, move the probe during the first 10 minutes of data collection. Be careful to keep the probe in, and not above, the ice as it forms. When 10 minutes have gone by, stop moving the probe and allow it to freeze into the ice. Continue to stir the ice-water bath. Add more ice cubes as the original ice cubes get smaller.
7. When 15 minutes have passed, data collection will stop.
8. Make and record observations as the water freezes.
9. On the displayed graph, analyze the flat part of the curve to determine the freezing temperature of water.
  - a. Move the mouse pointer to the beginning of the graph's flat part. Click and drag across the flat part to select it.
  - b. Click Statistics, . The mean temperature value for the selected data is listed in the statistics box on the graph. This is your value for the freezing temperature of water. Record it in your data table.
10. Sketch or print the graph as directed by your teacher. Label the freezing temperature on your graph.
11. Do not attempt to remove the Temperature Probe from the ice! Place the test tube into a beaker of warm water to melt the ice, then remove the Temperature Probe.

## OBSERVATIONS

### DATA

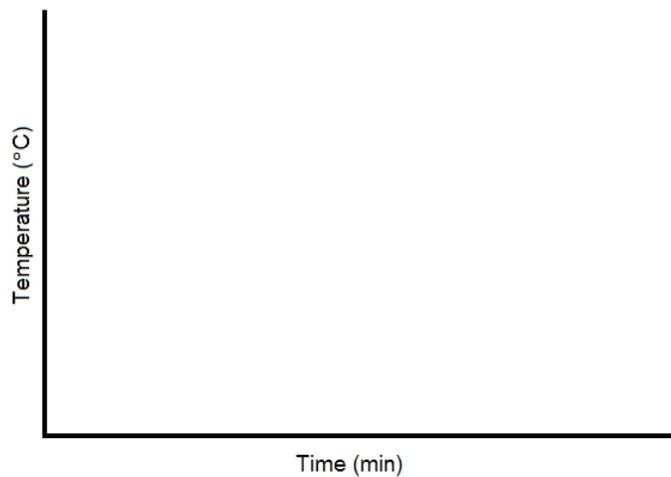
Freezing temperature of water: \_\_\_\_\_ °C

### PROCESSING THE DATA

1. Describe your temperature vs. time graph.
2. What happened to the temperature of the water during freezing?



3. Phenyl salicylate has a freezing temperature of  $41.5^{\circ}\text{C}$ . In the space to the right, sketch and label a freezing curve for phenyl salicylate. Be sure to indicate the freezing temperature on the graph.



### **EXTENSION**

Modify the procedure to study the freezing of another substance suggested by your teacher.



## Freezing Temperature of Water

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources. The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in *Graphical Analysis Pro*, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.
2. Size 18 × 150 mm test tubes work well for this experiment. Sizes 20 × 150 mm and 25 × 150 mm work as well.
3. A water sample size of 5 mL works well. Larger samples will take more time than is provided in this procedure.
4. As it is written, this experiment directs students to print graphs. If you prefer to have your students graph by hand, instruct them to record data from the table at half-minute intervals for this purpose.
5. If you want your students to also determine the melting temperature of water, have them monitor temperature after removing the test tube from the cold-water bath. For best results, the probe should not be moved during melting.
6. Moving the temperature probe during freezing gives more constant freezing temperature readings and delays the drop of temperature below freezing temperature. No probe movement, in contrast, gives more constant temperature readings during melting.
7. Some possible substances for use in a modified version of this experiment are:
  - Palmitic acid (Hexadecanoic acid) (m.p. = 63°C)
  - Lauric acid (Dodecanoic acid) (m.p. = 44°C)
  - tert-Butanol (2-Methyl-2-Propanol) (m.p. = 25.5°C)

**Note:** Treat all laboratory chemicals with caution. Prudent laboratory practices should be observed. See Appendix D for additional safety information.

## Experiment 14

- For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
- If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

## ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS1.A Structure and Properties of Matter PS3.A Definitions of Energy	Cause and effect Systems and system models Energy and matter Structure and function Stability and change

## SAMPLE RESULTS

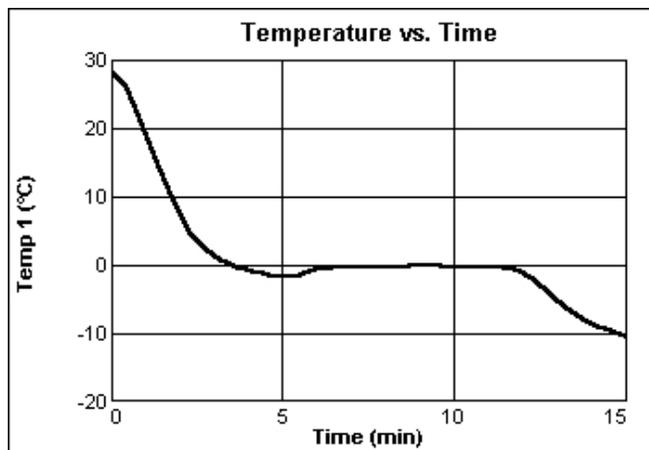


Figure 1 Freezing of water

## ANSWERS TO QUESTIONS

- Answers will vary.
- The temperature stays relatively constant at about 0°C during freezing.

3. The graph should have the same shape as the water-freezing curve. The plateau should be at 41.5°C, phenyl salicylate's freezing temperature, instead of 0°C.



# How Low Can You Go?

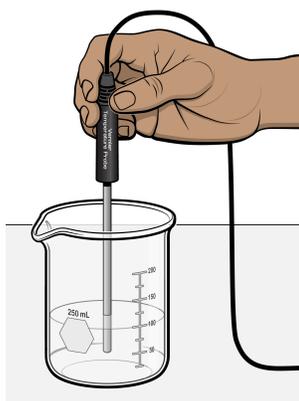
In this experiment, you will first find the normal melting temperature of ice. Then by adding salt to melting ice, you will see the effect of salt on the melting temperature of ice. You will next make and test a plan for reaching the coldest temperature using water, ice, and salt. Finally, you will have a contest to see which group can make their mixture reach the lowest temperature.

## OBJECTIVES

- Measure temperature.
- Find the normal melting temperature of ice.
- See the effect of adding salt on ice's melting temperature.
- Plan and test an experiment to find the salt and ice combination that will make the coldest temperature.
- Compete with other groups trying to reach the coldest temperature.
- Apply the results of the experiment.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Temperature Probe  
250 mL beaker  
crushed ice  
salt  
balance



*Figure 1*

## PROCEDURE

### Part I The Melting Temperature of Ice

1. Connect the Temperature Probe. Start the Vernier data-collection program and open the file “15 How Low Can You Go” from the *Middle School Science with Vernier* folder.
2. Put 100 mL of crushed ice into a 250 mL beaker.
3. Place the Temperature Probe into the ice, then click  to begin data collection.
4. Hold the beaker in one hand and the Temperature Probe with your other hand. Stir the ice until a steady temperature is reached. Record this temperature. It is the normal melting temperature of ice.

### Part II The Effect of Salt on Ice’s Melting Temperature

5. Add 5.0 grams of salt to the ice water and stir. Continue stirring until the temperature stops dropping.
6. Record the lowest temperature reached. Then click  to end data collection.

### Part III Finding the “Coldest” Mixture

7. Make and test a plan for finding the coldest possible temperature using 5.0 grams of salt and the materials used in Parts I and II. Outline your plan in the Contest Plan section.

### Part IV The Coldest-Temperature Contest

8. Set up the equipment as in Part I.
9. Put the amounts of water and ice you found to be best in Step 7 into the 250 mL beaker.  
**Note:** All student groups should do this part of the experiment at the same time.
10. Get 5 grams of salt from your teacher. Add this salt to the water and ice. Place the Temperature Probe into the water, ice, and salt mixture and then click  to begin data collection.
11. Stir until your coldest temperature is reached. Then click  to end data collection.

## DATA

Part I: Normal melting temperature of ice (°C)	
Part II: Coldest salt and ice-water temperature (°C)	



## CONTEST PLAN

### PROCESSING THE DATA

1. How does the melting temperature of water (ice) compare with its freezing temperature?  
**Hint:** See your results for Experiment 14, “Freezing Temperature of Water.”
2. What is the effect of adding salt on ice’s melting temperature?
3. If you had a chance to repeat the contest, what would you do differently?
4. List some uses for the ideas studied in this experiment.



# Freezer Bag Ice Cream

As you have learned, the freezing temperature of water is lowered when salt is added. Using this knowledge, you are going to make vanilla ice cream!

## MATERIALS

### Ice Bag

4 L (1 gallon) zip-top freezer bag  
90 mL (6 tablespoons) table salt  
2 double handfuls of ice  
250 mL (1 cup) water

### Ice Cream Bag

1 liter-size (1 quart) zip-top freezer bag  
250 mL (1 cup) milk  
30 mL (2 tablespoons) sugar **or** equivalent  
sweetener  
5 mL (1 teaspoon) vanilla

### Also Needed

cup or bowl  
spoon

## PROCEDURE

**Caution:** *If you have medical problems with any of these ingredients, see the teacher.*

1. Put the milk, vanilla, and sugar into the smaller bag.
2. Seal this bag after squeezing out most of the air.
3. Put the ice, salt, and water into the larger bag.
4. Place the “ice-cream” bag into the “ice” bag and seal the “ice” bag.
5. Hold the top corners of the “ice” bag and gently slosh it side to side. Do this gently, or the bag could break.
6. Slosh until the contents of the bag start to get firm.
7. Mix the contents of the “ice-cream” bag by squeezing it to keep the ice cream from being both frozen and runny.
8. Slosh until the “ice cream” has the feel of play dough.
9. Remove the “ice cream” bag. Empty the “ice” bag into a sink.
10. Very quickly rinse the “ice cream” bag with cold water to wash off some of the salt.
11. Do not open the bag! Cut off one of the lower corners and squeeze the ice cream into a cup and enjoy it. **Note:** Do not eat directly from the bag. This melts the ice cream quickly and causes a mess!



## How Low Can You Go?

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. This experiment works best with crushed ice, but it will also work well with small ice cubes. Take the ice out of the freezer for a few minutes prior to the beginning of the experiment.
3. Part III is considered by many teachers to be the most important part of this experiment. Be sure to devote adequate time and effort to this part and shape it to fit your style and situation.
4. To ensure a fair contest, have 5.0 g portions of salt measured out prior to the contest.
5. Offer prizes to the contest winners to increase the interest level.
6. For safety reasons, you should take your students to a home economics or lunchroom for the optional "Freezer Bag Ice Cream" activity found at the end of the student pages of the experiment.
7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
8. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

We estimate that together, Parts I and II of this experiment can be completed in one 45–60 minute class period. Parts III and IV direct students to design and test materials to find the coldest possible temperature; this can take an additional one or two periods depending on how much structure you provide. The optional activity "Freezer Bag Ice Cream" also takes an additional class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS1.A Structure and Properties of Matter PS3.A Definitions of Energy	Cause and effect Systems and system models Energy and matter Structure and function Stability and change

## SAMPLE RESULTS

Part I: Normal melting temperature of ice (°C)	0
Part II: Coldest salt and ice-water temperature (°C)	-9.2

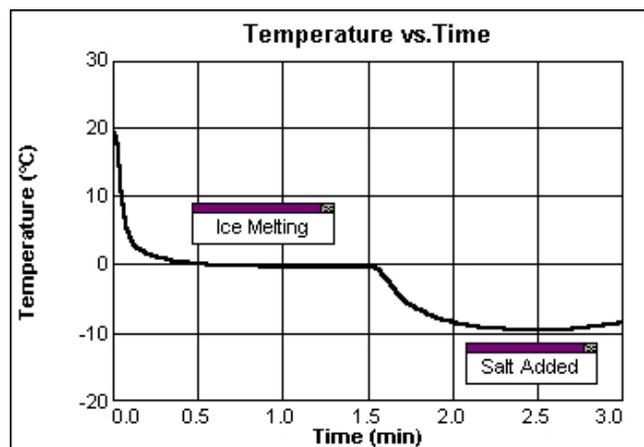


Figure 1 Stirred slush without and then with salt added

## ANSWERS TO QUESTIONS

1. The melting temperature of water, 0°C, is the same as its freezing temperature, also 0°C.
2. Adding salt lowers the melting temperature of ice.
3. Answers will vary.
4. Melting ice on roads and sidewalks and ice cream making are some common uses of the ideas studied in this experiment.

## **ACKNOWLEDGMENT**

We are grateful to Dan Keith for the “Ziplock<sup>®</sup> Ice Cream” recipe (also known as the "Freezer Bag Ice Cream" recipe).





# A Good Cold Pack

Cold packs are used to treat sprained ankles and similar injuries. A cold pack is typically made of a thin plastic inner bag containing water. That bag, in turn, is surrounded by a heavier plastic bag containing a solid substance. When the pack is twisted, the inner bag breaks and releases the water. As the solid substance dissolves in the water, energy is absorbed and the resulting mixture gets colder.

In this experiment, you will first determine temperature changes as several different solid substances dissolve in water. You will then develop and test a plan for making the best cold pack using 3.0 grams of one of the substances and the best amount of water.

## OBJECTIVES

- Measure temperature.
- Determine temperature changes as solid substances dissolve in water.
- Design and test a plan for making the best cold pack.
- Report your results.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Temperature Probe  
goggles  
balance  
weighing paper  
50 mL beaker  
250 mL beaker  
10 mL graduated cylinder  
water  
ammonium chloride,  $\text{NH}_4\text{Cl}$   
citric acid,  $\text{H}_3\text{C}_6\text{H}_5\text{O}_7$   
potassium chloride,  $\text{KCl}$   
sodium bicarbonate,  $\text{NaHCO}_3$   
sodium carbonate,  $\text{Na}_2\text{CO}_3$

**WARNING:** *Treat all laboratory chemicals with caution. Safe laboratory practices should be observed.*

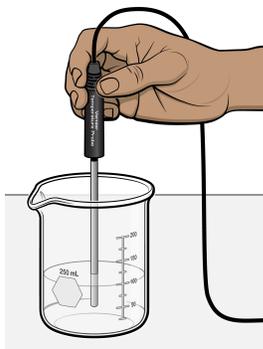


Figure 1

## PROCEDURE

### Part I Finding Temperature Changes

1. Obtain and wear goggles.
2. Connect the Temperature Probe. Start the Vernier data-collection program and open the file “16 A Good Cold Pack” from the *Middle School Science with Vernier* folder.
3. Measure out 3.0 g of each of the test substances. Use and label a new piece of weighing paper for each substance.
4. Use a 10 mL graduated cylinder to measure out 10 mL of room-temperature water into a clean 50 mL beaker.
5. Collect temperature data.
  - a. Place the Temperature Probe into the 50 mL beaker containing the 10 mL of water.
  - b. Gently stir with the probe and note the temperature displayed in the meter.
  - c. When the temperature stops changing, click  to begin data collection.
  - d. Monitor the temperature for 5 seconds to establish the initial temperature of the water.
  - e. Carefully add the solid ammonium chloride to the water. Stir gently with the Temperature Probe.
  - f. When the temperature stops changing, click  to end data collection.
  - g. Click Statistics,
6. Repeat Steps 4–5 for each of the remaining substances. Clean the probe after each run and place it into a 250 mL beaker containing room-temperature water to bring the probe back to room temperature.

### Part II Finding the Best Cold-Pack Mixture

7. Make and test a plan for making the coldest temperature using 3.0 g of one of the solid substances and the best amount of water. Turn in a report that includes your procedure and results.

**DATA**

Substance	Maximum temperature (°C)	Minimum temperature (°C)	Temperature change (°C)
Ammonium chloride (NH <sub>4</sub> Cl)			
Citric acid (H <sub>3</sub> C <sub>6</sub> H <sub>5</sub> O <sub>7</sub> )			
Potassium chloride (KCl)			
Sodium bicarbonate (NaHCO <sub>3</sub> )			
Sodium carbonate (Na <sub>2</sub> CO <sub>3</sub> )			

**PROCESSING THE DATA**

1. In the space provided in the data table, subtract to calculate the temperature changes. If the temperature went down, mark the answer with a down arrow (↓). If the temperature went up, mark the answer with an up arrow (↑).
2. Which substance caused the greatest temperature decrease?
3. Which substance is the most unsuitable for a cold pack? Explain.
4. How did your Part II results compare with those of other student groups?
5. Which factors other than cooling ability might be considered when choosing a substance for use in a cold pack?

**EXTENSIONS**

1. Research the types of injuries that are treated with the use of a cold pack.
2. Make a cold pack using your suggested substance, water, and bags.



## A Good Cold Pack

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources.
2. Vials can be used instead of the 50 mL beakers. It is, however, more difficult to transfer the solids into vials, and the solids tend to stick to the sides of them.
3. Baking soda is sodium bicarbonate,  $\text{NaHCO}_3$  (GHS Signal Word: **WARNING**). Non-sodium salt substitutes commonly have KCl (GHS Signal Word: **WARNING**) as their main ingredient. Both are available in grocery stores.
4. Ammonium nitrate,  $\text{NH}_4\text{NO}_3$ , is commonly used in commercial cold packs. Because of its hazards, however, we have elected not to include it in this procedure. Ammonium chloride,  $\text{NH}_4\text{Cl}$  (GHS Signal Word: **WARNING**), also gives a large temperature drop and is safer to use.
5. Your students may be surprised when the temperature goes up as sodium carbonate dissolves. Be ready to make the most of this opportunity.
6. You may wish to use the terms *endothermic* for processes that absorb heat and *exothermic* for processes that release heat.
7. Table salt,  $\text{NaCl}$ , is a possible substitute whose dissolving is an endothermic process. Calcium chloride,  $\text{CaCl}_2$  (GHS Signal Word: **WARNING**), is a possible substitute whose dissolving is an exothermic process.
8. You might want to have a contest to see which student group can obtain the coldest temperature using their Part-II procedure.
9. You may wish to have your students calculate heat energy absorbed or released per gram of solid used. The heat energy may be calculated using the equation

$$H = \Delta t \cdot m \cdot C_p$$

where  $H$  = heat energy absorbed or released (in J),  $\Delta t$  = change in temperature (in  $^{\circ}\text{C}$ ),  $m$  = mass of water (in g), and  $C_p$  = specific heat capacity (4.18 J/g $^{\circ}\text{C}$  for water). Dividing the

## Experiment 16

resulting energy value by grams of solid dissolved gives the heat energy absorbed or released per gram of solid used (in J/g).

- For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
- If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

## ESTIMATED TIME

We estimate that Part I of this experiment can be completed in one 45–60 minute class period. Part II directs students to design and test their own cold pack; this can take an additional one or two periods depending on how much structure you provide.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models	PS1.B Chemical Reactions	Patterns
Planning and carrying out investigations	PS3.A Definitions of Energy	Cause and effect
Analyzing and interpreting data	ETS1.A Defining Engineering Problems	Scale, proportion, and quantity
Using mathematics and computational thinking		Systems and system models
Constructing explanations and designing solutions		Energy and matter
		Stability and change

## HAZARD ALERTS

The chemical safety signal words used in this experiment (DANGER and WARNING) are part of the Globally Harmonized System of Classification and Labeling of Chemicals (GHS). Refer to the Safety Data Sheet (SDS) that came with the chemical. These can also be found online from the manufacturer. See Appendix D for more information. See the Preface for additional chemical safety information.

Ammonium chloride, solid,  $\text{NH}_4\text{Cl}$ : **WARNING:** Do not eat or drink when using this product—harmful if swallowed. Causes serious eye irritation.

Calcium chloride, anhydrous, solid,  $\text{CaCl}_2$ : **WARNING:** Do not eat or drink when using this product—harmful if swallowed. Causes serious eye irritation.

Calcium chloride, dihydrate, solid,  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ : **WARNING:** Causes eye irritation and mild skin irritation.

Citric acid, monohydrate, solid,  $\text{H}_3\text{C}_6\text{H}_5\text{O}_7 \cdot \text{H}_2\text{O}$ : **WARNING:** Causes skin and eye irritation.

Potassium chloride, solid,  $\text{KCl}$ : **WARNING:** May be harmful if swallowed.

Sodium bicarbonate, solid,  $\text{NaHCO}_3$ : **WARNING:** May be harmful if swallowed. Treat as a non-food-grade chemical. Prudent laboratory practices should be observed.

Sodium carbonate, anhydrous, solid,  $\text{Na}_2\text{CO}_3$ : **WARNING:** May be harmful if swallowed. Causes eye irritation and mild skin irritation.

Sodium carbonate, monohydrate, solid,  $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$ : **WARNING:** Causes eye irritation and mild skin irritation.

Sodium chloride, solid,  $\text{NaCl}$ : **WARNING:** May be harmful if swallowed. Treat as a non-food-grade chemical. Prudent laboratory practices should be observed.

## **SAMPLE RESULTS**

Substance	Maximum temperature ( $^{\circ}\text{C}$ )	Minimum temperature ( $^{\circ}\text{C}$ )	Temperature change ( $^{\circ}\text{C}$ )
Ammonium chloride ( $\text{NH}_4\text{Cl}$ )	24.6	10.5	14.1 (↓)
Citric acid ( $\text{H}_3\text{C}_6\text{H}_5\text{O}_7$ )	24.5	18.6	5.9 (↓)
Potassium chloride ( $\text{KCl}$ )	24.5	14.5	10.0 (↓)
Sodium bicarbonate ( $\text{NaHCO}_3$ )	24.6	22.5	2.1 (↓)
Sodium carbonate ( $\text{Na}_2\text{CO}_3$ )	33.9	24.6	9.3 (↑)

## **ANSWERS TO QUESTIONS**

1. See the Sample Results.
2. The substance with the greatest temperature decrease was ammonium chloride.
3. Sodium carbonate is the most unsuitable for use in a cold pack because it causes a temperature rise.
4. Answers will vary.
5. Factors other than cooling ability that might be considered when choosing a substance for use in a cold pack are cost and safety.





# Lemon “Juice”

“Juice” is a slang term sometimes used for electricity. Batteries are made up of one or more cells. Cells often consist of two different materials in a solution that are connected to each other by a wire. In this experiment, you will study some basic principles of cells using the juice of a lemon as the cell solution.

## OBJECTIVES

- Build several cells.
- Measure cell voltages.
- Discover which combinations produce a voltage.
- Decide which combination makes the “best” battery.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Voltage Probe  
2 alligator clip leads  
lemon  
scalpel  
graphite pencil (C)  
iron nail (Fe)  
magnesium strip (Mg)  
zinc strip (Zn)  
paper towel

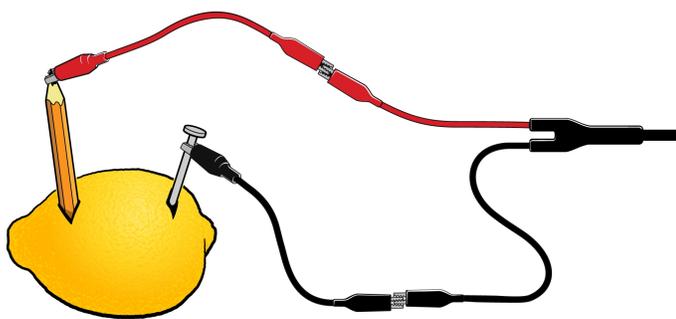


Figure 1

## PROCEDURE

1. Use a pen to make two parallel marks 1 cm long and 2 cm apart on a lemon. Use a scalpel to cut 2 slits in the lemon peel at the marks.

## Experiment 17

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2. Attach the red Voltage Probe lead to one alligator clip and the black lead to a second alligator clip as shown in Figure 1. You will be attaching the alligator clips to the test materials during this experiment in order to prevent corrosion of the Voltage Probe leads.
3. Connect the probe to the computer interface. Start the Vernier data-collection program and open the file "17 Lemon Juice" from the *Middle School Science with Vernier* folder.
4. Insert a short graphite pencil, sharpened at both ends, into one of the slits and an iron nail into the other. Hook the alligator clip attached to the red probe lead to the pencil. Hook the alligator clip attached to the black probe lead to the iron nail.
5. Record the voltage reading. Observe whether the voltage reading stays constant, rises, or drops. Record your observations.
6. Switch the positions of the alligator clips. Record the voltage reading and your observations.
7. Repeat Steps 4–6 for the other combinations listed in the data table. Dry the materials after each use.

### DATA

Red probe lead	Black probe lead	Voltage (V)	Observations	Red probe lead	Black probe lead	Voltage (V)	Observations
C	Fe			Fe	C		
C	Mg			Mg	C		
C	Zn			Zn	C		
Fe	Mg			Mg	Fe		
Fe	Zn			Zn	Fe		
Mg	Zn			Zn	Mg		

### PROCESSING THE DATA

1. What happens to the voltage reading if a cell is hooked up backwards?
2. Which combination gives the highest voltage?
3. Which combination(s) gives the steadiest voltage?
4. Which combination would make the best battery? Explain.
5. The chemical activity of metal is shown by the size of the voltage reading when the metal is paired with carbon in a cell. A high voltage indicates high chemical activity. Rank the three metals (Fe, Mg, and Zn) according to chemical activity, from highest to lowest.

## **EXTENSIONS**

1. Measure the voltage of “lemon cells” connected in series and in parallel.
2. Try the experiment using other fruits and vegetables.
3. Do the experiment using other metals, such as aluminum, copper, and lead.



## Lemon “Juice”

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and Graphical Analysis). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. Number 2 pencils cut to a length of about 15 cm and sharpened at both ends serve well as carbon electrodes.
3. Iron nails, 4 cm lengths of magnesium ribbon, and 4 cm × 1 cm pieces of zinc work well.
4. Consider cutting the slits in the lemons prior to class. The lemons can be reused.
5. The *Logger Pro*/*Logger Lite* procedure directs students to record voltage data from the meter (without clicking ). Another possibility is to have them use the Selected Events mode in *Logger Pro* or Events with Entry in *Logger Lite*. The *Logger Pro* file for this experiment is already set up for this Selected Events option. Simply have your students click  and then click  when the reading is stable. This saves the reading along with its trial number in the table. The *Logger Lite* file for this experiment is already set up for Events with Entry mode. Simply have your students click  and then click  when the reading is stable. They will need to enter the sample number when prompted.
6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
7. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS2.B Types of Interactions	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change

## SAMPLE RESULTS

Red probe lead	Black probe lead	Voltage (V)	Observations	Red probe lead	Black probe lead	Voltage (V)	Observations
C	Fe	0.71	rises slowly	Fe	C	-0.49	steady
C	Mg	1.80	drops slowly	Mg	C	-1.59	steady
C	Zn	1.21	steady	Zn	C	-0.88	steady
Fe	Mg	1.32	drops	Mg	Fe	-0.94	steady
Fe	Zn	0.58	steady	Zn	Fe	-0.25	drops slowly
Mg	Zn	-0.50	steady	Zn	Mg	0.87	drops quickly

## ANSWERS TO QUESTIONS

1. If the cell is hooked up backwards, the reading is 0 or negative depending on the type of sensor used.
2. The carbon-magnesium cell gives the highest voltage reading.
3. The carbon-zinc cell usually gives the steadiest reading. Carbon-iron readings are sometimes very constant, too.
4. If the criterion is highest voltage reading, then the carbon-magnesium cell is the “best.” If a steady reading is wanted, then the carbon-zinc cell would be chosen as “best.”
5. The activity ranking of the three metals (from highest to lowest) is Mg, Zn, Fe. Their standard reduction potentials are  $-2.37$ ,  $-0.76$ , and  $-0.44$ , respectively.

# Get a Grip!

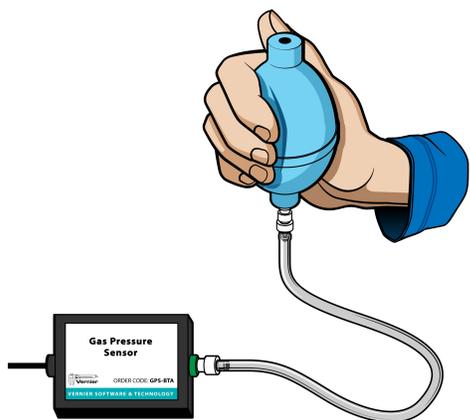
In this experiment, you will measure your gripping power. You will see if your gripping power changes as you grip an object over a period of time. You will also compare your gripping power with your classmates.

## OBJECTIVES

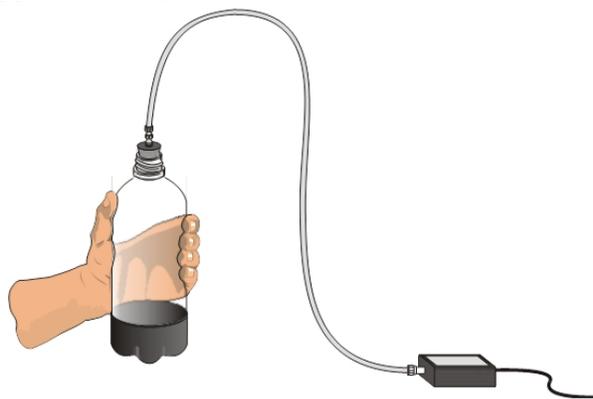
- Use a gas pressure sensor to measure your gripping power.
- See which of your hands has the greater gripping power.
- Learn what happens to your gripping power as time goes by.
- Compare your gripping power with your classmates.

## MATERIALS

computer  
 Vernier computer interface  
 Vernier data-collection software  
 Vernier Gas Pressure Sensor  
 equipment for your setup:  
 plastic tubing and bulb assembly  
**or**  
 plastic bottle and plastic tubing with stopper assembly



*Figure 1*



*Figure 2*

## PROCEDURE

1. Connect the bulb to the Gas Pressure Sensor as shown in Figure 1. If you are using a plastic bottle, see Figure 2.

## Experiment 18

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- Connect the sensor to the computer interface. Start the Vernier data-collection program and open the file “18 Get a Grip” from the *Middle School Science with Vernier* folder.
- Grip the bulb or bottle as hard as you can with one hand, then click **Collect** to begin data collection. Keep gripping as hard as you can until data collection ends. **Note:** Do not lean your hand or arm on anything.
- When the 60 seconds are up and data collection ends, record your data.
  - Click Statistics, . Then record your mean (average) grip (in kPa) for the 60 s period.
  - Drag the Statistics box to the right side of the screen.
  - Select the 0–10 s section of the graph by dragging across it.
  - Click Statistics, . Then record your mean grip for the 0–10 s period.
  - Drag this Statistics box to the bottom of the screen.
  - Select the 50–60 s section of the graph by dragging across it.
  - Click Statistics, . Then record your mean grip for the 50–60 s period.
  - Close all of the Statistic boxes.
- Repeat Steps 3–4 using your other hand, recording your statistics when data collection is complete.

## DATA

Table 1: Your Results		
	Left hand	Right hand
0–60 s grip average (kPa)		
0–10 s grip average (kPa)		
50–60 s grip average (kPa)		
Difference between 0–10 s avg. and 50–60 s avg.		

Table 2: Group and Class Results	
Name	Strong hand average for 0–60 s (kPa)
Group average	
Class average	



## **PROCESSING THE DATA**

1. In the space provided in Table 1, subtract to find the difference between your 0–10 s average and your 50–60 s average for each hand.
2. Record the 0–60 s results for the other students in your group in Table 2. Calculate and record your group average. Calculate and record the class average for 0–60 s.
3. Which of your hands is stronger? Explain your decision.
4. Did your gripping power increase or decrease during the 60 s period? Why did it change?
5. How does your grip compare with the class average?
6. What did you learn about your strength in this experiment? Were you surprised?

## **EXTENSION**

See if you can increase your gripping power with practice.



## Get a Grip!

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., Logger *Pro* and Graphical Analysis). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 Logger *Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources. The Graphical Analysis Pro file for this experiment includes video of the first trial showing data collected for the right hand. Data for the left hand of the same subject can be found in the data table in the Graphical Analysis file; video of this trial is not included.

The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in Graphical Analysis Pro, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.

2. 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).
3. If you are using Go Direct sensors, see [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect your sensor.
4. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking	LS1.A Structure and Function	Cause and effect Scale, proportion, and quantity Energy and matter Structure and function Stability and change

## SAMPLE RESULTS

	Left hand	Right hand
0–60 s grip average (kPa)	120.9	121.5
0–10 s grip average (kPa)	123.9	124.6
50–60 s grip average (kPa)	117.5	118.4
Difference between 0–10 s avg. and 50–60 s avg.	6.4	6.2

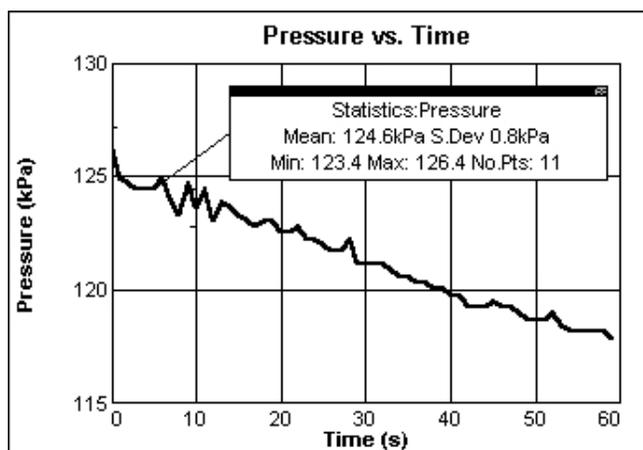


Figure 1

## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. See the Sample Results.
3. Answers will vary.
4. Gripping power generally decreases during the 60 s period because of fatiguing.

5. Answers will vary.
6. Answers will vary. Some students will be surprised at how quickly they fatigue.



## Fun with Pressure

The pressure of a gas is influenced by its volume, number of particles, and temperature. When you push a tire pump handle down, you increase pressure by decreasing the volume. You can increase the pressure in a bicycle tire by adding air particles. If an empty container of hair-spray is heated, the pressure may become dangerously high inside. In this contest, you will use a clean, dry container and what you know about gases in an attempt to produce the highest pressure.

### OBJECTIVES

- Measure pressure.
- Apply your knowledge of gases.
- Have fun.

### MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Gas Pressure Sensor  
clean, dry container  
1-hole stopper with a tapered valve  
rigid-wall tubing

### GUIDELINES

1. You must use a clean, dry container.
2. The container is to be connected to a Gas Pressure Sensor using stoppers and tubing supplied by the teacher.
3. You may change the volume of the container, temperature, and the amount of air in the container in your attempt to produce the highest pressure reading for your class. You may only use your body, and those of your teammates. You may not use any heater, piston, or other tool.
4. You are encouraged to experiment and practice before the contest.
5. During the contest, you will have one minute to produce your highest pressure using the equipment provided by your teacher. Your score will be the highest reading saved during the one minute period.





## Fun with Pressure

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. This is a good activity for wrapping up a study of gases. It also works well on the last day of a term.
3. Prior to the start of class, connect the piece of thick-wall plastic tubing and rubber stopper assembly to the end valve of the Gas Pressure Sensor with a gentle half turn. Connect the other end of the plastic tubing to a single-hole rubber stopper using one of the tapered, ribbed valves included with a Gas Pressure Sensor (see Figure 1). If the single-hole rubber stopper that came with the valve is the wrong size for your bottle, the tapered valve can be pulled out of the stopper and pushed into a stopper that fits the bottle. If you need additional valves, you can obtain them by purchasing the Pressure Sensor Accessories Kit from Vernier Software & Technology (order code: PS-ACC).

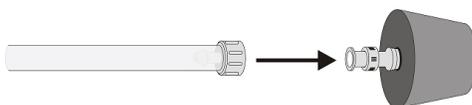


Figure 1

4. You should have an assortment of one-hole stopper assemblies, two-hole stopper assemblies, rigid-wall tubing, and flexible-wall tubing (short pieces to serve as adapters) available.
5. To minimize the possibility of puncture injuries, we suggest that you fit the stopper assemblies into the student containers.
6. If your students need ideas to get going, put out usable plastic containers during class periods prior to the contest day. Give them opportunities to experiment and test their ideas.
7. Students generally get the best results with a combination of increasing the amount of air in a container and then reducing its volume. Soft-plastic containers with volumes less than 350 mL usually win—students seem to be better able to compress small containers with a foot (or feet). Most teams use bottles, but tubes are probably better. Many teams use a two-hole

## Experiment 19

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stopper assembly to add air to the container to be compressed. They do this by blowing breath into the container, or by squeezing air into the container from another container. Changing temperature does not cause a large pressure increase, since it is difficult to increase absolute temperature by more than a few percent.

8. Caution students against jumping on the bottle as the sensor could be damaged. The standard Gas Pressure Sensor will not read higher than approximately 210 kPa, and could be damaged if the pressure goes above 400 kPa. The Go Direct Gas Pressure Sensor can read up to 400 kPa and can withstand up to 450 kPa without damage. The most fun-filled aspect of the contest is how different teams compress their containers
9. For data collection, with Logger *Pro* or Logger *Lite*, prepare the computer for data collection by opening the “19 Fun with Pressure” file in the *Middle School Science with Vernier* folder.
10. Use Statistics to determine the highest pressure value for each trial.
11. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
12. If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS1.A Structure and Properties of Matter	Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Stability and change

# Water Hardness Study

When water passes through or over mineral deposits such as limestone, the levels of certain ions present in the water increase greatly and cause the water to be classified as *hard water*. This term results from the fact that calcium or magnesium ions in water combine with soap molecules, forming a sticky scum that interferes with soap action and makes it “hard” to get suds. *Soft water*, such as rainwater or melted snow, is mostly free of these ions. Soft water, when mixed with soap will form suds. A Conductivity Probe can be used to test for ions in water. Hard water, because of the ions it contains, gives a high conductivity reading. Soft water gives a low conductivity reading.

In Part I of this experiment, you will learn how to test water hardness and find the hardness of the tap water in your school. In Part II, you will plan and perform a water-hardness study.

## OBJECTIVES

- Use soap to find water hardness.
- Use a Conductivity Probe to find water hardness.
- Find the hardness of the water in your school.
- Apply what you learn as you do a water-hardness study.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Conductivity Probe  
25 mL graduated cylinder  
3 small beakers  
3 test tubes with stoppers  
distilled water  
very hard water  
tap water  
test-tube rack  
Ivory<sup>®</sup> liquid soap  
dropper  
ruler



Figure 1

## PROCEDURE

### Part IA Soap Sudsing Tests

1. Place 10 mL of distilled water in one test tube. Place 10 mL of very hard water in a second test tube. Place 10 mL of tap water in a third test tube. **WARNING:** *Treat all laboratory chemicals with caution. Safe laboratory practices should be observed.*
2. Add one drop of Ivory liquid soap to each test tube and insert the stoppers. Shake each test tube the same number of times.
3. Use a ruler to measure the suds height (in cm) in each test tube. Record the results in your data table.

### Part IB Conductivity Tests

4. Fill a clean beaker halfway with distilled water. Fill a second beaker halfway with very hard water, and the third beaker halfway with tap water.
5. Set the Conductivity Probe to the 0–2000  $\mu\text{S}/\text{cm}$  position and connect it to the computer interface.
6. Start the Vernier data-collection program and open the file “20 Hard Water Study” from the *Middle School Science with Vernier* folder
7. Measure the conductivity for each of the three water samples.
  - a. Place the end of the Conductivity Probe into the beaker until the hole in the probe end is completely submerged in the solution, as shown in Figure 1. Swirl the solution briefly.
  - b. Once the reading is steady, record the conductivity reading.
  - c. Before testing the next sample, carefully blot the probe dry with a tissue.

**Part II A Water Hardness Study**

8. Use the skills you gained in Part I and do a study of water available in your community. You might compare surface water (from streams and ponds) with groundwater (from wells and springs). A study of the different bottled waters sold at local stores can also be done. Explain the hardness of the waters you test.

**DATA**

	Suds height (cm)	Conductivity ( $\mu\text{S}/\text{cm}$ )
Distilled water		
Very hard water		
Tap water		

**PROCESSING THE DATA**

1. Is the tap water hard? Explain how you decided on your answer.
2. Where does your tap water come from? How does that source affect the hardness of the water?
3. How did the hardness of the samples you tested in Part II compare?
4. Explain why each of the samples you tested in Part II is hard or soft?

**EXTENSIONS**

1. Study the effectiveness of different water softeners.
2. Study the hardness of tap water at various places in your community.
3. Compare the hardness of hot tap water with the hardness of cold tap water.
4. Find out what makes hard water hard.



## Water Hardness Study

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and Graphical Analysis). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources.
2. Ivory® liquid soap works very well in this experiment. Alternatively, you can shave flakes of unscented hand soap into a small volume of distilled water and mix to make a soap solution. Instruct your students to use 20 drops of this solution for each test.
3. We recommend 18 × 150 mm test tubes for this experiment. You can use cork or rubber stoppers. If you do not have enough test tubes and stoppers of the same size for your entire class, make sure each group has three test tubes that are the same size.
4. We suggest that you set up the Conductivity Probes before the experiment. If your Conductivity Probes have switches, set them to the 0–2000 μS/cm range. If your probes do not have switches, the range is automatically set.
5. For purposes of this experiment, very hard water is any calcium-ion-rich solution with conductivity greater than 1000 μS/cm. You can prepare such a solution by adding calcium chloride, CaCl<sub>2</sub> (GHS Signal Word: **WARNING**), to a sample of local water, with stirring, until a conductivity reading of 1000 μS/cm is reached.
6. Part II is the more important part of this experiment. Be sure to devote adequate time and effort to it.
7. Tap water in soft-water areas can have conductivity values less than 50 μS/cm. For example, the tap water in Portland, Oregon, the home of Vernier Software & Technology, has a value of about 25 μS/cm. The highest tap-water value we have measured was 1440 μS/cm for water from Sigonella, Italy.
8. The conductivity values reported in this experiment are really a reflection of all dissolved ions in samples. In this experiment, however, we are making the assumption that most of these ions are “hard water ions,” such as Ca<sup>2+</sup>, Mg<sup>2+</sup>, and HCO<sub>3</sub><sup>-</sup>. Other ions found in freshwater samples, such as Na<sup>+</sup>, K<sup>+</sup>, or Cl<sup>-</sup>, would make a much smaller contribution toward the conductivity values reported.
9. The *Logger Pro*/*Logger Lite* procedure directs students to record conductivity data from the meter (without clicking  **Collect**). Another possibility is to have students use the Selected Events mode in *Logger Pro* or Events with Entry in *Logger Lite*. The *Logger Pro* file for this

## Experiment 20

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experiment is already set up for this Selected Events option. Simply have your students click  and then click  when the reading is stable. This saves the reading along with its trial number in the table. The Logger Lite file for this experiment is already set up for Events with Entry mode. Simply have your students click  and then click  when the reading is stable. They will need to enter the sample number when prompted.

10. If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.
11. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.

### ESTIMATED TIME

We estimate that Part I of this experiment can be completed in one 45–60 minute class period. Part II directs students to conduct their own water study; this can take an additional one or two periods depending on how much structure you provide.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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 Engaging in argument from evidence	ESS2.A Earth Materials and Systems ESS2.C The Roles of Water in Earth's Surface Processes PS1.A Structure and Properties of Matter	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter



## HAZARD ALERTS

The chemical safety signal words used in this experiment (DANGER and WARNING) are part of the Globally Harmonized System of Classification and Labeling of Chemicals (GHS). Refer to the Safety Data Sheet (SDS) that came with the chemical. These can also be found online from the manufacturer. See Appendix D for more information. See the Preface for additional chemical safety information.

Calcium chloride, dihydrate, solid,  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ : **WARNING**: Causes eye irritation and mild skin irritation.

Calcium chloride, solid,  $\text{CaCl}_2$ : **WARNING**: Do not eat or drink when using this product—harmful if swallowed. Causes serious eye irritation.

## SAMPLE RESULTS

	Suds height (cm)	Conductivity ( $\mu\text{S}/\text{cm}$ )
Distilled water	4	0
Very hard water	0	1005
Tap water	0	740

## ANSWERS TO QUESTIONS

- Answers will vary. The tap water in the Sample Results would be considered hard because the sudsing test gave no suds and the conductivity value is approaching  $1000 \mu\text{S}/\text{cm}$ .
- Answers will vary. The tap water tested above was groundwater from a region where the soil is rich in soluble calcium ( $\text{Ca}^{2+}$ ), iron(III) ( $\text{Fe}^{3+}$ ), and magnesium ( $\text{Mg}^{2+}$ ) ions. Surface water in the same area tends to be softer because of lower concentrations of these ions.
- Answers will vary.
- Answers will vary.



# Diffusion: How Fast?

Diffusion is a process that allows particles to move from where they are more concentrated to where they are less concentrated. This process allows particles to move through a cell membrane. Diffusion enables cells to get food and get rid of waste.

A Conductivity Probe can measure the concentration of ions in a solution. A salt solution contains ions. In this experiment, you will use a Conductivity Probe to measure the diffusion of salt through a membrane. You will also study the effect of salt concentration on diffusion rate.

## OBJECTIVES

- Measure conductivity.
- Measure the diffusion of salt through a membrane.
- See the effect of salt concentration on diffusion rate.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Conductivity Probe  
5% and 10% saltwater  
ring stand  
utility clamp  
stirring rod  
50 mL beaker  
400 mL beaker  
dialysis tubing  
dropper  
scissors  
2 dialysis tube clamps or dental floss  
distilled water



Figure 1

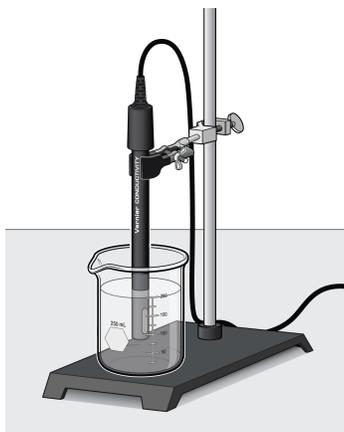


Figure 2

## PROCEDURE

### Part I Measuring Diffusion

1. Connect the Conductivity Probe to the computer interface. The Conductivity Probe should be set on the 0–2000  $\mu\text{S}/\text{cm}$  position.
2. Start the Vernier data-collection program and open the file “21 Diffusion” from the *Middle School Science with Vernier* folder.
3. Get a wet dialysis tube and a dialysis tube clamp or a short length of dental floss. Using the clamp or floss, tie one end of the tube closed about 1 cm from the end, as in Figure 1.
4. Put 5% saltwater into the dialysis tubing.
  - a. Get about 15 mL of 5% saltwater in the 50 mL beaker.
  - b. Use a dropper to transfer about 10 mL of the 5% saltwater into the tube. **Note:** To open the tube, you may have to rub it between your fingers.
  - c. Tie off the top of the tube. Try not to allow any air to stay in the tube.
  - d. Wash the outside of the tubing with tap water to wash away any saltwater.
5. Put 250 mL of distilled water into the 400 mL beaker. Position the Conductivity Probe in the distilled water as shown in Figure 2.
6. Put the dialysis tube into the water. Make sure it is completely covered with water. **Important:** The Conductivity Probe and the tube must be the same distance apart in both parts of the experiment.
7. After stirring the water for 15 seconds, click  to begin data collection. Stir the water slowly and continuously for the next 120 seconds. Data collection will end automatically after 120 seconds.
8. Determine the diffusion rate for the 5% salt solution.
  - a. Click Examine, .
  - b. Use your mouse to move along the data points. Select two data points and record the time and conductivity values for both points.

Table 1: 5% Salt	
x : Time (s)	y : Conductivity ( $\mu\text{S}/\text{cm}$ )
$x_1 =$	$y_1 =$
$x_2 =$	$y_2 =$

- c. The diffusion rate is equal to the slope,  $m$ , value in units of  $\mu\text{S}/(\text{cm}\cdot\text{s})$ . Use the points in the table above to find the diffusion rate of the conductivity vs. time graph. Record the rate in the data table.

$$m = \frac{y_2 - y_1}{x_2 - x_1} =$$

- d. Close the Examine box.

### Part II The Effect of Salt Concentration on Diffusion

9. Use a tissue to carefully blot the Conductivity Probe dry.
10. Prepare the dialysis tubing for reuse.
  - a. Remove one of the clamps. If the tubing is tied off with floss, use scissors to carefully cut one of the dental floss strings. Discard the floss.
  - b. If you cut the tubing, replace it.
  - c. Empty all of the liquid out of the dialysis tube.
  - d. With your fingers, squeeze out any remaining liquid.
  - e. Wash the outside of the tubing with tap water to wash away any saltwater.
11. Repeat Steps 4–7 using 10% saltwater.
12. Determine the diffusion rate for the 10% salt solution.
  - a. Click Examine, .
  - b. Use your mouse to move along the data points. Select two data points and record the time and conductivity values for both points.

Table 2: 10% Salt	
x : Time (s)	y : Conductivity ( $\mu\text{S}/\text{cm}$ )
$x_1 =$	$y_1 =$
$x_2 =$	$y_2 =$

- c. The diffusion rate is equal to the slope,  $m$ , value in units of  $\mu\text{S}/(\text{cm}\cdot\text{s})$ . Use the points in the table above to find the diffusion rate of the conductivity vs. time graph. Record the rate in the data table.

$$m = \frac{y_2 - y_1}{x_2 - x_1} =$$

## DATA

Table 3	
Salt concentration (%)	Diffusion rate $\mu\text{S}/(\text{cm}\cdot\text{s})$
5	
10	

## PROCESSING THE DATA

1. Describe what happened in this experiment.
2. What evidence is there that salt diffused through the membrane?
3. From which saltwater solution did salt diffuse faster? How could you tell?

## EXTENSION

Design an experiment to find the effect of temperature on the diffusion of salt. Perform the experiment you designed.

## Diffusion: How Fast?

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. Provide each group with pre-cut, hydrated dialysis tubing—2.5 cm × 12 cm is the recommended size. The tubing must be soaked in water for at least 10 minutes prior to use. The tubing should be soft and flexible.
3. Dental floss works well for tying off the dialysis tubing. Other types of string can be used. Special dialysis tubing clamps, available from Flinn Scientific and other suppliers, work even better. You may want to show students how to tie off the dialysis tubes.
4. Have students check their dialysis tubes for leakage before each experiment. Leaky tubes should be replaced.
5. To prepare 5% salt solution, add 50 grams of NaCl to make one liter of solution. To prepare 10% solution, add 100 grams of NaCl to make one liter of solution.
6. If you are collecting data with the EasyData App (calculators), the following procedure can be used to display graphs of 2 (or 3) successive runs.
  - a. After the first run, select  $\overline{\text{File}}$  from the Main screen, and then select **STORE RUN**.
  - b. Select  $\overline{\text{OK}}$  to store your latest data and overwrite the data in Lists 3 and 4 (L3 and L4).
  - c. Collect data for another run. **Note:** Do not save your last run.
  - d. From the Graph screen, select  $\overline{\text{Adv}}$  and then select L2 AND L3 VS L1 (or L2, L3 AND L4 VS L1 if you have 3 runs).
7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
8. If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

## Experiment 21

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	LS1.A Structure and Function	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change

### SAMPLE RESULTS

Salt concentration (%)	Diffusion rate $\mu\text{S}/(\text{cm}\cdot\text{s})$
5	2.52
10	4.68

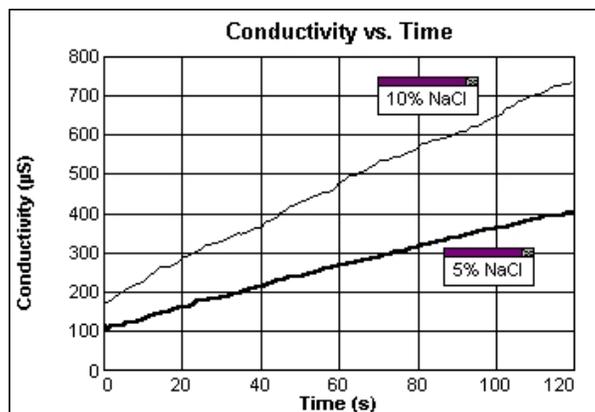


Figure 1 Diffusion of salt

### ANSWERS TO QUESTIONS

- Answers will vary.
- The rising conductivity readings give evidence of the diffusion of salt through the membrane.



3. The salt diffuses through the membrane faster from the 10% saltwater solution. The  $m$  value (this is the slope of the regression line) for this solution was greater. The diffusion rate of the 10% solution should be approximately two times greater than that of the 5% solution.

## **ACKNOWLEDGMENT**

We wish to thank Kelly Redding and David Masterman for their help in developing and testing this experiment.



# A Water Field Study

When finding water quality, there are many measurements that can be made. In this experiment, you will measure water temperature, conductivity, and pH. Water temperatures in streams can range from 0°C in the winter to above 30°C in the summer. Cooler water in a stream is generally considered healthier than warmer water. Problems generally occur when changes in water temperature are noted along one stream on the same day. Some sample data are listed in Table 1.

Site	Season	Temperature (°C)	Season	Temperature (°C)
Hudson River, Poughkeepsie, NY	Winter	5	Summer	25
Mississippi River, Memphis, TN	Winter	7	Summer	29
Rio Grande, El Paso, TX	Winter	16	Summer	21
Missouri River, Garrison Dam, ND	Winter	3	Summer	14
Willamette River, Portland, OR	Winter	9	Summer	22

Conductivity values in lakes and streams are typically found to be in the range of 100 to 500  $\mu\text{S}/\text{cm}$ . In areas of especially hard water or high salinity, conductivity values may be as high as 1000  $\mu\text{S}/\text{cm}$ . Drinking water usually has conductivity in the 50 to 1000  $\mu\text{S}/\text{cm}$  range. Some sample data are listed in Table 2.

Site	Season	Conductivity ( $\mu\text{S}/\text{cm}$ )	Season	Conductivity ( $\mu\text{S}/\text{cm}$ )
Hudson River, Poughkeepsie, NY	Spring	180	Fall	238
Mississippi River, Memphis, TN	Spring	266	Fall	440
Rio Grande, El Paso, TX	Spring	1020	Fall	1220
Sacramento River, Keswick, CA	Spring	142	Fall	120
Ohio River, Benwood, WV	Spring	600	Fall	286

The best pH range for most aquatic organisms is pH 6.5 to 8.2. The pH values of streams and lakes are usually between pH 7 and 8. Hard water will often have pH values between 7.5 and 8.5.

When doing this experiment, you might choose to compare water quality at two or more points on the same stream, in two or more different streams or lakes, or in a lake and a stream that runs into it.

## OBJECTIVES

- Use a Temperature Probe to measure water temperature.
- Use a Conductivity Probe to measure the conductivity of water.
- Use a pH Sensor to measure the pH of water.
- Make visual observations at the test sites.
- Compare water quality.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Temperature Probe  
Conductivity Probe  
pH Sensor  
colorless plastic bottle  
plastic cup or beaker

## PROCEDURE

1. Fill the plastic bottle with water taken below the water surface at a point one meter from the shore. **Caution:** Take all necessary precautions to ensure your safety!
2. Measure the temperature of the sample water.
  - a. Connect the Temperature Probe to the computer interface.
  - b. Start the Vernier data-collection program and open the file “22a Water Field Study–Temp” from the *Middle School Science with Vernier* folder.
  - c. Place the Temperature Probe in the sample water. When the reading has stabilized, record it in your data table.
  - d. Disconnect the Temperature Probe from the computer interface.
3. Measure the pH of the sample water.
  - a. Connect the pH Sensor to the computer interface.
  - b. Open the file “22b Water Field Study–pH” from the *Middle School Science with Vernier* folder.
  - c. Remove the pH Sensor from its storage bottle.
  - d. Rinse the pH Sensor with sample water.
  - e. Place the pH Sensor in the sample bottle and gently swirl. When the reading has stabilized, record it in your data table.
  - f. Rinse the pH Sensor with distilled water and return it to its storage bottle.
  - g. Disconnect the pH Sensor from the computer interface.
4. Measure the Conductivity of the sample water.
  - a. Set the Conductivity Probe to the 0–2000  $\mu\text{S}/\text{cm}$  position and connect it to the computer interface.



Figure 1

- b. Open the file “22c Water Field Study–Con” from the *Middle School Science with Vernier* folder.
  - c. Rinse the Conductivity Probe with sample water.
  - d. Place the Conductivity Probe in the sample bottle. When the reading has stabilized, record it in your data table.
  - e. Disconnect the Conductivity Probe from the computer interface.
5. Note and record the clarity (clearness) of the water sample.
  6. Make and record other observations (concerning algae, plants, water “critters,” animals, flow rate, etc.) related to water quality at the site.
  7. Repeat Steps 1–6 at one or more other sites.

## DATA AND OBSERVATIONS

Site		
Temperature (°C)		
Conductivity (μS/cm)		
pH		
Clarity		
Other observations		

## PROCESSING THE DATA

1. How did the water quality at the different sites compare?
2. What differences did you find? Explain the differences.
3. What similarities did you find? Explain the similarities.
4. At which site was the water “best”? Explain why it was the best.
5. What new ideas for testing water quality did you come up with while doing this experiment?

## EXTENSIONS

1. Test water quality at the same site at different times.
2. Test the effects of rain or snow on water quality.

## *Experiment 22*

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3. Test water quality at sites upstream and downstream from a wastewater treatment plant.

## A Water Field Study

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources.
2. Take great care to ensure the safety of your students while collecting data and observations in the field. Follow local guidelines concerning field-trip chaperones.
3. In this activity, students take the data-collection equipment outside in order to collect data. The preferred data-collection method is to use an interface, such as a LabQuest, that can function as a standalone device. If your interface must be connected to a computer (e.g., LabQuest Mini or LabQuest Stream) If you usually use computers in the classroom, each group will need a laptop, mobile device, or Chromebook.
4. There are obviously many possible variations of this experiment in addition to those offered in the introduction and Extensions.
5. As an alternative to the student Procedure, your students could measure water temperature on site then collect samples in completely filled and sealed bottles, make visual observations on site, and then measure conductivity and pH in the classroom.
6. In the Procedure, students are directed to take readings successively because the Conductivity Probe and pH Sensor interfere with each other while taking readings in the same solution (or region of a stream) when connected to the same interface. **Note:** This is not a concern for Go Direct sensors.
7. The *Logger Pro* procedure directs students to record data from the meter (without clicking ). Another possibility is to have them use the Selected Events mode in *Logger Pro* or Events with Entry in *Logger Lite*. The *Logger Pro* file for this experiment is already set up for this Selected Events option. Simply have your students click  and then click  when the reading is stable. This saves the reading along with its trial number in the table. The *Logger Lite* file for this experiment is already set up for Events with Entry mode. Simply have your students click  and then click  when the reading is stable. They will need to enter the sample number when prompted.

## Experiment 22

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8. In addition to Temperature Probes, Conductivity Probes, and pH Sensors, Vernier Software & Technology offers an extensive array of equipment for use in water quality studies and a lab book, *Water Quality with Vernier* (order code: WQV), that is dedicated to measuring water quality. For additional information about water quality and Vernier visit [www.vernier.com/water-quality](http://www.vernier.com/water-quality)
9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
10. If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and carrying out investigations	ESS2.A Earth Materials and Systems	Patterns
Analyzing and interpreting data	ESS2.C The Roles of Water in Earth's Surface Processes	Cause and effect
Using mathematics and computational thinking	ESS3.A Natural Resources	Scale, proportion, and quantity
Constructing explanations and designing solutions		Energy and matter



## SAMPLE RESULTS

Site	200 m upstream	Effluent from sewage plant	200 m downstream	2000 m downstream
Water temperature (°C)	6.9	11.5	7.2	7.0
Conductivity ( $\mu\text{S}/\text{cm}$ )	1010	2590	1210	1010
pH	7.7	7.2	7.6	7.7
Clarity	Slightly muddy and not colorless	Clearer than river water, but yellowish	Slightly muddy and not colorless	Slightly muddy and not colorless
Other observations	River flowing gently, a few ducks nearby, no apparent algae growth, suspended material in the water	Rapid flow into river, several ducks in water, a suds trail from where effluent enters river	Suds trail from sewage outlet still observable, but dissipating, otherwise the water looks like water upstream	Fisherman nearby, river flowing gently, no apparent algae growth, suspended material in the water

## ANSWERS TO QUESTIONS

- Answers will vary. In the Sample Results, the effect of a wastewater-treatment plant on river water quality was investigated. Although the effluent from the wastewater-treatment plant was warmer, had higher conductivity, and had a lower pH when compared to the river water, these differences were apparently diluted away as the effluent mixed into the large volume of river water.
- Answers will vary. In the Sample Results, the effluent was warmer—apparently because it had been inside and underground during the cold weather at the time of the experiment. The effluent conductivity was higher than the river water—apparently due to additional dissolved material. The effluent has a lower pH—apparently due to dissolved materials it contained.
- Answers will vary. In the Sample Results, the measurements made 2000 m downstream from the wastewater-treatment plant were essentially the same as those made 200 m upstream from the wastewater-treatment plant. The effluent apparently becomes so diluted that its presence has a negligible effect on water quality at this point downstream.
- Answers will vary. In the Sample Results, the water 200 m above and the water 2000 m below the wastewater-treatment plant were arguably better because they contained lower concentrations of waste material.
- Answers will vary.

## **ACKNOWLEDGEMENT**

We wish to thank Robyn Gastineau, Kelly Redding, Dan Holmquist, and David Masterman for their help in developing and testing this experiment.

# Cooling Rates: Shaq vs. Suzie

Animals have different ways to keep cool in hot weather and during activities. Jackrabbits lose heat through their big ears, dogs pant, and humans sweat. The rate at which animals cool down is affected by their body size. Shaquille “Shaq” O’Neal is the 315-pound, seven-foot, one-inch, former center for the Los Angeles Lakers basketball team. Suzie is the 100-pound, five-foot, one-inch point guard for the Springfield Middle School Hawks. Who cools faster—Shaq or Suzie? In this experiment, you will predict who cools faster and then do an experiment to test your prediction.

## OBJECTIVES

- Predict which cools faster, a large body or a small one.
- Test your prediction.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
2 Temperature Probes  
hot tap water  
large plastic bottle  
small plastic bottle  
2 modified lids for the bottles or one-hole stoppers that fit the bottles

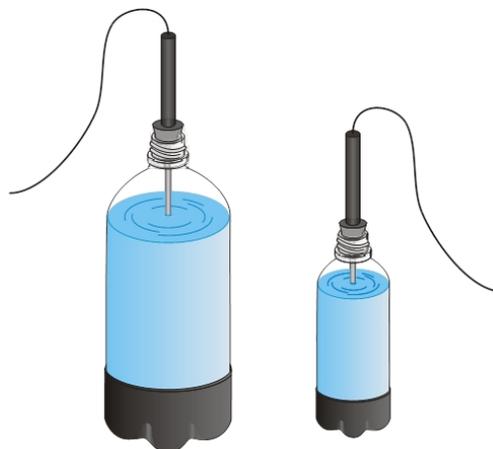


Figure 1

## PRE-LAB PREDICTION

Which do you think cools faster—a large body (Shaq) or a small body (Suzie)? Discuss this question with your group, then record your prediction in the space provided after the Procedure.

## PROCEDURE

1. Slip a modified lid or a one-hole stopper that fits the large bottle onto Probe 1. Slip a modified lid or a one-hole stopper that fits the small bottle onto Probe 2.
2. Connect the Temperature Probes. Start the Vernier data-collection program and open the file “23 Cooling Rates” from the *Middle School Science with Vernier* folder.
3. Fill the large plastic bottle and the small plastic bottle with hot tap water. **Caution:** *Be careful not to burn yourself!*

## Experiment 23

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- Place Probe 1 into the large bottle and Probe 2 into the small bottle. Carefully twist the lids on to the bottles or press in the stoppers.
- Watch the temperature readings on the screen. When they both stop rising click  to begin data collection.
- When data collection is complete (data has been collected for 20 minutes), click the Statistics button, , then click  to display a Statistics box for each probe.
- Record the minimum temperature and the maximum temperature for each bottle.
- Print copies of the graph as directed by your teacher.

### PRE-LAB PREDICTION

Which will cool faster—a large body (Shaq) or a small body (Suzie)?

### DATA

	Large bottle (Probe 1)	Small bottle (Probe 2)
Beginning temperature (°C)		
Final temperature (°C)		
Temperature change (°C)		

### PROCESSING THE DATA

- In the space provided in the data table, subtract to find the temperature change for each bottle.
- Was there any difference in the cooling rates of the bottles? Try to explain the difference.
- Do the results support your prediction about Shaq and Suzie?
- Who, Shaq or Suzie, sweats more during a game? Why?

## Cooling Rates: Shaq vs. Suzie

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. The EasyData (calculator) student version of this activity contains two methods. Use Method 1 if you are collecting data with an EasyTemp or a Temperature Probe connected to an EasyLink. Use Method 2 if you are collecting data with two Temperature Probes and multi-port interface (e.g., LabPro or CBL 2).
3. Any combination of large and small plastic bottles should work. We collected the Sample Data using a 4 liter (1 gallon) milk bottle and a 0.5 L plastic cola bottle.
4. Holes in the bottle lids can easily be made by an adult using a hot nail or a knife. Size-2, size-3, and size-4 one-hole stopper fit various beverage bottles.
5. Make sure the water is not hotter than 50°C. If hot tap water is not available, a hot plate, maintained at a low setting, can be used to heat the hot water.
6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
7. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

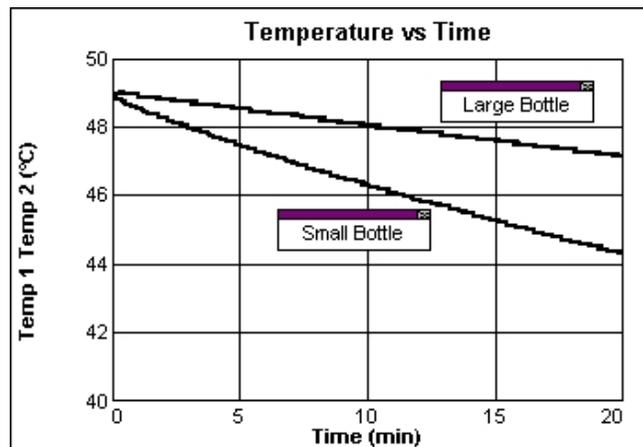
We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	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 Structure and function Stability and change

## SAMPLE RESULTS

	Large bottle (Probe 1)	Small bottle (Probe 2)
Maximum temperature (°C)	49.1	49.0
Minimum temperature (°C)	47.2	44.3
Temperature change (°C)	1.9	4.7



## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. The smaller bottle cooled faster. Large objects cool slower because internal heat must move farther to the surface where it is lost to its surroundings.
3. Answers will vary.

4. A larger person, who radiates excess heat less efficiently than a smaller person, probably will sweat more. Accordingly, Shaq would be expected to sweat more.





# Yeast Beasts in Action

Yeast is a microorganism that can break hydrogen peroxide down into water and oxygen gas. In this experiment you will investigate yeast activity in acidic, neutral, and basic mixtures. You will observe yeast activity by measuring pressure caused by the oxygen gas they produce.

## OBJECTIVES

- Use a Gas Pressure Sensor to measure pressure.
- Measure and compare yeast activity in acidic, neutral, and basic mixtures.
- Make a conclusion about yeast activity.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Gas Pressure Sensor  
1-hole stopper with tapered valve  
10 mL graduated cylinder  
3 test tubes  
test tube rack  
3% hydrogen peroxide  
yeast suspension  
dropper  
acidic mixture (diet soft drink)  
neutral mixture (non-fat milk)  
basic mixture (stomach antacid)

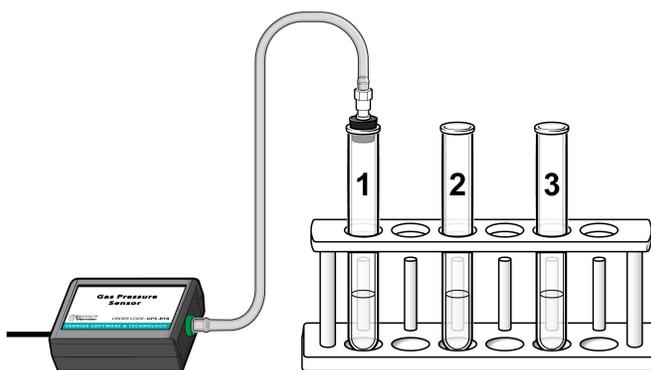


Figure 1

**PROCEDURE**

1. Obtain and wear goggles. **WARNING:** *Treat all laboratory chemicals with caution. Safe laboratory practices should be observed.*
2. Connect the sensor to the computer interface. Start the Vernier data-collection program and open the file “24 Yeast Beasts” from the *Middle School Science with Vernier* folder.
3. Place three clean test tubes in a test tube rack and label them A, N, and B (for acid, neutral, and base). Add 3 mL of hydrogen peroxide and 3 mL of each mixture to its test tube, as directed in the table below.

Mixture	Hydrogen peroxide (mL)	Mixture (mL)
A (acid)	3	3
N (neutral)	3	3
B (base)	3	3

4. Using a clean dropper, add 2 drops of yeast to Test Tube A. **Note:** Be sure not to let the yeast fall against the side of the test tube.
5. Insert the 1-hole stopper assembly into the test tube. **Note:** *Firmly* twist the stopper for an *airtight* fit. The plastic tubing should not yet be attached to the stopper assembly.

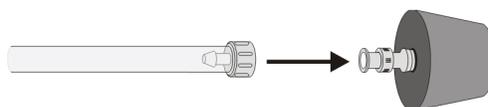


Figure 2

6. Swirl the tube to thoroughly mix its contents. Stand the test tube in the rack.
7. Click  to begin data collection.
8. Connect the free end of the plastic tubing to the connector in the rubber stopper as shown in Figure 2.
9. Data will be collected for 2 minutes. Do not shake the test tube during data collection.
10. When data collection ends, record the highest pressure for this run.
11. Choose Store Latest Run from the Experiment menu to store your data.
12. Disconnect the tubing from the rubber stopper and remove the rubber stopper from the test tube.
13. Repeat Steps 4–12 using Test Tube N.

- Repeat Steps 4–10 using Test Tube B.
- Print copies of the graph as directed by your teacher.

## DATA

Mixture	Highest pressure (kPa)
Acidic (diet soft drink)	
Neutral (non-fat milk)	
Basic (stomach antacid)	

## PROCESSING THE DATA

- In which mixture was the yeast activity greatest? Explain.
- In which mixture was the yeast activity least? Explain.
- What can you conclude from the results of your experiment?

## EXTENSIONS

- Prepare a bar graph of the results of your experiment.
- Observe yeast growing under a microscope.
- Measure the pH of each mixture used in this experiment.
- Design an experiment to find the best pH for yeast. Perform the experiment you designed.



## Yeast Beasts in Action

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., Logger *Pro* and Graphical Analysis). 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 Logger *Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources. The Graphical Analysis Pro file for this experiment includes video of the trial with the acidic solution (diet soda). To view data for the other solutions (neutral [skim milk] and basic [milk of magnesia]), see the data table or click or tap the vertical axis label and select the data you want to view. Note that videos of the other trials are not included.

The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in Graphical Analysis Pro, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.

2. To prepare the yeast mixture, dissolve 7 g (1 package) of dried yeast per 100 mL of 2% glucose solution. The 2% glucose solution can be prepared by adding 2 grams of glucose in distilled water to make 100 mL of mixture. Incubate the suspension in 37–40°C water for at least 10 minutes to activate the yeast. Test the experiment before the students begin. The yeast may need to be diluted if the reaction occurs too rapidly.
3. You can purchase 3% hydrogen peroxide (GHS Signal Word: **DANGER**) from any supermarket. If refrigerated, bring it to room temperature before starting the experiment.
4. Size 18 × 150 mm test tubes work well for this experiment.

## Experiment 24

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- Prior to students arriving for class, connect the piece of thick-wall plastic tubing and rubber stopper assembly to the end valve of the Gas Pressure Sensor with a gentle half turn. During the Procedure, students will connect the other end of the plastic tubing to a single-hole rubber stopper using one of the tapered, ribbed valves included with a Gas Pressure Sensor (see Figure 1). If the single-hole rubber stopper that came with the valve is the wrong size for your bottle, the tapered valve can be pulled out of the stopper and pushed into a stopper that fits the bottle.

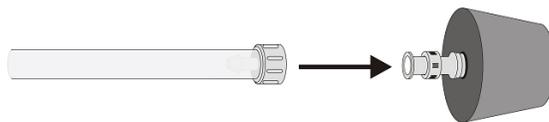


Figure 1

- The sample results were collected using Diet 7 Up® (pH = 3.1), skim milk (pH = 6.7), and 5% Milk of Magnesia® (pH = 9.9). The 5% Milk of Magnesia mixture can be prepared using 5 mL of Milk of Magnesia® per 100 mL of mixture. Other acidic, basic, and nearly neutral mixtures can be substituted. Buffer solutions can also be substituted. Vernier Software sells a pH buffer package for preparing buffer solutions with pH values of 4, 7, and 10 (order code: PH-BUFCAP). Simply add the capsule contents to 100 mL of distilled water to prepare the buffer solutions.
- If using Logger Pro, encourage your students to label their graphs and make clarifying remarks by choosing Text Annotation from the Insert menu. In Graphical Analysis, students can label their graphs and make clarifying remarks by clicking or tapping Graph Tools, , and choosing Add Annotation.
- We recommend that you have your students observe yeast budding under a microscope prior to doing this experiment.
- You may find Experiment 29, “Household Acids and Bases” found in *Physical Science with Vernier*, also available from Vernier Software, useful in your teaching. In that experiment, students use litmus paper, red-cabbage juice, and pH Sensors to test household acids and bases.
- The following procedure can be used to display graphs of 2 (or 3) successive runs when using the EasyData App.
  - After the first run, select **(File)** from the Main screen, and then select **STORE RUN**.
  - Select **(OK)** to store your latest data and overwrite the data in Lists 3 and 4 (L3 and L4).
  - Collect data for another run. **Note:** Do not save your last run.
  - From the Graph screen, select **(Adv)** and then select **L2 AND L3 VS L1** (or **L2, L3 AND L4 VS L1** if you have 3 runs).
- For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.

12. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

## ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	LS1.A Structure and Function LS1.B Growth and Development of Organism	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter

## HAZARD ALERTS

The chemical safety signal words used in this experiment (DANGER and WARNING) are part of the Globally Harmonized System of Classification and Labeling of Chemicals (GHS). Refer to the Safety Data Sheet (SDS) that came with the chemical. These can also be found online from the manufacturer. See Appendix D for more information. See the Preface for additional chemical safety information.

Glucose, solid,  $C_6H_{12}O_6$ : **N/A**: This chemical is considered nonhazardous according to GHS classifications. Treat all laboratory chemicals with caution. Prudent laboratory practices should be observed.

Hydrogen peroxide, 3%: **DANGER**: Causes skin and eye irritation.

## SAMPLE RESULTS

Mixture	Highest pressure (kPa)
Acidic (diet soft drink)	105.4
Neutral (skim milk)	120.1
Basic (stomach antacid)	123.7

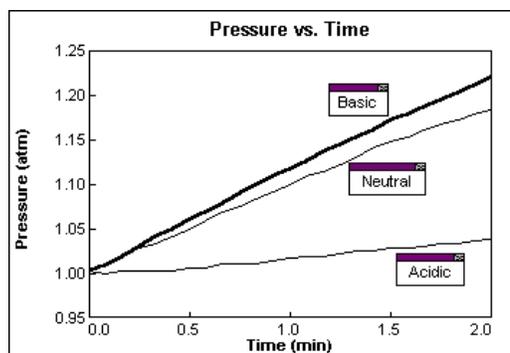


Figure 2 Yeast activity in various surroundings

## ANSWERS TO QUESTIONS

1. As is evidenced by the greatest pressure increase, yeast activity is greatest in basic surroundings.
2. As is evidenced by the least pressure increase, yeast activity is least in acidic surroundings. Students will generally conclude that yeast is most active in basic surroundings.

## ACKNOWLEDGMENT

We wish to thank Kelly Redding and David Masterman for their help developing this experiment.



# Heart Rate and Body Position

Does the position of your body affect your heart rate? In this experiment, you will use a Heart Rate Monitor to measure your heart rate while sitting, lying, and standing. You will then use your results to answer the questions.

## OBJECTIVES

- Use a Heart Rate Monitor to measure your heart rate while sitting, lying, and standing.
- Analyze the results of your experiment.
- Compare your results with those of other students.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Hand-Grip Heart Rate Monitor **or** Vernier Exercise Heart Rate Monitor  
timer

## PROCEDURE

1. Plug the receiver module of the Heart Rate Monitor into the Vernier computer interface.
2. Start the Vernier data-collection program and open the file “25 Heart Rate Position” from the *Middle School Science with Vernier* folder.

## Experiment 25

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- Set up the sensor, following the directions for your device.

### Using Hand-Grip Heart Rate Monitor

- If the hand grips use a Polar Transmitter Module, ensure that it is securely attached to the hand grips. The receiver is marked with a white alignment arrow as shown in Figure 1. Locate this arrow. If the handle is marked with an alignment arrow, locate this arrow as well.
- Have the subject firmly grasp the handles of the Hand-Grip Heart Rate Monitor so that the metal electrodes are against their palms. Hold the handles vertically.
- Another group member should hold the receiver near the handles so that the alignment arrow is pointing up as shown in Figure 1. If the Hand Grips have alignment arrows, make sure that the arrow on the receiver and the arrow on the Hand Grips are aligned in the same direction. **Note:** The receiver must stay within 60 cm of the handles during data collection.

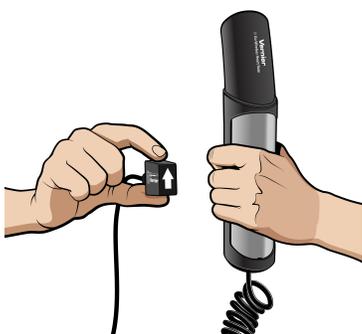


Figure 1

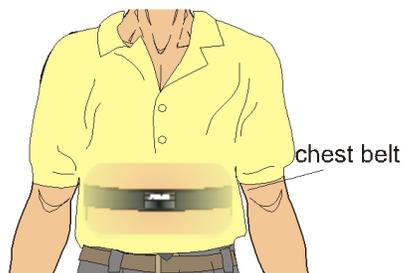


Figure 2

### Using an Exercise Heart Rate Monitor

- If the chest strap uses a Polar Transmitter Module, ensure that it is securely attached to the Exercise Heart Rate Strap.
  - Secure the Exercise Heart Rate Monitor against the skin directly, around the subject's chest as shown in Figure 2. Verify that the Polar Logo is located in the center of the chest in an upright position. Attach the hook to the other end of the strap to secure the sensor and adjust the elastic strap to ensure a tight fit.
  - Have another group member hold the receiver near the subject so that the alignment arrow is pointing up. Note: The receiver must stay within 60 cm of the subject during data collection.
- Click  to determine that the sensor is functioning correctly. There will be a 15 second delay while data are collected before the first point is plotted on the upper graph. Thereafter, a point will be plotted every 5 seconds. The readings should be consistent and within the normal range of the individual, usually between 55 and 90 beats per minute. Once it is apparent that the sensor is functioning correctly, click  and continue with the next step.
  - Have the subject sit quietly facing away from the computer and classmates. Once the subject has been seated quietly for about a minute, a group member should click  to begin monitoring heart rate.

6. After 4 minutes of data collection have gone by, the subject should recline on a clean surface or table, facing away from the computer monitor and all classmates. **Note:** A group member should tell the subject when it is time to recline. If using the Hand-Grip Heart Rate Sensor, remember to move the receiver along with the handles to keep the arrows aligned.
7. After 8 minutes of data collection have gone by, the subject should stand, facing away from the computer monitor and all classmates. Data collection will automatically stop after 12 minutes. **Note:** A group member should again tell the subject when it is time to stand.
8. Determine the subject's sitting heart rate.
  - a. Move the mouse pointer to the 2 minute line.
  - b. Press the mouse button and hold it down as you drag across the graph to the 4 minute line to select this part of the graph.
  - c. Click Statistics, . Record the Mean (average) sitting heart rate (in bpm).
9. Determine the subject's reclining heart rate.
  - a. Move the mouse pointer to the 6 minute line.
  - b. Press the mouse button and hold it down as you drag across the graph to the 8-minute line to select this part of the graph.
  - c. Click Statistics, . Record the Mean (average) reclining heart rate (in bpm).
10. Determine the subject's standing heart rate.
  - a. Move the mouse pointer to the 10 minute line.
  - b. Press the mouse button and hold it down as you drag across the graph to the 12-minute line to select this part of the graph.
  - c. Click Statistics, . Record the Mean (average) standing heart rate (in bpm).
  - d. Close all of the Statistics boxes.
11. Print copies of the graph as directed by your teacher.
12. Repeat Steps 3–11 with other members of the team serving as subjects.

## DATA

Subject's name			
Sitting heart rate (beats/min)			
Reclining heart rate (beats/min)			
Standing heart rate (beats/min)			
Difference between sitting and reclining heart rates (beats/min)			
Difference between standing and sitting heart rates (beats/min)			
Difference between standing and reclining heart rates (beats/min)			

## PROCESSING THE DATA

1. In the space provided in the data table, subtract to calculate the difference between the sitting and reclining heart rates for each subject.
2. Subtract to find the difference between the standing and sitting heart rates for each subject.
3. Subtract to find the difference between the standing and reclining heart rates for each subject.
4. Does the position of your body affect your heart rate?
5. Compare your results with those of other students.
6. Try to explain the results of the experiment.

## EXTENSION

Measure your heart rate while standing on your head. Compare the results with your other results.

## Heart Rate and Body Position

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources.
2. There are multiple versions of the Hand-Grip Heart Rate Monitor and the Exercise Heart Rate Monitor. To identify your monitor and discover additional tips for its use, see  
  
Hand-Grip Heart Rate Monitor: **vernier.com/til/3981**  
  
Exercise Heart Rate Monitor: **vernier.com/til/3982**  
  
Go Wireless Heart Rate Monitor: **vernier.com/til/3533**
3. It is important to have good contact between the transmitter belt and the test subject when using the Exercise Heart Rate Monitor. It is very important that the belt fits snugly, but is not too tight. To ensure a good connection between the skin and transmitter, wet the strap with water. Typical symptoms of inadequate contact with the electrodes are a noisy signal with erroneous peaks, missing heart beat rates, or a flat-line display. If the students receive a flat reading with no heart rate detected, have them move the transmitter and the receiver closer together. The range of the transmitter in the chest belt is 60 to 80 cm.
4. All electrical devices, including cell phones, laptop computers, and computer monitors, can be a source of electrical interference. Move the receiver module as far from electrical devices as possible.
5. The receiver module will receive signals from the closest transmitter source. To avoid confusion or erroneous readings, have the test subjects from different lab groups stay at least 2 m apart.
6. It is possible to alter your heart rate by simply decreasing your respiratory rate and relaxing. Encourage students to stay alert and to breathe normally.
7. If you are using Go Direct sensors, see See Visit **www.vernier.com/start/go-direct** for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

## Experiment 25

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

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions Engaging in argument from evidence	LS1.A Structure and Function	Cause and effect Scale, proportion, and quantity Structure and function Stability and change

### SAMPLE RESULTS

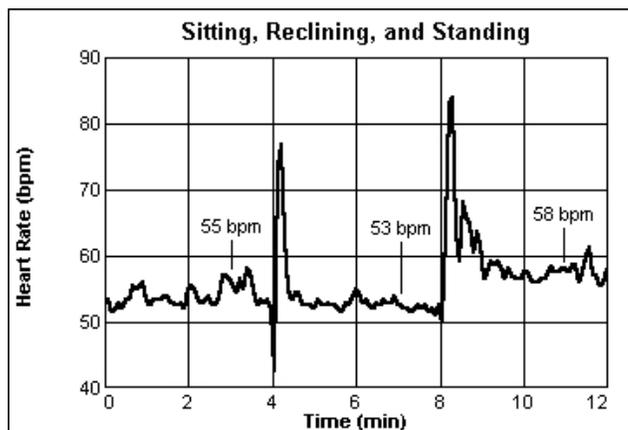


Figure 1 Heart rate and body position

Subject's name	Paulo	Rebekka	Chris
Sitting heart rate (beats/min)	55	74	63
Reclining heart rate (beats/min)	53	66	61
Standing heart rate (beats/min)	58	86	73
Difference between sitting and reclining heart rates (beats/min)	$55 - 53 = 2$	$74 - 66 = 8$	$63 - 61 = 2$
Difference between standing and sitting heart rates (beats/min)	$58 - 55 = 3$	$86 - 74 = 12$	$73 - 63 = 10$
Difference between standing and reclining heart rates (beats/min)	$58 - 53 = 5$	$86 - 66 = 20$	$73 - 61 = 12$

### **ANSWERS TO QUESTIONS**

4. Yes, body position affects heart rate. For the positions studied in this experiment, heart rates are generally lowest in the reclining position and highest in the standing position.
5. Answers will vary.
6. Heart rate generally goes down when a student moves from a sitting position to a reclining position. The forces of gravity do not have to be overcome for blood to flow while in a reclining position. Similarly, heart rate generally increases when a student moves from a reclining position to a standing position. The forces of gravity do have to be overcome while in a standing position.





# Heart Rate and Exercise

Heart rates increase during exercise. The heart rates of physically fit people increase less during exercise than those of less fit people. The heart rates of physically fit people recover to their resting rates more rapidly. In this experiment, you will use a Heart Rate Monitor to measure your heart rate as you stand quietly for 100 seconds, step onto and off a stool for 100 seconds, and then stand quietly for 200 seconds. You will then analyze a graph of the results to determine your standing heart rate, your maximum heart rate during the 100 seconds of exercise, and your recovery time.

**Important:** Do not attempt this experiment if physical exertion will aggravate a health problem. Inform your teacher of any possible health problems that might be affected if you participate in this experiment.

## OBJECTIVES

- Use a Heart Rate Monitor to measure your heart rate.
- Determine the effect of exercise on your heart rate.
- Determine your recovery time.
- Compare your results with those of other students.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Hand-Grip Heart Rate Monitor **or** Vernier Exercise Heart Rate Monitor  
timer  
stepping stool, 40 cm high

## PROCEDURE

1. Plug the receiver module of the Heart Rate Monitor into the Vernier computer interface.
2. Start the Vernier data-collection program and open the file “26 Heart Rate Exercise” from the *Middle School Science with Vernier* folder.

## Experiment 26

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- Set up the sensor by following the directions for your device:

### Using a Hand-Grip Heart Rate Monitor

- If the hand grips use a Polar Transmitter Module, ensure that it is securely attached to the hand grips. The receiver is marked with a white alignment arrow as shown in Figure 1. Locate this arrow. If the handle is marked with an alignment arrow, locate this arrow as well.
- Have the subject firmly grasp the handles of the Hand-Grip Heart Rate Monitor so that the metal electrodes are against their palms. Hold the handles vertically.
- Another group member should hold the receiver near the handles so that the alignment arrow is pointing up as shown in Figure 1. If the Hand Grips have alignment arrows, make sure that the arrow on the receiver and the arrow on the Hand Grips are aligned in the same direction. **Note:** The receiver must stay within 60 cm of the handles during data collection.

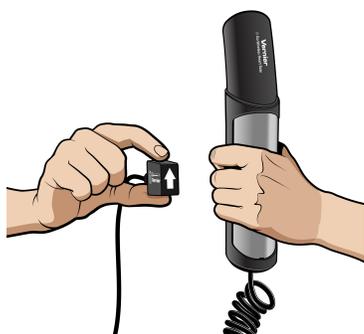


Figure 1

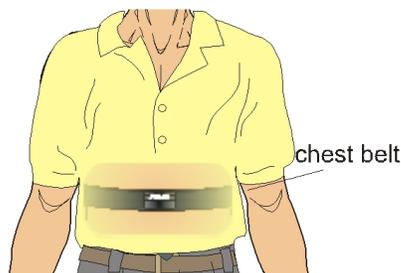


Figure 2

### Using an Exercise Heart Rate Monitor

- If the chest strap uses a Polar Transmitter Module, ensure that it is securely attached to the Exercise Heart Rate strap.
  - Secure the Exercise Heart Rate Monitor against the skin directly, around the subject's chest as shown in Figure 2. Verify that the Polar logo is located in the center of the chest in an upright position. Attach the hook to the other end of the strap to secure the sensor and adjust the elastic strap to ensure a tight fit.
  - Have another group member hold the receiver near the subject so that the alignment arrow is pointing up. **Note:** The receiver must stay within 60 cm of the subject during data collection.
- Click  to determine that the sensor is functioning correctly. There will be a 15 second delay while data are collected before the first point is plotted on the upper graph. Thereafter, a point will be plotted every 5 seconds. The readings should be consistent and within the normal range of the individual, usually between 55 and 90 beats per minute. Once it is apparent that the sensor is functioning correctly, click  and continue with the next step.
  - Have the subject stand quietly and face away from the computer and the other people in your group. Once the subject has been standing quietly for about a minute, a partner should click  to begin monitoring heart rate. There will be a 15 second delay while data are collected

before the first point is plotted on the upper graph. Thereafter, a point will be plotted every 5 seconds. The subject should stand quietly for 100 seconds.

6. When 100 seconds have gone by, immediately begin to exercise as follows:
  - a. Place your right foot on the top step of the stool.
  - b. Place your left foot completely on the top step of the stool next to your right foot.
  - c. Place your right foot back on the floor.
  - d. Place your left foot completely on the floor next to your right foot.
  - e. Each stepping cycle should take 3 seconds to complete.
  - f. Continue the step test for a total of 100 seconds.
7. After 100 seconds of stepping (a total of 200 seconds of data collection), stop stepping. Stand quietly for 200 seconds. Data collection will end automatically.
8. Determine the subject's standing heart rate.
  - a. Move the mouse pointer to the 0 second line.
  - b. Press the mouse button and hold it down as you drag across the graph to the 100 second line to *select* this part of the graph.
  - c. Click Statistics, . Record the Mean (average) standing heart rate (in bpm).
  - d. Close the Statistics box.
9. Determine the subject's maximum heart rate.
  - a. Click Examine, .
  - b. Move the cursor to the highest point on the graph.
  - c. Record the time and heart rate (HRT) displayed for this point.
10. Determine the time when the subject's standing heart rate returned to within 3 bpm of the standing rate.
  - a. Starting at the 200 second line, move the cursor to the right.
  - b. Stop where the displayed heart rate first reads within 3 bpm of the Step 11 value.
  - c. Record the time (to the nearest whole second) for this point
  - d. Close the Examine box.
11. Print copies of the graph as directed by your teacher.
12. Repeat Steps 3–11 with other members of the team serving as subjects.

## DATA

Subject's name				
Standing heart rate (bpm)				
Maximum heart rate (bpm)				
Time at maximum heart rate (s)				
Time at return to within 3 bpm of standing rate (s)				
Recovery time (s)				

## PROCESSING THE DATA

1. In the space provided in the data table, calculate the recovery time for each subject. (Subtract 200 from the time when the rate returned to within 3 bpm of the standing rate.)
2. Compare the standing heart rates of the members of your group.
3. How does your maximum heart rate compare to other students in your group? Is this what you expected? How do you account for this?
4. How does your recovery time compare to other students in your group? Is this what you expected? How do you account for this?
5. Why would athletes need to work longer and harder before their heart rates were at the maximum value? Explain.

## EXTENSION

Survey your classmates to determine how much they exercise each week. Determine if there is a relationship between amount of exercise and recovery time for your class.

## Heart Rate and Exercise

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources. The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in *Graphical Analysis Pro*, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.
2. In the Electronic Resources you will find a PDF of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. This is copyrighted material, so please do not post the content on a page that is accessible to the public. Sign in to your account at **vernier.com/account** to access the Electronic Resources.
3. This experiment was adapted from *Middle School Science with Vernier*, Experiment 26. Learn more at **vernier.com/msv**
4. There are multiple versions of the Hand-Grip Heart Rate Monitor and the Exercise Heart Rate Monitor. To identify your monitor and discover additional tips for its use, see  
  
Hand-Grip Heart Rate Monitor: **vernier.com/til/3981**  
  
Exercise Heart Rate Monitor: **vernier.com/til/3982**  
  
Go Wireless Heart Rate Monitor: **vernier.com/til/3533**
5. It is important to have good contact between the transmitter belt and the test subject when using the Exercise Heart Rate Monitor. It is very important that the belt fit snug, but not too tight. To ensure a good connection between the skin and transmitter, wet the strap with water. Typical symptoms of inadequate contact with the electrodes are a noisy signal with erroneous peaks, missing heart beat rates, or a flat-line display. If the students receive a flat reading with no heart rate detected, have them move the transmitter and the receiver closer together. The range of the transmitter in the chest belt is 60 to 80 cm.

## Experiment 26

- All electrical devices, including cell phones, laptop computers, and computer monitors, can be a source of electrical interference. Move the receiver module as far from electrical devices as possible.
- The receiver module will receive signals from the closest transmitter source. To avoid confusion or erroneous readings, have the test subjects from different lab teams stay at least 2 m apart.
- It is possible to alter your heart rate by simply decreasing your respiratory rate and relaxing. Encourage students to stay alert and to breathe normally.
- If you are using Go Direct sensors, see [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect your sensor.
- For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.

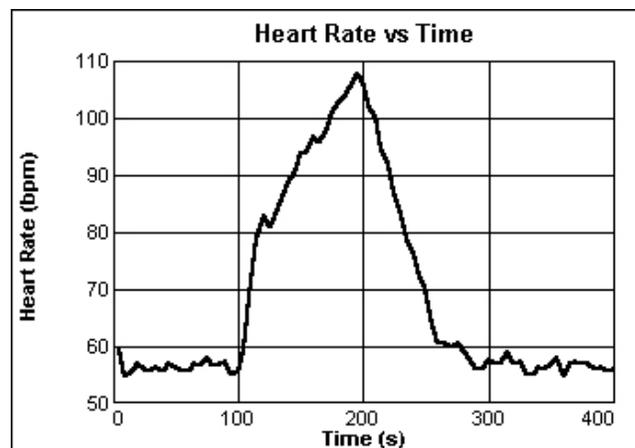
## ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	LS1.A Structure and Function	Patterns Cause and effect Scale, proportion, and quantity Structure and function Stability and change

## SAMPLE RESULTS



*Figure 1 Heart rate and exercise*

Subject's name	Hazel	Roger	Ivan	Maria
Standing heart rate (bpm)	57	84	69	76
Maximum heart rate (bpm)	108	154	143	134
Time at return to within 3 bpm of standing rate (s)	269	294	264	282
Recovery time in seconds (s)	69	94	64	82

### **ANSWERS TO QUESTIONS**

1. See the Sample Results.
2. Answers will vary.
3. Answers will vary. Factors such as weight, regular exercise, and health may influence maximum heart rate.
4. Answers will vary. Factors such as weight, regular exercise, and health may influence recovery time.
5. An athlete's heart is more efficient at moving blood through the body. Each contraction of an athlete's heart moves a greater volume of blood than for an average individual. More blood per contraction means more oxygen for the body's cells. Because of this an athlete must work harder to increase his or her heart rate to its maximum values.





# Mapping a Magnetic Field

The region around a magnet where magnetic force acts is called a *magnetic field*. In this experiment, you will map the magnetic field at one-centimeter intervals along a bar magnet.

## OBJECTIVES

- Measure and graph magnetic field strength at points along a bar magnet.
- Analyze data.
- Make conclusions about the magnetic field at various points on a bar magnet.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Magnetic Field Sensor  
bar magnet  
tape  
ruler



Figure 1

## PROCEDURE

1. Set the switch on the Magnetic Field Sensor to 6.4 mT (low amplification). Connect the Magnetic Field Sensor to the computer interface. Start the Vernier data-collection program and open the file “27 Magnetic Field” from the *Middle School Science with Vernier* folder.
2. Tape a meter stick to the table top with pieces of tape at about 50 cm and 95 cm.
3. Zero the Magnetic Field Sensor.
  - a. Position the Magnetic Field Sensor so the Sensor Location line is at the 0 cm mark (see Figure 1).
  - b. Make sure the bar magnet is far away from the sensor. You will position it next to the meter stick when it is time to collect data.
  - c. Click  to zero the sensor.
4. Click  to begin data collection.

## Experiment 27

5. Collect data.
  - a. Ensure the Magnetic Field Sensor is positioned so the Sensor Location line is at the 0 cm mark.
  - b. Position the bar magnet beside the ruler with the S-pole end of the magnet at the 3 cm mark (see Figure 1). Tape the magnet to the table top. If the poles are not marked, orient the magnet so that you get positive magnetic field readings. Keep the magnet in this position throughout data collection.
  - c. Type **0** in the edit box (for 0 cm).
  - d. Press ENTER. The magnetic field strength value for 0 cm is now saved.
6. Collect additional data.
  - a. Move the sensor so the Sensor Location line is at the 1 cm mark. **Important:** Keep the Magnetic Field Sensor parallel to the bar magnet during data collection, as shown in Figure 2.



Figure 2

- b. When the value has stabilized, click .
    - c. Type **1** in the edit box (for 1 cm) and press ENTER to store the data pair.
    - d. Move the sensor and repeat the data-collection procedure at 1 cm intervals until you have reached a point 3 cm beyond the N pole of the bar magnet.
7. Click  to end data collection.
8. Record the magnetic field values.
9. (optional) Print copies of the graph.

## DATA

Position (cm)	Magnetic field (mT)	Position (cm)	Magnetic field (mT)	Position (cm)	Magnetic field (mT)
0		6		12	
1		7		13	
2		8		14	
3		9		15	
4		10		16	
5		11		17	

## **PROCESSING THE DATA**

1. At what position beside the bar magnet was the largest positive magnetic field strength reading observed?
2. At what position beside the bar magnet was the most negative magnetic field strength reading observed?
3. At what position does your graph have a zero value magnetic field strength value? At what location is this on the bar magnet?
4. Why does the graph have both positive and negative magnetic field strength values?

## **EXTENSION**

Test the strengths of different magnet types at the same distance from the sensor. Which magnet types are strongest? Weakest?



## Mapping a Magnetic Field

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources.
2. When collecting data, it is important to be aware of the location of the sensor within the housing of the probe. It may be helpful to discuss this with students before they start collecting data.

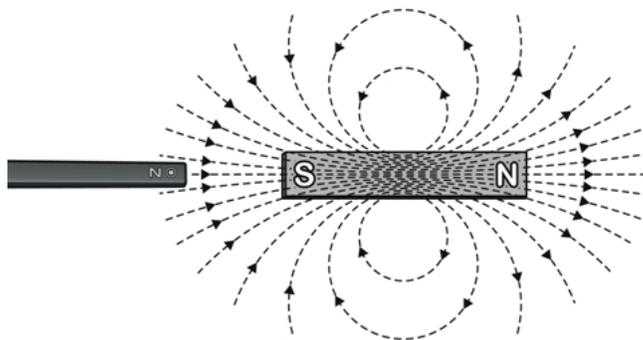
### Magnetic Field Sensor

There is a line, which we refer to as the Sensor Location line, marked about 0.9 cm from the tip of the Magnetic Field Sensor. This line indicates the location of the sensor within the Magnetic Field Sensor housing.

### Go Direct 3-Axis Magnetic Field Sensor

The end of Go Direct 3-Axis Magnetic Field has three dots: one at the tip and two on the sides labeled Y and Z. The location of these dots marks the position of the sensor within the wand and the Y and Z labels show the directions in which positive values are measured. The tip is the x-direction and measures positive values when the field has a component in the same direction that the tip of the wand is pointing.

3. One way to think of how our Magnetic Field Sensors work is that they measure the quantity and direction of the magnetic field lines that cut through the end of the probe (see Figure 1). **Note:** Figure 1 illustrates the Go Direct Magnetic Field Sensor. The standard Magnetic Field Sensor (order code: MG-BTA) works in the same way; it measures the direction and quantity of magnetic field lines cutting through the white dot at the tip of the probe.



*Figure 1 The x-direction measurement is positive when the wand points toward the south pole of the magnet.*

4. Bear in mind that magnets are sometimes mislabeled. All of our Magnetic Field SensorsThe sensors will read a positive value when pointed directly toward the S pole of the magnet, and a negative value when pointed directly toward the N pole of the magnet, regardless of how the ends of the magnet are labeled.
5. You may find it necessary to position the sensor farther to the side of stronger bar magnets. Positions too close to the sensor may have a magnetic field that is too strong for the sensor to measure. We have found that 2–3 cm to the side of the magnet generally works well. On the Go Direct 3-Axis Magnetic Field sensor, a reading of exactly 5.0 mT indicates the field is too strong to be measured at a given distance.
6. The Go Direct 3-Axis Magnetic Field Sensor has two ranges for measurement. The lower (and more precise) range of  $\pm 5$  mT generally works well for this experiment. The  $\pm 5$  mT range is the default for this sensor. However, if you would like to use the higher (and less precise) range of  $\pm 130$  mT, instruct students to select the Magnetic Field X-Axis 130 mT sensor after starting Graphical Analysis and connecting the sensor.
7. If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.
8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.

## ESTIMATED TIME

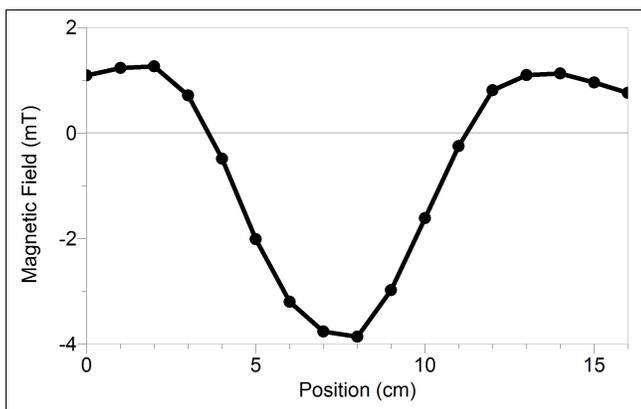
We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS2.B Types of Interactions	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function

## SAMPLE RESULTS

Position (cm)	Magnetic field (mT)	Position (cm)	Magnetic field (mT)	Position (cm)	Magnetic field (mT)
0	1.093	6	-3.201	12	0.813
1	1.230	7	-3.762	13	1.099
2	1.126	8	-3.861	14	1.130
3	0.710	9	-2.978	15	0.959
4	-0.485	10	-1.615	16	0.762
5	-2.010	11	-0.249	17	



*Figure 2*

## ANSWERS TO QUESTIONS

1. The largest positive magnetic field strength reading is obtained at one of the poles (at the S pole in the Sample Results).

### *Experiment 27*

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2. The most negative magnetic field strength reading is obtained in the center portion of the magnet.
3. The graph has a zero magnetic field strength value at two points towards the ends of the magnet.
4. The magnetic field strength values with opposite signs are caused by opposite magnetic field directions. (As this experiment is designed, the positive values correspond to the field being directed toward the right, and the negative values correspond to the field being directed toward the left.)



# Electromagnets

A magnetic field forms around a wire that has an electric current in it. Winding a wire around a piece of iron increases the strength of the magnetic field. A temporary magnet made in this way is called an electromagnet. In this experiment, you will use a Magnetic Field Sensor to study the relationship between number of wire winds and magnetic field strength of an electromagnet.

## OBJECTIVES

- Build an electromagnet.
- Measure magnetic field strength.
- Make conclusions about the relationship between number of wire winds and magnetic field strength.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Magnetic Field Sensor  
large iron nail  
1 m piece of insulated wire  
battery (size D)  
tape



Figure 1

## PROCEDURE

1. Tape a Magnetic Field Sensor to the tabletop. The white dot on the sensor should face directly upwards. Remove all magnetic material from near the sensor.
2. Set the Magnetic Field Sensor to 6.4 mT (low amplification). Plug the Magnetic Field Sensor into the computer interface. Start the Vernier data-collection program and open the file “28 Electromagnets” from the *Middle School Science with Vernier* folder.
3. Click  to zero the sensor.

## Experiment 28

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4. Collect data for zero winds.
  - a. Click .
  - b. Get a large iron nail and place its pointed end perpendicular to the top of the Magnetic Field Sensor at its very end, as shown in Figure 1. When the reading has stabilized, click .
  - c. Type **0** in the edit box (for 0 winds).
  - d. Press ENTER. The magnetic field strength value for zero winds is now saved.
5. Tape one bare end of a 1 m insulated wire to the bottom end of a flashlight battery.
6. Place the nail on the wire at a position 10–15 cm from the battery. Tightly wind the wire around the nail 3 times as shown in Figure 1.
7. Collect data for 3 winds.
  - a. Firmly press the other bare end of the wire to the top of the battery.
  - b. A partner should again touch the pointed end of the nail to the top of the sensor at its very end as shown in Figure 1. **Important:** If the reading decreases, reverse the connections.
  - c. When the reading has stabilized, click .
  - d. Type **3** in the edit box (for 3 winds).
  - e. Press ENTER. The magnetic field strength value for 3 winds is now saved.
8. Repeat Step 7 for 6, 9, 12, 15, 18, and 21 winds. **Caution:** The battery will become warm as it is used. To keep it from getting hot, and to save energy, remove the wire from the top of the battery immediately after  has been clicked. **Important:** Wrap all winds at nearly the same distance from the nail end.

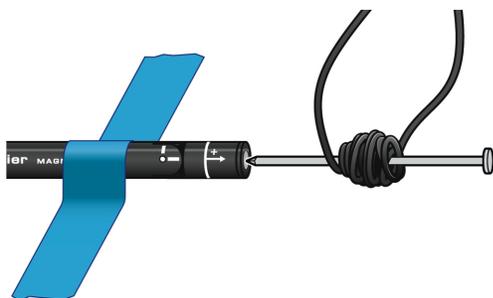


Figure 2 Correct wraps



Figure 3 Incorrect wraps

9. Click  to end data collection. Record the magnetic field strength values displayed in the table in your data table.
10. Print copies of the graph as directed by your teacher.

**DATA**

Winds	Magnetic field (mT)	Winds	Magnetic field (mT)
0		12	
3		15	
6		18	
9		21	

**PROCESSING THE DATA**

1. What is the relationship between number of winds and magnetic field strength?
2. According to your graph, what would the magnetic field strength reading be for 10 winds? For 30 winds? Explain.

**EXTENSIONS**

1. If you are using *Logger Pro*, answer Question 2 by adding a “best-fit” straight line to your graph and then analyzing this line.
  - a. To obtain a best-fit line, click Linear Fit, .
  - b. Choose Interpolate on the Analyze menu.
  - c. Move the cursor along the graph to a position above 10 winds—the x-value displayed on the screen should be 10. The y-value displayed on the screen is your magnetic field strength value for 10 winds. Record it.
  - d. Move the cursor along the graph until the x-value is 30. Read and record magnetic field strength, the y-value, for 30 winds.
2. See how many grams of iron filings your electromagnet will pick up with the same numbers of winds used in the above experiment. Compare mass of iron filings picked up to magnetic field strength.
3. Compare the magnetic field of the nail after the experiment with its magnetic field before it has been used in an electromagnet. Measure the magnetic field of the nail again after striking it on a hard surface. Explain these results using the idea of magnetic domains.



## Electromagnets

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. Magnetic Field Sensors (order code: MG-BTA) have a switch on the body of the sensor, and it should be set to 6.4 mT (low amplification) for this experiment. The Go Direct 3-Axis Magnetic Field Sensors have two ranges for measurement, which are set within the software. The lower (and more precise) range of  $\pm 5$  mT generally works well for this experiment. The  $\pm 5$  mT range is the default for this sensor; for this experiment, there is nothing you need to do to set the range.
3. Demagnetize the iron nails beforehand by striking them on something firm, like a ring stand base.
4. Use rubber or plastic-covered copper wire—22 or 24 gauge. This is sometimes called bell wire. Cut the wire in 1 m lengths and remove about 1 cm of covering at each end. Single-strand wire works best.
5. For best results, use D-cell battery holders to hold the batteries.
6. We strongly recommend the use of some or all of the extensions included with this experiment.
7. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
8. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

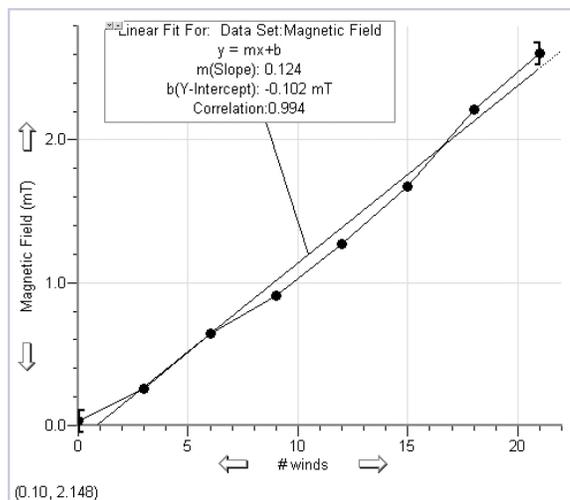
We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS2.B Types of Interactions	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change

## SAMPLE RESULTS

Winds (#)	Magnetic field (mT)	Winds (#)	Magnetic field (mT)
0	0.03	12	1.27
3	0.26	15	1.67
6	0.64	18	2.21
9	0.91	21	2.61



## ANSWERS TO QUESTIONS

1. Magnetic field strength varies directly with number of winds.
2. Answers will vary.

# Friction

## (Force Sensor)

Friction is a force that resists motion. It involves objects in contact with each other, and it can be either useful or harmful. Friction helps when you want to slow or stop a bicycle, but it is harmful when it causes wear on the parts of a machine. In this activity, you will study the effects of surface smoothness and the nature of materials in contact on sliding friction. You will use a Force Sensor to measure frictional force, in Newtons (N), as you pull a block across different surfaces.

### OBJECTIVES

- Measure sliding friction.
- Measure friction between a wooden block and smooth-surface wood.
- Measure friction between a wooden block and rough-surface wood.
- Make predictions about other surfaces.
- Test your predictions.

### MATERIALS

computer  
 Vernier computer interface  
 Vernier data-collection software  
 Vernier Force Sensor  
 wooden block (with a hook)  
 paper clip  
 wood with smooth surface  
 wood with rough surface  
 sandpaper

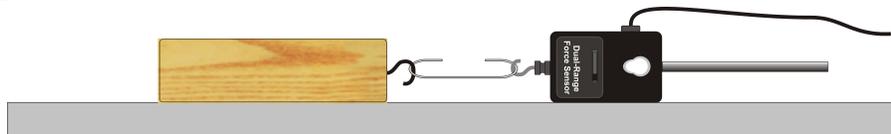


Figure 1

### PROCEDURE

#### Part I Smooth and Rough Surfaces

1. Connect the sensor to the computer interface. Start the Vernier data-collection program and open the file “29 Friction” from the *Middle School Science with Vernier* folder. If you are using a Dual-Range Force Sensor, set the range switch to 10 N.
2. Zero the Force Sensor.
  - a. Lay the Force Sensor on the tabletop in the position shown in Figure 1.
  - b. Click  to zero the sensor.

## Experiment 29

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3. Get a wooden block (with a hook on one end). Partly straighten a paper clip—leaving a hook at each end. Use the paper clip to attach the wooden block to the Force Sensor.
4. Slowly pull the wooden block across a piece of wood with a smooth surface. Hold the Force Sensor by its handle and pull it toward you, as demonstrated by your teacher. The Force Sensor should be held parallel to and about 1 cm above the surface. Once the wooden block is moving at a steady rate, click **Collect** to begin data collection.
5. After the data have been collected, look at the graph displayed on the screen. If the graph is reasonably flat, proceed to Step 6. If there are big peaks and valleys, repeat Step 4.
6. Click Statistics,  $\frac{\sqrt{2}}{\text{Stat}}$ . Record the Mean (average) force (in N).
7. Repeat Steps 4–6 as you pull the block over a piece of wood with a rough surface.

### Part II Predicting Friction

8. You will measure friction as the block is pulled across your desktop, the floor, and sandpaper. In the space provided in the data table below, predict the order of friction for these surfaces— from lowest to highest.
9. Repeat Steps 4–6 for each of the surfaces.

## DATA

Part I Smooth and rough surfaces		
Surface	Smooth wood	Rough wood
Force (N)		

Part II Predicting friction		
Predicted order of values for desktop, floor, and sandpaper		
(Lowest)		(Highest)

Surface	Desktop	Floor	Sandpaper
Force (N)			

## PROCESSING THE DATA

1. What is the effect of surface roughness on friction?
2. How did you decide the order of your predictions in Part II?
3. How good were your predictions? Explain.



4. Give two examples of situations where friction is helpful.
5. Give two examples of situations where it is best to reduce friction.
6. Summarize the results of this experiment.

## **EXTENSIONS**

1. Test the friction of other surfaces, such as glass, metals, rubber, and different fabrics.
2. Investigate how frictional force varies with contact area and mass.
3. Design an experiment to test methods of reducing friction.



# Friction

## (Sensor Cart)

Friction is a force that resists motion. It involves objects in contact with each other, and it can be either useful or harmful. Friction helps when you want to slow or stop a bicycle, but it is harmful when it causes wear on the parts of a machine. In this activity, you will study the effects of surface smoothness and the nature of materials in contact on sliding friction. You will use the force sensor built into a Sensor Cart to measure frictional force as you pull a block across different surfaces.

### OBJECTIVES

- Measure friction between a wooden block and smooth-surface wood.
- Measure friction between a wooden block and rough-surface wood.
- Make predictions about other surfaces.
- Test your predictions.

### MATERIALS

wooden block (with a hook)  
paper clip  
wood with smooth surface  
wood with rough surface  
sandpaper

*Figure 1*

### DATA

Part I Smooth and rough surfaces		
Surface	Smooth wood	Rough wood
Force (N)		

Predicted order of friction values for the desk top, the floor, and sandpaper:		
_____	_____	_____
lowest		highest

Surface	Desktop	Floor	Sandpaper
Force (N)			

## **PROCESSING THE DATA**

1. What is the effect of surface roughness on friction?
2. How did you decide the order of your predictions in Part II?
3. How good were your predictions? Explain.
4. Give two examples of situations where friction is helpful.
5. Give two examples of situations where it is best to reduce friction.
6. Summarize the results of this experiment.

## **EXTENSIONS**

1. Test the friction of other surfaces, such as glass, metals, rubber, and different fabrics.
2. Investigate either the relationship between frictional force and contact area or frictional force and mass.
3. Design an experiment to test methods of reducing friction.

## Friction

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources. There are two parts in this experiment; separate *Graphical Analysis Pro* files are included for each part.
  - For Part I, the video shows the first trial on the smooth board. To view the additional trials, see the data table or click or tap the vertical axis label and select the data you want to view. Note that the student procedures direct them to collect only one set of data for each surface. However, to show a meaningful difference, three trials for each type of board are provided.
  - For Part II, the video consists of still shots of the four surfaces used for sample data collection: a plastic desk, a cork floor, a rubber floor, and sandpaper. For this part, we recommend a slight deviation from the student procedures: start by having students look at the four surfaces in the video, then have them predict which surfaces will cause the most friction. Finally, have students view the data on the graph or in the data table to see if their predictions were correct.

The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in *Graphical Analysis Pro*, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.

2. A variety of sensors will work for this experiment. *Logger Pro* users will need a Dual-Range Force Sensor (order code: DFS-BTA). *Graphical Analysis* users can use the Dual Ranger Force Sensor (with an interface), Go Direct Force and Acceleration (order code: GDX-FOR), or Go Direct Sensor Cart (order code: GDX-CART).
3. A 15 cm (6 in) long wooden block cut from a 5 cm × 10 cm (2 in by 4 in) piece of wood works well. Insert a hook in the center of one end. Use a paper clip or a piece of string to attach it to the force sensor or sensor cart. Other flat-surface objects can be substituted.
4. Scrap pieces of wood obtained at a wood shop, building materials store, or a lumberyard can be used as surfaces for Part I.

## Experiment 29

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5. Illustrate proper technique for pulling a wooden block across a surface with the force sensor or sensor cart before the experiment.
6. Remind your students not to pull the block too fast.
7. Your students should get better results using the force sensor/sensor cart and average force values than they would with spring scales.
8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
9. If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS2.A Forces and Motion	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Stability and change

### SAMPLE RESULTS

Surface	Smooth wood	Rough wood	Desktop	Floor	Sandpaper
Force (N)	0.62	0.98	0.67	0.92	2.21

### ANSWERS TO QUESTIONS

1. Surface roughness increases friction.
2. Answers will vary.
3. Answers will vary.

4. Some examples of where friction is helpful are when it keeps you from slipping and sliding, between the brake lining and brake pads of a car, between a car's tires and the road during acceleration, snow tires, and a baseball player's use of rosin.
5. Some examples of where it is best to reduce friction are the bottoms of racing skis, between wheels and axles, between internal parts of a lock, between the cylinder walls and pistons of a car, and on a bicycle chain.
6. Friction depends on the nature of the materials in contact and the smoothness of their surfaces. Rough surfaces cause more friction than smooth surfaces.





# First Class Levers

## (Force Sensor)

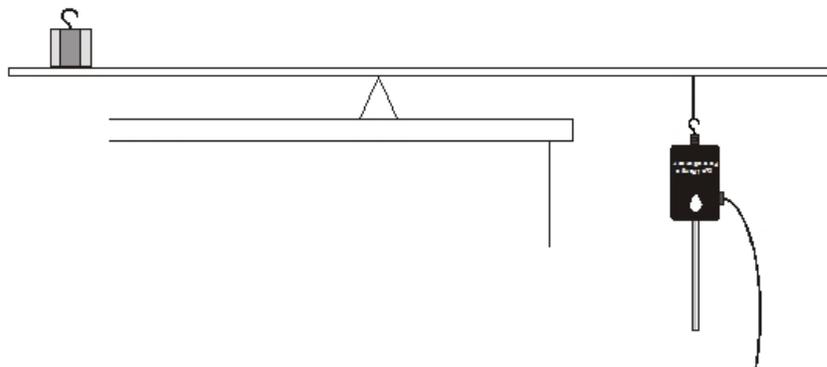
A *lever* is a simple machine used to make work easier. It consists of a long, rigid bar with a support that allows the bar to pivot. The point where the bar pivots is the *fulcrum*. There are three classes of levers—first, second, and third. In this experiment, you will examine first-class levers. Crowbars and scissors are examples of first-class levers. A lever can help you move an object by increasing the force you exert. Mechanical advantage (MA) is a value that tells the number of times a machine increases an applied force. You will use a Force Sensor to measure resistance force and effort force (in newtons). You will then use this information to calculate the mechanical advantage of each lever.

### OBJECTIVES

- Measure force.
- Calculate actual mechanical advantage (AMA).
- Calculate ideal mechanical advantage (IMA).
- Calculate percent difference.
- Make conclusions about levers.

### MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Force Sensor  
500 g mass  
loop of string  
meter stick  
fulcrum



*Figure 1*

## PROCEDURE

1. Connect the sensor to the computer interface. If you are using a Dual-Range Force Sensor, set the range switch to 10N. Start the Vernier data-collection program and open the file “30 First Class Levers” from the *Middle School Science with Vernier* folder.
2. Zero the Force Sensor with its hook pointing down.
  - a. Attach a loop of string to the hook of the Force Sensor.
  - b. Hold the Force Sensor in a vertical position with its hook pointing down. Make sure the hook and string are not touching anything.
  - c. Click  to zero the sensor.
3. To measure the resistance force ( $F_r$ ) for Trials 1, 2, and 3, hang the mass that will be used as the resistance from the Force Sensor. After the reading has stabilized, record this force reading in the Resistance Force blanks for Trials 1, 2 and 3.
4. Zero the Force Sensor with its hook pointing up.
  - a. Remove the loop of string from the Force Sensor.
  - b. Hold the Force Sensor in a vertical position with its hook pointing up. Rest the tip of its handle on the tabletop.
  - c. Click  to zero the sensor.
5. Place a fulcrum near the edge of your lab table. Balance the middle of a meter stick on the fulcrum as shown in Figure 1.
6. Place the center of the mass that is acting as your resistance force on the 90 cm line ( $D_r = 40$  cm).
7. Attach the loop of string to the hook of the Force Sensor. Loop the string over the meter stick at the 10 cm line ( $D_e = 40$  cm) as shown in Figure 1. With the fulcrum between the effort and the resistance, this is a first-class lever. Pull down with the Force Sensor until the meter stick is balanced. Record the force needed to balance the meter stick. This is the effort force ( $F_e$ ).
8. Place the center of the mass acting as the resistance force on the 70 cm line ( $D_r = 20$  cm). The position of the effort force (Force Sensor) should not change. Repeat Step 7.
9. Now move the center of the resistance force to the 60 cm line ( $D_r = 10$  cm). The position of the Force Sensor should not change. Repeat Step 7.

## DATA

Trial	Resistance distance (cm)	Resistance force (N)	Effort distance (cm)	Effort force (N)
1	40		40	
2	20		40	
3	10		40	

## PROCESSING THE DATA

1. Calculate the actual mechanical advantage for each of your three trials using the formula

$$AMA = F_r / F_e$$

where AMA = actual mechanical advantage,  $F_r$  = resistance force, and  $F_e$  = effort force. Record results in the table that follows Question 3.

2. Ideal mechanical advantage is determined by the formula

$$IMA = D_e / D_r$$

where IMA = ideal mechanical advantage,  $D_e$  = effort distance, and  $D_r$  = resistance distance. Calculate the ideal mechanical advantage of the levers you tested. Record results in the table that follows Question 3.

3. Calculate the percent difference between IMA and AMA for each of your trials using the formula

$$\% \text{ Difference} = \frac{\text{Difference between IMA and AMA}}{IMA} \times 100$$

Record the results in Table 2.

Table 2			
Trial	AMA	IMA	Percent difference
1			
2			
3			

4. What happened to the mechanical advantage as you shortened the resistance distance?
5. How did moving the resistance force closer to the fulcrum affect effort needed to balance it?
6. What was the mechanical advantage of the first lever you tested? Why would a lever like this be used?
7. Are your values for percent difference between IMA and AMA large or small?
8. Describe some factors that might contribute to the difference between IMA and AMA in this experiment.

## EXTENSION

Design and perform an experiment to test second-class and third-class levers. Include a data table, calculations, and conclusions.



# First Class Levers

## (Sensor Cart)

A *lever* is a simple machine used to make work easier. It consists of a long, rigid bar with a support that allows the bar to pivot. The point where the bar pivots is the *fulcrum*. There are three classes of levers: first, second, and third. In this experiment, you will examine first-class levers. Crowbars and scissors are examples of first-class levers. A lever can help you move an object by increasing the force you exert. *Mechanical advantage* (MA) is a value that tells the number of times a machine increases an applied force. You will use the force sensor built into a Sensor Cart to measure resistance force and effort force. You will then use this information to calculate the mechanical advantage of each lever.

### OBJECTIVES

- Measure force.
- Calculate actual mechanical advantage (AMA).
- Calculate ideal mechanical advantage (IMA).
- Calculate percent difference.
- Make conclusions about levers.

### MATERIALS

500 g mass  
loop of string  
meter stick  
fulcrum

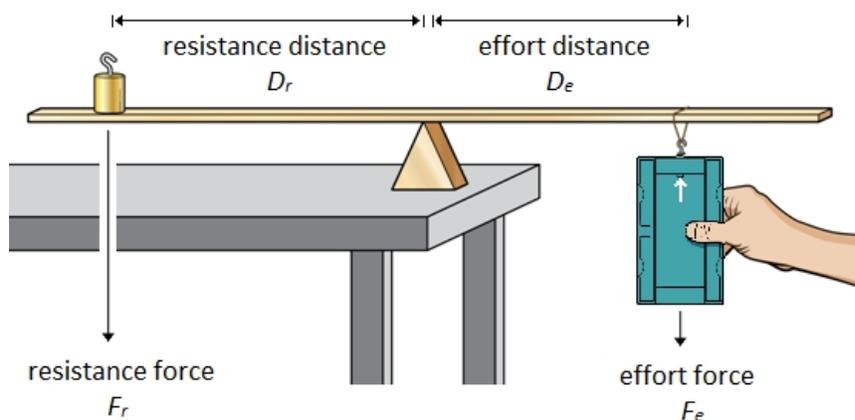


Figure 1

## DATA

Table 1				
Trial	Resistance distance, $D_r$ (cm)	Resistance force, $F_r$ (N)	Effort distance, $D_e$ (cm)	Effort force, $F_e$ (N)
1	40		40	
2	20		40	
3	10		40	

## PROCESSING THE DATA

1. Calculate the actual mechanical advantage for each of your three trials using the formula

$$\text{AMA} = \frac{F_r}{F_e}$$

where AMA = actual mechanical advantage,  $F_r$  = resistance force, and  $F_e$  = effort force. Record results in Table 2.

2. Ideal mechanical advantage is determined by the formula

$$\text{IMA} = \frac{D_e}{D_r}$$

where IMA = ideal mechanical advantage,  $D_e$  = effort distance, and  $D_r$  = resistance distance. Calculate the ideal mechanical advantage of the levers you tested. Record results in Table 2.

3. Calculate the percent difference between IMA and AMA for each of your trials using the formula

$$\% \text{ Difference} = \frac{\text{Difference between IMA and AMA}}{\text{IMA}} \times 100$$

Record the results in Table 2.

Table 2			
Trial	AMA	IMA	Percent difference
1			
2			
3			

4. What happened to the mechanical advantage as you shortened the resistance distance?
5. How did moving the resistance force closer to the fulcrum affect effort needed to balance it?
6. What was the mechanical advantage of the first lever you tested? Why would a lever like this be used?
7. Are your values for percent difference between IMA and AMA large or small?
8. Describe some factors that might contribute to the difference between IMA and AMA in this experiment.

## **EXTENSION**

Design and perform an experiment to test second-class and third-class levers. Include a data table, calculations, and conclusions.





## First-Class Levers

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. A variety of sensors will work for this experiment. *Logger Pro* users will need a Dual-Range Force Sensor (order code: DFS-BTA). *Graphical Analysis* users can use the Dual Ranger Force Sensor (with an interface), Go Direct Force and Acceleration (order code: GDX-FOR), or Go Direct Sensor Cart (order code: GDX-CART).
3. Fulcrums can be made from 2.5 cm × 2.5 cm (1 in × 1 in) pieces of wood cut diagonally. Use 15 cm pieces of string to make the string loops.
4. Students must zero the force sensor/sensor cart in different orientations during the Procedure. You may want to go over the steps with them before they get started. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
5. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS2.A Forces and Motion	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Structure and function Stability and change

## SAMPLE RESULTS

Trial	Resistance distance (cm)	Resistance force (N)	Effort distance (cm)	Effort force (N)
1	40	4.9	40	5.0
2	20	4.9	40	2.5
3	10	4.9	40	1.2

## PROCESSING THE DATA

- $40/40 = 1.0$                        $40/20 = 2.0$                        $40/10 = 4.0$
- $4.9/5.0 = 0.98$                        $4.9/2.5 = 1.96$                        $4.9/1.2 = 4.08$
- $0.02/1.0 = 2.0\%$                        $0.04/2.0 = 2.0\%$                        $0.08/4.0 = 2.0\%$

Trial	AMA	IMA	Percent difference
1	0.98	1.0	2.0
2	1.96	2.0	2.0
3	4.08	4.0	2.0

- Mechanical advantage increased as the resistance arm was shortened.
- The effort needed to balance the resistance lessened as the resistance was moved closer to the fulcrum.
- The mechanical advantage of the first lever was 1. Such a lever might be used to change the direction of movement.
- The percent error may be surprisingly small because of the relative absence of frictional forces.
- Factors that can contribute to error are placement of the mass, movement of the fulcrum, and inaccurate measurements.

# Pulleys

(Force Sensor)

A *pulley* is a simple machine having a string that passes over a grooved wheel. A fixed pulley (see Figure 1) is attached to a solid support and changes the direction of force. The resistance force is the weight of the object being lifted. This force is applied to one end of the string that goes over a fixed pulley. The effort force is exerted on the other end of the string, in opposition to the resistance force.

A movable pulley (see Figure 2) moves along the string with the resistance force, and the direction of the force is not changed. A pulley system may have a single pulley or a combination of pulleys (see Figure 3). Pulley systems are used to make work easier.

*Mechanical advantage* is a value that tells the number of times a machine increases the applied force. In this experiment, you will use a Force Sensor to measure the effort force (in N) for three different pulley systems and then determine the mechanical advantage of each system.

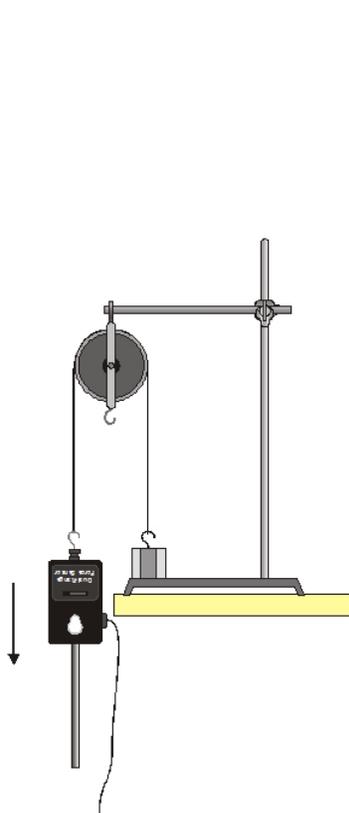


Figure 1

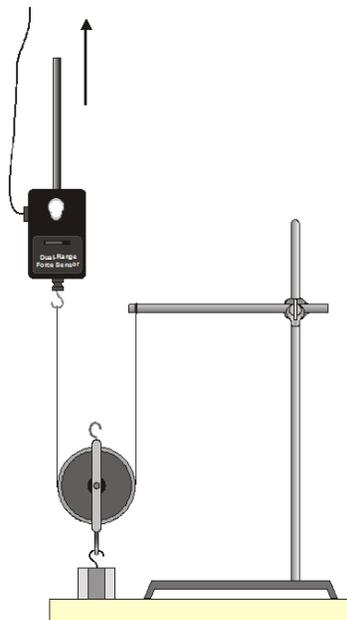


Figure 2

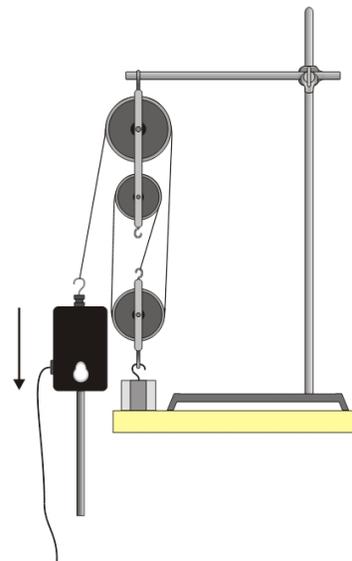


Figure 3

## OBJECTIVES

- Use a Force Sensor to measure force.
- Calculate actual mechanical advantage and ideal mechanical advantage.
- Determine efficiency.
- Make conclusions about pulley systems.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Vernier Force Sensor  
500 g mass  
string  
single pulley  
double pulley  
ring stand  
rod and right-angle clamp

## PROCEDURE

### Pulley System 1

1. Connect the sensor to the computer interface. Set the range switch on the Dual-Range Force Sensor to 10 N. Start the Vernier data-collection program and open the file “31 Pulleys” from the *Middle School Science with Vernier* folder.
2. Zero the Force Sensor with its hook pointing down.
  - a. Hold the Force Sensor in a vertical position with its hook pointing down. Make sure the hook is not touching anything.
  - b. Click  to zero the sensor.
3. Hang the mass to be used as the resistance from the Force Sensor. After the readings have stabilized, read the force (in N). This is the resistance force ( $F_r$ ) for all three pulley systems to be studied. Record this value in all three resistance-force blanks in the data table.
4. Zero the Force Sensor with its hook pointing up.
  - a. Hold the Force Sensor in a vertical position with its hook pointing up. Rest the tip of its handle on the tabletop.
  - b. Click  to zero the sensor.
5. Set up Pulley System 1. Attach a single pulley to a rod on a ring stand as shown in Figure 1.
6. Attach the Force Sensor to one end of the string and the resistance to the other end. Rest the resistance on the tabletop.
7. Raise the resistance 5 cm from the tabletop by pulling with the Force Sensor in the direction indicated in the figure (straight down for Pulley System 1). Read and record the effort force.

**Pulley System 2**

8. Zero the Force Sensor with its hook pointing down.
  - a. Hold the Force Sensor in a vertical position with its hook pointing down. Make sure the hook is not touching anything.
  - b. Click  to zero the sensor.
9. Set up Pulley System 2 as shown in Figure 2. Repeat Step 7.

**Pulley System 3**

10. Zero the Force Sensor with its hook pointing up.
  - a. Hold the Force Sensor in a vertical position with its hook pointing up. Rest the tip of its handle on the tabletop.
  - b. Click  to zero the sensor.
11. Set up Pulley System 3 as shown in Figure 3. Repeat Step 7.
12. Look at Figures 1–3 and count the supporting strings for each pulley system. All strings are considered to be supporting except a string that you pull downward (with the Force Sensor). A string that you pull upward counts as a supporting string. Record these numbers.

**DATA**

Table 1			
Pulley system	Resistance force (N)	Effort force (N)	Supporting strings
1			
2			
3			

**PROCESSING THE DATA**

1. Calculate the actual mechanical advantage for each pulley system using the formula

$$\text{AMA} = \frac{F_r}{F_e}$$

where AMA = actual mechanical advantage,  $F_r$  = resistance force, and  $F_e$  = effort force. Show your work below. Record results in the table that follows Question 3.

2. The ideal mechanical advantage of a pulley is equal to the number of supporting strings. See the supporting string numbers in your data table and record the IMA values in the table following Question 3.

## Experiment 31

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3. The efficiency of each pulley system can be calculated using the formula

$$\text{efficiency} = \frac{\text{AMA}}{\text{IMA}} \times 100$$

Calculate the efficiency of each pulley system. Record the results in Table 2.

Table 2			
Pulley system	AMA	IMA	Efficiency (%)
1			
2			
3			

- How did the mechanical advantage of the single-movable pulley (Pulley System 2) compare to the mechanical advantage of the single-fixed pulley (Pulley System 1)?
- How did increasing the number of pulleys affect the effort needed to raise the resistance?
- Diagram a pulley system (different from the ones used in this experiment) that has a mechanical advantage of 2.
- Discuss two factors that might have caused the efficiency values in this experiment not to be 100 percent.

### EXTENSIONS

- Test the pulley system you designed in Question 6. Calculate its AMA, IMA, and efficiency.
- Design and test pulley systems with higher mechanical advantages.

# Pulleys

## (Sensor Cart)

A *pulley* is a simple machine having a string that passes over a grooved wheel. A fixed pulley (see Figure 1) is attached to a solid support and changes the direction of force. The resistance force is the weight of the object being lifted. This force is applied to one end of the string that goes over a fixed pulley. The effort force is exerted on the other end of the string, in opposition to the resistance force.

A movable pulley (see Figure 2) moves along the string with the resistance force, and the direction of the force is not changed. A pulley system may have a single pulley or a combination of pulleys (see Figure 3). Pulley systems are used to make work easier.

*Mechanical advantage* is a value that tells the number of times a machine increases the applied force. In this experiment, you will use the force sensor built into a Sensor Cart to measure the effort force for three different pulley systems and then determine the mechanical advantage of each system.

Figure 1

Figure 2

Figure 3

## OBJECTIVES

- Measure force.
- Calculate actual mechanical advantage and ideal mechanical advantage.
- Determine efficiency.
- Make conclusions about pulley systems.

## MATERIALS

500 g mass  
string  
single pulley  
double pulley  
ring stand  
rod and right-angle clamp

## DATA

Table 1			
Pulley system	Resistance force, $F_r$ (N)	Effort force, $F_e$ (N)	Supporting strings
1			
2			
3			

## PROCESSING THE DATA

1. Calculate the actual mechanical advantage for each pulley system using the formula

$$\text{AMA} = \frac{F_r}{F_e}$$

where AMA = actual mechanical advantage,  $F_r$  = resistance force, and  $F_e$  = effort force. Show your work below. Record results in the table that follows Question 3.

2. The ideal mechanical advantage (IMA) of a pulley is equal to the number of supporting strings. See the supporting string numbers in your data table and record the IMA values in the Table 2.
3. The efficiency of each pulley system can be calculated using the formula

$$\text{efficiency} = \frac{\text{AMA}}{\text{IMA}} \times 100\%$$

Calculate the efficiency of each pulley system. Record the results in Table 2.

Table 2			
Pulley system	AMA	IMA	Efficiency (%)
1			
2			
3			

4. How did the mechanical advantage of the single-movable pulley (Pulley System 2) compare to the mechanical advantage of the single-fixed pulley (Pulley System 1)?
5. How did increasing the number of pulleys affect the effort needed to raise the resistance?
6. Diagram a pulley system (different from the ones used in this experiment) that has a mechanical advantage of 2.
7. Discuss two factors that might have caused the efficiency values in this experiment not to be 100%.

## EXTENSIONS

1. Test the pulley system you designed in Question 6. Calculate its AMA, IMA, and efficiency.
2. Design and test pulley systems with higher mechanical advantages.



## Pulleys

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. A variety of sensors will work for this experiment. *Logger Pro* users will need a Dual-Range Force Sensor (order code: DFS-BTA). *Graphical Analysis* users can use the Dual Ranger Force Sensor (with an interface), Go Direct Force and Acceleration (order code: GDX-FOR), or Go Direct Sensor Cart (order code: GDX-CART).
3. Other masses, in the 100 g to 1000 g range, may be used if 500 g masses are not available.
4. Students must zero the force sensor or sensor cart in different orientations during the Procedure. You may want to go over the steps with them before they get started.
5. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.
6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS2.A Forces and Motion	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Structure and function Stability and change

## SAMPLE RESULTS

Pulley system	Resistance force (N)	Effort force (N)	Supporting ropes
1	4.9	4.8	1
2	4.9	2.6	2
3	4.9	1.8	3

## PROCESSING THE DATA

1.  $4.9/4.8 = 1.02$        $4.9/2.6 = 1.88$        $4.9/1.8 = 2.72$

2. See the Sample Results.

3.  $1.02/1 \times 100\% = 102\%$        $1.88/2 \times 100\% = 94\%$        $2.72/3 \times 100\% = 91\%$

Pulley system	AMA	IMA	Efficiency (%)
1	1.02	1	102
2	1.88	2	94
3	2.72	3	91

4. The single movable pulley had a greater mechanical advantage than the single fixed pulley.
5. Increasing the number of pulleys reduced the effort needed to raise the resistance.
6. Answers will vary.
7. Friction and improper use of the Force Sensor are two factors affecting the efficiency values.

# Buoyancy

When an object is immersed in water, it pushes water aside. The buoyant force of water on the object reduces the weight of the object. In this experiment, you will determine and compare the buoyant force on an object and the weight of the water pushed aside (displaced) by the object for three objects. The Greek mathematician Archimedes first studied this relationship during the third century B.C.

## OBJECTIVES

- Use a force sensor to measure the weights of objects in and out of water.
- Determine the weight of water displaced by each object.
- Compare buoyant force to weight of water displaced for each object.
- Use the results of the experiment to explain why objects sink or float.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Dual-Range Force Sensor  
metal rod included with Force Sensor  
ring stand  
right-angle clamp  
string  
metal mass with a hook  
50 g piece of clay  
wooden pencil  
100 mL graduated cylinder  
water

## PROCEDURE

1. Obtain a metal mass, a 50 g piece of clay, and a pencil. Roll the piece of clay into a hot-dog shape that will fit into the 100 mL graduated cylinder.
2. Connect the sensor to the computer interface. Set the range switch on the Dual-Range Force Sensor to 10 N. Start the Vernier data-collection program and open the file “32 Buoyancy” from the *Middle School Science with Vernier* folder.
3. Zero the Force Sensor.

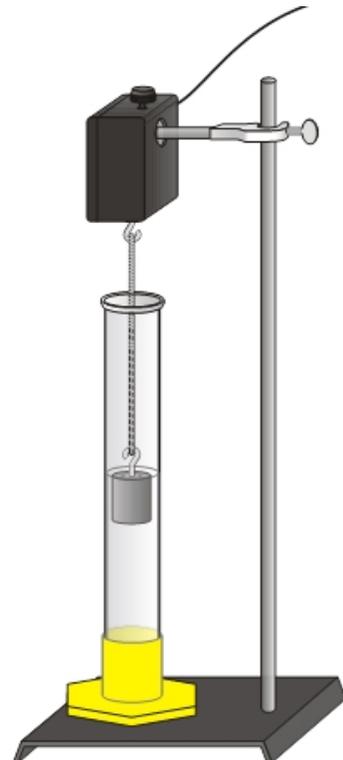


Figure 1

## Experiment 32

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- a. Fasten the Force Sensor to a ring stand as shown in Figure 1.
  - b. Tie a piece of string to the hook of the Force Sensor.
  - c. Click  to zero the sensor.
4. Measure the weight of the object in air.
- a. Hang a loop of string from the hook of the Force Sensor, and then hang the metal mass from the string.
  - b. When the readings stop changing, record the weight in the data table.
5. Collect data in water.
- a. Fill the graduated cylinder with enough water to cover the object.
  - b. Read and record the volume of the water alone (to the nearest whole mL).
  - c. Lower the object into the graduated cylinder.
  - d. If the object sinks, lower it until it is covered with water but not touching the bottom. If the object floats, let it float.
  - e. Record the weight of the object in water.
  - f. Read and record the volume of the water plus object.
6. Repeat Steps 4–5 for the clay and the pencil. Change the amount of water, if necessary.

## DATA

Table 1			
Object	Metal	Clay	Pencil
Weight in air (N)			
Weight in water (N)			
Volume of water alone (mL)			
Volume of water + object (mL)			

## PROCESSING THE DATA

1. Calculate the buoyant force on each object by subtracting its weight in water from its weight in air. Show your work, and record the results in the table in Question 3.
2. Find the volume of water displaced by each object. Subtract the volume of water alone from the volume of the water + object. Show your work, and record the results in Table 2.

- Find the weight of water displaced by each object. Multiply the volume of displaced water by 0.01 N/mL, giving you an approximate value for the weight of the water in Newtons. Show your work and record the results in Table 2.

Table 2			
Object	Metal	Clay	Pencil
Buoyant force (N)			
Volume of displaced water (mL)			
Weight of displaced water (N)			

- How does buoyant force compare to the weight of water displaced for each object? **Note:** The answer to this question is known as Archimedes' Principle.
- For which objects was buoyant force less than the weight in air? For which objects was buoyant force equal to the weight in air?
- Explain how buoyant force determines whether an object sinks or floats in water.

## **EXTENSIONS**

- Repeat the experiment using saltwater. Compare your saltwater results with the results of your first experiment.
- Investigate why boats float when made of materials that would normally sink. Shape and float a boat made from your clay. Measure the volume of water that it can hold. Compare this volume to volume it displaced as a lump of clay. Explain your results.
- Have a contest with your classmates to see whose clay boat, described in Extension 2, can hold the most mass without sinking.



## Buoyancy

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and Graphical Analysis). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. A 100 g hooked metal mass works well with a 100 mL graduated cylinder. Other metal masses and other graduated cylinders can be used.
3. Because they have larger volumes, unsharpened pencils work better than short, sharpened pencils. Larger wooden objects can be used with larger graduated cylinders.
4. Have 50 gram pieces of clay available.
5. Since 1 mL of water weighs approximately 0.01 N, students are instructed to multiply the volume of displaced water by 0.01 N/mL in Step 3 of the Processing the Data section.
6. The *Logger Pro*/*Logger Lite* procedure directs students to record force data from the meter (without clicking ). Another possibility is to have them use the Selected Events mode in *Logger Pro* or Events with Entry in *Logger Lite*. The *Logger Pro* file for this experiment is already set up for this Selected Events option. Simply have your students click  and then click  when the reading is stable. This saves the reading along with its trial number in the table. The *Logger Lite* file for this experiment is already set up for Events with Entry mode. Simply have your students click  and then click  when the reading is stable. They will need to enter the sample number when prompted.
7. Students enjoy the clay boat extension.
  - You may wish to have empty bottles available for student use as they roll out the clay for their boats.
  - Dishpans, large mouth jars, or large beakers work well for floating the clay boats.
  - Marbles or pennies can be used to determine which boat holds the most weight.
8. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
9. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

## ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models	PS1.A Structure and Properties of Matter	Patterns
Planning and carrying out investigations	PS2.A Forces and Motion	Cause and effect
Analyzing and interpreting data	PS2.B Types of Interactions	Scale, proportion, and quantity
Using mathematics and computational thinking		Systems and system models
Constructing explanations and designing solutions		Energy and matter
		Stability and change

## SAMPLE RESULTS

Object	Metal	Clay	Pencil
Weight in air (N)	0.98	0.54	0.06
Weight in water (N)	0.85	0.23	0
Buoyant force (weight lost) (N)	0.13	0.31	0.06
Volume of water alone (mL)	60	60	60
Volume of water + object (mL)	73	92	66
Volume of water displaced (mL)	13	32	6
Weight of water displaced (N)	0.13	0.32	0.06

## ANSWERS TO QUESTIONS

1. See the Sample Results.
2. See the Sample Results.
3. See the Sample Results.
4. The buoyant force exerted by the water on the object equals the weight of the water displaced by the object. **Note:** This is one way of stating Archimedes' Principle.
5. Buoyant force was less than the weight of the object in air for metal and clay. Buoyant force for the pencil was equal to its weight in air.



6. If buoyant force is less than the weight of an object in air, the object will sink. If buoyant force is equal to the weight of an object in air, the object will float.



# Graphing Your Motion

Graphs made using a Motion Detector can be used to study motion. A Motion Detector measures the distance to the nearest object in front of it by emitting and receiving pulses of ultrasound. In this experiment, you will use a Motion Detector to produce graphs of your own motion.

## OBJECTIVES

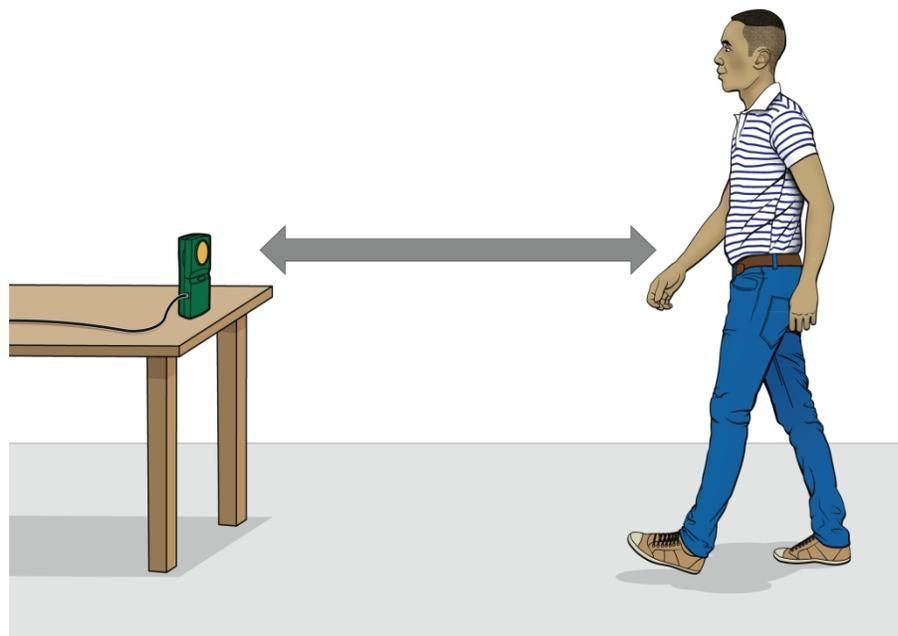
- Use a Motion Detector to measure position and velocity.
- Analyze and interpret graphs of your motion.
- Match position *vs.* time and velocity *vs.* time graphs.

## CHOOSE A METHOD

**Method 2: USB Connection**– You will measure your position and velocity relative to a stationary Motion Detector.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Motion Detector  
masking tape  
meter stick

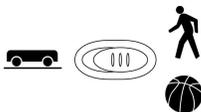


*Figure 1*

## PROCEDURE

### Part I Position

1. Fasten a Motion Detector to a table top facing an aisle. Connect the Motion Detector to a digital port on the interface. If your Motion Detector has a switch, set it to Ball/Walk.



2. Using masking tape, tape a 2 m straight line on the floor directly in front of the Motion Detector. Mark the tape at 0.5 m intervals from the Motion Detector.
3. Open the “35a Graphing Your Motion” file from the *Middle School Science w Vernier* folder. A blank position vs. time graph is displayed.
4. Stand at the 0.5 m mark on the tape line facing the Motion Detector and the computer screen. Have your partner click  , then slowly walk backwards away from the Motion Detector. Walk along the tape line and watch the screen. Discuss the results with your partners.
5. Choose Store Latest Run on the Experiment menu. Repeat Step 4, moving faster this time.
6. Print or sketch the graph produced on the screen.
7. Open the file “35b Graphing Your Motion.” A position vs. time graph should appear on the screen.
8. Try to match the line by moving toward or away from the Motion Detector. Print or sketch your results, and describe what you had to do to match the graph. Have everyone in your group try to match the graph line.
9. If time permits, challenge yourself to match another graph. Click Generate Graph Match, , (or choose Graph Match from the Analyze menu) to generate a random line to match.

## PROCESSING THE DATA (PART I)

1. Describe the difference between the two lines on your graph printed or sketched in Step 6. Explain why the lines are different.
2. How would the graph change if you walked toward the Motion Detector rather than away from it? Test your answer using the Motion Detector.
3. What did you have to do to match the graph you were given in Step 7?

4. Sketch a position vs. time graph for a car that moves slowly down the street, stops at a stop sign, then moves slowly again in the same direction as before.



**Part II Velocity**

10. Open the file “35c Graphing Your Motion.” A blank velocity vs. time graph should appear on the screen. The vertical axis will have velocity scaled from  $-2$  to  $2$  m/s. The horizontal axis will have time scaled from 0 to 3 seconds.
11. Stand at the 0.5 m mark on the tape line facing the Motion Detector and the computer screen. Have your partner click , then slowly walk backwards away from the Motion Detector. You may want to try several times, until your graph is fairly smooth and flat.
12. Choose Store Latest Run on the Experiment menu. Repeat Step 11, moving faster this time.
13. Print or sketch your graph.
14. Open the file “35d Graphing Your Motion.” A velocity vs. time graph, with a line, should appear on the screen.
15. Write down how you would walk to produce this graph.
16. To test your prediction, choose a starting position and stand at that point. Have your partner start data collection, and walk in such a way that the graph of your motion matches the target graph on the screen. It will be more difficult to match the velocity graph than it was for the position graph.
17. If you were not successful and want to match the same target graph again, repeat Step 16 until you are satisfied. Print or sketch the graph with your best attempt.

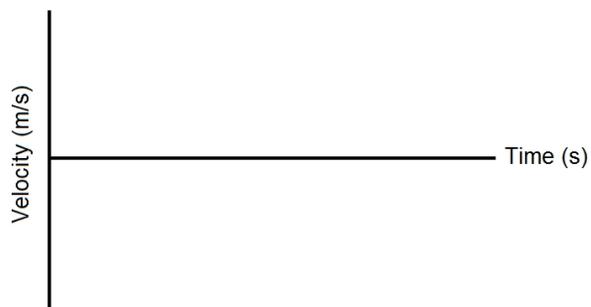
**PROCESSING THE DATA (PART II)**

5. Describe the difference between the two lines on the graph you sketched or printed in Step 13. Explain why the lines are different.
6. What is the definition of velocity?

### *Experiment 33*

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7. What did you have to do to match the graph you were given in Step 14? How well does your graph agree with the graph provided?
8. Sketch a velocity *vs.* time graph for a person who walks, stops for a few seconds, and then runs.



## Graphing Your Motion

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. This experiment may be the first time your students use the Motion Detector. A little coaching on its use now will save time later in the year as the Motion Detector is used in other experiments. Here are some hints for effective use of the Motion Detector.
  - In using the Motion Detector, it is important to realize that the ultra sound is emitted in a cone about 30° wide. Anything within the cone of ultrasound can cause a reflection and possibly an accidental measurement. A common problem in using Motion Detectors is getting unintentional reflections from a desk, chair, or computer in the room.
  - Often unintended reflections can be minimized by tilting the Motion Detector slightly.
  - If you begin with a velocity or acceleration graph and obtain a confusing display, switch back to a position graph to see if it makes sense. If not, the Motion Detector may not be properly targeting the target.
  - From our experience, the Motion Detector’s most effective range is 1–3.5 m. However, it can be challenging to find that much space when many groups are performing this activity. Using a 2 m maximum range is sufficient.
  - Sometimes a target may not supply a strong reflection of the ultrasound. For example, if the target is a person wearing a bulky sweater, the resulting graph may be inconsistent.
  - If the velocity graphs are noisy, try to increase the strength of the ultrasonic reflection from the target by increasing the target’s area. Having your students carry a book or large piece of cardboard held out in front of them as they move can result in smoother graphs.
  - See [www.vernier.com/til/5](http://www.vernier.com/til/5) for more tips on using the Motion Detector.
3. If printers are not available, have your students sketch their graphs. Graph shapes are more important than numerical values in this experiment.
4. Consider having a contest to see who can match the graphs best.
5. Additional graphs to match can be automatically generated by *Logger Pro*, *Graphical Analysis*, or *LabQuest*. In *Logger Pro*, click Generate Graph Match, . In *To create additional graphs to match in Graphical Analysis*, click or tap Graph Tools, , choose Add

### Experiment 33

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Graph Match, and then choose Position or Velocity. In LabQuest, choose Motion Match from the Analyze menu on the Graph screen.

- For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
- If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.
- Graphical Analysis users:** There are two methods of the experiment in the student pages. The method you will follow depends on the equipment you have. Use the following table to determine the appropriate method:

Platform and Interface	Go Direct Motion Detector (GDX-MD)	Motion Detector (MD-BTD)	Go! Motion (GO-MOT)
Mobile device (e.g., iPhone or Android tablet)	Method 1 (Bluetooth)	Not supported	Not supported
Chromebook or computer (Windows or macOS)	<b>Method 2 (USB)</b>	Not supported	<b>Method 2 (USB)</b>
<ul style="list-style-type: none"><li>Mobile device (e.g., iPhone or Android tablet)</li><li>No interface</li></ul>	<b>Method 1 (Bluetooth)</b>	Not supported	Not supported
<ul style="list-style-type: none"><li>Chromebook or computer (Windows or macOS)</li><li>No interface</li></ul>	<b>Method 2 (USB)</b>	Not supported	<b>Method 2 (USB)</b>
<ul style="list-style-type: none"><li>Chromebook or computer (Windows or macOS)</li><li>Vernier data-collection interface (e.g., LabQuest 2 or LabQuest Mini)</li></ul>	Not supported	<b>Method 2 (USB)</b>	Not supported
<ul style="list-style-type: none"><li>Mobile device (e.g., iPhone or Android tablet)</li><li>LabQuest Stream</li></ul>	Not supported	<b>Method 1 (Bluetooth)</b>	Not supported

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

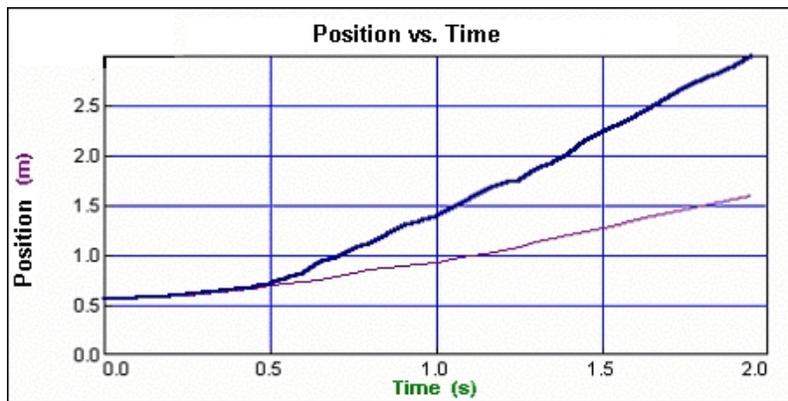


## NEXT GENERATION SCIENCE STANDARDS (NGSS)

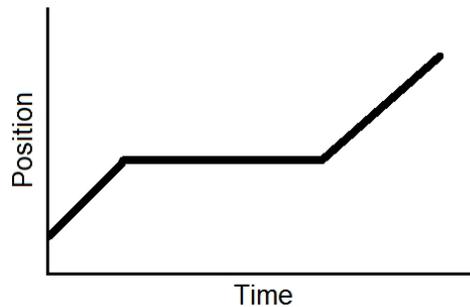
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking	PS2.A Forces and Motion	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Stability and change

## ANSWERS TO QUESTIONS

### Part I Position

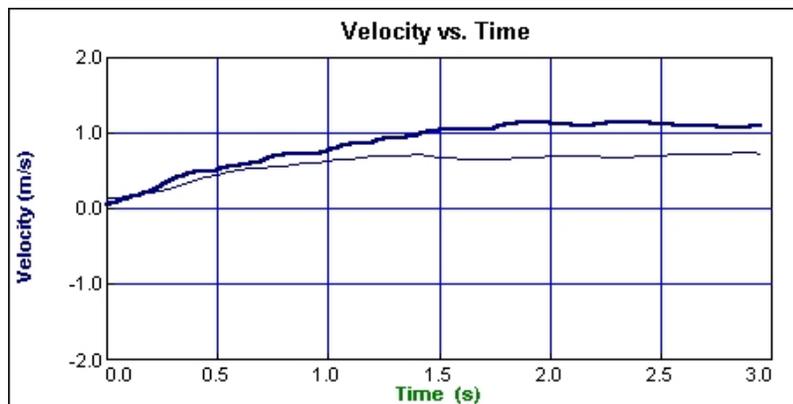


1. The slope of the graph is steeper when the student walks faster.
2. The line would slant in the opposite direction.
3. Answers will vary.
- 4.

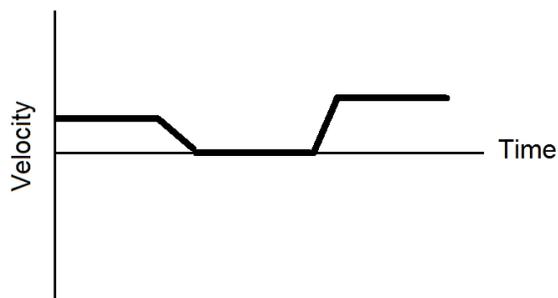


## Experiment 33

### Part II Velocity



5. The line on the second graph should be higher (have a greater average value) than the line on the first graph. The graphs should have the same general shape.
6. Velocity is change in position divided by the change in time.
7. Answers will vary.
- 8.



# Speeding Up

## (Motion Detector)

You may have noticed that an object rolling down a hill starts out slowly and then speeds up. In this activity, you will measure the maximum speed of a cart or toy car as it rolls down a ramp from different starting positions. You will use a Motion Detector to measure the speed of the car.

### OBJECTIVES

- Use a Motion Detector to measure speed.
- Record data.
- Graph results.

### MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Motion Detector  
1.5 m board  
cart or toy car  
3" × 5" index card  
meter stick  
books, bricks, or box to support ramp  
large book

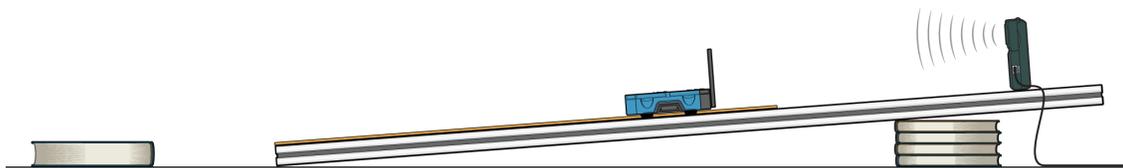


Figure 1

### PROCEDURE

1. Set up the ramp.
  - a. Set up the board as shown in Figure 1. The high end of the ramp should be no more than 30 cm from the floor.
  - b. Place a large book on the floor about 50 cm from the bottom end of ramp. This book will stop your car after it comes from the ramp.
  - c. If necessary, use tape or chalk to mark a line at 40 cm from the bottom of the ramp, 60 cm from the bottom of the ramp, and 80 cm from the bottom of the ramp.
2. Tape the index card to the back of the car.

## Experiment 34

- If your Motion Detector has a switch, set it to Cart (see Figure 2). Connect the Motion Detector to a digital port of the interface. Position the Motion Detector at the top and center of the track as shown in Figure 1.

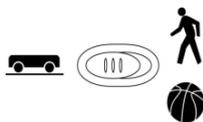


Figure 2

- Start the Vernier data-collection program and open the file “34 Speeding Up” from the *Middle School Science with Vernier* folder.
- Collect data.
  - Place your car on the board so the front edge of the car is at the 40 cm line.
  - Click  , and then release the car.
  - Examine the graphs. Did the Motion Detector detect only the car? Are the graphs smooth, with no abrupt changes? If not, make adjustments and repeat data collection until you have smooth graphs.
- Click Statistics,  . Record the maximum speed in your data table.
- Repeat Steps 5 and 6 two more times.
- Repeat Steps 5–7 with the front of the car at the 60 cm position and again with the front of the car at the 80 cm position.

## DATA

Table 1: Maximum Speed (m/s)			
Trial	40 cm	60 cm	80 cm
1			
2			
3			

Table 2	
Release position (cm)	Average maximum speed (m/s)

## **PROCESSING THE DATA**

1. Calculate the average maximum speed for each release position. Show your work, and write the average values in Table 2.
2. Graph these results on Page 2 of the experiment file. Plot Release Position (in cm) on the horizontal (x) axis and Average Maximum Speed (in m/s) on the vertical (y) axis. Describe the shape of the graph.
3. What happened to the maximum speed as you released the car from higher points?
4. Explain two ways to make the car's maximum speed greater, and explain why you think they would be successful.

## **EXTENSIONS**

1. Repeat the experiment with ramps of different heights.
2. Redo the experiment with different amounts of mass on the car. Summarize your results in a few sentences.



# Speeding Up

(Sensor Cart)

You may have noticed that an object rolling down a hill starts out slowly and then speeds up. In this activity, you will measure the maximum speed of a cart or toy car as it rolls down a ramp from different starting positions. You will use Graphical Analysis to measure the speed of a Sensor Cart.

## OBJECTIVES

- Measure speed.
- Record data.
- Graph results.

## MATERIALS

1.5 m board  
meter stick  
books, bricks, or box to support ramp  
large book

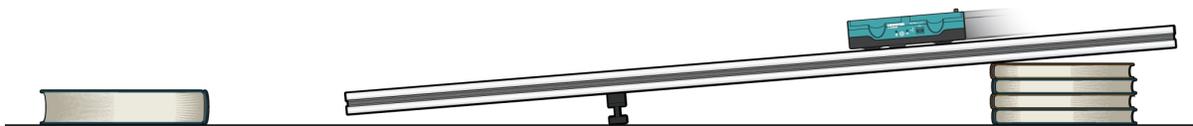


Figure 1

## DATA

Table 1: Maximum Speed (m/s)			
Trial	40 cm	60 cm	80 cm
1			
2			
3			

Table 2	
Release position (cm)	Average maximum speed (m/s)

## **PROCESSING THE DATA**

1. Calculate the average maximum speed for each release position. Show your work, and write the average values in Table 2.
2. Graph the results
  - a. Disconnect the Sensor Cart.
  - b. Click or tap File, , and choose New Experiment. Click or tap Manual Entry.
  - c. Enter the Release Position values in the first (x) column and enter the Average Maximum Speed in the second (y) column.
  - d. Change the column headings to Release Position (cm) and Average Maximum Speed (m/s).
  - e. Describe the shape of the graph.
3. What happened to the maximum speed as you released the cart from higher points?
4. Explain two ways to make the cart's maximum speed greater, and explain why you think they would be successful.

## **EXTENSIONS**

1. Repeat the experiment with a ramp with a different height.
2. Redo the experiment with different amounts of mass on the cart. Summarize your results in a few sentences.



## Speeding Up

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. A variety of sensors will work for this experiment. *Logger Pro* users will need a motion detector such as the Motion Detector 2 (order code: MD-BTD) or Go!Motion (order code: GO-MOT). *Graphical Analysis* users can use either of those motion detectors (the Motion Detector 2 requires an interface with a digital port), or they can use Go Direct Motion Detector (order code: GDX-MD) or Go Direct Sensor Cart (order code: GDX-CART).
3. Students may be confused that they are looking at a velocity *vs.* time graph to determine maximum speed. For the purposes of this experiment, speed and velocity are numerically the same. While the definitions of speed and velocity are not identical, researching the differences between the definitions can be a good short assignment for students.
4. If using a motion detector, make sure the motion detector is positioned at least 15 cm from the release point of the car. See [www.vernier.com/til/5](http://www.vernier.com/til/5) for more tips on using a motion detector.
5. Free-rolling toy cars and the Pencil Car described in the student pages of Experiment 3514, "Indy 100," work well. If you have access to dynamics carts and tracks, such as the Vernier Dynamics Cart and Track System (order code: DTS), they also work well.
6. In the Procedure, students using a motion detector are directed to tape an index card to the back of their car to act as an ultrasonic reflector. Painter's masking tape works well as it is sticky enough to hold the card in place while being easy to remove without leaving a sticky residue.
7. Tape a meter stick to the board to act as a guide for the cars, with 0 cm at the bottom of the ramp and 100 cm near the top of the ramp. If the cars are not staying on the ramp, you may want to tape two meter sticks to a ramp and run the cars between them. You may find it necessary to adjust the release positions and ramp height for your equipment.
8. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

## Experiment 34

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

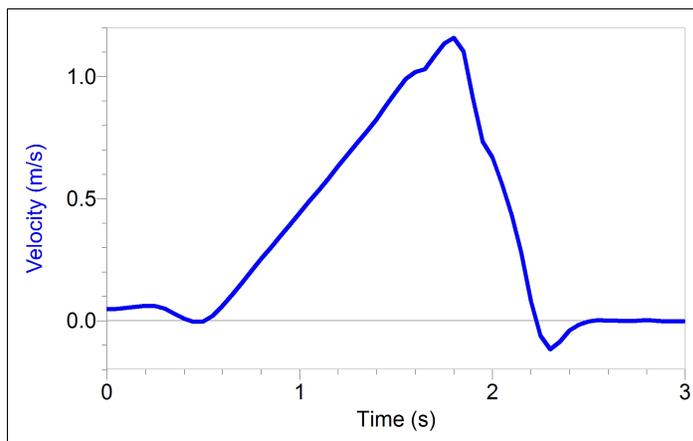
### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models	PS2.A Forces and Motion	Patterns
Planning and carrying out investigations	PS2.B Types of Interactions	Cause and effect
Analyzing and interpreting data		Scale, proportion, and quantity
Using mathematics and computational thinking		Systems and system models
Constructing explanations and designing solutions		Energy and matter
		Stability and change

### SAMPLE RESULTS

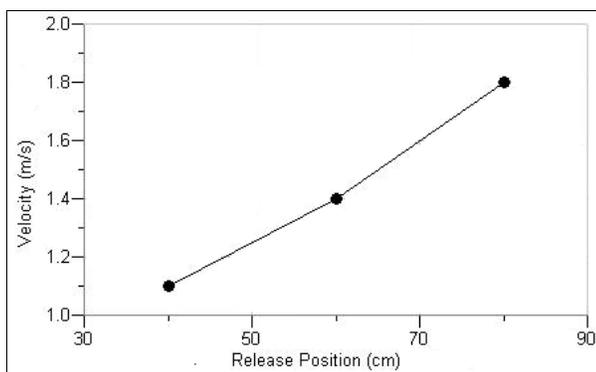


Release position (cm)	Average maximum speed (m/s)
40	1.1
60	1.4
80	1.8

## ANSWERS TO QUESTIONS

1. See Sample Results.

2.



3. The maximum speed increased as the cart was released from higher points.

4. Answers may vary. Moving the release position farther up the track should increase the maximum speed because the cart would have more time for speeding up. Increasing the height (or steepness) of the track should increase the cart's maximum speed because things go faster down steeper hills.



# The Indy 100

In this activity, you will race a car down a ramp. The fastest car will be the one that reaches the highest velocity going down the ramp. You will measure speed with a Motion Detector.

## OBJECTIVES

- Prepare a car for a race.
- Measure velocity using a Motion Detector.
- Determine the fastest car in your class.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Motion Detector  
1.5 m board  
several books  
meter stick  
masking tape  
car with a card attached

## GUIDELINES

1. You may build a car, use your own toy car, or temporarily modify a laboratory car supplied by your teacher. You are encouraged to make changes that will increase the speed of the car.
2. You will use the file “35 Indy 100” from the *Middle School Science with Vernier* folder.
3. All cars should start with their front wheels at the 100 cm mark on the same ramp.
4. The car must be released without being pushed or pulled.
5. You will be allowed two runs. The greatest speed measured during your two runs will be the one counted. The winning car will be the one with the greatest maximum speed measure during the two runs.
6. Experiment and practice with your car before the actual race.

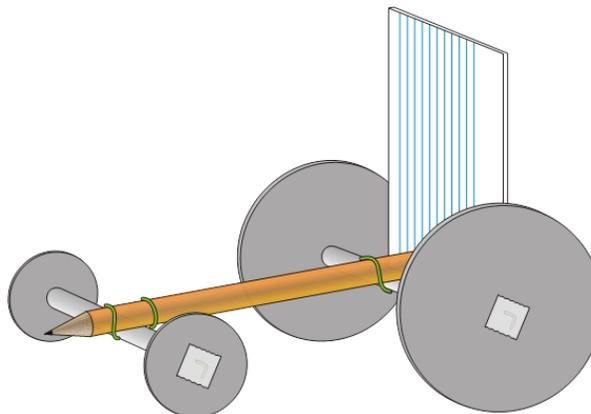


# Pencil Car

In this activity, you will make a car for the race in Experiment 3513, “The Indy 100.” The following instructions show one way that you might make a car. You may change the design.

## MATERIALS

pencil  
3 small index cards  
2 rubber bands  
masking tape  
compass (optional)  
2 paper clips  
pliers  
scissors  
straw  
ruler



*Figure 1*

## PROCEDURE

1. Draw four wheels on the index cards using a compass or by tracing around a circular object. The two back wheels should be larger than the front wheels. Carefully cut out the wheels. Poke a very small hole at the center of each wheel.
2. Straighten two paper clips using pliers. These straightened paper clips will be car axles. The straighter you make them, the better the car wheels will roll.
3. Cut a straw into two 8 cm long pieces for your axles. If you use a non-standard paper clip, make sure that approximately 1.5 cm of paper clip extends from each end of the straw.

## ***Experiment 35B***

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4. Fasten one back wheel to its axle.
  - a. Using pliers, bend one end of the straightened paper clip into the shape of an “L” at a point 1.5 cm from its end.
  - b. Put one of the large wheels on this end of the paper clip.
  - c. Bend the end into a second “L” that fits against the wheel as shown in Figure 1.
  - d. Put a piece of masking tape over the “L” to fasten it to the wheel.
5. Fasten the other back wheel to the axle.
  - a. Put the other end of the paper clip through one of the 8 cm pieces of straw.
  - b. Using pliers, bend that end of the paper clip into the shape of an “L.”
  - c. Put the other large wheel on this end of the paper clip.
  - d. Bend the end into a second “L” that fits against the wheel.
  - e. Put a piece of masking tape over the “L” to fasten it to the wheel.
  - f. Hold the straw in your fingers and spin the wheels to make sure they turn easily.
6. Repeat Steps 4 and 5 for the front wheels.
7. Attach the front wheels to the pointed end of a pencil using a rubber band.
  - a. Double the rubber band.
  - b. Hang the rubber band over the end of the pencil.
  - c. Place the axle under the pencil, next to the rubber band.
  - d. Fasten the axle to the pencil by pulling the hanging part of the rubber band under the axle and over the end of the pencil as shown in Figure 1.
  - e. Wrap any excess rubber band around the pencil, but do not bend the axle.
8. Use the Step 7 procedure to attach the back wheels to the eraser end of the pencil.
9. Make a hole near the bottom of the short side of your last index card. This hole should give a tight fit on the eraser end of the pencil. Push the card onto the eraser end of the pencil. Secure the card with masking tape, if necessary. The card acts as a reflective surface for the Motion Detector.
10. Test your car by rolling it across the floor or down a ramp. Make adjustments to make it roll better.



## The Indy 100

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. Students enjoy constructing, testing, and racing their own cars. Instructions for the construction of a simple car (the Pencil Car) are provided in the Student pages. Alternatively, you can have your students design their own cars. You may wish to set length and/or mass limits.
3. This is a good activity for wrapping up the study of motion. It also works well on the last day of a term.
4. On race day, give each team a few minutes to prepare and practice. Set up one data-collection station and use that setup for all participants. If using *Logger Pro*, use the file “35 Indy 100” from the *Middle School Science with Vernier* experiment files.
5. The ramp will get moved around during the contest. You may want to use tape or chalk to mark all beginning positions and return things to the original marked positions often.
6. Use tape to mark the starting line. Make sure all cars start with their front wheels at the same distance from the bottom end of the ramp.
7. Students often choose to modify their cars by changing the mass or with the use of a lubricant. Do not allow students to add a lubricant to the wheels of a Vernier dynamics cart.
8. You may wish to give prizes to the winners of the race.
9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
10. If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

## **ESTIMATED TIME**

We estimate that this experiment can be completed in one 45–60 minute class period if students use pre-made cars. If students build cars using the directions in "3514B Pencil Car" or design their own cars, it may take an additional one or two periods.

## **NEXT GENERATION SCIENCE STANDARDS (NGSS)**

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models	PS2.A Forces and Motion	Patterns
Planning and carrying out investigations	PS2.B Types of Interactions	Cause and effect
Analyzing and interpreting data	ETS1.A Defining Engineering Problems	Scale, proportion, and quantity
Using mathematics and computational thinking	ETS1.B Developing Possible Solutions	Systems and system models
Constructing explanations and designing solutions	ETS1.C: Optimizing the Design Solution	Energy and matter
		Stability and change

# Crash Dummies

## (Motion Detector)

What happens to people in automobile collisions is important information for car manufacturers. Crash dummies are often used in collision studies. Velocity is one of the most important factors in such collision studies. In this experiment, you will study the relationship between car velocity and the distance a “crash dummy” is thrown during a collision. You will use a Motion Detector to measure the velocity of a car and a ruler to measure the distance a crash dummy is thrown.

### OBJECTIVES

- Measure velocity.
- Measure distances an action figure is thrown.
- Calculate averages.
- Graph the results.
- Make conclusions from your results.

### MATERIALS

computer  
 Vernier computer interface  
 Vernier data-collection software  
 Motion Detector  
 1.5 m board  
 car  
 2 index cards  
 small action figure (10–12 cm tall)  
 books, bricks, or box to support a ramp  
 1 large book  
 meter stick  
 tape

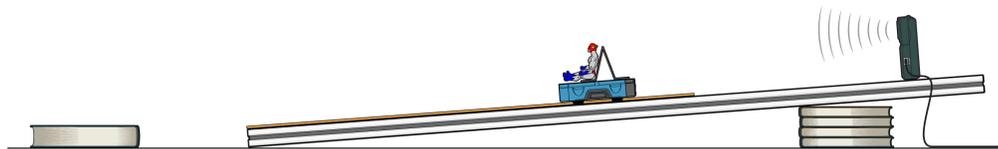


Figure 1

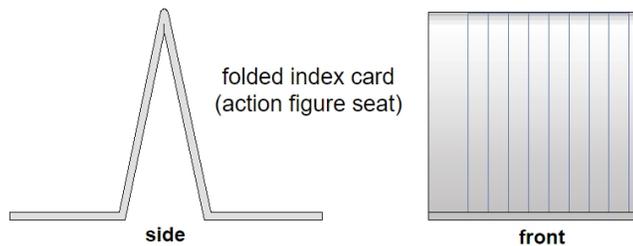


Figure 2

## PROCEDURE

1. Prepare the ramp.
  - a. Set up a ramp on books as shown in Figure 1. The high end of the ramp should be 45 cm above the floor.
  - b. Place a meter stick down the center of the ramp. The 0 cm mark on the meter stick should be at the very bottom of the ramp. Tape the meter stick to the ramp in two places. The meter stick will serve as a guide rail for your car.
  - c. Use tape to mark a distance 30 cm from the bottom end of the ramp. Place the bound edge of a heavy book on the 30 cm line where it will be struck head on by a car rolling off the ramp.
  - d. Fasten the Vernier Motion Detector at the top and center of the ramp as shown in Figure 1. Connect the Motion Detector. If your Motion Detector has a sensitivity switch, set it to Cart/Track.



Figure 3

2. Prepare a car for data collection.
  - a. Tape a card to the back of a car. This card serves as a reflector for the Motion Detector.
  - b. If your car does not have a seat for a crash dummy, fold another card in half. Fold each side up as shown in Figure 2. Tape this folded card to the car to serve as a seat for the crash dummy.
  - c. Position the action figure (crash dummy) in the car.
3. Start the Vernier data-collection program and open the file “36 Crash Dummies” from the *Middle School Science with Vernier* folder.
4. Collect data.
  - a. Place something heavy on the book to keep it from moving.
  - b. Place your car on the ramp with its front wheels at the 40 cm line.
  - c. Click  , and then release the car. **Note:** The car should hit the book.
  - d. When data collection has ended, click Statistics,  . Record the maximum velocity in the data table.
  - e. Measure the distance the crash dummy was thrown (to the nearest cm). Record this value in Table 2. Measure from the seat of the car to the seat of the action figure.
5. Repeat Step 4 two times for a total of three trials at the same distance.
6. Repeat Steps 4 and 5 with the front wheels of the car at the 60 cm position and again with the front wheels of the car at the 80 cm position.

**DATA**

Table 1: Maximum Speed of Car (m/s)			
Release point	40 cm	60 cm	80 cm
Trial 1			
Trial 2			
Trial 3			
Average			

Table 2: Distance Thrown (cm)			
Release point	40 cm	60 cm	80 cm
Trial 1			
Trial 2			
Trial 3			
Average			

**PROCESSING THE DATA**

1. Calculate the average maximum speed for each release point. Record the results in the Table 1.
2. Calculate the average distance that the crash dummy was thrown for each release point. Record the results in the Table 2.
3. Graph your results using the average values. Plot Average Maximum Speed (in m/s) on the horizontal or x-axis and Distance Thrown (in cm) on the vertical or y-axis.
4. What happened to the maximum speed of your car as it was released from higher release points?
5. How did increased speed affect the distance that your crash dummy was thrown?
6. Do you think there would be more serious injuries in a high-speed or a low-speed collision? Explain.
7. What is the purpose of seat belts?

**EXTENSIONS**

1. Repeat the experiment with your car crashing into a moveable car instead of a book. Explain any differences in your results.
2. Fasten the crash dummy into your car using a seat belt. Collect data while releasing the car from the 80 cm release point. Explain your results.



# Crash Dummies

(Sensor Cart)

What happens to people in automobile collisions is important information for car manufacturers. Crash dummies are often used in collision studies. Velocity is one of the most important factors in such collision studies. In this experiment, you will study the relationship between car velocity and the distance a “crash dummy” is thrown during a collision. You will use a Sensor Cart to measure the velocity of the cart and a ruler to measure the distance a crash dummy is thrown.

## OBJECTIVES

- Measure velocity.
- Measure distances an action figure is thrown.
- Calculate averages.
- Graph the results.
- Make conclusions from your results.

## MATERIALS

1.5 m board  
index cards  
small action figure (10–12 cm tall)  
books, bricks, or box to support a ramp  
1 large book  
meter stick  
tape

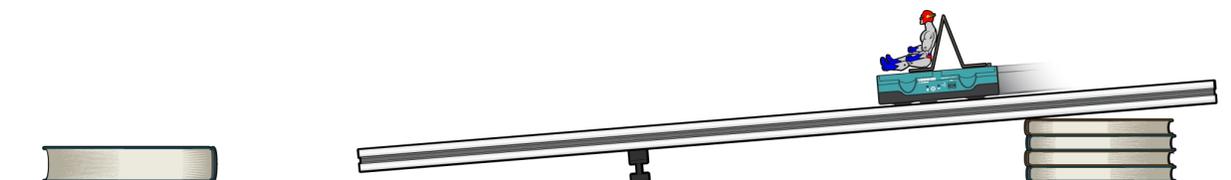


Figure 1

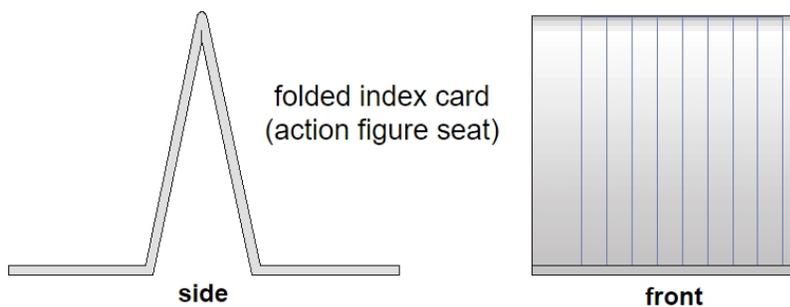


Figure 2

**DATA**

Table 1: Maximum Speed of Car (m/s)			
Release point	40 cm	60 cm	80 cm
Trial 1			
Trial 2			
Trial 3			
Average			

Table 2: Distance Thrown (cm)			
Release point	40 cm	60 cm	80 cm
Trial 1			
Trial 2			
Trial 3			
Average			



## **PROCESSING THE DATA**

1. Calculate the average maximum speed for each release point. Record the results in the Table 1.
2. Calculate the average distance that the crash dummy was thrown for each release point. Record the results in the Table 2.
3. To graph the results, first disconnect the Sensor Cart. Click or tap File, , and choose New Experiment. Click or tap Manual Entry. Enter the Average Maximum Speed values in the first (x) column and enter the Distance Thrown values in the second (y) column.
4. What happened to the maximum speed of your car as it was released from higher release points?
5. How did increased speed affect the distance that your crash dummy was thrown?
6. Do you think there would be more serious injuries in a high-speed or a low-speed collision? Explain.
7. What is the purpose of seat belts?

## **EXTENSIONS**

1. Repeat the experiment with your car crashing into a moveable cart instead of a book. Explain any differences in your results.
2. Fasten the crash dummy into your cart using a seat belt. Collect data while releasing the car from the 80 cm release point. Explain your results.



## Crash Dummies

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources.
2. Any dynamics cart, such as the Vernier Standard Dynamics Cart (order code: DTS-CART-S), works well in this experiment. Other cars can be substituted.
3. A variety of sensors will work for this experiment. *Logger Pro* users will need a motion detector such as the Motion Detector 2 (order code: MD-BTD) or Go!Motion (order code: GO-MOT). *Graphical Analysis* users can use either of those motion detectors (the Motion Detector 2 requires an interface with a digital port), or they can use Go Direct Motion Detector (order code: GDX-MD) or Go Direct Sensor Cart (order code: GDX-CART).
4. If using a motion detector, make sure the motion detector is positioned at least 15 cm from the car. See [www.vernier.com/tit/5](http://www.vernier.com/tit/5) for more tips on using the motion detector.
5. This experiment is probably best done on the classroom floor.
6. Standard 7.6 cm × 12.7 cm (3" × 5") index cards can be attached to the cars to serve as ultrasound reflectors (when using a motion detector) and be shaped into car seats. Painter's masking tape works well as it is sticky enough to hold the card in place while being easy to remove without leaving a sticky residue.
7. Clay figures can be substituted for the action figures. Give each student team 100 g of clay to be shaped into a simple figure.
8. This experiment can also be done as an energy study. Kinetic energy can be expressed by the formula

$$KE = \frac{1}{2}mv^2$$

where KE = kinetic energy,  $m$  = mass (in g), and  $v$  = velocity (in m/s). In this case, students would mass the car and crash dummy and calculate kinetic energy. The graph would show the relationship between kinetic energy and distance thrown.

9. If doing the seat belt Extension, seat belts can be made from string or rubber bands.

## Experiment 36

- For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
- If you are using Go Direct sensors, see See Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

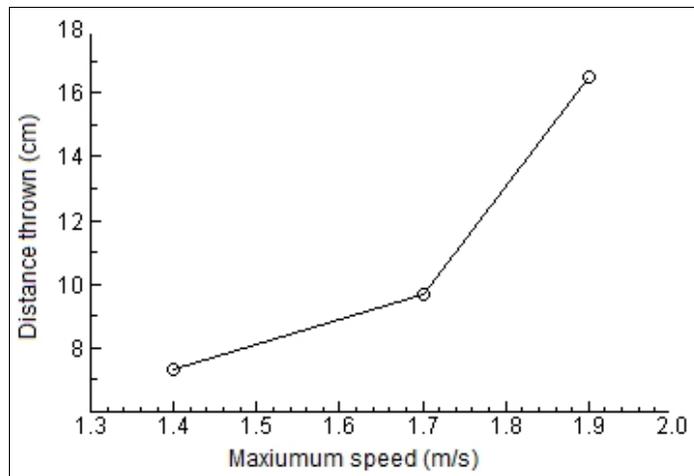
## ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS2.A Forces and Motion PS2.B Types of Interactions	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Stability and change

## SAMPLE RESULTS



Release point (cm)	40	60	80
Maximum speed (m/s)	1.4	1.7	1.9
Distance thrown (cm)	7.3	9.7	16.5

## **ANSWERS TO QUESTIONS**

- 1–3. See Sample Results.
4. The maximum speed increased as the car was released from higher release points.
5. The distance the crash dummy was thrown increased as maximum speed increased.
6. High-speed accidents are more likely to cause serious injury because of the greater energies involved.
7. Seat belts are worn to reduce injuries in collisions.



# Falling Objects

Galileo tried to prove that all falling objects accelerate downward at the same rate. Falling objects do accelerate downward at the same rate in a vacuum. Air resistance, however, can cause objects to fall at different rates in air. Air resistance enables a skydiver's parachute to slow his or her fall. Because of air resistance, falling objects can reach a maximum velocity or *terminal velocity*. In this experiment, you will study the velocities of two different falling objects.

## OBJECTIVES

- Use a motion detector to measure distance and velocity.
- Produce position *vs.* time and velocity *vs.* time graphs.
- Analyze and explain the results.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Motion Detector  
ring stand  
metal rod  
right-angle clamp  
basket-style coffee filter  
3 books  
meter stick

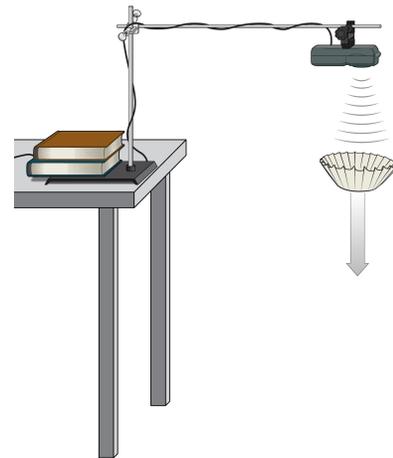


Figure 1

## PROCEDURE

1. Set up the apparatus as shown in Figure 1.
  - a. Place two books on the base of a ring stand to keep it from falling.
  - b. Use a right-angle clamp to fasten a metal rod to the ring stand.
  - c. Fasten a Motion Detector under one end of the rod. The Motion Detector should face down and be parallel to the floor.
  - d. Move the right-angle clamp, rod, and Motion Detector to the top of the ring stand.
  - e. Use a piece of tape to mark a spot on the ring stand that is 0.3 m (30 cm) below the Motion Detector.
  - f. Place the ring stand, with the Motion Detector attached, at the edge of your lab table. The Motion Detector must extend 0.5 m beyond the table edge.
2. Connect the Motion Detector. If your Motion Detector has a sensitivity switch, set it to Ball/Walk.

## Experiment 37

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3. Start the Vernier data-collection program and open the file “37 Falling Objects” from the *Middle School Science with Vernier* folder.
4. Collect data for a falling coffee filter.
  - a. Hold a basket coffee filter with the open side facing up at a position of 0.5 m from (at the 0.5 m mark on the ring stand) and directly below the Motion Detector.
  - b. Click  to begin data collection.
  - c. When you hear sound coming from the Motion Detector, allow the coffee filter to drop straight down.
5. Store data for a good coffee-filter run.
  - a. Repeat the coffee-filter drop, if necessary, until you have “smooth” curves for both graphs.
  - b. Choose Store Latest Run from the Experiment menu to store your good run. Your coffee-filter run will be stored as Run 1.
6. Repeat Step 4 using a book.
  - a. Repeat the book drop, if necessary, until you have “smooth” curves for both graphs.
  - b. Do not choose to store this good book run. It will be kept as the Latest Run.
7. Click Examine, . The time and position values for both runs will be displayed as the mouse pointer is moved across the graph.
8. Determine and record the coffee filter’s position data.
  - a. Move the mouse pointer to the lowest part of the position *vs.* time graph. Find the position value displayed for the coffee filter in the examine box. This is a measure of the coffee filter’s distance from the Motion Detector at the drop point. Record this value in your data table.
  - b. Move the mouse pointer to the highest part of the position *vs.* time graph. Find the position value displayed for the coffee filter in the examine box. This is a measure of the coffee filter’s distance from the Motion Detector at the landing point. Record this value in your data table.
9. Determine and record the coffee filter’s time data.
  - a. Move the mouse pointer back to the first part of the curves and determine the time when the coffee filter was dropped. Record this value in your data table.
  - b. Move the mouse pointer to the highest part of the position *vs.* time graph. Record the time when the coffee filter landed. Consider both curves as you choose this landing time.
10. Determine the velocity at the highest part of the coffee filter’s velocity *vs.* time curve.
  - a. Move the mouse pointer to highest point of the coffee filter on the velocity *vs.* time graph. Record the velocity at this point.
  - b. Note and record the shape of the curve in the region of the maximum velocity.
11. Repeat Steps 8–10 to determine and record the falling book’s data.
12. Print graphs showing the coffee filter and the book results.
  - a. Click Examine, , to turn off the examine feature.
  - b. Print the position *vs.* time and the velocity *vs.* time graphs.
  - c. Hand label your graphs with the data you recorded in Steps 8–10.

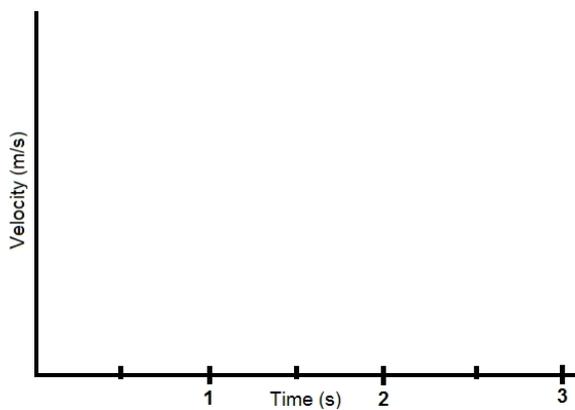


**DATA****Falling Coffee Filter**

	Coffee Filter		Book	
	Position (m)	Time (s)	Position (m)	Time (s)
Drop point				
Landing point				
Falling time (s)				
Highest velocity (m/s)				
Curve shape in maximum region				

**PROCESSING THE DATA**

1. Calculate the distance fallen (in m) for each object. (Subtract the drop-point position from the landing-point position.)
2. How do the distances compare? Why do the distances compare this way?
3. Calculate the falling time (in s) for each object. (Subtract the drop-point time from the landing-point time.)
4. How do the falling times compare?
5. Which object fell faster? Why?
6. How are the two position *vs.* time graphs different? Explain the differences.
7. How are the two velocity *vs.* time graphs different? Explain the differences.
8. Compare the highest velocities of your two objects. Which object was falling faster when it landed? Why was it falling faster?
9. For which object is air resistance more important? Why does air resistance affect this object more than the other object?
10. Which of your velocity *vs.* time graphs would be more like the velocity *vs.* time graph of an object falling in a vacuum? Why?
11. Sketch a velocity *vs.* time curve for an object that is released at 0.5 s, falls with increasing velocity until 1.5 s, falls at constant velocity from 1.5 s to 3.0 s, and lands at 3.0 s. An object that falls at constant velocity is said to have reached *terminal velocity*.



12. Did either of your objects reach terminal velocity? If so, which one? How do you know?

### **EXTENSIONS**

1. Determine the average terminal velocity of a coffee filter in five falls.
2. Study the falling behavior of stacks of 1, 2, 3, 4, and 5 coffee filters.

## Falling Objects

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at [vernier.com/account](http://www.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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at [www.vernier.com/account](http://www.vernier.com/account) to access the Electronic Resources. The accompanying student instructions were written with hands-on experimentation in mind. You may wish to edit them to match your teaching situation and the needs of your students. Keep in mind that if you are using these instructions in conjunction with the sample experiments in *Graphical Analysis Pro*, any changes you make could render the sample data obsolete. This is copyrighted material, so please do not post the content on a page that is accessible to the public.
2. Have the experiment area as free of obstacles as possible. Ultrasound reflections from tables, desks, and their edges can give unexpected results.
3. One way to attach the Motion Detector to the horizontal rod is to use the Motion Detector Clamp (order code: MD-CLAMP). For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit [www.vernier.com/manuals](http://www.vernier.com/manuals) and download the appropriate user manual.
4. The Motion Detector must extend 50 cm beyond the table edge. Alternatives to the ring stand, right-angle clamp, and rod for suspending the Motion Detector include taping it to a board or rigid meter stick supported by a book shelf, cabinet, or stack of books on a table.
5. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in *Graphical Analysis*.

### ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

## NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	PS2.A Forces and Motion PS2.B Types of Interactions	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Stability and change

## SAMPLE RESULTS

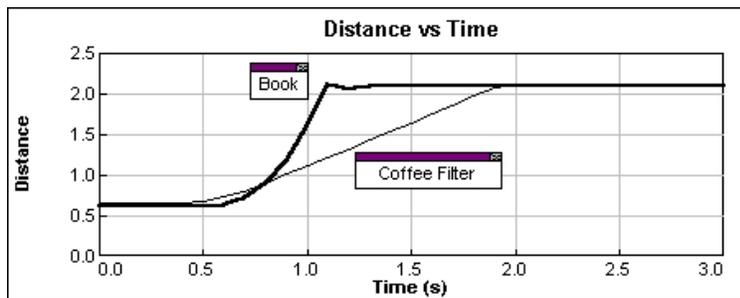


Figure 1 Distance versus time

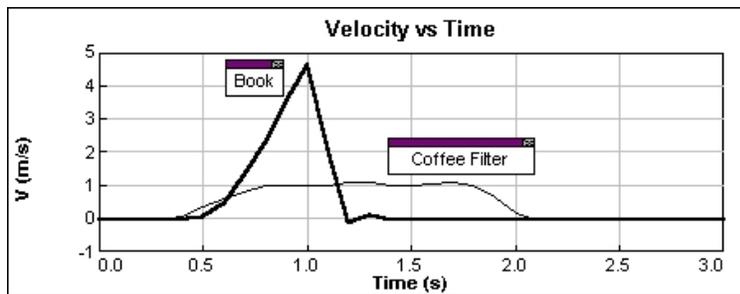


Figure 2 Velocity versus time

	Falling coffee filter		Falling book	
	Position (m)	Time (s)	Position (s)	Time (s)
Drop point	0.66	0.40	0.61	0.50
Landing point	2.12	2.00	2.10	1.20
Maximum velocity (m/s)	1.14		4.67	
Curve shape in maximum region	Flat		Pointed	

## ANSWERS TO QUESTIONS

1. Distance fallen:

$$\text{Coffee filter: } 2.12 \text{ m} - 0.66 \text{ m} = 1.46 \text{ m}$$

$$\text{Book: } 2.10 \text{ m} - 0.61 \text{ m} = 1.49 \text{ m}$$

2. The distances fallen by the two objects should be nearly equal because the two objects were dropped to the floor from nearly the same point.

3. Falling times:

$$\text{Coffee filter: } 2.00 \text{ s} - 0.40 \text{ s} = 1.60 \text{ s}$$

$$\text{Book: } 1.20 \text{ s} - 0.50 \text{ s} = 0.70 \text{ s}$$

4. The falling time of the coffee filter is greater.

5. The book fell faster because it has a greater mass to surface area ratio.

6. The book's position vs. time graph is steeper because the falling book took less time to reach the floor.

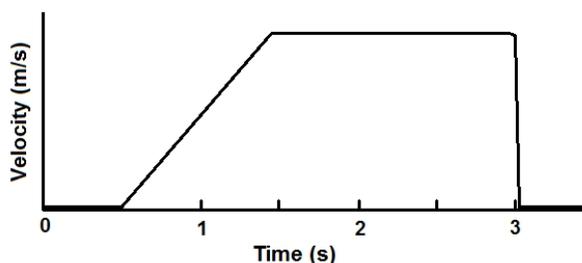
7. The velocity vs. time graph for the coffee filter leveled off as the falling coffee filter reached terminal velocity. In contrast, the book's velocity time graph has a sharp peak because the book increased in velocity until it hit the floor.

8. The book's maximum velocity is greater than that of the coffee filter (4.67 m/s versus 1.14 m/s in the Sample Data). The book was falling faster because it has a higher mass to cross-sectional area ratio.

9. Air resistance is more important for the coffee filter because it has a low mass to cross-sectional area ratio.

10. The falling book's velocity vs. time graph looks more like that of an object in a vacuum than that of the falling coffee filter because the book is slowed much less by air resistance. There is no air resistance in a vacuum.

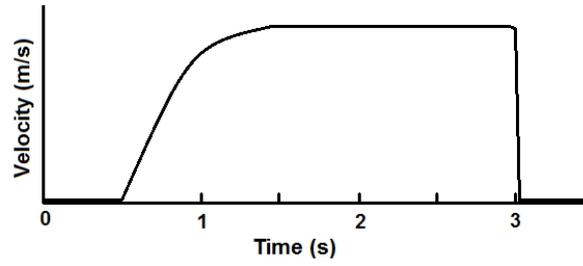
11. One basic correct answer is



One correct answer that better matches the velocity graphs for the coffee filter

*Experiment 37*

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12. A falling coffee filter can reach terminal velocity.

# A Speedy Slide

You have probably been familiar with playgrounds and slides since you were a small child. The force of gravity pulls you down a slide. The force of friction prevents you from going super fast. In the first part of this experiment, you will use a Motion Detector to determine your velocity going down a playground slide. In the second part, you will experiment with different ways to increase your velocity going down the slide.

## OBJECTIVES

- Use a Motion Detector to determine your velocity going down a slide.
- Experiment with ways to increase your velocity going down the slide.
- Explain your results.

## MATERIALS

computer  
Vernier computer interface  
Vernier data-collection software  
Motion Detector  
playground slide

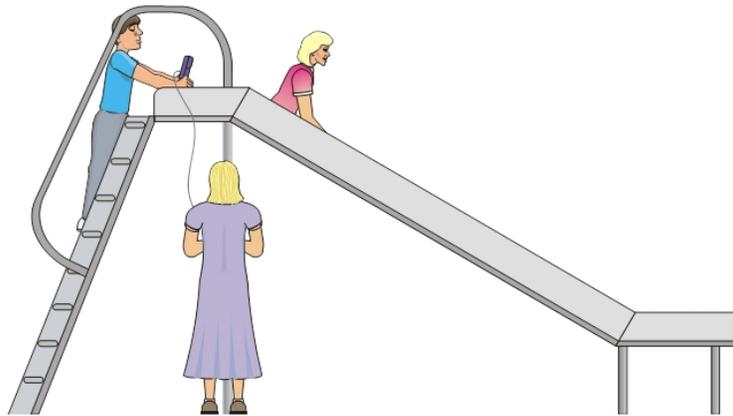


Figure 1

## PROCEDURE

### Part I Sliding Velocity

1. If your Motion Detector has a sensitivity switch, set it to Ball/Walk. Connect the Motion Detector. Start the Vernier data-collection program and open the file “38 A Speedy Slide” from the *Middle School Science with Vernier* folder.

## Experiment 38

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2. Take your preliminary data-collection positions.
  - a. One member of the group should first go up the slide steps and sit at the top of the slide.
  - b. A second person, while holding the Motion Detector, should go high enough on the slide steps to hold the Motion Detector behind the person who will slide.
  - c. The third person should stand on the ground next to the slide, while holding the interface.
3. Take your final data-collection positions.
  - a. The slider, while holding on, should move forward enough to allow a 30 cm distance between his or her back and the Motion Detector.
  - b. The person holding the Motion Detector should hold the Motion Detector steady and aim it at the slider's back.
  - c. The person holding the interface should move to a comfortable position that does not cause a pull on the Motion Detector cable.
4. Collect data.
  - a. Click .
  - b. The slider should begin to slide when you hear clicking from the Motion Detector.
  - c. When data collection is done for this trial, the person with the Motion Detector should come down to the ground. **Caution:** No student should attempt to pass another person while he or she is on the steps.
5. Determine the slider's speed.
  - a. When data collection has ended, click Statistics, . Record the maximum velocity in your data table.
  - b. Close the Statistics box.
6. Repeat Steps 2–5 two more times.

### Part II A Speedier Slide

7. Design a plan to increase the slider's speed.
  - a. Try out some ideas for increasing the slider's speed. You may not coat the slide with anything that must be washed off.
  - b. Decide on a plan to best increase the slider's speed.
  - c. Describe your plan in the Speedier Slide Plan section.
8. Test your plan using Steps 2–6.

### SPEEDIER SLIDE PLAN



**DATA**

	Maximum speed (m/s)			
	Trial 1	Trial 2	Trial 3	Average
Part I				
Part II				

**PROCESSING THE DATA**

1. Calculate the average maximum speed for your three trials in Part I and record the average in the data table. Then, calculate and record the average maximum speed for Part II.
2. Subtract your Part I average speed from your Part II average speed to determine how much your team improved its velocity.
3. What methods did other groups use to improve their velocity?
4. Which of the methods worked best? Explain why it worked best.
5. If you could increase the height of the slide, how would the slider's maximum speed be affected?
6. What is the purpose of the level portion at the bottom of many slides?

**EXTENSIONS**

1. Design and carry out a plan to measure your velocity on a different piece of playground equipment.
2. Have a contest to see who in your class or group can obtain the greatest velocity going down a slide.



## A Speedy Slide

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., *Logger Pro* and *Graphical Analysis*). 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 *Logger Pro* versions of the experiments. In the Electronic Resources you will find PDF and word-processing files of the student experiment. You can print the PDF, distribute it to students electronically, or post the file to a password-protected class web page or learning management system. Edit the word-processing file if you would like to tailor the experiment to suit your equipment and students. Sign in to your account at **www.vernier.com/account** to access the Electronic Resources.
2. In this experiment, students collect data outside on a slide. Ensure all your battery-powered equipment is well charged before the day of the activity. If you have wired connections (e.g., a LabQuest sensor connected to a LabQuest Mini connected to a laptop), you may need to carefully orchestrate students' positions during data collection. If you use LabQuest 2 interfaces and normally connect them to a computer/laptop, use them in standalone mode and follow the directions in the LabQuest App folder in the Electronic Resources.
3. The use of a playground area with several slides is preferable for this experiment.
4. The slides should be straight. Slides with other shapes could be used in an extension.
5. You may wish to carry the data-collection equipment to the playground area in a box or boxes, and distribute the equipment to your students there.
6. For safety reasons, remind your students not to attempt to pass each other while on the slide steps.
7. Depending on the type of slides that are available, you may wish to change the way your students position themselves for data collection. Some slides have large platforms where the student with the Motion Detector and the student with the calculator and interface can be located.
8. Students can use wax paper, slippery cloth, sand, and other materials to increase their speed. To enable your students to be prepared, be sure to alert them to Part II in advance.
9. If time permits, you may wish to allow class members to have their sliding rates determined.
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.

## Experiment 38

11. If you are using Go Direct sensors, see Visit [www.vernier.com/start/go-direct](http://www.vernier.com/start/go-direct) for information about how to connect to your Go Direct sensors in Graphical Analysis.

### ESTIMATED TIME

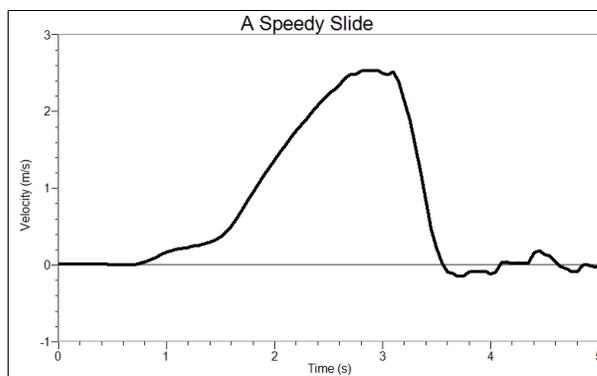
We estimate that this experiment can be completed in one 45–60 minute class period.

### NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models	PS2.A Forces and Motion	Patterns
Planning and carrying out investigations	PS2.B Types of Interactions	Cause and effect
Analyzing and interpreting data	ETS1.A Defining Engineering Problems	Scale, proportion, and quantity
Using mathematics and computational thinking	ETS1.B Developing Possible Solutions	Systems and system models
Constructing explanations and designing solutions	ETS1.C: Optimizing the Design Solution	Energy and matter
		Stability and change

### SAMPLE RESULTS

	Maximum speed (m/s)			
	Trial 1	Trial 2	Trial 3	Average
Part I	1.97	2.02	2.00	2.00
Part II	2.80	3.07	2.82	2.90



### ANSWERS TO QUESTIONS

1. See the Sample Results.
2. In the Sample Results, the Part II speed was 0.90 m/s greater than the Part I speed. Wax paper was used to decrease friction and increase speed.

3. Answers will vary. Speeds will differ because of differences such as contact area, weight, streamlining, and the use of low-friction materials.
4. Answers will vary.
5. Increasing the height of the slide should increase speed.
6. The stone dropped from the top of the slide should hit the ground first because friction and the incline of the slide slow the rolling stone more.
7. The level part at the bottom of a slide prevents you from hitting the ground too hard. Answers will vary.



# 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**

 **Middle School 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 app you will find folders containing the PDF and Word files of each of the experiments.

 **EasyData**—Supports the EasyData calculator app.

 **Graphical Analysis**—Supports Graphical Analysis 4 app on computers, Chromebooks, and iOS and Android devices. The PDF and Word subfolders contain files for each of the experiments in this book.

 **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 LabQuest sensors connected 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 Pro**—Supports Logger *Pro* 3 version 3.14 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.

**NONCONSUMABLES**

Item	Amount	Experiment
aprons or lab coats	class set	all
balance	2	1B, 13, 15
basting bulb	8	1B
beaker, 100 mL	24	5 (all methods), 12A, 13
beaker, 250 mL	16	1B, 2 (O <sub>2</sub> ), 2 (Gas Pressure), 4B, 12A, 12B
beaker, 400 mL	8	1A, 2 (O <sub>2</sub> )
beaker, 600 mL	24	1B, 2 (Gas Pressure), 4B, 6B (opt. 2)
beaker, 1 L	16	5 (Gas Pressure), 6A
BioChamber 250	8	5 (CO <sub>2</sub> and O <sub>2</sub> )
blender	1	15, 16
bottle, Nalgene, 250 mL	8	2 (O <sub>2</sub> ), 5 (CO <sub>2</sub> ), 5 (O <sub>2</sub> )
bottle, spray	2	9
brush, camel's hair	8	7, 11
Bunsen burner	8	3
clamp, dialysis tubing	16	1A, 1B
clamp, plastic tubing	16	1B, 9
clamp, utility	16	1A, 1B, 5 (Gas Pressure), 9
clock or stopwatch	8	4B, 5 (Gas Pressure), 6A, 6B (opt. 2)
clothespins	8	1B, 3, 9
coin	8	4A, 8
cup, large, Styrofoam®	8	1B, 6A, 6B (opt. 2), 12A

Item	Amount	Experiment
3-ring notebook	8	36
balance	8	15, 16
beaker, 50 mL	8	16, 21
beaker, 100 mL	24	20
beaker, 250 mL	8	1, 4, 5, 13, 15, 16, 22
beaker, 400 mL	8	2, 14, 21
beaker, 600 mL	16	3
board, rough	8	29
board, smooth (1 m)	8	12, 29
board, smooth (1.5 m)	8	34, 35
bottle, plastic with lid (soft drink bottles work well)	8	11, 18, 22
car, free rolling (or dynamics cart)	8	34
clamp, right-angle	8	32, 37
clamp, utility (buret clamp)	8	2, 7, 10, 13, 14, 21
clip, alligator	16	17
dropper	8	20, 21, 24
globe	8	10
goggles	30	all

**Appendix B**

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Item	Amount	Experiment
graduated cylinder, 10 mL	8	14, 16, 24
graduated cylinder, 25 mL	8	20
graduated cylinder, 100 mL	8	5, 32
hot plate	8	13
lamp	8	2, 3, 6, 10, 11
light bulb, (100 W)	8	2, 3, 6, 10, 11
magnet, bar	8	27
mass, 100 g	8	32
mass, 500 g	8	30, 31
meter stick	8	8, 30, 33, 34, 35, 37
nail, large iron	8	17, 28
pan	16	2
pencil, wooden	16	17, 32, 35
pliers	8	35
pulley, single	8	31
pulley, double tandem	8	31
ring (for ring stand)	8	31
ring stand	8	2, 7, 10, 13, 14, 21, 31, 32, 37
rinse bottle	8	5
rod, metal	8	37
ruler	8	2, 3, 8, 10, 11, 20, 27, 34, 35, 36
sand	1000 g	2
scalpel	1	17
scissors	8	21, 35
shoelace	2	4
sock, cotton	16	9
sock, wool	8	9

Item	Amount	Experiment
stirring rod	8	21
stool	8	26
stopper, #1	24	20
stopper, #1 1-hole	16	2
test tube, 18 × 150 mm	24	2, 14, 20, 24
test tube rack	8	2, 20, 24
timer	8	25, 26
wire, insulated bell	8 m	28
wooden block, 5 × 10 × 15 cm	8	29

**CONSUMABLES**

Item	Amount	Experiment
aluminum foil	¼ roll	7
battery, D-cell	8	28
bottle, large plastic, with lid (soft drink bottles work well)	8	23
bottle, small plastic, with lid (soft drink bottles work well)	16	9, 23
bowl, small	8	15
box, cardboard	16	12
card, small index	24	34, 35
cardboard, pieces		11
clay	500 g	21
dental floss	1/4 roll	21
dialysis tubing	1/2 roll	21
distilled water	2 L	5, 20, 21
filter, "basket" coffee	8	37
ice	2 bags	14, 15
lemon	8	17

**Appendix B**

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Item	Amount	Experiment
milk, skim	50 mL	24
milk, whole	2 L (1/2 gallon)	15
paper (colors other than white and black)	16 pieces	7
paper, black	16 pieces	6, 7
paper, filter	24 pieces	5
paper, white	16 pieces	6, 7
paper clip	16	29, 35
rubber band	16	8, 35
salt	1 box	14, 15, 21, 26
sand paper	8 sheets	29
soap, Ivory <sup>®</sup> liquid	10 mL	20
soft drink	50 mL	24
soil	see T pages	3
spoon	many	14, 15
stomach antacid	50 mL	24
straw, plastic	16	35
string	1 roll	8, 10, 30, 31, 32
sugar	180 mL (16 US tbsp)	15
tape, masking	2 rolls	3, 4, 6, 10, 11, 12, 27, 28, 32, 33, 34, 35, 36
towels, paper	32	1, 17
vanilla	40 mL (8 tsp)	15
wrap, plastic	1 roll	3
yeast	1 package	24
zip-top freezer bag, 1 quart	8	15
zip-top freezer bag, 1 gallon	8	15

**CHEMICALS**

Item	Amount	Experiment
ammonium chloride	100 g	16
citric acid (monohydrate)	50 g	16
hydrogen peroxide, 3%	100 mL	24
magnesium ribbon	50 cm	17
potassium chloride	50 g	16
sodium bicarbonate	50 g	16
sodium carbonate, monohydrate	50 g	16
zinc, sheet	1/4 sheet	17

## **SUPPLIERS**

Carolina Biological Supply  
1-800-334-5551  
[www.carolina.com](http://www.carolina.com)

Central Scientific  
1-260-424-2400  
[sciencecentral.org](http://sciencecentral.org)

Fisher Science Education  
1-800-955-1177  
[www.fisheredu.com](http://www.fisheredu.com)

Flinn Scientific Inc.  
1-800-452-1261  
[www.flinnsci.com](http://www.flinnsci.com)

Frey Scientific  
1-800-225-FREY  
[www.freyscientific.com](http://www.freyscientific.com)

NASCO  
1-800-558-9595  
[www.enasco.com](http://www.enasco.com)

Sargent-Welch Scientific Co.  
1-800-727-4368  
[www.sargentwelch.com](http://www.sargentwelch.com)

Ward's Science  
1-800-962-2660  
[www.wardsci.com](http://www.wardsci.com)



# Chemical Safety Information

For all chemicals used in this book, refer to the Safety Data Sheet (SDS) that came with the chemical for proper handling, storage, and disposal information. These can also be found online from the manufacturer.

The signal words DANGER and WARNING, as used in the Globally Harmonized System of Classification and Labeling of Chemicals (GHS), are included throughout this book to help identify hazardous chemicals. However, they are not meant to replace safety training, guidance, and monitoring by the instructor.

The *Science Catalog Reference Manual*, published yearly by Flinn Scientific, Inc., is an outstanding reference that can be used as you order chemicals, store chemicals, mix solutions, use chemicals in your classroom, and dispose of chemicals. We strongly urge you to obtain and use a current copy of the *Science Catalog Reference Manual* by contacting Flinn Scientific at 800-452-1261 or through their website, [www.flinnsci.com](http://www.flinnsci.com)



# Transferring Data

You may elect to transfer data collected using supported data collection software (e.g., LabQuest App) to a computer using Logger *Pro* 3 software. Logger *Pro* 3 has many graphing features, such as bar graphs, labels and units for axes, and modification of axes values. Additionally, printed graphs will have a better resolution and appearance than printed screens of the LabQuest or TI graphing calculator display. Logger *Pro* 3 also provides advanced data-analysis features, such as exporting data to Google Maps™ or ArcGIS, curve fitting, statistical analysis, and calculated spreadsheet columns.

## Transfer Data from Graphical Analysis 4 to Logger *Pro* 3

1. In Graphical Analysis 4, export the data as a file type that can be imported into Logger *Pro* 3 (e.g., a CSV file).
2. Transfer the file to a computer that has Logger *Pro* 3. There are many ways this can be done including sending the file as an email attachment, transferring it over a network, or using a USB storage device.
3. Start Logger *Pro* 3 on your computer.
4. Choose Import from ► File type (e.g., CSV) from the File menu in Logger *Pro*.
5. Select the file you want to import.

## Transferring Data from LabQuest to Logger *Pro* 3

1. Save the file on LabQuest.
2. Connect LabQuest to your computer with a USB cable.
3. Start Logger *Pro* on your computer.
4. Choose LabQuest Browser ► Open... from the File menu in Logger *Pro*.
5. Select the file name you want, and then click Open. Logger *Pro* will open the LabQuest file, and display any data, graphs, and notes.

## Transferring Data From a TI Graphing Calculator to Logger *Pro* 3

1. If you are using the TI-83 family of calculators, connect the TI Connectivity cable to the USB port of your computer and to the port at the bottom edge of the calculator.

If you are using the TI-84 family of calculators, connect the TI unit-to-computer cable to the USB port of your computer and to the USB port at the top edge of your calculator.

2. Turn on the calculator.
3. Start Logger *Pro* on your computer.
4. Choose Import from ► TI Device from the File menu in Logger *Pro*. A dialog box appears with directions for importing data.

5. From the drop-down Port menu, make the appropriate choice for your connection.
6. Click the Scan for Device button. The calculator model you are using should now be identified, and you should see a message, “Ready to Import.”
7. Select the lists that you wish to import by clicking each of them. **Note:** To select more than one list on a Macintosh, drag your cursor across the desired lists or hold down the Command key while you click to select individual lists.
8. Click OK to send the lists to the computer. The lists will appear in columns in the data table in *Logger Pro*. If you want to rename the lists or add units, double-click the heading in the data table and enter new labels or units.

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