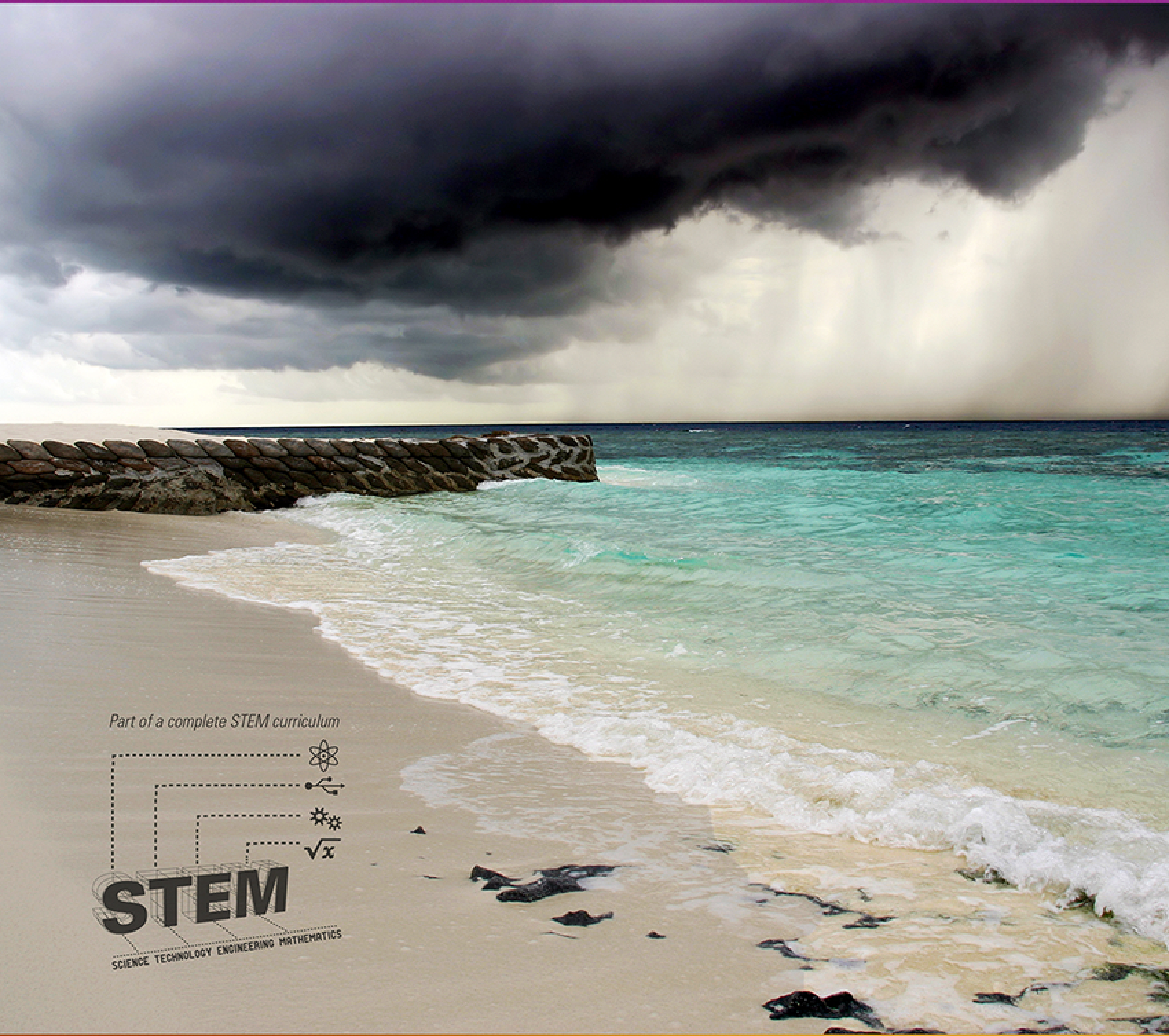
EARTH SCIENCE
MIDDLE SCHOOL

PASCO®
21st CENTURY SCIENCE



TEACHER GUIDE | PS-3851

Middle School Earth Science
Teacher Guide

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Middle School Earth Science

Teacher Guide
21st Century Science

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Introduction

PASCO scientific's probeware and laboratory investigations move students from the low-level task of memorization of science facts to higher-level tasks of data analysis, concept construction, and application. For science to be learned at a deep level, it is essential to combine the teaching of abstract science concepts with "real-world" science investigations. Hands-on, technology-based, laboratory experiences serve to bridge the gap between the theoretical and the concrete, driving students toward a greater understanding of natural phenomenon. Students also gain important science process skills that include: developing and using models, carrying out investigations, interpreting data, and using mathematics.

At the foundation of teaching science are a set of science standards that clearly define the science content and concepts, the instructional approach, and connections among the science disciplines. The Next Generation Science Standards (2012)© are a good example of a robust set of science standards.

The Next Generation Science Standards (NGSS) position student inquiry at the forefront. The standards integrate and enhance science, technology, engineering, and math (STEM) concepts and teaching practices. Three components comprise these standards: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts. The lab activities in PASCO’s 21st Century Science Guides are all correlated to the NGSS (see http://pasco.com).

- The *Science and Engineering Practices* help students to develop a systematic approach to problem solving that builds in complexity from kindergarten to their final year in high school. The practices integrate organization, mathematics and interpretive skills so that students can make data-based arguments and decisions.
- *Disciplinary Core Ideas* are for the physical sciences, life sciences, and earth and space sciences. The standards are focused on a limited set of core ideas to allow for deep exploration of important concepts. The core ideas are an organizing structure to support acquiring new knowledge over time and to help students build capacity to develop a more flexible and coherent understanding of science.
- *Crosscutting Concepts* are the themes that connect all of the sciences, mathematics and engineering. As students advance through school, rather than experiencing science as discrete, disconnected topics, they are challenged to identify and practice concepts that cut across disciplines, such as "cause and effect". Practice with these concepts that have broad application helps enrich students' understanding of discipline-specific concepts.

PASCO’s lab activities are designed so that students complete guided investigations that help them learn the scientific process and explore a core topic of science, and then are able to design and conduct extended inquiry investigations. The use of electronic sensors reduces the time for data collection, and increases the accuracy of results, providing more time in the classroom for independent investigations.

In addition to supporting the scientific inquiry process, the lab activities fulfill STEM education requirements by bringing together science, technology, engineering, and math. An integration of these areas promotes student understanding of each of these fields and develops their abilities to become self-reliant researchers and innovators. When faced with an idea or problem, students learn to develop, analyze, and evaluate possible solutions. Then collaborate with others to construct and test a procedure or product.

Information and computer tools are essential to modern lab activities and meeting the challenge of rigorous science standards, such as NGSS. The use of sensors, data analysis and graphing tools, models and simulations, and work with instruments, all support the science and engineering practices as implemented in a STEM-focused curriculum, and are explicitly cited in NGSS. PASCO's lab activities provide students with hands-on and minds-on learning experiences, making it possible for them to master the scientific process and the tools to conduct extended scientific investigations.

About the PASCO 21st Century Science Guides

This manual presents teacher-developed laboratory activities using current technologies to help you and your students explore topics, develop scientific inquiry skills, and prepare for state level standardized exams. Using electronic-sensor data collection, display and analysis devices in your classroom fulfills STEM requirements and provides several benefits. Sensor data collection allows students to:

- observe phenomena that occur too quickly or are too small, occur over too long a time span, or are beyond the range of observation by unaided human senses
- perform measurements with equipment that can be used repeatedly over the years
- collect accurate data with time and/or location stamps
- rapidly collect, graphically display, and analyze data so classroom time is used effectively
- practice using equipment and interpreting data produced by equipment that is similar to what they might use in their college courses and adult careers

The Data Collection System

"Data collection system" refers to PASCO's DataStudio®, the Xplorer GLX™, SPARKvue™, and SPARK Science Learning System™ and PASCO Capstone™. Each of these can be used to collect, display, and analyze data in the various lab activities.

Activities are designed so that any PASCO data collection system can be used to carry out the procedure. The DataStudio, Xplorer GLX, SPARKvue, or SPARK Science Learning System Tech Tips provide the steps on how to use the data collection system and are available on the storage device that came with your manual. For assistance in using PASCO Capstone, refer to its help system.

Getting Started with Your Data Collection System

To help you and your students become familiar with the many features of your data collection system, start with the tutorials and instructional videos that are available on PASCO's website (www.pasco.com).

Included on the storage device accompanying your manual is a Scientific Inquiry activity that acts as a tutorial for your data collection system. Each data collection system (except for PASCO Capstone) has its own custom Scientific Inquiry activity. The activity introduces students to the process of conducting science investigations, the scientific method, and introduces teachers and students to the commonly used features of their data collection system. Start with this activity to become familiar with the data collection system.

Teacher and Student Guide Contents

All the teacher and student materials are included on the storage device accompanying the Teacher Guide.

Lab Activity Components

Each activity has two components: Teacher Information and Student Inquiry Worksheets.

Teacher Information is in the Teacher Guide. It contains information on selecting, planning, and implementing a lab, as well as the complete student version with answer keys. Teacher Information includes all sections of a lab activity, including objectives, procedural overview, time requirements, and materials and equipment at-a-glance.

Student Inquiry Worksheets begin with a driving question, providing students with a consistent scientific format that starts with formulating a question to be answered in the process of conducting a scientific investigation.

This table identifies the sections in each of these two activity components.

TEACHER INFORMATION	**STUDENT INQUIRY WORKSHEET**
Objectives	Driving Questions
Procedural Overview	
Time Requirement	
Materials and Equipment	Materials and Equipment
For teacher demonstrations	
For each student or group	For each student or group
Concepts Students Should Already Know	
Related Labs in This Guide	
Using Your Data Collection System	
Background	
Pre-Lab Discussion and Activity	
Preparation and Tips	
Safety	Safety
Driving Question	
Thinking about the Question	Thinking about the Question
Sequencing Challenge	Sequencing Challenge
Investigating the Question	Investigating the Question
Part 1 – Making predictions	Part 1 – Making predictions
Part 2 or more – procedure	Part 2 or more – procedure
Sample Data	
Answering the Question	Answering the Question
Analysis Questions	Analysis Questions
Multiple Choice Questions	Multiple Choice Questions
True/False Questions	True/False Questions
Key Term Challenge	Key Term Challenge
Further Investigations	

Electronic Materials

The storage device accompanying this manual contains the following:

- Complete Teacher Guide and Student Guide with Student Inquiry Worksheets in PDF format.
- The Scientific Inquiry activity for SPARK™, SPARKvue™, Xplorer GLX®, and DataStudio® and the Student Inquiry Worksheets for the laboratory activities are in an editable Microsoft™ Word format. PASCO provides editable files of the student lab activities so that teachers can customize activities to their needs.
- Tech Tips for the SPARK, SPARKvue, Xplorer GLX, DataStudio, and individual sensor technologies in PDF format.
- User guides for SPARKvue and GLX.
- DataStudio and PASCO Capstone® Help is available in the software application itself.

International Baccalaureate Organization (IBO*) Support

IBO Diploma Program

The International Baccalaureate Organization (IBO) uses a specific science curriculum model that includes both theory and practical investigative work. While this lab guide was not produced by the IBO and does not include references to the internal assessment rubrics, it does provide a wealth of information that can be adapted easily to the IB classroom.

By the end of the IB Diploma Program students are expected to have completed a specified number of practical investigative hours and are assessed using the specified internal assessment criteria. Students should be able to design a lab based on an original idea, carry out the procedure, draw conclusions, and evaluate their own results. These scientific processes require an understanding of laboratory techniques and equipment as well as a high level of thinking.

Using these Labs with the IBO Programs

The student versions of the labs are provided in Microsoft Word and are fully editable. Teachers can modify the labs easily to fit a problem-based format.

For IB students, pick one part of the internal assessments rubrics to go over with the students. For example, review the design of the experiment and have students explain what the independent, dependent, and controlled variables are in the experiment. Ask students to design a similar experiment, but change the independent variable.

Delete certain sections. As students become familiar with the skills and processes needed to design their own labs, start deleting certain sections of the labs and have students complete those parts on their own. For example, when teaching students to write their own procedures, have the students complete one lab as it is in the lab guide. In the next lab, keep the Sequencing Challenge, but have students write a more elaborate procedure. Finally, remove both the Sequencing Challenge and the Procedure sections and have students write the entire procedure.

Encourage students to make their own data tables. Leave the procedure, but remove the data tables and require the students to create them on their own. In another lab, leave the driving question and procedure, but remove the analysis questions and have students write their own analysis, conclusion, and evaluation.

Use only the driving question. As students' progress through their understanding of the structure of an experiment, provide them with just the driving question and let them do the rest. Some of the driving questions are too specific (they give the students the independent variable), so revise them appropriately.

Extended inquiry. After students complete an activity in the lab guide, use the extended inquiry suggestions to have the students design their own procedure, or the data collection and processing, or both.

About Correlations to Science Standards

The lab activities in this manual are correlated to a number of standards, including United States National Science Education Standards, the Next Generation Science Standards, and all State Science Standards. See http://pasco.com for the correlations.

Global Number Formats and Standard Units

Throughout this guide, the International System of Units (SI) or metric units is used unless specific measurements, such as air pressure, are conventionally expressed otherwise. In some instances, such as weather parameters, it may be necessary to alter the units used to adapt the material to conventions typically used and widely understood by the students.

Reference

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Master Materials and Equipment List

Italicized entries indicate items not available from PASCO. The quantity indicated is per student or group. NOTE: Some activities also require protective gear for each student (for example, safety goggles, gloves, apron, or lab coat).

Teachers can conduct some lab activities with sensors other than those listed here. For assistance with substituting compatible sensors for a lab activity, contact PASCO Teacher Support (800-772-8700 inside the United States or http://www.pasco.com/support).

Act	Title	Materials and Equipment	Qty
1	**Acid Rain and Weathering** Use a pH sensor to test a simulated acid rain's reaction with a variety of materials.		
	Teacher Demonstration	*Bottle of carbonated beverage, unopened*	1
		Funnel	1
		Spoon	1
		White vinegar	50 mL
		Baking soda	~2 tsp
		Bottle, 500-mL (or any clean soda bottle 16 oz. or smaller)	1
		Water	~200 mL
		Balloon, 10" or 12" in diameter	1
	Student or Group	Data Collection System	1
		PASPORT pH Sensor	1
		Bottle, 500-mL (or any clean soda bottle 16 oz or smaller)	1
		Graduated cylinder, 50-mL or 100-mL	1
		Beakers, 150-mL	2
		Pipet or eye dropper	1
		Balloon, 10" or 12" in diameter	1
		Straw	1
		Iron nail	1
		Rock samples, small -marble, limestone , chalk, or similar	1 piece of each sample
		White vinegar	50 mL
		Water	~200 mL
		Spoon	1
		Funnel	1
		Bromothymol Blue indicator solution	20 mL
		Baking soda	1.5 tbsp

Act	Title	Materials and Equipment	Qty
2	**Exploring Environmental Temperatures** Use a temperature sensor to explore temperatures variations in multiple locations in the environment, organize and compare the information in simple tables, and identify relationships the temperature patterns reveal.		
	Teacher Demonstration	Data Collection System PASPORT Temperature Sensor* *Thermometer that measures temperature in degrees Celsius* *Cup of cold water* *Cup of warm water*	1 1 1 1 1
	Student or Group	Mobile Data Collection System PASPORT Temperature Sensor*	1 1
3	**Investigating Evaporation and Condensation** Use a relative humidity sensor to gain an understanding of the water cycle and evaporation.	Data Collection System PASPORT Relative Humidity Sensor PASPORT Sensor Extension Cable *Beaker, glass, 400 mL* *Hand lens or magnifying glass* *Aluminum foil, 10 cm x 10 cm* *Water, cold* *Water, warm* *Cup, paper or plastic, filed with ice* *Tape* *Paper towel*	1 1 1 1 1 1 400 mL 400 mL 1 20 cm 1
4	**Investigating Seismic Waves** Use a light sensor to measure the amplitude and frequency of vibrations during three simulated earthquakes.	Data Collection System PASPORT Light Sensor PASPORT Sensor Extension Cable Meter stick *Lamp stand with clear, incandescent, 60 to 100 watt light bulb* *Table (same height as lamp stand)* *Books (if needed to raise lamp stand to height of table)* *Tape* *Clay*	1 1 1 1 1 1 1 or more 1 roll 60 g
5	**Mapping the Ocean Floor** Use a motion sensor to scan a cross-section of a simulated ocean floor terrain.		
	Teacher Demonstration	Data Collection System PASPORT Motion Sensor *Kabob skewer or similar thin wooden stick* *Shoebox* *Classroom objects for simulated ocean floor (desks, chairs, books, et cetera)*	1 1 1 1 Several
	Student or Group	Data Collection System PASPORT Motion Sensor *Graph paper* *Classroom objects for simulated ocean floor (desks, chairs, books, et cetera)*	1 1 1 Several

* Either the PASPORT Fast Response Temperature Sensor or the PASPORT Stainless Steel Temperature Sensor can be used for this activity.

Act	Title	Materials and Equipment	Qty
6	**Monitoring Weather** Use a weather sensor to monitor weather outdoors at various times in the day and over an extended period of time.	Mobile Data Collection System PASPORT Weather Sensor PASPORT Sensor Extension Cable *Clipboard and pencil*	1 1 1 1
7	**Night and Day** Use a light sensor to measure the light level that falls on a simulated "earth's" surface as it turns through several rotations.		
	Teacher Demonstration	Data Collection System PASPORT Light Sensor *Utility lamp or flashlight*	1 1 1
	Student or Group	Data Collection System PASPORT Light Sensor *Utility lamp or flashlight* *Index card, 3 in x 5 in* *Marker (dark color)* *Tape*	1 1 1 2 1 1 roll
8	**Observing Clouds** Use a weather sensor to measure meteorological conditions over a period of one week or more.		
	Teacher Demonstration	*Gallon glass or plastic jar, wide mouth (such as a pickle jar or sun tea jar)* *Rubber gloves (such as Playtex™ brand cleaning gloves)* *Matches* *Laser pointer (optional)* *Tap water, warm, to cover bottom of jar to depth of 2 cm* *Food dye, blue and green (optional)* *Large rubber band (the type that come on bunches of produce work well)*	1 1 pair Several 1 2 to 3 drops each color 1
	Student or Group	Data Collection System PASPORT Weather Sensor Cloud chart *Digital camera (optional)* *Pencil* *Notebook* *Graph paper* *Calculator (optional)*	1 1 1 1 1 1 1 1

Act	Title	Materials and Equipment	Qty
9	**Seasons** Use a light sensor to investigate the relationship between the earth's tilt on its axis, its revolution around the sun, and the seasons.		
	Teacher Demonstration	Data Collection System PASPORT Light Sensor PASPORT Sensor Extension Cable *Flashlight* *Globe* Meter stick or straightedge *String, to suspend paper model* *Sticky tape* *Marking pens, various colors* *Protractor* *Compass* *Graph paper, 1 sheet* *Scissors* *Sheet of tag board, card stock, or construction paper, 12" x 18"*	1 1 1 1 1 1 ~1 m 1 Several 1 1 1 sheet 1 1
	Student or Group	Data Collection System PASPORT Light Sensor *Flashlight* Meter stick or straightedge *String, to suspend paper model* *Sticky tape* *Marking pens, various colors* *Protractor* *Compass* *Thumbtack or pushpin (optional)* *Scissors* *Sheet of tag board, card stock, or construction paper, 12" x 18"*	1 1 1 1 ~1 m 1 Several 1 1 1 1 1

Act	Title	Materials and Equipment	Qty
10	**Soil Characteristics** Use a pH sensor to investigate the pH of different soil samples.		
	Teacher Demonstration	Data Collection System	1
		PASPORT pH Sensor	1
		Beaker, 250 mL	1
		Small digging tool	1
		Measuring spoons	1 set
		Re-sealable plastic bags	3
		Permanent marker	1
		Soil samples, 60 mL (3 different types)	3
		Different soil mulches (from the garden store)	Several
		Gardening sulfur (from garden store)	~5 g
		Gardening lime (dolomite or dolomitic limestone)	~5 g
		Distilled water	250 mL
		Buffer solution pH 4	25 mL
		Buffer solution pH 10	25 mL
	Student or Group	Data Collection System	1
		PASPORT pH Sensor	1
		Beakers, 250 mL (4)	1
		Balance	1 per class
		Rinse bottle, with distilled water	1
		Stirring rod	1
		Measuring spoons (optional)	1 set
		Re-sealable plastic bags	3
		Permanent marker	1
		Soil samples, 60 mL (3 different types)	3
		Gardening sulfur (from garden store)	~5 g
		Gardening lime (dolomite or dolomitic limestone)	~5 g
		Distilled water (for soil samples)	250 mL

Act	Title	Materials and Equipment	Qty
11	**Soil Salinity** Use a conductivity sensor to measure the level of conductivity of various water and soil samples.		
	Teacher Demonstration	Data Collection System	1
		PASPORT Conductivity Sensor	1
		Test tube	1
		Beaker, 250-mL	1
		Test tube stopper	1
		Soil sample	1
		Salt	2 to 4 Tbsp.
		Radish seeds	1 packet
		Paper towels for seed germination	2 to 4
		Water	250 mL
		Plastic bags	2
		Distilled water	25 mL
		Wash bottle with distilled water	1
	Student or Group	Data Collection System	1
		PASPORT Conductivity Sensor	1
		Graduated cylinder, 25- or 50-mL	1
		Beaker, 250-mL	1
		Test tubes	8
		Test tube stoppers	4
		Water samples from different locations	3
		Soil samples	4
		Distilled water	100 mL
		Paper towels, for spills	3
		Wash bottle with distilled water	1
		Small funnel	1

Act	Title	Materials and Equipment	Qty
12	**Water – The Universal Solvent** Use a conductivity sensor to classify substances based on their ability to dissolve in water and measure the changes in the conductivity of water as substances dissolve in it.		
	Teacher Demonstration	Data Collection System PASPORT Conductivity Sensor *Beaker, glass, 250-mL* *Wash bottle with distilled water* *Spoon or stirring rod* *Sugar cube* *Thread* *Salt* *Pencil* *Powdered drink mix, any flavor* *Pepper* *Baking soda* *Borax* *Epsom salt* *Alum* *Sample papers* *Distilled water*	1 1 1 1 1 1 ~40 cm 1 tsp. 1 1 packet 1 tsp 1 tsp 1 tsp 1 tsp 1 tsp 1 per sample 100 mL
	Student or Group	Data Collection System PASPORT Conductivity Sensor *Beakers, 250-mL* *Wash bottle with distilled water* *Beaker for waste water* *Sugar cube* *Thread* *Pencil* *Solute samples to dissolve and test* *Sample paper* *Distilled water*	1 1 4 1 1 1 ~40 cm 1 3 1 per sample 400 mL

Act	Title	Materials and Equipment	Qty
13	**Water's Role in Climate** Use two stainless steel temperature sensors to investigate how water and land act together to stabilize temperatures.		
	Teacher Demonstration	Data Collection System PASPORT Stainless Steel Temperature Sensor *Small container for water, 50-mL* *Plastic food storage containers with lids, 750 to 1000 mL* *Teaspoon* *Dry sand or white rocks* *Table salt* *Awl* *Water* *100-W lamp (optional)*	1 2 1 2 1 1000 mL (4 cups) 5 g (2 tsp) 1 100 mL 1
	Student or Group	Data Collection System PASPORT Stainless Steel Temperature Sensors *Small container for water, 50-mL* *Plastic food storage containers with lids, 750 to 1000 mL* *Teaspoon* *Dry sand or white rocks* *Table salt* *Water* *Teaspoon*	1 2 1 2 1 1000 mL (4 cups) 5 g (2 tsp) 100 mL 1

Calibration materials

If you want to calibrate various sensors, you will need the following:

pH Sensor

Item	Quantity	Where Used
Buffer solution, pH 4 Buffer solution, pH 10 Beaker, small Wash bottle with deionized or distilled water	25 mL 25 mL 3 1	11

Activity by PASCO Sensors

This list shows the sensors and other PASCO equipment used in the lab activities.

Items Available from PASCO	**Qty**	**Activity Where Used**
Data Collection System	1	1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13
Mobile Data Collection System	1	2, 6
PASPORT Conductivity Sensor	1	11, 12
PASPORT Light Sensor	1	4, 7, 9
PASPORT Motion Sensor	1	5
PASPORT pH Sensor	1	1, 10
PASPORT Relative Humidity Sensor	1	3
PASPORT Stainless Steel Temperature Sensor	2	13
PASPORT Temperature Sensor*	1	2
PASPORT Weather Sensor	1	6, 8
PASPORT Sensor Extension Cable	1	3, 4, 6, 9

* Either the PASPORT Fast Response Temperature Sensor or the PASPORT Stainless Steel Temperature Sensor can be used for this activity.

Normal Laboratory Safety Procedures

Overview

PASCO is concerned with your safety and because of that, we are providing a few guidelines and precautions to use when exploring the labs in our Middle School Science guide. This is a list of general guidelines only; it is by no means all-inclusive or exhaustive. Of course, common sense and standard laboratory safety practices should be followed.

Regarding chemical safety, some of the substances and chemicals referred to in this manual are regulated under various safety laws (local, state, national, or international). Always read and comply with the safety information available for each substance or chemical to determine its proper storage, use and disposal.

Since handling and disposal procedures vary, our safety precautions and disposal comments are generic. Depending on your lab, instruct students on proper disposal methods. Each of the lab activities also has a Safety section for procedures necessary for that activity.

General Lab Safety Procedures and Precautions

- Follow all standard laboratory procedures
- Absolutely no food, drink, or chewing gum is allowed in the lab.
- Wear protective equipment (for example, safety glasses, gloves, apron) when appropriate.
- Do not touch your face with gloved hands. If you need to sneeze or scratch, take off your gloves, wash your hands, and then take care of the situation.
- Wash your hands after handling samples, glassware, and equipment.
- Know the safety features of your lab such as eye-wash stations, first-aid equipment or emergency phone use.
- Insure that loose hair and clothing are secure when in the lab.
- Handle glassware with care.
- Insure you have adequate clear space around your lab equipment before starting an activity.
- Do not wear open-toe shoes in the laboratory.
- Allow heated objects and liquids to return to room temperature before moving.
- Never run or joke around in the laboratory.
- Do not perform unauthorized experiments.
- Students should work in teams of 2 or more in case of trouble and help is needed.
- Keep the work area neat and free from any unnecessary objects.

Water Related Safety Precautions and Procedures

- Keep water away from electrical outlets.
- Keep water away from all electronic equipment.

Chemical Related Safety Precautions and Procedures

- Consult the manufacturer's Material Safety Data Sheets (MSDS) for instructions on handling, storage, and disposing of chemicals. Your teacher should provide the MSDS documents of the chemicals you are using. Keep these instructions available in case of accidents.
- Many chemicals are hazardous to the environment and should not be disposed of down the drain. Always follow your teacher's instructions for disposing of chemicals.
- Sodium hydroxide, hydrochloric acid, and acetic acid are corrosive irritants. Avoid contact with your eyes and wash your hands after handling. In case of skin exposure, wash it off with plenty of water.
- Always add acids and bases to water, not the other way around, as the solutions may boil vigorously.
- Diluting acids and bases creates heat; be extra careful when handling freshly prepared solutions and glassware, as they may be very hot.
- Handle concentrated acids and bases in a fume hood; the fumes are caustic and toxic.
- Wear eye protection, lab apron, and protective gloves when handling acids. Splash-proof goggles are recommended. Either latex or nitrile gloves are suitable. Use nitrile gloves if you have latex allergy.
- Read labels on all chemicals and pay particular attention to hazard icons and safety warnings.
- When handling any bacterial species, follow aseptic techniques.
- Wash your hands before and after a laboratory session.
- If any solution comes in contact with skin or eyes, rinse immediately with a copious amount of running water for a minimum of 15 minutes.
- Follow the teacher's instructions for disposing of chemicals, handling substances.
- Check the label to verify it is the correct substance before using it.
- Never point the open end of a test tube containing a substance at yourself or others.
- Use a wafting motion when smelling chemicals.
- Do not return unused chemicals to their original container.
- Keep flammable chemicals from open flame.

Dangerous or Harmful Substance Related Lab Safety Precautions

- When handling any bacterial species, follow aseptic techniques.
- Always flame inoculating loops and spreaders before setting them down on the lab bench.
- Pipetting suspension cultures can create an aerosol. Keep your nose and mouth away from the tip of the pipet to avoid inhaling any aerosol
- Use caution when working with acids.
- Use appropriate caution with the matches, burning splint and foods, and other hot materials.
- Be careful using a knife or scalpel.

Outdoor Safety Precautions

- Practice appropriate caution around water bodies, steep terrain, and harmful plants or animals.
- Treat plants, animals and the environment with respect.
- Inspect all equipment for damage (cracks, defects, etc.).
- Require students to use a buddy system and specify the procedure to use in case of trouble.

Other Safety Precautions

- If water is boiled for an experiment involving heat, make sure it is never left unattended. Remember, too, that the hot plate will stay hot well after it is unplugged or turned off.
- Any injury must be reported immediately to the instructor, an accident report has to be completed by the student or a witness.
- If you are suffering from any allergy, illness, or are taking any medication, you must inform the instructor. This information could be very important in an emergency.
- Try to avoid wearing contact lenses. If a solution spills in your eye, the presence of a contact lens makes first aid difficult and can result in permanent damage. Also, organic solvents tend to dissolve in soft contact lenses, causing eye irritation. If contact lenses must be worn, use a style of goggles called "eye cup."

Additional Resources

- Flinn Scientific
- The Laboratory Safety Institute (LSI)
- National Science Education Leadership Association (NSELA)/Safe Science Series

Rubric

Use this rubric for scoring students' accomplishments and performance in the different sections of this laboratory activity.

Category	4 points	3 points	2 points	1 point
Pre-Lab Preparation	Excellent participation in pre-lab discussion. All vocabulary terms, and equations, if applicable, are used correctly.	Good participation in pre-lab discussion. Most vocabulary terms, and equations, if applicable, are used correctly.	Good participation in pre-lab discussion. Some vocabulary terms, and equations, if applicable, are used correctly.	Limited participation in pre-lab discussion. Few vocabulary terms, and equations, if applicable, are used correctly.
Activity Set-up	All instructions are read, by all lab group members, prior to beginning set-up. Set-up reflects lab group needs and safety rules.	All instructions are read, by some lab group members, prior to beginning set-up. Set-up reflects lab group needs and safety rules.	Some instructions are read, by some lab group members, prior to beginning set-up. Set-up reflects lab group needs and safety rules.	Activity instructions can't be verified by any lab group members, prior to beginning set-up. Set-up does not reflect lab group needs and/or safety rules.
Data Collection	Data is collected for the specified amount of time in a reliable manner.	Data is collected for almost the specified amount of time, in a reliable manner.	Data is collected in a manner lacking reliability, safety, or specified amount of time.	Data is collected in such a way that it cannot be analyzed.
Lab Notebook or Record	Lab notebook includes a complete record of the activity, including properly drawn and labeled diagrams, data, observations, modifications, reasons for modifications, and some reflection about the strategies used and the results.	Lab notebook includes a nearly complete record of the activity, including properly drawn and labeled diagrams, data, observations, modifications, reasons for modifications, and some reflection about the strategies used and the results.	Lab notebook includes all but two records of the activity: properly drawn and labeled diagram(s), data, observations, modifications, reasons for modifications, and some reflection about the strategies used and the results.	Lab notebook lacks more than two records of the activity: properly drawn and labeled diagram(s), data, observations, modifications, reasons for modifications, and some reflection about the strategies used and the results.
Safety	Great care taken during activity to ensure that all lab members follow all safety rules.	One safety violation during the activity.	Two safety violations during the activity.	More than two safety violations during the activity.
Activity Clean-up	All members of lab group collaborate to complete all clean-up instructions in time allotted.	All clean-up is accomplished in time allotted, by majority of lab group members.	All clean-up is accomplished in time allotted, by minority of lab group members, OR all lab group members collaborate but exceed time limit.	Clean-up is not accomplished.

Lab Activities

1. Acid Rain and Weathering

Ruined Rocks

Objectives

Students make simulated acid rain and test its reaction with a variety of materials as they:

- Relate the acidity of a solution to its pH factor
- Measure the change in pH of water as carbon dioxide is bubbled through it
- Demonstrate how acid rain can affect and damage materials

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to produce carbon dioxide gas by reacting baking soda and vinegar, and trapping the gas in a balloon
- Bubbling the carbon dioxide gas through a straw into a beaker of distilled water to lower its pH, making a solution that simulates acid rain
- Testing the effect of the carbonic acid "rain" solution on various materials such chalk, an iron nail, limestone, and marble, and observing for signs of any chemical reactions

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	50 minutes
■ Lab activity, Part 2 – Creating simulated acid rain	50 minutes
■ Lab activity, Part 3 – Investigating the effects of acid rain on materials	25 minutes
■ Analysis	25 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Bottle of carbonated beverage, unopened
- ☐ Funnel
- ☐ Spoon
- ☐ White vinegar, 50 mL
- ☐ Baking soda
- ☐ Bottle, 500-mL (or any clean soda bottle 16 oz. or smaller)
- ☐ Water
- ☐ Balloon, 10" or 12" in diameter

For each student or group:

- ☐ Data collection system
- ☐ pH sensor
- ☐ Bottle, 500-mL (or any clean soda bottle 16 oz or smaller)
- ☐ Graduated cylinder, 50-mL or 100-mL
- ☐ Beakers (2), 150-mL
- ☐ Pipet or eye dropper
- ☐ Balloon, 10" or 12" in diameter
- ☐ Straw
- ☐ Iron nail
- ☐ Rock samples, small -marble, limestone , chalk, or similar
- ☐ White vinegar, 50 mL
- ☐ Water
- ☐ Spoon
- ☐ Funnel
- ☐ Bromothymol blue indicator solution
- ☐ Baking soda, 1.5 Tbsp.

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- A solution results when one substance, the solute, dissolves in another substance, the solvent. Solutions may consist of solids dissolved in liquids, and also of gas dissolved in liquids.
- The difference between physical and chemical changes
- Indications that a chemical change, or reaction, has occurred
- The characteristics of sedimentary, metamorphic and igneous rocks
- Process skills such as transferring a powder using a funnel, measuring liquid volume, and using a pipet

Related Labs in This Guide

Labs conceptually related to this one include:

Suggested Prerequisite:

- Introduction to Acids and Bases

Additional Related Labs:

- Acid Rain and Seed Germination
- Acid's Effect on Teeth

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Recording a run of data �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)
- Printing �(11.2)

Background

Pure water is neutral with a pH of 7. We know that gases are soluble in water. Some of these gases, most notably carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur oxides (SO_x), form acids when they are dissolved in water.

Carbonic acid is formed in water by the dissolution of carbon dioxide. It is a weak acid, bringing the water to about pH 5. In fact, often tap water from the faucet initially has a pH of between 5 and 6 because of the CO_2 which is dissolved in it. The nitrogen and sulfur oxides from car and industrial emissions form much stronger acids when they dissolve in water. These substances, when absorbed by rain as if falls through the atmosphere make rain with a pH as low as 3, an acid level very close to vinegar.

Rain water falling through the atmosphere containing these gases will absorb the gases and become more acidic. This is what we call "acid rain." The nitrogen and sulfur oxides from car exhaust and industry are the most serious causes of acid rain, but it is dangerous to generate those gases in the lab.

Carbon dioxide forms carbonic acid in water, which also makes water slightly acidic. It is easy and safe to generate CO_2 in the lab and demonstrate its effect when bubbled though water.

This is an example of a *simulation* of acid rain formation. In this reaction

Sodium bicarbonate ($NaHCO_3$) chemically reacts with vinegar (acetic acid, $HC_2H_3O_2$). This reaction produces sodium acetate ($NaC_2H_3O_2$), water (H_2O), and carbon dioxide gas (CO_2).

$$NaHCO_3(s) + HC_2H_3O_{2(aq)} \rightarrow NaC_2H_3O_{2(aq)} + H_2O(l) + CO_2(g)$$

When bubbled through water containing bromothymol blue indicator the indicator should turn yellow, indicating that the solution has become more acidic. This can be compared to the color of the water of the control beaker. In addition students can use the computer and sensor to monitor and record changes to pH.

This experiment is to show how a certain gas dissolved in water can make the water more acidic. Secondly we want to show how acid rain affects different materials such as chalk and marble.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Demonstrate to students the well-known effect of opening a carbonated beverage and allowing the dissolved gas to come out of solution. Shake the container a bit before opening it, and pour some of the soda into a clear container so students can see the bubbles. Ask students where the gas was before you opened the beverage.

> Students should suggest that the gas was dissolved in the liquid.

Remind students that gases, as well as solids, can dissolve in a liquid. Explain that this is the case with acid rain.

Direct the students to “Thinking About the Question.”

After students have had the opportunity to formulate their lists of ten buildings or structures, have each group share with the class. Make a list on the board of some of the most commonly mentioned structures, as well as the materials from which they are constructed.

Tell students that some of the gases present in the atmosphere become dissolved in rain drops that pass through the air on their way to the ground. If enough gases and solid particles of pollutants become absorbed by the rain, its pH can be lowered to the point that it becomes acidic.

Explain to students that they will be using simulated acid rain for this activity, composed of distilled water with carbon dioxide gas dissolved in it. Tell students that the role of the bromothymol blue is to indicate the changing pH of the water, showing that it becomes more acidic.

Demonstrate to students how to fill a balloon with baking soda and place it over the mouth of a 500 mL plastic bottle. Demonstrate how to tip the baking soda into the bottle to allow mixing of the reactants. It may also be helpful to demonstrate to students how to "capture" the gas produced in the balloon by the reaction and direct it through the straw into a beaker of water.

Ask students to recall the indicators of chemical change or reaction.

> Indications that a chemical reaction has take place include the giving off or absorbing of energy in the form of heat (a change in temperature can be observed), a change in color, and the formation of a gas or a precipitate.

Direct the students to “Investigating the Question”.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Bromothymol blue indicator solution (0.04% aqueous) can be purchased from scientific supply houses.

If you are unable to obtain bromothymol blue indicator solution, a suitable alternative is red cabbage juice pH indicator. The directions for its preparation can be found in the Preparation and Tips section of the suggested prerequisite lab *pH Factor* located in this manual.

- Calibrate the pH sensors �(3.6) for students ahead of time, unless the students know how to do this and time permits them to calibrate the sensors.

Safety

Add these important safety precautions to your normal laboratory procedures:

- Wear aprons to protect clothes.
- Wear safety goggles.
- Handle all equipment with care and ensure computers and/or data collection systems are protected from liquids.

Driving Question

What effect can acid rain have on architectural materials?

Thinking about the Question

Working together with the members of your group, make a list of ten buildings or structures around the world that are well-known, famous, or important. For each building or structure also list the material from which it is made, if you know. If you do not know, leave that part of your list blank. Be prepared to share your list with the rest of the class.

Answers will vary. One student group answered as follows: 1) The Statue of Liberty, metal; 2) the Eiffel Tower, metal; 3) the Parthenon, marble; 4) the Pyramids, limestone; 5) Stonehenge, basalt or granite rock; 6) the Taj Mahal, marble; 7) the Golden Gate Bridge, metal; 8) the Pentagon, limestone; 9) Notre Dame Cathedral, limestone; 10) the Roman Coliseum, travertine, brick, and marble.

Structures made of stone, brick, concrete, and metal can be affected by acid rain. Are any of the buildings or structures in your list made of these materials?

Students should suggest that most of the structures they listed are made of one or more of these materials.

As you know, an acid is a substance that has a pH factor lower than 7.0. The pH scale goes from 0 to 14, with those substances whose pH factors are below 7 classified as acids, and those whose pH factors are above 7 are bases, or alkalis. You know the 7 on the pH scale represents neutral.

In this activity, you will be using your knowledge of acids, bases, and the pH scale to help you investigate the effects of acid rain on the materials used to construct buildings and other structures.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

5	1	4	2	3
Place several drops of the simulated acid rain onto each sample of material.	Make certain that each member of your lab group is aware of the safety rules and procedures for this activity.	Use a straw to bubble carbon dioxide gas into water, so the gas dissolves in the water, creating simulated acid rain.	Test the pH of the simulated acid rain (the solution of water and carbon dioxide).	React baking soda with vinegar to produce carbon dioxide gas.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Write your prediction for the following:

   a. What will happen to the pH of a beaker of distilled water when carbon dioxide is added to it?

   Answers will vary. The pH of the water will decrease as it becomes more acidic.

2. ☐ Complete Table 1 by predicting how acid rain will react with the listed materials.

Table 1: Predicted acid rain reactions

	Chalk	Iron (nail)	Limestone	Marble
Predicted Reaction	Will react by bubbling the most	Will react by bubbling	Will react by bubbling somewhat	Will react by bubbling somewhat

Part 2 – Creating simulated acid rain

3. ☐ Pour 50 mL of vinegar into a 500-mL soda bottle.

4. ☐ Pour about 40 mL of water into each 150-mL beaker

5. ☐ Add a few drops (it may need as much as half a pipet) of the bromothymol blue indicator solution to the water in the beakers. It should turn the water blue or blue-green.

6. ☐ Start a new experiment on the data collection system. �(1.2)

7. ☐ Connect a pH sensor to the data collection system. �(2.1)

8. ☐ Display pH on the y-axis of a graph with Time on the x-axis. �(7.1.1)

9. ☐ Insert the pH sensor into one of the beakers.

   Note: Remember to remove the storage bottle from the pH sensor tip, and set the bottle aside.

10. ☐ Using the funnel, put one heaping tablespoon of baking soda into the balloon.

11. ☐ Carefully place the end of the balloon over the top of the bottle, taking care to prevent the baking soda from falling in.

12. ☐ Once the balloon is in place, lift it up, allowing the baking soda to fall into the bottle.

13. ☐ The carbon dioxide formed in the reaction between vinegar and baking soda should inflate the balloon.

14. ☐ Pinch or twist the balloon to save the gas, and while holding the gas in the balloon, remove the balloon from the bottle.

15. ☐ Twist the end of balloon around one end of a straw. Then place the other end of the straw in the water in beaker with the previously inserted pH sensor.

16. ☐ Start data recording. �(6.2)

17. ☐ *Slowly* release the pinch or twist that is holding the gas in the balloon, allowing the gas to bubble into the water.

18. ☐ Once the balloon is empty, stop data recording. �(6.2)

19. ☐ Label and print your graph according to your teacher's instructions. �(11.2)

20. ☐ What happened to the color of the indicator?

The indicator changed color from blue to a yellowish-green color.

21. ☐ What is the pH of the water?

Answers will vary, but should be between pH 6 and 7.

22. ☐ How does acid rain change the pH of water?

Acid rain lowers the pH of water.

Part 3 – Investigating the effects of acid rain on materials

23. ☐ Place several drops of the simulated acid rain water on each of the samples of materials. Observe each sample carefully for signs of reaction.

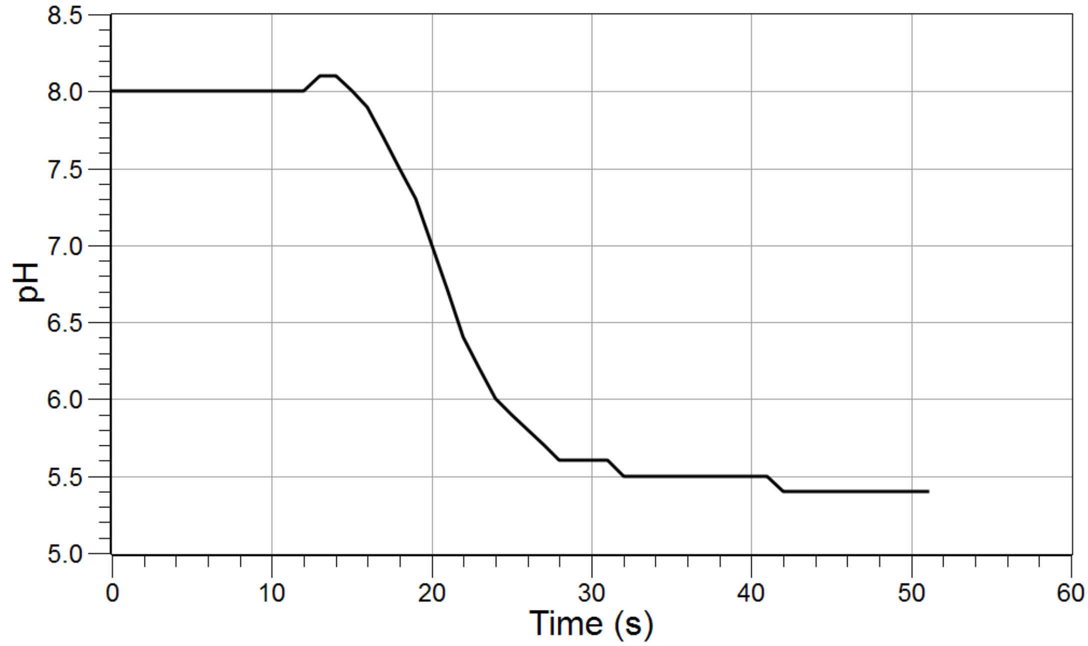
Note: For the nail, you may need to place it in the beaker of simulated acid rain and observe for changes.

24. ☐ Complete Table 2 after testing the reaction of your acid rain solution with each of the listed materials.

Table 2: Acid rain reactions

	Chalk	Iron (nail)	Limestone	Marble
Reaction	Answers will vary. One student group answered as follows: We observed the most bubbles forming, almost immediately	Answers will vary. One student group answered as follows: We observed several bubbles forming after about 5 minutes	Answers will vary. One student group answered as follows: We observed several bubbles forming after about 4 minutes	Answers will vary. One student group answered as follows: We observed several bubbles forming after about 5 minutes

Sample Data



Answering the Question

Analysis

1. How did your predictions from Part 1 compare to the results from Part 2 and 3?

   Answers will vary. One group answered as follows: We predicted that all of the substances would react with the simulated acid rain. When we tested them, they did react. Some took more time than others to form bubbles.

2. What factors do you think contributed to your findings?

   Answers will very. One group answered as follows: We think that some of the substances reacted more slowly because they were denser or less porous than the other materials. For example, chalk reacted by forming bubbles before we could see bubbles on any other material, possibly because chalk is porous, meaning that air or water can get into tiny spaces between its particles. We think the nail and the marble took longer to form bubbles because these materials are denser and harder.

3. What signs did you observe that indicated that a chemical change was taking place when you tested the acid rain and the material samples?

   Students should have observed bubbling, foaming, or fizzing in the drops of simulated acid rain water.

4. What relationship is there between acid rain levels and changes to certain rocks?

   Answers will vary. One group answered as follows: The more acidic the rain is the more damage it is likely to do to certain types of porous rocks that react with acid, such as marble and limestone.

5. Suppose you are visiting a cathedral that was built of limestone blocks several hundred years ago. In walking around and looking at the carvings depicting people and animals, you notice that the finer details such as the facial features of people have become worn and unrecognizable. As you listen to the guide giving the tour, you learn that acid rain is a problem in the area, due to pollution sources upwind. Is it possible that acid rain could be responsible for the damage to the carved stone faces? Explain your thinking.

Answers will vary. One group answered as follows: We think acid rain could be responsible for the damage done to the faces of the animals and people carved on the cathedral. In this lab activity we saw that acid rain reacts with limestone by bubbling and forming a gas, which is one of the indicators of a chemical change. Since there was a chemical change that we observed, some of the material was changed into a new substance. This same thing could happen to any part of the limestone cathedral that is exposed to the weather and gets rain falling on it.

6. Weathering refers to any process that decomposes rocks and turns them into loose particles such as gravel, sand, clay or soil. Explain how acid rain could be considered a weathering process.

Answers will vary. One group answered as follows: Since acid rain decomposes the kinds of sedimentary and metamorphic rocks we tested (limestone and marble) by causing a chemical reaction, some original bits of these rocks became small particles which we observed crumbling away.

True or False

Enter a "T" if the statement is true or an "F" if it is false.

F 1. Substances whose pH factors are above 7 are classified as acids.

T 2. Soil consists of weathered rocks and decomposed organic materials.

T 3. Acid rain can be the result of human-caused pollution.

F 4. Acids have no effect on such materials as limestone and chalk.

F 5. Sedimentary rocks are never damaged by acid rain.

T 6. Some structures made of marble have become damaged by acid rain's effects.

T 7. As water passes through the water cycle, it dissolves minerals and gases.

T 8. One substance that can lower the pH of water, when dissolved in it, is carbon dioxide.

Key Term Challenge

Fill in the blanks from the randomly ordered words below:

a chemical reaction	product	pH	weathering
sedimentary	gas	acid	water

1. The process by which rocks are broken down to form smaller particles such as gravel, sand, and clay is called ____weathering______.

2. Vinegar and sodium bicarbonate (baking soda) undergo ____a chemical reaction______to form a/an________gas_________.

3. When rain absorbs gaseous pollutants in the atmosphere the _______pH______of the rain is lowered, resulting in________acid______rain.

4. Buildings constructed of limestone or other ____sedimentary______rocks, as well as certain metamorphic rocks such as marble, can be damaged by the weathering that occurs with acid rain.

5. Because of its ability to dissolve so many substances, including solids and gases, ____water__ is able to carry minerals as well as pollutants as it moves throughout the earth's surface.

6. Carbon dioxide, the ____product_______of a chemical reaction, produces an acid when dissolved in water.

Further Investigations

Do research to find out of there is such a thing as acid fog.

Prepare a presentation for your class on structures that have been damaged by acid rain. Is there anything that can be done to preserve such structures, or even reverse the effects?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

2. Exploring Environmental Temperatures

Under a Rock, Up a Tree

Objectives

In this activity, students explore temperatures variations in multiple locations in their environment. Students collect data using the temperature sensor and organize and compare their information in simple tables. Students will then be able to identify relationships the temperature patterns reveal.

Students investigate areas and objects at different temperatures related to their surroundings while they:

- Recognize that heat can be transferred through a substance
- Recognize that the sun is the major source of energy for phenomena, such as weather, climate, and the food web, on the earth's surface
- Gain skills and confidence in using scientific measurement tools, the temperature sensor, as well as the graphing capability of a computer to represent and analyze data
- Design and conduct a scientific investigation

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment to measure environmental temperatures
- Selecting locations to measure temperatures
- Measuring the temperatures at ten pre-determined locations

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Selecting the locations and Part 2 – Making predictions	50 minutes
■ Parts 3 – Taking temperature measurements	50 minutes
■ Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Thermometer that measures temperature in degrees Celsius
- ☐ Temperature sensor
- ☐ Cup of cold water
- ☐ Cup of warm water

For each student or group:

- ☐ Mobile data collection system
- ☐ Temperature sensor

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- How to read and interpret a coordinate graph
- SI units of measure for temperature (degrees Celsius)
- The basics of using the data collection system

Related Labs in This Guide

Labs conceptually related to this one include:

- Night and Day
- Seasons
- Water's Role in Climate

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Monitoring live data �(6.1)
- Displaying data in a digits display �(7.3.1)

Background

Have you ever considered why jackets keep you warm? Have you ever wondered if there is a temperature difference under a rock? Just as students often think that a coat provides the warmth when they go outside in the cold, many will believe that it will be cooler above small rocks than below them. In reality, the coat provides a buffer between the heat given off by your body and the temperature outside. The temperature variance that the students discover above and below small rocks will depend on the temperature of the air and the ground that the rocks are on.

An area gets hotter when it is heated by the sun, and cools by dispersing the heat over the land and up into the atmosphere. The coldest time of the day is usually just before sunrise, after the earth has been losing heat at night. The earth largely heats our atmosphere from below. The energy from the sun is first absorbed by water, rocks, and soil and changed into heat. These warmed substances then heat the layer of air closest to the surface.

Knowing the difference between heat and temperature is important in order to have a clear understanding of energy. Temperature is a number that is related to the average kinetic energy of the molecules of a substance. Heat is a form of energy transfer, and can be thought of as the internal energy of a substance. The internal energy of an object may be increased by transferring energy from an object at a higher temperature (a hotter object) – this is referred to as heating.

Pre-Lab Discussion and Activity

Display the local newspaper's weather page or find another source of weather maps to display in the classroom for students to see. Call attention to the lines of equal temperature, called isotherms, which are shown on weather maps and reports. Discuss the isotherms they see on the weather maps as regions of areas with different temperatures. Challenge them to think about conditions that could cause the difference in temperatures. It might be useful to have the groups make a list of these factors. After a few minutes, ask student groups to share some of their ideas. Weather conditions are related to storm systems, the jet stream, time of the year, location on the earth, ocean currents, et cetera.

If students have not used a temperature sensor before, briefly demonstrate how it works in cups of cold and warm water using both the temperature sensor and a thermometer. Explain that the sensor will permit them to note small temperature variations (to 0.10 degrees Celsius). Ask the class how accurate the thermometer is compared to the sensor. Point out that the temperature sensor will also permit them to record and view data for analysis after their investigations.

Direct students to “Thinking About the Question.”

After a few minutes, ask students to share with the class those areas in the environment they suspect have different temperatures.

Direct students to “Investigating the Question.”

Encourage them to think about locations that can be paired with another for comparison. For example, students may suggest taking temperature readings on the floor and ceiling of a room or side of a building and on the roof, or on opposite sides of a building.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- The stainless steel temperature sensor registers temperatures relatively rapidly, but differently in water and air. Due to the mass of the stainless steel rod, students will need to wait 15 seconds for stable readings in a liquid. Students will need to wait 30 to 60 seconds for stable readings in air.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Care should be taken to not disturb the environment.

Driving Question

Does the temperature vary at different places in my local environment?

Thinking about the Question

Is the temperature in an attic the same as in a basement? What is the difference between the temperature in the shade versus that in direct sunlight? How does the surface temperature of the ground differ from areas below the surface? How different are the temperatures next to a window and next to a heating duct? Is the temperature warmer above or underneath a rock?

As various environmental conditions change in your surroundings, the temperature measured by your sensor changes. Humidity, pressure, airflow, and time of day are just a few of the factors that can alter your readings.

Discuss with the group members areas in your local environment that vary in temperature.

> Answers will vary. Students should suggest that shaded areas are cooler than sunny areas; higher areas in a room or building are warmer than lower areas in the same room or building; the undersides of rocks, logs, or leaf piles are warmer than those areas that are exposed to air on a cold day, but on a hot day the opposite will be true – the undersides will be cooler than the surrounding air. Students may also suggest that dark colored surfaces will be warmer than light colored surfaces on a sunny day.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	4	3
Decide on some locations in the room, the building, or outdoors to investigate.	Make sure each lab group member is aware of safety rules and procedures for this lab.	Collect temperature data from the different locations on your list.	In your lab notebook or worksheet, name and describe the locations you will test.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Selecting the locations

1. ☐ Choose at least ten sites to investigate that will provide you with different temperature readings as a result of changing conditions or factors in the surrounding environment. These sites could include various parts of rooms and buildings, open and wooded areas, and locations around buildings. List them in Table 1.

Table 1: Locations

Locations	
1. Under tree	6. Under a fence
2. On sidewalk	7. Next to a car
3. Next to building (North side)	8. On the roof
4. On parking lot	9. Next to building (South side)
5. Resting on window sill	10. On playground

2. ☐ Write your observations and descriptions for each location in Table 2. Include the following in your description if you feel they will affect the temperature reading:

Is the site in full sunlight?

How protected is the location by surrounding objects, trees, or buildings?

What is the material covering the site?

Does the location have a certain color?

What were the local weather conditions?

Table 2: Locations with observations and descriptions

Locations	Observations and descriptions
1. Under tree	Shady, no direct sunlight
2. On sidewalk	White, hard surface, next to building
3. Next to building (North side)	Early morning, shaded from the sun due to building, in green grass
4. On parking lot	Black surface in full sun
5. Resting on window sill	Window in full sunlight
6. Under the fence	Shaded area
7. Next to a car	In full sun on a black surface
8. On the roof	Black asphalt roof that is flat
9. Next to building (South side)	Full sunlight in green grass
10. On playground	Full sunlight on black surface

Part 2 – Making predictions

3. ☐ Predict the temperatures of each selected location. Record your predictions in Table 3.

Table 3: Predicted temperatures for each location

Locations	Predicted temperature (°C)
1. Under tree	20
2. On sidewalk	40
3. Next to building (North side)	25
4. On parking lot	50
5. Resting on window sill	30
6. Under the fence	20
7. Next to a car	50
8. On the roof	50
9. Next to building (South side)	40
10. On playground	50

4. ☐ Explain your predictions in Table 4.

Table 4: Predicted temperatures with explanations for each location

Locations	Predicted temperature (˚C)	Explanations
1. Under tree	20	No direct sunlight
2. On sidewalk	40	White surface reflects
3. Next to building (North side)	25	Shaded by building
4. On parking lot	50	Full sun and black absorbs
5. Resting on window sill	30	White sill but in sun
6. Under the fence	20	Shaded
7. Next to a car	50	Full sun on absorbing black surface
8. On the roof	50	No shade and absorbing black surface
9. Next to building (South side)	40	Full sun with green not black surface
10. On playground	50	Black absorbing surface

Part 3 – Taking temperature measurements

5. ☐ Start a new experiment on the data collection system. �(1.2)

6. ☐ Connect a temperature sensor to the data collection system. �(2.1)

7. ☐ Display Temperature in a digits display. �(7.3.1)

8. ☐ Go to your first location and monitor data without recording. �(6.1) After the temperature reading stabilizes, record the temperature in Table 5.

9. ☐ Repeat the previous step, recording the temperature reading taken at each site in Table 5.

Table 5: Temperature readings for each location

Locations	Predicted temperature (°C)	Temperature reading (°C)
1. Under tree	20	14.2
2. On sidewalk	40	21.3
3. Next to building (North side)	25	15.2
4. On parking lot	50	22.1
5. Resting on window sill	30	15.3
6. Under the fence	20	10.1
7. Next to a car	50	22.0
8. On the roof	50	22.5
9. Next to building (South side)	40	16.2
10. On playground	50	21.9

10. ☐ Discuss with your lab partners how temperatures vary from location to location. List any patterns or findings below.

    If the location is in direct sun, it will be hotter than if it is in the shade. If the surface of the location is darker in color, it will absorb more energy than if it is lighter in color. Since it was a sunny day, all of the temperatures were higher than if it had been overcast.

Answering the Question

Analysis

1. How did your temperature predictions compare to the actual temperatures? If there were differences, explain why you think they occurred.

   Answers will vary. The temperature may be lower than expected by the students. In the United States, Celsius is not the temperature scale that weather reporters mention daily. Students may have mistakenly recorded their predictions in degrees Fahrenheit. It can be a great teaching moment to discuss the different temperature scales with students at this point.

2. How does the amount of sunlight affect the temperature of a location?

   The more the sunlight, the hotter the surface is according to the sensor. The sunlight provides more energy to the surfaces.

3. How does the amount of protection from surrounding objects, buildings, or trees affect the temperature of the location?

   Buildings, trees, and cars will shade some of the locations from direct sunlight. When this happens, the temperature is lower. Some of the locations may experience wind currents and will register a lower temperature.

4. How does the type of material covering the location affect the temperature?

   Flat, hard surfaces like the parking lot may register a higher temperature. Uneven surfaces that have little ripples or bumps may cause the light to be deflected and less energy to be absorbed, resulting in a lower temperature being recorded.

5. How does the color of the location affect the temperature?

   Darker colors absorb more energy from the sun. Lighter surfaces reflect energy and will register a lower temperature.

6. How did local weather conditions affect the temperature of each location?

   Answers will vary. Students should find that if it is a bright, still day, the temperatures will be higher. On a windy day, the temperatures will be lower. If it is overcast, lower temperatures will also be obtained. Depending upon the time of the year, students should discuss differences in atmospheric temperature and those of the surfaces.

7. Discuss with your lab partners how temperatures vary from location to location. List any patterns or findings below. Be prepared to share your findings with the class.

   Locations with similar colors and exposure to sunlight should register about the same temperature. Students should be able to relate how weather conditions (overcast versus sunny) will also impact the temperatures recorded.

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___ 1. Temperatures in the environment depend on many factors, including exposure to the sun.

___T___ 2. The area underneath a rock can be warmer than the area near the rock, on a very cold day.

___T___ 3. Generally, the upper part of a room is warmer than down at the floor.

___F___ 4. On a hot, sunny day, a dark colored object will absorb less energy from the sun than a light colored object.

___T___ 5. The coolest time of the day is just before dawn.

___F___ 6. On a very hot day, the outdoor temperatures at different locations around the outside of a building will all be the same.

Key Term Challenge

Fill in the blanks from the randomly ordered words below:

energy	sun	light	wind
dark	temperature	surface	degrees Celsius

1. The ___sun is___ the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle.

2. In the SI system, temperature is measured in ___degrees Celsius___.

3. Surfaces that are ___dark___ in color tend to absorb more energy from the sun than surfaces that are ___light___ in color.

4. ___Temperature___ is a measure of the average kinetic energy of the particles that make up a substance.

5. Light and heat are both a form of ___energy___ provided by the sun.

6. Any ___surface___ protected from frost or sunlight will not register the same temperature as a nearby exposed area.

7. Whether or not an area is sheltered from ___wind___ is a factor affecting its temperature.

Further Investigations

Use a GPS sensor and Geographic Information Systems (GIS) software to map your location outside your school building. Record environmental changes in temperature for each location on your map. Record the changes throughout the day and night or during different seasons of the year.

Design a method to protect outside locations and lower the environmental temperature at each site. Consider changing the color of the asphalt, adding tenting, changing the surface material, et cetera. Record the temperatures at each outside location after your plan is in place.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

3. Investigating Evaporation and Condensation

Water Cycle

Objectives

In this activity, students use a relative humidity sensor to gain an understanding of the water cycle. Students measure water content in air to develop an understanding of evaporation.

Students investigate and observe how relative humidity changes over cold water, warm water, and ice while:

- Understanding that water covers the majority of the earth's surface and investigating where most of the water on earth can be found
- Understanding that water circulates around the earth in what is known as the "water cycle"
- Investigating evaporation and condensation qualitatively and quantitatively
- Gaining skills and confidence in using scientific measurement tools, the relative humidity sensor, as well as the graphing capability of a computer to represent and analyze data

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	30 minutes
■ Lab activity, Part 2 – Evaporation above cold water	25 minutes
■ Lab activity, Part 3 – Evaporation above warm water and Part 4 – Evaporation above ice	25 minutes
■ Analysis	30 minutes

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ Relative humidity sensor[1]
- ☐ Sensor extension cable
- ☐ Beaker, glass, 400 mL
- ☐ Hand lens or magnifying glass
- ☐ Aluminum foil, 10 cm x 10 cm
- ☐ Water, cold
- ☐ Water, warm
- ☐ Cup, paper or plastic, filed with ice
- ☐ Tape
- ☐ Paper towel

[1]This is included as a part of the weather anemometer multi-measure sensor.

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Water covers the majority of the earth's surface. About 70 percent of the planet is covered in ocean water. About 2 percent of the earth's water is fresh, with around 1.6 percent of the water locked up in polar caps and glaciers.
- Water is in a constant cycle and circulates through the crust, oceans, and atmosphere in what is known as the "water cycle."
- Relative humidity is the ratio of the amount of water in the air at a given temperature to the maximum amount it can hold at that temperature, expressed as a percentage.
- Basics of using the data collection system.

Related Labs in This Guide

Labs conceptually related to this one include:

- Monitoring Weather
- Observing Clouds
- Water's Role in Climate
- Water – the Universal Solvent
- Acid Rain and Weathering

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

Starting a new experiment on the data collection system �(1.2)

Connecting a sensor to the data collection system �(2.1)

Recording a run of data �(6.2)

Displaying data in a graph �(7.1.1)

Adjusting the scale of a graph �(7.1.2)

Displaying multiple data runs on a graph �(7.1.3)

Saving your experiment �(11.1)

Background

In this activity, students examine where all the water on earth is located. To make these numbers less abstract for the various categories (oceans, rivers, biological water, and water held in the air), fill a 2-liter bottle with water. If all the water in the world were scaled down to fit in a 2-liter bottle, how much of the bottle would be ocean water, and how much would be fresh water in various forms? Some rough answers to these questions are listed below.

	% of water	**liters**	**drops**
Oceans, seas, and bays	98.5	1.83	38,800
Ice caps, glaciers, and permanent snow	1.74	0.0348	696
Groundwater	1.7	0.034	680
Ground ice and permafrost	0.022	0.00044	8.8
Lakes	0.013	0.00026	5.2
Soil moisture	0.001	0.00002	0.4
Atmosphere	0.001	0.00002	0.4
Swamp water	0.0008	0.000016	0.32
Rivers	0.0002	0.000004	0.08
Biological water	0.0001	0.000002	0.04
Total	99.9781	1.999562	

The vast majority, 1.93 liters, is salt water in oceans, seas and bays. But when it comes to water held in the air, the volume is less than half a drop. All the rivers in the world contain less than 1/10 of a drop. Interestingly, the amount of water held in the air is nearly negligible when compared with the total amount of water on earth. Yet this small amount of water plays a vitally important role in the water cycle. Without evaporation and condensation, the water cycle would not exist.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Importance of Water

Students may have an intuitive grasp of some of the visible aspects of the water cycle – ice melting, rivers flowing, clouds forming, rain falling, and so on. This activity is focused on the invisible (or less visible) aspects of the water cycle – evaporation and condensation. Before investigating the water cycle, begin with a general discussion of the importance of water. In what ways does water help support life on earth?

> Students should suggest that water is necessary for all living things to carry on life processes, such as photosynthesis, transpiration, nutrition, and maintaining cellular functions. In addition, a great many organisms live in water throughout part or all of their life cycle.

The Water Cycle

Discuss with students how the water cycle is like a marvelous circulatory system for earth, moving water around the planet. In the human circulatory system, the heart pumps blood. Ask students if the water cycle has a similar pump. If not, what is the mechanism?

> The mechanism for water's movement through the earth is the water cycle: evaporation, condensation, and precipitation.

Ask the students how water moves around the planet. This general discussion will help set the stage for the importance of understanding what is actually happening during evaporation and condensation.

> Answers will vary. Students may suggest that liquid water moves around the planet by falling as rain or by flowing downhill until it reaches a body of water, while solid water moves around the planet by falling as snow, sleet, or hail, or as glaciers or ice caps that melt and join with liquid water. Water in the vapor form moves around as clouds, air, and fog.

Direct students to "Thinking About the Question." Have students share with the class where all the water on earth is located.

Using the Relative Humidity Sensor

Before directing students to "Investigating the Question", discuss why it is important to position the relative humidity sensor in the air directly above an evaporating surface. It is important to have the "sensitive" part of the relative humidity sensor exposed to the evaporating surface (about 1 cm away from the surface).

In this activity, the relative humidity sensor is used to help visualize the process of water moving from liquid to vapor and back which is otherwise difficult to see since water vapor is not visible. After collecting data above cold water, warm water, and ice, follow-up by asking students what is happening during evaporation and what is happening during condensation. Ask students how using a relative humidity sensor helped to answer this question.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- To successfully measure the relative humidity in the air directly above an evaporating surface, it is important to have the "sensitive" part of the relative humidity sensor exposed to the evaporating surface (about 1 cm away from the surface).

- The relative humidity sensor cannot be held by hand because the sensor has to be perfectly steady. Even slight variations in distance will produce differences in the measured relative humidity that will make interpreting the data difficult.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Warm water should not exceed 40 degrees Celsius. Severe burns may result.

Driving Question

Where on the earth is our water found?

Thinking about the Question

Talk with your lab group members and generate a list of places where water is found (for example, in a lake, stream, clouds, et cetera.) Write your list below.

> Water can be found in oceans, lakes, rivers, streams, puddles, ice caps, snow, rain, underground springs, clouds, and in the air as vapor.

In your list, what places have water in the form of a liquid, solid (ice or snow), or a vapor? Sort your list above into the following categories.

Liquid:

> Oceans, lakes, rivers, streams, puddles, rain, and underwater springs are examples of water in liquid form.

Solid (ice):

> Ice, snow, glaciers, and icebergs are examples of water in solid form.

Gas (vapor):

> Air, clouds, and fog are examples of water in a gaseous form.

Water moves around the earth in what is known as the water cycle. You have listed where the water is on earth. What do you know about how it moves around? Be prepared to share your understanding with the class.

> Answers will vary. In general, the motion of liquid water is the most easily understood aspect of the water cycle. Solid forms of water melting and joining liquid water are also generally understood. The most difficult aspects of the water cycle for students to understand are the transitions when water turns to a gaseous form (evaporation) or when water leaves a gas and becomes a liquid (condensation).

You have looked at where water can be found on the earth and how much is in various areas. How do you think water moves from place to place? Where does water go? Get together with your group members and describe this aspect of the water cycle. Include in your description your understanding of how water naturally goes upward. Be prepared to discuss your thoughts with the class.

Answers will vary. Water naturally flows downward via streams and rivers to lakes, oceans and to underground water tables. During this process, water is constantly evaporating back up into the atmosphere. Most evaporation occurs from the water in the world's oceans. Water is also used by living creatures, and in the case of plants and trees, water is transpired upward into the atmosphere (transpiration is evaporation of water from plants).

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

5	1	2	3	4
Record relative humidity data over the beaker of water.	Make sure each lab group member is aware of safety rules and procedures for this lab.	Fill a beaker to just below the brim with tap water.	Connect a relative humidity sensor to a sensor extension cable and then to the data collection system.	Position and secure the relative humidity sensor over a beaker of water, using tape to secure the sensor and cable.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Write your predictions for the following:

   a. Will the relative humidity be higher above a dry surface or one from which water is evaporating? Explain your reasoning.

Answers will vary. The relative humidity will be higher above the surface that has water evaporating from it.

   b. How will the relative humidity above cold water compare to the relative humidity above warm water?

Answers will vary. The relative humidity above cold water will be lower than that above warm water.

c. Will the relative humidity above ice be higher or lower compared to the relative humidity above cold or warm water?

Answers will vary. The relative humidity above ice will be lower than above either temperature of water.

Part 2 – Evaporation above cold water

2. ☐ Obtain a piece of smooth aluminum foil and enough cold water to dampen a paper towel.

3. ☐ Dampen the paper towel. Wipe the aluminum foil with the damp paper towel and observe it for a few minutes. It may be helpful to view it with a magnifying glass.

4. ☐ Try watching the smallest drop of water you can find on the foil. What happens to the water on the surface of the aluminum foil? Where do you think the water is going? Be prepared to discuss your thoughts with the class.

As time passes, the water disappears. We think it goes into the air.

5. ☐ Start a new experiment on the data collection system. �(1.2)

6. ☐ Use the sensor extension cable to connect the relative humidity sensor to the data collection system. �(2.1)

7. ☐ Display Relative Humidity on the y-axis of a graph with Time on the x-axis. �(7.1.1)

8. ☐ Place the relative humidity sensor face down on top of an empty 400-mL beaker. Use tape to secure the relative humidity sensor on the rim of the beaker so the sensor openings that contain the sensing elements are directly over the inside of the beaker. Make sure the sensor is oriented "face down," so that the lettering is facing the bottom of the beaker.

9. ☐ Change the sample rate to take one measurement each second. �(5.1)

10. ☐ Begin data recording. �(6.2)

11. ☐ Continue data recording for 2 minutes. Stop data recording �(6.2) and remove the sensor from the beaker.

12. ☐ Fill the 400-mL beaker nearly to the rim with cold tap water.

13. ☐ Use tape to secure the relative humidity sensor on the rim of the beaker so the sensor openings that contain the sensing elements are directly above the water. Make sure the sensor is oriented "face down," so that the lettering is facing the water.

14. ☐ Begin data recording. �(6.2) This will be your second run of data.

15. ☐ Continue data recording for 2 minutes. Stop data recording �(6.2) and remove the sensor from the beaker.

Part 3 – Evaporation above warm water

16. ☐ Empty the beaker and then fill it nearly to the rim with warm tap water.

17. ☐ Secure the relative humidity sensor on the rim of the beaker with tape as before.

18. ☐ Begin data recording. �(6.2) This is the third run of data.

19. ☐ Continue data recording for 2 minutes. Stop data recording �(6.2) and remove the sensor. Note any observations below.

We observed that the relative humidity was higher over the warm water than it was over the cold water.

Part 4 – Evaporation above ice

20. ☐ Empty the beaker and then fill it nearly to the rim with ice.

21. ☐ Secure the relative humidity sensor on the rim of the beaker with tape as before.

22. ☐ Begin data recording. �(6.2) This is the fourth run of data.

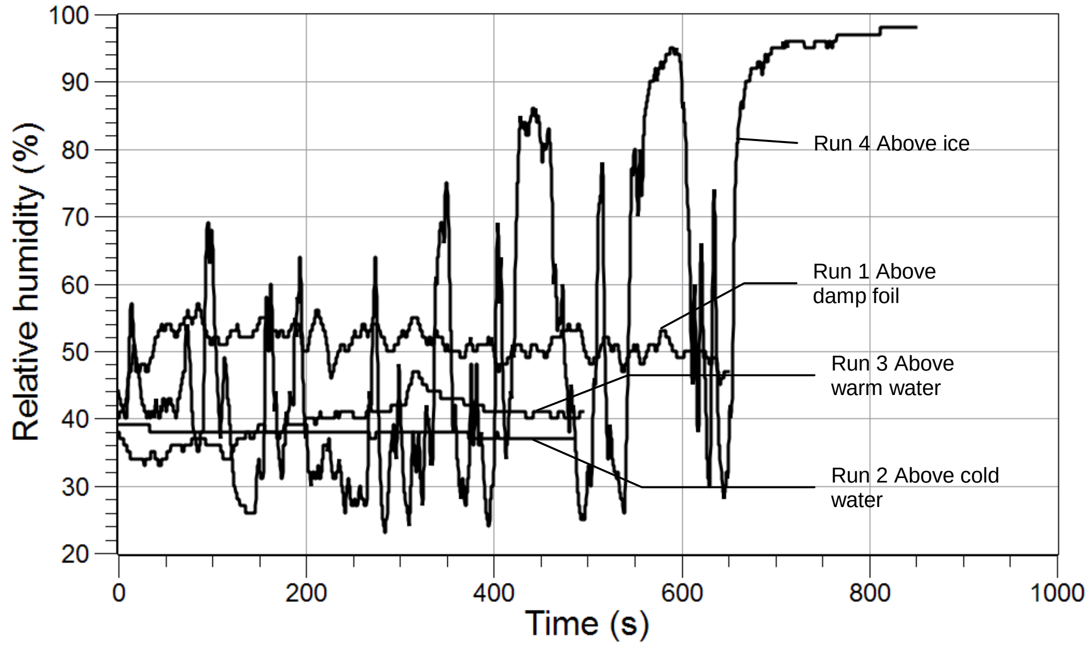
23. ☐ Continue data recording for 2 minutes. Stop data recording. �(6.2)

24. ☐ Remove the relative humidity sensor from the beaker and set it aside.

25. ☐ Observe the sides of the beaker. (You may want to use the hand lens for this observation.) Do you see any droplets forming on the glass? Note any observations below.

We observe that there are tiny droplets of water beginning to form on the sides of the glass beaker.

Sample Data



Answering the Question

Analysis

1. How did your predictions in Part 1 compare to the results from Part 2?

We predicted that the relative humidity would be higher over water than over a dry surface. This is what happened in our experiment.

2. Look back over your data. You may need to adjust the scale of the graph �(7.1.2) or look at different runs of data. �(7.1.3) Your graphs show the relative humidity for the air over the cool water, over warm water, over ice, and for the normal air. What do you notice about the relative humidity readings?

   We noticed that the relative humidity is lower over the cool water and higher over the warm water, but that the relative humidity is lower over the ice than even over the cool water. We did not predict this.

3. Based on what you have observed qualitatively and quantitatively in this activity, would you expect the amount of water held in the air to be greater near the equator where the ocean is warmer, or near the Arctic Circle where the ocean is cooler? Why do you think this? Explain your reasoning.

   We expect the air to hold more water near the equator than near the Arctic Circle because the warmer ocean water allows more evaporation to occur than does the cooler water or the ice.

4. Where do you think the water droplets on the beaker of ice are coming from?

   Answers will vary. One student group answered as follows: We think the water droplets are coming from the air. The water is in vapor form in the air, but it condenses when it touches something cold, such as a container of ice.

5. What you have just seen—water coming out of the air—is called condensation. Can you think of some examples in nature when condensation occurs?

Some examples of condensation include the moisture that appears when you breathe on a glass or a mirror, dew forming on grass, clouds, and fog.

6. Air can only hold a certain amount of water vapor, and warm air can hold more than cold air. The dew point is the temperature at which the air becomes saturated, or 100% full of water vapor, and the vapor can begin to condense into its liquid form. Based on what you have observed, which type of air would you expect to have a greater relative humidity: The air on a very cold morning where no dew or frost has formed on the grass, or the air on a cool morning where the grass is very damp with dew? Explain why you think this.

Answers will vary. One student group answered as follows: The air would have a higher relative humidity on the day where dew had formed on the grass because the temperature was cool but not cold. This means that the water vapor began condensing at a higher temperature because there was more water vapor in the air.

7. Based on the evidence you have seen in this lab activity, what are the parts of the water cycle that are invisible to our eyes? Describe them briefly and tell why you think this.

Answers will vary. One student group answered as follows: There are some parts of the water cycle we cannot see. For example, we cannot see evaporation happening, we can only see liquid water decreasing in volume. We also cannot see condensation happening, just the liquid water once it has reached a large enough size of droplets.

8. How did using a relative humidity sensor help you to "see" evidence of where water is when it appears invisible to your eyes?

Answers will vary. One student group answered as follows: By using the relative humidity sensor and the data collection system we could make a graph of relative humidity versus time. We could look at several different conditions graphically and compare them. We could tell from our graphs which conditions had the highest and lowest relative humidity. The sensor allowed us to measure the different amounts of water vapor in the air over the container, and we could see the graph showing our measurements.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. Water vapor represents which phase or state of matter?

   A. Liquid
   B. Solid
   C. **Gas**

2. When water boils in a pot on the stove, a misty steam rises above the pot and then disappears into the air. The water has:

   A. Been lost and will not be recovered by any means
   B. **Evaporated and undergone a process of the water cycle**
   C. Become separated into hydrogen and oxygen atoms

3. Which of the following is *not* a part of the water cycle?

   A. Evaporation
   B. **Saturation**
   C. Condensation

4. About how much of the earth's water is immediately available for our use as fresh water?

   A. About 70%
   B. About 3%
   C. **Less than 3%**

5. Which of the following best describes what happens to water that has evaporated from the earth's surface?

   A. Evaporated water is now lost to all future use, and diminishes the supply available to us.
   B. Evaporated water remains locked in the atmosphere until winds carry it over the equator.
   C. **Evaporated water cools as it rises, and then condenses into rain or snow.**

6. What evidence did you observe in this activity that water was evaporating from the beaker of water?

   A. **The relative humidity, or amount of water vapor held in the air, increased near the sensor.**
   B. The outside of the beaker tended to become the same temperature as the water or ice it contained.
   C. Water droplets formed on the outside of the beaker when it contained ice.

7. Suppose you had no access to fresh water, but you did have access to salty ocean water. What parts of the water cycle could you use to produce fresh drinking water from the salt water?

   A. It simply is not possible to obtain fresh drinking water from salty ocean water.
   B. **Boil the salty water to evaporate it, then capture the steam and cool it to condense it back into liquid water that will now contain no salt**
   C. Freeze the salty water to make it solid ice, then chop and crush it into small pieces which can easily be melted again, back into fresh water.

8. Which of the following places contain the earth's fresh water?

   A. **Oceans, lakes, and rivers**
   B. Lakes, rivers, underground rocks
   C. Glaciers, polar ice caps, oceans

9. Which of the following best describes the water cycle?

   A. Glaciers and polar ice caps melt, adding water to the oceans, which in turn provides habitat for many species of living creatures.
   B. Water particles, or molecules, are made of two hydrogen atoms and one oxygen atom, and have the chemical symbol H_2O.
   C. **Water circulates continuously through the earth's crust, oceans, and atmosphere.**

10. What happened to the water that was in the earth's oceans when the dinosaurs were alive?

    A. **That water continues to circulate through the water cycle today, and is still part of earth's water.**
    B. That water disappeared from the earth at about the same time the dinosaurs did.
    C. No one knows what happened to that water, because we were not there to observe it directly.

Further Investigations

Conduct research to find out how the approximately 1% of earth's usable water is distributed among the humans who need it? Does everyone in the world have equal access to drinking water?

Design and test a system to take water from its liquid phase, to its gas phase, and back to its liquid phase again. What parts of the water cycle does this system model? Be sure to check with your teacher to get approval for your design before you test it.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

4. Investigating Seismic Waves

Damping Vibrations

Objectives

In this activity, students measure the amplitude (size), period (time from one wave to the next wave), and the time it takes a vibration to die out for their simulated building (meter stick) using a light sensor. They compare and organize their information in graphs to identify relationships the vibration patterns reveal.

Students investigate and observe how vibrations change over time while:

- Understanding that during an earthquake the earth experiences shock waves (vibrations)
- Realizing that shock waves do not continue forever
- Understanding that energy is transferred in many ways
- Making explanations and predictions from evidence and drawing logical conclusions
- Gaining skills and confidence in using a scientific measurement tool, the light sensor, as well as the spreadsheet and graphing capability of a computer to represent and analyze data

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up materials and equipment to simulate a building undergoing vibrations during an earthquake
- Using the light sensor to measure the amplitude and frequency of vibrations during three simulated earthquakes
- Conducting three trials, varying the mass of the building by adding clumps of clay, and observing and measuring the effect on the vibrations
- Using math skills to analyze the graphical data

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Set up and earthquake simulation	50 minutes
■ Lab activity, Part 2 – Vibrations on light-weighted buildings	25 minutes
■ Lab activity, Part 3 – Vibrations on heavier-weighted buildings	25 minutes
■ Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Sensor extension cable
- ☐ Meter stick
- ☐ Lamp stand with clear, incandescent, 60 to 100 watt light bulb
- ☐ Table (same height as lamp stand)
- ☐ Books (if needed to raise lamp stand to height of table)
- ☐ Tape
- ☐ Clay

For each student or group:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Sensor extension cable
- ☐ Meter stick
- ☐ Lamp stand with clear, incandescent, 60 to 100 watt light bulb
- ☐ Table (same height as lamp stand)
- ☐ Books (if needed to raise lamp stand to height of table
- ☐ Tape
- ☐ Clay

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- The types of seismic waves associated with earthquakes, their relative speeds, and the media through which each type of waves travels
- Vocabulary associated with earthquakes
- Building techniques designed to mitigate earthquake damage, such as base isolation
- The role and function of various seismic monitoring instruments, including the seismograph
- One wavelength is the distance between a one crest and the same point on the next crest of the wave, or one trough and the same point on the next trough of the wave. The amplitude of a wave is the maximum distance from the equilibrium point, or half the distance from a crest to the following trough.

Related Labs in This Guide

Labs conceptually related to this one include:

- Simple Harmonic Motion

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collections system �(2.1)
- Recording a run of data �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)
- Saving your experiment �(11.1)

Background

Scientists use a seismograph, an instrument that detects and records the waves of an earthquake. The seismograph operates on the principle that a pendulum weight will remain still rather than swing back and forth when its supporting structure is shaken violently. In the simplest seismographs, a pen is attached to the weight of the pendulum so that its point barely touches the paper on a recording drum. When the earth moves, the drum moves too, and the stationary pen traces this movement on the paper.

In this "seismic" activity, students should understand that a meter stick lying horizontally and not vertically represents the simulated building. The meter stick will move back and forth (up and down) during a vibration. The light sensor acts as a detector that measures the changing vibrations of the meter stick. As the meter stick moves, the light sensor measures the changing the light intensity between the bulb and the meter stick. As a result, the graph of the changing light intensity measures the motion of the meter stick. The more the meter stick moves, the bigger the earthquake.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Ask students what causes seismic waves to be generated. What types of wave motion cause vibrations in the earth?

> Seismic waves known as body waves and surface waves cause vibrations in the earth. They result from faults in the earth's crust sliding or slipping during what we call earthquakes.

Photographs of San Francisco taken immediately after the Great Earthquake of 1906 show two of the buildings that survived at Third and Market streets. One of the tall buildings was the Mutual Savings Bank; the other was the Call Building. Both are still standing today, though the Call Building was drastically modernized in the 1930s, and is today known as Central Towers. Ask the students why some buildings survive an earthquake while others don't.

Direct students to "Thinking About the Question." Have the students share with the class how proper construction of a building prevents vibrations.

Before directing students to "Investigating the Question", discuss how to determine the amplitude (height) and period (length) of vibration.

Explain to the students that after the first motion of the meter stick, clay will be added to the top of the mounted light sensor to change the mass of their simulated buildings. To properly show a comparison between different masses on their simulated buildings, each clump of clay should be approximately the same mass. In addition, students should be aware that adding clay may cause the meter stick to fall below the center of the bulb. Adding a small book may be needed to align the meter stick again.

Finally, have the students review the graphical data from each vibration with and without the addition of clay. Ask each group to describe and explain why each vibration dampened out over time.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Set up a light sensor and meter stick earthquake simulation apparatus, and position it appropriately from the lamp. Allow students to see this model as they are setting up their own.
- Light sensors work best in this activity when set at the 0 — 26,000 Lux sensitivity level.
- Encourage students to practice plucking, tapping, or striking the meter sticks to cause vertical vibrations that they can repeat consistently.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Do not look directly at the 60 to 100 Watt lamp. Permanent damage to your eyes may result.

Driving Question

Do earthquake vibrations continue forever?

Thinking about the Question

During an earthquake the shaking caused by the motion of the earth damages buildings and other structures. There are two major kinds of shock waves. Body waves that travel within the earth have the highest velocity, the lowest amplitudes, and cause the least amount of damage to human-made structures. Body waves may be compression waves called P-waves, or shear waves called S-waves. P-waves deform the earth's crust in the same way that a spring stretches and compresses. S-waves deform the earth's crust in the same way that an ocean wave "deforms" the smooth, calm surface of the water. Surface waves have the lowest velocity, the highest amplitudes, and cause the most damage.

Have you ever felt an earthquake? Whether an earthquake was small or strong, scientists can record and display the earth's vibrations.

Discuss with your lab group members what types of construction techniques may help to protect buildings from damage caused by an earthquake's vibrations.

During an earthquake the shaking of the earth damages the buildings. There are various factors that affect the amount of damage, including: building design and construction, such as isolating the base of the building from the ground and allowing the building to be somewhat flexible instead of completely rigid; building period (length) of vibration; and type of geologic material the building is mounted on.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	3	4	5	1
Attach a light sensor to a meter stick, using tape, so that the sensor's opening is just at the end of the meter stick, next to the bulb.	Tap the meter stick near the light sensor, to make it vibrate up and down in front of the lamp bulb.	Begin data recording.	Record three runs of light data, one for each of for three different conditions - unweighted, weighted lightly, and more heavily.	Make certain that each lab group member is aware of the safety rules and procedures for this activity.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Set up and earthquake simulation

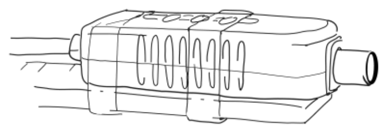
1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect a light sensor to the data collection system using a sensor extension cable. �(2.1)

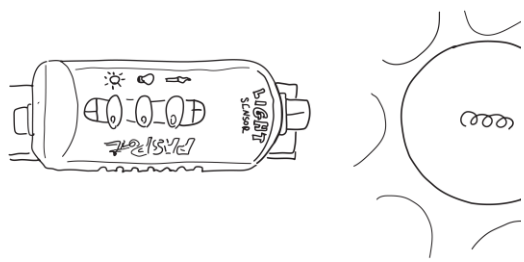
   Note: The light sensor should be set to the 0 – 26,000 Lux sensitivity.

3. ☐ Display Light intensity on the y-axis of a graph with Time on the x-axis. �(7.1.1)

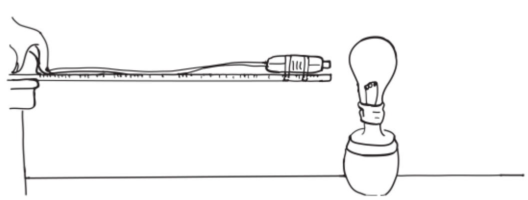
4. ☐ Attach the light sensor securely to the end of the meter stick with tape.



5. ☐ Extend the meter stick over the end of a table with the light sensor directed at the center of the incandescent bulb mounted in the lamp. If necessary, use some books to raise the lamp bulb to the proper height.



6. ☐ Place the meter stick on the table with around 50 centimeters extended toward the lamp. Support the meter stick with your hand. Make sure that all connecting cords to the sensor are free of the meter stick.



7. ☐ Make sure the meter stick is aligned with the center of the bulb. The distance separating the meter stick and the bulb should be around 10-20 centimeters depending on the wattage of the bulb.

8. ☐ Try practicing consistent jolting or tapping the meter stick at the end to produce a vibration on the meter stick to prevent any side-to-side movement.

9. ☐ Start monitoring live data. �(6.1)

10. ☐ Try several "earthquakes" on the same graph. Adjust the placement of the lamp if necessary, since the light sensor will show saturation or a flat line if it is too close. If this occurs, move the lamp further away from the light sensor.

11. ☐ Stop monitoring data. �(6.1)

12. ☐ Start data recording. �(6.2)

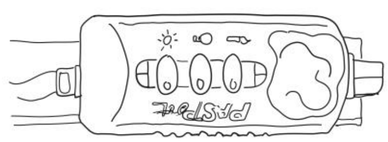
13. ☐ Tap the meter stick to begin an "earthquake." The meter stick should stop vibrating before 30 seconds have elapsed.

14. ☐ Carefully observe the motion of the meter stick.

15. ☐ Stop data recording. �(6.2)

Part 2 –Vibrations on light-weighted buildings

16. ☐ Add a clump of clay to the light sensor mounted on the meter stick. Be careful to avoid pushing the clay down into the buttons or into the opening.



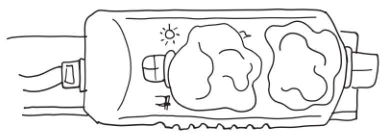
17. ☐ Start data recording on the same graph. �(6.2) The meter stick should stop vibrating before 30 seconds has elapsed.

18. ☐ Carefully observe the motion of the meter stick.

19. ☐ Stop data recording. �(1.2)

Part 3 – Vibrations on heavier-weighted buildings

20. ☐ Add another piece of clay to the top of the light sensor.



21. ☐ Start data recording on the same graph. �(6.2) The meter stick should stop vibrating before 30 seconds has elapsed.

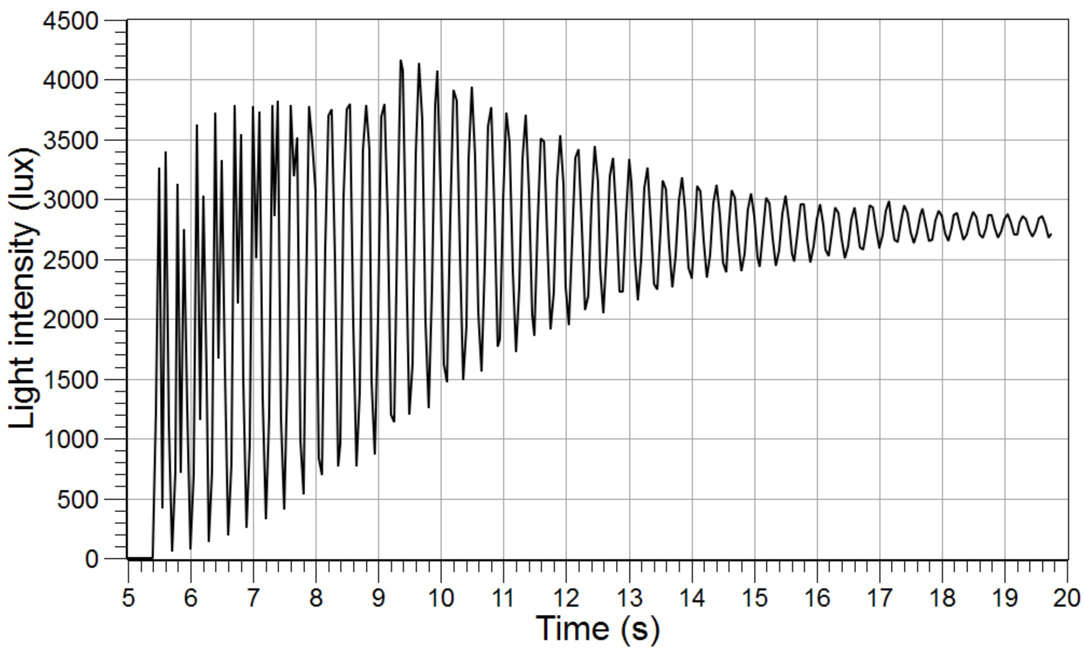
22. ☐ Carefully observe the motion of the meter stick.

23. ☐ Stop data recording. �(6.2)

Sample Data

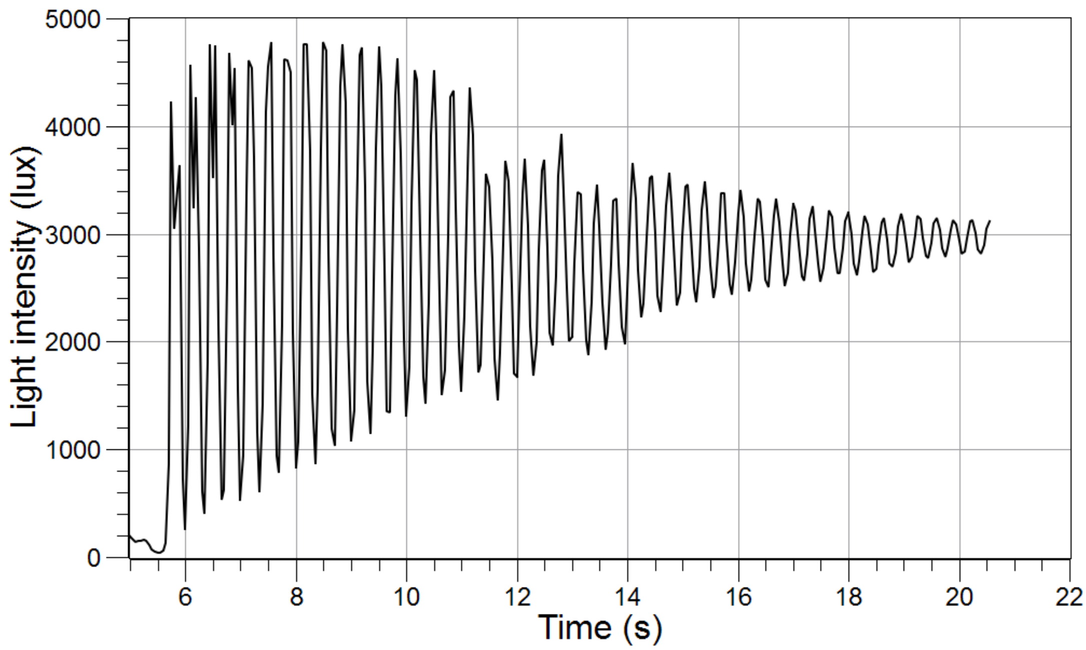
Part 2: Observing vibrations on light weighted buildings

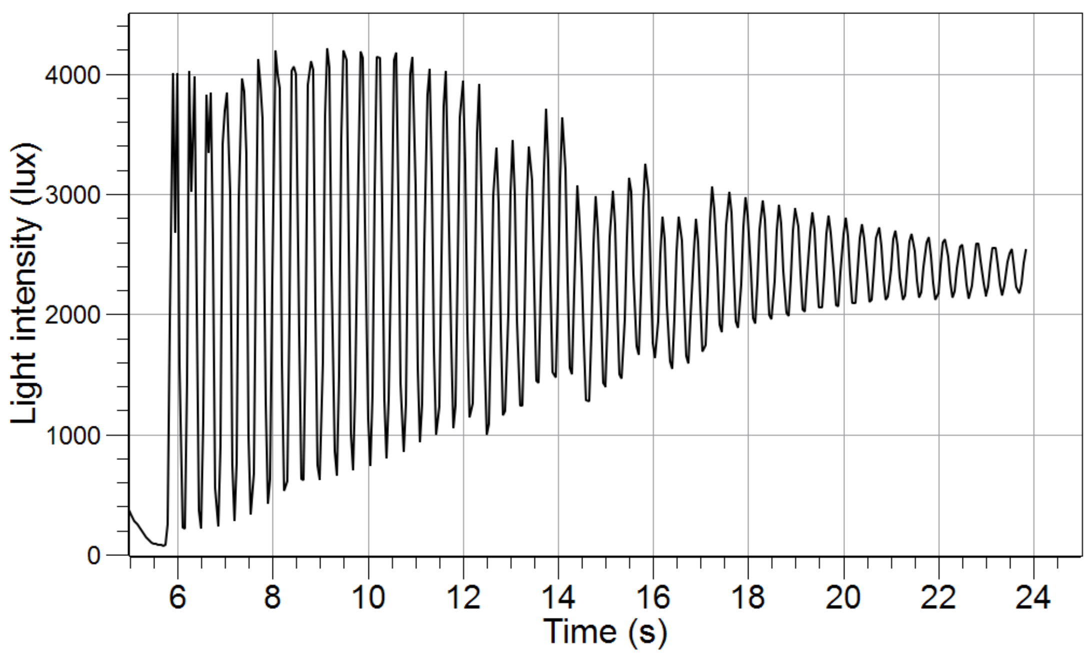
Sample data may vary. Below is a possible graph.



Part 3: Observing vibrations on heavier weighted buildings

Sample data may vary. Below are possible graphs.





Answering the Question

Analysis

1. The light sensor taped on the meter stick is a model for a building undergoing vibrations during an earthquake.

   a. What part of this model represents the ground?

   In this model the ground is represented by the meter stick.

   b. What part of this model represents a light-weight building? A heavy-weighted building?

   The light sensor without clay represents a light-weight building, and the heavy-weighted building is represented by the light sensor with two pieces of clay stuck to it.

   c. What does the tape represent?

   The tape represents the building's attachment to the ground, such as its foundation.

2. Describe the vibration of the meter stick. Did the vibrations remain the same, increase, or decrease? If the vibration increased or decreased, did it do this in a consistent manner?

   The vibration started with large amplitude that decreased in a consistent manner until the vibration finally died (damped) out.

3. Look back over your graph and find a region of data where you can count the number of vibrations in a 10-second period of time. How many vibrations occurred in this period of time in the first "earthquake" from Part 1?

   Answers will vary. One student group reported 36 vibrations in a 10-second period for the undamped vibration of the light sensor and meter stick in Part 1.

4. How many vibrations occurred in a 10-second period of time in the "earthquakes" in Part 2 and Part 3?

   Answers will vary. One student group reported 31 vibrations in a 10-second period for the vibration damped with one clump of clay in Part 2, and 29 vibrations of the light sensor and meter stick in Part 3 with two clumps of clay.

5. How did the increase of mass from the addition of clay change the vibration?

   The larger the mass achieved by adding clumps of clay, the larger the period (time between) vibrations, the larger the amplitude (size) of the initial wave and the longer the vibration took to die out. This was especially evident with the two clumps of clay.

6. Why did the vibrations die out?

   Energy is transferred from the simulated building (meter stick) to the surrounding table (earth).

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___F___ 1. Seismic waves travel through the earth but not across the earth's surface.

___F___ 2. A more massive building is affected by seismic wave vibrations in exactly the same way a much lighter building is.

___T___ 3. Another way to say that vibrations "die out" is to say that they are damped.

___F___ 4. Ten vibrations in one second is the same thing as ten seconds per vibration.

___T___ 5. Earthquake vibrations travel differently through different types of material.

___T___ 6. Energy may be transferred from the earth to a building, and then from the building back to the earth, during an earthquake.

___T___ 7. One of the tools scientists use to gain more information about earthquakes is a seismograph.

Key Term Challenge

Fill in the blanks from the randomly ordered words below:

vibrations	amplitude	seismic waves	ground
damped	seismograph	seismic	damage

1. Scientists monitor seismic activity using an instrument called a/an ___seismograph___, which records vibrations at and beneath the earth's surface.

2. The ___amplitude___ of a vibration or wave describes how big the vibration is, while the frequency tells how many times each second the vibration occurred.

3. Buildings that withstand earthquakes often have some means of damping ___vibrations___.

4. Surface waves are a type of ___seismic waves___ that cause the ground to ripple during an earthquake.

5. If the amplitude of a vibration continues to get smaller as time goes on, the vibration is said to be ___damped___. Such vibrations, then, do not continue forever.

6. One factor that can influence the size and frequency of vibrations a building experiences during an earthquake is the type of ___ground___ on which it is built.

7. The waves that travel through the earth and across its surface during an earthquake are called ___seismic___ waves.

Further Investigations

Investigate various heights of your simulated building by extending the meter stick to different lengths on the table. How did the length of the vibrations (dampening time) compare for the different lengths without and with the clay?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

5. Mapping the Ocean Floor

Sonar in the Science Lab

Objectives

In this activity, students use a motion sensor to create several features of an "ocean floor" using books, toys, et cetera. Students will be able to draw several parallels between the operation of the motion sensor and the concepts of sonar, radar, and echo sounding, among others.

Students investigate how to use a motion sensor to map an area while they:

- Analyze and draw inferences from a graph of Position versus Time
- Evaluate the feasibility of studying and using certain seafloor structures
- Apply their knowledge of motion sensor technology to the concept of sonar, radar, and echo sounding
- Analyze their experimental results to determine why they appear "different" than an actual profile of the ocean floor

Procedural Overview

Students gain experience conducting the following procedures:

- Simulating the variety of terrain found on an ocean floor with objects from the classroom
- Using the motion sensor to scan a cross-section of the simulated ocean floor terrain

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	50 minutes
■ Lab activities, Parts 2 and 3	25 minutes
■ Analysis	25 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Motion sensor
- ☐ Kabob skewer or similar thin wooden stick
- ☐ Shoebox
- ☐ Classroom objects for simulated ocean floor (desks, chairs, books, et cetera)

For each student or group:

- ☐ Data collection system
- ☐ Motion sensor
- ☐ Graph paper
- ☐ Classroom objects for simulated ocean floor (desks, chairs, books, et cetera)

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Students should understand how the motion sensor works.
- Geographical vocabulary terms associated with landforms
- Some familiarity with topographic maps

Related Labs in This Guide

There are no labs conceptually related to this on in this guide.

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Recording a run of data �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)
- Deleting a data run �(8.1)
- Saving your experiment �(11.1)

Background

For the better part of human history, sea floor topography has been of little interest. Although the ocean basin makes up 70% of the earth's crust, little was understood about it prior to the nineteenth century. Most people believed the sea floor to be relatively featureless. What little was known of the ocean floor was the result of leadline measurements. A lead-weighted line was dropped from the side of a boat. When the line struck a surface, researchers would note the distance from the ocean surface to the end of the line. A series of measurements was conducted over a small area, which, once aggregated, provided a simple picture of a small area of the ocean basin.

Through the use of various technologies scientists have created topographic maps of the oceans' floors. Ocean floor mapping technology has become more sophisticated in recent years. Sonar technology is often used to gather data about the ocean basin. Ships that are used to map the sea floor do so by sending a signal, or energy wave, from a ship's bottom to the ocean floor. A receiver on the ship records the amount of time it takes for the signal to be reflected and travel back to the ship. With knowledge about the velocity of the energy waves the distance to the bottom is calculated and plotted. The process is repeated for many locations until the shape of the structures becomes evident.

The motion sensor used in this activity works in the same fashion. Sound waves are sent out from the sensor, reflect from an object, and are received back by the sensor. The computer calculates the distance the sound waves traveled and plots the distance on the graph. As a result, shorter distances are plotted lower on the y-axis (which is the distance axis) while larger distances are plotted higher on the y-axis. This causes the graph to appear "upside down" compared with the objects height from the floor since the taller objects are actually closer to the motion sensor. Bathymetry is the science of measuring ocean depths to determine the topography of the sea floor. In this exploration, students will be making simulated bathymetric measurements to map the contour of an "ocean floor".

Research has provided evidence that the structures on the sea floors are much larger in magnitude than the corresponding structures on the continents. For instance, Mt. Everest would not even come close to being as tall as the Mariana Trench is deep. Not surprisingly, there is less research about the abyssal plains, which cover more than half of the ocean floor, than the continental shelves because the ocean depth is very great causing such high pressure and such low temperatures that studying is extremely difficult. As technologies continue to improve, scientists will gradually gain greater understanding of the ocean basins.

Pre-Lab Discussion and Activity

Landform Above and Below the Ocean

Initiate the discussion by asking students what the bottom of the ocean looks like. Does the bottom of the ocean look like the land above water? If you have already started to study landforms, discuss the types of landforms above and below the ocean. Discuss the characteristics of the following landforms: hills, plains, ridges, trenches and seamounts, continental slope, trench, basin, continental shelf, and range.

Direct students to "Thinking About the Question"

Introduce the Concept of Mapping

In order to introduce students to the idea of mapping something they cannot see, require them to try it.

You will need a kabob skewer, a shoebox, and a landform that fits inside the box when the lid is on. To prepare, make a grid of holes, just big enough for the skewer or stick to fit through, about one centimeter apart over the entire lid of the box. Place the landform inside and tape the box shut.

During class ask students to try to determine the shape of the object in the box by poking a skewer through the holes and observing the depth of the "ocean" at each location. Students will need to choose a row or column of holes to investigate. Be sure they hold the stick perpendicular to the box at each location and that they do not slide the stick around inside the box. Students should record the depth to which they can insert the stick into the box at each point. Finally, have students plot the points on graph paper. Compare students' graphs and discuss the features of the landform inside the box.

Have each student sketch the shape of what they believe is in the box.

Direct students to "Investigating the Question"

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- The lab requires the student hold the motion sensor above the "ocean floor" and walk at a constant speed to gather the data. This could cause some inconsistencies in the data. Some possible setups to try are:
  - Have two students hold a large rod over the "ocean floor" and have the third student slide the motion sensor along the rod.
  - Attach a large table clamp to the edge of a table. Insert a long rod in the clamp so it points out from the table. Build the "ocean floor" under the rod. Slide the motion sensor along the rod.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Look where you are going when walking with the motion sensor.

Driving Question

How do we map the ocean floor?

Thinking about the Question

We have all seen a map of the world. Have you ever wondered how these maps are made? What about a map of the ocean floor? How can we know what the ocean floor looks like under all that water? Why would we want to map the ocean floor? Discuss with your partners.

One of the first methods developed to map the ocean floor was the use of a leadline. A lead-weighted line was dropped from the side of a boat. When the line struck a surface, researchers would note the distance from the ocean surface. A series of measurements over a small area provided a simple picture of a small area of the ocean basin. With your group, try this method with your shoebox models.

Mark your measurements on graph paper to build your model.

What are the limitations to this method? Could we map the whole ocean this way?

> Answers will vary. Students may suggest that because the ocean is so vast, it would take an impossibly large number of these types of measurements to create a very useful map.

Sonar technology is often used to gather data about the ocean basin. Ships send a signal, or energy wave, to the ocean floor. A receiver on the ship records the time it takes for the signal to be reflected and travel back to the ship. With knowledge about the velocity of the energy waves the distance to the bottom is calculated and plotted. The process is repeated for many locations until the shape of the structures becomes evident.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	5	3	4
Choose several items that you can use to model ocean floor features.	Make sure that each lab group member is aware of safety rules and procedures for this lab.	Walk at a constant velocity beside the "ocean floor" as you hold the motion sensor at a fixed height above it.	Position the items you have chosen to make the features of your ocean floor model.	Decide an appropriate height above your "ocean floor" to hold the motion sensor.

Investigating the Question

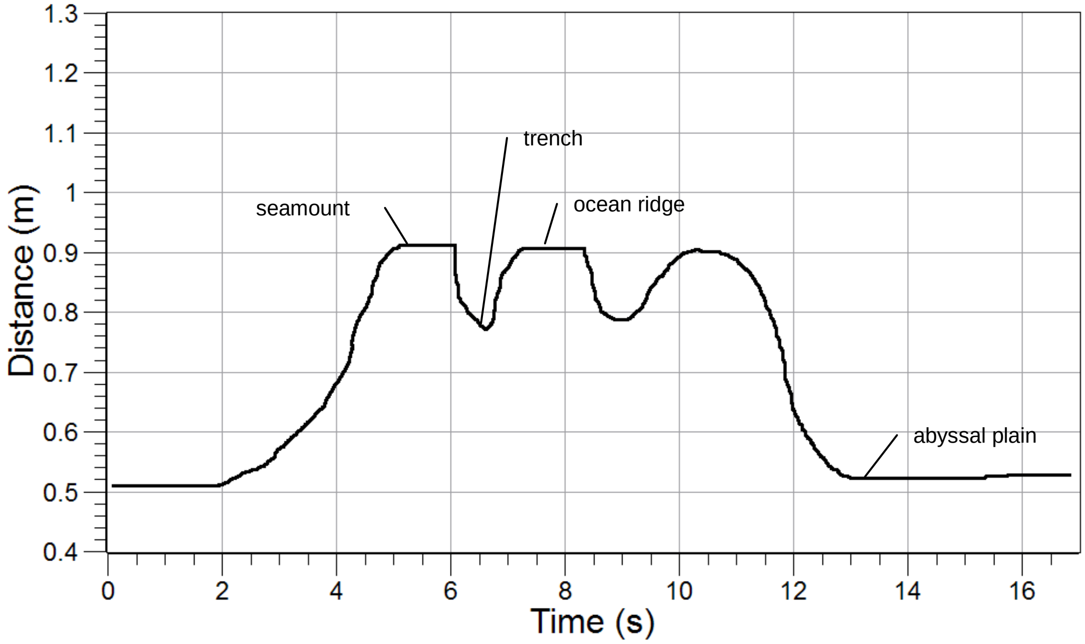
Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Setup and Prediction

1. ☐ Arrange the objects on the floor to simulate ocean floor features. Include any combination of seamounts, ocean ridges, trenches, abyssal plains or other sea floor structures.

2. ☐ Draw a prediction of the profile of the structures you have placed on the floor that you expect to see when graphed by a motion sensor.

Labeled Sketch of Ocean floor



Part 2 – Mapping the ocean floor

3. ☐ Start a new experiment on the data collection system.� (1.2)

4. ☐ Connect a motion sensor to the data collection system.� (2.1)

5. ☐ Display Position on the y-axis of a graph with Time on the x-axis.� (7.1.1)

6. ☐ Rotate the gold disk on the motion sensor so it points to the floor. Select the cart icon on the motion sensor.

7. ☐ Hold the motion sensor at arm's length over at the beginning of the "ocean floor".

8. ☐ Start data recording. �(6.2)

9. ☐ Immediately after pressing start you must begin slowly, but at constant velocity, walking with the motion sensor held over the "ocean floor".

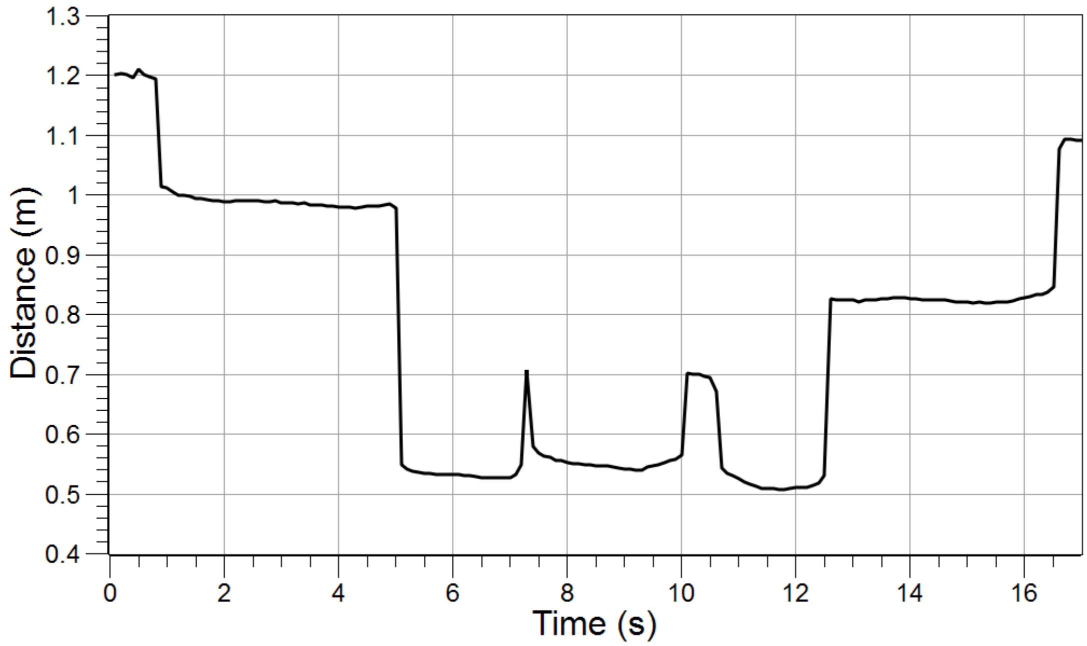
10. ☐ Why do you think it is important to move at a constant velocity?

Answers will vary. One student group answered as follows: It is important to move at constant velocity so that an appropriate number of position measurements are recorded for the objects that represent our ocean floor features. If we slow down over one place, more measurements will be taken there, and as a result that feature will look wider than it actually is. The scale of the model will not be accurate if we vary our velocity.

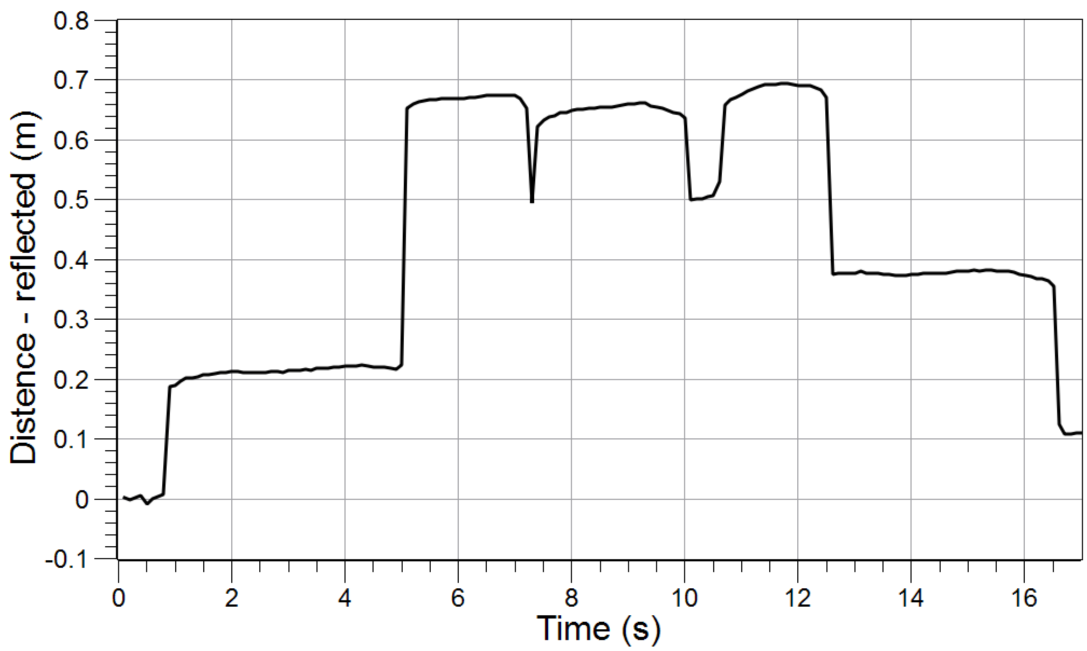
11. ☐ Stop data recording� (6.2) immediately when you reach the opposite end of the "ocean floor".

Note: This could take some practice. Do not be afraid to stop collection early and try again.

Sample Data



Measured data



Reflected data

Answering the Question

Analysis

1. How does the graph compare to your prediction?

   Answers will vary.

2. Explain any differences between your prediction and your actual position data.

   Answers will vary. One student group answered as follows: Our graph shows the highest places where there were actually the lowest places in our model, and the lowest places where we actually had the highest points in our model. We think the results were opposite or reversed because the motion sensor is measuring distance from itself to the object. When the distance is small, the object is near, but on the graph this looks like a low point because the y-axis is numbered from zero to 8 meters.

3. What would you need to do to make this graph look exactly like the profile of your "ocean floor?"

   Answers will vary. One student group answered as follows: One way we could make our graph look exactly like the profile of our ocean floor model would be to transform our data by reflecting it over the x-axis. To do this, we could leave each x-coordinate the same, but multiply each y-coordinate by –1.

4. How is sonar or radar used by scientists to map the floor of the earth's oceans?

   Answers will vary. One student group answered as follows: Scientists use sonar or radar to send signals or energy waves to the bottom of the ocean, where they bounce off the ocean floor and are received again on board the ship. The distance is calculated from the ship to the ocean floor so a map can be built up one section at a time.

5. To make your results more accurate, what could be graphed on the x-axis instead of time?

   To get more accurate results, we could plot the distance we walked, or length of our model, on the x-axis instead of time.

6. Why is it important to map the ocean floor?

   Answers will vary. One student group answered as follows: Scientists do not know very much about the ocean floors yet. Since about 70% of our planet is covered by oceans, this is like saying that scientists do not know very much yet about our planet. Mapping the oceans' floors is one way to begin learning more about them, and more about our planet.

7. How has technology changed our understanding of the ocean floor?

   Answers will vary. One student group answered as follows: By being able to use technology such as sonar or radar, scientists have been able to become more familiar with the ocean floor. By mapping the features of the oceans' floors, scientists have learned more about the earth in general. For example, it is now known that the ocean floors are not flat and featureless, but that there are huge mountain chains and very deep trenches. This information has helped scientists understand more about plate tectonics.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. An area of the ocean floor that plunges steeply to a very great depth is a/an

   A. Continental shelf

   B. Trench

   C. Abyssal plain

2. What was a leadline was used for in past centuries by mariners?

   A. Determining the depth of the water or the distance to the bottom of the ocean floor

   B. As a means of reckoning the speed of a ship through the water

   C. A primitive type of ship-to-ship communications device

3. A principal drawback of using a leadline was

   A. Mariners and sailors had difficulty using it properly

   B. It took a lot of effort to produce a small amount of data

   C. Ships using leadlines were more vulnerable to pirate attacks

4. How would an ocean floor map produced with sonar mainly be different from one produced without the use of such technology?

   A. The sonar map would give the actual depth for a particular location

   B. The sonar map would contain much more data

   C. The sonar map would show where the best fishing grounds would be

5. How is the motion sensor similar to the sonar devices used to map the ocean floor?

   A. The motion sensor can be used to determine an object's position, velocity, and acceleration.

   B. The motion sensor must be held still at all times

   C. The motion sensor sends out energy waves which are reflected back to their source

6. Suppose you want to model a trench, followed by a seamount, followed by an abyssal plain. Which three objects would you choose to use to build this model?

   A. A waste basket, a traffic cone, a tall box

   B. A chair, a desk, a waste basket

   C. An upside-down traffic cone, a tall box, a desk

7. Suppose you are walking in the dark with only a data collection system and a motion sensor, and you come to a gap in the path you do not want to fall into in case it is too deep. What position data from the motion sensor would most help to convince you to step into the gap?

   A. The maximum distance from the level ground to the bottom of the gap is less than 100 centimeters (cm)

   B. The minimum distance from the level ground to the bottom of the gap is 200 centimeters (cm)

   C. Each time you check the position data across the gap, there is an upward spike on the position graph

8. An area of the ocean floor that resembles a mountain chain is a/an

   A. Continental shelf

   B. Trench

   C. Mid-ocean ridge

9. What type of information would scientists *not* be able to learn from mapping the ocean floor?

   A. Whether or not organisms may be able to live in a particular location

   B. Where the continental shelf begins to slope upward toward land

   C. The likeliest direction an underwater landslide may flow

10. If you were on a sonar-carrying ship, with no land anywhere in sight, and you saw that the depth readings were decreasing steadily as you continued traveling in a particular direction, what might you conclude about the shape of the ocean floor over which you were sailing?

   A. The ship must be approaching an island or continent

   B. The ocean floor must be getting deeper

   C. The ocean floor must be getting shallower

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___ 1. One form of technology used to map the floors of earth's oceans is sonar.

___T___ 2. The motion sensor sends out a sound energy beam that reflects off a nearby object back to the sensor.

___F___ 3. The position versus time graph of a simulated ocean floor appears exactly like the profile of the objects used to build the model.

___T___ 4. Any change in position with respect to a reference point is known as motion.

___T___ 5. By mapping the ocean floor, scientists can learn a great deal about the earth.

Further Investigations

1. Develop a way to make a more complete topographic map using the motion sensor method. How would a three-dimensional map of all the runs look?

2. Create a temperature field map using a temperature sensor. Make a map of the room. Place a heat source (electric heater) in one corner and a heat sink (open window during the cold months) in another area. Collect thirty or forty temperatures equidistant from the floor and record them on the corresponding locations on the map.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

6. Monitoring Weather

Live from Weather Central

Objectives

This extended investigation provides students with a detailed look at weather and the type of measurements made by meteorologists as they study weather. During this activity, students:

- Recognize the components of weather
- Investigate and observe local weather conditions
- Collect and analyze data
- Identify how weather changes from one location to another as well as over time

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to monitor weather data outdoors at various times in the day and over an extended period of time
- Monitoring weather data at 6:00 am, noon, and 5:00 pm and recording these data in writing
- Recording weather data over a one-hour period of time at a chosen location
- Recording weather data for two different 24-hour periods of time at the same chosen location

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	40 minutes
■ Lab activity, Part 2 – Measuring weather at specific points in time	15 minutes + 12 hours of data monitoring
■ Lab activity, Part 3 – Measuring weather over a time period	60 minutes
■ Lab activity, Part 4 – Temperature	15 minutes + 24 hours of data collection
■ Lab activity, Part 5 – Relative humidity	15 minutes + 24 hours of data collection
■ Analysis	50 minutes

Materials and Equipment

For each student or group:

- ☐ Mobile data collection system
- ☐ Weather sensor
- ☐ Sensor extension cable
- ☐ Clipboard and pencil

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- The difference between weather and climate
- Weather terms
- Familiarity with the types of symbols frequently used to represent weather data on weather maps
- The components and functioning of the water cycle
- Local, national and global variations in climate; that is, climatic zones

Related Labs in This Guide

Labs conceptually related to this one include:

- Observing Clouds
- Investigating Evaporation and Condensation
- Exploring Environmental Temperatures

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Monitoring live data �(6.1)
- Recording a run of data �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)

- Displaying multiple variables on the y-axis �(7.1.10)
- Displaying multiple graphs �(7.1.11)
- Displaying data in a digits display �(7.3.1)
- Adding a measurement to a digits display �(7.3.2)
- Saving your experiment �(11.1)

Background

Weather is the daily state of the atmosphere and its short-term variation (from a matter of minutes to as long as a few weeks). Commonly, weather is thought of as the combination of temperature, humidity, precipitation, cloudiness, visibility, and wind. Weather is spoken of in terms such as "What will it be like today?", "When will that storm hit our part of the state, province, or country?" and "How cold is it right now?"

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

This lab consists of 4 main parts

- Making predictions about weather
- Collecting data
- Identifying variations from place to place as well as over time
- Identifying how weather can impact us

It is important to begin by using students' prior knowledge and clearly differentiating between climate and weather. Remember the lab focuses on monitoring weather conditions.

Understanding Weather

What is the difference between weather and climate?

> Weather is the current state of affairs in the atmosphere, and includes temperature, precipitation, humidity, visibility, cloud cover, and wind. Climate, on the other hand, is the long-term average behavior in the weather patterns for a particular region and time period, usually taken over 30-year periods.

What makes up our weather?

> Weather consists of such things as temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure.

How do we record weather?

Meteorologists record data about the weather with instruments such as anemometers, barometers, temperature sensors, and other devices like rain gauges. They use computers to help collect, display, and analyze the data. In the past, measurements were made with different technology (no use of electronic components, for example), and written down by hand. Often weather information is recorded on maps with specialized symbols that represent a large amount of information in compact form.

Data collection

What does the collected weather data show us?

Data that has been collected on the weather shows us how the weather changes from day to day and season to season. After enough years of weather data has been collected, the trends that appear can show us what the climate is like.

Why is it important to collect this data?

It is important to collect weather data because it is needed to understand how weather in the future may behave. It is also important because it serves as a basis for comparison so we know how trends may change over time.

Using the Data

Who could use this data?

This weather data could be used by many people, including meteorologists, climate scientists, governments, travelers, NASA or other space agencies, and citizens.

How has data collection changed over the last 50 years?

Fifty years ago, computers were extremely rare, so weather data was not collected using computers. Glass thermometers were used 50 years ago, as well as mercury-filled barometers and mechanical wind gauges. For nearly all weather measurements made now, a computer-based or electronic device is used. In addition, over the past 50 years many satellites have been put into orbit for the purpose of collecting weather data from space, so our data is not just from the ground or weather balloons. Nowadays, weather information can be delivered by the Internet and people can look at weather virtually all over the globe by accessing webcams and streaming weather data.

Direct students to “Thinking About the Question.”

Direct students to “Investigating the Question.”

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Divide this lab activity into 4 sections and ensure that students will be able to work through each section.
- Students will need access to computers or to power supplies for their data collection systems to allow recording over a 24 hour period.
- Students will need to be able to observe and record weather in different locations.
- If precipitation is expected, protect the data collection systems and sensors from becoming wet.

Safety

Follow all standard laboratory safety practices.

Driving Question

What is weather?

Thinking about the Question

Discuss with your lab group members what weather means to you. Be prepared to share your thoughts with the class.

List changes that you have seen in weather over a 24-hour period and from one location to another.

> Answers will vary. Students should suggest that weather can change dramatically over a 24-hour period, going from calm to stormy or vice versa. Students should point out that weather can vary from place to place; for example, it may be sunny in one location and cloudy or raining just a short distance away. Elevation differences can mean that it snows in one location while just a short distance away the precipitation may fall as rain.

How does weather impact us?

> Answers will vary. Weather can affect almost all aspects of our daily lives. We decide how to dress, what activities are feasible, what form of transportation to take, when to schedule a trip, and sometimes even what we eat, all based on the weather.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

3	1	4	5	2
Connect a sensor extension cable to the weather anemometer.	Make certain that each member of your lab group is aware of the safety rules and procedures for this activity.	Connect the weather anemometer to a data collection system that can remain outdoors.	Monitor live data without recording, making a note of weather data at three different times of the day.	Decide on a suitable outdoor location to set up a weather monitoring experiment.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Choose one location in your school environment and then complete Table 1 below, writing your predictions for the data and times listed:

Table 1: Predictions

	6 am	Noon	5 pm
Temperature	9 °C	13 °C	15 °C
Relative Humidity	45%	40%	35%
Wind Direction	West	West	West
Wind Speed	2 km/hr	2 km/hr	7 km/hr
Dew Point	10 °C	9 °C	8 °C
Precipitation	No	No	No
Barometric Pressure	101 kPa	101 kPa	101 kPa
Cloud Cover	0%	0%	0%

2. ☐ Write your predictions for the following:

   a. When are maximum and minimum temperatures likely to occur during a 24-hour period?

   The minimum temperature is likely to occur just before dawn, and the maximum temperature is likely to occur between mid-afternoon and late-afternoon.

   b. How will relative humidity change over a 24-hour period?

   The relative humidity is usually higher in the morning and decreases throughout the day and then begins increasing again during the night.

Part 2 – Measuring weather at specific points in time

3. ☐ Start a new experiment on the data collection system. �[(1.2)]

4. ☐ Connect a weather anemometer sensor to the data collection system using a sensor extension cable. �(2.1)

5. ☐ Display Temperature, Relative Humidity, Barometric Pressure, Dew Point, and Wind Speed in a digits display. �(7.3.1) (7.3.2)

6. ☐ Using the sensor and your observations, monitor the weather conditions at the same location and times that your predictions were made. �(6.1) Complete Table 2 below.

Table 2: Weather conditions

	6 am	**Noon**	**5 pm**
Temperature	12.1 °C	24.3 °C	20.1 °C
Relative Humidity	84%	36%	38%
Wind Direction	West	West	West
Wind Gust	0 km/hr	1.6 km/hr	0 km/hr
Dew Point	8.8 °C	7.6 °C	4.3 °C
Precipitation	No	No	No
Barometric Pressure	99.5 kPa	99.4 kPa	99.5 kPa
Cloud Cover	<25%	75%	50%

7. ☐ What changes in the weather did you notice? Write your observations.

Answers will vary depending on local weather conditions.

Part 3 – Measuring weather over a time period

8. ☐ Display Temperature, Relative Humidity, Dew Point and Air Pressure on the y-axis of a graph with Time on the x-axis. �(7.1.10)

   Note: If you are using the Spark Science Learning System, you will need to display the graphs on multiple pages.

9. ☐ Change the periodic sampling rate to take a measurement every 30 seconds. �(5.1)

10. ☐ Choose a location in the school yard to collect weather data and then start data recording. �(6.2)

11. ☐ After 60 minutes, stop data recording. �(6.2)

12. ☐ Save your experiment according to your teacher's instructions. �(11.1)

13. ☐ Based on your graph, describe the relationship between

    a. Temperature and relative humidity

From our graph it seems that as temperature increases, the relative humidity decreases and vice versa.

    b. Temperature and dew point

From our graph it seems that as temperature decreases, the dew point also decreases.

    c. Barometric pressure and temperature

For the first portion of our graph, as the barometric pressure went down, so did the temperature. Then in the second half of our graph, the pressure increased while the temperature continued to decrease.

Part 4 – Temperature

14. ☐ Start a new experiment on the data collection system. �(1.2)

15. ☐ Connect a weather sensor to the data collection system. �(2.1)

16. ☐ Display Temperature on the y-axis of a graph with Time on the x-axis. �(7.1.1)

17. ☐ Set up your mobile data collection system in the same location you used for Part 3 and start data recording. �(6.2) Record data for 24 hours.

18. ☐ After 24 hours, stop data recording. �(6.2)

19. ☐ Save your experiment according to your teacher's instructions. �(11.1)

Part 5 – Relative humidity

20. ☐ Start a new experiment on the data collection system. �(1.2)

21. ☐ Connect a weather sensor to the data collection system. �(2.1)

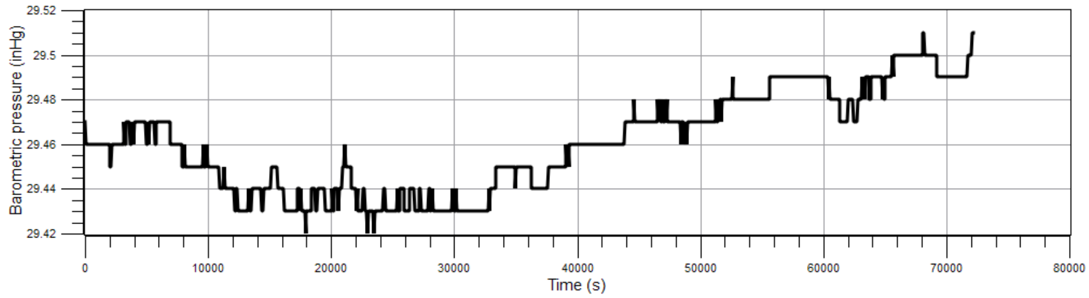
22. ☐ Display Relative Humidity on the y-axis of a graph with Time on the x-axis. �(7.1.1)

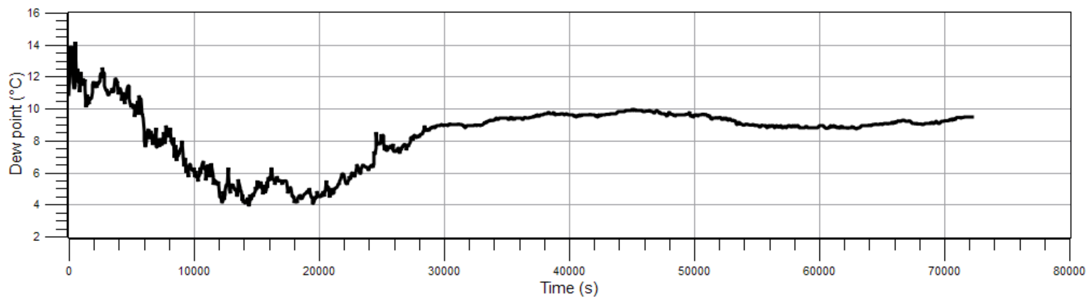
23. ☐ Set up your mobile data collection system in the same location you used for Part 3 and start data recording. �(6.2) Record data for 24 hours.

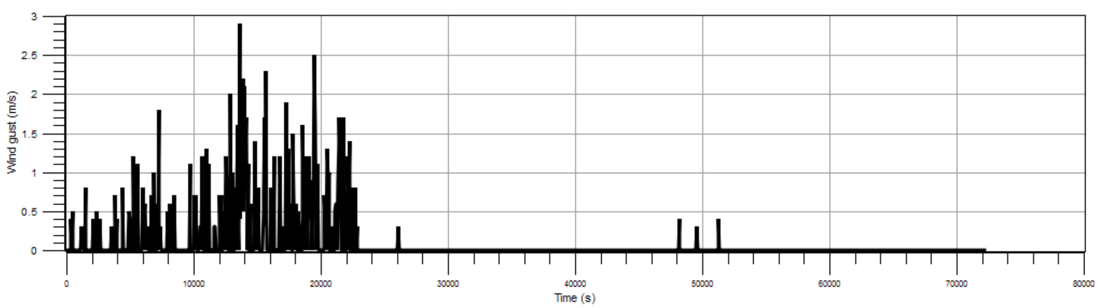
24. ☐ After 24 hours, stop data recording. �(6.2)

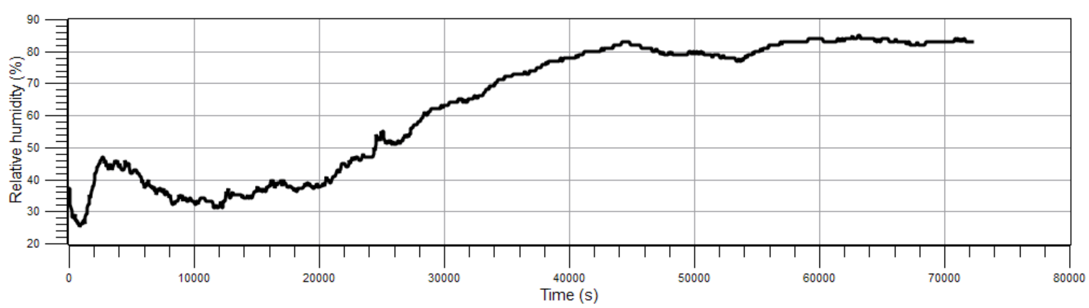
25. ☐ Save your experiment according to your teacher's instructions. �(11.1)

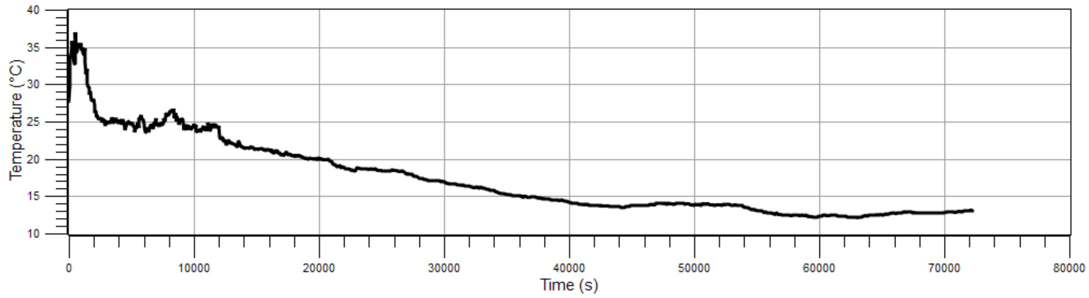
Sample Data











Answering the Question

Analysis

1. How did your predictions from Part 1 compare to the results from Parts 2 to 5?

   Answers will vary. One group answered as follows: Our predicted temperatures were all several degrees cooler than the temperatures we actually measured. It was much more humid in the early morning than we predicted or expected, but it turned out that a storm was coming in which changed the weather. We made our predictions thinking that the weather was going to stay nice. It was not as windy as we predicted, at the moments we measured the wind speed, even though it was a very windy storm. One thing we predicted correctly was that the wind would be coming from the west, which did happen. We predicted 101 kPa of barometric pressure, and the actual pressure was a little lower, possibly because of the storm.

2. What factors determine whether or not a location receives precipitation?

   Answers will vary. One group answered as follows: In order for us to get precipitation, there must be clouds that hold moisture. The moisture must condense into droplets heavy enough to fall. Since we live on the western slope of a tall mountain range, the clouds that come in from the ocean often encounter the mountains, which force them higher up in elevation, so their water vapor cools and condenses.

3. How does monitoring weather data over a period of time help you become more familiar with the weather you experience in your area?

   Answers will vary. One group answered as follows: By measuring all of this weather data, we have gotten much more familiar with the different types of things that make up our weather. For example, we now think of relative humidity and dew point, but before doing this project we mainly thought of temperature, wind, and precipitation.

4. Which aspect of this investigation did you find most surprising or different from your predictions? Be prepared to share your thoughts with the rest of the class.

   Answers will vary. One group answered as follows: We were surprised by how quickly some of the weather measurements could change. For example, one day during our experiment, the temperature and relative humidity changed more in a two-hour block of time than they did the entire rest of the 24-hour period. This big change happened as clouds were blowing in.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. The amount of water vapor in the air refers to:

   A. Rain
   B. Snow
   C. Sleet
   D. **Humidity**

2. Lines connecting areas of equal atmospheric pressure are known as:

   A. Isotherms
   B. **Isobars**
   C. Fronts
   D. Isohyets

3. The scale used to measure wind speeds by visible signs is known as the _______ scale.

   A. **Beaufort**
   B. Richter
   C. Palmer
   D. Bergeron

4. A tornado watch is issued:

   A. During every thunderstorm
   B. When a tornado has been spotted
   C. **When conditions are favorable for the formation of tornados**
   D. Only in the spring

5. Which of the following is not a way of producing clouds?

   A. Lifting air over a mountain
   B. Lifting air along a weather front
   C. Warming the surface of the earth
   D. **Subsidence**

6. Why do hurricanes not occur all year long?

   A. Winds are not strong enough in the winter
   B. In the winter, there is not sufficient shear in the atmosphere
   C. Convection does not occur in the winter
   D. **The water temperatures are not warm enough to foster the growth of the storms**

Key Term Challenge

Fill in the blanks from the randomly ordered words below:

barometer	temperature	relative humidity	weather
climate	precipitation	water vapor	clouds

1. Changes in the condition of the atmosphere on a daily basis or even on an hourly basis are referred to as weather.

2. The part of the water cycle that produces rain, hail, or snow is precipitation.

3. Up until about fifty years ago, the barometer was the instrument primarily used for measuring atmospheric pressure.

4. The climate describes the long-term weather trends of a region and is based on data measured over a period of at least thirty years.

5. The amount of water vapor in the air compared to the amount the air is able to hold at a given temperature is known as relative humidity and is usually expressed as a percent.

6. Just before dawn is the time of day when the lowest temperature is often recorded.

7. The formation of clouds is dependent upon there being enough moisture in the air and a temperature which allows that moisture to condense into liquid form.

Further Investigations

Students can study weather maps and forecast weather conditions, conduct research on the history of weather and the instruments used to record it, or on severe weather. Students can be encouraged to make a presentation to the class on their findings.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

7. Night and Day

The Way the World Turns

Objectives

In this activity, students model one of the motions found in the solar system, rotation. They investigate the relationship between Earth's rotation and the cycle of night and day that we experience because of this rotation.

Students investigate the rotational motion of Earth while they:

- Measure the intensity of light that reaches the light sensor during each portion of rotation
- Interpret information about the cyclical nature of night and day by exploring a light intensity versus time graph
- Gain skills and confidence in using scientific measurement tools, the light sensor, as well as the graphing capability of a computer to represent and analyze data

Procedural Overview

Students gain experience conducting the following procedures:

- Kinesthetically modeling night and day on the earth
- Playing the role of the earth, rotating through a complete circle or series of circles while being illuminated by a lamp or flashlight
- Playing the role of the sun by shining a lamp or flashlight on the "earth"
- Measuring the light level that falls on the "earth's" surface as it turns through several rotations.

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	50 minutes
■ Lab activity, Part 2 – Measuring light through one rotation	25 minutes
■ Lab activity, Part 3 – Measuring light through a series of rotations	25 minutes
■ Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Utility lamp or flashlight

For each student or group:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Utility lamp or flashlight
- ☐ Index card, (2) 3 in. x 5 in.
- ☐ Marker (dark color)
- ☐ Tape

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- The earth rotates on its axis, completing one rotation every 24 hours. This defines our night and day.
- The earth is tilted on its axis by 23.5 degrees.
- The earth revolves around the sun in an elliptical path, completing one revolution in 365.26 days. This defines our year.
- How to read and interpret a coordinate graph.
- The basics of using the data collection system.
- Light intensity is measured in lux.

Related Labs in This Guide

Labs conceptually related to this one include:

- Seasons

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connect a sensor to the data collection system �(2.1)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)

- Selecting data points in a graph �[(7.1.4)]

- Saving your experiment �[(11.1)]

Background

The term rotation refers to the spinning of the earth on its axis. Because of rotation, the earth's surface moves at the equator at a speed of about 467 meters per second, or about 1675 kilometers per hour. If we could look down at our planet's north pole from space we would notice that the direction of rotation is counterclockwise. We would see the earth rotating clockwise if we were able to view it from a similar vantage point over the South Pole. One rotation takes exactly twenty-four hours and is called a *mean solar day*.

Our planet's rotation is responsible for the repeating cycles of night and day. At any one instant in time, one half of the earth is in sunlight, while the other half is in darkness. The edge dividing the daylight from night is often called the circle of illumination, or the terminator. In addition to the night and day, the earth's rotation also creates the apparent movement of the sun across the horizon.

The location on the earth where the sun is directly overhead at solar noon is known as the subsolar point. The subsolar point occurs on the equator during the two equinoxes. On these dates, the equator is lined up with the ecliptic plane and the poles are in line with the circle of illumination. During the summer solstice, the subsolar point moves to the *Tropic of Cancer* (23.5° north latitude) because at this time the North Pole is inclined 23.5° toward the sun. The subsolar point gradually changes from one day to the next over a period of one year. The subsolar point is located at the *Tropic of Capricorn* (23.5° south latitude) during the December solstice when the South Pole is angled 23.5° toward the sun

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Show students a globe. Have a volunteer shine the beam of a flashlight so it strikes the surface of the globe at your town's location. After students have had a chance to see this, slowly spin the globe so it rotates counterclockwise (as seen from the North Pole). Ask students to tell you when it is "night" in your town, and when it is "day." As you continue to spin the globe slowly and steadily, students should be able to repeat in a rhythmic way, "night," "day," "night," "day," et cetera. This gives a visual and auditory reinforcement to the connection between Earth's rotation and our cycle of night and day.

Direct students to "Thinking About the Question."

Demonstrate for students how to position themselves and the data collection system and light sensor, as well as the flashlight or lamp, to model the earth-sun system. Rehearse the motions students will perform until they clearly understand what they will do.

Help students as necessary in choosing volunteers to play the role of the earth and sun. Assign these roles if it is more practical than allowing students to make the choice.

Direct students to "Investigating the Question."

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- In order to get good data, the room will need to be dark. You may need to temporarily cover windows to darken the room adequately.
- Help student groups stand so that their own flashlight or lamp is not shining simultaneously on another group's light sensor. If space does not allow it, consider having only one or two groups collecting data at a time, or doing this activity as a demonstration.
- Encourage students to practice rotating slowly and steadily.
- Do not allow students playing the role of the sun to shine their lights directly into others' eyes.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Do not shine any light directly into others' eyes.

Driving Question

How does the sun's light fall on our planet as it rotates?

Thinking about the Question

People have observed the sky for many thousands of years. The most obvious objects in the sky, of course, are the sun in the day and the moon at night. Ancient people thought that the sun and the moon both revolved around the earth. We no longer believe this because we know that the earth rotates, or spins like a basketball on the tip of a player's finger. It is this rotation that is the cause for our night and day on Earth. Rotation is one of the types of motion found in our solar system and in the universe. Can you think of any other types of motion that occur in the solar system?

> Students should suggest motion in a straight line, such as that of an asteroid being pulled by the gravity of a larger planet or moon, and circular or elliptical motion such as that of an orbiting planet or satellite.

Ancient people were excellent observers of the night sky. They also had the benefit of very dark nights, in which the stars, the planets, and even the Milky Way—our own galaxy—were visible. This was because their only source of illumination was fire, so consequently there was very little light pollution. In addition, many of the world's great cultures were extremely interested in astronomical observations for religious or for practical reasons, such as knowing when to plant and harvest crops.

To these observers, it was evident that the celestial bodies traveled around the earth. How would their observations have been different if this type of motion really was occurring? Discuss in your group how the path traveled by the sun and moon would appear if the earth was *not* rotating, and the sun and the moon were orbiting the earth. Be prepared to share your thoughts with the rest of the class.

> Students should suggest that the apparent motion of the sun and moon would look exactly as it does. There is no way to tell which object is in motion and which is at rest because there is no fixed frame of reference.

In this activity you will be working within your group to model Earth's rotational motion and how the sun's light falls upon the rotating planet. You will observe how this rotation causes night and day to happen in a regular, repeating cycle. You will need to have one volunteer to play the role of the earth, and a second volunteer to play the role of the sun.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

4	1	3	2
Turn off the lights in the room and slowly turn in a circle, finishing exactly where you began.	Make sure each lab group member is aware of safety rules and procedures for this lab.	Begin recording light intensity data	Stand holding the light sensor facing away from the lamp or flashlight.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Write your predictions for the following:

   a. What will happen to the level of light that falls from a light source onto the light sensor as it is rotated in a complete circle by one of your classmates?

We predict that the light level will be low when the sensor faces away from the light or flashlight, and high when it faces toward the light. We think the light level might be at a medium intensity when the sensor is facing at an angle to the light source.

   b. If the light sensor is rotated several times, what will a graph of light intensity versus time look like?

We predict that the graph of light intensity versus time will look like a pattern that has peaks and valleys, or like a wave with crests and troughs.

c. Would you be able to tell from the graph how many rotations the light sensor made? Explain your reasoning.

We predict that the way to tell how many rotations were made by the light sensor would be to count the number of crests or the number of troughs in the graph.

d. If the student playing the role of the earth has the direction "east" taped to his or her left shoulder and the direction "west" taped to his or her right shoulder, which direction will the student turn to make the "sun" appear to rise in the east and set in the west?

We predict the student will have to turn or rotate counterclockwise to make the sun rise in the east and set in the west.

Part 2 – Measuring light through one rotation

In this activity one group member volunteers to play the role of the earth, and will be responsible for data recording. Another group member volunteers to play the role of the sun, and will be responsible for shining the lamp or flashlight on the "earth." Data recording is carried out with the room darkened.

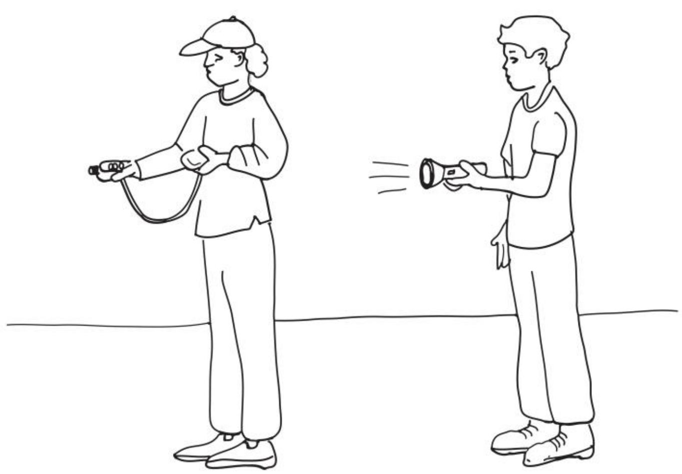
2. ☐ Mark one index card with a large "E" and the other with a large "W."

3. ☐ Tape the compass direction east to the "earth's" left shoulder, and tape west to the "earth's" right shoulder.

4. ☐ Start a new experiment on the data collection system. �(1.2)

5. ☐ Connect a light sensor to the data collection system. �(2.1) Select the medium sensitivity range (0–260 lux) for the light sensor.

6. ☐ Display Light intensity on the y-axis of a graph with Time on the x-axis. �(7.1.1)



7. ☐ The "earth" begins by holding the light sensor pointing outward, and facing away from the "sun," whose light should be shining on the "earth's" back.

8. ☐ Begin data recording. �(6.2)

9. ☐ The "earth" turns slowly and steadily in a circle so that the left, or "eastern," shoulder is illuminated first, and so that the complete rotation takes between 30 and 40 seconds.

10. ☐ After completing the rotation, stop data recording. �(6.2)

11. ☐ Observe your graph of light intensity data. You may need to adjust the scale of the graph to view all of your data. �(7.1.2) Record your observations below.

    The light intensity started out very low, then got higher as the earth turns toward the sun. It was most intense when the earth was directly facing the sun with the light sensor. After turning away from the sun, the light intensity got lower again, and was lowest when facing directly away from the sun.

Part 3 – Measuring light through a series of rotations

As in Part 2, in this activity one group member volunteers to play the role of the earth, and will be responsible for data recording. Another group member volunteers to play the role of the sun, and will be responsible for shining the lamp or flashlight on the "earth." Data recording is carried out with the room darkened.

12. ☐ The "earth" begins by holding the light sensor pointing outward, and facing away from the "sun," whose light should be shining on the "earth's" back.

13. ☐ Begin data recording. �(6.2)

14. ☐ The "earth" turns slowly and steadily in circles so that the left, or "eastern," shoulder is illuminated first, and so that each rotation takes between 20 and 30 seconds. The "earth" should rotate through at least 5 complete days and nights.

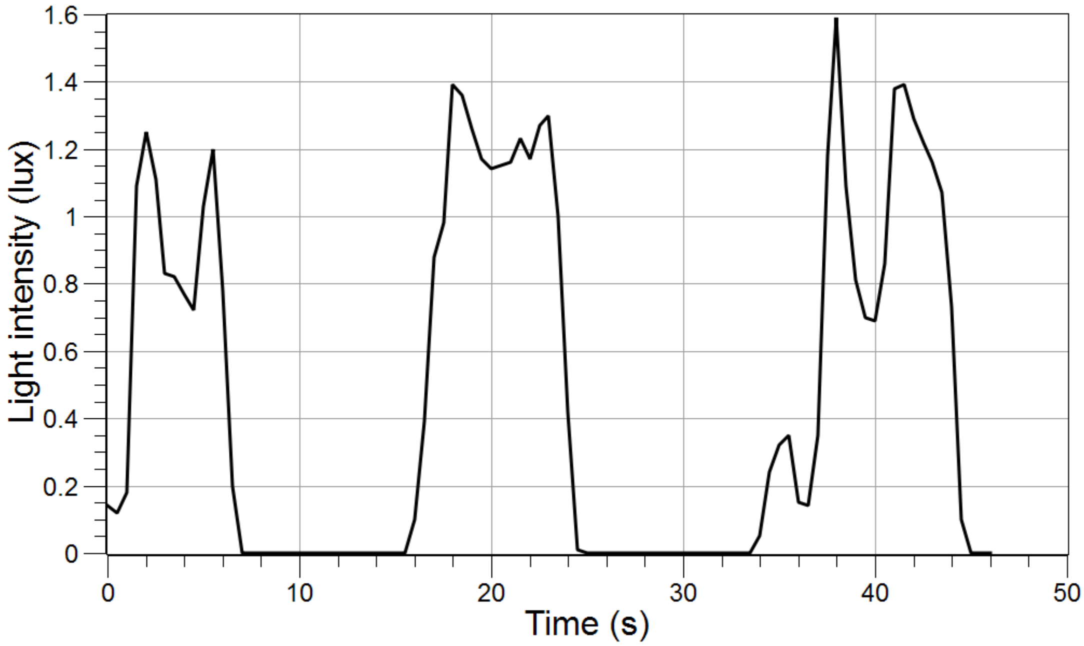
15. ☐ After completing the rotations, stop data recording. �(6.2)

16. ☐ Observe your graph of light intensity data. You may need to adjust the scale of the graph to view all of your data. �(7.1.2) Record your observations below.

    We observed that there is a peak in light intensity every time the earth and light sensor directly face the sun and flashlight. There is also a valley or low point in the graph every time the earth and light sensor face way from the sun.

17. ☐ Save your experiment according to your teacher's directions. �(11.1)

Sample Data



Answering the Question

Analysis

1. How did your predictions from Part 1 compare to your results in Part 2?

   We predicted that the light intensity would be lowest when the sensor faced away from the flashlight, and highest when it faced toward the flashlight, and of a medium intensity in the directions in between. This is what happened when we tried the experiment.

2. How did your predictions from Part 1 compare to your results in Part 3? How many cycles of night and day did your group make?

   We predicted that we could count the peaks and valleys of the graph to tell how many nights and days of rotation the earth made. We could tell just by looking at the graph. Our "earth" volunteer had to turn counterclockwise to make the sun rise on her east shoulder and set on her west shoulder. Our group made 7 complete night and day cycles.

3. The term "solar noon" refers to the point when the sun has risen to its maximum height in the sky before appearing to begin its descent toward the west. Examine your light intensity versus time data. Can you tell from your data when it was "solar noon" at the light sensor on the "earth's" surface? Explain your thinking.

Answers will vary. One group answered as follows: We can tell that it is noon at the light sensor because that is when the graph shows the highest light intensity.

4. Imagine you were living 2500 years ago in ancient Greece, and did not have access to a light sensor to assist in your observations of the night or day sky. How might you have used shadows cast by trees or other objects to determine when it was noon? Explain your reasoning.

   Answers will vary. One group answered as follows: We would have observed the shadow of a tree and noticed when it was getting longer, and then tried to find the time when it stopped getting longer and began to get shorter. The time when the shadow was at its maximum length would be the solar noon, because after that time the shadow would be getting shorter again, which would mean that the sun was appearing to descend toward the west.

5. Examine your data from Part 3 again. Can you tell how much time passes between the brightest point, or solar noon, of one day and the darkest point of the "night" by looking at the graph? You may need to adjust the scale of the axes or zoom in to a portion of the graph. Selecting specific data points in your graph �(7.1.4) may help you in your analysis.

   Answers will vary. One group answered as follows: In our data from part 3, it took 11.8 seconds to rotate between noon and night.

6. Through how many degrees did the "earth" rotate in the time between noon and night in the previous question?

   The "earth" rotated through 180 degrees in that amount of time.

7. Through how many degrees does the earth rotate for the following amounts of time: one complete night and day cycle, two complete night and day cycles, and three complete night and day cycles?

   The Earth rotates through 360 degrees in one complete cycle, through 720 degrees in two complete cycles, and through 1080 degrees in three complete cycles.

8. How long does earth take to rotate through 540 degrees? If you began counting the time at solar noon, would it be night or day when the rotation just passed 540 degrees?

   It would take the earth one complete day and one half of a day, or 36 hours, to complete 540 degrees of rotation. If we began counting at solar noon, it would be midnight at the 540-degree point.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. If it is midnight at your location on Earth's surface, what is true of your position on Earth?

   A. You are located on the side of our planet that is directly opposite the sun.
   B. The sun has traveled around behind your position on Earth's surface.
   C. You are located on Earth's surface at a right angle to the sun.

2. Which term is used to describe the motion that is responsible for Earth's nights and days?

   A. Spinning
   B. Axis-tilt
   C. Rotation

3. At any given moment in time, what fraction of the earth's surface is illuminated by the sun?

   A. This information cannot be determined.
   B. One half of the earth's surface is illuminated.
   C. Between one-fourth and one-third of the earth's surface is illuminated.

4 Which statement best describes solar noon?

   A. The time at which a location on the earth's surface is facing directly toward the sun.
   B. The exact moment in time when the earth has completed one rotation.
   C. The point in the earth's rotation when a location on the earth's surface is facing away from the sun.

5. Suppose there is a planet that takes 52 hours to rotate through 360 degrees. How long is one complete night and day cycle on that planet?

   A. 24 hours
   B. 360 hours
   C. 52 hours

6. The sun and moon appear to us to rise in the east and set in the west because the earth

   A. Rotates at a steady rate, turning through 360 degrees in the same amount of time for each rotation.
   B. Rotates on its axis, which is an imaginary line that goes through the earth's center from the North to the South Poles.
   C. Rotates in a counterclockwise direction when viewed from the North Pole.

7. Which of the following ancient cultures were observers of astronomical phenomena?

   A. The Babylonians and the Chinese
   B. The Chinese and the Greeks
   C. The Babylonians, the Chinese, and the Greeks

8. If our planet did not rotate on its axis every 24 hours, which of the following would be true?

   A. The sun would appear to move through the sky
   B. The moon would appear to rise in the west and set in the east
   C. There would be no cycle of night and day

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___ 1. Because the sun and the moon appear to travel across the sky from east to west, ancient people thought the earth did not rotate, but that these celestial bodies travel in a circular path around our planet.

___T___ 2. From our frame of reference on the earth's surface, it is not possible to determine which is moving – the earth or the sun.

_______F______ 3. Rotation and revolution refer to the same types of motion.

_______T______ 4. Someone standing on a particular point on the earth's surface will travel through 360 degrees of a rotation in 24 hours.

_______T______ 5. If you watch a sunset, you are seeing the moment in time where the earth's rotation carries you from the illuminated part of the planet to the part that is not illuminated.

_______F______ 6. The only place on Earth to see the sun appear to rise in the west and set in the east is on the equator.

Further Investigations

Research the length of a day on the other planets of our solar system.

Research the type of pollution called "light pollution." Find out how it affects our ability to study celestial phenomena.

Design a way to teach younger students how the earth's rotation causes the cycle we call night and day.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

8. Observing Clouds

Is Any Water Up There?

Objectives

Students will:

- Investigate and observe the characteristics of clouds and their relationship to particular weather conditions
- Identify types of clouds
- Record data from their observations relating to clouds and weather conditions

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to measure meteorological conditions over a period of one week or more
- Observing and identifying clouds as they appear throughout the period of observation
- Using math and spatial skills to calculate the percent of cloud coverage of the sky

Time Requirement

Introductory discussion and lab activity, Part 1 – Making predictions	50 minutes
Lab activity, Part 2 – Cloud Types and Cloud Coverage	50 minutes
Lab activity, Part 3 – Observing Clouds	one week
Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Gallon glass or plastic jar, wide mouth (such as a pickle jar or sun tea jar)
- ☐ Rubber gloves (such as Playtex™ brand cleaning gloves)
- ☐ Matches
- ☐ Laser pointer (optional)
- ☐ Tap water, warm, to cover bottom of jar to depth of 2 cm
- ☐ Food dye, blue and green (optional)
- ☐ Large rubber band (the type that come on bunches of produce work well)

For each student or group:

- ☐ Data collection system
- ☐ Weather sensor
- ☐ Cloud chart
- ☐ Digital camera (optional)
- ☐ Pencil
- ☐ Notebook
- ☐ Graph paper
- ☐ Calculator (optional)

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- The water cycle
- The difference between climate and weather
- Climatic zones and associated characteristics

Related Labs in This Guide

Labs conceptually related to this one include:

- Monitoring Weather
- Water's Role in Climate
- Water – The Universal Solvent
- Boyle's Law

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Recording a run of data �(6.2)
- Displaying data in a table �(7.2.1)
- Changing the sampling rate �(5.1)
- Saving your experiment �(11.1)

Background

In addition to nitrogen, oxygen, and other gases, the atmosphere contains water vapor, water droplets, and dust. When warm humid or moist air rises to higher altitudes it cools. It also expands because at higher altitudes, the pressure is lower. You may have noticed this when opening bags of peanuts or chips on an airplane; the decrease in pressure results in the atmospheric pressure inside the bag to exert more force on the inside surface than the pressure at altitude is able to exert on the outside surface.

Clouds form when invisible water vapor in the air cools enough to condense and form tiny droplets of liquid water. As the expanding, cooling water vapor condenses, the water molecules lose energy, slow down, and begin to clump together. Once the condensing water droplets become visible, they appear as clouds. This process is greatly aided by the presence of dust and other small particles in the atmosphere, by providing the water droplets a nucleus around which to form.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Show students the cloud-forming apparatus. Assembly instructions for this apparatus are located in the Preparation and Tips section. Explain that it is a model for part of the water cycle and cloud formation. Ask students what stage of the water cycle or aspect of earth's geography each part of the jar may represent.

> Possible answers include: the water in the jar represents the ocean or other water which evaporates from earth's surface; the jar itself represents an area of earth's atmosphere above the surface; the air inside the jar represents the atmosphere and all of the gases it contains; the glove's purpose is to produce changes in pressure that model pressure changes in the atmosphere. Students may also suggest that evaporation and condensation will both occur in this system.

Demonstrate the formation of a cloud with the apparatus. As you pull the glove out and release it, ask students to describe the conditions present in the jar that make possible the formation of a cloud. They should recognize that humid air contains water vapor, and adding the smoke provides nuclei for the vapor to condense on when the pressure decreases.

Share with students the following information:

Water is constantly evaporating from oceans, lakes and rivers. In the air the water vapor condenses into very tiny droplets that continue to float. As air and water molecules in the cloud bump into each other they pick up positive or negative charges, and behave like tiny magnets. These charges help hold the cloud together

Clouds are moved primarily by the wind. Wind happens when air moves from an area of high pressure into an area of low pressure. For the most part, clouds are simply carried along by the wind.

Even with no wind, clouds may still be attracted to each other due to their positive and negative static electric charges.

The three main types of clouds are cumulus, stratus and cirrus, but there are many subtypes. Clouds are classified by shape and altitude. We're concerned with just five kinds.

- Cirrus are high wispy clouds made up of ice crystals. Cirrostratus and cirrocumulus are types of cirrus clouds.

- Cumulus clouds are bright white, fluffy and round. They indicate fair weather. Over time they may develop into storm clouds. Altocumulus and stratocumulus are just cumulus clouds at higher altitudes with a greater potential to bring bad weather.

- Cumulonimbus clouds are thunderclouds. They are sometimes called thunderheads and are known by their anvil like shapes. These clouds are often accompanied by high winds, thunder and lightning. Think of them as "super" cumulus clouds.

- Stratus clouds are thick, gray, low-altitude layers that usually bring light rain or fog. They like to spread outward in sheets and sometimes cover higher ground.

- Nimbostratus clouds are low altitude versions of stratus clouds. They often mean bad weather such as fog, snow, or rain

Direct students to “Thinking About the Question.”

Direct students to “Investigating the Question.”

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Assemble the cloud-forming apparatus as follows:

  a. Pour enough warm tap water into the gallon jar to cover the bottom of the jar to a depth of about 2 centimeters. Add one or two drops of food dye to the water so students can see it.

  b. Position the glove, fingers down, inside the jar, using the open end of the glove over the mouth of the jar to seal it.

  c. When you perform the demonstration, you will place your hand into the glove and pull it quickly up and outward without disturbing the jar's seal. Practice this to make sure you can do it without breaking the seal. Nothing should happen inside the jar, because not all of the necessary conditions exist for cloud formation. Next, remove the glove, drop a lit match into the jar, and reseal the jar with the glove (this provides smoke particles on which the water vapor can coalesce). Pull rapidly outward on the glove again. A "cloud" forms inside the jar when you pull the glove outward and disappears again when you let the glove snap back. You will be able to repeat the cloud formation process several times again before the smoke particles settle and you need to drop in another lit match. For better visualization of the "cloud" in the jar, shine the beam of a laser pointer through the jar; when the cloud is present students will be able to see the beam of light because the particles reflect and scatter it. When the cloud evaporates, the beam will no longer be visible.

- Ensure relevant information on cloud types is available including photographic images.
- This lab will need to be conducted over a period of time (a week at an absolute minimum) to ensure students actually view different types of cloud and associated weather conditions. It may be set up as a lab over a period of a semester and actually become an independent research assignment.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Supervise students according to school policy when they are outdoors.

Driving Question

Can we observe and record the changing patterns of clouds during varying weather conditions?

Thinking about the Question

Discuss with the members of your group the following questions. Be prepared to share your thoughts with the class.

What is weather?

> Students should suggest that weather is how the atmosphere behaves in the short term, and can change over relatively small amounts of time, from months and days to minutes. Students may be familiar with the saying "Climate is what you expect, and weather is what you get." Students should suggest that weather is usually described by such data as temperature, precipitation, wind, atmospheric pressure, cloudiness, and humidity.

What are clouds?

> Clouds are visible bunches of water droplets or frozen ice crystals in the atmosphere.

What conditions do we need for the creation of clouds?

> In order for clouds to form there needs to be humid air that is cooling to the point that the water vapor condenses to form droplets of liquid water or ice crystals. There also need to be nucleation particles on which the vapor can coalesce.

How are clouds classified?

> Clouds are classified based upon their altitude or height, and their shape and texture - whether they are puffy or flat. The three main types of clouds are cirrus, stratus, and cumulus.

What weather conditions are associated with different clouds?

> Cirrus clouds form at altitudes where the air is so cold that the particles are ice; these clouds can be seen on sunny days and do not produce rain. Stratus clouds may spread out over the sky because they are formed from condensing water vapor at the same altitude that the air has stopped rising. They are associated with gray, overcast skies and may produce rainfall, often steadily for days on end. Cumulus clouds are associated with the rising of warm air, often on hot summer afternoons. If these clouds produce precipitation, they are often accompanied by lightning and thunder, and sometimes intense hail storms.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

3	2	5	4	1
Observe a quarter of the sky and make an accurate sketch of the cloud cover.	Familiarize yourself with the four cardinal directions of the compass so you can choose a quarter of the sky to observe.	Calculate the percentage of cloud cover in your quarter of the sky.	Place graph paper over your cloud sketch to count the number of squares covered by clouds.	Make certain each lab group member is aware of safety rules and procedures for this lab.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

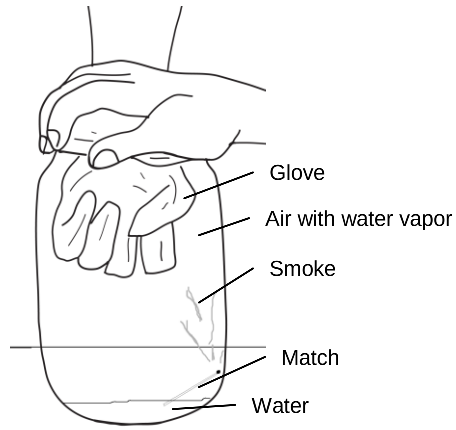
1. ☐ Predict how the relative humidity, temperature, and barometric pressure will change between a sunny day and a cloudy day.

   Answers will vary. One student group answered as follows: We predict that on the sunny day the temperature and barometric pressure will be higher, but the humidity will be lower, and on the cloudy day the temperature and barometric pressure will be lower but the humidity will be higher.

2. ☐ Predict what types of clouds you will see on a cold, dry day compared to a windy, rainy day.

   Answers will vary. One student group answered as follows: We predict that on the cold dry day we would see no clouds at all, or cirrus clouds. On a windy, rainy day we predict that the clouds would be both cumulonimbus and nimbostratus.

3. ☐ Draw a labeled diagram showing the cloud-forming demonstration. Label each part of the apparatus and include a brief explanation of how it works.



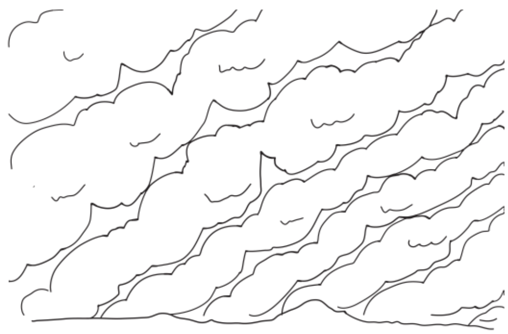
The air inside the jar contains water in the form of vapor, zooming around without sticking together. When the teacher pulled the glove up, the air inside the jar expanded and the pressure and temperature dropped. The water vapor condensed and clumped around the smoke particles until they made droplets that were big enough to be seen, and that is when we called it a cloud.

Part 2 – Cloud Types and Cloud Coverage

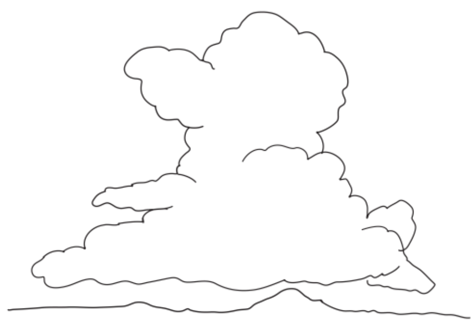
4. ☐ Draw sketches to show each of the clouds described below.

   a. Altocumulus: Thick blue-gray blanket-like clouds made of ice and water at middle heights. Rain or snow likely or at least, cloudy skies.

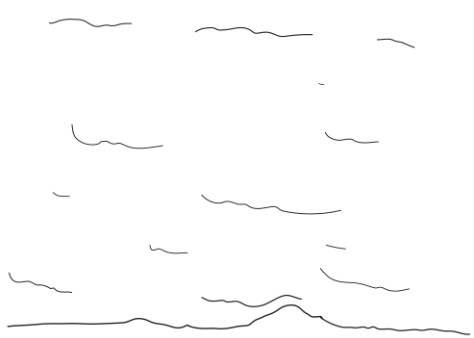
b. Stratocumulus: Dark, heavy water-droplet clouds at low or lower middle heights. Rain or snow very likely.



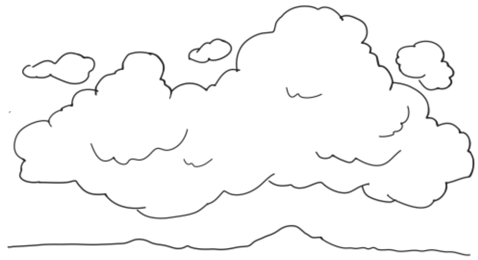
c. Cumulonimbus: Giant thunderhead clouds that tower to high heights. Thunderstorms with heavy rain, hail, winds, and lightning are on the way.



d. Stratus: Flat layer of low clouds. Light rain, drizzle, or flurries likely, overcast skies at best.



e. Cumulus: Fluffy lower clouds that often “grow” during sunny days. Usually mean fair weather unless they grow tall late in the day.



f. Cirrus: High wispy ice clouds. Often seen in clear skies and mean good weather, but can mean a change in the weather!

5. ☐ Select a viewing direction; that is, North, South, East or West. Take photos or sketch the clouds you can see in your quarter of the sky.

6. ☐ Place a piece of graph paper over the cloud sketch and count the number of squares that are covered by cloud. Calculate the percentage of cloud cover.

Total squares divided by squares covered X 100 = % cloud cover

Answers will vary. One student group answered as follows: Our graph paper has 18 by 24, or 432 squares on it. Of these, 215 squares are covered by clouds we sketched.

$$\frac{215\text{squares}}{432\text{squares}} \times 100 = 49.8\%$$

In our quarter of the sky we have almost 50% of it covered by clouds.

7. ☐ Consider both the type of clouds you observed and the percentage of cloud coverage you calculated. Based on this evidence, predict whether or not there will be precipitation within the next 24 hours.

Answers will vary. One student group answered as follows: Although much of the sky is covered with clouds, they are mostly cirrus clouds. Based on this, we predict that no precipitation will fall within the next 24 hours.

Part 3 – Observing Clouds

8. ☐ Over a period of at least one week, observe cloud cover and record weather conditions for particular clouds in Table 1. You may use the summary and descriptions below as a reference for cloud types. Each day during your period of observation, carry out the following procedure to measure weather data:

   a. Start a new experiment on the data collection system. �(1.2)

   b. Connect a weather sensor to the data collection system. �(2.1)

   c. Change the sampling rate to take one measurement twice each minute (every 30 seconds). �(5.1)

   d. Display Wind Speed, Air Pressure, Relative Humidity, Dew Point, and Temperature in a table. �(7.2.1)

   e. Record data for five minutes, then stop data recording. �(6.2)

Abbreviated cloud summary and description

Type	Description
Cirrus	Very high, white, wispy
Cirrocumulus	Very high, white, separate, small, heaped
Cirrostratus	Very high, white, wispy, form a halo around the sun
Altostratus	High, white, layers, sun only faintly seen
Nimbostratus	Low, dark, heavy rain
Stratus	Low, white, no rain
Altocumulus	High, heaped
Cumulonimbus	Low to high, vertical, dark, rain
Cumulus	Low, white, fluffy, heaped
Stratocumulus	Low, dark, heaped

Table 1: Cloud cover and weather conditions

Observations Location and Time	Cloud type	Cloud cover (%)	Wind Speed	Barometric Pressure	Rainfall	Relative Humidity (%) and Dew Point (°C)	Temp (°C)

Answering the Question

Analysis

1. Look over your data and observations. What patterns have you observed in the relationship between cloud cover, temperature, dew point, and relative humidity?

   Answers will vary. One student group answered as follows: We have noticed that on days where we saw cumulonimbus, stratus, or nimbostratus clouds, the relative humidity was higher than on days where there were no clouds or on days where there were only cirrus clouds. We also noticed that cloud cover does not automatically mean that the temperature will be lower. At least two of our cloudy days were warmer than the sunny days.

2. Review your data and observations. Is there any relationship between wind, cloud cover, and barometric pressure?

We noticed on two of the sunny, clear days when the wind was blowing, the weather changed and became cloudy before the end of the day. The wind would begin to blow before we observed clouds, but the clouds began to appear within no longer than 12 hours after the wind was measured. What we noticed for both storms we observed during our experiment, was that the wind blew the hardest when the clouds and storm were arriving, but once the rain had started and had been falling for about an hour, the wind had died down.

3. What patterns have you observed in the relationship between cloud cover, cloud type, and barometric pressure?

Answers will vary. One student group answered as follows: We noticed that there is a connection between cloud cover and a lower barometric pressure, mainly for clouds that will bring rain. On days where there were cumulonimbus or nimbostratus clouds, the pressure was lower than days where there were cirrus clouds or no clouds at all. On days where there were no clouds, the pressure was the highest.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. The word nimbus, or the prefix nimbo-, refers to:

   A. The altitude at which a cloud may exist
   B. Any type of cloud that precipitates
   C. A particular texture observed in clouds

2. Which type of cloud will most likely bring rain?

   A. Cumulonimbus
   B. Cirrus
   C. Altostratus

3. Clouds are made of:

   A. Droplets of water or small crystals of ice that cling together in the atmosphere
   B. Water molecules that exist in the gas phase
   C. Carbon dioxide in liquid and solid phases

4. Masses of warm air that rise to great heights and allow water vapor to condense as it rises often form:

   A. Cirrus clouds
   B. Stratus clouds
   C. Cumulus clouds

5. Which stage of the water cycle results in water vapor being added to the atmosphere?

   A. Condensation
   B. Precipitation
   C. Evaporation

6. What weather data would most likely be recorded on a day where you observe cirrus clouds drifting slowly across the sky?

A. Lower pressure, higher relative humidity, strong wind
B. Higher pressure, lower relative humidity, no wind
C. Higher pressure, extremely high relative humidity, no wind

7. Meteorologists and earth scientists refer to the amount of water vapor in the air compared to the maximum it can hold at a particular temperature as:

A. Dew point
B. Evaporation
C. Relative humidity

8. Static electricity helps in the formation of clouds by:

A. Causing small particles to acquire positive or negative charges that then make them attracted to particles of opposite charges
B. Causing water molecules in the gas phase to change phase and become liquid
C. Causing small movements in the air which in turn cause the larger movements we call wind

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___ 1. All three phases of the water cycle can occur simultaneously.

___T___ 2. The presence of wind is one indication of a difference in pressure between two regions of the atmosphere.

___F___ 3. Cloud classification is based entirely on whether or not precipitation will occur.

___T___ 4. Precipitation can only occur when water vapor condenses and forms droplets heavy enough to fall back to the earth.

___F___ 5. Cirrus and cirrostratus clouds almost always precipitate.

Further Investigations

Research cloud seeding and its impact upon the weather

Research to find out what a "rain shadow" is and where some rain shadows are located.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

9. Seasons

What Makes Us Fall Into Winter?

Objectives

In this activity, students investigate the relationship between the earth's tilt on its axis, its revolution around the sun, and the seasons while they:

- Measure the intensity of light that reaches the light sensor when the earth's north polar axis is pointed toward the sun and away from the sun
- Interpret information about the amount of sunlight reaching the earth's surface depending on the angle at which the light strikes the surface by exploring a light intensity versus time graph
- Gain skills and confidence in using scientific measurement tools, the light sensor, as well as the graphing capability of a computer to represent and analyze data

Procedural Overview

Students gain experience conducting the following procedures:

- Constructing an accurate paper model of the earth tilted on its axis
- Constructing the equator, the polar axis, the Tropic of Cancer, the Tropic of Capricorn, and the angle of tilt off the polar axis
- Modeling the sun with a flashlight directed at the paper model of the earth
- Modeling the seasons by varying the earth's position relative to the flashlight to represent two of the four important dates in the year — September equinox and March equinox
- Positioning the light sensor at the Tropic of Cancer to measure light intensity from the flashlight at the two dates represented
- Recording light intensity as a function of the angle at which it strikes the light sensor

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	25 minutes
■ Lab activity, Part 2 – Making a model of the earth	50 minutes
■ Lab activity, Part 3 – Modeling and measuring the earth's seasons	25 minutes
■ Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Sensor extension cable
- ☐ Flashlight
- ☐ Globe
- ☐ Meter stick or straightedge
- ☐ String, to suspend paper model (~1 m)
- ☐ Sticky tape
- ☐ Marking pens, various colors
- ☐ Protractor
- ☐ Compass[1]
- ☐ Graph paper, 1 sheet
- ☐ Scissors
- ☐ Sheet of tag board, card stock, or construction paper, 12” x 18”

[1]Blackboard compass or string-and-tack method; see Preparation and Tips section for additional notes.

For each student or group:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Flashlight
- ☐ Meter stick or straightedge
- ☐ String, to suspend paper model (~1 m)
- ☐ Sticky tape
- ☐ Marking pens, various colors
- ☐ Protractor
- ☐ Compass[1]
- ☐ Thumbtack or pushpin (optional)
- ☐ Scissors
- ☐ Sheet of tag board, card stock, or construction paper, 12” x 18”

[1]Blackboard compass or string-and-tack method; see Preparation and Tips section for additional notes.

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Basic geometry concepts related to circles, including vocabulary terms such as diameter, radius, arc, cord, and circumference
- Use of a compass to construct circles and a protractor to measure and construct angles
- The equator divides the earth into two hemispheres; in the northern hemisphere there exists the Tropic of Cancer and in the southern hemisphere is the Tropic of Capricorn. Locations on Earth are described by lines of latitude and longitude.
- The earth is tilted on its axis by 23.5 degrees.
- The earth revolves around the sun in an elliptical path, completing one revolution in 365.26 days. This defines our year.
- How to read and interpret a coordinate graph
- Basics of using the data collection system
- Light intensity is measured in lux

Related Labs in This Guide

Prerequisite:

- Night and Day

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

Starting a new experiment on the data collection system �(1.2)

Connecting a sensor to the data collection system �(2.1)

Recording a run of data �(6.2)

Displaying data in a graph �(7.1.1)

Adjusting the scale of a graph �(7.1.2)

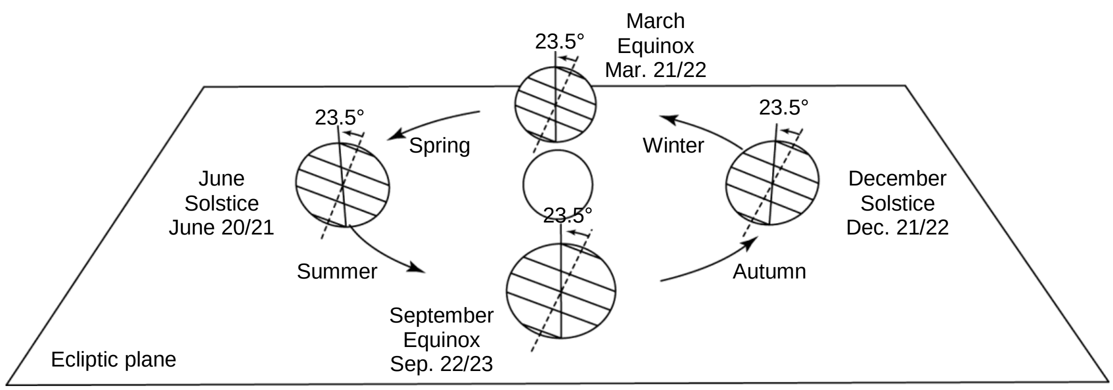
Saving your experiment �(11.1)

Background

The tilt of the earth's axis relative to the ecliptic plane is responsible for our cycle of seasons.

We can think of the ecliptic plane as an imaginary two-dimensional flat surface that intersects with the earth's orbit, or path, around the sun. On this plane, the earth's axis is not perpendicular to this surface; it is instead slanted at an angle of approximately 23.5 degrees from the perpendicular. The angle of Earth's axis relative to the ecliptic plane and the North Star on the two equinoxes and two solstices (as well as every point in the path around the sun) remains constant. The relative position of the earth's axis to the sun *does* change during this cycle. This situation is responsible for the yearly variation in the height of the sun above the horizon. It is also the cause of the seasons, because it results in the variation in the intensity and duration of sunlight received by locations on the earth.

At any given time one-half of the earth is illuminated by sunlight. During the two equinoxes the circle of illumination cuts through the North Pole and the South Pole. On the June solstice, the circle of illumination is tangent to the Arctic Circle (66.5 degrees north latitude) and the part of Earth above this latitude receives 24 hours of daylight. The Arctic Circle receives 24 hours of darkness during the December solstice.



Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Tape a sheet of graph paper to the board. Ask students to predict what shape a flashlight's beam will have when it hits the graph paper straight on. What shape will it have when it hits the graph paper from an angle? How will the angle of the flashlight affect the shape of the patch of light on the graph paper?

> Students should predict that the light striking straight on will make a circle, while the light hitting at an angle will make an ellipse. The greater the angle at which the light strikes the paper, the more "stretched out" the ellipse will appear.

Now shine the flashlight on the graph paper, and allow students to verify their predictions. If necessary, suggest that greater angles of incident light lead to longer ellipses of light. Ask students to consider the amount of light coming out of the flashlight: is it changing, or is it the same each time you shine it on the paper? Call students' attention to how many squares of the graph paper are covered by each patch of light the flashlight makes. Lead students to an understanding that direct light, or light from straight overhead, concentrates all of the light energy into the smallest possible area, while light that arrives at an angle is spread out, so that the same amount of light energy must be "shared" over a greater area. While you hold the flashlight, have a student volunteer mark the outline of each shape with a marker, for reference, when the flashlight is off.

Shine the flashlight on the globe, and ask students if the angle affects the shape of the beam on the globe's surface in a similar way to the graph paper. Students should be able to observe the same characteristic change from a circle to an ellipse on the globe.

Direct students to "Thinking About the Question."

After students have had the opportunity to discuss the seasons in each hemisphere and the Olympic Games, have them discuss the solstices and equinoxes and the seasons for which each date signals the beginning.

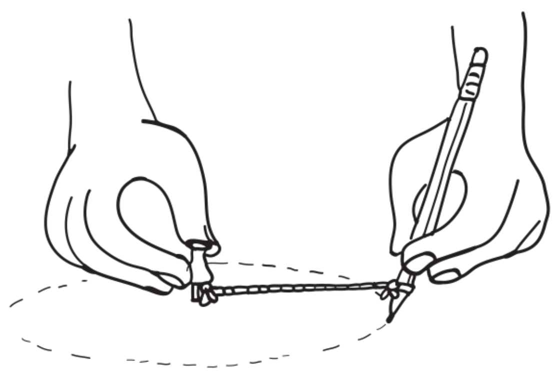
Direct students to "Investigating the Question."

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Make an example of the paper earth model ahead of time to show students so they have an example of how the finished product should look. Have this on display from the beginning of this activity. The paper for this model should be stiff enough to withstand being taped and suspended, but not so stiff that students cannot fold it in half and then in quarters. Paper models should be at least 30 cm (12 inches) in diameter.

- If you do not have access to a blackboard compass, a good way to make a large circle is to use a string tied to a thumbtack, with a pencil tied to the other end of the string, as shown. Students can be shown how to use this method as well.



- If students are unfamiliar with the use of a compass, a protractor, or making straight line segments, demonstrate these skills and allow time for students to practice. Even if students are familiar with the use of the tools, most middle school students have not had enough practice using them. In consequence, they often lack the confidence that comes with practicing and mastering a skill. Offer help and reassurance during this part of the activity.

- In order to get good data, the room will need to be dark. You may need to temporarily cover windows to darken the room adequately.

- Help student groups stand so that their own flashlight is not shining simultaneously on another group's light sensor. If space does not allow it, consider having only one or two groups collecting data at a time, or doing Part 3 of this activity as a demonstration.

- Do not allow students to change the angle or tilt of the axis when recording light intensity data. Make sure they un-tape the light sensor and re-tape it on the other side of the model. This is so any misconceptions are not reinforced. The earth's axis tilt does not vary; it does not shift to point toward or away from the sun. Instead it is the earth's point in its revolution around the sun that causes the tilt to "lean toward" or "lean away from" the sun.

Safety

Add these important safety precautions to your normal laboratory procedures:

- Do not shine any light directly into others' eyes
- Use caution with sharp objects such as scissors and compass points

Driving Question

How does the earth's position in its revolution around the sun give us the seasons?

Thinking about the Question

You have experienced bright, sunny days in the winter as well as in the summer. You have probably noticed, however, that a winter sun is not able to warm you as much as a summer sun. In fact, if you live in a climate that has very cold winters, you may even have observed that the sun can shine on snow and ice all day long without melting it. How is it possible for the sun to shine so brightly, yet give so much less warmth than it does in the summer? The answer lies in the fact that the sun's light strikes the earth at more of an angle in the winter, while in the summer the sun's light strikes the earth more directly.

As you know, the Olympic Winter Games are held every four years, always at a cold, snowy location. Since the Games began in 1924 with the participation of sixteen European and North American countries, they have always been held during the northern hemisphere's winter, usually in February. Likewise, the Summer Games have been held in the northern hemisphere's summer. With only two exceptions, Melbourne, Australia in 1956, and Sydney, Australia in 2000, the Summer Games have been held in the northern hemisphere. Currently, over 200 nations participate in the Olympic Summer Games. What are some of the issues associated with holding the Summer and Winter Games primarily in the northern hemisphere? In your lab group, discuss the following questions:

1. When do countries in the southern hemisphere experience summer and winter?

   Southern hemisphere countries experience summer between the months of December and March, while they experience winter between the months of June and September.

2. If the Summer Games are held in Australia in July, in what season will the athletes compete?

   In Australia in July, it will be winter.

3. When could an alpine nation in the southern hemisphere, such as Argentina or Chile, host the Winter Games?

   A southern hemisphere nation could host the Winter Games during their winter, which is between the months of June and September.

4. How would northern hemisphere athletes be able to train for the Winter Games if they were held in the southern hemisphere?

   Answers will vary. Students should suggest that athletes may have to train at indoor facilities such as ice rinks that are climate-controlled the year round. They may suggest that athletes would have to travel to the southern hemisphere to train for certain events.

During the year, there are four dates that are very special because they divide the year into the four seasons: winter, spring, summer, and autumn. These dates have been known since ancient times, and used to mark and regulate many of our most important human activities, such as planting and harvesting crops, organizing religious festivals, locating compass directions for navigation and for situating certain types of buildings. These dates are the solstices and equinoxes.

You may already know that a solstice occurs in June and again in December, and that the equinoxes occur in March and again in June. Discuss with your lab group members what season begins on each of these dates. Does the same hold true for both hemispheres? Be prepared to share your thoughts with the rest of the class.

> June solstice signals the beginning of summer in the northern hemisphere and of winter in the southern hemisphere. September equinox signals the beginning of autumn in the northern hemisphere, and of spring in the southern hemisphere. December solstice signals the beginning of winter in the northern hemisphere and of summer in the southern hemisphere. March equinox signals the beginning of spring in the northern hemisphere and of autumn in the southern hemisphere.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	4	3	5
Construct a paper circle to represent Earth, using either a compass or a thumbtack and string.	Make sure each lab group member is aware of safety rules and procedures for this lab.	Label each part of the Earth model. Tape a light sensor to the Tropic of Cancer.	Cut out the circle and fold it in half and in fourths to make creases in the paper to represent the equator and the polar axis.	Connect a light sensor to the data collection system. Record light data from the flashlight shining on the Tropic of Cancer.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Write your predictions for the following:

   a. Is it possible to fold a paper circle so that it contains two creases that are at right angels to each other? If so, how could it be done?

   Answers will vary. Students should say that it is possible to make these folds. They should suggest that the circle can be folded in half, creasing it through the center, then that semicircle is folded in half again, forming a quarter-circle.

   b. How will the light intensity change when you shine a flashlight almost straight on to the light sensor compared to shining it at an angle to the light sensor?

   We predict that the light intensity will be highest when we shine the flashlight almost straight on to the light sensor, and not as intense when we shine it at an angle.

Part 2 – Making a model of the earth

In this part of the activity, you will use your geometry math skills to construct a circle, several diameters and chords, and to measure angles.

2. ☐ Using the method your teacher shows you, construct a large circle on your paper. As you work, be sure to mark the center of the circle to use as a landmark for some folds you will make in the following steps.

3. ☐ Cut out the circle. The circle represents the earth.

4. ☐ Fold the circle in half, making sure the fold goes right through the center of the circle. This crease represents Earth's equator. Why is it so important that this fold makes a crease right through the center of the circle?

   The center or the circle is important because we are making a diameter to represent the equator on Earth. The diameter is the longest chord in a circle, and is formed by a segment that connects one point on the circumference to another point on the circumference and intersects the center of the circle.

5. ☐ Fold the circle into quarters, forming a second crease that represents Earth's polar axis, the imaginary line that connects the north and south poles. To make this fold, first fold the circle in half at the equator, then in half again. When you open the circle up, you will have made a crease perpendicular to the equator.

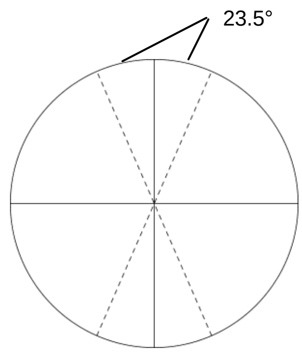
6. ☐ Use a meter stick or straightedge and marking pens to draw in the equator and label it with its name and zero degrees of latitude. Also mark East and West on the appropriate end of the equator.

7. ☐ Draw in and label the polar axis in the same way you did for the equator. Also mark North and South on the appropriate end of the polar axis. The north pole is at 90 degrees of latitude.

8. ☐ Use the protractor to mark an angle of 23.5 degrees off the north pole.

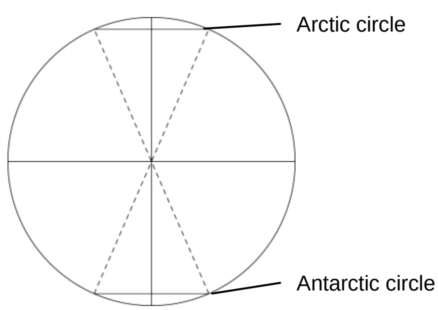
9. ☐ Construct a radius that forms the 23.5 degree angle with the polar axis.

10. ☐ Use the protractor to make three more radii, each forming 23.5 degree angles with the polar axis, to the right and to the left of the north and south poles. Your radii should form an "X" as in the diagram. These radii form diameters, which now represent the degree of Earth's tilt off its polar axis.



11. ☐ Construct a chord that connects the top of the "X." This chord represents the Arctic circle, which is located at 66.5 degrees north latitude. Draw and label the Arctic circle.

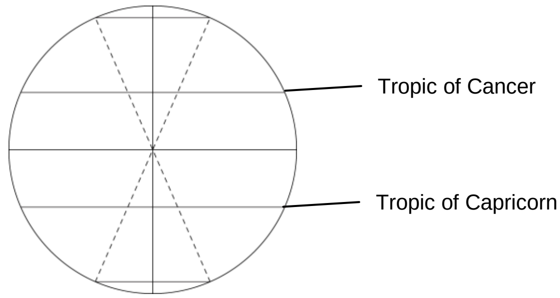
12. ☐ Construct a chord that connects the bottom of the "X." This chord represents the Antarctic circle, which is located at 66.5 degrees south latitude. Draw and label the Antarctic circle.



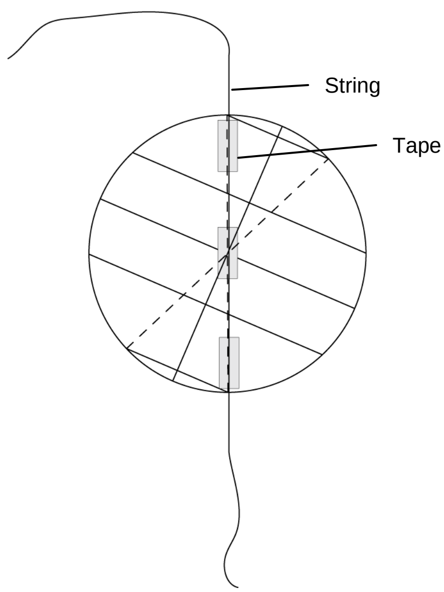
13. ☐ Use the protractor to mark angles that are 23.5 degrees above and below each half of the equator. Do not draw in these radii; make a mark on the circumference of the circle where the radii would intersect.

14. ☐ Construct a chord by connecting the two marks 23.5 degrees above the equator. This chord represents the Tropic of Cancer, which is located at 23.5 degrees north latitude. Draw and label the Tropic of Cancer.

15. ☐ Construct a chord by connecting the two marks 23.5 degrees below the equator. This chord represents the Tropic of Capricorn, which is located at 23.5 degrees south latitude. Draw and label the Tropic of Capricorn.



16. ☐ Tape string carefully along the diameter that connects the *left* side of the Arctic circle to the *right* side of the Antarctic circle. If you let your earth model hang from the string, the north pole should be angled to the right (at about where 1:00 would be on the face of a clock). Attach the string so that it extends beyond the edges of the circle.



Part 3 – Modeling and measuring Earth's seasons

17. ☐ Use tape to attach the light sensor to your earth model, directly on the Tropic of Cancer so that the black opening is even with the circumference. By measuring light intensity on the Tropic of Cancer, which hemisphere are you using as the reference for your seasons?

We are using the northern hemisphere as our reference for the seasons.

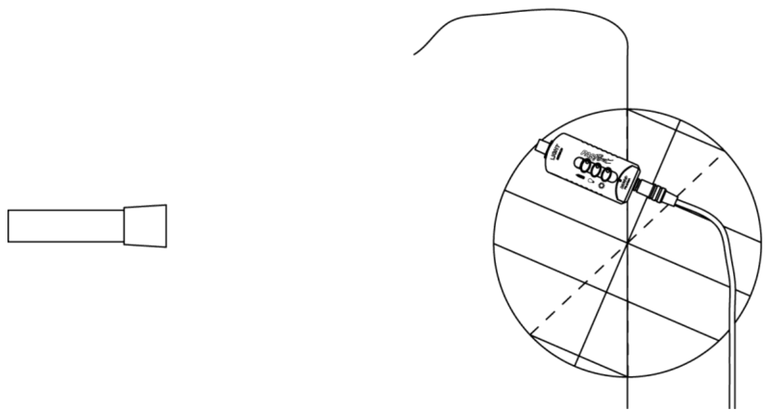
18. ☐ Start a new experiment on the data collection system. �(1.2)

19. ☐ Use the sensor extension cable to connect the light sensor to the data collection system. �(2.1) Select the maximum sensitivity range (0 – 2.6 lux) for the light sensor.

20. ☐ Display Light Intensity on the y-axis of a graph with Time on the x-axis. �(7.1.1)

21. ☐ Hold the earth model by the string, both from the top and the bottom. If necessary, tape your paper earth to the wall or blackboard according to your teacher's instructions. Notice how the axis tilt causes the Tropics of Cancer and Capricorn to be angled.

22. ☐ Model the sun as follows: standing about a meter away from the model, shine a flashlight onto the opening of the light sensor. Be sure to hold the flashlight so its beam is horizontal (parallel to the floor).



23. ☐ Darken the room.

24. ☐ Begin data recording. �(6.2)

25. ☐ After you have recorded between 20 and 40 seconds of light intensity data, stop recording. �(6.2)

26. ☐ Remove the tape from the light sensor. Now tape the light sensor on the Tropic of Cancer pointing in the opposite direction.

27. ☐ Take the model earth around to the opposite side of the sun.

28. ☐ Shine the flashlight onto the opening of the light sensor, as you did before. Hold the flashlight so its beam is horizontal (parallel to the floor), at the same height above the ground as before. Why is it so important to the model that the sun remains in the same place all the time?

Answers will vary. One student group answered as follows: It is important for the sun to stay in the same spot because the sun is the center of the solar system and does not move compared to the planets. The planets, including Earth, all revolve around the sun.

29. ☐ Begin data recording. �(6.2)

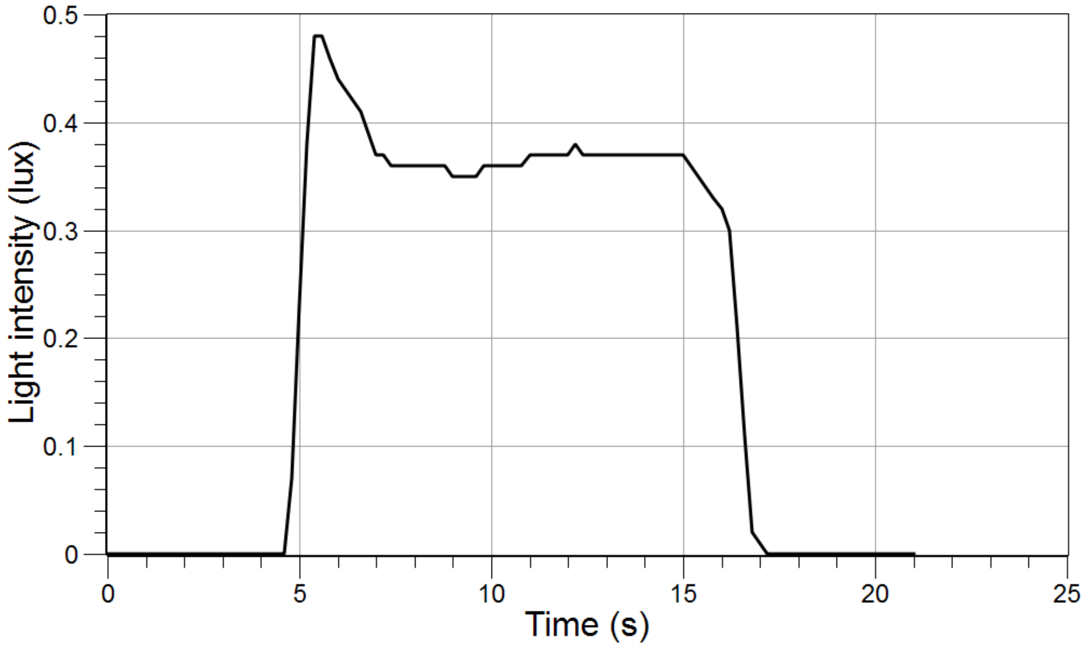
30. ☐ After you have recorded between 20 and 40 seconds of light intensity data, stop recording. �(6.2)

31. ☐ Observe your graph of light intensity data. You may need to adjust the scale of the graph to view all of your data. �(7.1.2) Record your observations below.

We observed that when the light sensor on our Earth was angled up and the north pole was tilted away from the flashlight, the intensity was lower. When the light sensor was angled down and the north pole was tilted toward the sun, the light intensity was higher.

32. ☐ Save your experiment according to your teacher's directions. �(11.1)

Sample Data



Answering the Question

Analysis

1. How did your predictions from Part 1 compare to your results in Part 2?

Answers will vary. One student group answered as follows: We predicted that we could fold our circle in half, then in half again, which worked when we tried it.

2. How did your predictions from Part 1 compare to your results in Part 3?

Answers will vary. One student group answered as follows: We predicted that there would be higher light intensity when the flashlight shines more directly on the light sensor, and lower intensity when the flashlight shines at more of an angle. When we tried this, we found that the results agreed with our predictions.

3. What season were you modeling when the north pole of your paper earth was tilted toward the flashlight? What season was modeled when the north pole was tilted away from the sun?

Summer was the season modeled when the north pole was tilted toward the flashlight. When the north pole was tilted away, it was a model for winter.

4. Review your graph of light intensity versus time. What evidence do you see in your data that different amounts of light energy strike the earth's surface during different seasons?

Answers will vary. One student group answered as follows: We can see from our data that the light intensity from the flashlight is higher when the north pole is tilted toward the sun, and the intensity is less when the north pole is tilted away from the flashlight.

5. Recall the demonstration at the beginning of this lab activity involving the flashlight shining on the graph paper. How does this demonstration relate to the angle of the light hitting the light sensor on you paper earth?

Answers will vary. One student group answered as follows: The angle of the light from the flashlight hitting our earth model is like the shape of the light from the flashlight shining on the graph paper. The more spread out over an area the light is, the less intense it is. The less spread out it is, the more intense it is. Since our model showed tilting toward summer and winter, we think that the same amount of light was spread out over a greater area when our model was tilted with the north pole away from the flashlight, so there was less light for the sensor to record.

6. According to the work you did with your model earth, is it possible for the part of the model above the Arctic circle to receive no light from the flashlight's beam? If so, when is this possible (which season were you modeling at the time)?

Answers will vary. One student group answered as follows: When our Earth's north pole was tilted away from the flashlight, no part of the flashlight's beam could shine on the part at the top of the circle, above where we drew the Arctic circle. At the time, we were modeling winter in the northern hemisphere.

7. Based on your knowledge of geography and of Earth's night and day cycle, where and when does this actually happen?

Answers will vary. One student group answered as follows: The Arctic circle gets 24 hours of darkness during the winter solstice in December.

8. Alaska, in the United States, is often referred to as the "Land of the Midnight Sun." Where on your paper earth would you tape the light sensor to model and record data for this scenario?

Answers will vary. One student group answered as follows: We would tape down our light sensor on the Arctic circle line segment on our earth model.

9. The Tropic of Cancer in the northern hemisphere marks the farthest point north on the earth where the sun's rays strike the earth's surface directly straight on. This happens just once in each year. On which of the four special days (equinoxes or solstices) and at what time in the day does this happen?

Answers will vary. One student group answered as follows: The sun's rays hit the earth directly as far north as the Tropic of Cancer only at noon on the September equinox.

10. Based on earlier class discussion and on your light intensity data, why do you think that the surface of the earth receives more of the sun's light and heat energy in the summer compared to the winter?

Answers will vary. One student group answered as follows: In the summer, the light from the sun strikes the earth more directly, and in the summer the sun's light strikes the earth at more of an angle, so less directly.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below. You may want to look at a globe as you answer these questions.

1 The earth is tilted on its axis by

A. 66.5 degrees
B. 23.5 degrees
C. 90 degrees

2. Farmers in ancient Egypt would have awaited which of these special days to signal the wait for the Nile River's flood and the beginning of the spring planting season?

A. March equinox
B. June solstice
C. September equinox

3. Inhabitants of the ________________________experience winter between June and September.

A. Equatorial region
B. Southern hemisphere
C. Northern hemisphere

4. The Olympic Winter Games are held every four years during ________________________, from the perspective of the inhabitants of the southern hemisphere.

A. The winter
B. The spring
C. The summer

5. Which of the following does *not* actually happen?

A. Earth travels in an elliptical path around the sun every 365 days, causing a regular cycle of summer, autumn, winter, and spring we call the seasons.
B. The axis on which the earth is tilted shifts back and forth to vary the North Pole's angle, creating the seasons.
C. In part of the earth's trip around the sun, the north pole happens to be tilted toward the sun, while in the opposite part of the trip, it happens to be tilted away from the sun.

6. The Tropic of Capricorn is the point farthest south on the earth's surface where

A. The solstices can occur
B. Ancient people would have been able to observe an equinox
C. Light from the sun strikes the earth's surface directly

7. Light from the sun that strikes the earth's surface is less intense when it

   A. Does not spread out at all
   B. Strikes the surface directly
   C. Spreads out over a larger area

8. Organize the following in order from the least amount of the sun's energy to the greatest amount of the sun's energy falling on one location:

   A. June solstice in New Zealand, September equinox in New Zealand, December solstice in New Zealand
   B. June solstice in Canada, September equinox in Canada, December solstice in Canada
   C. December solstice in New Zealand, September equinox in New Zealand, June solstice in New Zealand

9. Which best describes the arrival of spring in the northern hemisphere?

   A. As the earth experiences September equinox its path around the sun brings it closer to having the North Pole tilted directly away from the sun
   B. As the earth experiences March equinox its path around the sun brings it closer to having the North Pole tilted directly toward the sun
   C. As the earth experiences December solstice its path around the sun brings it to the point where the North Pole is tilted directly away from the sun

10. Which statement is *not* accurate?

   A. Rotation refers to the earth spinning on its axis, giving us the regular cycle of night and day
   B. Revolution refers to the earth traveling in an elliptical path or orbit around the sun, giving us the regular cycle of seasons
   C. The terms rotation and revolution refer to the same types of motion found throughout the solar system

Key Term Challenge

Fill in the blanks from the randomly ordered words below. Note that not all of the words may be used:

solstice	equinox	hemispheres	Tropic of Cancer
Tropic of Capricorn	equator	axis	tilt
revolution	orbit	rotation	seasons
poles			

1. A/an ___solstice___ occurs once in June, when the day is longest in the northern hemisphere, and once in December when the day is shortest in the northern hemisphere.

2. The ___equator___ is located at zero degrees latitude, meaning that it is neither north nor south, but exactly in the middle, while the ___poles___ are located at 90 degrees of latitude.

3. On Earth, it takes 365 days to complete one ___revolution___ and to experience all of the seasons, while it takes 24 hours to complete one ___rotation___ and experience a complete cycle of night and day.

4. The ___seasons___ are the result of the earth's tilt on its axis relative to its path around the sun.

5. The earth is divided into two ___hemispheres___ which experience opposite seasons during any given month.

6. At 23.5 degrees of south latitude there is an imaginary line, called the ___Tropic of Capricorn___ on maps, and marking the farthest point south that the sun's rays strike the earth directly.

7. Earth's ___axis___ is tilted by 23.5 degrees, with the result that we experience seasons because the surface of our planet receives sunlight at different angles depending on our path around the sun.

Further Investigations

Investigate how you could redesign this lab to model the seasons in three dimensions instead of two.

Research how Eratosthenes of Cyrene (276 – 195 BC) used the angle of the sun's light striking the earth and his geometry skills to determine the circumference of the earth.

How could you incorporate a temperature sensor into this model for an investigation of the earth's seasons? What type of equipment would you need in addition to a flashlight?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

10. Soil Characteristics

What's the Dirt on Soil pH?

Objectives

In this activity, students learn about soil pH levels while they:

- Compare the acidity or alkalinity of each soil sample to a typical pH range for healthy plants
- Determine the effects of adding substances that adjust pH levels

Procedural Overview

Students gain experience conducting the following procedures:

- Collecting soil samples and prepare them for measuring the soil pH
- Using a pH sensor to investigate the pH of soil samples that they provide
- Relating the pH of the soil to its fitness for growing various crops
- Describing the type of soil particular crops might thrive in, and suggesting methods to alter the soil to improve its usefulness for growing agricultural crops

Time Requirement

Introductory discussion and lab activity, Part 1 – Making predictions	25 minutes
Lab activity, Part 2 – Testing the pH of the soil	25 minutes
Lab activity, Part 3 – Adjusting the pH of the soil (optional; please see Preparation and Tips)	25 minutes
Analysis	25 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ pH sensor
- ☐ Beaker, 250 mL
- ☐ Small digging tool
- ☐ Measuring spoons
- ☐ Re-sealable plastic bags (3)
- ☐ Permanent marker
- ☐ Soil samples, 60 mL (3 different types)
- ☐ Different soil mulches (from the garden store)
- ☐ Gardening sulfur (from garden store), ~5 g each
- ☐ Gardening lime (dolomite or dolomitic limestone)
- ☐ Distilled water, 250 mL
- ☐ pH buffer solutions for sensor calibration

For each student or group:

- ☐ Data collection system
- ☐ pH sensor
- ☐ Beakers, 250 mL (4)
- ☐ Balance
- ☐ Rinse bottle, with distilled water
- ☐ Stirring rod
- ☐ Measuring spoons (optional)
- ☐ Re-sealable plastic bags (3)
- ☐ Permanent marker
- ☐ Soil samples, 60 mL (3 different types)
- ☐ Gardening sulfur (from garden store), ~5 g each
- ☐ Gardening lime (dolomite or dolomitic limestone)
- ☐ Distilled water, 250 mL (for soil samples)

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- How soils are classified, including a basic understanding of soil orders, textures, and colors
- Most organisms function best within a narrow range of pH
- The pH scale has a range of 0 to 14, with 7 being neutral
- A substance with a pH below 7 is classified as an acid, while a substance with a pH above 7 is classified as an alkaline, or base
- The lower the pH, the stronger the acid, and the higher the pH, the stronger the base

Related Labs in This Guide

Labs conceptually related to this one include:

Suggested Prerequisite:

- Introduction to Acids and Bases

Additional related labs:

- Soil Salinity
- Acid Rain and Seed Germination

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system. Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Calibrating the pH sensor �(3.6)
- Monitoring live data �(6.1)
- Displaying data in a digits display �(7.3.1)
- Saving your experiment �(11.1)

Background

Chemically, acids are defined as substances which, when mixed with water, form hydronium ions, H_3O^+. Bases are defined as substances which form hydroxide ions, OH^-, when mixed with water.

To more specifically define an acidic or basic substance, scientists formulated a numerical scale, called a pH scale, to categorize a substance as an acid or base. Numerically, the scale is from 0 to 14, with 7 being the midpoint. Any solution or substance having a pH value of less than 7 is known as an acid and above 7 is considered a base. A pH of 7 is considered neutral.

In agriculture, the pH value of soil is an important consideration for farmers. Particular crops and plants require a specific pH to thrive and produce high yields. Soil pH affects the ability of the soil to release the nutrients in fertilizer.

Blueberries like an acid soil with a pH level below 7. Peas and beans grow best in a more alkaline soil with a pH above 7. Most plants grow best within a pH range of 6.5 to 7.2; however some plants have a tolerance down to about 5.5, while others can tolerate up to 7.5.

If the pH is not close to what these plants require, some nutrients, such as phosphorus, calcium and magnesium, will not be dissolved when the soil is watered. If the nutrients are not dissolved, the plants cannot absorb them. The plants will not grow or produce to their full potential.

Whether it is growing tomatoes in a small garden or soybeans over many hundreds of acres, knowing and maintaining the correct soil pH is a must. To raise the pH of soil (neutralize soil acidity), the best way is to add lime (sold as dolomite, hydrated lime, ground limestone, and mixed lime) to the soil. To reduce the pH of soils (increase soil acidity) organic material (increasing the soil microorganisms) such as peat moss, compost, manure, and sawdust can be added. Additionally, ground rock (elemental) sulfur can be carefully applied to lower soil pH.

Pre-Lab Discussion and Activity

Direct students to "Thinking About the Question."

Mention to students that soil pH affects the ability of the soil to release the nutrients in fertilizer. If the pH level is too high or too low, nutrients are trapped and become unavailable to plants. Display a pH sensor and explain that this sensor can be used to determine the acidity or alkalinity of the soil. If the pH is 7, the soil is neutral. If the pH is less than 7, the soil is acidic. If the pH is greater than 7, the soil is basic.

Model the setup of the apparatus for students. Remind students to remove the plastic cover bottle from the pH sensor prior to its use.

Direct students to "Investigating the Question."

Preparation and Tips

Note: This lab may be shortened or made less challenging if the teacher wishes, by doing Part 1 - Making predictions and Part 2 - Testing the pH of the Soil and omitting Part 3 - Adjusting the pH of the soil.

These are the materials and equipment to set up prior to the lab:

- The day before the lab, ask students to collect a soil sample from their yard, their garden, or some area near their home, to bring in to class. Tell students to collect enough soil to fill a re-sealable plastic sandwich bag. This will allow students to share a portion of their sample with another group, if necessary. Students should be directed to label their soil samples with the location from which they were obtained. They should also be directed to seal the bags, to maintain the moisture content of the samples.

- Collect several different soil samples (sand, silt, and clay) from around home or school as examples for class discussion prior to the activity. Include samples of organic materials such as leaves, twigs, needles; peat moss, vermiculite, and mulch.

- Obtain garden lime and sulfur. These are sold at nurseries and garden stores. The smallest package or container of each will be sufficient. Sulfur often comes in pellet form (pellets the size of lentils); these pellets will need to be crushed or ground up by you prior to the lab.

- Depending on the results of the soil pH testing, students will need to decide if they need sulfur or lime to adjust the pH up or down for Part 3 of the activity. Make these materials available for students at the beginning of Part 3.

- Demonstrate to students how to break up and crush a soil sample in a plastic bag. Students may have difficulty doing this without ripping the bag. Advise students to work over a tray or container of some sort, in case spilled soil needs to be recovered.

- Unless students are experienced at calibration of the pH sensors, and time permits them to do this part of the procedure, calibrate the pH sensors before the lab.[(3.6)] Calibration is an important part of this activity because of the narrow range of pH values which are expected.

Safety

Add these important safety precautions to your normal laboratory procedures:

- Wear safety glasses and lab coats or aprons.
- Wear gloves when handling sulfur and lime.

Driving Question

Why is it important to know the pH of soil?

Thinking about the Question

If you have ever helped plant and care for a garden, you know that plants prefer certain types of soils, and that each type of plant has its own requirements in order to produce the best fruit, or flowers, or leaves.

Most plants thrive within a narrow range of soil pH conditions. If the soil pH is above or below this range, soil conditions may not allow plants to grow ideally. Plants may suffer from poor health in such soil. For example, the roots may be unable to take in the necessary nutrients or anchor the plant properly in the soil, the stems may not be able to grow strong enough, the leaves may not develop fully, and the flowers or fruits may not be able to complete the plants' reproductive cycle. Soil that is too acidic can cause some naturally occurring metals, such as iron, nickel, aluminum, and manganese, to become too concentrated for plants' healthy growth, while also making it difficult for the plants to absorb the phosphorus, calcium, or magnesium that they need to grow properly. This can affect agricultural practices, such as applying fertilizers and pesticides. Because a change in pH can alter the fate of an agricultural crop, pH has become an invaluable tool for measuring soil fitness.

The pH range that crops can tolerate varies. Corn, cucumbers, and cotton may be able to grow in soils as acidic as pH 5.5. Lettuce, beans, and onions won't grow well at all in soil that is more acidic than 6.0. Peanuts, peppers, and strawberries don't grow well in soil that has a pH higher than 6.5. Cabbage, carrots, and spinach prefer pH neutral soil which is neither acidic nor basic.

Some crops can tolerate a wider range of pH than others. For example, potatoes are relatively intolerant of variation, growing best in soil that is acidic, between pH 5.0 and 5.25. Alfalfa on the other hand, which is a crop used to feed livestock and other animals, is relatively tolerant to variations in pH. It can grow in soils that range from pH 5.2 to 7.8.

Discuss with your group members the different ways that gardeners and farmers amend, or improve, the soil for their crops. Be prepared to share your thoughts with the class.

> Students should suggest that farmers and gardeners add fertilizers to the soil, including compost, manure, peat moss, mulch, and other types of organic materials. Depending on the level of exposure to and experience with gardening or agriculture students have, they may already be aware that chemical compounds can be added to the soil to alter the pH, including sulfur or lime.

In this activity you will investigate the pH of different soil samples. You will decide which soils are best suited to which types of plants, and also determine how to change the pH of a soil that is too high or too low.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	4	3	5	1
Remove large particles such as rocks, twigs, and leaves from collected soil samples.	Place soil samples in beakers, and add 60 mL distilled water to each beaker.	Crush soil samples in re-sealable plastic bags.	Use the pH sensor to measure the pH of each soil sample.	Make sure each lab group member is aware of safety rules and procedures for this lab.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Write your predictions for the following:

   a. Which soil samples in your group will be higher in pH (more basic) and which will be lower in pH (more acidic)?

   Answers will vary, depending on the variety of samples collected.

   b. Which soil samples in your class will be higher in pH (more basic) and which will be lower in pH (more acidic)?

   Answers will vary depending on the variety of samples collected.

   c. How will the pH of the soil samples collected by your teacher compare to those contributed by the class?

   Answers will vary. Students may suggest that the samples collected from the teacher's home or from the school will have different pH values than those they collected themselves.

   d. Will it be possible to change soil pH by adding sulfur or lime to the soil?

   Students should suggest that it will be possible to change the pH of soil samples.

Part 2 – Preparing the soil for testing

2. ☐ Label a beaker for each soil sample as you did with the sample bags.

3. ☐ Remove any rocks, sticks, or foreign objects from the sample bags.

4. ☐ Leaving the soil sample inside the bag, crush the soil with your fingers, or if necessary with a digging tool, and mix the crushed particles thoroughly.

5. ☐ Place 10 g (or 2 tablespoons) of the first soil sample in the beaker labeled for that sample.

6. ☐ Add 60 mL of distilled water to the beaker and mix thoroughly with a stirring rod.

7. ☐ Let the soil-water mixture stand for five minutes prior to data recording to allow the particles of the soil to dissociate into ions.

8. ☐ Repeat the steps to prepare the other two soil samples. Why is it important to crush the soil samples before mixing them with distilled water?

   The soil needs to be pulverized to increase the surface area that is available, so when water is added, a representative sample of the minerals in the soil becomes dissolved.

Part 3 – Testing the pH of the soil

9. ☐ Start a new experiment on the data collection system. �[1.2]

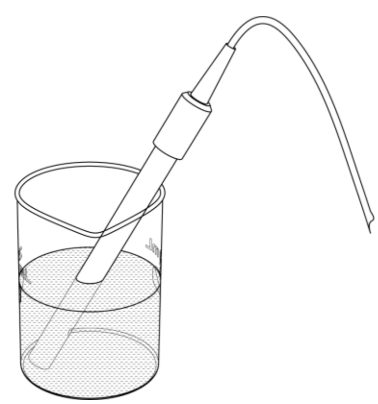
10. ☐ Connect a pH sensor to the data collection system using a sensor extension cable. �[2.1]

11. ☐ Display pH in a digits display. �[7.3.1]

12. ☐ Remove the plastic bottle from the pH electrode, and set the bottle aside.

13. ☐ Using the wash bottle, rinse the pH sensor with distilled water over the empty beaker. This beaker will hold waste rinse-water.

14. ☐ Monitor live data. � [(6.1)]



15. ☐ Lower the sensor into the first soil-water mixture, and gently stir the solution with the sensor during data collection.

16. ☐ Wait for the reading to stabilize (as much as 60 seconds).

17. ☐ Record the pH in Table 1 below.

18. ☐ Remove the sensor and rinse it with distilled water.

19. ☐ Repeat the previous steps for the other two soil samples.

20. ☐ Stop data monitoring. � (6.1)

20. ☐ Mark the pH value on each resealable bag with the permanent marker.

Part 4 – Adjusting the pH of the soil

22. ☐ Select a soil sample that measured outside the 6.5 to 7.2 range of pH. If none of the samples was outside this range, select the sample whose measured pH was farthest from a neutral pH of 7.0. If your goal is to bring this soil sample's pH back to neutral, will you to raise or lower its pH? Which substance will you need to add to the soil sample to achieve this goal?

Answers will vary based on students' results. If pH is above 7.0, students will need to lower the pH by adding sulfur. If pH is below 7.0, students will need to raise the pH by adding lime.

23. ☐ As appropriate, select lime to raise the pH (decrease acidity) or sulfur to lower the pH (increase acidity). Your teacher will make these materials available to you.

Note: Avoid breathing the dust from sulfur or lime as it may cause irritation.

24. ☐ Rinse the sensor with distilled water.

25. ☐ Monitor live data. �(6.1)

26. ☐ Lower the sensor into the soil-water mixture and gently stir the solution with the sensor during data collection.

27. ☐ Wait for the reading to stabilize (as much as 60 seconds).

28. ☐ Add either the lime or sulfur, beginning with 0.2 g (1/8 of a teaspoon) and stirring with the pH sensor until the reading stabilizes.

29. ☐ Continue adding the lime or sulfur in 0.2 gram increments until the soil solution is within the acceptable range of pH. Record the total amount of lime or sulfur added to the soil solution.

Total amount added: 1.6 grams

Substance added: lime

30. ☐ Enter the pH in Table 2 below.

31. ☐ Stop data monitoring. �(6.1)

32. ☐ Remove the sensor and rinse it with distilled water. Replace the sensor in its plastic bottle.

33. ☐ Clean up according to your teacher's instructions.

Table 1: Stabilized pH readings for soil samples

Soil sample and Location	1	2	3
pH	5.3	7.1	6.4

Table 2: pH measurements of soil before and after adjusting mixture with lime or sulfur

Location	**pH before adjusting the mixture**	**pH after adjusting the mixture**	**Substance used to adjust the mixture (lime or sulfur)**	**Amount of substance used**
Sample 1 from Tommy's Back Yard	5.3	6.1	Lime	1.6 g

Answering the Question

Analysis

1. Do you think the soil samples you collected were good for growing plants?

   Answers will vary. Students should relate that samples within the pH range of 6.5 to 7.2 are within the optimal pH range for most plants.

2. What features near your soil collection sites might have influenced the pH of the soil samples?

   Answers will vary. Students may refer to animals or small organisms found in the area. They may refer to man-made features such as asphalt, cement, or gravel. They might say the area is treated with fertilizers.

3. Were you able to adjust the pH of the soils to within the acceptable range? What did the sulfur or lime do to the pH of the soil-water mixtures?

   Answers will vary. For soil samples out of the pH range of 6.5 to 7.2, students should report that adding lime decreased acidity and raised pH and that adding sulfur increased acidity and lowered pH.

4. Can you adjust the pH of a real garden applying the method you used in this activity?

   Answers will vary. Students should suggest that they were applying lime and sulfur, which are examples of techniques used in real gardens.

5. Suppose you are a farmer planning to plant a large field of blueberries. Blueberries grow on bushes that need relatively acidic soil with a pH of 4.5 to 5.5. After careful analysis of the soil in your field, you learn that its pH is 6.5. Will you be able to successfully grow the blueberry crop in this field as it is, or will you need to make changes to the soil? Describe how you would go about preparing this field for planting your blueberry bushes.

   Answers will vary. One student group answered as follows: We could not successfully grow blueberries in this field because its soil is not acidic enough. The soil actually is acidic, because its pH is below 7, which is neutral on the pH scale. However, it needs to be even lower for blueberry bushes to grow well. We would lower the pH of the soil in this field, to make it more acidic, by adding sulfur to it. Since it is a big field, the sulfur would probably need to be added by a tractor.

6. Some gardeners have compost bins or piles to which they add plant clippings, wood chips, and such kitchen scraps as fruit and vegetable peelings and rinds, and even egg shells. Over a few weeks, this material breaks down into a healthy additive for garden soil. Given that egg shells contain calcium carbonate, a key ingredient in garden lime, why might a gardener choose to include more or fewer egg shells in her compost? Explain your reasoning.

Answers will vary. One student group answered as follows: If the gardener needed to make her soil less acidic, she would want more egg shells in her compost bin because that would add more lime to the compost mix which would raise the pH of the compost she plans to put in her garden. If the garden's soil was not acidic enough for the crop, she would not want to add as many egg shells to her compost, or maybe even no egg shells at all.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. When a substance has a pH of 3.7, it is classified as a/an

   A. Neutral substance
   B. Acid
   C. Base

2. Farmers and gardeners need to know the pH of soil in which they grow crops because

   A. Different types of plants have different tolerances for acidic or basic soil
   B. Changes in pH can affect only certain types of crops
   C. Neutralizing acidic soil is important to all crops grown for our food supply.

3. Plants absorb nutrients available in the soil by taking them in through

   A. Photosynthesis
   B. Their leaves
   C. Their roots

4. Which of the following could be caused by a fruit-bearing plant's soil being too basic or alkaline for the plant?

   A. A greater than average number of fruits on the plant
   B. Poor production of fruits
   C. Abundant leaves that appear green and healthy

5. Which of the following is a likely result of adjusting the pH of a garden's soil so it is within the preference of the plants to be grown?

   A. A harvest of fruits or vegetables that is at least average and possibly above average
   B. A failure of the plants to produce fruits or vegetables
   C. Leaves and stems that are yellowish rather than green, indicating that they are unhealthy

6. When testing the pH of a soil sample with the pH sensor, it is necessary to mix the sample with distilled water

A. In case the pH sensor has not been removed from its plastic bottle
B. So that the pH measured is the pH of *only* the water
C. Because the pH sensor cannot measure pH in a dry material

7. Which statement is true about using the pH sensor to test the pH of soil samples?

A. The large parts of a soil sample such as rocks, twigs, or leaves are necessary for the soil's pH to be measured by the pH sensor.
B. The pH of a dry soil sample can be measured as well as a sample that has been added to water.
C. It is important to crush the soil sample so that minerals contained in the sample can dissolve in water.

8. Farmers who produce large crops that provide food for many people analyze the pH of the soil in which they grow crops because

A. This information is helpful during times of drought or water shortage
B. pH is a good indicator of the soil's fitness for a particular crop
C. Potatoes tolerate only a very narrow pH variation in their soil

9. A crop such as blueberries, which needs an acidic soil, would *not* grow well in a field whose soil pH is between

A. 4.5 and 5.5
B. 5.0 and 5.3
C. 6.0 and 6.5

10. A crop such as alfalfa, which tolerates a wider variation of soil pH, would probably grow well in every field *except* one whose soil has a pH of

A. 9.4
B. 7.1
C. 5.8

Further Investigations

Investigate the acceptable pH range for specific types of vegetables (cabbage, tomatoes, and such). Adjust a pot of soil for the correct pH and grow your vegetables.

Investigate the acceptable pH range for specific types of flowers (azaleas, roses, and such). Adjust a pot of soil for the correct pH and grow your flowers.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

11. Soil Salinity

Let the Radish Decide

Objectives

In this activity, students will:

- Become familiar with the way salt levels can vary within an ecosystem
- Measure the conductivity of different soil and water samples
- Gain skills and confidence in using a scientific measurement tool, the conductivity sensor, as well as the graphing capability of a computer to represent and analyze data

Procedural Overview

Students gain experience conducting the following procedures:

- Collecting and labeling soil and water samples gathered from the local ecosystem
- Setting up the equipment and work area to measure the level of conductivity in different solutions
- Measuring the conductivity levels of various water and soil samples

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	25 minutes
■ Lab activity, Part 2 – Testing the water samples	25 minutes
■ Lab activity, Part 3 – Testing the soil samples	25 minutes
■ Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Conductivity sensor
- ☐ Test tube
- ☐ Beaker, 250-mL
- ☐ Test tube stopper
- ☐ Soil sample
- ☐ Radish seeds, 1 packet
- ☐ Paper towels for seed germination (2 to 4)
- ☐ Water
- ☐ Plastic bags (2)
- ☐ Distilled water, 25 mL
- ☐ Wash bottle with distilled water

- ☐ Salt, 2 to 4 Tbsp.

For each student or group:

- ☐ Data collection system
- ☐ Conductivity sensor
- ☐ Graduated cylinder, 25- or 50-mL
- ☐ Beaker, 250-mL
- ☐ Test tubes (8)
- ☐ Test tube stoppers (4)
- ☐ Water samples from different locations (3)
- ☐ Soil samples (4)
- ☐ Distilled water, 100 mL
- ☐ Paper towels, for spills
- ☐ Wash bottle with distilled water
- ☐ Small funnel

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Soil characteristics
- The meaning of solution and mixture
- Distilled water is a very pure form of water because it is made by heating water then capturing the condensed steam, which leaves behind most substances that were dissolved in it
- The rock cycle, the water cycle, and their inter-relationship
- Process skills such as using measuring beakers and test tubes, and with the set up of lab apparatus including how to place a stopper in the mouth of a test tube to seal it
- How to read and interpret a simple coordinate graph
- The basics of using the data collection system, ideally having done the lab Water, the Universal Solvent as a prerequisite to this activity

Related Labs in This Guide

Prerequisite:

- Water, the Universal Solvent

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)

- Setting up a conductivity sensor for a particular sensitivity �(4.2)
- Monitoring live data �(6.1)
- Displaying data in a digits display �(7.3.1)

Background

Soil and fresh water salinity is a massive problem. Salinity is hard to comprehend and harder still to stop. There is salt everywhere, mostly located underground. It has built up over many thousands of years, originating from the weathering of rock minerals or the simple act of sea salt dropping via rain or wind.

Increases in salinity levels in our soil and fresh water reserves are continuing to cause concern to governments and environmentalists throughout the world. It is a tragic irony that the felling of many billions of trees to make room for farming and led to prosperity in many countries worldwide has caused an environmental crisis, destroying a natural balance that existed for millennia.

Farmers and scientists are declaring for the first time that there are no practical answers yet. The problems are complex and systemic, and go well beyond agriculture. Dryland salinity also causes serious damage downstream from where the clearing occurred. Aquatic ecosystems are suffering, as is biodiversity and urban infrastructure as saline groundwater rises in country towns and attacks foundations, roads, and bridges.

Increased farming and irrigation has introduced a new variable into the water cycle increasing the amount of water passing through soils as well as the rate that salts are moved. In addition, changing climate and high evaporation rates have severely changed many natural ecosystems, especially in terms of salt levels within soils and underground water reserves.

Rivers, creeks, and ponds also suffer from increased salinity as related to increased use of land for agriculture and urban development. Many of our agricultural systems are unsustainable. They "leak" not only water but also nutrients, and we do not yet know how to design new systems that will capture the water and nutrients in the way that natural ecosystems do.

To assess the level and severity of salt concentration in soils and water, scientists take conductivity measurements to measure the quality of soils and water. A conductivity sensor measures a solution's ability to conduct electrical current. As the concentration of salt increases in a solution, the measure of conductivity also increases. High levels of salinity in soil can cause yellowing or browning of leaves, leaf drop, root death, wilting, and nutrient deficiency symptoms. Evaluating the conductivity capacity of a soil can help determine whether it is suitable to support plant growth.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Have students examine the radish seeds that you have prepared for this activity. Ask students if they can tell which of these seeds appear to have successfully germinated? Is it possible to tell if the seeds are healthy? Which seeds have grown the most or have the longest roots? Are any leaves evident, and if so, from which sample are they?

Answers will vary based on the results of the radish seed germination. Students should be able to observe and suggest that the seeds soaked in fresh (tap) water germinated and are growing in a healthy fashion, while those soaked in salt water may not all have germinated, and may have shorter roots, fewer leaves, or none at all. Students may suggest that the number of sprouts in the fresh water sample is larger than the number of sprouts in the salt water sample.

Direct the students to “Thinking About the Question.”

Show students how to place a soil sample into a test tube, add 25 mL of distilled water to it, place the stopper in the test tube, and mix the soil and water. Ask students why it is important to add the water to the soil, and why the water needs to be distilled instead of supplied from the tap.

The conductivity sensor can only measure the conductivity of solutions, not solids, so water has to be added. We need to use distilled water rather than tap water because the tap water itself may have dissolved solids which affect the conductivity level. This would introduce another variable into the experiment.

Show students how to rinse the conductivity sensor between measurements, using the wash bottle and a beaker.

Direct the students to “Investigating the Question.”

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- At least one week before the lab, obtain a packet of radish seeds. Soak ten radish seeds in tap water for an hour, and another ten seeds in a saturated solution of salt water for an hour. To make the saturated solution, mix table salt into room temperature tap water in a 250-mL beaker until no more salt will dissolve. Place each of the ten seeds soaked in fresh water onto a dry paper towel, and moisten the paper towel with fresh water. Do the same for the ten seeds soaked in salt water, but moisten their paper towel with salt water. Label each sample set of radish seeds to indicate whether they were soaked in fresh or salt water. Place the moistened paper towels containing the seeds into plastic bags so they will not dry out. Allow the seeds to germinate, which will take approximately 3 to 5 days. Check to make sure that the seeds and their paper towels remain moist for the entire period.

- Ask students to collect and bring in water samples from their homes, yards, or surroundings. Each student group should have three water samples; students may share one another's samples, or you may instruct them to collect more than one sample from different locations around their home or local area. The volume of water collected for each sample should be at least 100 mL. Students may use clean glass or plastic containers recycled from their homes. Instruct students to label each sample with an accurate description of its location.

- Ask students to collect and bring in soil samples from their yard or from the surroundings in their local area. If possible, encourage students to gather soil samples from a wide variety of locations. The amount of soil collected for each sample should be about 50 mL, or 1/4 of a cup. Students may use plastic resealable bags, plastic containers, or even paper bags for their soil samples. Instruct students to label each sample with an accurate description of its location.

- If students do not have access to locations from which to collect soil and water samples, then provide samples of each for each lab group.

- When collecting water samples it is best to take them from different locations in terms of the water flow and amount of vegetation within the aquatic ecosystem.

- Students may need guidance in selecting the appropriate sensitivity range for their conductivity sensor.

Safety

Add these important safety precautions to your normal laboratory procedures:

- Wear aprons to protect clothes
- Use gloves if you have a cut or break in your skin
- Wash your hands with soap and water after this activity

Driving Question

What impact can increased salinity have upon ecosystems?

Thinking about the Question

You may have read or seen movies about characters stranded on desert islands, who now must survive by their wits and skills. In such scenarios, it is always important for the character to find a source of fresh water, even when the ocean and all of its water is right there. Why can the stranded person not just drink the salt water?

> Students may suggest that the salty ocean water does not taste good, or that it would make a person sick. Students may also suggest that too much salt is unhealthy.

Discuss with your lab group members how you can tell that salt has been dissolved in water.

> Answers will vary. Students may suggest that if they were allowed to taste the sample they would be able to discern the salty taste. They may say that salt water may perhaps appear less clear than fresh water if a large amount of salt is dissolved in it. Some students may suggest that the density of salt water is greater than that of fresh water, and so an object would float differently in the different samples. If students have used the conductivity sensor in a previous lab, they should be able to suggest that a higher conductivity measurement indicates more dissolved solids or electrolytes in the water, and that these electrolytes may be the sodium and chloride ions from the dissolved salt.

The amount of dissolved salt, or the "saltiness" of water or soil is known as salinity. Why should we be concerned about salinity levels in our soils and water systems?

> Answers will vary. Students should suggest that high salinity levels are unhealthy for people and animals and that plants do not thrive in salty conditions. If salinity levels were to rise in our water system and our soils, our ability to provide for our most basic needs of food and water would be compromised.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

5	2	3	4	1
Place a stopper in the test tube to seal it, and shake to mix the soil and distilled water.	Collect and label water and soil samples.	Remove sticks, rocks, and other large particles from the soil samples.	Place each soil sample in a test tube and add distilled water to the soil.	Make sure each lab group member is aware of the safety rules and procedures for this lab.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Write your predictions for the following:

   a. Ocean water generally has a conductivity of about 53,000 µS/cm. Predict which, if any, of your water or soil samples will have a conductivity close to that of ocean water.

   Predictions will vary. Students should predict that none of their samples will have a conductivity resembling that of ocean water unless they collected samples from the ocean.

   b. Predict how the conductivity of your soil samples will differ from the conductivity of your water samples.

   Predictions will vary. Students may predict that the conductivity of the soil samples will be greater than the water if they have been collected from areas that were fertilized or polluted.

Part 2 – Testing the water samples

2. ☐ Identify each sample of water according to its origin. Label the test tubes "A", "B", "C", and "D". Fill test tubes A, B, and C about half full; fill each with a different water sample. Fill test tube D about half full with distilled water.

3. ☐ Start a new experiment on the data collection system. �[(1.2)]

4. ☐ Connect a conductivity sensor to the data collection system. �(2.1) Select the appropriate range of sensitivity for the conductivity sensor. �(4.2)

5. ☐ Display Conductivity in a digits display. �(7.3.1)

6. ☐ Insert the conductivity sensor into test tube A and monitor in the digits display without recording. �(6.1)

7. ☐ When the reading has stabilized, record the conductivity in Table 1 below.

8. ☐ Rinse the conductivity sensor with distilled water, using the wash bottle and beaker.

9. ☐ Repeat these conductivity test steps for the other three water samples and record the results in Table 1.

Table 1: Water sample conductivity

	Test Tube A	**Test Tube B**	**Test Tube C**	**Test Tube D**
Conductivity (µS/cm)	153	191	58	11

Part 3 – Testing the soil samples

10. ☐ Carefully remove any large particles from the soil samples including sticks, twigs, leaves, or rocks.

11. ☐ Place 1/2 teaspoon of each soil sample in separate test tubes, using the funnel if necessary. Label the test tubes "1", "2", "3", and "4".

12. ☐ Add 25 mL of distilled water to each test tube.

13. ☐ Place a stopper into each test tube and shake gently.

14. ☐ Remove the stopper from test tube 1 and insert the conductivity sensor. Make sure that you have selected the appropriate range for the conductivity sensor. �(4.2) Monitor conductivity in the digits display without recording. �(6.1)

15. ☐ When the reading has stabilized, record the conductivity in Table 2 below.

16. ☐ Rinse the conductivity sensor with distilled water, using the wash bottle.

17. ☐ Repeat these conductivity test steps for the other three soil samples and record the results in Table 2.

Table 2: Soil sample conductivity

	Test Tube 1	Test Tube 2	Test Tube 3	Test Tube 4
Conductivity (μS/cm)	121	65	44	82

Answering the Question

Analysis

1. How did your predictions from Part 1 compare to the results in Parts 2 and 3?

   Answers will vary. One student group answered as follows: None of our samples had conductivity measurements as high as for ocean water, which agreed with our predictions.

2. The conductivity sensor measures a solution's ability to conduct electrical current. How is conductivity related to the salinity of a solution?

   Answers will vary. One student group answered as follows: When salt is dissolved in water, water is able to conduct electricity. The more salt is dissolved, the more easily the solution can conduct electricity, so a higher conductivity measurement means a higher concentration of salt is dissolved in the water.

3. Why did you measure the conductivity of distilled water? What is the purpose of this sample in the experiment?

   Answers will vary. One student group answered as follows: We measured the conductivity of distilled water because it is almost pure water. It should not have any dissolved salt or any other solids in it. This sample could be our basis for comparison or the control in our experiment.

4. What factors do you think contributed to your findings?

   Answers will vary. One student group answered as follows: Our soil and water samples that had the highest conductivity each came from the creek just after a rainfall. We think that the run-off water that flowed into the creek contributed to the higher conductivity because it added more dissolved solids from the streets, parking lots, and fields to the water. We gathered our sandy soil from the bank of the creek, where it was moist.

5. What relationship is there between soil salinity and water salinity?

   Answers will vary. One student group answered as follows: If soil is watered or irrigated with salty water, the salt in the water will increase the salinity of the soil. Also, if water flows across or through salty soil, then the water itself will increase in salinity. Since salt dissolves so easily in water, salt can be carried around an ecosystem by water.

6. How will salinity impact the health of an ecosystem?

   Answers will vary. One student group answered as follows: Any ecosystem could suffer from too high of a salinity level for the organisms that live there. Plants and animals need the correct level of salt in their water and soil, but not too much. If the salinity of an ecosystem increases too much, organisms could die.

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___1. The conductivity sensor measures the ability of a solution to conduct an electrical current.

___T___2. The unit in which conductivity is measured is the microsiemens per centimeter, abbreviated µS/cm.

___T___3. Water is able to dissolve many different types of solids, including salts.

___F___4. The higher the conductivity measurement, the lower the concentration of dissolved salts in the solution measured.

___T___5. Ocean water generally has a conductivity of around 53,000 µS/cm.

___T___6. Rinsing the conductivity sensor between measurements helps avoid contamination from one sample to the next.

___T___7. In order for the conductivity of a substance to be measured, it must be in liquid form.

___F___8. Radish or other types of seeds will probably germinate and thrive in soil that has a salinity of 100,000 µS/cm.

Key Term Challenge

Fill in the blanks from the randomly ordered words below. Words may be used more than once:

solvent	universal solvent	salinity	solution
mixture	water	solute	control

1. Water is often called the ___universal solvent___ because of its ability to dissolve so many substances.

2. The amount of dissolved salt in water or soil is known as ___salinity___.

3. In Part 2 of this lab activity, the conductivity of distilled water was measured because it was the ___control___ in this experiment.

4. Any substance capable of dissolving another substance is known as a/an ___solvent___.

5. A/an ____solution______results when one substance, often a solid, dissolves in another substance, often a liquid, and results in a mixture in which each substance retains its characteristic properties.

6. A/an _______mixture______such as sugar water or salt and pepper can be separated into the substances that make it up, based on the physical properties of the individual substances.

7. In a salt water solution, the salt is the ____solute______and the water is the___solvent________.

8. Many different substances, including gases, liquids, and solids, can dissolve in ____water_ to form solutions.

Further Investigations

Prepare solutions of salt and water by heating the water until no more salt can dissolve. Allow the solution to cool and observe what happens to the solute. Explain the outcome.

Research the types of minerals that dissolve in water and how they subsequently form crystals.

Research how dissolved minerals form the stalactites and stalagmites found in caves.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

12. Water – The Universal Solvent

Dissolve Away!

Objectives

In this activity, students:

- Classify substances based on their ability to dissolve in water
- Measure the changes in the conductivity of water as substances dissolve in it
- Relate water's ability to dissolve different substances to some geological formations

Procedural Overview

Students gain experience conducting the following procedures:

- Dissolving a variety of substances in water
- Observing the solvent and solute as the dissolving process occurs
- Setting up the equipment and work area to measure the level of conductivity in different solutions
- Measuring the conductivity level of three different solutions

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	50 minutes
■ Lab activity, Part 2 – Observing a sugar cube in water	25 minutes
■ Lab activity, Part 3 – Making and testing solutions	25 minutes
■ Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Conductivity sensor
- ☐ Beaker, glass, 250-mL
- ☐ Wash bottle with distilled water
- ☐ Spoon or stirring rod
- ☐ Sugar cube
- ☐ Thread, ~40 cm
- ☐ Salt, 1 tsp.
- ☐ Pencil
- ☐ Powdered drink mix, any flavor, 1 packet
- ☐ Pepper, 1 tsp.
- ☐ Baking soda, 1 tsp.
- ☐ Borax, 1 tsp.
- ☐ Epsom salt, 1 tsp.
- ☐ Alum, 1 tsp.
- ☐ Sample papers
- ☐ Distilled water, 100 mL

For each student or group:

- ☐ Data collection system
- ☐ Conductivity sensor
- ☐ Beakers (4), 250-mL
- ☐ Wash bottle with distilled water
- ☐ Beaker for waste water
- ☐ Sugar cube, 1
- ☐ Thread, ~40 cm
- ☐ Pencil
- ☐ Solute samples to dissolve and test (3)[1]
- ☐ Sample paper
- ☐ Distilled water, 400 mL

[1] For a list of possible solutes, refer to the Preparation and Tips section

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the water cycle.
- Water is a solvent and when mixed with some gases, liquids, and solids will form substances that are detrimental to living organisms.
- Ions are charged particles.
- Ions in an aqueous (water) solution enable the solution to conduct electrical current.

Related Labs in This Guide

Labs conceptually related to this one include:

- Water Cycle
- Soil Salinity
- Seasonal Pond Exploration

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting multiple sensors to the data collection system �(2.1)
- Setting up a conductivity sensor for a particular sensitivity �(4.2)
- Monitoring data without recording �(6.1)
- Displaying data in a digits display �(7.3.1)

Background

Dissolving is a physical, rather than a chemical process. Solutions are mixtures that are formed not through any chemical process but by means of extremely thorough mixing at the particle level. In a solution, the main ingredient, or component, is called the solvent, and the other components or ingredients present in smaller quantities are called solutes. Solutes are dissolved in the solvent. The resulting mixture is the solution.

Water is an excellent solvent for many substances. For this reason, it has been referred to as "the universal solvent." When a solution has water as its main ingredient, it is termed an *aqueous* solution, from aqua, the Latin word for water.

Some compounds dissolve in water as molecules, with each of their molecules becoming surrounded by water molecules. Other compounds, called electrolytes, dissociate and dissolve not as neutral molecules but as charged particles known as ions. For example, in a solution of salt water, the sodium ions (with a charge of +1) and the chloride ions (with a charge of –1) are distributed evenly throughout the water molecules.

Compounds which exist as solid ionic crystals dissolve in water as ions, and most of them are highly soluble in water. Ordinary table salt ($NaCl$) is an example of such a compound.

Pre-Lab Discussion and Activity

Solutes and Solvents

Display a sugar cube and labeled samples of salt, powdered drink mix, pepper, baking soda, borax, and alum for students to see. Ask students to consider how each of these common substances is used. If students are unfamiliar with borax and alum, explain that borax is a laundry additive and alum is an astringent, often used in making and preserving pickles.

Ask students the following questions:

1. Which of these substances is used as is, in granular or powdered form?

   Students should suggest that most of the substances need to be added to or dissolved in water for use. Pepper and baking soda are often used in this form, but baking soda can also be dissolved in water and used as an antacid.

2. Describe the properties of the beverage that results when powdered drink mix is added to water. For example, does the first sip of the drink taste the same as the next, or do different parts of the drink taste very different?

   Students should suggest that because the drink mix is stirred into the water with a spoon, it has dissolved and the beverage tastes the same throughout. In addition, the beverage is the same color throughout.

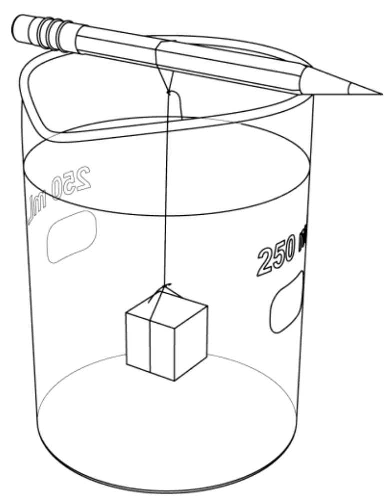
3. Why do you think the manufacturers of the drink mix make this product water soluble, or able to dissolve in water? Would people enjoy drinking a beverage in which a solid did not uniformly mix throughout the glass of water?

   Students should suggest that manufacturers make the mix water-soluble so that it will dissolve thoroughly, because people would probably not like to drink a beverage that is inconsistent in taste or texture. Clumps of undissolved solids are not generally acceptable in beverages.

The Universal Solvent

Explain to students that water is special because of its ability to dissolve so many substances. Water is called the "universal solvent" because it is able to dissolve more substances than any other liquid. As a result, wherever water goes, it transports along with it chemicals, nutrients, and minerals—throughout our bodies or throughout the ecosystem.

Direct students to “Thinking About the Question.” After students have had an opportunity to discuss the question, list several of their suggestions on the board under the heading "solutes." Explain to students that any substance that dissolves is referred to as the solute in a solution.



Prepare Students for Lab Activity

Show students how to tie a thread around a sugar cube so it can be suspended in a beaker of water. Explain to students that once the cube is suspended from the thread, it can be held in place a fixed depth in a beaker of water by tying the other end of the thread to a pencil that is placed across the top of the beaker. Show this setup so that students have a model to follow. You may have to help some groups tie the thread around their sugar cube.

Show students the conductivity sensor, focusing on the three sensitivity selection buttons. Explain to students how to use the sensor, including how to select the appropriate probe range (1X or 10X) and measurement range. Write the symbol abbreviation for microsiemens per centimeter (μS/cm) on the board and explain that it is the unit of measure for conductivity. Tell students that they may stir the solution with the sensor.

Direct students to “Investigating the Question.”

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Provide students with samples of ionic compounds to dissolve and test with the conductivity sensor. Ionic compounds that work well include salt ($NaCl$), Epsom salt ($MgSO_4$), alum ($KAl(SO_4)_2$, borax ($Na_2B_4O_7$ or $Na_2[B_4O_5(OH)_4]$, sports drink mixes that explicitly state they contain electrolytes, and salt substitutes that contain potassium chloride (KCl). All of these items are available at grocery stores.

- Because some of the substances used for solutes, such as alum, are sold in small quantities, it is helpful to measure out solute samples for students ahead of time. Give each group the same volume of each substance. A minimum sample size should be 1/2 teaspoon, while a maximum sample size should be 1 teaspoon.

- Do not use sugar as one of the solutes to be tested with the conductivity sensor. Sugar is not an ionic compound, and will not produce ions in the water. The conductivity sensor needs to have dissolved ions to give meaningful data.

Safety

Add these important safety precautions to your normal laboratory procedures:

- Wear aprons to protect clothes.

- Wear safety goggles throughout this activity

Driving Question

What happens when a substance dissolves in water?

Thinking about the Question

You probably have a lot of experience dissolving substances in water. For example, if you have ever stirred sugar into a glass of tea or lemonade to sweeten it, or if you have added salt to a boiling pot of water to cook pasta, you have made a solution by dissolving a substance in water.

Discuss with your lab group members what substances dissolve in water. Consider substances in addition to food, such as medicines, fertilizers, and even pollutants that can be dissolved in streams, lakes, rivers, or the ocean. Remember that matter in all three phases commonly experienced on earth—solids, liquids, and gases—can dissolve in water. As you develop a list of substances, classify them according to whether the substances are helpful or harmful to humans. Be prepared to share with your class.

Students may suggest common kitchen substances such as sugar, salt, food dye, and various spices; beverages such as various sodas and colas which have flavoring, coloring, and carbon dioxide gas dissolved in water; fertilizers such as plant food, household products such as soaps, detergents, and cleaners. Students may also suggest that fertilizers, detergents, and cleaners can be carried by rainwater as runoff into water sources, causing pollution.

Note: Some students may be aware that there are currently five states of matter that scientists are aware of: solid, liquid, gas, plasma, and Bose-Einstein condensate.

In this lab activity you will be using the conductivity sensor to measure the conductivity of different solutions you make. When you dissolve a solute in water, the charged particles (the ions) of the solute allow electrical current to be conducted through the solution. How do you think the amount of solute is related to the solution's ability to conduct electrical current?

Students should suggest that the more solute has been dissolved in the solution, or the higher the concentration, the greater the conductivity will be.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

3	1	5	4	2
Place a sample of solute into the beaker of distilled water, stirring to dissolve.	Make sure each lab group member is aware of the safety rules and procedures for this lab.	Rinse the conductivity sensor with distilled water before making the next measurement.	Measure the conductivity of the solution.	Add distilled water to a beaker.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Write your predictions for the following:

   a. What will happen to the sugar cube when you suspend it in a beaker of water and do not stir the water?

   Students should predict that the sugar cube will slowly dissolve and become smaller as it does. They may say that it will get smaller and smaller until eventually it falls out of its thread loop, and may eventually disappear completely.

   b. Approximately how long will you have to stir to dissolve 1/2 teaspoon of salt in 100 mL of water?

   Answers will vary. Students should predict lengths of time that range from several seconds to a minute or two.

c. Of the substances you are given to test, how many do you predict will fully dissolve in water? Explain why you think this.

Answers will vary depending on samples provided to students. One student group predicted as follows: We predict that all of our samples will dissolve because one sample, the Epsom salt, looks like salt but with bigger crystals, another sample is orange sports drink mix, and another sample is alum, which also looks like salt. Since salt dissolves in water, we predict that substances that look like salt will probably also dissolve like salt.

Part 2 – Observing a sugar cube in water

2. ☐ Carefully tie a long thread around a sugar cube so the sugar cube can be hung in a beaker.

3. ☐ Pour 100 mL of distilled water into a beaker.

4. ☐ Loop the thread around a pencil or pen and place across the top of the beaker so that the sugar cube is hanging fully submerged in the water.

5. ☐ Observe the sugar cube as it rests suspended in the water. You may have to look very closely, lowering your eye level to that of the beaker. Kneel down beside the table if necessary. Note any observations in the space below.

Students should be able to observe the sucrose in the sugar cube going into solution in the surrounding water, especially near the bottom of the sugar cube. The density of sucrose is greater than that of water, so the sucrose will appear to flow down.

Part 3 – Making and testing solutions

6. ☐ Label the three solute samples "A", "B", and "C".

7. ☐ Pour 100 mL of distilled water into a beaker.

8. ☐ Start a new experiment on the data collection system. �(1.2)

9. ☐ Connect the conductivity sensor to the data collection system. �(2.1) Select the appropriate range of sensitivity for the conductivity sensor. �(4.2)

10. ☐ Display Conductivity in a digits display. �(7.3.1)

11. ☐ Insert the conductivity sensor into the beaker and monitor in the digits display without recording. �(6.1)

12. ☐ Slowly add solute sample A to the beaker, stirring to dissolve. Observe how the conductivity level changes as you stir and then let the solution stand still.

13. ☐ When the reading has stabilized, record the conductivity in Table 1 below.

Table 1: Solution sample conductivity

	Solute A	Solute B	Solute C
Conductivity (µS/cm)	30,029	5420	2344

14. ☐ Rinse the conductivity sensor with distilled water, using the wash bottle and beaker.

15. ☐ Repeat these conductivity test steps in Part 3 for the other two solute samples and record the results in Table 1.

Answering the Question

Analysis

1. How did your predictions in Part 1 compare to your results in Parts 2 and 3?

   Answers will vary. One student group answered as follows: We predicted that the sugar cube would dissolve in the water, and it did even though we did not stir. We predicted that it would take about one minute to dissolve 1/2 teaspoon of salt in the water. It did not take that long, but it took about 30 seconds. We predicted that all of our samples would dissolve, which they did.

2. How could you tell that the sugar cube was dissolving in the water? Describe your observations. Were your observations of the sugar cube qualitative or quantitative?

   Answers will vary. One student group answered as follows: We saw the sugar cube appear to be slowly leaking wavy, clear fluid of a slightly different texture or density than water, at the bottom. After a few minutes the edges and corners were more rounded than they were at the beginning when we first put it in the water. Also, the faces of the cube began to get rougher and more irregular. The cube also got smaller slowly as time went on. Our observations were qualitative because we made no numerical measurements, we just used our sense of sight.

3. At what point in the procedure was the conductivity the lowest? How can you explain this low reading?

   Answers will vary. One student group answered as follows: We measured a conductivity of zero µS/cm at the very beginning of testing each sample, when the only thing in the beaker was the distilled water. We think this was because at this time, there was nothing dissolved in the water which would allow the water to conduct an electrical current. Distilled water is very pure. This would also explain why the conductivity level went up as soon as we began adding our samples to the water.

4. At what point in the procedure was the conductivity the highest? How can you explain this high reading?

   Answers will vary. One student group answered as follows: We measured the highest conductivity level when we finished adding all of our sample to the water. With the Epsom salt, we measured a conductivity of 9644 µS/cm when we had dissolved all of the crystals into the water. We think the reading was highest when all of the Epsom salt was dissolved because the dissolved particles let the water conduct an electrical current the best, and this is what the conductivity sensor is measuring.

5. Water is often called the universal solvent because of its ability to dissolve so many substances. Check with other lab groups in your class to see how many substances tested in class were unable to dissolve in water. What evidence from the class supports the idea that water is a good solvent?

Answers will vary. One student group answered as follows: In our class, every lab group had all of their samples dissolve in distilled water except one group that had a sample of pepper. The pepper floated on top of the water for a while, but then after a lot of stirring, some of it sank. The pepper turned their water a little cloudy, which we think means that at least part of the pepper was soluble in water. The fact that all but one of the samples dissolved shows that many common substances are soluble in water.

6. Use what you have observed in this lab activity to explain how salt contaminating the soil in a field could travel for several miles and enter a stream after a rainstorm.

Answers will vary. One student group answered as follows: If it rained on a field that had contaminated soil, the salt would be dissolved in the rainwater, then any place the rainwater flowed, the salt would be carried along. The runoff water from the field could travel downhill all the way to the nearest stream. This is how watersheds work.

7. Organize the following substances into two categories, water-soluble and non-water soluble: salt, sugar, vegetable oil, pepper, lemon juice, hand soap, baking soda, powdered drink mix

Water soluble: sugar, salt, lemon juice, baking soda, powdered drink mix

Non-water soluble: vegetable oil, pepper

8. Suppose a stream flows over a type of rock composed of a water soluble mineral. The stream meanders along and then disappears underground, where it flows through the rock layers and drips out slowly from the ceiling of a cave. Based on your understanding of solvents, solutes, and solutions, do you think that this mineral could accumulate in the cave? Support your answer with evidence.

We think that the mineral from the rock would get dissolved in the stream water and the stream bed might be more eroded there because of this. The mineral would travel along in the stream's water, since it forms a solution with the stream water. When the stream goes underground, the mineral also goes with it. Each drip of the water from the roof of the cave would have some of the dissolved mineral particles in it. As time goes on, more and more drips would fall from the roof, bringing more and more mineral with it.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. In a solution the substance that does the dissolving is the:

   A. Solute
   B. Solvent
   C. Solution

2. In a solution the substance that is dissolved is the:

   A. Solute
   B. Solvent
   C. Solution

3. Which of the following does *not* describe a solution?

A. Salt stirred until it seems to disappear in water
B. Lemon juice mixed into iced tea until the flavor is uniformly spread throughout the tea
C. Olive oil added to vinegar, floating on top to give the appearance of layers

4. Which of the following is true about water?

A. Water is not capable of dissolving a wide variety of substances.
B. Water dissolves more substances than any other liquid.
C. Water dissolves only those substances that exist as crystalline solids.

5. Suppose a bag of salt has been spread on the melting snow at the top of a mountain. Of the following scenarios, which is most likely to occur?

A. The snow will have little to no effect on the salt, nor will the salt have any effect on the snow.
B. The salt will evaporate along with the melting snow, and enter the water cycle through evaporation.
C. The salt will dissolve in the melting snow and be carried down the mountain side until it flows into the watershed.

6. In order to be called a "universal solvent," water must:

A. Dissolve a great many different substances
B. Be able to exist in all three phases—solid, liquid, and gas
C. Be able to conduct an electrical current

7. Those substances that are able to dissolve in water are classified as which type of substance?

A. Ionic
B. Salts
C. Water-soluble

8. In order for a substance to be a solute, what must it be able to do?

A. Dissolve other substances
B. Dissolve into another substance
C. Melt at a relatively low temperature

9. Suppose you had measured the conductivity of three solutions but forgot to label your data results. Use what you have learned in this lab activity to figure out which set of data is most likely from salt water made with 1/2 teaspoon of salt, distilled water, and salt water made with 1 teaspoon of salt.

A. 443 µS/cm, 1652 µS/cm, 1203 µS/cm
B. 1203 µS/cm, 1721 µS/cm, 443 µS/cm
C. 443 µS/cm, 11 µS/cm, 1203 µS/cm

10. Imagine that you and a friend are spelunking (exploring a cave) and come across what look like icicles hanging from the ceiling of the cave. Upon closer examination, the "icicles" seem to be made of solid rock. These formations in caves are called stalactites. Which of the following is a possible source of mineral that contributed to the formation of this cave's stalactites?

A. Water that has seeped into the ground above the cave and is dripping from the ceiling

B. Occasional rainstorms that wash large amounts of debris into the cave

C. Material deposited by bats and other cave-dwelling organisms

Further Investigations

1. Investigate how much of a particular substance will dissolve in a sample of room temperature water. Heat the water and see if more of the substance will now dissolve. What can you conclude about the temperature of the solvent and its ability to dissolve solute?

2. Research how minerals are seeded and grown from supersaturated solutions. Make such a solution of alum and water, and grow some seed crystals. Try using a seed crystal to grow a large alum crystal.

3. Research how the rate of cooling of a solution affects the size of the crystals that form from the solution. Use this information to explain how rocks can have different sizes of crystals, from nearly microscopic to coin-sized. Find out which types of igneous rocks cool quickly enough to form no crystals at all.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

13. Water's Role in Climate

Ocean Effect

Objectives

In this activity, students investigate how water and land act together to stabilize temperatures. They collect data using two temperature sensors, then compare and organize their information in simple tables or graphs to identify relationships the temperature patterns reveal.

Students investigate and observe how temperature changes near bodies of water while:

- Understanding that oceans have a major effect on climate because water in the oceans can absorb a large amount of heat
- Realizing the effects of oceans and lakes on land
- Understanding that energy is transferred in many ways
- Making explanations and predictions from evidence and drawing logical conclusions
- Gaining skills and confidence in using a scientific measurement tool—the temperature sensor—as well as the spreadsheet and graphing capability of a computer to represent and analyze data

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to measure temperature changes in two different containers of sand
- Measuring the change in temperature over a ten minute period in a container of sand only and a container of sand and salt water, both placed in the sun

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	25 minutes
■ Lab activity, Part 2 – Modeling land and coastline and Part 3 – Measuring temperature changes	50 minutes
■ Analysis	25 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Temperature sensor, stainless steel (2)
- ☐ Small container for water, 50-mL
- ☐ Plastic food storage containers with lids (2), 750 to 1000 mL
- ☐ Teaspoon
- ☐ Dry sand or white rocks, 1000 mL (4 cups)
- ☐ Table salt, 5 g (2 teaspoons)
- ☐ Awl
- ☐ Water, 100 mL
- ☐ 100-W lamp (optional)

For each student or group:

- ☐ Data collection system
- ☐ Temperature sensors (2)
- ☐ Small container for water, 50-mL
- ☐ Plastic food storage containers with lids (2), 750 to 1000 mL
- ☐ Teaspoon
- ☐ Dry sand or white rocks, 1000 mL (4 cups)
- ☐ Table salt, 5 g (2 teaspoons)
- ☐ Water, 100 mL
- ☐ 100-W lamp (optional)

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Water covers the majority of the earth's surface. About 70 percent of the planet is covered in ocean water.
- About 2 percent of the earth's water is fresh, with around 1.6 percent of the water locked up in polar caps and glaciers.
- Water is in a constant cycle and circulates through the crust, oceans, and atmosphere in what is known as the "water cycle."
- Water evaporates from the earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground.

Related Labs in This Guide

Labs conceptually related to this one include:

- Investigating Evaporation and Condensation
- Exploring Environmental Temperatures
- Monitoring Weather

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Connecting multiple sensors to the data collection system �(2.2)
- Changing the sample rate �(5.1)
- Monitoring live data �(6.1)
- Recording a run of data �(6.2)
- Displaying data in a table �(7.2.1)

Background

Water has a high capacity for storing energy. It requires a relatively large amount of heat energy to bring about a small temperature change in water. The water's surface reflects only a small amount of solar energy. An object that reflects very little sunlight absorbs a great deal of energy.

Consider a desert area such as the Sahara, Mojave, or the Atacama. These regions experience extreme temperature differences because they do not have a nearby water source to moderate their temperatures. They are therefore very hot during the daylight hours, but can become cold at night.

Changes in water temperature occur very gradually and seasonal changes are small in comparison to those on land. While air temperatures warm only a few degrees, the oceans can absorb and store a huge amount of heat from the sun in the daytime and summer. At night and during winter, the gradually cooling water of the oceans can warm the air. Because of water's ability to store heat, the water that covers most of the earth's surface keeps temperature changes within limits. Since water absorbs a large amount of energy and because oceans cover about 70 percent of the earth, water has a strong modifying effect on weather and climate.

During the summer on the coastline, cooling winds blow in from the ocean during the day. The sandy beaches and ocean waters work together to stabilize and prevent sudden, excessive changes in temperatures along the coastline. As water evaporates, the remaining surface waters cool. The evaporative cooling of oceans contributes to the stable temperature on land. During the day, the beaches heat more rapidly than the ocean waters. During the night, the beaches cool more rapidly than the ocean waters. At night the stored energy is released from the ocean warming the air and creating land breezes. During the day the ocean cools the air, creating sea breezes.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Ask students to explain how water circulates on Earth. Have students draw a diagram of how water moves from the atmosphere to the land, oceans, and lakes. Encourage students to use words such as evaporation and condensation to describe the process. Ask them how energy impacts the water cycle.

Direct students to "Thinking About the Question." Have students share with the class how oceans moderate the earth's climate.

Before directing students to "Investigating the Question", discuss why it is important to compare the temperature of the air to the temperatures inside each container. Finally, have students review the data from each container for each minute and compare it to the outside temperature. Ask each group to explain why the water in one of the containers prevented temperature extremes on the sand.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Construct an example container, with temperature sensor inserted through the side and almost enough sand to cover the stainless steel portion of the sensor. Allow students to view and examine the example container, so they have an idea of what their finished models will look like.
- Students may need to work in groups to collect the temperature data since two temperature sensors need to be used at the same time on two different containers.
- Students need to take measurements for ten minutes outside during a sunny day. This requires access to an outside site in full sunlight. If this is not possible, a lamp could be used within the classroom.
- With the awl, punch a hole through the sides of the plastic containers so that a temperature sensor can be inserted.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Do not look directly at the sun or 100-W lamp. Permanent damage to your eyes may result.

Driving Question

Do the oceans protect us from sudden changes in temperature?

Thinking about the Question

Water changes temperature very slowly. This resistance to sudden changes in temperature makes water an excellent place for organisms to live. Changes in water temperature occur very gradually and seasonal changes are small compared to those on land.

Discuss with your lab group members how oceans moderate the earth's climate.

The oceans and surface waters absorb a considerable amount of energy from the sun. As water evaporates, the remaining surface waters cool. The evaporative cooling of oceans contributes to the stable temperature on land.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

3	2	4	5	1
Fill each container half full with sand, so that each temperature probe is covered with sand.	Insert the temperature sensors into the plastic food containers.	Add a salt water solution to one of the containers of sand.	Cover each container with its clear lid and place in the sun to warm.	Make sure each lab group member is aware of safety rules and procedures for this lab.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Think about a sandy shoreline next to an ocean. How does the presence of the water affect the temperature of the shoreline?

   While air temperatures warm only a few degrees, the oceans can absorb and store a huge amount of heat from the sun in the daytime and summer.

2. ☐ Predict what the difference in temperature would be without the ocean present. Explain your reasoning. Be prepared to share your prediction with the class.

   Answers will vary. Without the oceans, the sandy shore would increase drastically in temperature during the day, and cool off excessively at night.

Part 2 – Modeling land and coastline

3. ☐ Obtain two plastic food storage containers with clear lids from your teacher. The containers should have a hole punched through their sides that will allow a temperature sensor to slip through the side of the container.

4. ☐ Obtain a small container. Place 1 teaspoon of table salt and 50 ml of tap water into the glass cup. Stir the water in the glass cup until all of the salt is dissolved.

5. ☐ Start a new experiment on the data collection system. �(1.2)

6. ☐ Connect one temperature sensor to the data collection system. �(2.1)

7. ☐ Monitor live data to measure the temperature of the air in the location where you will be conducting your experiment. �(6.1) Record the temperature in the space below:

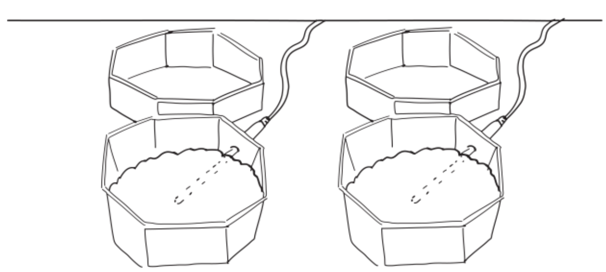
   Air temperature = 21.1 degrees Celsius

8. ☐ Connect a second temperature sensor to the data collection system. �(2.2)

9. ☐ Change the sample rate to take one measurement per minute. �(5.1)

10. ☐ Display Time, Temperature 1 (sand only), and Temperature 2 (sand and salt water) in a table. �(7.2.1)

11. ☐ Place one temperature sensor through the side of each container so that the metal of the sensor is placed entirely inside the container. Fill each container approximately half full with sand so that each temperature sensor is completely covered with sand.

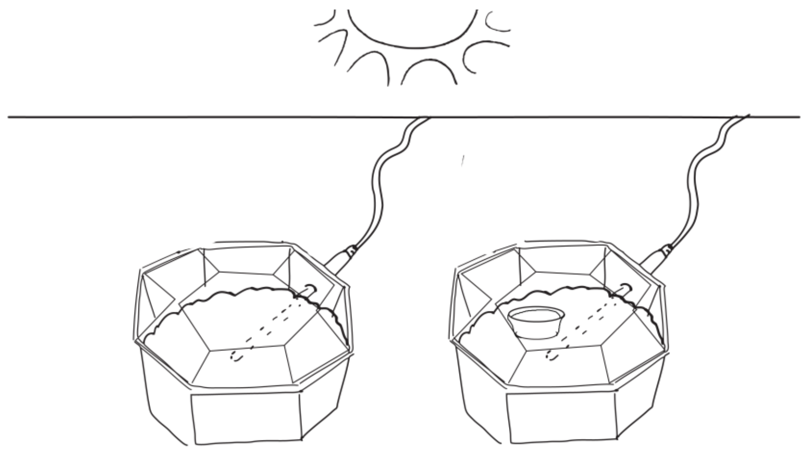


12. ☐ Place the small cup of salt water in one of the containers, pressing it down into the sand if necessary so it will fit when the lid of the container is closed.

13. ☐ Attach the lids to each container.

Part 3 – Measuring temperature changes

14. ☐ Place both containers side by side outside in warm overhead sunshine. If sunlight is not available, use a 100 W lamp approximately 1/2 meter above the containers.



15. ☐ Start data recording on both temperature sensors. �(6.2) Continue collection for 10 minutes for both containers. You will enter your temperature data in a table below; you may write this data as it is being recorded, or you may wait until the end of data collection.

16. ☐ After 10 minutes, stop data recording. �(6.2)

17. ☐ Complete Table 1 below, if you have not done so already.

Table 1: Temperatures 1 and 2

Time (minutes)	Temperature 1 (˚C) (Sand only)	Temperature 2 (˚C) (Sand and salt water)
1	18.0	17.2
2	18.2	17.2
3	18.6	17.4
4	18.6	17.6
5	18.8	17.6
6	19.2	17.6
7	19.4	18.0
8	19.6	18.2
9	19.8	18.2
10	20.0	18.4

Answering the Question

Analysis

1. How did the temperatures of the sand in each container compare with the temperature outside the containers?

   Answers will vary. The sand in both containers may be cooler than the outside temperature originally.

2. How does the temperature of the sand in the sand-only container compare to the temperature of the sand inside the other container that has water and sand? Did the container with only sand heat up faster?

   The temperature in the container with just the sand should increase in temperature faster.

3. How did the presence of salt water in one container affect the temperature? Be prepared to share your answer with the class.

   The temperature was lower in the container that had water.

4. Did the water in the container prevent major temperature fluctuations in the sand? Explain your thinking.

   The water absorbed the energy from the sun more than the sand and acted as a buffer to lower the temperature.

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___ 1. Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle."

___T___ 2. Approximately 70% of the earth's surface is covered with water.

___T___ 3. Water has the property of being able to resist sudden changes in its temperature.

___F___ 4. Oceans have no effect on temperature.

___T___ 5. Breezes blow near the shore of oceans because of differences in temperature over the land and over the water.

___F___ 6. During the night, the beaches cool more slowly than the ocean waters.

___T___ 7. Seasonal changes in the ocean are smaller than seasonal changes on land.

Key Term Challenge

Fill in the blanks from the randomly ordered words below. You may change the form of a word, for example by making a singular word plural. You may not use every word, and you may use a word more than once:

gains	energy	sun	shore
loses	sand	temperatures	water
oceans	70%	glacier	polar ice caps

1. Water ___gains___ energy by absorbing it from the ___sun___ during the day.

2. Sand ___loses___ energy more quickly than water does.

3. Earth's ___oceans___ help our planet maintain stable ___temperatures___ that remain within limits.

4. Almost all of the ___energy___ on Earth comes from the ___sun___.

5. Much of our fresh ___water___ is stored in the solid form in the ___polar ice caps___.

Further Investigations

Does water impact all coastlines the same? What about a rocky shore along the ocean? Design an investigation to test a rocky shore using black rocks and salt water. How does a different color, the dark rocks compared to the white sand, change the results?

Since water covers over 70% of the earth’s surface, its ability to store heat strongly affects our climate. Think about what would happen if oceans only covered 25% of the earth’s surface? Design an investigation to test the effect of more or less water present in your container.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.