Elementary School

Teacher Guide

PASCO®

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Elementary School

Introductory Science Experiments

Teacher Guide
21st Century Science

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Contents

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

In this manual, "data collection system" refers to the system employed by students to record, visualize, and analyze sensor data during their experiments. The system consists of all components necessary to connect a sensor to a device containing the software that detects the sensor measurement and collects, records, and displays this data.

Some systems, such as the Xplorer GLX® or SPARK Science Learning System™, are stand-alone systems. These contain built-in software applications, and students simply attach a sensor and begin collecting data. Other systems use a computer or tablet with downloaded software applications. In these systems a USB or Bluetooth® interface is used to connect a sensor to the device. Software options for these include SPARKvue® and PASCO Capstone™ software.

The activities are designed so that any PASCO data collection system can be used to carry out the procedures.

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.

Activity Components

Teacher Information and the completed Student Activity Worksheets are in the Teacher Guide binder. It contains the information to guide the teacher with selecting, planning, and implementing the activity. Listed on the first page of each activity are the objectives, procedural overview, time requirements, and materials.

Kindergarten to Grade 3. For kindergarten through third grade, each activity has three components: Teacher Information, completed student response sheet, and the student response sheet. Only the teacher has the written procedure for the activity. Student response sheets for kindergarten and first grade contain illustrations related to the concept of the activity. Student response sheets for second and third grades may contain a combination of prediction questions, blank graphs, multiple choice (text and or illustrations), true/false, and vocabulary questions.

Grades 4 to 5. For fourth grade and fifth grades, each activity has two components: Teacher Information and Student Activity Worksheets. Student Activity Worksheets contain the written procedure and an assessment component. The Teacher Information contains the complete student version with the answers.

Student Activity 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. Activity worksheets also include 1) the materials list, 2) safety precautions, 3) the procedure for carrying out the activity, collecting and recording data, and analyzing results, and 5) a combination of multiple choice, true/false, and vocabulary questions. The Student Activity Worksheets are included in electronic format on the storage device that accompanies this manual.

The following table lists the sections in the components of each grade level. For kindergarten through third grade students have a student response sheet.

Elementary School: Student Handout Masters

Student response sheet (K-1)	Student response sheet (2-3)	Student Activity Worksheet (4-5)
Title	Title	Title
Predict	Predict	Driving Questions
Draw	Draw	Materials
Circle picture choices	Test your prediction	Safety
	Conclusions	Investigation
		Get Started
		Let's Explore
		Explain It
		Tell Me More
		Sum It Up
		Assessment
		Key Term Challenge
		True/False
		Multiple Choice

Activity components for each grade level

Teacher Information (K-1)	Teacher Information (2-3)	Teacher Information (4-5)
Title	Title	Title
Recommended Grade Level	Recommended Grade Level	Recommended Grade Level
Objectives	Objectives	Objectives
Procedural Overview	Procedural Overview	Procedural Overview
Time Requirement	Time Requirement	Time Requirement
Materials	Materials	Materials
	Activity at a Glance	Activity at a Glance
	Get Started	Get Started
	Let's Explore	Let's Explore
	Explain It	Explain It
	Tell Me More	Tell Me More
	Sum It Up	Sum It Up
Safety	Safety	Safety
Preparation	Preparation	Preparation
Background	Background	Background
		Pre-Activity Discussion with Driving Question and Variables
Activity with Answer Key and Teacher Tips	Activity with Answer Key and Teacher Tips	Activity with Answer Key and Teacher Tips
Driving Question	Driving Question	
Get Started	Get Started	Get Started
Let's Explore	Let's Explore	Let's Explore
Explain It	Explain It	Explain It
Tell Me More	Tell Me More	Tell Me More
Sum It Up	Sum It Up	Sum It Up
		Assessment
		Multiple Choice
		True/False
		Key Term Challenge
Further Investigations	Further Investigations	Further Investigations
Student response sheet	Student response sheet	

Electronic Materials

The storage device accompanying this manual contains the following:

- Complete Teacher Guide and Student Guide: Handout Masters (with Student Activity Worksheets for grades four and five, and student response sheets for kindergarten to third grade in PDF format
- Student Activity Worksheets of the activities for grades four and five and student response sheets for kindergarten to grade three in an editable format (Microsoft® Word 97–2003 format).
- DataStudio, PASCO Capstone, and SPARKvue 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.

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 activities in our Elementary 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 activities also has a Safety section for procedures necessary for that activity. Convey these procedures to your students.

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 facility 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

- 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.
- 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.
- 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 and 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

- Use caution when working with acids.
- Use appropriate caution with matches, burning splints, and other hot materials.
- When an activity calls for warm water, do not use temperatures above 35 °C (95 °F) for children in grades K–1, or above 40 °C (104 °F) for children in grades 2–3, or above 49 °C (120 °F) for children in grades 4–5.
- 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

Master Materials List

Italicized entries indicate items not available from PASCO. NOTE: These activities may 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).

Lab	Title	Materials and Equipment	Qty
Kindergarten – First Grade			
1	Heavy and Heavier Use a force sensor to learn about the property called weight that can be measured, and to recognize that an object's weight is not necessarily related to its size.	Data Collection System PASPORT Force Sensor with hook installed Container (bucket or basket) to attach to the force sensor hook Toy car, truck, or other vehicle Balloon, inflated and tied Apple, potato, or other small fruit or vegetable Melon, eggplant, or other large fruit or vegetable Polystyrene (foam) packing material, picnic cooler, or purchased polystyrene craft material, as large as possible String, to hang the container on the force sensor hook	1 1 1 1 1 1 1 1 Several pieces
2	Near and Far Use a motion sensor to describe the position of an object as being near or far from another object and to recognize that an object in motion changes its position.	Data Collection System PASPORT Motion Sensor Large playground ball Meter stick	1 1 1 1
3	Mixing Water Use a temperature sensor to understand that mixing hot and cold water results in a new temperature that is between the hot and cold.	Data Collection System PASPORT Temperature Sensor Small paper cups (2) Large paper or plastic cup Ice water, approximately 5 °C Warm water, approximately 40 °C Towels	1 1 2 1 200 mL 200 mL Several

4	Light and Dark Use a light sensor to determine how light is related to what the students see.	Data Collection System PASPORT Light Sensor PASPORT Sensor Extension Cable Strips of construction paper, 3 cm × 8 cm (1 in. × 3 in.), different colors or colored wooden craft sticks	1 1 1 1
5	Exploring Temperatures Use a temperature sensor to explore temperature changes to observe the property of temperature, and to learn that temperature is a measure of how hot or cold something is compared to a standard scale (has both teacher demonstration and student groups). Teacher Demonstration	Mobile Data Collection System PASPORT Temperature Sensor Mobile Data Collection System PASPORT Temperature Sensor Bag of clothing, warm- and cold-weather clothing Large outdoor thermometer Paper meter (construction paper or paper plates and a brad) Paper thermometer (can be written on) Thermometer, oral	1 1 Variety 1 1 1 1
6	Hot and Cold Use a temperature sensor to observe the property of temperature, and that this property can be measured using a thermometer or temperature sensor.	Data collection system PASPORT Temperature Sensor Buckets or containers for ice cubes and bottles Towels Ice cubes Plastic water or soda bottles filled with warm water (no warmer than 30 °C or 86 °F), tightly capped	1 1 2 Several Several Several
7	Weather Instruments Use a weather sensor to make measurements to determine weather conditions and to develop the language for describing weather conditions.	Mobile Data Collection System PASPORT Weather Sensor PASPORT Sensor Extension Cable Leaf Feather	1 1 1 1 1

Grade 2 – Grade 3			
8	Freezing and Melting Water Use a temperature sensor to measure the temperature of water in different forms and to learn that water can exist in different forms and can be changed from one form to another by heating or cooling.	Data Collection System PASPORT Temperature Sensor Ice cubes weighing 0.5 g or less Small paper cup Snack size plastic bag, re-sealable, 16.5-cm × 8.25-cm Tape Spoon Rock salt-ice bath (ice to fill a utility tub half full; 300–400 g of rock salt, tap water to cover ice) Paper towels Water Projection system (for the teacher only) Ice chest (for the teacher only)	1 1 Enough to half-fill the paper cup 1 1 1 piece 1 2–3 per class 1 per student 15 mL 1 1
9	Conservation of Matter Use a force sensor to determine that the weight of a whole object is the same as the sum of the weight of each part that makes up the whole object.	Data Collection System PASPORT Force Sensor, with hook attached Bag to attach to force sensor hook Objects of varying weights, 1 to 5 pounds such as a textbook, bottle of water, large box of crayons, hand weight, an orange, a hammer Flashlight (containing D batteries) Object made of parts, 1 to 5 pounds, such as a student backpack, a lunch box, a large bolt with a nut and washer attached, tool box Projection system (for the teacher only)	1 1 1 4 1 1 1
10	Hunting with Light Use a light sensor to compare how organisms, including humans, are able to see and compare that to what an electronic light sensor can detect. Teacher Demonstration	Data Collection System PASPORT Light Sensor Paper, solid colors Tissues Paper, plain white Crayon, dark colored Large eye diagram (photocopy) Large pictures of animal eyes (photocopy)	1 1 3 per group 1 per person 2 per person 1 1 1
11	Investigating Sound Levels Students recognize that continuous sound is made by vibrating objects, and can be described by its pitch and volume. Students explore different continuous sounds by studying the changing volume	Data Collection System PASPORT Sound Level Sensor PASPORT Sensor Extension Cable Sheet of paper to make a sound tube, 21-cm × 28-cm (8.5-in. × 11-in.)	1 1 1 1

12	Feeling and Measuring Temperature Use a temperature sensor to compare the results of measuring temperature to how the temperature feels.	Data Collection System PASPORT Temperature Sensor Thermometer. digital Thermometer, bulb-type Plastic cup, 400-mL or 12-oz Water, cool Water, warm Paper or cardboard sheet for fan (21-cm × 28-cm or 8.5-in. × 11-in.)	1 1 1 1 1 ~100 mL ~100 mL 1
13	Cars and Heat Use a temperature sensor to determine how the temperature inside a car parked in the sun compares to the temperature of the air outside the car.	Mobile Data Collection System PASPORT Temperature Sensor Shoe box model car, assembled Shoe box Black paper Plastic food wrap to cover the shoe box Paper cup, modified to fit within the shoe box Yarn, cotton balls, other craft supplies Markers, a variety of colors Glue stick Tape	 1 1 Enough to line the shoe box 1 1 A variety 1 1 ~30 cm
	Teacher Demonstration	Mobile Data Collection System PASPORT Temperature Sensor Projection system Shoe box model car, assembled	1 1 1 1
14	Observing Clouds Use a weather sensor to show that clouds in the sky have properties that can be observed and described, and that students associate cloud formation with specific weather conditions such as temperature and humidity.	Mobile Data Collection System PASPORT Weather Sensor Cloud Types handout PASCO Cloud Finder handout Scissors Glue Paper fastener (brad) Weather Journal handout Tagboard or card stock, 14-cm × 14-cm Compass Ribbon, 12–15 cm long	1 1 1 1 1 1 1 1 1 1 1
	Teacher Demonstration	Mobile Data Collection System PASPORT Weather Sensor Glass canning jar, 1-quart Plastic wrap and rubber band Posters or pictures of cloud types, in color Sponge Turkey baster Water, hot Water, ice Wooden stick matches	1 1 1 1 1 1 1 20 mL 50 mL 1

15	Can Plants Survive without Light and Water? Use a light sensor to explore weather or not plants need light and water to survive and what adaptations help them survive.	Data Collection System PASPORT Light Sensor Ruler	1 1 1
	Teacher Demonstration	Data Collection System PASPORT Light Sensor Potted plants, young plants, all the same kind Roots of plants Leaves of plants, a variety Growing light (optional) Markers Ruler	1 8 A variety A variety 1 A variety 1
Grade 4 – Grade 5			
16	Temperature and Change Use a temperature sensor to determine the effect of temperature on the time it takes for a sugar cube to dissolve or an antacid tablet to react with vinegar.	Data Collection System PASPORT Temperature Sensor Beaker, 250-mL Stir rod Tape, ~3 in. piece Sugar cube Water, room temperature Water, cold Water, hot Beaker, 600-mL Antacid tablet piece, ~ 0.5 g Vinegar, room temperature Vinegar, hot Ice	1 1 1 1 Several 3 300 mL 200 mL 200 mL 1 3 200 mL 100 mL 300 mL
	Teacher Demonstration	Data Collection System PASPORT Temperature Sensor Wooden block Ice cube, 0.5 g or less Tape, ~3 in. piece Balance Projection system	1 1 1 2 1 1 1
	Preparation	Bucket to hold ice water Thermos® Balance	1 1 1

17	The Water Cycle Use a weather sensor to measure the conditions in a water cycle model. Teacher Demonstration	Data Collection System PASPORT Weather Sensor PASPORT Sensor Extension Cable Utility lamp with clip (with a 60-W or 75-W incandescent bulb) Scissors Clean 2-L soda bottles Ice cubes Transparent packing tape Meter stick Data Collection System PASPORT Weather Sensor PASPORT Sensor Extension Cable Scissors Ice cubes Permanent marker, black or dark color Assembled water cycle tower Clean 2-L soda bottles Razor blade or sharp knife Transparent packing tape	1 1 1 1 1 3 ~350 mL ~2 m 1 1 1 1 1 ~350 mL 1 3 ~2 m
18	Conductor or Not Use a voltage sensor to test the conductivity of different materials.	Data Collection System PASPORT Voltage Sensor AA-cell battery fully charged Holiday mini-light bulb with wire ends stripped Alligator clips Wire, 20 cm, with stripped ends Masking tape Paper clip Penny Plastic spoon Eraser Piece of chalk Clay	1 1 1 1 2 2 ~30 cm 1 1 1 1 1 1
19	Electric Circuits Use a voltage sensor to measure the voltage across elements in series and in parallel in an electric circuit.	Data Collection System PASPORT Voltage Sensor AA-cell battery Miniature holiday light bulbs with stripped wire ends Masking tape, Wide rubber band Alligator clip or other pieces of wire with stripped ends	1 1 2 2 ~30 cm 1 2
20	What is an Electromagnet? Use a voltage sensor to determine the strength of an electromagnet with different numbers of coils and different magnitude of the voltage source.	Data Collection System PASPORT Voltage Sensor AA-cell battery Paper clip Alligator clip Scissors Masking tape Large iron nail, 3 to 4 inches long Insulated bell wire, 22 to 26 gauge with ends stripped of insulation for 5 cm	1 1 2 10 to 15 2 1 ~20 cm 1 1 m

21	Determining Sound Levels Use a sound level sensor to measure the sound levels from different objects, to determine the source of sound, and to find the relationship of vibration to sound level.	Data Collection System PASPORT Sound Level Sensor Balloon, cut open to make a drumhead Can opener (teacher use only) Drinking straw Notebook or copy paper Paper clip Paper or plastic cup, 350-mL (12-oz) Paper towel Pliers (teacher use only) Rubber band Scissors Square plastic food storage container, 1-qt Tin can, open at both ends Water	1 1 1 1 1 3 to 4 sheets 1 1 2 to 3 sheets 1 2 to 3 1 1 1 ~300 mL
22	Keeping Warm Use a temperature sensor to understand which materials conduct heat and which don't, and why they do or don't.	Data Collection System PASPORT Temperature Sensor Cup with cold water Cup with hot water Funnel Insulating clothing materials such as cotton, Polartec®, and wool Paper towels Rubber band (optional) Tape (optional) Test tube rack Test tubes Water, hot Data Collection System PASPORT Temperature Sensor Clothing items, articles of wool, synthetic fleece such as Polartec, real or synthetic fur, down, cotton, and polyester or acrylic fibers; a mitten and a glove Projection system	1 1 1 1 1 A variety 2 to 3 1 Several pieces 1 2 ~500 mL 1 1 A variety 1

23	Heating Land and Water Use a temperature sensor to determine a property of materials that allows some to heat up faster than other materials and then draw conclusions about water's influence on a region's climate.	Data Collection System PASPORT Temperature Sensor Construction paper, skin-tone (8 cm × 12 cm) (3 in. × 5 in.) Dry sand and other materials, such as grass, dirt, foil, waxed paper, wood, chocolate, milk, material, glass, ground charcoal, paint, or any other materials that would provide a variety of textures and surfaces Meteorology records on the Internet Meter stick Petri dish or small shallow dish or jar lid Scissors Table or stool to clamp lamp Utility lamp with clip, 75 W, 100 W, or sunlamp Water, room temperature World map or globe	1 1 1 40 mL to 50 mL A variety 1 2 1 1 1 40 mL to 50 mL 1

24	Chemical Reactions Use a temperature sensor to measure the change in temperature as two substances chemically react.	Data Collection System	1
		PASPORT Temperature Sensor	1
		Sugar cube	1
		Beaker half full of water	1
		Steel wool, ~1 g	2
		Beaker	Any size
		Cracker on a paper towel	1
		Bowl, big enough to hold water from beaker half full of water	1
		Balance (optional)	1
		Water	200 mL
		Beaker, 250-mL	2
		Beaker, 50-mL	1
		Stir rod	1
		Plastic spoon	1
		Tape	1 roll
		Sugar	5 g
		Alum	5 g
		Ammonia	30 mL
		Paper towel	1
		Tincture of iodine	15 drops
		Cracker	1
		Sugar cube	1
		Cheese	Any amount
		Notebook paper	Any amount
		Potato slice	Any amount
		Paper towel	Several
		Steel wool, ~1 g each2	2
		Distilled white vinegar with 4 to 8% acidity	75 mL
		Baking soda	~2 g
	Teacher Demonstration	Beaker half full of water	2, any size
		Stir rod	1
		Plastic spoon	1
		Effervescent antacid tablet	1
		Table salt	5 g
		Balance (optional)	1

25	Weather Station Use a weather sensor to measure temperature, dew point, humidity and atmospheric pressure over a period of time and determine any correlation between the data collected to observable weather conditions.	Mobile Data Collection System PASPORT Weather Sensor PASPORT Sensor Extension Cable USB flash drive Weather Journal White plastic milk container with lid, 1.89 liter (0.5 gallon) Index card cut to 2-cm × 6-cm 3-meter wooden stake Hammer Duct tape Masking tape Plastic utility tub Brick String	1 1 1 1 1 1 1 1 1 1 1 1 1 1 m
	Teacher Demonstration	Computer with Internet weather websites bookmarked Computer overhead projection system Grounded outdoor extension cord Clouds poster Weather maps Utility knife	1 1 1 1 Several 1
26	Dew and Frost Use a fast-response temperature sensor and a model to simulate the weather conditions responsible for the formation of dew and frost.	Data Collection System PASPORT Fast Response Temperature Sensor PASPORT Weather Sensor Beaker, 250-mL or cup or jar of similar size Stirring stick or spoon Crushed ice Water, distilled Salt Rubber band Soda bottle terrarium Data Collection System PASPORT Temperature Sensor Potting soil Gravel, vermiculite or perlite Large bowl to mix the soil Pie pan Plastic storage bag, gallon sized, re-sealable Soda bottle, clear, cleaned, 2-L Small plants of the same variety Scissors Tape Water, warm Dry ice, broken up Tongs for handling the dry ice	1 1 1 1 1 180 mL 125 mL 20 mL 1 1 1 1 500 mL 200 mL 1 1 1 1 3 1 Several pieces 100 mL 1 block 1

27	Microclimates Use a weather sensor to compare the temperature and humidity of various sites and determine the reason for any variations. Teacher Demonstration	Mobile Data Collection System PASPORT Weather Sensor Notebook and pencil Data Collection System PASPORT Temperature Sensor PASPORT Weather Sensor Ecochamber or terrarium or house plants	1 1 1 each 1 1 1 1
28	How a Greenhouse Works: Light Use a temperature sensor to determine how light or brightness depends on the angle at which the sun's light strikes the surface of the ground and how this changes throughout the day.	Data Collection System PASPORT Light Sensor Reflector lamp or desk lamp with 60-watt incandescent light bulb Shoebox or cardboard box of comparable size White legal size typing paper, white butcher paper or white bulletin board paper, 21 cm × 28 cm (8.5 in. × 11 in.) Clear or transparent plastic wrap, 30-cm (12 in.) Wax paper, 30-cm (12 in.) Glad Press 'N Seal® Wrap, 30-cm (12 in.) Any other translucent material, such as parchment paper, paper towels, or sheer material, 30-cm (12 in.) Scissors Protractor Pencil Transparent adhesive tape Metric ruler and a meter stick	1 1 1 1 2 to 3 sheets 1 piece 1 piece 1 piece 1 piece 1 1 1 ~30 cm 1
29	How a Greenhouse Works: Heat Use a temperature sensor to measure the heat generated in a model greenhouse by altering the types of material that light passes through.	Data Collection System PASPORT Temperature Sensor Greenhouse models from the "How a Greenhouse Works: Light" activity Light source such as a swivel desk lamp or reflector lamp with a 60-watt incandescent bulb Electric heating pad Scissors Metric ruler or meter stick Adhesive tape Clear plastic wrap, 30-cm (12 in.) Wax paper, 30-cm (12 in.)	1 1 1 1 1 1 1 ~30 cm 1 piece 1 piece

Activity by PASCO Sensors

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

Items Available from PASCO	Activity Where Used
Data Collection System	1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29
Mobile Data Collection System	5, 7, 13, 14, 25, 27
PASPORT Fast Response Temperature Sensor	26
PASPORT Force Sensor	1, 9
PASPORT Light Sensor	4, 10, 15, 28
PASPORT Motion Sensor	2
PASPORT Sensor Extension Cable	4, 7, 11, 17
PASPORT Sound Level Sensor	11, 21
PASPORT Temperature Sensor	3, 5, 6, 8, 12, 13, 16, 22, 23, 24, 26, 27, 29
PASPORT Voltage Sensor	18, 19, 20
PASPORT Weather Sensor	7, 14, 17, 25, 26, 27

Grades K-1

1. Heavy and Heavier

Recommended Grade Levels: K – 1

Objectives

Students learn that objects have a property called weight that can be measured, and that an object's weight is not necessarily related to its size.

Procedural Overview

To understand this content, students:

- Observe properties of matter such as size, weight, and shape
- Classify objects as heavy and heavier

Time Requirement

■ Teacher Preparation	10 – 15 minutes
■ Activity	20 – 30 minutes
■ Student Response Sheet	5 – 10 minutes

Materials

- ☐ Data collection system
- ☐ Force sensor with hook installed
- ☐ Container (bucket or basket) to attach to the force sensor hook[1]
- ☐ Toy car, truck, or other vehicle
- ☐ Balloon, inflated and tied
- ☐ Apple, potato, or other small fruit or vegetable
- ☐ Melon, eggplant, or other large fruit or vegetable
- ☐ Polystyrene (foam) packing material, picnic cooler, or purchased polystyrene craft material, as large as possible
- ☐ String, to hang the container on the force sensor hook

[1] A recycled butter tub or other container with 2 or 3 holes for string works well.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

- Inflate a balloon large enough to fit in your bucket and tie the end.
- Set up your data collection system to measure force.

1. Start a new activity on the data collection system.
2. Connect the force sensor to the data collection system.
3. Display Force, pull positive on the y-axis of a graph with Time on the x-axis.
4. Adjust the scale of the graph to best represent the range of forces you will measure.

Background

Heaviness: Mass versus Weight

What is mass, and how is it related to weight? If you hold a watermelon at arm's length and shake it, you will find it more difficult to shake than if you were holding an inflated balloon. This would be true whether you were standing on the Earth, on the moon, or in space far from any planet or star. Mass is the amount of matter in an object. In common daily language we often hear the terms weight and mass used interchangeably. However, to scientists, weight is the pull of gravity on any object with mass. The more massive an object is, the more it weighs. In this activity, "heaviness" is actually "weight."

Force Sensor Explained

The "heaviness-measuring tool," or force sensor, measures the strength of pushes and pulls. It measures force in newtons.

In this activity, where the force sensor is used to find the weight of objects, it measures the pull of gravity on each object. "Weight" is what we call this pull. This is why you sometimes hear references to a person "weighing less on the moon" than on Earth. The moon has less mass than the Earth, and therefore has less gravitational pull on objects. The property that does not change is mass. If you actually did travel to the moon, your mass would remain the same, but gravity would pull you down with less force.

The Relationship between Size and Heaviness

An object's heaviness is not necessarily related to its size. For example, a large piece of foam may weigh much less than a piece of wood half its size. Size and heaviness are two different properties of matter. Size can also be referred to as volume, or the amount of space an object takes up. Heaviness, on the other hand, refers to an object's weight. Although these are different properties, their relationship is an important concept in science known as density. Density is the ratio between the mass and volume of an object. This can be written as a word equation: density equals mass divided by volume.

Heaviness, Mass, Volume, and Density

Students will ultimately have to know the various terms for describing the size and composition of an object, but we recommend for this activity that you use the term "weight" only. Weight can be described as "related" to the amount of matter in an object. One of the secondary goals of the activity is to show that there is not a direct relationship between size (volume) and weight, in an effort to prepare students for later discussions of mass and density.

Activity with Answer Key and Teacher Tips

There is a box next to each step. (☐) If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

How do you know if an object is heavy or heavier?

Get Started

1. ☐ Set out the following objects in students' view: the large piece of polystyrene, the large and small fruits or vegetables, the toy vehicle, and the inflated balloon.

   Note: Any objects may be used, but they need to be between 1 and 50 newtons in weight (0.1 to 4 kg in mass), and should vary enough so that no two objects are similar in mass. Experiment to find out which objects work best.

2. ☐ Pick up the inflated balloon and take it for a walk around the room as if it were very heavy. Exaggerate all of your movements.

3. ☐ Follow up on students' reactions to your behavior with such questions as:

   Q Do you think this balloon is heavy?

   Q What makes you think this balloon is heavy?

4. ☐ Have students point to one of the objects they think is not heavy. Ask them to tell why they think it is not very heavy.

   Answers will vary and may center on previous experience with an object.

5. ☐ As you listen to their answers and comments, discuss their ideas about the size of the objects and the materials the objects are made of.

6. ☐ Help students understand that the word "light" can be used to mean "not heavy."

7. ☐ Next have students point to one of the objects they think is heavy. Guide a similar discussion about why they think the object is heavy. Ask questions such as:

   Q Is it heavy because it is big?

   Q Is it heavy because it is made of wood (or metal, or other material)?

Let's Explore

8. ☐ Have students take turns picking up and holding each of the objects.

9. ☐ Ask students to sort the objects into two group: heavy and heavier.

Explain It

10. ☐ Ask students, "How do you know if something is heavy?"

    Pick it up and compare how difficult it is to lift versus other objects.

11. ☐ Ask, "Which object would make a louder thud if you dropped it on the table from here?" (Have the object at a height of ½ inch above the table.)

    Q Is it heavier because it is larger?

    Q Is it heavier because it is shinier?

    Q Is it heavier because there are no holes in it?

    Q Is there one of these objects that you would rather not have dropped on your bare foot?

Tell Me More

12. ☐ Ask, "What tool can be used to measure heaviness?"

    Students may be familiar with a bathroom scale or food scale at the market.

13. ☐ Have students examine the parts of the force sensor.

14. ☐ Once the bucket is hanging from the hook, zero the force sensor and then start recording a run of force data.

    Teacher Tip: If students are curious about the zeroing operation, it may be instructive to tell them the bucket has weight, but we are interested in the weight of the objects we put in the bucket. If your students want to know more, begin collecting data before adding the bucket, and then add the bucket and press the zero button.

15. ☐ Measure the heaviness of the bucket as more objects are added to it.

16. ☐ Help students observe that the heavier the bucket is, the higher the graph goes.

Sum It Up

17. ☐ Have students look at the graph of heaviness (force) data. Ask students

    How the graph helps show us when heavier objects are put into the bucket?

    Students should be able to look at the graph and point to places where the line is higher and relate the higher points to heavier items in the bucket. They should be able to point to lower points on the graph and relate these to less heavy items in the bucket, or an empty bucket altogether.

18. ☐ How do you know if an object is heavy or heavier?

Students may say they need to have two objects to compare in order to determine if an object is heavy or heavier.

19. ☐ Have students complete the student response sheet.

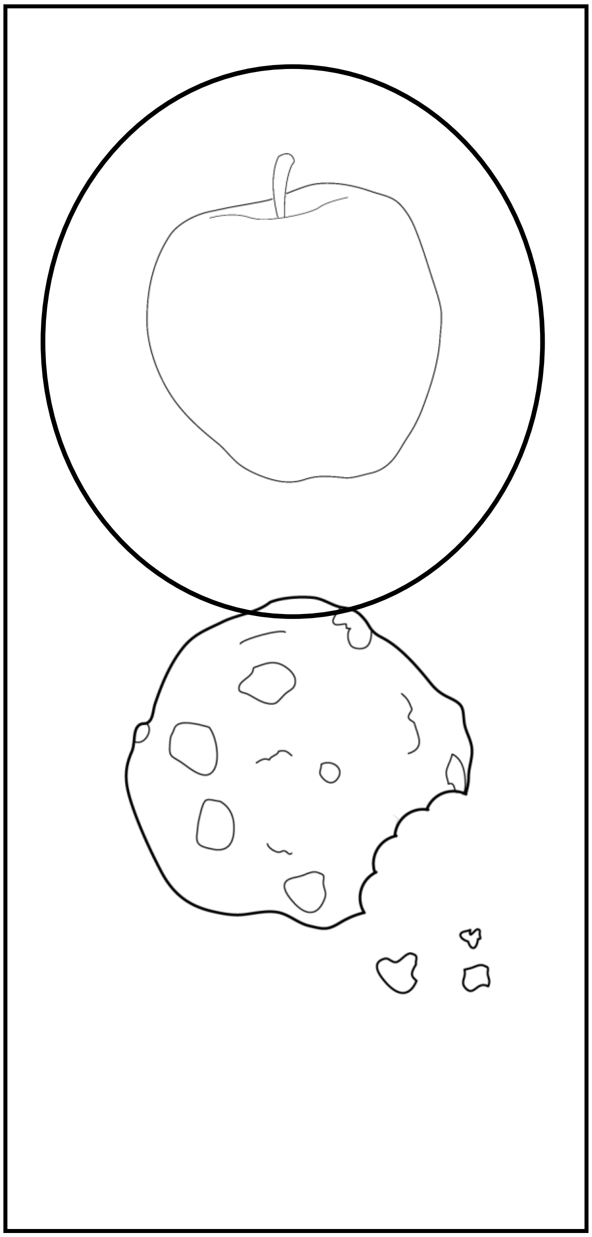
Further Investigations

Provide your students with three identical opaque closed containers, each with a different material inside with a significantly different density. Have your students guess what the material inside the container might be based on the weight of the container

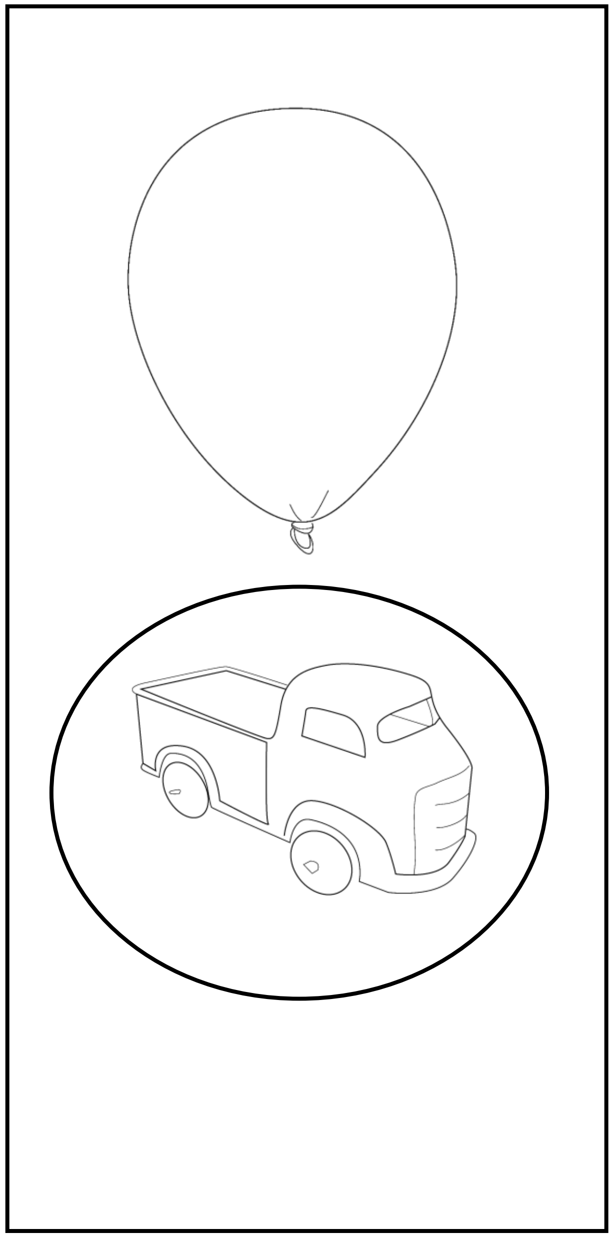
If something has more weight, we say it is:

heavier

Which one is heavier? (circle one)



Which one is heavier? (circle one)



2. Near and Far

Recommended Grade Levels: K – 1

Objectives

Students learn to describe the position of an object as being near or far from another object and they recognize that an object in motion changes its position.

Procedural Overview

To understand this content, students:

- Observe the movement of objects and classmates.
- Describe the location of objects and classmates relative to other objects, such as a reference point or the motion sensor.

Time Requirement

Teacher Preparation	10 – 15 minutes
Activity	20 – 30 minutes
Student Response Sheet	5 – 10 minutes

Materials

- ☐ Data collection system
- ☐ Motion sensor
- ☐ Large playground ball
- ☐ Meter stick

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

- Clear a space at least 2 meters in front of the motion sensor for student safety and to ensure that no other object is reflecting the signal of the motion sensor.
- Set up your data collection system for motion detection.

    1. Start a new activity on the data collection system.
    2. Connect the motion sensor to the data collection system.
    3. Display Position on the y-axis of a graph with Time on the x-axis.

4. Adjust the scale of the graph to best show the range of positions you will measure.

Background

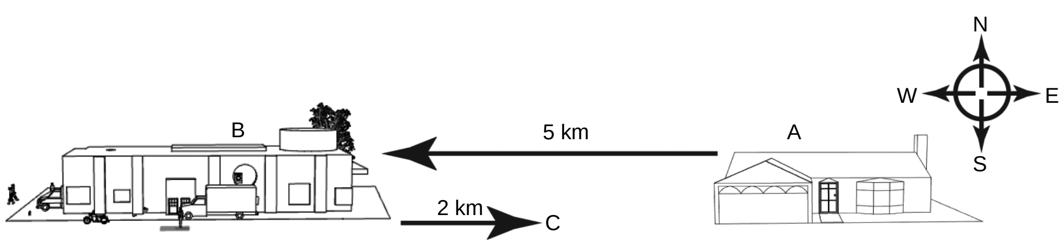
The terms "distance," "position," and "distance traveled" are often used interchangeably in everyday language. This can cause confusion when students begin their study of motion because these terms have different meanings.

"Motion" is defined as a change in position relative to an object or the background. We can visualize the motion of an object by creating a "trace" of the object's change in position over time. A position includes both direction and distance from an object or specified part of the background. It is good practice with young students to get them in the habit of describing position this way.

For example, when using the motion sensor you might describe your position as, "I am 1 meter in front of the motion sensor." If your students are not ready for units of measure like meters, you might try something more concrete such as, "I am two steps in front of the motion sensor." Students may, in fact, notice that one person's steps are longer than another person's steps, or people taking the same number of steps end up at different positions. This is an opportunity to show them a meter stick and let them know that this is why a scale is used for measuring. If everyone uses the same scale, we can more readily describe what we mean when we say, "near" or "far."

Distance versus Position versus Distance Travelled

If you tell someone the distance to your house, you might say "five kilometers" (5 km). However, if you tell someone the position of your house (point A), you might say, "5 kilometers east of the mall" (point B).



In this picture, the distance is 5 km, the direction is east, and you are measuring distance relative to the mall. "Distance traveled" is the total distance required to get from one position to another.

Assuming that you travel on a straight road to the mall, the distance traveled is 5 km and your position is 5 km west of your home. Now imagine that you turn around and travel from this position toward your house, going a distance of 2 km (point C). The total distance traveled is then 7 km (5 km plus 2 km), but your position is 3 km (5 km minus 2 km) west of your house. In this example, your final position is a distance of 3 km, the direction is west, and you are measuring relative to your house.

Near and far are relative terms, so you may need to take extra time to review examples that are familiar to your students. For example, the door to your classroom may be far from you relative to the distance of a student standing next to you, but the door may be near to you relative to the distance to the principal's office.

How the Motion Sensor Works

The motion sensor measures the time it takes for an ultrasonic pulse to travel to an object and back to the sensor. Using the speed of sound, it can determine the distance to the object. This is a rough approximation of the way dolphins and bats use echo location to determine the distance to an object.

Activity with Answer Key and Teacher Tips

There is a box next to each step. (☐) If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

How do you know if something is near or far?

Get Started

1. ☐ Hold a large playground ball on your hands at arm's-length.

2. ☐ Slowly and steadily draw the ball in closer to your face until it is just touching your nose.

3. ☐ Repeat this two or three times.

4. ☐ Ask students to tell you when the ball is near your nose and when the ball is far from your nose.

5. ☐ Place the ball near a student's nose and ask the class:

   Q Whose nose is the ball near now?

   Q Is the ball far from my nose or near to my nose?

6. ☐ Move the ball back to touch your nose and ask students:

   Q Is the ball near [student's name] nose or far from his or her nose?

7. ☐ Follow up on students' reactions with such questions as:

   Q Was the ball near because it is round?

   Q Was the ball near because it is bouncy?

   Q Was the ball far because it is [color]?

   Q Was the ball far because it is bigger than a pumpkin?

Let's Explore

8. ☐ Choose an object in the room to use as a reference point for near and far. An object such as the door, your desk, or other large, obvious classroom landmark in the students' line of sight works well.

9. ☐ Ask pairs of students to stand near and far from the reference point object. Tell which student to stand near and which student to stand far, but let each student decide where to stand.

Explain It

10. ☐ As pairs of students take their places, ask the class: Who is standing near the object? Who is standing far from the object?

    Students should be able to point to the students who are near and far.

11. ☐ Ask students, "How do you know if someone is near or far?"

    Student answers will vary. Some students may focus on the fact that we are using our eyes to see the difference, but try to direct students to the fact that they are comparing the relative positions of two things.

12. ☐ Help students develop their understanding of near and far with the following questions.

    Q Is he near because he is a boy? Is she near because she is a girl?

    Q Is she far because her name is [student's name]?

    Q Is he near because we are inside the classroom?

    Q Where would you like to stand if there was something really stinky on the [reference object]?

Tell Me More

13. ☐ What tools can be used to measure near and far?

    Students may be familiar with rulers or tape measures. Add "motion sensor" to the list.

14. ☐ Have students examine the parts of the motion sensor. Call attention to the round metal screen which is the reference point.

    Note: Students do not need to know this, but you should be aware that the metal screen is on the front of the motion sensor. The motion sensor cannot detect where they are if the metal screen is not pointing at them.

15. ☐ Begin recording a data run of position versus time data (motion).

16. ☐ Measure your position to show you are standing 15 cm (6 in.) in front of the motion sensor.

17. ☐ Continue measuring your position as you back away from the motion sensor and then walk toward it and stop.

18. ☐ Stop data recording.

19. ☐ For this activity, it is best to show only one run of data at a time, so if necessary, hide the data runs before beginning the next one.

20. ☐ Help a student volunteer walk close to and move away from the front of the motion sensor. It may be necessary to walk with the student to make sure he or she does not step outside of the motion sensor's beam.

21. ☐ Show students that the motion sensor measures "near" and "far." "Far" is higher on the graph than "near" is.

Sum It Up

22. ☐ Display the position versus time graph of the student volunteer. Have the class look at the motion graph of near and far (position) data. Ask:

    - How did the graph help show us whether someone is near or far?

      Students should be able to look at the graph and point to places where the line is higher and lower and relate the higher points to the student being far from the sensor. They should be able to point to lower points on the graph and relate these to the student being near the sensor.

22. ☐ Identify for your students the part of the graph where the student volunteer was changing position.

23. ☐ As a class, have your students describe in words the parts of the graph of Position versus Time.

    For example: [Student name] was near the front of the motion sensor and then changed position by walking away from the motion sensor until he or she was far from the front of motion sensor.

24. ☐ Have students complete the student response sheet.

Further Investigations

Introduce a distance scale:

1. ☐ To further your students' understanding of measuring, place the meter stick on the ground in front of the motion sensor.

2. ☐ Explain, "Instead of measuring the distance to the sensor as steps, I want to use a scale that people have agreed to."

3. ☐ Stand one meter away from the motion sensor and say, "I am one meter way from the motion sensor."

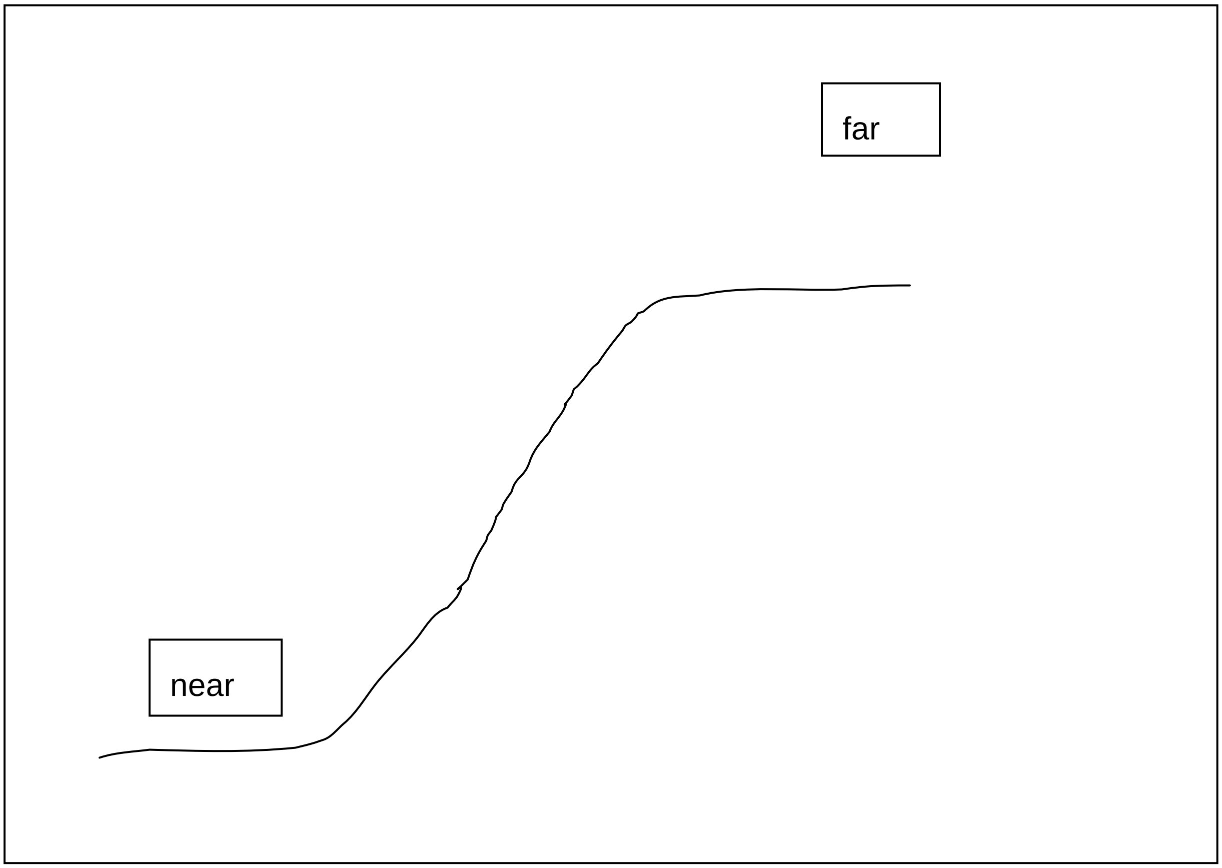
4. ☐ Pick up the meter stick and hold it up next to the y-axis of your graph.

5. ☐ Tell students, "We use a scale like a meter stick so we can all measure the same way."

6. ☐ With the meter stick on the floor, let your students take turns moving back and forth in front of the motion sensor.

   Note: Remember the motion sensor has a minimum distance that it can measure of 15 centimeters.

Draw the graph of position in the box. Label the graph using the words NEAR and FAR



Name something that is near to you.

desk

Name something that is far from you.

door

3. Mixing Water

Recommended Grade Levels: K – 1

Objectives

Students understand that mixing hot and cold water results in a new temperature that is between the hot and cold.

Procedural Overview

To understand this content, students:

- Identify the temperature of different objects
- Recognize that the position of the line on a graph relates to the hot or cold temperature of the object
- Predict the resulting temperature of mixing hot and cold water

Time Requirement

Teacher Preparation	10 – 15 minutes
Activity	15 - 20 minutes
Student Response Sheet	5 – 10 minutes

Materials

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Small paper cups (2)
- ☐ Large paper or plastic cup
- ☐ Ice water, approximately 5 ˚C, 200 mL
- ☐ Warm water, approximately 40 ˚C, 200 mL
- ☐ Towels

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

- Fill one small paper cup with hot water and one with ice water.
- Set up your data collection system for measuring the temperature of the hot and cold water.
    1. Start a new activity on the data collection system.

2. Connect the temperature sensor to the data collection system.

3. Display Temperature on the y-axis of a graph with Time on the x-axis.

4. Set the data collection systems to the temperature scale that is most familiar to your students.

5. Adjust the scale of the graph to best represent the range of temperatures you will measure.

Background

Most students will only be familiar with one temperature scale. Use the scale that is most familiar to your students for the activity.

Temperature: A Measure of Internal Energy

All objects in the universe have some internal energy. This internal energy is due to the energy of the random motion of an object's particles (atoms or molecules). Energy associated with motion is called kinetic energy, while energy associated with position is called potential energy. Temperature is a measure of the average kinetic energy of the particles in a substance.

Temperature Scales

In the United States, temperature is most commonly measured using the Fahrenheit scale. On this scale, the freezing point of water at sea level is 32 degrees and the boiling point of water is 212 degrees. Elsewhere the metric or Celsius scale is used to measure temperature. This is also the temperature scale used frequently in science. This scale is sometimes referred to as the centigrade scale because there are 100 degrees between the freezing point and the boiling point of water at sea level. In the Celsius scale, 0 degrees is defined to be the freezing point of water, with the boiling point at 100 degrees.

Scientists also use the Kelvin scale to measure temperature. On this scale, water freezes at 273 Kelvin, so 273 Kelvin refers to the same temperature as 0 degrees Celsius. A difference in temperature of 1 degree is the same in the Kelvin and Celsius scales, but 1.8 times the difference of 1 degree Fahrenheit.

How Cold Can It Go?

Zero on the Kelvin scale (–273 degrees Celsius) is known as absolute zero. It is a theoretical point at which molecules and atoms have zero kinetic energy and has never been reached in laboratory experiments. Scientists can currently achieve low temperatures of about one-billionth of a degree above absolute zero.

Energy Flows from Warmer to Cooler

Energy is transferred between objects as heat. This energy is transferred because one object is at a higher temperature than the other. If two objects at different temperatures are in contact with one another, the energy will be transferred from the warmer object to the colder object until both reach the same temperature. The point at which each object is the same temperature is referred to as the "point of equilibrium."

When a pie comes out of the over and is placed on a counter to cool, the hot pie transfers heat to the air and counter that come into contact with the pie until they all reach the same temperature. When we mix hot and cold water, heat energy is transferred from the hot water to the cold water until both are at the same temperature. This is similar to the way we change the temperature of a room by mixing warm and cool air.

Activity with Answer Key and Teacher Tips

There is a box next to each step. (☐) If you find it helpful place a check mark in the box after you complete that step.

Driving Question

What happens when you mix a hot thing and a cold thing together?

Get Started

1. ☐ Set out two small paper cups filled with hot and cold water.

2. ☐ Ask the students the following questions:

   Q Which one of the cups has COLD water in it?

   Q How do you know the water in that cup is cold?

   Q Which one of the cups has HOT water in it?

   Q How do you know the water in that container is hot?

   Q If you saw a pot full of water on the stove in the kitchen, can you tell by looking at it if the water is hot or cold?

   Q When you take a bath, how do you make sure the water is not too hot or too cold?

Let's Explore

3. ☐ Have students take turns putting their fingers in the ice water and into the warm water.

   - Encourage students to have one finger in the cold water and one finger from the other hand in the warm water at the same time, so they can feel the difference.

   - Keep towels handy to help students dry their hands.

Explain It

4. ☐ Ask students:

   - What things are cold? What things are hot?

     Student answers will vary. Cold things may include ice, snow, refrigerator, or air from an air conditioner. Hot items might include stoves, fire, cocoa, or the sun.

- How do you know if something is hot or cold?

  Student answers will vary. We primarily sense hot and cold by touch, but we can see steam coming off hot water.

- How do you think you can you make something warm?

  Student answers will vary. They may suggest placing the object in contact with something warmer, or placing the object close to something that radiates heat, such as a heater or camp fire.

Tell Me More

5. ☐ Ask, "What tools can be used to measure hot or cold?"

   Thermometers or temperature sensors

6. ☐ Have students examine the temperature sensor.

7. ☐ Start recording a run of temperature data.

8 ☐ Insert the temperature sensor in the ice water in the cup to measure the temperature. Allow the temperature graph to go as low as it will go (20-40 seconds).

9. ☐ Move the temperature sensor to the cup of hot water. Measure the temperature of the hot water. Allow the temperature graph to go as high as it will go.

10. ☐ Help students observe that "hot" is higher on the graph than "cold" is.

11. ☐ Mix the hot water and the cold water together in the large cup. Ask students to predict what the water will feel like.

12. ☐ Ask students to predict where the line on the graph will show up when the temperature sensor is placed in the mixed water cup.

13. ☐ Place the temperature sensor in the large cup containing the mixed water. Allow the temperature graph to reach a stable temperature.

14. ☐ Stop data recording.

Sum It Up

15. ☐ Have students look at the graph of hot, cold, and warm temperature data. Ask them, "How did the graph help show us whether something is hot or cold or in between?"

    Students should be able to look at the graph and point to places where the line is higher and lower, and relate the higher points to the hotter water. They should be able to indicate lower points on the graph and relate these to the cold water.

16. ☐ Ask students, "What happens when you mix a hot thing and a cold thing together?"

    The resulting temperature is somewhere between the two starting temperatures.

17. ☐ Have students complete the student response sheet, copying the graph of temperature and adding the words "hot," "cold," and "mild" at the correct places.

Further Investigations

Continue the activity by developing the idea of a temperature scale.

1. ☐ Start recording a run of temperature data.

2. ☐ Remove the temperature sensor from the mixed water, dry it quickly, and let it measure the room temperature.

3. ☐ Stop data recording.

4. ☐ Note the difference between the temperature of the mixed water and the room temperature, and identify the room temperature as "mild" (not too hot and not to cold).

5. ☐ Ask the following questions:

   - What do we call something that is hotter than the room but not hot?

     Warm

   - What do we call something that is colder than the room but not quite cold?

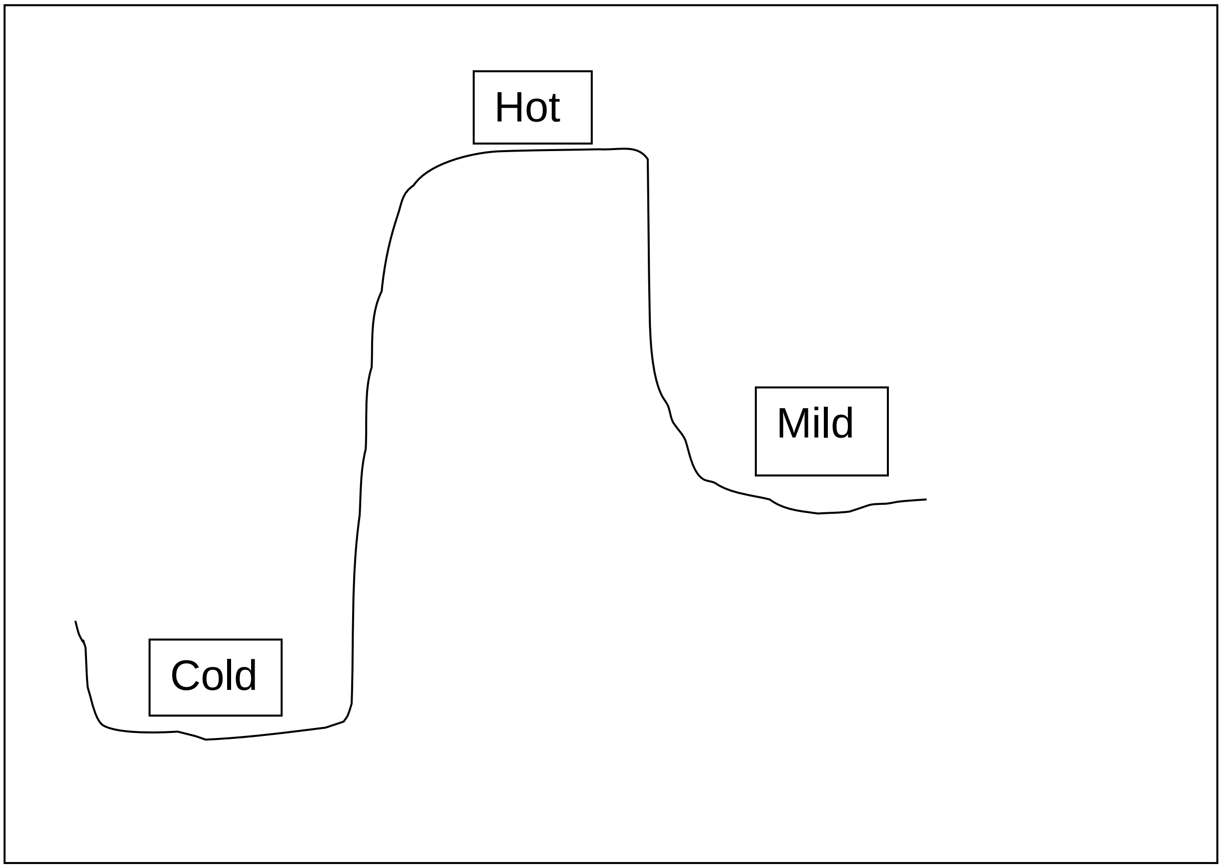
     Cool

6. ☐ Explain that they have created their own temperature scale.

7. ☐ Draw a thermometer and add the new scale starting on the bottom with "cold," and working your way up the thermometer with "cool," "mild," "warm," and "hot."

8. ☐ Have your students identify items in the room that would be in each temperature range and add them to your drawing.

Draw the graph of temperature to show cold, hot, and mild.



Write hot, cold, and mild on the graph of temperature.

What do you get when you mix hot and cold?

mild

4. Light and Dark

Recommended Grade Levels: K – 1

Objectives

Students determine how light is related to what they see.

Procedural Overview

To understand this content, students:

- Observe how the presence and absence of light affects what they see
- Observe the level of light from a light source versus the light reflected from a surface

Time Requirement

Teacher Preparation	10 – 15 minutes
Activity	20 – 30 minutes
Student Response Sheet	5 – 10 minutes

Materials

- ☐ Data collection system
- ☐ Light sensor
- ☐ Sensor extension cable
- ☐ Strips of construction paper, 2.5 cm x 8 cm (1 in. x 3 in.) different colors, 1 per student[1]

[1] Each student should be given one strip of construction paper so that there are a variety of colors within the class. Colored wooden craft sticks may also be used.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

- Set up your data collection system for measuring light.

    1. Start a new activity on the data collection system.

    2. Connect the light sensor to the data collection system.

    3. Display Light Intensity on the y-axis of a graph with Time on the x-axis.

Background

Light – Part of the Electromagnetic Spectrum

The electromagnetic spectrum represents the range of waves that can travel through empty space at the speed of light (approximately 300,000 kilometers/second). Electromagnetic waves, as they are called, carry energy and can behave as waves while they travel but are emitted and absorbed as particles. The spectrum, or variety, of waves includes radio waves, microwaves, infrared waves, visible light, ultraviolet light, X rays, and gamma rays. The lower the frequency of an electromagnetic wave, the longer its wavelength becomes. Each color of visible light has a unique wavelength. The color with the longest wavelength is red while the shortest wavelength belongs to violet.

Sunlight is a form of electromagnetic wave. It consists of several types of waves that our eyes and bodies can distinguish. We see visible light, we feel the warmth of infrared light on our skin, and we try to avoid the damage our skin may experience from ultraviolet light.

Light Sensor Explained

The “light-and-dark measuring tool,” or light sensor, measures light intensity as perceived by our eyes. Light intensity is measured in units called lux (abbreviated “lx”). The light sensor has a small aperture, or opening, surrounded by a short black tube. Light rays must shine through this opening in order for their intensity to be measured. This structure is analogous to the iris in our eyes because it admits light.

The Light Sensor Is Like Our Eyes

Both the light sensor and our eyes must have light enter them in order to “see.” If the opening of the light sensor is covered over with a finger, for example, it “sees” no light. A graph of light intensity will show zero intensity until the finger is removed from the opening. Likewise our eyes cannot perceive form or color without some amount of light entering through the iris and striking the retina at the back of the eye.

Activity with Answer Key and Teacher Tips

There is a box next to each step. (☐) If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

How is light related to what we see?

Get Started

1. ☐ Darken the room or go into a closet. In the dark, hand each student a colored strip of paper or a colored craft stick.

   Note: Be sure not to let students see the paper or craft sticks before they are in the dark.

   Teacher Tip: For best results, this part of the activity needs to be carried out in a very dark environment. Explain to students ahead of time how the room will be darkened or that they will be going into a dark room such as a coat room or closet. You may even want to practice being in the dark so that when you do the activity, students' attention can be focused on looking for the color of their paper, rather than on the novelty of being in the dark.

2. ☐ Ask students to tell what color their paper strip or craft stick is.

Let's Explore

3. ☐ After turning on the light, ask students again what color their paper strip or craft stick is.

   Students should discover the color of their paper or stick.

4. ☐ Follow up on students' reactions to their experience:

   Q What color did you say your paper or stick was when we were in the dark?

   Q What color did you say it was when the lights were on again?

   Q Do you think your paper (or craft stick) changed color or was it the same color the whole time?

   Q Could you tell what color it really was when it was dark?

5. ☐ Encourage students to compare their color results in the dark to their results in the light.

Explain It

6. ☐ Collect the paper strips if you will be saving them for another class.

7. ☐ Affirm that the presence of light made it possible to see the color clearly, and ask students:

Q Where does light come from?

Q Where does light go?

Q Can light go through things?

Q Is it easier to see things in the light or in the dark?

8. ☐ Ask students to think of examples of when someone in their family has had difficulty seeing something in the dark.

9. ☐ Ask students where it would be easier to find a lost toy:

Q Under your bed or in the middle of the room?

Q Outside in the day or outside at night?

Q In the dark with a flashlight or without a flashlight?

10. ☐ Ask students, "When you shine a flashlight on something the light travels straight out from the flashlight, so how does the light get back to your eye so you can see the object?"

A portion of the light is reflected back to your eye.

Tell Me More

11. ☐ Ask students, "What tool can be used to measure light and dark?"

A light sensor can be used to measure the intensity of the light.

12. ☐ Have students examine the parts of the light-and-dark measuring tool (light sensor).

13. ☐ Show students the “eye” of the light and dark measuring tool and explain that it can “see” light and dark. When light gets into the tool’s "eye," it can see. Light is higher on the graph, and dark is lower on the graph.

Note: If you are using a Temperature/Sound Level/Light MultiMeasure® sensor, point out to students that the black plastic tube is where the “eye” is located.

14. ☐ Start recording a data run of light intensity versus time. Have a student volunteer use his or her hand or finger to cover and uncover the “eye” of the light-and-dark measuring tool.

15. ☐ Adjust the scale of your graph to clearly see the range of intensities in your room.

16. ☐ Ask the class to tell when the tool’s “eye” is “open” and when it is “closed” as the volunteer covers and uncovers the light sensor.

17. ☐ Ask students,

■ If we cover up the light sensor (close the eye), how much light is getting into it?

None of the light is getting into the sensor. Point to the graph to affirm that no light is being measured.

- So when we say something is dark, what does this mean?

  No light is present.

18. ☐ Point the light sensor directly at a room light.

19. ☐ Remind your students that the light is going directly from the room light to the light sensor.

20. ☐ Point the light sensor at a surface in the room, and ask the following questions:

    - Is the light from the surface more or less than the light coming from the room light?

      The light intensity will be much less. Help your students understand that higher on the graph means more light.

    - Where does the light coming from the surface originally come from?

      The light is reflected from the room light.

21. ☐ Stop recording data.

Sum It Up

22. ☐ Have students look at the graph of light and dark data and ask,

    - How did the graph help show us when the "eye" was open and closed? How did the graph help us know when it was light and dark?

      Students should be able to look at the graph and point to places where the line is higher and lower, and relate the higher points to the "eye" being open and seeing light. They should be able to point to lower points on the graph and relate these to the "eye" being closed and not seeing any light, or dark.

23. ☐ Ask students, "How is light related to what we see?"

    Light is needed in order to see. What we see is the light reflected from an object that reaches our eyes. If there is no light, we can't see.

24. ☐ Have students complete the student response sheet.

Further Investigations

Help your students better understand the usefulness of sensors and "sensing" in doing scientific investigations with the following questions:

Q How can the light sensor be used to see into places where we cannot reach?

Q How might this be helpful to us?

Q Can we use the light sensor to find out if the light goes off in a refrigerator when the door is closed?

Another activity that might help students understand how light is reflected is to bring a playground ball and a flashlight into the dark room. Hold up the ball and have a student shine the light from the side so that half of the ball is illuminated. Remind them how the moon looks in the sky at night. Have the student with the flashlight slowly move around the ball. The light from the sun (the flashlight) strikes the moon and is reflected back to us, so we only see the parts that are reflecting the sunlight.

What do we need to see things?

light

What is it like when there is no light?

dark

What do we use to see light?

our eye

5. Exploring Temperatures

Recommended Grade Levels: K – 1

Objectives

Students understand that all matter has the observable property of temperature, and that temperature is a measure of how hot or cold something is compared to a standard scale.

Procedural Overview

To understand that temperature is a measurable property of matter, students:

- Explore temperature changes by the use of graphs and meters for measuring temperature
- Guess which places in the classroom and around the school will be warm and which places will be cool
- Check guesses with a temperature sensor
- Compare the range of warm and cool places inside and outside

Time Requirement

Teacher Preparation	15 minutes
Activity	30 minutes
Student response sheet	15 minutes

Materials

For teacher demonstration:

- ☐ Mobile data collection system
- ☐ Temperature sensor
- ☐ Bag of clothing[1]
- ☐ Large outdoor thermometer
- ☐ Paper meter [2]
- ☐ Paper thermometer scale (can be written on)
- ☐ Thermometer, oral

[1]Clothing should include both hot and cold weather clothing.

[2]Refer to the Preparation section for the simple construction of the meter.

For student groups:

- ☐ Mobile data collection system[1]
- ☐ Temperature sensor[1]

[1]The number of mobile data collection systems and temperature sensors depends on the size of the groups. If you lead the whole class, 1 set is required, otherwise have 1 set per group leader (aide or other class assistant).

Safety

Add this important safety measure to your normal classroom procedures:

- Care should be taken not to disturb the environment.

Preparation

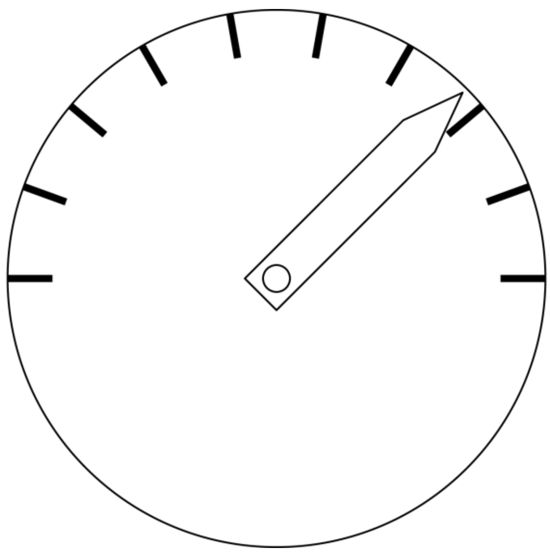
These are the materials and equipment to set up prior to the activity.

- Paper meter construction

  Use construction paper or paper plates and a brad to construct the meter shown below.

- For kindergarten, leave the numbers off, but put marks at evenly spaced points around the meter.

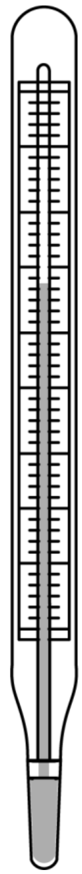
- For first grade, use the Fahrenheit scale, writing whole numbers in the range of 0 °F to 100 °F, counting by tens.



- Paper thermometer construction

- Use construction paper or butcher paper to construct the thermometer shown below.

- Numbers are not necessary; this is just to give a qualitative context to high and low temperature.



- Set up the data collection system for displaying the temperatures of ice water and warm water during the "Tell Me More" portion of the activity:

    1. Start a new activity on the data collection system.
    2. Connect the temperature sensor to the data collection system.
    3. Display Temperature in a meter display.
    4. Display Temperature on the y-axis of a graph with Time on the x-axis.
    5. Adjust the scale of the graph to best represent the range of temperatures you will measure.
    6. Set the data collection system displays to the temperature scale that is most familiar to your students.
    7. Set the sampling rate to 1 Hz.
    8. If your classroom has a projection system and you want to display the graph and meter to the whole class at once, follow your usual classroom procedure to connect your data collection system to the projection system. You will need the correct software on your computer for your data collection system.

Background

Very young children can distinguish between “cooler” and “warmer.” If your students are unfamiliar with the term “temperature,” you can start a discussion with comparisons between how they feel when they stand in the shade versus standing in the sunshine, and how they feel when they get hot while playing on the playground or when lying on a cool floor.

Students often think that a coat generates heat when they go outside in the cold. In reality, the coat provides a buffer between the heat given off by their body and the varying temperature of the air outside. This activity focuses on measuring the air temperature in different locations

Air is a gas and has all of the properties of matter attributed to solids and liquids. The property focused on in this activity is temperature. Air temperature is a measure of the amount of thermal energy in the air. Thermal energy is added to the air directly by the sun and indirectly by the re-radiation of thermal energy from the Earth's surface, once it has been warmed by the sun. Heat energy in the local air is reduced when a lower temperature air mass mixes into it.

As heat always flows from a warmer to a cooler object, when a cool air mass mixes with a warm air mass, the warm air mass cools and the temperature is lowered. (Wind is the cause of air masses mixing.)

Raising or Lowering Temperature

Work is done to raise or lower the temperature of a room. Indoors, furnaces add hot air to the classroom and the warmth of peoples' bodies also adds heat energy. Heat energy is reduced in the classroom air by the addition of cold air from the air conditioner and the drawing of warm air out of the room through open windows.

Measure Temperature, Not Heat

The temperature sensor does not directly measure heat energy; the sensor measures how hot or cold the air is with respect to a standard. The temperature will change on the thermometer or sensor until the air and the sensor reach "thermal equilibrium". At this point, heat energy stops being transferred between the sensor and the matter being measured. The sensor displays the temperature at the point of equilibrium.

Be careful to distinguish between heat and temperature. When a thermometer is used to measure your body temperature or the air temperature, it is measuring thermal equilibrium. For young students, guide them to say they are measuring temperature, not heat.

Activity with Answer Key and Teacher Tips

There is a box next to each step. (☐) If you find it helpful, place a check mark in the box after you complete that step.

Driving Questions

Does the air have a temperature?

Is the temperature of the air different in different places?

Get Started

1. ☐ Ask students to explain how they feel on a hot day, and what kinds of activities they like to do on a hot day. Have the same conversation about a cold day.

2. ☐ Use questions like the following to introduce the words "warm" and "cool," and then order "cold," "cool," "warm," and "hot" for students

   Q Do you sometimes feel sort of hot but not too hot? This feeling is called "warm."

   Q Where have you felt warm but not too hot?

   Q Would you rather feel warm or hot?

   Q Do you sometimes feel not too cold but only a little cold? This feeling is called "cool."

   Q Where have you felt cool but not cold?

   Q Would you rather feel cool or cold?

3. ☐ Have a grocery bag containing various pieces of clothing appropriate for cold days and hot days. Items can include a bathing suit, a rain coat, a hat and scarf, mittens, sunhat, tank top, shorts, sweat pants.

4. ☐ Pull the pieces of clothing out of the bag one by one and display them for the class.

   As you pull out each item, ask students to tell you if they would wear the item on a cold day or on a hot day.

   Q If it were a hot day outside, would you feel cool or warm?

   Q If it were a cold day outside, would you feel cool or warm?

5. ☐ Next, ask students to think about the air inside the classroom.

   Q Is the air in the classroom cold or hot?

   Q What is it in the classroom that makes it feel cold or hot?

   Teacher Tip: Guide students' comments to the fact that the air in the classroom is not in direct sunlight, so it stays cooler. Students may want to talk about furnaces and air conditioners here.

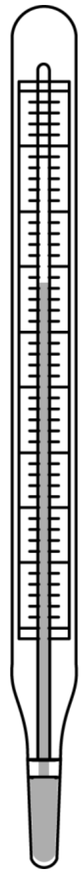
6. ☐ Begin a discussion about ways to measure temperature

   Ask students if they have been sick, and felt too hot or too cold.

   Ask if a parent has ever had to take their temperature. Have students describe how their parents take their temperature.

7. ☐ Show them an oral thermometer and describe the way the red liquid (alcohol) inside the thermometer moves higher on the scale if they have a high temperature.

8. ☐ Show students a large paper thermometer, like the drawing below, and show them how the red liquid could go higher or lower.



9. ☐ Explain to students that temperature is how we measure the hotness or coldness of objects, or of the air.

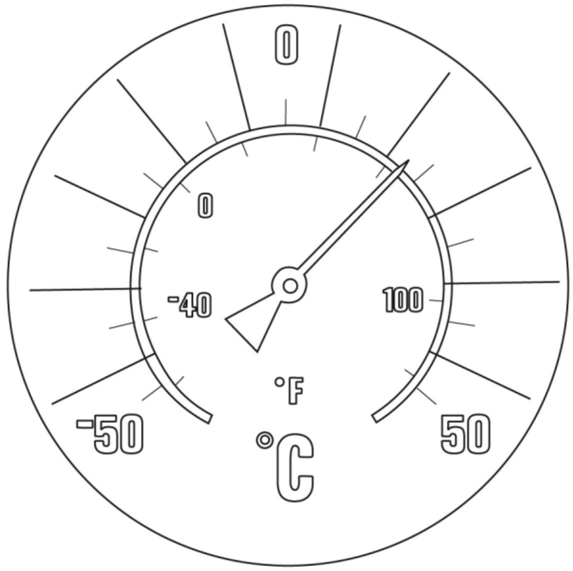
10. ☐ Explain that we can measure the temperature of lots of things to find out how hot or cold they are. Use questions like the following to remind students of temperature measurements in their lives:

    Q Does your parent measure the temperature of a turkey in the oven? (Use any appropriate familiar situation.)

    Q Do you have a thermometer outside in your yard to measure the temperature of the air outside?

    Note: Some students will be unfamiliar with any of these measuring tools, but some will be very familiar with such experiences. Allow them to share their experiences for the benefit of all.

11. ☐ Show students a large outdoor thermometer (the kind with the circular face). Also, have the paper meter you can manipulate.



12. ☐ Using the thermometer and the meter, ask students to demonstrate how high the red liquid would go or where the needle would point if it were a cold day or a hot day.

    a. For kindergarten, this is just a lower–higher comparison.

    b. For first grade, elicit the idea that 30 °F is a day for coats, scarves and mittens, and 100 °F would be a day for bathing suits and swimming.

Let's Explore

13. ☐ Demonstrate how the sensor records temperature with a line on the graph and a pointer on the meter.

    a. Start recording data.

    b. Moisten the tip of the temperature sensor, then swing the sensor in the air and show the students how the line on the graph drops lower and the meter's arrow moves to the left.

    c. Warm the sensor in the palm of your hand and show how the line on the graph goes up and levels off, and how the meter pointer moves to the right.

    d. Repeat this process several times, asking the students to explain to you how the sensor is measuring the temperature.

    The sensor measures how hot or cold the air is with respect to a standard. The temperature will change on the thermometer or sensor until the air and the sensor reach "thermal equilibrium".

    e. Ask where on the graph the temperature is colder, and where it is warmer. Ask the same questions for the meter.

    Students should understand that if the line goes lower on the graph, the temperature is measuring something cooler. They should also know that the needle moving to the left on a meter means cooler.

    f. Stop recording data.

14. ☐ Compare temperatures around your classroom together.

a. Start recording temperature data.

b. As a group, predict where the temperature in the classroom will be warmer (or cooler).

c. After each prediction, walk to that location and hold the temperature sensor in place for a few seconds.

d. Show the results to the students and let them decide if their prediction was supported by the data or not supported.

e. Stop recording data.

15. ☐ Have your students break into their smaller groups and ensure each group leader has a mobile data collection system and a temperature sensor.

    a. Encourage each student group to think about locations that can be paired with another location for comparison. For example, take temperature readings of the floor and ceiling of a room.

    b. Have each student group start recording data.

    c. Send each student group to the locations they have chosen to measure.

    d. After students have returned, have them stop data collection.

16. ☐ Give each student group a moment to determine from their data which location was the warmest and which place was the coolest.

17. ☐ Have each group share their results in turn by asking the following questions.

    Q What is the warmest temperature you found?

    Q Why do you think it was so warm?

    Q What was the coolest temperature?

    Q Why was it cooler?

Explain It

18. ☐ Come back together as a class for discussion. Was there a big difference between your warmest spot and your coolest spot, or was there a little difference?

    Students will likely notice that there was only a little difference between the warmest and the coolest places in the classroom, because the air temperature in a classroom is controlled.

19. ☐ What makes the air temperature warm?

    Answers may vary. Students will say being under covers, or in sunshine through a window, or by a hot air duct, it will be warmer.

20. ☐ What makes the air temperature cool?

Answers may vary. Students will say that being indoors is cooler than being in the sun; they will point to the air conditioning or the fan, or mention the cool floor if it is not carpeted. They may also point to an open window.

21. ☐ How do you think outside temperatures will compare to inside temperatures?

Kindergarten students can describe the differences as hotter or colder. First graders can predict a value in degrees Fahrenheit.

Tell Me More

22. ☐ Have your group leaders prepare the mobile data collection system by hiding any previous runs of data.

23. ☐ Ask students, “How can we measure warm and cool temperatures outside?”

Encourage students to explain how they will take their temperature sensor outside and explore air temperature in different locations, just as they did inside. Listen for the use of action words and simple ordering of steps.

24. ☐ To elicit a good procedure, ask students:

Q What will you do first?

Q When will you push the start button?

Note: The goal is to help students to plan what they will do before they do it and explain in words what they will do.

25. ☐ Ask students to predict where they think the temperature of the air will be the warmest? The coolest?

Q Where do you want to take the temperature?

Teacher Tip: Limit each student group to measuring the temperature at only two or three locations.

Q How hot or cool do you think it will be?

Q What will make it warmer or cooler?

26. ☐ Group students again with a classroom helper or aide as group leader, and have each group plan the locations they will go to outside to measure the temperature.

a. Have each group start recording temperature data.

b. Send the groups off to their first location.

c. Group leaders should allow the sensor to adjust to the temperature in each location before moving to the next.

d. Have the groups go to each location where they chose to measure the temperature.

e. Stop recording data and return to the classroom.

27. ☐ Each group should look at the line on their graph to discuss the following.

Q Where did the temperature go up by a large amount?

Q What made the temperature go up in these places?

Q Where did the temperature go down by a large amount?

Q What made the temperature go down in these places?

28. ☐ Come back together as a class and let each group share their data.

Sum It Up

29. ☐ Ask students to compare the outside temperatures with the inside temperatures.

Q For kindergarten: Did the outside temperatures change a lot or a little?

Q For first grade: What was your highest outside temperature? What was your lowest outside temperature?

30. ☐ Determine the hottest places outside and the coolest places outside and sum up with the students what makes these places hot and cold.

31. ☐ Review what the line on the graph did when the temperature was really hot.

The line goes higher on the graph when the temperature was hot.

32. ☐ Discuss what the line on the graph did when the temperature was the coolest.

The line goes lower on the graph when the temperature is measuring something cooler.

33. ☐ Compare locations from different groups and try to find the warmest and coolest locations overall. Can the class see any patterns to the values? What made certain areas warmer or cooler?

34. ☐ Ask students:

Q Does the air have a temperature?

Q Is the temperature of the air different in different places?

35. ☐ Have students complete the student response sheet.

Further Investigations

Ask your students what the coldest thing they can think of is. Answers will vary, but direct them toward blizzard-like temperatures outside or a freezer in their home, whichever is more appropriate. Ask them what happens when we put water in these conditions. Try the following:

1. ☐ Set your data collection system to collect one sample per minute.

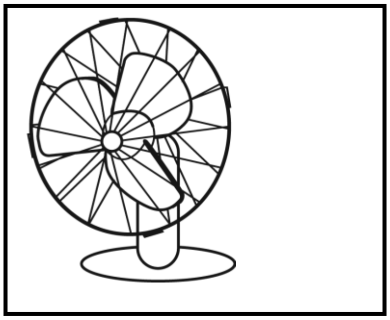
2. ☐ Place the tip of the sensor in a container of water and record the temperature of the water overnight.

3. ☐ Show the graph to your students the next day.

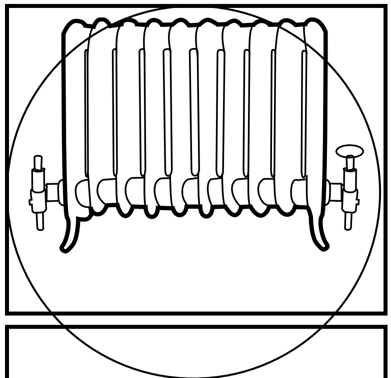
4. ☐ Repeat the data recording the following night with the water container in a freezer. Bring in the data and block of ice for your students to see.

For Inside Temperatures

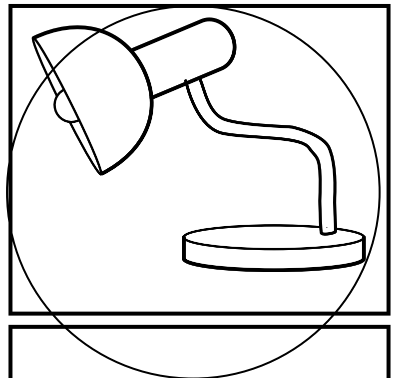
Circle the pictures that show places where the temperature will be warm or hot.



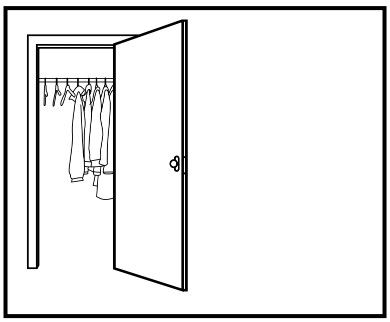
Near a fan



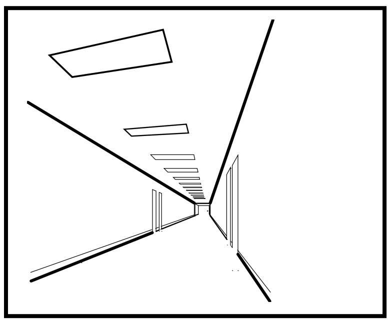
Near a heater



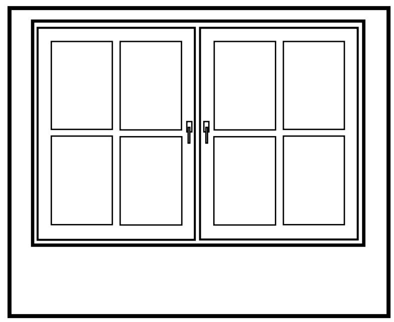
Near a lamp



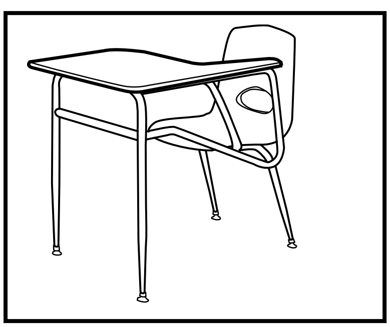
In a dark place



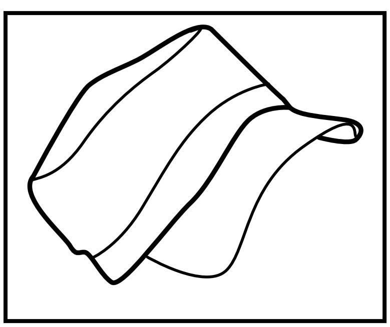
In a hallway



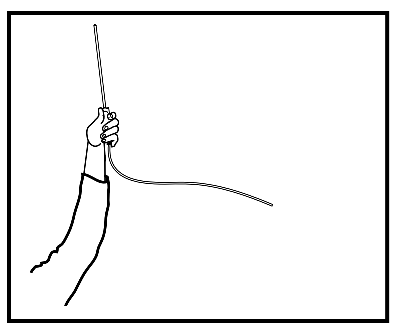
Near the window



Under a desk



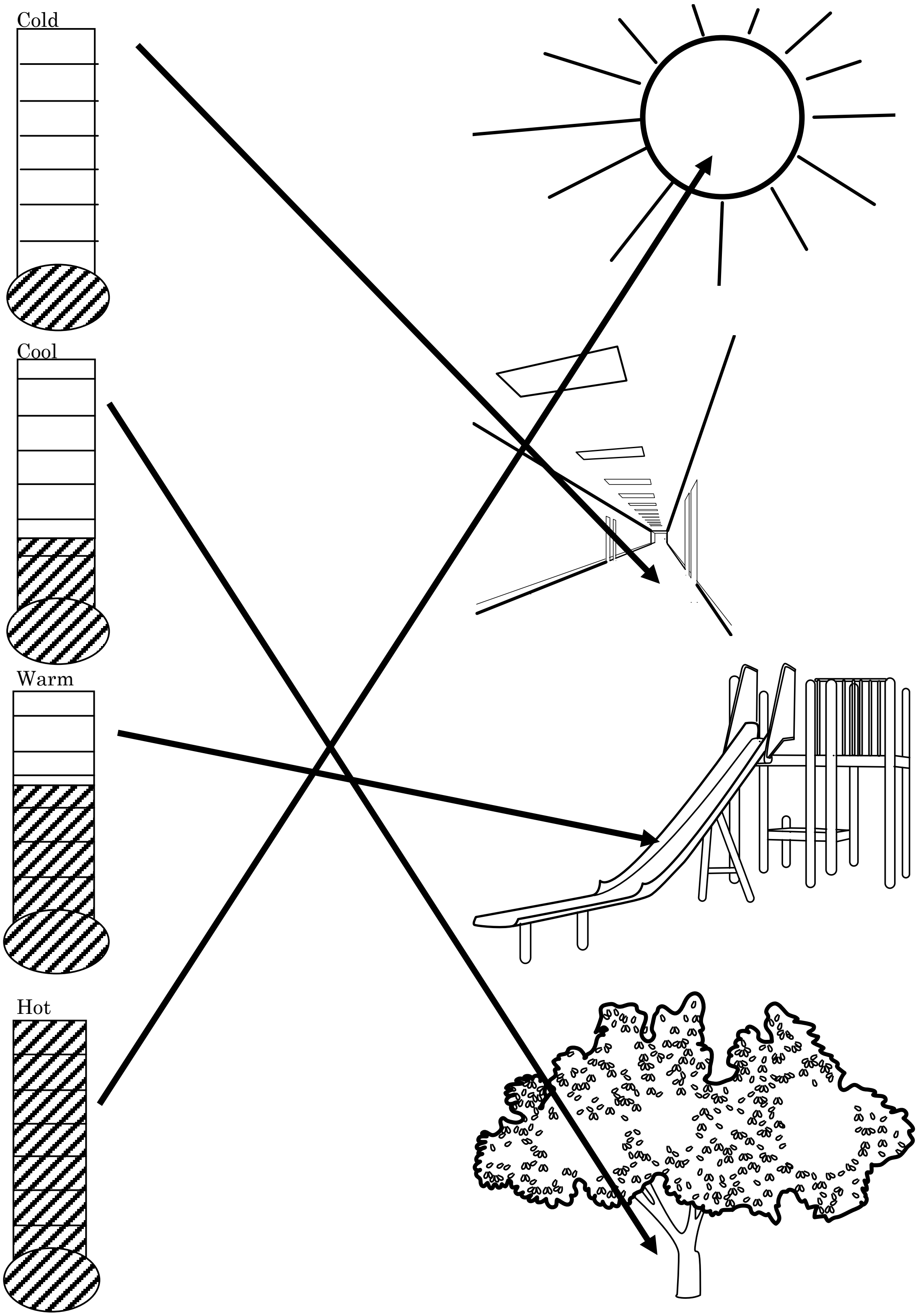
Under a hat



High up in the air

For Outside Temperatures

Draw lines to connect the pictures with the words. Color the thermometer to match the words.



Answers will vary based on your local conditions

6. Hot and Cold

Recommended Grade Levels: K – 1

Objectives

Students recognize that one of the observable properties of objects is temperature, and that this property can be measured using a thermometer or temperature sensor.

Procedural Overview

To understand this content, students:

- Observe the temperature of different objects
- Classify materials as cold or hot

Time Requirement

Teacher Preparation	10 – 15 minutes
Activity	20 – 30 minutes
Student Response Sheet	5 – 10 minutes

Materials

For teacher demonstration:

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Buckets or containers for water[1] (2)
- ☐ Towels
- ☐ Ice cubes (several[1]), for cold water container
- ☐ Plastic water or soda bottles, several,[1] filled with warm water (no warmer than 30 °C or 86 °F), tightly capped[2]

[1]The size of the buckets, number of ice cubes and number of bottles depend on the size of your class and the number of students you want to be able to hold them simultaneously.

[2]Recycled 500-mL water bottles, with labels removed, work well for this activity.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

- Place the ice in one bucket and bottles of warm water in the other bucket.
- Set up the data collection system for displaying the temperatures of ice and warm water during the "Tell Me More" portion of the activity:

a. Start a new activity on the data collection system.

b. Connect the temperature sensor to the data collection system.

c. Display Temperature on the y-axis of a graph with Time on the x-axis.

d. Set the data collection systems to the temperature scale that is most familiar to your students.

e. Adjust the scale of the graph to best represent the range of temperatures you will measure.

Background

Most students will only be familiar with one temperature scale. Use the scale that is most familiar to your students for the activity.

Temperature: A Measure of Internal Energy

All objects in the universe have some internal energy. This internal energy is due to the energy of the random motion of an object's particles (atoms or molecules). It is also due to the energy resulting from how tightly bound the particle is to surrounding particles. Energy associated with motion is called kinetic energy, while energy associated with bonding is called potential energy. Temperature is a measure of the average kinetic energy of the particles in a substance.

Temperature Scales

In the United States, temperature is most commonly measured using the Fahrenheit scale. On this scale, the freezing point of water is 32 degrees and the boiling point of water 212 degrees. Elsewhere the metric or Celsius scale is used to measure temperature. This is also the temperature scale used frequently in science. This scale is sometimes referred to as the centigrade scale, because there are 100 degrees between the freezing point and the boiling point of water. In the Celsius scale, 0 degrees is defined to be the freezing point of water, with the boiling point at 100 degrees at sea level.

Scientists also use the Kelvin scale to measure temperature. On this scale, water freezes at 273 Kelvin, so 273 Kelvin refers to the same as 0 degrees Celsius. A difference in temperature of 1 degree Celsius is the same as 1 Kelvin, but 1.8 times the difference of 1 degree Fahrenheit.

How Cold Can It Go?

Zero on the Kelvin scale (–273 degrees Celsius) is known as absolute zero. It is a theoretical point at which particles have zero kinetic energy and has never been reached in laboratory experiments. Scientists can currently achieve low temperatures of about one-billionth of a degree above absolute zero. At such low temperatures matter can behave strangely. For example, metals can conduct electricity with no resistance (superconductivity) and liquid helium can flow with no viscosity (superfluidity).

Energy Flows from Warmer to Cooler

Energy is transferred between objects as heat. This energy is transferred because one object is at a higher temperature than the other. Heat itself does not flow, nor does cold; heat is energy "on the move." If two objects at different temperatures are in contact with one another, the energy will be transferred from the warmer object to the colder object until both reach the same temperature. The point at which each object is the same temperature is referred to as the "point of equilibrium."

Activity with Answer Key and Teacher Tips

There is a box next to each step. (☐) If you find it helpful, place a check mark in the box after you complete that step.

Driving Questions

What do we mean when we say "hot" and "cold?"

How do we tell if something is hot or cold?

Get Started

1. ☐ Set out a container or bucket of ice cubes where students can see them.

2. ☐ Pick up an ice cube and react as if it is warm or even hot. Exaggerate all of your movements.

   Follow up on students' reactions to your behavior with such questions as:

   Q Do you think ice cubes are hot?

   Q What makes you think an ice cube is hot?

   Have students point to the container holding the objects or materials they think are cold. Ask questions such as:

   Q Are these things cold because they are shiny?

   Q Are they cold because they are clear or see-through?

   Q Are they cold because they taste like water?

Let's Explore

3. ☐ Have students take turns picking up and holding an ice cube and a bottle of warm water in their hands.

   Encourage students to hold an ice cube in one hand, then a bottle of warm water in the same hand before holding it in the other hand. The bottle of water may seem to students to be two different temperatures.

   Note: Not all students may be willing to hold an ice cube.

   Teacher Tip: Keep towels handy to help students dry their hands after holding the ice cubes.

4. ☐ Ask students to sort the ice cubes and water bottles into two groups, cold and hot.

Explain It

5. ☐ Ask students:

   Q Which things are cold?

   Q Which things are hot?

   Q How do you know if something is hot or cold?

6. ☐ What do you think ...?

   Q Is it hot because it is made of water?

   Q Is it hot because it is wet?

   Q Is it cold because it has this shape?

   Q Is there one of these things that you would not like to have put down the back of your shirt?

Tell Me More

7. ☐ Ask, "What tool can be used to measure hot or cold?"

   Thermometer or temperature sensor

8. ☐ Have students examine the temperature sensor.

9. ☐ Begin recording a run of temperature data.

10. ☐ Insert the sensor in the bucket with ice to measure the temperature of the ice cubes. Allow the temperature graph to go as low as it will go.

11. ☐ Move the temperature sensor to the container with the bottles of hot water. Measure the temperature of the hot water in the bottles: Open the lid of one of the bottles and place the temperature sensor inside.

12. ☐ Allow the temperature graph to go as high as it will go.

13. ☐ Help students observe that "hot" is higher on the graph than "cold" is.

Sum It Up

14. ☐ Ask students:

    Q What do we mean when we say "hot" and "cold?"

    Q How do we tell if something is hot or cold?

15. ☐ Have students look at the graph of hot and cold temperature data. Ask them how the graph helped show us whether something is hot or cold.

Students should be able to look at the graph and point to places where the line is higher and lower, and relate the higher points to the hotter water. They should be able to point to lower points on the graph and relate these to the ice.

16. ☐ Have students complete the student response sheet.

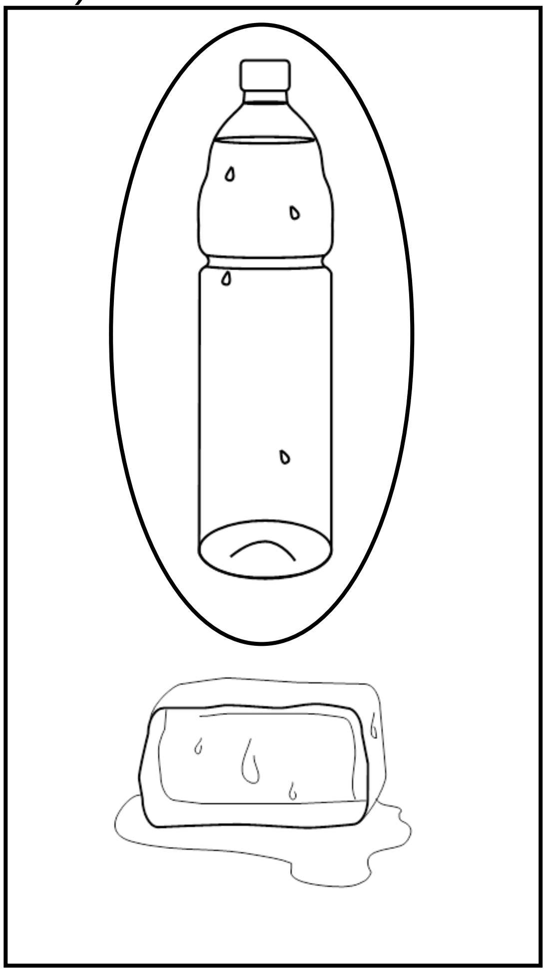
Further Investigations

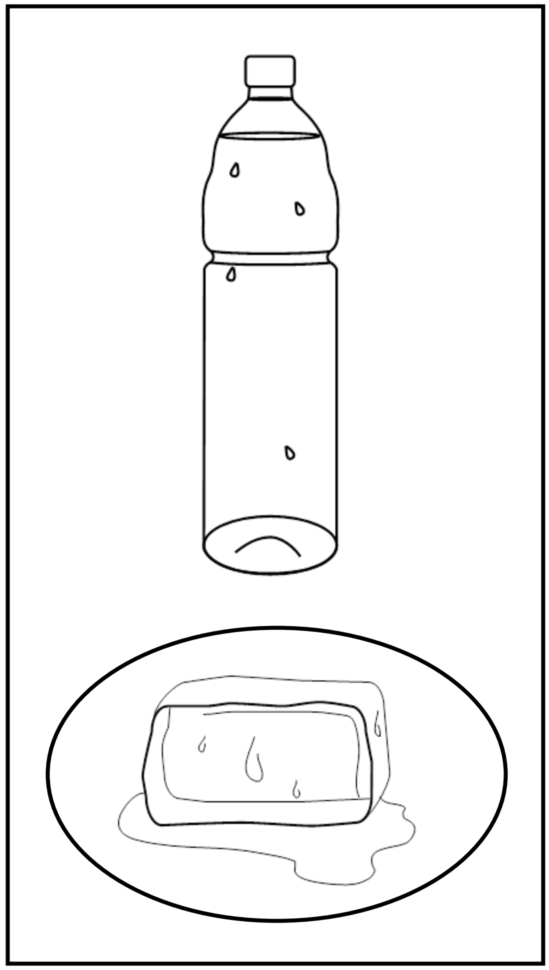
Let your students measure the temperature around the classroom. Have them place the temperature sensor in their arm pit to compare their temperature to the room temperature. The idea is to get them familiar with expressing temperature as a number, and with seeing the range of temperatures associated with objects in their environment.

1. Display Temperature in a digits display.
2. Change the units of the temperature if necessary.

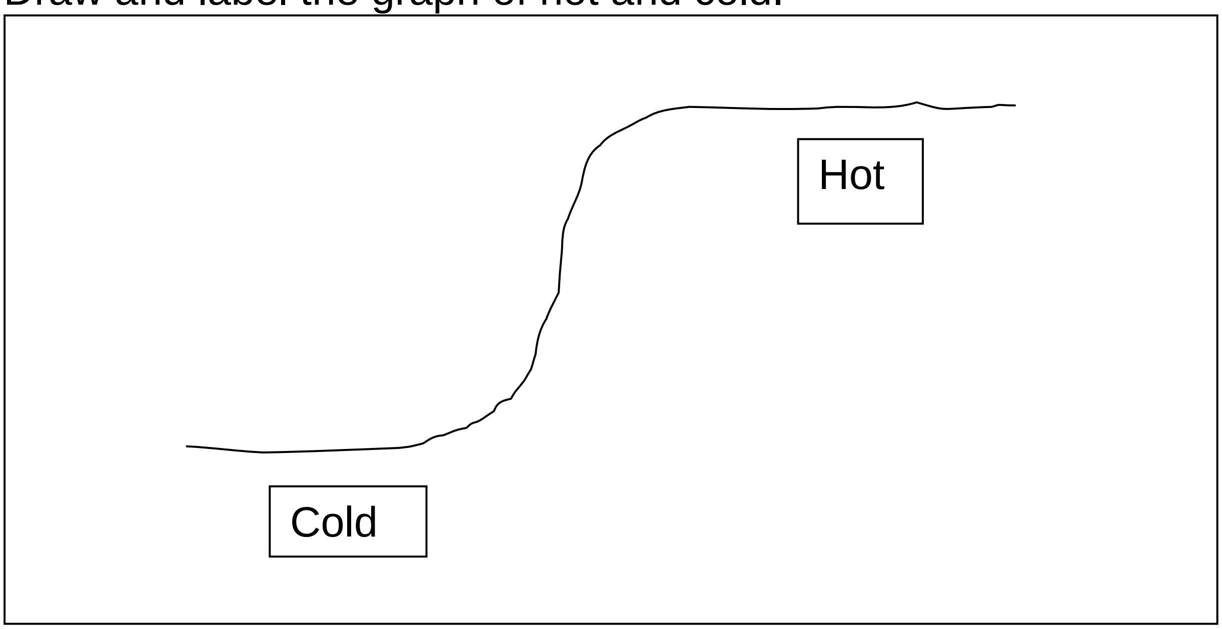
Note: The temperature sensor is not for internal use.

Which one is hot? (circle one) Which one is cold? (circle one)





Draw and label the graph of hot and cold.



7. Weather Instruments

Recommended Grade Levels: K – 1

Objectives

Students develop the language for describing weather conditions, and observe the measurements used to determine weather conditions.

Procedural Overview

To understand this content, students:

- Observe and describe the weather they see out their window.
- Compare the weather they see from one day to the next.

Time Requirement

■ Teacher Preparation	10 – 15 minutes
■ Activity	20 – 30 minutes
■ Student Response Sheet	5 – 10 minutes

Materials

☐ Mobile data collection system[1]	☐ Leaf
☐ Weather sensor	☐ Feather
☐ Sensor extension cable	

[1]A mobile data collection system is necessary if you plan to measure weather conditions outdoors,

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

- Set up your data collection system for measuring the weather.

    1. Start a new activity on the data collection system.
    2. Connect the weather sensor to the data collection system.
    3. Display Temperature on the y-axis of a graph with Time on the x-axis.
    4. Change the units of temperature data to units that are most appropriate for your students.

Background

Weather or Climate?

Weather is the term used to describe atmospheric conditions at any given moment. Such conditions include temperature, moisture, and wind. Averaged over several decades, the patterns of weather experienced in a region make up that region's climate. When we think of a region's climate, we often think about the temperature and precipitation we can expect in a particular season.

Moisture and Precipitation

Moisture in the air in the form of water vapor is what causes precipitation. Humidity refers to the amount of water vapor in the air. Meteorologists, or weather scientists, may speak of absolute or relative humidity. The absolute humidity is the mass of water vapor in a given volume of air. Air can hold only a certain amount of water vapor. Cold air can hold less water vapor than warm air.

Relative humidity is the amount of water vapor in the air compared to the maximum amount it can hold at a given temperature. Relative humidity is usually expressed as a percent.

When moist air cools as it rises, clouds form. Rain, snow, hail, and sleet come from clouds that form from moisture that has risen, cooled to its dew point, and condensed. Tiny cloud droplets are so light they can take as long as 48 hours to fall one kilometer (1000 meters or about 3300 feet). They evaporate before they reach Earth's surface. However, the tiny droplets of water may clump together, or coalesce, into drops heavy enough to fall all the way down to the Earth's surface. Rain, snow, hail and sleet are collectively known as precipitation.

Wind

Wind blows because there are regions of different pressures in the atmosphere. These pressure differences exist vertically and horizontally, and are the result of the uneven heating of the atmosphere by the sun. You may be familiar with the rush of "wind" that accompanies the opening of a vacuum-sealed tin of coffee, or a container of new tennis balls. The pressure in the container is lower than the pressure in the surrounding atmosphere of the room, so the air from the room rushes into the container. Likewise, you can experience the "wind" produced by an inflated balloon that is allowed to deflate. The air inside the balloon is at a greater pressure than the surrounding atmosphere of the room, and so it rushes into the room.

On the Earth's surface, the wind flows toward areas of lower pressure and away from areas of higher pressure. Typically, only horizontal airflows are called wind.

Temperature

There are three main ways that air cools. The heat absorbed by the Earth from the sun during the day radiates away at night, so the land, water, and air become cooler. Air cools as it rises because it expands. The expansion occurs because the pressure decreases with altitude. You may have noticed this if you have ever opened a bag of chips on an airplane. The bag contains air from the factory where the chips were packed, which is at a higher pressure than the cabin pressure of the airplane. The expansion of the air due to a decrease in pressure requires the air to do work, using up some of its energy, and cooling in the process. Air also cools when it comes into contact with a cooler surface. Moisture in the air may condense on cool surfaces as dew or frost.

The Weather Sensor

The weather sensor allows students to collect and observe six key measurements: temperature, barometric pressure, relative and absolute humidity, dew point and altitude. It can be used to take a current reading or to monitor weather over an extended period of time, such as days or weeks. If you plan to monitor weather over time and leave the sensor outdoors, it needs to be protected from becoming wet or from being immersed in water. For examples and ideas of how to construct and operate a weather station, see the Weather Station (Grades 4–5) activity in this manual.

Activity with Answer Key and Teacher Tips

Each step has a box next to it. (☐) If you find it convenient, after you complete a step or answer a question, check off that step.

Driving Question

How do we describe the weather?

Get Started

1. ☐ Sing or read the following poem to students:

   Like a Leaf or a Feather

   Like a leaf or a feather

   In the windy, windy weather,

   We will twirl around

   And all sink down—together.

   —Anonymous

   Note: If you enjoy singing with your students, make up a tune for this poem and teach the class to sing it. At the line "And all sink down—together" everyone sinks or falls in unison. At the same time, drop the leaf and feather.

2. ☐ Ask students:

   Q What happens to a leaf or a feather in windy weather?

   Q What happens to raindrops and snowflakes?

   Q Do they fall down?

   Q Do they sometimes fall sideways?

   Teacher Tip: Accept all answers. Help students describe what they have seen or experienced during windy or stormy weather. If students have seen lightning or heard thunder, they may mention these events at this time. If you live in an area that experiences severe weather such as hurricanes or tornadoes, students may discuss these weather events.

Let's Explore

3. ☐ Look outside the windows of the classroom, or go outside into the play yard to observe today's weather.

4. ☐ Ask students to describe what the weather is like today.

   Depending on the weather typical in your area, students may be familiar with terms used to describe certain conditions such as "humidity." They may use words they have heard at home, including humid, muggy, and damp. This is an opportunity for you to assess students' prior knowledge about weather and the language they use to describe it.

Explain It

5. ☐ Return to your regular class positions.

6. ☐ Lead your students in a discussion to describe the weather with the following questions:

   Q Is there wind today?

   Q Is there rain or snow today?

   Q Is the weather warm or cold today?

   Q Is it sunny or cloudy?

   If there is wind, ask students:

   Q Where will a leaf go if we drop it?

   Q What does this tell us about the direction the wind is coming from?

   Q Is the wind strong enough to blow a feather? How about a jacket or a backpack?

   If there is rain or snow, ask students:

   Q Where are those raindrops or snowflakes coming from? Are there clouds?

   Q What happens to the raindrops or snowflakes when they fall on the ground?

   Q How does our play yard look different today from a sunny day?

7. ☐ Guide students in a discussion about how rain makes surfaces wet and forms puddles in some places and how snowflakes pile up and get deeper if they don't melt.

8. ☐ Ask students to describe how their play is different when the weather is rainy or snowy from when it is sunny.

9. ☐ Compare the weather you are currently experiencing to a day that had very different weather.

10. ☐ Discuss how quickly weather can change with the following questions:

    Q Have you ever woken up to a sunny day, but had rain by lunch time?

Q Have you ever seen a week of rain followed by a week of clear skies and sunshine?

Q Have you ever had fog early in the morning that was gone by the middle of the morning?

11. ☐ Take a moment to discuss changes due to seasons:

Q How does lunch time in the summer compare to lunch time in the winter?

Q Is the weather in the spring different from the weather in the fall?

Tell Me More

12. ☐ What tools can be used to measure the weather we see and feel today? What is the temperature today? How can we measure the temperature?

13. ☐ Have students examine the weather sensor. Show them the slits in the end and explain that the air can go inside the tool so its temperature can be measured.

Note: Although the weather sensor measures barometric pressure, absolute humidity, relative humidity, dew point, and relative altitude in addition to temperature, students will most likely not have experience with these concepts or measurements.

14. ☐ Start recording a data run of weather data, and display a graph of temperature versus time.

15. ☐ Measure the air temperature inside the classroom and then outdoors.

16. ☐ If there is a noticeable difference in the indoor and outdoor temperatures, help students compare the measurements of air temperature.

- The weather sensor measures temperature. Show students the graph and point out that warmer air is higher on the graph than colder air is.

17. ☐ Stop recording data.

Sum It Up

18. ☐ Ask students, "How did the graph show us where the air was warmer and where it was cooler? Could we use this tool to tell us the weather again tomorrow?"

Students should be able to look at the graph and point to places where the line is higher and lower, and relate the higher points to the air being warmer. They should be able to indicate that lower points on the graph signify cooler air.

19. ☐ Ask students, "How do we describe the weather?"

Answers should include the various terms they've discussed as well as the method of using the weather sensor and other tools to obtain data that helps describe the weather.

20. ☐ Depending on the level of your class, you may wish to add a discussion of humidity:

a. Change the y-axis of your graph of Temperature versus Time to Relative Humidity versus Time to show your students the graph of humidity.

b. Let your students know that you we can also measure the amount of water in the air.

21. ☐ Ask students, "Why do you think we are interested in the amount of water in the air?"

Answers will vary; remind your students of your discussion of clouds, rain, and snow.

22. ☐ Have students complete the student response sheet.

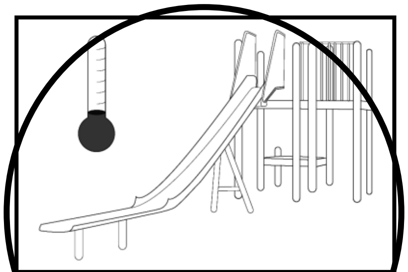
Further Investigations

Explain why there are many different measurements that are made of the weather. Show your students another weather measurement, such as barometric pressure.

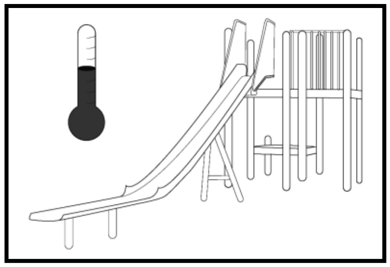
Record a set of temperature data overnight to show students how temperature changes over time.

Circle the pictures that describe the weather today.

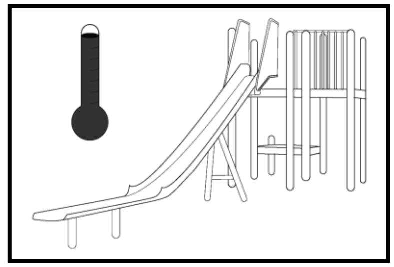
Note: Answers will vary depending on weather conditions.



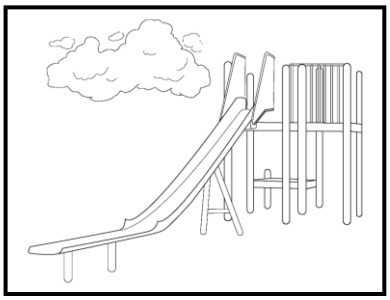
Cold



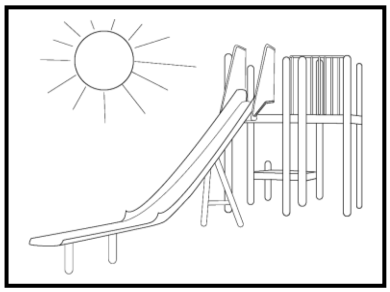
Mild



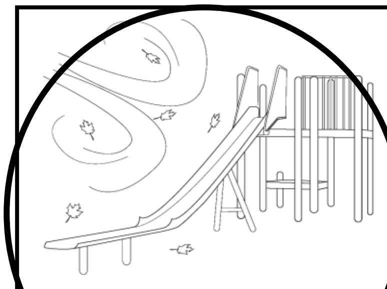
Hot



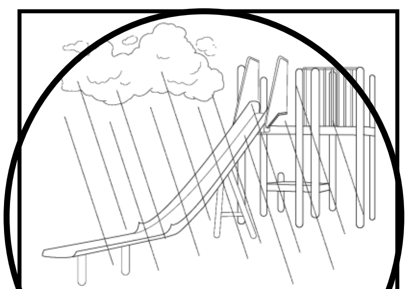
Cloudy



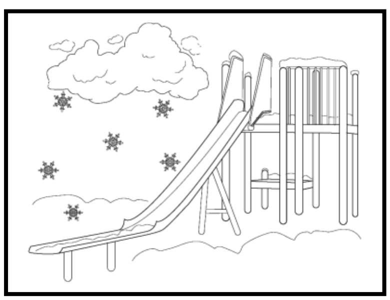
Sunny



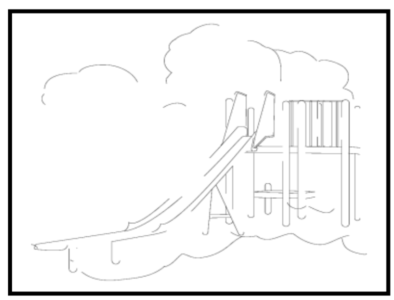
Windy



Raining



Snowing



Foggy

Grades 2-3

8. Freezing and Melting Water

Recommended Grade Levels: 2 – 3

Objectives

Students recognize that water can exist in different forms and can be changed from one form to another by heating or cooling.

Procedural Overview

To understand this content, students:

- Measure the temperature of their hand and the temperature of an ice cube
- Allow ice to melt in their hand and explain that heat from their hand caused the ice to melt
- Measure the temperature of a rock salt-ice bath and room temperature water
- Freeze room temperature water by placing it in a rock salt-ice bath

Time Requirement

Teacher Preparation	10 minutes
Get Started	10 minutes
Let's Explore	20 - 30 minutes
Explain It	15 - 20 minutes
Tell Me More	20 - 30 minutes
Sum It Up	10 minutes

Materials

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Ice cubes, in a small paper cup[1]
- ☐ Snack size plastic bag, re-sealable 16.5 cm × 8.25 cm
- ☐ Tape
- ☐ Spoon
- ☐ Rock salt-ice bath (2 - 3 per class)[2]
- ☐ Paper Towels
- ☐ Water, ~15 mL
- ☐ Projection system (for the teacher only)
- ☐ Ice chest (for the teacher only)

[1]The ice cubes should each weigh about 0.5 g or less. Very small crushed ice will be about this size. Use enough ice cubes to fill the small paper cup about halfway.

[2]Combine rock salt, ice, and water in a plastic utility tub to create the rock salt-ice bath. Refer to the Preparation section for step by steps instructions.

Activity at a Glance

Get Started

- ☐ Engage students by talking about life experiences they have had with water in different forms – ice, liquid water, or steam.

Let's Explore

- ☐ Have the students predict what will happen to an ice cube when it is placed in the palm of their hand.
- ☐ Students measure the temperature of their hand and the temperature of ice.
- ☐ Students describe what happened to the ice cube that was placed in their hand.

Explain It

- ☐ Define the term melting and explain that melting occurs when (enough) heat is added to an object.
- ☐ Explain that ice is the solid form of water and it exists in cold environments and water is the liquid form of water which exists in warm environments.
- ☐ Review the following vocabulary with the students: temperature, temperature sensor, solid, liquid, melting, and freezing.

Tell Me More

- ☐ Have the students predict how they can make water freeze.
- ☐ Students measure the temperature of the rock salt-ice bath and room temperature water.
- ☐ Students describe what happened when they put their water in the rock salt-ice bath.

Sum It Up

- ☐ Review with the students the different forms of water and melting and freezing.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

Let's Explore

Fill a small paper cup half full with crushed ice. Prepare one cup of crushed ice for each student group. Store the cups in the ice chest until they are used.

Tell Me More

Prepare 2 or 3 rock salt-ice baths for your students. Follow the steps below to make each rock salt-ice bath:

1. Fill a plastic utility tub half full with ice.
2. Add about 2 cups (300 – 400 grams) of rock salt to the ice.

3. Add enough water to cover the ice.

4. Stir the rock salt-ice bath to dissolve as much of the salt as possible.

Background

Forms of Matter

Matter exists in three main forms: solid, liquid, and gas. The form that matter exists in depends on the temperature of the environment it is in. For example, water exists as a solid (ice) when the temperature is 0 ˚C or lower, as a liquid when the temperature is between 0 ˚C and 100 ˚C, and has a gas (vapor) when the temperature is 100 ˚C or higher.

Changing Forms of Matter

Matter can change from one form to another form by adding and removing heat. Melting is the process of matter changing from a solid to a liquid and boiling is the process of matter changing from a liquid to a gas. Both melting and boiling require that heat be added. All matter will melt and boil at a unique temperature called the melting point and boiling point. Water, for example melts at 0 ˚C and boils at 100 ˚C. At the melting and boiling point two forms of matter exist simultaneously.

Matter can also change from one for to another by having heat removed (cooling). Freezing is the process of matter changing from a liquid to a solid and condensation is the process of changing from a gas to liquid. Both freezing and condensing require that heat be removed from the matter.

Temperature and Heat

The terms heat and temperature are used differently in everyday conversation than they are in science. In everyday conversation heat is the quality of being hot or having a high temperature and temperature is a measure of the amount of heat present in an object. The definitions are very similar and in many cases the words are used interchangeably. This activity sets the stage for the students to understand the scientific difference between heat and temperature, but still uses the common definitions that students are familiar with. Developmentally, elementary school aged students are not ready to differentiate between heat and temperature.

In science, the terms heat and temperature are different. An understanding of the atomic nature of matter is necessary to understand the difference between heat and temperature. Matter is made up of particles (atoms or molecules) that are constantly moving. Since the particles are moving they have kinetic energy. Temperature is a measure of the average kinetic energy of the particles in a substance. Hot objects contain particles that move fast and therefore have high temperatures. Cold objects, on the other hand, contain particles that move slower and therefore have lower temperatures. Temperature can easily be measured using a temperature sensor or thermometer.

Heat is the transfer of energy from one object to another because of a difference in temperature. Heat is different than temperature in two main ways. First of all, heat cannot be measured directly. Heat is often confused with temperature because temperature changes are used to indirectly measure heat. The second difference is that an individual object does not contain heat. For energy to transfer, two objects, with different temperatures, must be present. Energy from the hotter object will transfer to the cooler object. Although individual objects do not contain heat, they do contain thermal energy. Thermal energy is the total internal kinetic energy of all the particles that make up an object.

Activity with Answer Key and Teacher Tips

There is a box next to each step. (☐) If you find it helpful, place a check mark in the box after you complete that step.

Driving Questions

This activity investigates the following questions:

- What are the different forms of water?
- How does water change from a solid to a liquid and from a liquid back to a solid?

Get Started

1. ☐ Have a discussion with your students about their experiences with the different forms of water (ice, liquid water, and water vapor or steam).

   Q Where do we find water?

   Q Can water be found in different forms (solid, liquid, gas)?

   Q Where have you seen solid water (ice)?

   Q Where have you seen liquid water?

   Q Does water exist as a gas? How do you know?

2. ☐ Ask your students if they have ever noticed water on the grass or windshields of cars when they come to school in the morning. Explain to the students that this water is called dew. Ask the students what happens to the dew on mornings when it is very cold outside?

   On very cold mornings, the dew freezes into ice (frost).

3. ☐ Ask the students, what happens to the ice on the grass after the sun comes up?

   When the sun comes up, it warms the earth and the ice (frost) will melt. If you live in a very cold area, where frost can stay all day, be sure to direct student thinking to times when the frost will melt.

4. ☐ Have your students brainstorm ideas about how water changes from one form to another.

   Q How can liquid water be changed into ice (solid water)?

   Q How can ice (solid water) be changed into liquid water?

   Q What is the difference between liquid water and ice (solid water)?

Let's Explore

In this section the students explore melting.

5. ☐ Ask your students to predict what will happen to an ice cube when it is placed in the palm of their hand. Have the students make their prediction and explain their thinking on the student response sheet under student response 1.

6. ☐ Use your classroom projection system to guide the students through the following steps to determine the temperature of their hand:

   a. Start a new experiment on the data collection system.

   b. Connect the temperature sensor to the data collection system.

   c. Create a digits display of temperature.

   d. Begin data recording.

   e. Have the students place the tip of the temperature sensor in the palm of their hand.

   f. Have the students wait until the temperature stabilizes (about a minute) and then stop data recording.

6. ☐ Have the students write the temperature of the ice cube under student response 2.

7. ☐ Ask the students whether they think the temperature of the ice cube will be greater than, lower than, or equal to the temperature of their hand.

   The students should predict that the temperature will be lower than their hand because an ice cube feels cold.

8. ☐ Pass out a small paper cup half full of ice cubes and a paper towel to each student.

9. ☐ Have the students measure the temperature of the ice cubes:

   a. Begin data recording.

   b. Have the students submerge the tip of the temperature sensor in the cup of ice.

   c. Have the students wait until the temperature stabilizes (about a minute) and then stop data recording.

10. ☐ Have the students write the temperature of their hand under student response 2.

11. ☐ Direct the students to place the ice cube in their hand and watch what happens.

12. ☐ Continue to have the students hold their ice cube until it has completely melted.

13. ☐ As students hold the ice, guide the students in a discussion to help them recognize that water exists as a solid (ice) and as a liquid (water).

   Q What form of water is ice?

   Q Is the form of water changing?

   Q What is happening to your ice cube?

14. ☐ Once the ice cube has melted have the students clean up using their paper towel.

15. ☐ Have the students describe what happened when the ice cube was placed in their hand under student response question 3.

Explain It

Help your students understand that water can exist in different forms depending on the temperature of the environment the water is in. Also help the students to understanding that adding heat (warming) causes ice to melt while removing heat (cooling) causes water to freeze.

16. ☐ Have the students review what happened when the ice was placed in their hand.

    Teacher Tip: One way to have students review is to have them turn to a neighbor and listen to what the neighbor says. Then when you call upon students, they tell you what their neighbor described.

17. ☐ Explain to the students that when a solid changes into a liquid this is called melting. Review with the students that ice is the solid form of water and the liquid form of water is simply called water.

    Q What do we call the solid form of water?

    Q Does ice exist in environments that are cold, warm, or hot?

    Q What do we call the liquid form of water?

    Q Does liquid water exist in environments that are cold, warm, or hot?

18. ☐ Explain to the students that adding (enough) heat to a solid will cause the solid to melt. Ask the students to think about where the heat came from that caused their ice cubes to melt.

    The heat came from our hands (and the air). Look at the temperature data below to confirm this answer.

19. ☐ Remind the students that temperature is a measure of hotness and coldness and therefore, can be used to help us explain why the ice cube melted in our hands.

20. ☐ Ask the students to share their temperature data with the class. As the students share the temperature of their hand and the temperature of the ice record the values on a large table in front of the class.

Object	Student 1	Student 2	Student 3	Student 4	Student 5
Temperature of your hand:	31.6 ˚C	33.8 ˚C	35.6 ˚C	32.3 ˚C	34.9 ˚C
Temperature of the ice cubes:	1.6 ˚C	2.0 ˚C	1.0 ˚C	1.4 ˚C	2.4 ˚C

21. ☐ Ask the students how the temperature of their hand compared to the temperature of the ice. Which was hotter?

The temperature of the hand is much warmer than the temperature of the ice. Our hands are hotter than ice.

22. ☐ Help the students draw the following conclusions:

- Ice is the solid form of water and exists in cold environments.
- Water is the liquid form of water and exists in warm environments.
- Heating causes melting to occur.
- In this activity, the heat from our hand caused the ice cube to melt.

23. ☐ Now transition your students into the concept of freezing. Ask the students how liquid water can be changed into a solid (ice).

The students may suggest that the water will freeze if it is placed into a freezer or if it is placed outside on a very cold winter day. The students should realize that water has to be placed in a cold environment in order to freeze.

24. ☐ Have the students discuss freezing and melting by asking the following questions:

Q What is freezing?

Q What is melting?

Q How are freezing and melting similar?

Q How are freezing and melting different?

25. ☐ Review the following vocabulary words with your students. Relate each of the vocabulary words to the ice cube melting activity that the students just completed.

Temperature	A measure of hot and cold
Temperature sensor	An electronic tool that is used to measure temperature
Solid	A form of matter with definite shape and volume (example: ice)
Liquid	A form of matter with that takes the shape of its container and has a definite volume
Melting	To change from a solid to a liquid
Freezing	To change from a liquid to a solid

Tell Me More

In this section the students explore freezing. In this section, you will need 2 to 3 tubs of a rock salt-ice mixture for the students to share.

26. ☐ Ask your students to predict how they can make water freeze. Have the students record their answer and explain their thinking on the student response sheet under student response 4.

27. ☐ Show the students the rock salt–ice bath and explain that adding salt to the ice water makes the water much colder than a normal ice–water mixture. Explain to your students that the method of adding rock salt to ice was used to make ice cream in the olden days.

28. ☐ Have the students measure the temperature of the rock salt–ice bath. Guide them through this process as necessary:

    a. Start a new experiment on the data collection system.

    b. Connect the temperature sensor to the data collection system.

    c. Create a digits display of temperature.

    d. Begin data recording.

    e. Have the students submerge the tip of the temperature sensor in the rock salt–ice bath.

    f. Have the students wait until the temperature stabilizes (about a minute) and then stop data recording.

29. ☐ Tell the students to write the temperature of the rock salt–ice bath under student response 5.

30. ☐ Have the students pour one spoonful of water into a snack size, re-sealable, plastic bag.

31. ☐ Direct the students to take the temperature reading of the water in their bag. Guide them through this process as necessary.

32. ☐ Tell the students to write the temperature of their water under student response 5.

33. ☐ Have the students make sure that their plastic bag is completely sealed and then have them write their name on a piece of tape and use that piece of tape to secure their bag of water to the tub so that the water in the bag is completely submerged beneath the rock salt–ice mixture.

34. ☐ It will take between 10 and 15 minutes for the students' water to freeze. During this time guide the students through a discussion about what they expect to happen and why. The students should be able to explain that the temperature of the rock salt–ice bath is colder than the water and will therefore remove heat from the water. The students may or may not know that water freezes at 0°C. This is not the goal of this lab, but it may come up in the discussion.

    Q Do you think the rock salt–ice bath is cold enough to freeze the water in your bag? Why or why not?

    Q What form of water is in the bag?

    Q What form of water do you expect to form if the water is cold enough?

Q Is the rock salt-ice bath adding heat or removing heat from the water in your bag? How do you know?

35. ☐ After 10 minutes, check the bags of water. Once the water has frozen have the students remove their bags from the rock salt–ice bath.

36. ☐ Allow the students a few minutes to observe the ice that has formed.

37. ☐ Have the students describe what happened to the bag of water that was placed in the rock salt-ice bath under student response 6.

Sum It Up

Review with the students what they have learned during this activity.

38. ☐ Review what the students have learned by having them answer the following questions:

Q What are two forms of water?

Q When does water exist as a solid?

Q When does water exist as a liquid?

Q What is melting?

Q What causes melting?

Q What is freezing?

Q What causes freezing?

Further Investigations

Have the students continue their exploration of melting and freezing by making ice cream or popsicles.

Have the students test whether or not the mass of water changes when it freezes or melts. The students should find that solid and liquid water have the same mass.

Incorporate the third form of matter, gases, by having the students explore boiling and evaporation. Have the students investigate what happens when water is left in an open container versus a closed container.

Have students use a mobile data collection system to find the temperature of the water in the school's drinking fountains and sinks.

1. What will happen to an ice cube when it is placed in your hand? Darken the circle of the best answer.

Ⓐ The ice cube will melt.

Ⓑ The ice cube will freeze.

Ⓒ Nothing will happen to the ice cube.

Explain your thinking:

Because the ice gets hot in my hand.

2. Record the temperature data:

Temperature of your hand:	34.2 °C
Temperature of the ice cube:	1.4 °C

3. Describe what happened when an ice cube was placed in your hand.

The ice cube slowly melted.

The ice cube made my hand cold.

4. How can you make liquid water freeze? Circle the best answer.

Ⓐ Add heat to the liquid (warm it)

Ⓑ Remove heat from the liquid (cool it)

Ⓒ Liquid water is not able to freeze

Explain your thinking:

I want the water to get colder.

5. Record the temperature data:

Temperature of rock salt-ice bath:	-3.7 °C
Temperature of the water:	22.5 °C

6. Describe what happened when the bag of water was placed in the rock salt-ice bath.

The water in my bag turned into ice.

9. Conservation of Matter

Recommended Grade Levels: 2 – 3

Objectives

Students determine that the weight of a whole object is the same as the sum of the weight of each part that makes up the whole object. Through this activity, students

- Learn that most things are made up of parts
- Observe properties of matter such as size, weight, and shape

Procedural Overview

To understand this content, students:

- Classify objects by weight (light objects versus heavy objects)
- Use a force sensor to graph the weight of different objects
- Compare the weight of the whole flashlight to the weight of all the pieces of the flashlight

Time Requirement

Teacher Preparation	10 - 15 minutes
Get Started	15 - 20 minutes
Let's Explore	20 -30 minutes
Explain It	15 - 20 minutes
Tell Me More	20 - 30 minutes
Sum It Up	15 - 20 minutes

Materials

- ☐ Projection system (for the teacher only)
- ☐ Data collection system
- ☐ Force sensor, with hook attached
- ☐ Bag, to attach to force sensor hook
- ☐ Objects of varying weights, 1 to 5 pounds (4) [1]
- ☐ Flashlight (containing D batteries)
- ☐ Object made of parts, 1 to 5 pounds[2]

[1]The objects could be a textbook, bottle of water, large box of crayons, hand weight, an orange, hammer, and others.

[2]Ideas include a student backpack, a lunch box, a large bolt with a nut and washer attached, tool box, and others.

Activity at a Glance

Get Started

- ☐ Discuss with the students the meaning of the term "weight" by having the students classify objects as heavy (less weight) and heavier (more weight).
- ☐ Discuss how weight is measured and introduce the force sensor as a tool that is used to measure weight.
- ☐ As a class explore how the force sensor is used and interpret graphical data that is collected using the force sensor.

Let's Explore

- ☐ Ask students to identify and list as many parts of a flashlight as they can.
- ☐ Have the students make a prediction about how the weight of a flashlight compares to the weight of all the pieces of the flashlight.
- ☐ Have the students test their predictions using a force sensor (which measures weight). To do this, the students will graph the weight (force) of the whole flashlight and then the weight (force) of all the parts of the flashlight.

Explain It

- ☐ Explain the terms weight, whole, parts, and force (weight) sensor.
- ☐ Review the meaning of the data that was collected in the Let's Explore section.
- ☐ Explain to the students that scientists have to test an idea many times before it is accepted as a scientific theory or law. Then test the weight of a whole and its parts using another object.

Tell Me More

- ☐ Students are assigned an additional object that is made of parts to explore (such as a filled backpack, a lunch box, or a tool box).
- ☐ Students record the object they are testing, the parts it is made of, and a prediction of how the weight will compare between the whole object and the parts of the object.
- ☐ The students use the force sensor to determine the weight of the whole object and the object broken into its pieces. They record their results and write a conclusion about what they have learned.

Sum It Up

- ☐ The students share the results and conclusion from the Tell Me More section with the rest of the class.
- ☐ The students discuss what they have learned about weight, whole objects, and parts of objects.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

1. Set up the data collection system to display a graph of Force, pull positive versus Time:

a. Starting a new experiment on the data collection system.

b. Connect the force sensor to your data collection system.

c. Create a graph of Force, pull positive on the y-axis and Time on the x-axis.

d. Force is displayed in units of newtons. Optionally, change the units of force to pounds.

Note: Leaving the force measurement in newtons will result in larger numbers (and more whole numbers) that may be easier for the students to understand when showing the students that the sum of the parts equals the whole.

e. Practice recording runs of data.

f. Practice hiding runs of data.

2. Practice connecting the data collection system to your classroom projection system and projecting the data you record in front of the class.

Background

Wholes versus Parts (Conservation of Matter)

The law of conservation of matter states that matter cannot be created or destroyed during any physical or chemical change (the law of conservation of matter does not apply to nuclear reactions, where matter may be changed to energy). Thus, when an object is broken into its parts, the weight of the whole object is equal to the sum of the weight of each part. This is an important concept for the students to develop because it prepares them for understanding the law of conservation of matter at the atomic level in chemical reactions and physical changes in later grades. This is also a great way of helping students understand that almost all things are made up of parts which will lead to the idea that some things are made up of parts that are too small to see without magnification.

Weight (versus Mass)

What is mass, and how is it related to weight? If you hold a watermelon at arm’s length and shake it, you will find it more difficult to shake than if you were holding an inflated balloon. This would be true whether you were standing on the Earth, on the moon, or in space far from any planet or star. Mass is the amount of matter in an object. In common daily language we often hear the terms weight and mass used interchangeably. However, to scientists, weight is the pull of gravity on any object with mass. The more massive an object is, the more it weighs. In this activity, “heaviness” is actually "weight."

In this activity, the term weight is used instead of mass because mass is not generally understood by second and third grade students. Introducing the term mass too early may cause students to confuse the term mass with massive which may lead to misconceptions between the terms mass and size.

Force Sensor Explained

The force sensor measures pushes and pulls. In this activity, where it is used to find the weight of objects, it measures the pull of gravity on each object. Weight is what we call this pull. This is why you sometimes hear references to a person “weighing less on the moon” than on Earth. The moon is smaller, and has less gravitational pull on objects because of this. The property that does not change is mass. If you actually did travel to the moon, your mass would remain the same, but gravity would pull you down with less force.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

How does the weight of a whole object compare to the weight of the parts of that object?

Get Started

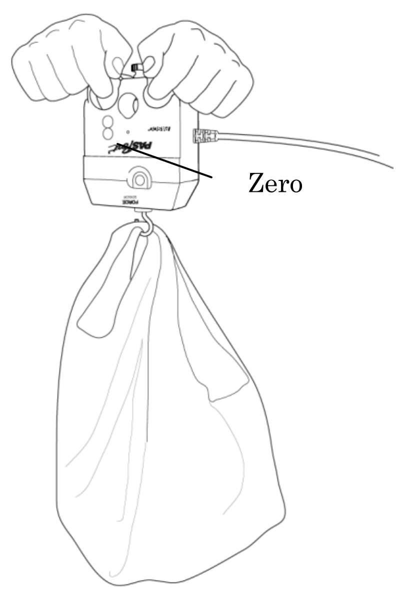
1. ☐ Provide each student group with four objects of varying weights between 1 and 5 pounds (such as a textbook, a piece of fruit, a hammer, and a box of crayons). Have the students classify the objects as light (weight) or heavy.

2. ☐ Ask the students how they decided which objects were light weight) and which objects were heavy.

3. ☐ Explain to the students that heavy objects have a lot of weight and light objects have less weight. Then, ask the students how weight can be measured.

   Weight can be measured using a scale or a balance such as a bathroom scale or a triple-beam balance).

4. ☐ Explain to the students that a force sensor, like a balance or a scale, can be used to measure weight. Show the students the force sensor and how it can be used to compare the weight of different objects.



   a. Project a graph of Force, pull positive on the *y*-axis and Time on the *x*-axis in the front of the room.

   b. Have a student hold the force sensor with a bag attached to it.

   c. Have the student press the zero button on the force sensor.

   d. Add an object the students classified as "light" to the bag. Then collect data for 30 seconds.

   e. Explain to the students that the *y*-axis is measuring the force weight) of the object and state the weight (with units) of the object being measured. Then ask the students:

   Q Where would you expect the graph of an object that weighs more (is heavier) to be

on this graph?

Q Where would you expect the graph of an object that weighs less (is lighter) to be on this graph?

Q Where would you expect the graph of an object that has the same weight to be on this graph?

Teacher Tip: If you are projecting on a whiteboard, write the name of the object on its graph and then write more weight above, less weight below, and equal weight next to the line. You can also write these words on pieces of paper and have the students tape them onto the projected graph.

f. Remove the object from the bag and hold up an object that the students classified as "heavy" and ask the student to predict whether the graph will be above or below the first object tested.

g. Add the object to the bag and then collect a run of data for about 30 seconds.

h. Discuss the results with the students by asking the students:

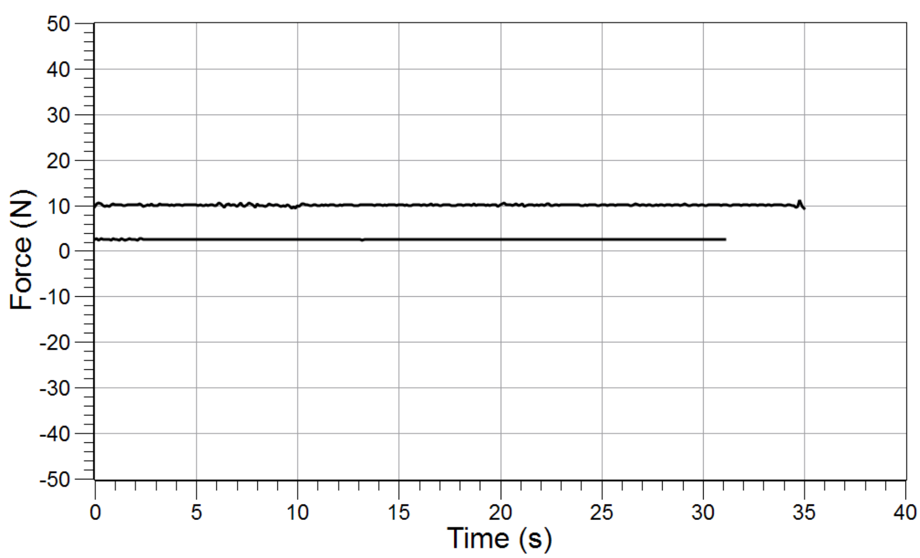
Q Was our guess correct?

Q Does object 2 have more weight or less weight than object 1? How do you know?

i. Have the students predict which object is lighter than both and collect a run of data to determine if they were correct or not.

Sample Data:

Light and Heavy Objects



Let's Explore

5. ☐ Tell the students that many objects are made up of parts. Have the students pick an object that is made up of parts and list the parts.

6. ☐ Show the students a flashlight and ask them to identify as many parts of the flashlight as they can.

   A flashlight is made up of a case, switch, light bulb, batteries, lens, and lid.

7. ☐ Ask the students whether or not taking the flashlight apart changes its weight. Have the students circle their prediction and explain their thinking on the student response sheet under student response numbers 1 and 2.

8. ☐ Have the students test their predictions using the force sensor. Guide the students through the following steps:

   a. Turn on the data collection system and start a new experiment.

   b. Connect a force sensor to the data collection system.

   c. Create a graph of Force, pull positive on the *y*-axis and Time on the *x*-axis.

   d. Place a bag on the hook of the force sensor.

   e. Press the zero button on the force sensor.

   f. Place the flashlight inside the bag.

   g. Collect data for 60 seconds.

   h. Remove the flashlight from the bag.

   i. Take the lid off the flashlight and remove the batteries.

   j. Place the lid of the flashlight in the bag.

   k. Start collecting data.

   l. Adjust the scale of a graph.

   m. After 20 seconds, gently place the case of the flashlight into the bag.

   Teacher Tip: If an object is dropped in the bag the graph will spike due to the acceleration with which the object hits the bag.

   n. Wait 20 more seconds, and then gently place the batteries into the bag.

   o. After 60 seconds, stop data collection.

   p. Save the experiment.

9. ☐ Have the students copy the Force (weight) versus Time graph that they collected on under student response number 3.

10. ☐ Discuss the results with the students by asking the following questions:

Q What was the weight of your whole flashlight?

Q Was the weight of all the pieces together more than, less than, or equal to the whole flashlight? How do you know?

Q Why does the graph with the parts of the flashlight look like steps?

11. ☐ Have the students write their conclusion about the relationship between the weight of a whole flashlight and the weight of all the parts of the flashlight under student response number 4.

Explain It

12. ☐ Go over the following vocabulary words with your students. Relate each of the vocabulary words to the flashlight activity they just completed.

Weight	Heaviness
Whole	Together in one piece
Part	A piece of an object
Force sensor	An instrument that is used to measure weight

13. ☐ Project a graph of sample data collected in the Explore It section. Review with the students the graphs that were collected and what they mean:

    a. Hold up the whole flashlight and ask the students what part of the graph represents the whole flashlight.

    b. Take the flashlight apart and ask the students to explain how each part and all the parts together are represented on the graph.

    c. Explain to the students that the weight of the flashlight is the sum of the weight of each individual piece added together. Walk the students through math using the sample data displayed:

    Whole flashlight: 4.0 N

    Flashlight parts: lid – 0.2 N, case – 0.8 N, batteries – 3.0 N (0.2 N + 0.8 N + 3.0 N = 4.0 N)

    d. Conclude that the whole flashlight weighs the same as all the parts of the flashlight added together.

14. ☐ Ask the students to list other objects in the room that are made up of parts.

15. ☐ Pick one of the objects that the students suggest (that weighs between 1 and 5 pounds and can easily be taken apart) and use the force sensor to test that the weight of a whole object equals the weight of all the parts of an object.

    Teacher Tip: Objects that weight less than one pound can still be broken into parts and the sum of the parts will still equal the weight of the whole object. To test light weight object, an instrument more sensitive than the force sensor is needed.

16. ☐ Explain to the students that scientists have to test an idea many times before it is accepted as a scientific law. So far your students have tested the idea that the weight of the whole object is equal to the sum of the parts. It still needs to be verified by testing it a lot more.

Tell Me More

17. ☐ Give each student group an object that is made up of parts and have each student draw the whole object and the parts of the object under student response number 5.

18. ☐ Have the students work together in their group to come up with a prediction. Have the students write their prediction under student response number 6.

19. ☐ Have the students test their predictions using the force sensor. Guide the students through this process. If needed, refer to the steps listed in the Let's Explore section above.

20. ☐ Have the students copy the Force (weight) versus Time graph that they collected under student response number 7.

21. ☐ Have the students work with their group members to analyze their results and write their conclusion under student response number 8.

Sum It Up

22. ☐ Have the students share the results and conclusion from the Tell Me More section with the rest of the class.

23. ☐ Ask the students what they have learned about weight, whole objects, and parts of objects.

Further Investigations

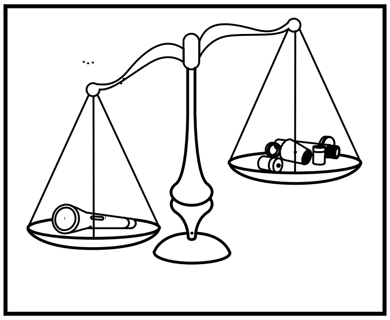
Have the students investigate the weight of ingredients in play dough and then mix the ingredients to make the play dough and weigh the final product. Take this a step further and investigate the properties of the individual ingredients and how they change when the final product is made.

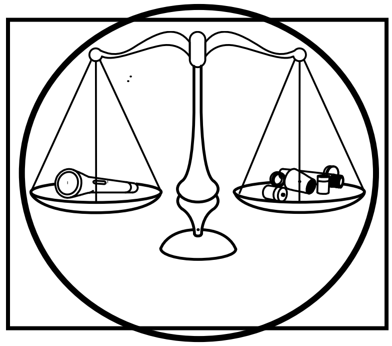
Have the students investigate the conservation of matter during a phase change. Fill a 2-L bottle with water and weigh it. Then allow the water to freeze and weigh it again. The students should see that freezing and melting do not change the mass of the substance.

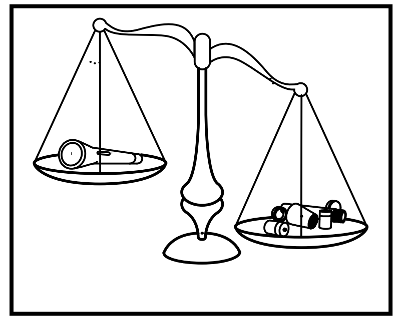
Further investigate the idea that most things are made of parts. Explain that sometimes the parts are too small to see without a magnification tool. Use magnifying glasses to look at the crystals that make up rocks or salt.

Have the students investigate whether or not changing the shape of an object (such as a piece of clay) changes its mass. Have the students weight a piece of clay. Then have the students shape the clay and weigh it again. The students should see that changing the shape of an object does not affect its mass.

1. Predict: Circle the picture that you think best illustrates how the weight of a whole flashlight compares to the weight of all the pieces of a flashlight.



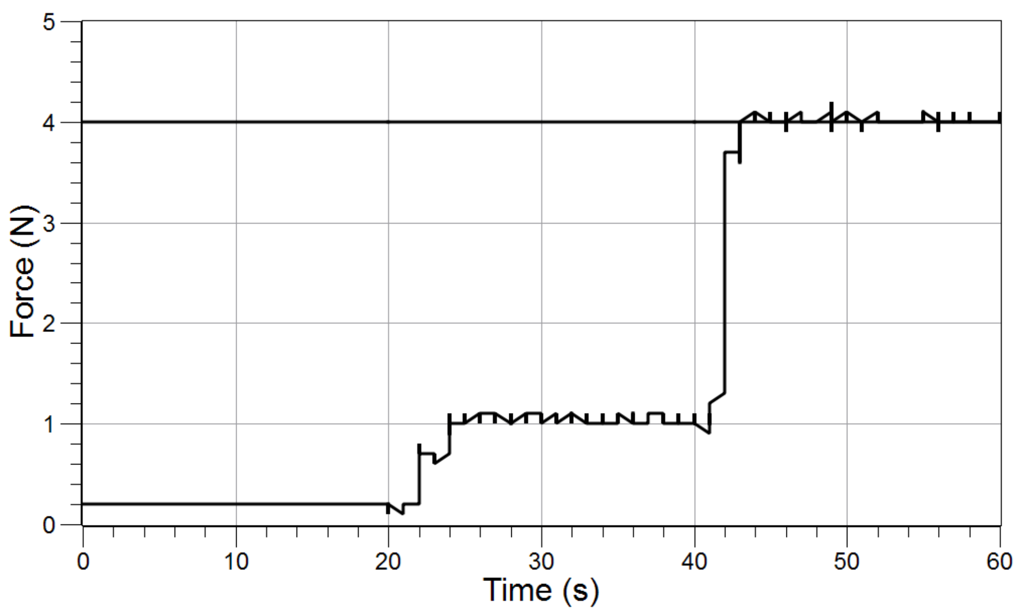




2. Explain your thinking:

The weight of each piece of the flashlight will equal the whole flashlight.

3. Draw the results from your experiment.



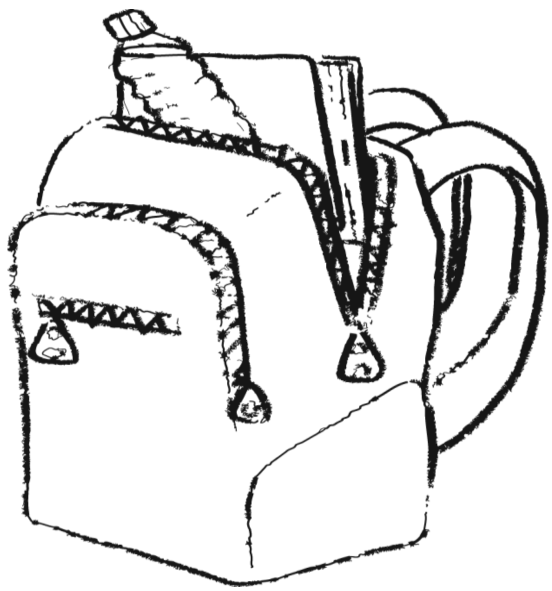
Whole flashlight and the Sum of the Flashlight Parts

4. Conclusion:

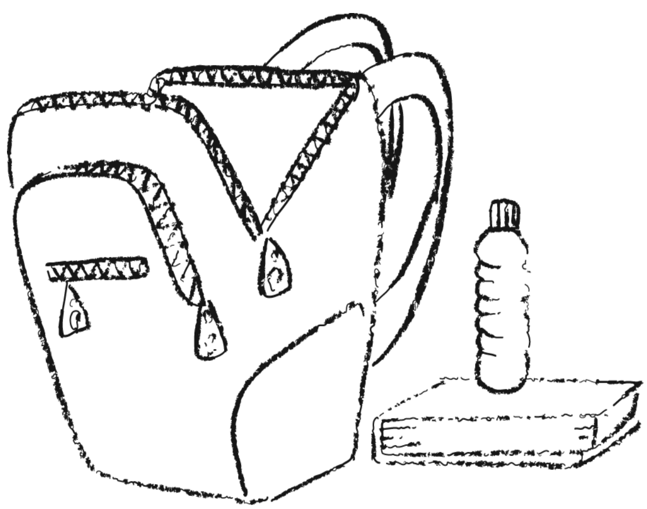
The weight of the whole flashlight equals the weight of all the parts.

5. Draw your object and the parts of your object.

Whole Object



The Parts of My Object

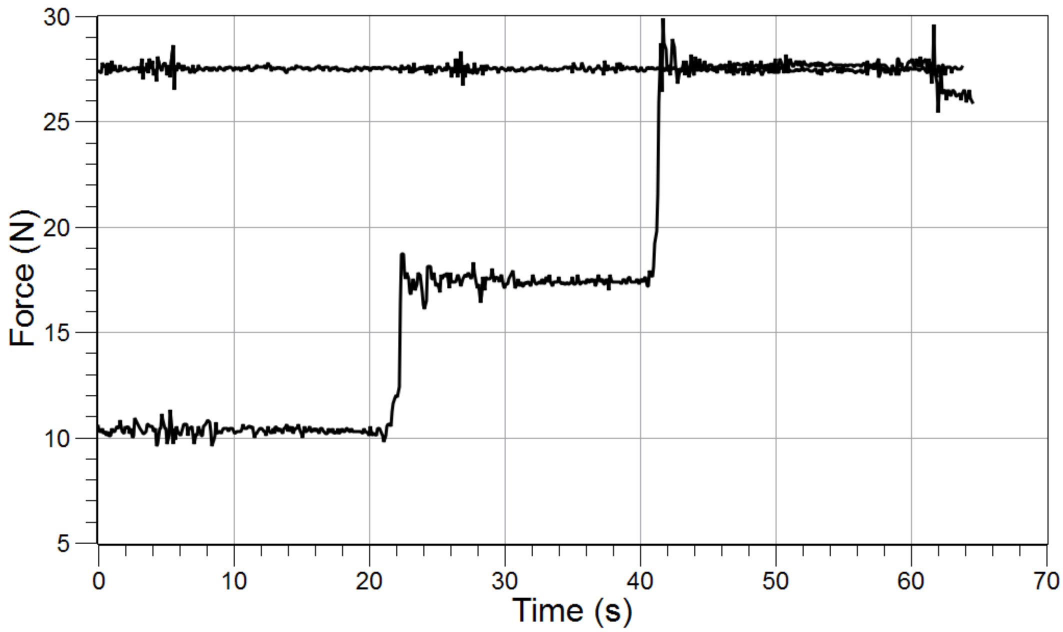


6. The weight of the ______backpack________ will be

______equal to__________________________ the weight of all its parts.
(greater than, less than, equal to)

7. Draw the results from your experiment.

Whole flashlight and the Sum of the Flashlight Parts



8. Conclusion:

The weight of the backpack was equal to the sum of the weight of each part________

of the backpack. ____

10. Hunting with Light

Recommended Grade Levels: 2 - 3

Objectives

Students compare how organisms, including humans, are able to see compared to what an electronic light sensor can detect. Through this activity, students:

- Learn the parts of the eye (iris, pupil, lens, pupil) and their functions
- Recognize that humans use light to see shape, color, size and brightness of matter
- Realize that light intensity measures the amount of light reflected or emitted by an object

Procedural Overview

To understand this content, students:

- Observe the eyes of other animals and discuss how the physical adaptations of their eyes help them survive
- Use the light sensor to measure the light intensity reflected from a variety of objects found in the classroom.
- Use the light sensor as an "eye" to hunt for an animal hidden on a paper.

Time Requirement

Teacher Preparation	15 minutes
Get Started	30 minutes
Let's Explore	30 minutes
Explain It	20 minutes
Tell Me More	30 minutes
Sum It Up	20 minutes

Materials

For teacher demonstration in the Get Started section:

- ☐ Large eye diagram[1]
- ☐ Large pictures of animal eyes[1]
- ☐ Hand lens
- ☐ Projection system

[1]Refer to the preparation section for obtaining these pictures.

For each student group:

- ☐ Data collection system
- ☐ Tissues, 1 per person
- ☐ Light sensor[1]
- ☐ Paper, plain white, 2 per person
- ☐ Objects[2] (4)
- ☐ Crayon, dark colored

[1]Set the sensitivity of your light sensor to the lowest level. If your light sensor has only one setting, you will have to do the activity outdoors.

[2]The students are given an opportunity to choose four objects. The objects should be small enough to fit on their desk.

Activity at a Glance

Get Started

- ☐ Discuss the parts of the eye (iris, pupil, lens, retina) and their functions.
- ☐ Students look at images of the eyes of other animals and discuss how the physical adaptations of their eyes help them survive.

Let's Explore

- ☐ Students list characteristics of what they see: shape, color, size, brightness.
- ☐ Students use the light sensor to explore the amount of light reflected by different surfaces. They learn that the light sensor measures brightness.

Explain It

- ☐ Explain to the students, that humans, other animals, and the light sensor "see" by having light enter their eyes.
- ☐ Differentiate between a light source and reflected light.
- ☐ Review the following vocabulary with the students: pupil, lens, iris, retina, reflect, brightness, light intensity.

Tell Me More

- ☐ Students cover their eyes with a tissue to learn about limited sight.
- ☐ Students try to find an animal hidden on a piece of paper by using their light sensor.

Sum It Up

- ☐ Students analyze their experience of "hunting with light" and relate the experience to what they have learned about light intensity in this activity.
- ☐ Students review how organisms, including humans, see compared to what an electronic light sensor can detect.

Safety

Add these important safety measures to your normal classroom procedures:

- Do not look directly into a light source; you could damage your eyes.
- Do not move around the room with your eyes closed or covered unless a friend guides you.

Preparation

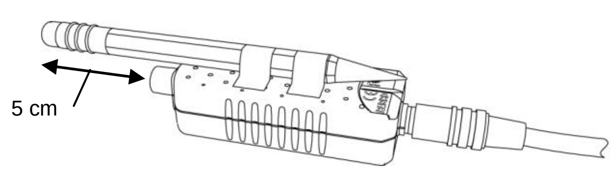
These are the materials and equipment to set up prior to the activity.

Get Started

- You will need the large illustrations of the human eye and the animal eyes provided at the end of the lab. You should copy them as large as possible. Alternatively, you can display the images on a computer projection system, or use a trade book of animal eyes. A third option would be to prepare a PowerPoint® of animal and human eyes.

Let's Explore and Tell Me More

- Set up your data collection systems in advance:
- Start a new experiment on the data collection system.
- Connect the light sensor to the data collection system.
- Display the light intensity in a digits display.
- Practice collecting a couple of runs of data.
- Project the digits display so that all the students can see it.
- Tape a pencil onto the light sensor, so the students will only hold the light sensor a standard distance from the objects they are measuring. A good distance is 5 cm.



Background

The Human Eye

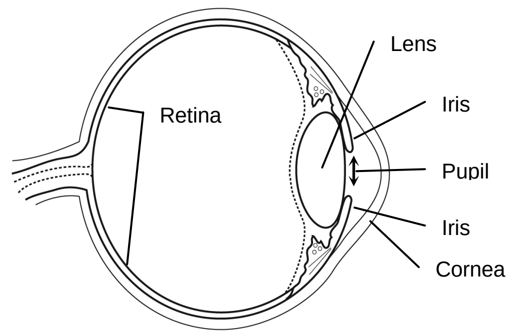
Vision is a very powerful sense, and our eyes are complex and unique in the animal kingdom. Features that make our eyes unique include a full range of vision, binocular vision, and our ability to see in three dimensions. Only higher apes share the full range of vision that we possess. Binocular vision means that both eyes are able to focus on one point, and each eye sends its data to the brain where it is combined with data from the other eye. This stereoscopic combination of perspectives allows us to place objects in three dimensions.

We see when light from a light source reflects off surfaces and enters our eye through the pupil, passes through the lens and falls on the retina in the back of the eye. Cells in the retina are stimulated and send their signal to the brain where the image is interpreted.

Some children think that our eyes beam out a light which helps us see. This idea is fed by comics of super heroes with laser vision. To help counter this misconception, guide students to realize that they can see in the dark once their eyes adjust to low light.

Parts of the Human Eye

The important parts of the eye for students to understand include the iris, the lens, the pupil, and the retina. The iris is the colored part of the eye and the color is an inherited characteristic. The pupil is the opening in the center of the iris which expands and contracts to let in less light when it is very bright out, and more light when you move into a dark room. A fun thing for students to watch is the expansion of the pupil (and the contraction of the iris) when a light is suddenly turned on after it has been dark. It is amazing to young children that the pupil is a hole in the eye covered by a thin clear film called the cornea.



The lens sits right behind the pupil. A hand lens, magnifying glass, or any convex lens can model the lens of the eye. The lens focuses light on the retina.

The retina is the back lining of the inside of the eyeball that contains special cells called rods and cones. When light enters the pupil and lands on any of these sensitive cells, they send a signal to the brain that allows you to understand what you are seeing. A healthy retina is critical for vision. You cannot see the retina by looking at your eyes in a mirror, so it is hard to talk about the retina with young children. Children can understand that the retina is the inside of the eye where the light goes after it enters the eye.

Summary of Animal Eyes and Vision

Animals have different kinds of eyes and see the world differently because of the shape of their lenses and pupils, the position of their eyes on their heads, and the complexity of their retinas. These are called physical adaptations and help the animal survive. You may want to get a book on animal eyes and leave it out for your students to use during this investigation.

The following animals have color vision: humans, chimpanzees and apes, birds, diurnal lizards (those active during the day), turtles, and some fish. Most other mammals see in shades of gray, including dogs. Most fish see everything with an amber hue. Bees and butterflies can perceive ultraviolet light, but see the color red as gray or black. Predators have eyes facing forward and prey animals have eyes on the sides of their heads. Some predators have pupils that converge into vertical slits to restrict the amount of light that enters the eye and allow them to focus directly on their prey.

Hoofed grazing animals have horizontal slits in their pupils to see the horizon better. This allows grazers to watch for predators on the horizon. Some animals have weak eyes or are blind if they live underground, like moles and shrews. Some animals have eyes up on stalks or tentacles to see around corners, like snails or lobsters. Insects and spiders have a variety of compound eyes (more than one lens per eye) or multiple eyes (6 or 8 simple eyes per animal). The animals with the sharpest long range eyesight of all are birds of prey.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Questions

This activity investigates the following questions:

- What parts are eyes made of?
- How do organisms, including humans, see compared to what an electronic light sensor can detect?

Get Started

In this section students learn about the parts of the eye and compare the eyes of a variety of animals.

1. ☐ Have students pair up and look very closely into the eyes of their partner. The goal is to examine the iris and the pupil.

2. ☐ While students are paired, darken the classroom. It will be hard for them to continue to see details of their partners' eyes, but encourage them not to look away. At the count of three, turn on the lights and tell students to watch their partner's pupils contract.

3. ☐ Ask students what the black part that changed its shape is called. If they don't know write the word pupil on the board. Explain that it is an opening in the eye for light to go in. It is covered over by a clear film so dirt can't get into your eye, but light can.

4. ☐ Ask students' "Why do our pupils contract and expand?"

   Students will say that pupils contract or expand to let in different amounts of light. Sometimes the light is too bright, so the pupil contracts to let in less light. Other times it is dark, so the pupil expands to let in more light. (Actually, the iris expands and contracts, changing the size of the pupil which is just an opening.)

5. ☐ Show the diagram of the human eye and point out the pupil and the iris.

6. ☐ Have the students look at their partners eyes again and discuss the following questions:

   Q Look at one iris. Is it all the same color or many different colors?

   Q Compare the iris in both of your partner's eyes. Are they identical?

   Q Look at the pupils in both of your partner's eyes. Are they identical?

7. ☐ Explain to the students that while irises are different from person to person the pupils are all the same.

8. ☐ Point out the lens on the eye diagram. Show students that the lens is clear and curved, just like the glass in a hand lens or magnifying glass, or like a pair of glasses. Everybody has one lens in each of their eyes, behind the pupil.

9. ☐ Discuss with students the question, “What could a lens be for?” Tell them to think about glasses, and why people wear glasses.

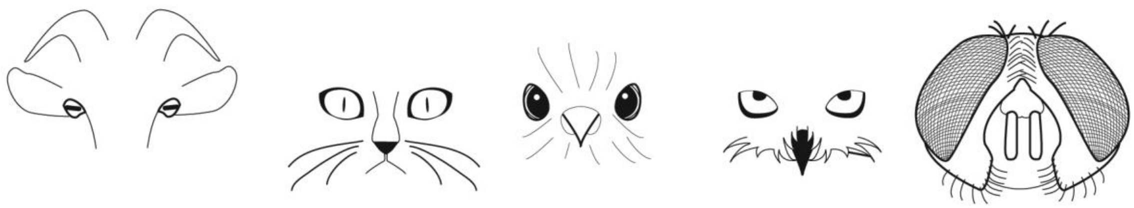
   Students will think about glasses helping us see better. We have a lens in our eye to help us see. The correct expression is that the lens changes the direction of the light when light passes through it, so that the light is focused on the back of the eye.

10. ☐ Pass a hand lens around the class so that students can feel that it is thicker in the middle and thinner on the edges, just like the lens in our eyes.

    - When students look through the hand lens, they can see that it makes close things larger.
    - Explain that the lens helps us see by focusing the light so that it strikes the retina in the back of our eye.

11. ☐ Discuss the last important part of the eye, the retina, with your students. Explain that the retina is a layer of light receptors in the back of our eyes. The light receptors in the retina receive light and pass it onto our brain which allows us to see an image.

12. ☐ Put the images of animal eyes in a location for all students to see. Have students examine the images of animal eyes and guess what type of animal belongs to each type of eye.



Goat, Cat, Chicken, Owl, Insect

13. ☐ Explain to the students that animals don't see things in the same way as we do. Have students roll up a piece of paper into a small tube and peer through it. Ask them to describe how this changes what they can see.

    Students will notice that they can see much less of their surroundings. Point out that some animals have limited vision, and some animals are even blind because they always live underground.

14. ☐ Ask the following questions about the eyes of different animals:

    a. Why would a goat need a pupil that is horizontal? Have students hold their hands in front of their eyes with a horizontal slit between them for peeking through and ask them to describe how their view is changed.

       Students will only be able to see a horizontal slit of a view, like a horizon. Herbivores are grazers, and need to keep an eye on the wide horizon for predators while they graze.

    b. Why would a cat need pupils that have a vertical slit? Have students hold their hands in front of their eyes with a vertical opening between the hands for peeking through and ask them to describe how their view is changed.

       Students will see only a limited amount of light, but will be able to look very specifically at one thing in the center of their vision. This limits the amount of light but aids a predator in concentrating on his victim.

    c. Why would a little bird like a dove or a chick need eyes on the sides of its head?

       Students may guess that it is to watch out for predators trying to sneak up on it. It is almost like having 360 degree vision.

    d. Why would an owl need two eyes straight forward like ours are?

       Students will guess that it would help the owl spot prey down in the fields as it flies overhead. They see very much like we see, except that they have a special lens that acts like a magnifying glass. It makes the vision of birds of prey sharper than any other type of animal.

    e. What is different about the eyes of a fly?

       Accept any answer. Tell them that the insect's eye is actually made up of dozens of lenses. It is called a compound eye.

    Teacher Tip: If you have a magnifying glass or bug jar with a magnifying top, or a microscope, catch a fly or bee and display the eyes for students to look at closely.

15. ☐ Have students answer questions 1 and 2 on their student response sheet.

Let's Explore

In this section students explore the properties of human vision and compare them to the properties of how the light sensor "sees".

16. ☐ Ask your students to describe the properties they see. Once they have described what they see, explain that not all animals "see" with the same properties. Use the following questions to help your students describe what they see.

    Q Can you see different shapes?

    Q Can you see different colors?

    Q Can you see brightness and darkness?

    Q Are some things too bright to look at?

17. ☐ Discuss with the students how animals see differently and why vision is important to the survival of animals. Use the following questions as needed:

    Q Why is it important for animals to see?

    Q Do all animals see the same colors that we, humans, see?

18. ☐ Explain to the students, that many animals see differently than humans see. Some animals do not see the same colors as we do. Some see more colors and some see fewer. Other animals do not see color at all, but rely on brightness (how light or dark something is) to survive. Refer to the table below (Properties of Vision in Animals).

Properties of Vision in Animals

Animal	Color Vision? (Number of primary colors seen)	Binocular Vision? (Good depth perception)	Other
Humans	Yes - trichromatic (three color vision)	Yes	
Apes and chimpanzees	Yes - trichromatic	Yes	
Monkeys	No – dichromatic (see blues and yellows better than greens and reds)	Yes	
Dogs	No - dichromatic	Yes, for the most part	Humans see distant objects better than dogs. Dogs see flickering objects better.
Cats	Yes, and perhaps better seeing blues than reds	Yes, almost as well as humans	See close objects better than far objects.
Birds of Prey	Yes, and can see in the ultraviolet range as well	Yes	The best far vision of all other animals.
Chickens	Yes - trichromatic	No –see with both eyes together but not nearly as well as with one eye at a time	
Fish	Yes, but limited. (closer to dichromatic)	No	
Lizards (Diurnal)	Yes - trichromatic	Yes	
Horses	No – dichromatic	Yes, but also see very well to either side	
Goats	No – dichromatic	Yes, but see better to the sides	

19. ☐ Show the students the light sensor that you have attached to your data collection system that is being projected.

20. ☐ With a digits display of light intensity displayed for all the students to see, point the light sensor toward a bright light. And ask the students, "What is the light sensor reporting?"

    The student should report the number being displayed on the board.

21. ☐ Then move the light sensor to an area with less light and ask the students, "Now what is the light sensor reporting?

Now the light sensor is reporting lower numbers.

Teacher Tip: You may have to move the light sensor back and forth from bright to dark several times to convince students that the light intensity values are significantly different.

22. ☐ Explain to the students that the light sensor measures light intensity which is a numerical value for the brightness of an object. High numbers mean higher light intensity. Lower numbers mean lower light intensity. Brightness is our perception of light intensity.

23. ☐ Explain that the units of light intensity are lux. Remind students of other units such as kilograms for mass and degrees Celsius for temperature.

24. ☐ Explain to the students that they are going to measure the light intensity of different objects in the room.

25. ☐ Have students select four objects and bring them to their desk. Have them order the objects on their desk from brightest to darkest.

26. ☐ Have students write their ordered prediction in Table 1 under student response question 3.

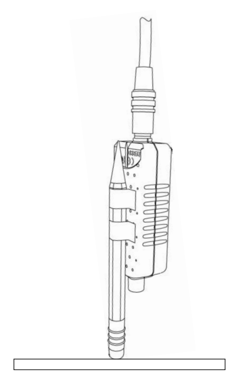
27. ☐ Guide the students through the process of determining the light intensity of their four objects.

a. Start a new experiment on the data collection system.

b. Connect the light sensor to the data collection system.

c. Display the light intensity in a digits display.

d. Have the students hold the light sensor so that the pencil taped to the light sensor is touching the object.



Teacher Tip: The pencil is used to standardize the distance the light sensor is from the objects they are measuring.

e. Begin data recording.

f. Once the light intensity value has stabilized, stop data recording.

g. Have the students record the light intensity into Table 1 under student response question 3.

h. Have the students repeat the process for their remaining three objects.

28. ☐ Help the students analyze their results to determine if their prediction is correct by asking the following questions:

Q How do you know which object is the brightest based on the light intensity measured?

Q How do you know which object is the darkest based on the light intensity measured?

Q Did you rank them in the right order?

29. ☐ Have the students re-list their objects according to their light intensity in Table 2 under student response question 4.

30. ☐ Ask, "How is the light getting into the sensor? Does the light sensor have a pupil and a lens like we do?"

Students will notice the hole that looks like a pupil, and inside it they will see a glass bubble that looks like it could be a lens.

31. ☐ Under student response question 5, have the students draw a picture of the light sensor. On their drawing, have the students:

- Label the "eye" of the sensor.
- Draw an arrow that shows the direction the light sensor is "looking".

Explain It

Explain the difference between a light source and reflected light. Explain that humans, animals, and light sensors "see" when light enters their eyes, and that light intensity is a numerical measure of the brightness of light.

32. ☐ Review with your students that humans, animals, and light sensors all "see", but that the properties they see can be different. Some animals, like humans, have very good vision and can see detailed shapes, lots of shapes, objects that are both near and far away, and a variety of colors. Other animals, however, may not be able to see as well, but their sight is good enough for them to survive.

33. ☐ Ask the students to summarize what they learned about what a light sensor "sees" compared to what humans see.

The students should explain that a light sensor "sees" brightness and gives it a numerical value. Humans can see brightness and attach meaning to it. Humans see so much more than a light sensor and our brains give meaning to all we see.

34. ☐ Ask the students, "How do our eyes interact with light to allow us to see?"

Light from an object enters our eye through the pupil and is focused onto the retina by the lens. The retina sends an image of the object to our brain which then helps us identify the object we are seeing.

35. ☐ Explain to students that our pupils expand and contract to control the amount of light that enters our eyes. The light sensor, on the other hand, has a fixed opening where light enters. We can control the amount of light entering our eyes, but a light sensor cannot. Therefore, the light sensor measures the actual amount of light in the environment while our pupils adjust the environmental light to meet our needs.

Teacher Tip: Remind students to think about the beginning of this activity when you were looking into your partner's eyes and the pupil changed.

36. ☐ Help students focus on the difference between reflected light and sources of light.

Q Name some things that produce their own light (shine)?

Q Can a lamp that is not plugged in produce light? Explain.

Q Did the objects you measured earlier produce their own light?

37. ☐ Explain to the students that light can enter our eyes directly from objects that emit their own radiant energy such as the sun or a light bulb. These types of objects are called light sources. Most objects, however, do not emit their own light. Instead, light from a light source hits the object and is reflected (bounced off) from the object. This reflected light enters our eyes and allows us to see the object.

38. ☐ Check for student understanding: ask them to tell you if the following items "give off light" or "reflect light."

- The sun (Gives off light)
- A lake (Reflects light)
- A mirror (Reflects light)
- A flashlight turned on (Gives off light)
- A flashlight not turned off (Reflects light)
- A lamp turned on (Gives off light)

39. ☐ Review the following vocabulary terms with your students.

Iris	The colored part of the eye that controls the pupil size
Pupil	The opening in the center of the iris that lets light into the eye
Lens	Clear oval disc behind the pupil that focuses light on the retina
Retina	A layer at the back of the eye that contains light receptors. The light receptors receive light and pass the light information to the brain.
Reflect	When light bounces off of surfaces
Brightness	Our perception of the amount of light reflected or given off by an object
Light intensity	A numerical measure of brightness

Tell Me More

In this part of the activity, students play a game in which they hunt for an animal (hidden on a piece of paper) using the light sensor as their "eyes".

One partner will be the "predator" and will hunt for the "prey" that the other partner has drawn on the piece of paper. The predator partner is allowed to see the screen of the data collection, but not the piece of paper with the animal drawn on it. The predator partner uses the light sensor to hunt for the "prey" that is drawn on the paper. The partner who has drawn the "prey" holds the paper screen to block the view of the predator partner. The predator partner will find the hiding animal when the reading on the display drops (the animal drawn in a dark marker reflects less light). The goal is to find the animal, but not necessarily to identify the animal.

40. ☐ Ask students to consider what it would be like if they were an animal whose eyes could only detect brightness (like a light sensor).

41. ☐ Give each student a tissue and ask them to hold the tissue over their eyes and look around. Have them discuss what they can and cannot see.

    Students will get a sense for how limited their vision becomes, and they will only be able to see brightness and dimness.

42. ☐ Give students a sheet of plain white paper and ask them to draw a secret animal somewhere on the paper (not necessarily the center) and fill it completely in with a solid dark color. Tell them to leave the rest of the picture bare. The animal should be at least as big as their fist. Tell them to make sure that their partner does not see their drawing.

43. ☐ Have the students use a second sheet of paper to screen their animal drawing from their partner's view.

44. ☐ Ask students to predict if they can find the animal by using the light sensor measurement displayed on the data collection system. Ask them how they will know if they find the animal.

Students will be able to use the light sensor. They will be looking for a change in brightness.

45. ☐ Have one partner place their animal paper on the desk with the paper screen blocking the view from the other partner.

46. ☐ Make sure the students have their data collection system set up to display light intensity in a digits display (to review this process see the Let's Explore section) and that their light sensor still has the pencil taped in the correct position.

47. ☐ Have one student hold the light sensor and ”hunt” for the animal by watching the screen on the data collection system and have the other student hold a piece of paper up so that the first student can't see where the animal is.

48. ☐ When the student with the sensor thinks, by looking at the light intensity numbers displayed, that the animal has been located, they can shout, "I found you!" The other student should answer yes or no.

49. ☐ Have the students switch roles until all the students have had the opportunity to “hunt” for an animal.

Sum It Up

50. ☐ Review the hunting with light game by asking the students the following questions:

a. How could you tell where the animal was based upon the light sensor measurement?

Students will say that the brightness of the paper changed, and they saw the light intensity reading decrease.

b. Did the color of the animal make a difference?

Students will note that color does not help or hurt their ability to find the animal.

c. Did the shape or size of the animal make a difference? Explain your answer.

Shape or size does not make a difference.

d. If an animal could only see brightness and darkness, would it be able to hunt for food?

Answers will vary.

51. ☐ Complete the activity by having the student discuss the following questions:

Q What are the main parts of an eye?

Q What is light intensity?

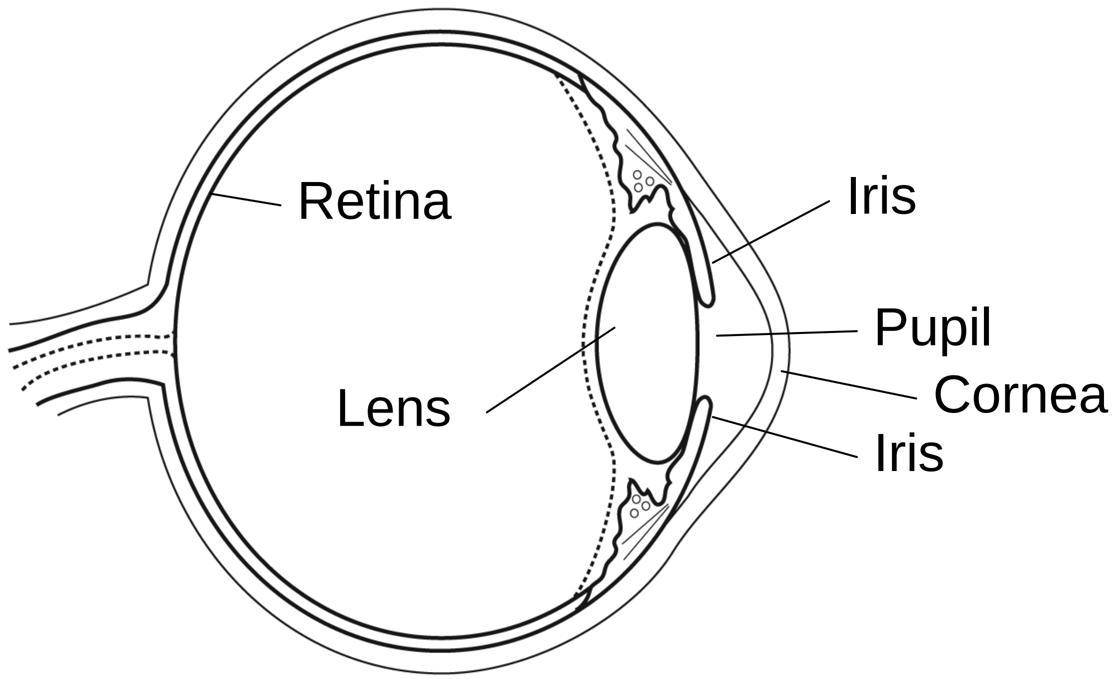
Q How do organisms, including humans, see compared to what an electronic light sensor can detect?

Further Investigations

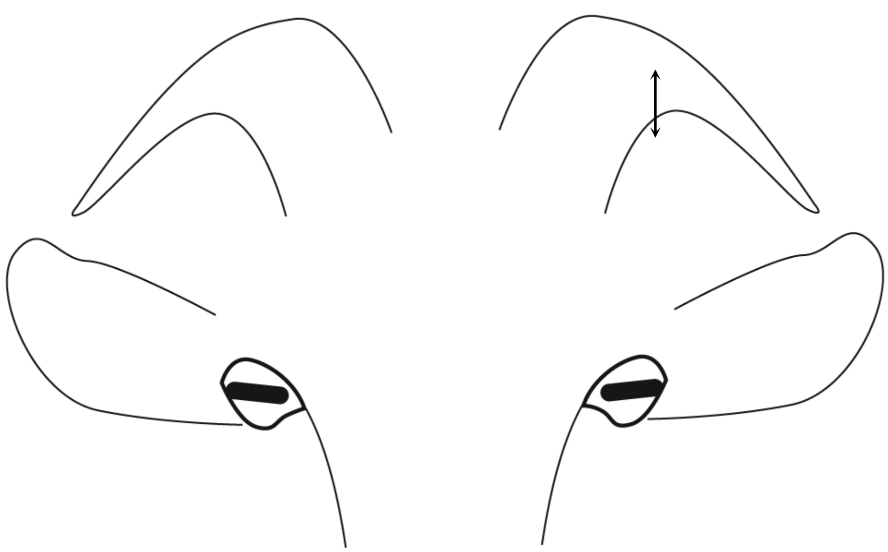
Your students may want to investigate camouflage, and how this tricks the vision of other animals. Have animal books about camouflage available for students. Connect camouflage to this discussion by identifying the predator and prey animals' type of eyes. Discuss if there is a connection between the type of eye and the camouflage strategy.

Teacher Resources

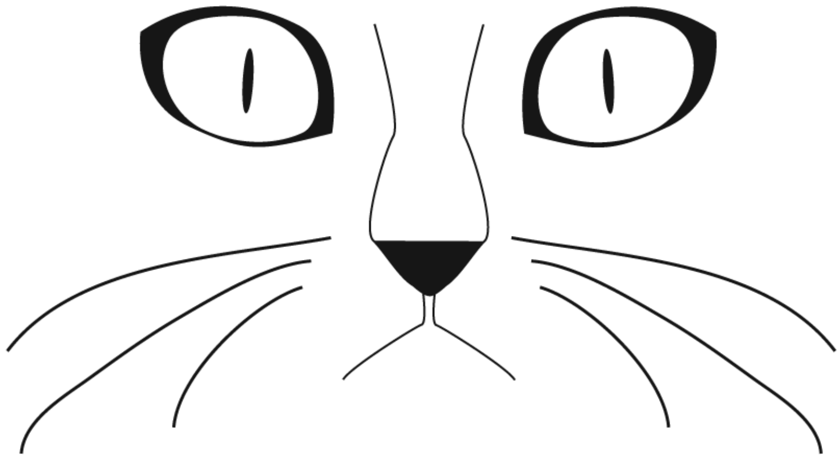
Diagram of the Human Eye



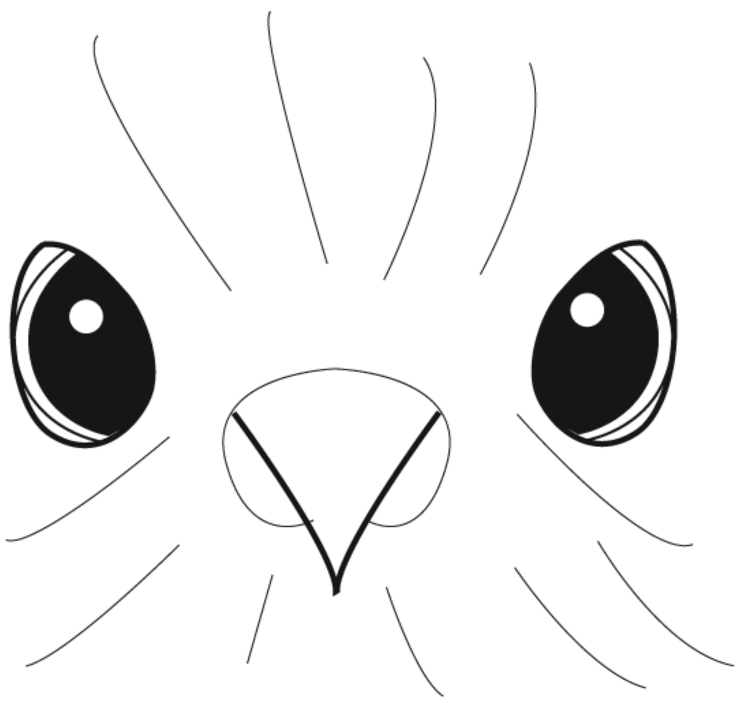
Images of Animal Eyes



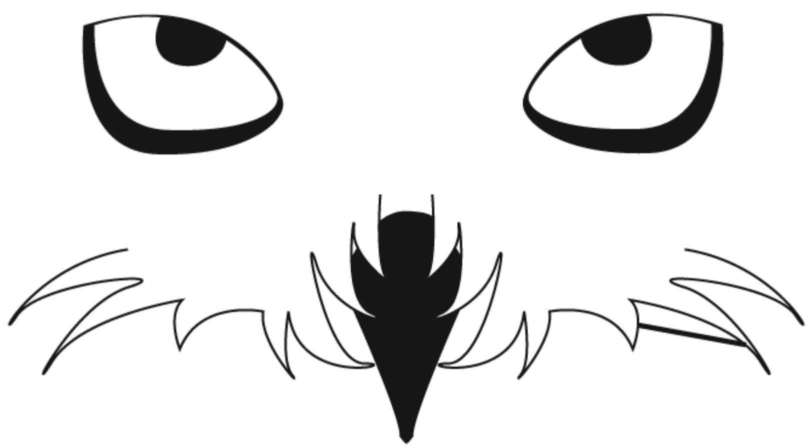
Goat



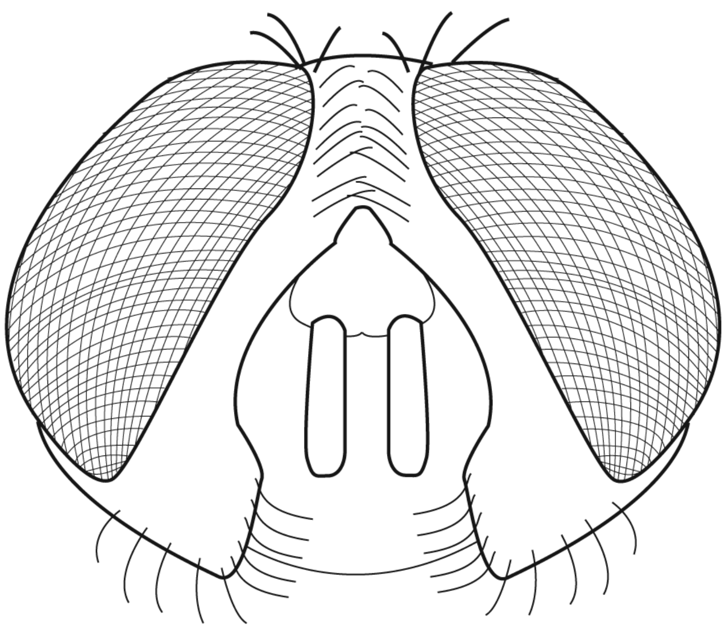
Cat



Chick

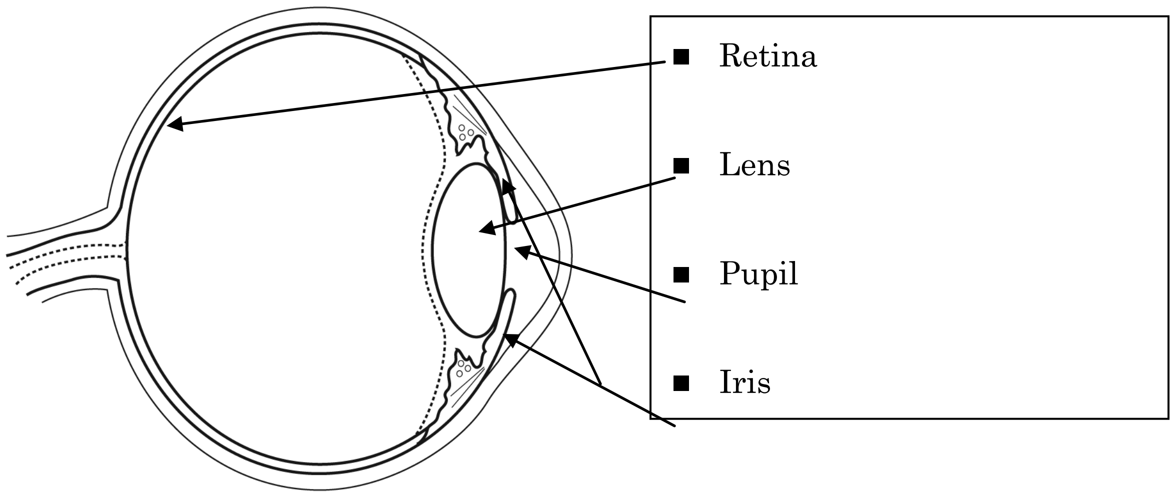


Owl



Insect

Draw lines from each word on the right to its location on the eye:



2. Draw a line from the animal to its shape of eye or pupil.

owl	horizontal pupil
bee	vertical pupil
cat	eyes on side of head
goat	eyes on front of face
dove	compound eyes

3. List the object you chose in order from brightest to darkest. Then measure the light intensity.

Table 1: Predicting the brightness of objects.

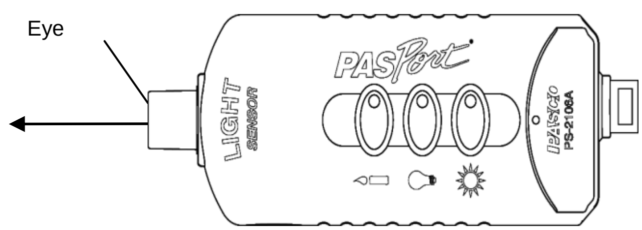
	Name of Object	Light Intensity (lux)
Bright	book	0.75
	eraser	0.83
	ruler	0.52
Dark	binder paper	1.64

4. Re-list your objects according to their light intensity values. List the object with the most light intensity first.

Table 2: Objects listed according to light intensity.

	Light Intensity (lux)	Name of Object
Most intense	1.64	binder paper
	0.83	eraser
	0.75	book
Least Intense	0.52	ruler

5. Draw a picture of the light sensor. Label the “eye” of the sensor and draw an arrow to show the direction it is "looking".



11. Investigating Sound Levels

Recommended Grade Levels: 2 – 3

Objectives

Students recognize that continuous sound is made by vibrating objects, and can be described by its pitch and volume. Students explore different continuous sounds by studying the changing volume.

Procedural Overview

To understand this content, students:

- Describe sound volume using drawings and verbal descriptions
- Hum in a variety of ways near the sound sensor and test the effect of a "megaphone"
- Compare graphs of sound levels and draw conclusions about sound and vibrations

Time Requirement

Teacher Preparation	5 – 10 minutes
Get Started	10 - 15 minutes
Let's Explore	10 - 15 minutes
Explain It	15 - 20 minutes
Tell Me More	15 - 20 minutes
Sum It Up	10 - 15 minutes

Materials

- ☐ Data collection system
- ☐ Sound level sensor
- ☐ Sensor extension cable
- ☐ Sheet of paper to make a sound tube

Activity at a Glance

Get Started

- ☐ Students hum while holding fingers over their throats to feel the vibrations of the vocal cords.

Let's Explore

- ☐ Students predict how the graph of a louder hum will differ from that of a quieter hum, and they record this prediction on the student response sheet.
- ☐ Students hum into the sound sensor at two different sound volume levels and compare their graphs.

Explain It

- ☐ Students make a variety of humming sounds into the sound sensor with their mouths closed and then again with mouths open. They compare the graphs of sound level.
- ☐ Review the following vocabulary with the students: vibration, volume, and sound level sensor.
- ☐ Students copy the sound level graphs onto the student response sheet.

Tell Me More

- ☐ Students hum into the sound sensor with a paper sound tube and then without the sound tube the same distance from the sensor. They compare the graphs of sound level.
- ☐ Students illustrate the function of a sound tube and the volume data on the student response sheet.

Sum It Up

- ☐ Guide a class discussion in which students share results and conclusions.

Safety

Add these important safety measures to your normal class procedures:

- Do not make loud noises close to other people's ears. You may damage their eardrum.

Preparation

These are the materials and equipment to set up prior to the activity.

- Prior to the activity, you may want to set up the data collection system to display a graph of Sound Level versus Time:

  1. Start a new experiment on the data collection system.
  2. Connect the force sensor to your data collection system.
  3. Create a graph of Sound Level versus Time.

     Note: Sound level is displayed in units of decibels (dBA).

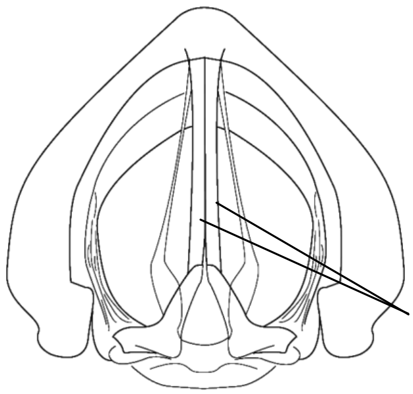
  4. Practice recording runs of data and hiding runs of data.

- If possible, connect the data collection system to the classroom projection system. Even if students will be using data collection systems in smaller groups, it is valuable to have the activity projected for reference with the whole class.

Background

Sound and the Vocal Cords

Vocal cords moving back and forth cause pressure variations in the air. These variations travel through the air and make the eardrum move when they arrive there. Young students may not understand the concept of air pressure. They may also notice that sounds travel through solid things and water. A way to describe it more simply is to say that the vibrations cause disturbances in the air, or in a solid or water, as the case may be. These disturbances travel through the medium and cause a disturbance when they arrive at something that can vibrate, such as the surface of a drum.



Objects that vibrate within our range of hearing — 30 to 15,000 vibrations per second, or hertz (Hz) — and transmit that vibration to the air make sounds that we can hear.

Students often confuse loudness (amplitude of the vibration) with pitch (frequency of the vibration). Since our voices usually get louder as we raise the pitch, students may confuse these two factors. Be sure to focus the students on the same sound with different sound level intensities.

The Sound Level Sensor and Decibels

The sound level sensor displays measurements in units called decibels, abbreviated as dBA. The "A" in the abbreviation indicates that this is the "A-weighted" scale or system. Decibels are an expression of the relative loudness of sounds in air as perceived by the human ear. In the A-weighted system, a correction is made at low frequencies because the human ear is less sensitive below about 1000 Hz than it is at higher frequencies.

Decibels are defined in terms of power per unit of surface area, on a scale where 0 dB is just at the threshold of human hearing, up to the threshold of pain, which is considered to be between 120-140 dB. For example, the sound level of an average adult conversation is about 60 dB; average home entertainment (television and music) levels are about 85 dB; a loud rock concert is about 110 dB, and standing near a jet engine is about 150 dB.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

- How can you make sounds at different volumes?

Get Started

Our throat muscles pull on our vocal cords, much like fingers pulling on a rubber band. The muscles pull less hard on them when we sing a soft note and pull harder when we sing a loud note. The windpipe carries air from our lungs to our mouth.

Students cannot observe their vocal cords directly, but they can feel how their vocal cords vibrate and hear how resulting sounds are made.

Note: Make sure that all of the students locate their vocal cords and feel them vibrating while they hum.

1. ☐ Have students hum softly to themselves while holding their fingers over their throats so they can feel their vocal cords vibrating.

2. ☐ Discuss with students that continuous sounds come from objects that are vibrating, that is, moving back and forth in a regular way. Ask the students if their vocal cords are vibrating when they hum.

   Q What do you feel when you hum softly?

3. ☐ Have students hum again while holding their fingers over their throats. Tell them to make their humming louder this time.

   Q What do you do to make your voice louder?

Let's Explore

4. ☐ Set up the data collection system to display a graph of Sound Level versus Time:

   a. Start a new experiment on the data collection system.

   b. Connect the sound level sensor and sensor extension cable to your data collection system.

   c. Create a graph of Sound Level versus Time.

   d. Start data recording.

5. ☐ Have a student volunteer hum softly directly into the sound sensor.

   Teacher Tip: Encourage the student volunteer to hum steadily at the same volume for ten seconds.

6. ☐ Stop data recording.

7. ☐ After observing the graph, ask students to predict what the graph will look like when a student volunteer repeats the humming at a louder sound level. Have the students complete the prediction section on the student response sheet for question 1.

8. ☐ Have the students test their predictions using the sound level sensor:

   a. Start data recording.

   b. Have a student volunteer hum loudly directly into the sound sensor.

c. Stop data recording.

9. ☐ Ask students how the graph of the loud hum compares to that of the soft hum.

Students should observe that the louder they hummed, the greater the sound level they recorded (corresponding to the line higher on the graph).

Explain It

In this part of the activity, students further investigate the effect on sound level of humming with their mouths open and closed.

10. ☐ Explain to students that the next two volunteers will make sounds first with their mouth closed, and then with their mouth open.

    Teacher Tip: The important feature for each graph is loudness—the intensity of sound—evident as a value higher on the graph. Prompt the students to appreciate that making louder sounds requires more energy.

11. ☐ Start data recording.

12. ☐ Have students try out the sound sensor for 30 seconds by humming directly into the sound sensor. Tell students, “Make as many different kinds of humming sounds with your voice as you can with your mouth closed.”

13. ☐ Stop data recording.

    Note: You may choose to hide or keep displayed the run of data just collected.

14. ☐ Start data recording.

15. ☐ Have students try out the sound level sensor for 30 seconds. Now tell the students, “Make as many different kinds of humming sounds with your voice as you can with your mouth open.”

16. ☐ Stop data recording.

17. ☐ Show students the data for the open mouth humming and also for the closed mouth humming.

18. ☐ Have the students copy the Sound Level versus Time graphs they collected on the student response sheet response 2.

19. ☐ Discuss the results with the students by asking the following questions:

    Q Was the sound level of the humming from a closed mouth louder than or not as loud as the humming from an open mouth?

    Q How can we tell from the graphs where the loudest and quietest humming was?

20. ☐ In their investigations of sound levels students learned some new scientific ideas. These ideas have their own scientific terms. It is important to be able to discuss results using these words and terms correctly.

Discuss with the students the meaning of the following terms in their own words, using what they have learned from the activity.

Vibration	Moving back and forth
Volume	The amount of loudness or intensity of sound
Sound level sensor	Tool to measure the loudness of sound

Tell Me More

In this part of the activity students use a sound tube made of a piece of paper. They test the level of different sounds with and without the sound tube. Many of the students will be surprised that the sound tube appears to amplify (make louder) the sound, even though they are further away. Just as the outer ear collects and funnels vibrations into the ear canal, the paper tube directs sound to the sensor instead of allowing it to spread out.

21. ☐ Start data recording.

22. ☐ Have a student volunteer hum directly into the sound sensor for 10 seconds. Ask the student to try changing how loudly he or she hums. Stop data recording.

Q What feature in the graph shows you how loud the sound is?

23. ☐ Start data recording.

24. ☐ Have a student volunteer hum close to the sound sensor, then farther away. Tell the student not to change the loudness of his or her hum.

25. ☐ Stop data recording.

26. ☐ Show students the graph and discuss the way it varied.

Q What changes do you notice in the graph?

27. ☐ Make a tube by rolling up a piece of paper.

28. ☐ Start a new experiment on the data collection system.

29. ☐ Display Sound Level on the *y*-axis of a graph with Time on the *x*-axis.

30. ☐ Start data recording.

31. ☐ Put one end of the tube near the sound sensor and have a student volunteer hum into the other end.

Write the result from the graph on the board:

The sound level is 74 dB .

32. ☐ Now take away the tube and ask the same student volunteer to hum with exactly the same loudness and at the same distance from the sound level sensor as with the tube.

    Write the result from the graph on the board:

    The sound level is 58 dB .

    Have the students copy the sound levels from the board onto the student response sheet for question 3.

Sum It Up

33. ☐ Have the students share the results and conclusions from the Tell Me More section with the rest of the class.

34. ☐ Ask the students what they have learned about sound and vibrating objects. Their responses should answer the driving question: How can you make sounds at different volumes?

    Sound level increases when an object vibrates with more energy or by using a tube to prevent the air vibrations from spreading out and diminishing.

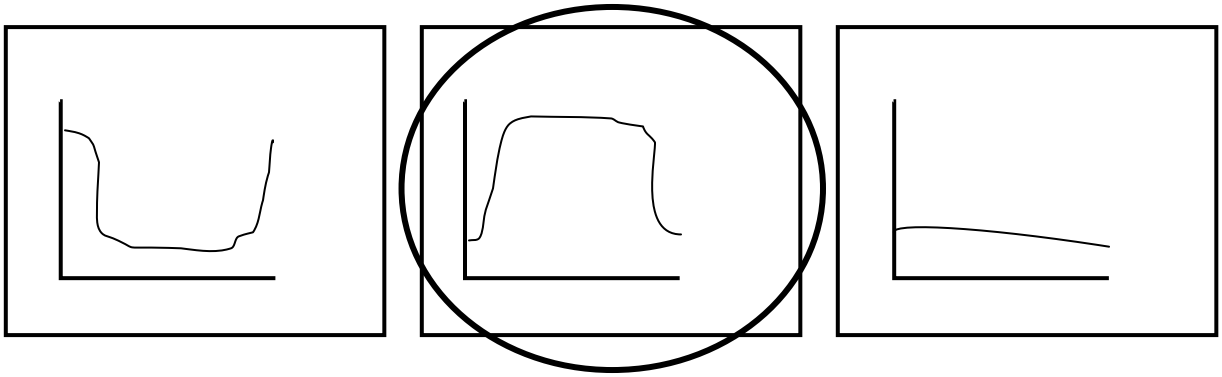
35. ☐ Have students draw a diagram of how they used the sound tube to cause the vibrations from their vocal cords to reach the sound level sensor. Direct students to question 4 on the student response sheet.

Further Investigations

Collect a variety of objects that vibrate. Include some musical instruments of different types, such as a stringed instrument and a drum or tambourine. Include other objects that aren't associated with music, such as paper or plastic bags or a balloon to pop, rocks to bang together, and paper to tear. Use each of the objects to make sounds. Ask students to tell what is vibrating in each case. Students may not realize that the air is being disturbed (is vibrating). Point this out as you demonstrate each object.

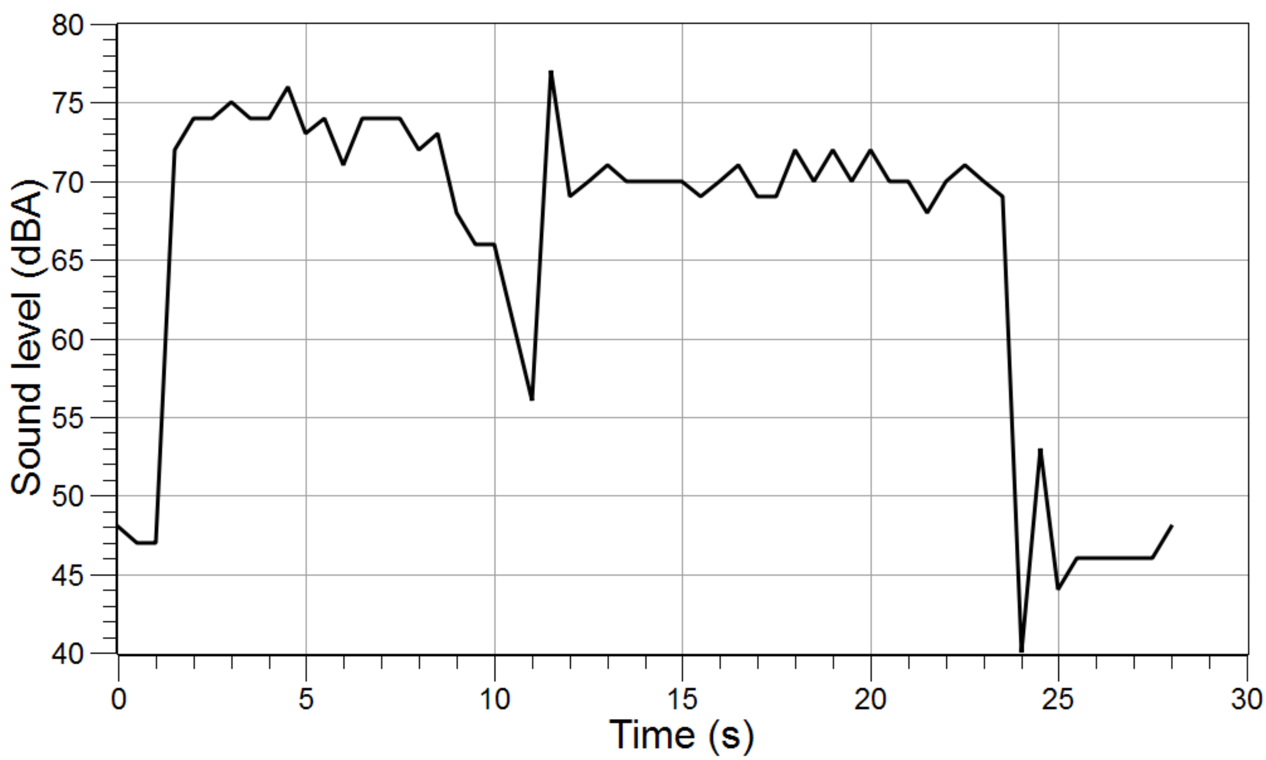
Use the sound level sensor to monitor the noise in the classroom. Project the graph of sound level versus time. Try this at first without telling students the purpose of the graph. See how quiet the class can become based on the graph. You can also ask the class to make a specific type of noise, such as snapping their fingers in unison or whispering a word or vowel sound and watching what happens to the sound level.

1. Predict: Circle the picture you think best shows what the graph of louder humming will look like compared to softer humming.

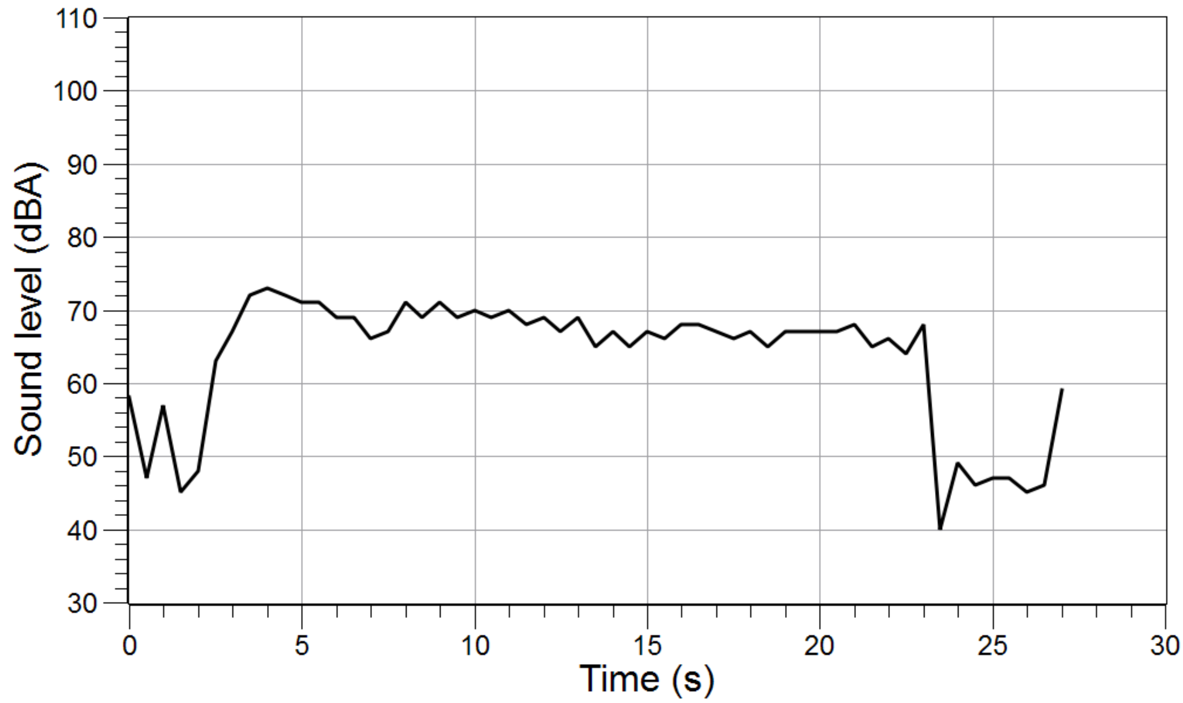


2. Draw the graph that shows the results from humming with an open mouth and a closed mouth:

Humming with Mouth Open



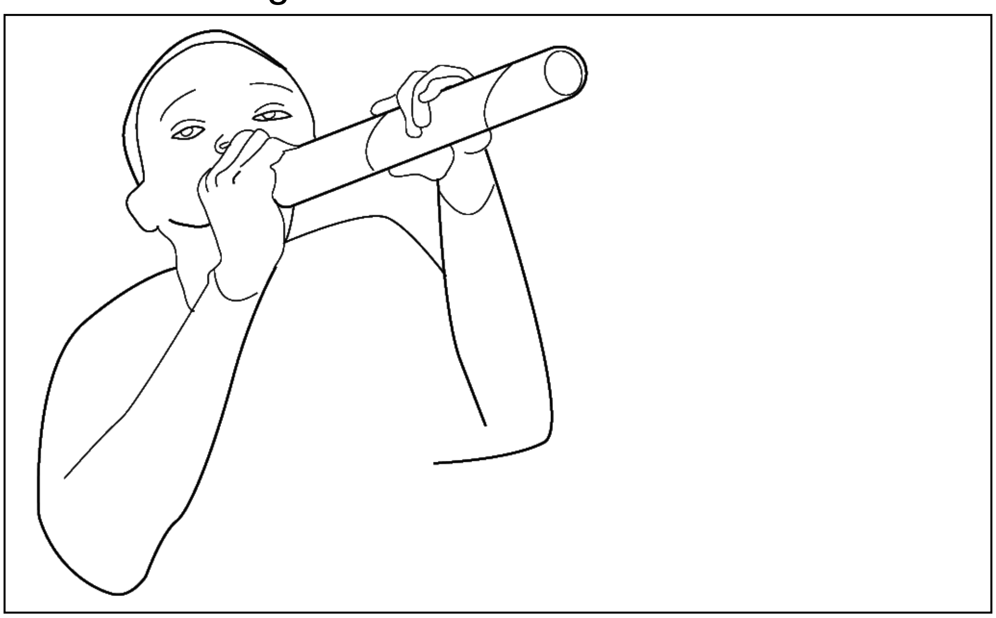
Humming with Mouth Closed



3. Sound level with sound tube: 74 dBA

   Sound level without sound tube: 58 dBA

4. Draw a diagram to show how the sound tube works:



12. Feeling and Measuring Temperature

Recommended Grade Levels: 2 – 3

Objectives

Students learn the about the differences between feeling temperature and measuring temperature.

Procedural Overview

- Students compare the feeling of still air and moving air against their bare arm
- Use a temperature sensor to measure the temperature of still air and moving air
- Predict how water and air at the same temperature will feel and test the prediction by measuring the temperature of air and water and then feeling the two samples

Time Requirement

Teacher Preparation	10 – 15 minutes
Get Started	15 - 20 minutes
Let's Explore	20 – 30 minutes
Explain It	15 - 20 minutes
Tell Me More	20 – 30 minutes
Sum It Up	10 - 15 minutes

Materials

For each student or group:

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Thermometer, bulb-type
- ☐ Metal object[1]
- ☐ Wooden object[1]
- ☐ Projection system (teacher only)
- ☐ Paper or cardboard sheet for fan, 21 cm x 28 cm (8½ in. x 11 in.)
- ☐ Plastic cup (3), 400 mL or 12 oz
- ☐ Water, cool, 100 mL
- ☐ Water, warm, 100 mL

[1]Any metal and wooden object will work. Ideally use objects that are already in the classroom such as the metal leg of a desk and the wooden surface of a desk.

Activity at a Glance

Get Started

- ☐ Discuss how we use our fingers to sense temperature and compare that with the use of a temperature sensor (or thermometer) to sense temperature.
- ☐ Have the students feel a metal object and a wooden object and then, as a class, project the actual temperature of each object using a temperature sensor and a classroom projection system.

Let's Explore

- ☐ The students use their arm to feel the temperature of still air and moving air.
- ☐ The students measure the temperature of still air and moving air using a temperature sensor.

Explain It

- ☐ The students compare the results of feeling temperature and measuring temperature using the comparison between moving air and still air.
- ☐ Explain to the students that feeling (sense of touch) and measuring are different. Go over the importance of feeling and measuring with your students.
- ☐ Review the following vocabulary with the students: temperature, temperature sensor, feeling, and measurement.

Tell Me More

- ☐ Have the students predict how water and air at the same temperature will feel.
- ☐ Have the students test their prediction by measuring the temperature of the air, creating a cup of water that has the same temperature as the air, and feeling the two samples.
- ☐ Help the students analyze their data and draw a conclusion about the difference between feeling of temperature and measuring temperature.

Sum It Up

- ☐ Have the students discuss what they have learned about feeling and measuring temperature.

Safety

Add these important safety measures to your normal classroom procedures:

- Do not use hot water. It may cause burns.

Preparation

These are the materials and equipment to set up prior to the activity.

Getting Started:

- Set up the data collection system to display a digits display of temperature:
    1. Start a new experiment on the data collection system.
    2. Connect the temperature sensor to your data collection system.

3. Create a digits display of temperature.
4. Temperature is displayed in units of degrees Celsius. Optionally, change the units to degrees Fahrenheit.
5. Practice recording a run the temperature of data.

- Practice connecting the data collection system to your classroom projection system and projecting the temperature you collected in front of the class.

Tell Me More:

- Fill one cup with approximately 100 mL of warm water for each student group.
- Fill one cup with approximately 100 mL of cool water for each student group.

Background

Feeling temperature vs. measuring temperature

There are special nerves in the skin that sense hot and cold—different from the nerves that sense pressure or pain. Different parts of the body are more and less sensitive to temperature. To explore this, touch your skin with an ice cube wrapped in plastic. Try your finger, inner and outer arm, forehead, leg, and cheek. There are many situations where the body and the temperature sensor don't give the same results. The reason is that they measure different things. The temperature sensor measures the absolute temperature, but the skin senses the difference between its own temperature and the environment, because that's what matters to our body.

If the surroundings are colder than the skin and the conduction of heat away from the skin is increased, then the skin cools down and the body detects coldness. Examples include moving air (Let's Explore), which carries heat away better than still air and water (Tell Me More), which conducts heat much better than air. Also, the feeling of a room temperature metal surface, which conducts heat away from the skin very quickly and will feel very cold, compared to a room temperature wood surface, which is less of a conductor and will feel warmer. Another example is bare skin, compared to skin insulated with clothes or blankets or dry clothes, compared to wet clothes.

The reverse is also true. If the surroundings are warmer than the skin and conduction is increased, then the skin heats up and the body detects warmth. Examples include hot water which is much more dangerous than hot air, again because water conducts better than air. For this same reason, the air in an oven might be above 100 ˚C. It will make your hand feel hot, but won't instantly burn it, as boiling water would. Another example is a cloth hot pad that protects your hand from the hot metal handle of a frying pan, which would conduct heat very quickly to your skin and burn it.

Temperature sensor

The temperature sensor detects the absolute temperature, because it is designed to do that. "Temperature" has a specific physical meaning that scientists have agreed upon: the average kinetic energy, or energy of motion, of the molecules. Temperature sensors have been made to measure this in a consistent way, so that scientists working all over the world, in many different experimental situations, can understand and repeat each other's results. The temperature sensor is a very important scientific tool.

Celsius and Fahrenheit

This investigation is written using Celsius (˚C) temperature units. In the Celsius system, water freezes at 0 degrees C and boils at 100 ˚C. This scale may be difficult for students who are used to the Fahrenheit (˚F) system, for which water freezes at 32 ˚F and boils at 212 ˚F. You may spend some time comparing these scales if you wish, but it's not necessary for the investigation, which uses graphs as well as numerical values to display temperature.

Cooling by evaporation vs. cooling by moving air

Cooling by evaporation is different from cooling by moving air. Students have experienced both and probably think they work the same way. Unlike moving air, evaporative cooling affects both the skin and the temperature sensor. When you wave around a wet finger or a wet temperature sensor, the water molecules evaporate into the air, cooling off the surface. It not only feels cooler, it is cooler. In very hot weather, or when we are working hard and our muscles produce a lot of heat inside our bodies, we cool off by sweating: our skin secretes water, which then evaporates and cools us.

Body temperature control and climates

The feeling of hot and cold is essential to survival. All animals face changes in the temperature of their surroundings that are greater than their bodies can tolerate. For instance, the interior of our bodies must stay close to 37 ˚C for us to stay alive. Animals must be able to detect the surrounding temperature and have strategies for maintaining their proper body temperature. Here are some examples, and students can think of others: Many mammals have hair or fur that creates a thin layer of still air near their skin, which is a better insulator than moving air. Musk oxen and polar bears have heavy fur coats with several layers of fur that keep them warm even in winter in the far north.

When our skin temperature gets too high, we sweat and the evaporating water cools us down. Some fur animals, like rabbits, lose extra heat from their ears.

Whales and seals have layers of fat (blubber) that insulate them from cold arctic waters. Water birds like ducks have oil in their feathers that keep the water away from their skin. Cold-blooded animals, like reptiles and insects, take different approaches from warm-blooded animals, such as mammals. Their body temperatures are not as constant, and their activity level often changes depending on the temperature.

One reason that people can live all over the world, and many animals cannot, is that people can make themselves clothes that protect them from heat, cold, and wet.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

- How is feeling and measuring temperature different?

Get Started

In this section, the students are introduced to measuring temperature with the human sense of touch as well as with tools such as a temperature sensor (or thermometer).

1. ☐ Explain to the students that our skin is very sensitive to temperature and that we often use our fingers to feel how hot or cold something is.
2. ☐ Discuss why the ability to feel hot and cold is essential for survival. Use the following questions to guide the discussion:

   Q What if you couldn't feel hot or cold?

   Q What would happen if you touched a hot stove, but could not sense the heat?

   Q What if you were given a cup of hot cup of tea, but could not sense the heat?

   Q How does the ability to feel hot and cold help humans survive?

3. ☐ Ask the students if they know of any tools that are used to measure hot and cold?

   The students will likely suggest a thermometer or temperature sensor.

4. ☐ Project a digits display of temperature and display room temperature. Show the students both a typical thermometer and a temperature sensor.

   Teacher Tip: Since students may have more experience with a bulb-type thermometer, you should demonstrate the conventional thermometer and the electronic sensor side by side, to show they measure the same thing.

5. ☐ Have students discuss how tools (thermometers and temperature sensors) compare to our bodies ability to sense temperature. Through this discussion help the students to understand that tools provide objective numerical temperature readings whereas our sense of feel just give comparative sensations (warm or cold).

   Q Which of our five senses do we use to detect temperature?

   Q How do you describe the temperature of objects?

   Q What does a temperature sensor tell you? Does it state whether an object is hot or cold?

   Q Have you and a friend ever disagreed on whether a room is hot or cold?

   Q Are there times when your senses cannot be trusted?

6. ☐ Have the students touch a metal object near them with one hand and a wooden object with their other hand. Then ask them how the objects feel and whether or not the two objects have the same temperature.

7. ☐ Use the data collection system that is connected to your classroom projection system to determine the temperature of the two items. Record the results on the board:

Table 1: Temperature of a metal and wooden object

Object	Temperature
Metal	24.8 °C
Wood	24.8 °C

8. ☐ Summarize the activity with the students by explaining that the two objects feel like they are different temperatures, but the temperature data collected from the temperature sensor shows that the two objects have the same temperature (or very similar temperatures).

9. ☐ Tell the students that they are going to experiment with other examples of how feeling and measuring temperatures can produce different results.

Let's Explore

In this section the students will compare the temperature of still air to the temperature of moving air using their sense of touch and using the temperature sensor.

Teacher Tip: It is important to avoid telling students what we think they should discover. Instead, keep asking students what they have observed and what the experiment shows. When there is a conflict between what they believe and what they observe, it is only natural for students to ignore their observations in favor of what they believe. So, while students measure the same temperature for moving air and still air, they will cling to the idea that moving air is cooler. Only through reflection and discussion will they understand why measuring and feeling temperature are different.

10. ☐ Have the students think about how their bare arms feel in still (not moving) air.

11. ☐ Have the students make air move across their arm by waving a piece of paper or cardboard back and forth, like a fan.

12. ☐ Explain to the students that they are using their bare arm to feel how the temperature of still air compares to moving air.

13. ☐ Have the students explain how moving air feels compared to still air when they use their arm to feel the difference. Direct the students to write their observation on the student response sheet under student response 1.

14. ☐ Ask the students how they think the temperature of still air will compare to the temperature of moving air when the temperature of each is measured with a temperature sensor. Have the students make their prediction by answering student response 2.

15. ☐ Have the students measure the temperature of still air by guiding them through the following steps:

    Teacher Tip: Depending on the air circulation in your classroom, you may need to have the students find or build an area where they can test still air. Drafts and air circulation systems will cause variation in the data.

    a. Start a new experiment on the data collection system.

    b. Connect the temperature sensor to the data collection system.

    c. Display the temperature data in a graph with Temperature on the y-axis and Time on the x-axis.

    d. Begin data recording.

    e. Adjust the scale of the graph to clearly see the temperature data.

    f. After one minute, stop data recording.

16. ☐ On the same graph, have the students collect a second run of temperature data this time measuring the temperature of moving air. Use the following steps to guide them through this process:

    a. Have one student constantly wave a piece of paper or cardboard back and forth, like a fan to create a moving air.

    b. Have a second student hold the temperature sensor in the moving air.

    c. Begin data recording.

    d. After one minute of holding the temperature in the moving air, stop data recording.

17. ☐ Have the students copy both runs of data onto their student response sheet under student response question 3. Have them label each run of data.

18. ☐ Ask the students how the measured temperature of moving air compares to the measured temperature of still air?

    The measured temperature of the moving air is the same as that of still air.

19. ☐ Have the students write their conclusion about how the measured temperature of moving air compares to that of still air under student response question #4.

Explain It

In this section, help your students analyze how the data they collected while feeling was different than the data they collected when measuring. Then explain to the students how feeling and measuring are different.

20. ☐ Discuss with students how the results from feeling the difference between moving air and still air compared to the measuring the difference in temperature between moving air and still air.

    Q How did moving air feel compared to still air? (student response 1)

Q What was the measured temperature of moving air compared to still air? (student response 4)

Q Do we sense temperature the same way the temperature sensor does?

21. ☐ Have the students state whether or not feeling and measuring gave the same results by answering question 5 on their student response sheet.

22. ☐ Explain to the students that our senses (in this activity, touch) are different than electronic sensors (temperature sensor). Senses and sensors measure different things. A thermometer measures absolute temperature and our fingers sense the difference between our body and our surroundings. While feeling is great for survival, measuring is better for science.

23. ☐ Discuss with your students why feeling is important for survival, while measuring is better for science by going over the following information:

Table 2: Feeling versus measuring

Feeling (important for survival)	**Measuring with a Sensor (important for science)**
Sensations may change depending on the setting and previous experience.	A sensor will measure the same value in the same situation, again and again.
It may vary from person to person.	Data collected using a sensor can be displayed on a time graph so that you can watch changes take place and find patterns.
Give sensations like “cool” or “warm”.	Give numerical values.
Can make comparisons like A is warmer than B.	Can express how much warmer or cooler different objects are.
We can process feelings quickly and make immediate decisions.	Sensors can sometimes measure smaller differences than humans can.

24. ☐ Go over the following vocabulary words with your students. Relate each of the vocabulary words to the feeling and measuring air temperature activity that the student just completed.

Table 3: Vocabulary and definitions

Temperature	A measure of hot and cold.
Temperature sensor	An electronic tool that is used to measure temperature.
Feeling	Make an observation by using the sense of touch.
Measurement	To find the value or amount of something with a device or tool that uses standardized units.

Tell Me More

In this section, the students determine how water and air that have the same measured temperature feel relative to each other.

25. ☐ Discuss with your students their predictions about how water and air at the same temperature will feel. Use the following questions as a needed.

    Q If you measure the water temperature and the air temperature with a temperature sensor and they are the same, do you think they will feel the same?

    Q Will the water feel cooler, feel warmer, or feel the same temperature as the air?

    Q What makes you believe this is true?

26. ☐ Have your students record their prediction under student response question 6.

27. ☐ Guide your students through the process of measuring the temperature of the air.

    a. Start a new experiment on the data collection system.

    b. Connect the temperature sensor to the data collection system.

    c. Display temperature in a digits display.

    d. Hold the temperature sensor in the air, and begin data recording.

    e. Allow the temperature to stabilize, then stop data recording.

28. ☐ Have the students copy the air temperature into the table under student response question 7.

29. ☐ Provide each student group with a cup of warm water, a cup of cool water, and an empty cup.

30. ☐ Guide the students through the following steps of mixing their warm and cool water until they create water that has the same temperature as the air (within one degree):

    a. Have one student hold the temperature sensor in the empty cup and start collecting data (in the digits display).

    b. Have another student slowly add some warm and cool water into the cup while monitoring the temperature.

    c. Once the temperature stabilizes, the students may have to add a little more warm or cool water to adjust the temperature in the cup so that it the same temperature as the air.

    d. Once the temperature of the water is the same as the air temperature, have the students stop recording data

    e. Have the students copy the water temperature into the table under student response question 7.

31. ☐ Direct the students place one of their fingers into the water and another in the air.

    Q How does the water feel on your finger compared to air?

    Q Does the water feel cooler, warmer, or the same as the air?

32. ☐ Have the students record their observations under student response question 8.

33. ☐ Help the students analyze their data and then draw a conclusion about the difference between the feeling of temperature and the measurement of temperature. Direct the students to write their answer under student response question 9.

Sum It Up

Review with the students what they have learned during this activity.

34. ☐ Have the students share what they have learned in this activity with a partner.

35. ☐ Have the students discuss the following questions:

    Q How are human and electronic sensors different?

    Q How are feeling and measuring different?

    Q If you were doing a science experiment, which would be better for measuring temperature—using your finger or a temperature sensor? Why?

    Q What if you touch two objects and it feels like they are at different temperatures. Then, you measure both objects with a temperature sensor and find they are at the same temperature. Which would you believe, your senses or the temperature sensor? Why?

Further Investigations

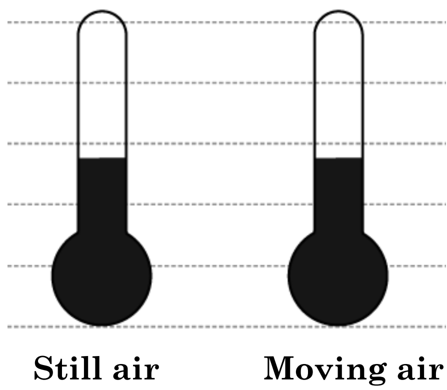
Fool your fingers. Make three pitchers of water—one hot, one cold, and one medium. Put one hand in the hot water and one in the cold. Wait for one minute. Put both hands in the medium water. Does it feel the same to both hands? Measure the three pitchers with the temperature sensor. Can you explain what is going on?

With your finger, touch several materials that have been sitting in the classroom for a while: wood, plastic, metal, glass. Do they all feel the same temperature? Then measure each one with the temperature sensor. Use tape, and not your fingers, to hold the sensor against the material. Do the materials measure the same temperature? What do you think is going on?

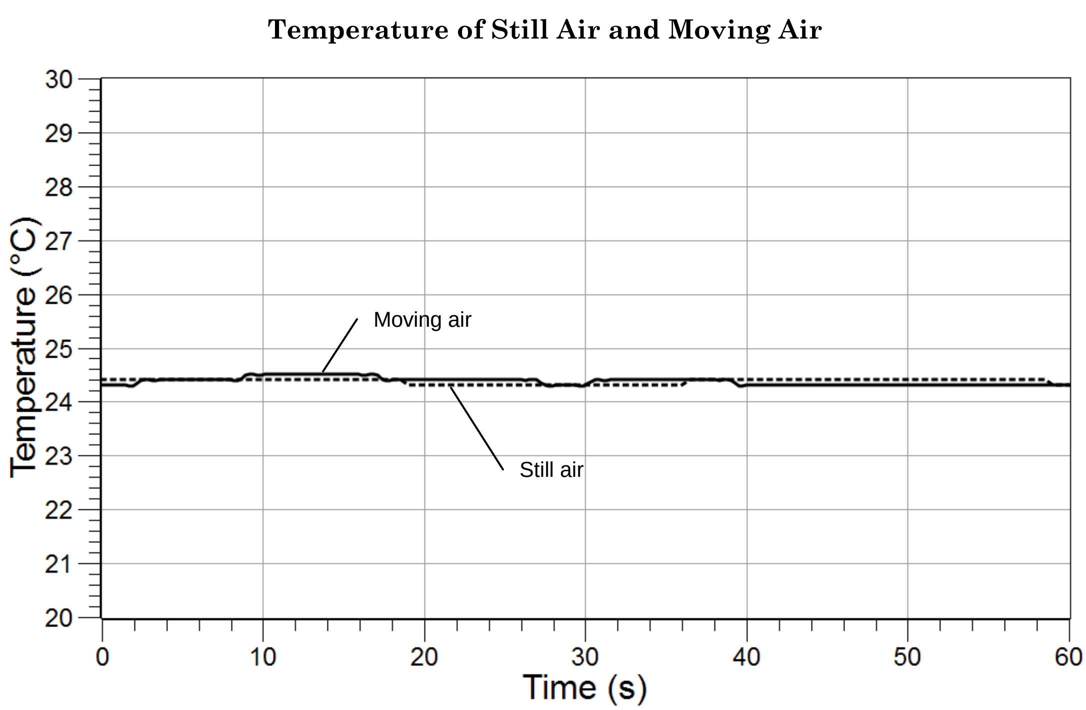
1. How does moving air <u>feel</u> compared to still air?

Moving air feels cooler than still air.

2. Color in the thermometer to show how you think the <u>measured</u> temperature of still air will compare to moving air.



3. Draw the results from your experiment.



4. Measuring temperature conclusion:

Still air and moving air are the same temperature.

5. Do the results for feeling and measuring temperature for air temperatures agree? Circle the best answer.

YES NO

6. Water that has the same temperature as the air will feel

the same as the air.
(the same as, warmer than, cooler than)

7. Measured temperatures:

Air temperature is: 23.5° C

Water temperature is: 23.4° C

8. How does the water feel on your finger compared to air?

Water feels cooler than air.

9. Is there a difference between the feeling, and the measurement of temperature?

Yes. Even though the temperature of air and water was the same it felt different.

13. Cars and Heat

Recommended Grade Levels: 2 – 3

Objectives

Students determine how the temperature inside a car parked in the sun compares to the temperature of the air outside the car. Through this activity, students

- Realize that when light is absorbed by an object the temperature of that object can increase
- Observe that air movement within an object affects the temperature inside that object
- Learn that some objects reflect light and heat better than other objects

Procedural Overview

To understand this content, students:

- Build a simple model of a car and passenger from a shoe box, black paper, paper cup and other items
- Use a temperature sensor to measure the temperature in their model car when it is placed in the sun and left open, and then when it is covered with plastic food wrap
- Compare the temperature graphs and examine the data to draw conclusions about the temperature inside of parked cars

Time Requirement

Teacher Preparation	10 – 15 minutes
Get Started	5 - 10 minutes
Let's Explore	20 - 30 minutes
Explain It	15 - 20 minutes
Tell Me More	20 - 30 minutes
Sum It Up	10 - 15 minutes

Materials

For teacher guided discussion in the Get Started section of the activity:

- ☐ Mobile data collection system
- ☐ Temperature sensor
- ☐ Projection system
- ☐ Shoe box model car, assembled[1]

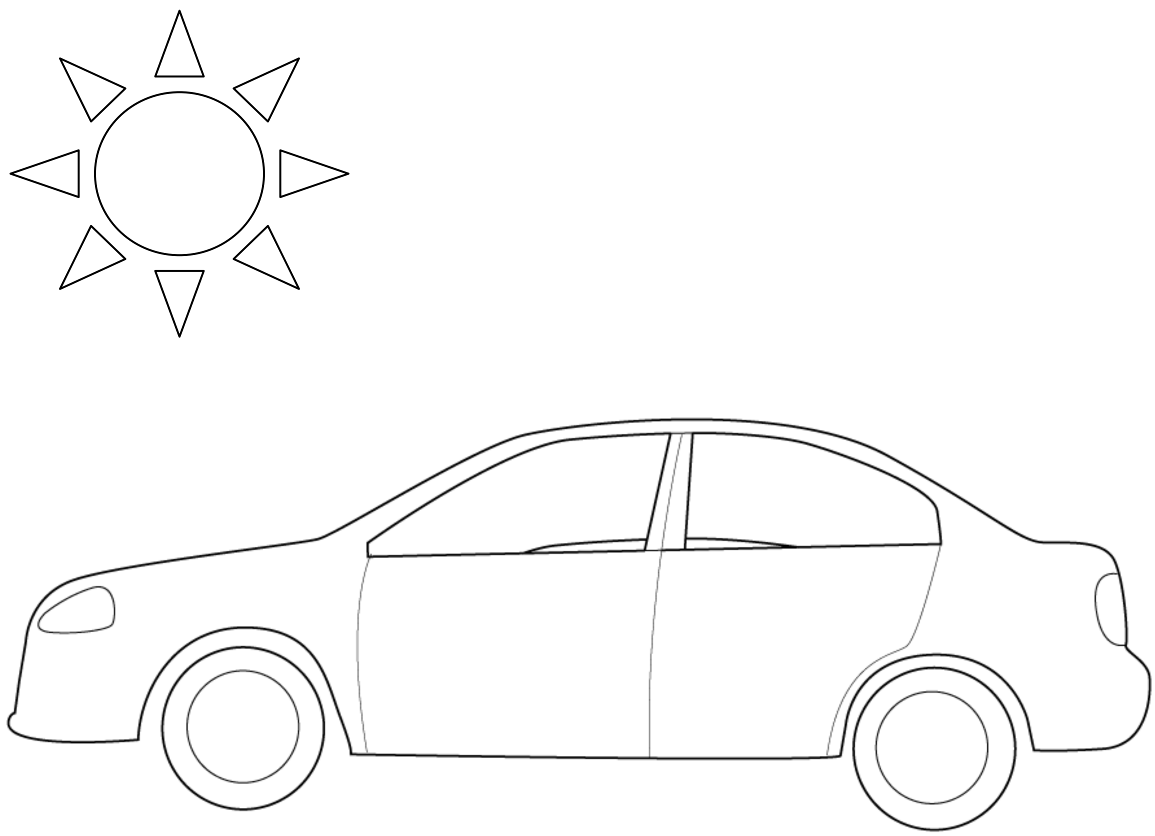
[1]The materials needed to assemble the shoe box model are the same as the materials listed for each student group below. Refer to the Preparation section for instructions on how to build the model car.

For each student group:

- ☐ Mobile data collection system
- ☐ Temperature sensor
- ☐ Shoe box[1]
- ☐ Black paper[2]
- ☐ Plastic food wrap to cover shoe box
- ☐ Paper cup[1]
- ☐ Yarn, cotton balls, other craft supplies
- ☐ Markers
- ☐ Glue stick
- ☐ Tape, ~30 cm

[1]Exact size does not matter; the modified cup must be able to fit entirely into the shoe box.

[2]Enough black paper is needed to line all 5 inside surfaces of the shoe box.



Activity at a Glance

Get Started

- ☐ Lead the students in a discussion about how sunlight contributes to the overall temperature on earth.
- ☐ Use a temperature sensor to measure the temperature outside and project it for all the students to see.
- ☐ Students predict how the temperature inside a parked car will compare to the temperature of the air outside the car.

Let's Explore

- ☐ Students build a model of a car and passenger with a shoe box, black paper, and a paper cup.
- ☐ Students draw and label their model of a car on student response sheet.
- ☐ Students measure the temperature inside their model for five minutes as it sits in the sun.

Explain It

- ☐ Help the students analyze the data they recorded to determine the temperature in the model car after it had been in the sun for five minutes.
- ☐ Have the students brainstorm why the temperature is hotter in a parked car than outside and what people do to keep a parked car cool on a warm, sunny day.
- ☐ Review the following vocabulary with the students: temperature, temperature sensor, absorb, reflect, light, and heat.

Tell Me More

- ☐ Students predict whether a car with open, partially open, or closed windows gets the hottest when it is parked in the sun.
- ☐ Students test their predictions by measuring the temperature in their covered model car as it sits in the sun for five minutes.
- ☐ Students copy the graph of temperature data they collected onto their student response sheet.

Sum It Up

- ☐ Help the students analyze their data to determine whether the temperature became hotter in the open model car or the closed model car.
- ☐ Have the students review what they have learned by doing this activity.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

Get Started

In this section the class is working together rather than individually. The teacher projects the data and leads the class in discussion.

1. Set up the data collection system to display a digits display of temperature:

    a. Start a new experiment on the data collection system.

    b. Connect the temperature sensor to your data collection system.

    c. Create a digits display of temperature.

    d. Temperature is displayed in units of degrees Celsius. Optionally, change the units to degrees Fahrenheit.

    e. Practice recording a run the temperature of data.

2. Practice connecting the data collection system to your classroom projection system and projecting the temperature you collected in front of the class.

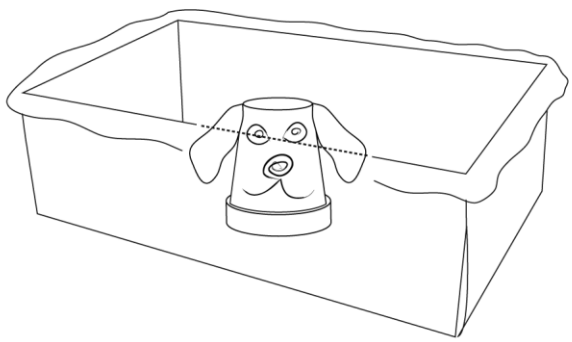
Let's Explore

In this section, the students make a shoe box model car and paper cup passenger. The students place the model in the sun and measure the temperature for 5 minutes. Prepare a sample shoe box model car and paper cup passenger to show the students.

1. Line all five of the inside surfaces of a shoe box with black paper. Use glue or tape to secure the paper in place.

2. Make a passenger by decorating an inverted paper cup. Draw a face on the cup and embellish it as you wish to make it look more realistic.

3. Place the paper cup passenger in the middle of the lined shoe box.



Background

The Sun's Radiation and Your Car

Energy from the sun arrives at Earth's surface in the form of electromagnetic radiation. We perceive some of the wavelengths of this radiation as light, while other wavelengths we perceive as heat.

Solar radiation can be absorbed, reflected or scattered. Cars can act like a greenhouse because they have the ability to do all of these things. Glass lets some of the light from the sun go through it, and reflects some. In particular, infrared "light" (which you cannot see) will not go through the opaque exterior of a car. Light is absorbed by the exterior of the car and heats up the interior regardless of whether the windows are closed or open. If the windows are shut, heat is basically trapped in the car where temperatures can rise to over 90 degrees Celsius (200 degrees Fahrenheit) possibly causing the windows in the car to blow-out as the air expands within the car due to heating. Additionally, this can pose danger for animals and infants if left in cars without adequate ventilation and water.

Albedo and Surface Reflection

Scientists use the term albedo to define the percentage of solar energy reflected back by a surface. Albedo can be thought of as the "reflectivity" of a surface. Sunlight falling on a white shiny surface is strongly reflected back into space; such a surface is said to have high albedo. This results in very little heating of the surface. Sunlight falling on a dark matte surface is strongly absorbed; this type of surface has low albedo. This results in a large amount of heating of the surface.

If you cover the inside of your windshield with a sunshade, your car will be cooler. The surface reflects light and does not scatter it much. So it reflects the light right back through the window without converting much of the light to infrared light. The best sunshade is metallic (high albedo), as a nonmetallic (low albedo) sunshade tends to absorb some of the light and heat up your car. A white sunshade will produce less infrared light, and your car will be cooler. A glossy surface on the sunshade will reflect some of the light and scatter less, and make your car cooler.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful place a check mark in the box after you complete that step.

Driving Questions

This activity investigates the following questions:

- How does the temperature inside a parked car compare to the temperature of the air outside the car?
- Do you think the temperature inside the car will be greater if the car windows are open or closed?

Get Started

In this section the class is working together rather than individually. The teacher projects the data and leads the class in a discussion about the impact of sunlight on the earth.

1. ☐ Have the students think about how heat from sunlight generally contributes to the overall temperature on earth and changes in seasons. Start by asking the following questions:

   Q How is the temperature different in the summer and the winter? Why?

   Q How does the temperature in the morning compare to the temperature in the afternoon? Why?

   Q Does sunlight heat all surfaces equally? On a hot summer day would you rather stand barefoot on blacktop or grass? Why?

2. ☐ Ask the students what instrument could be used to measure the current temperature outside.

   An electronic temperature sensor or thermometer could be used to measure the temperature outside.

3. ☐ Show the students the temperature sensor that is connected to the mobile data collection system. Take the data collection system to the door and have a student volunteer hold the temperature sensor in the air outside while you record the temperature.

4. ☐ Project a digits display of the outside temperature for all the students to see and have the students record today's temperature on the student response sheet under student response number 1.

5. ☐ Ask the students to think about how the temperature outside compares to the temperature inside a parked car.

Q How will the temperature inside a parked car compare to the temperature of the air outside the car?

6. ☐ Have students record their prediction on the student response sheet by circling their best choice under student response number 2.

7. ☐ Tell the students that during the summer months of the year we often hear how important it is never to leave our pets or children in a parked car. Have the students think about whether or not this warning could be due to a change in temperature inside the car.

8. ☐ Explain to the students that they will test their predictions by building a model car and measuring the temperature inside the car when it is placed in the sun.

Let's Explore

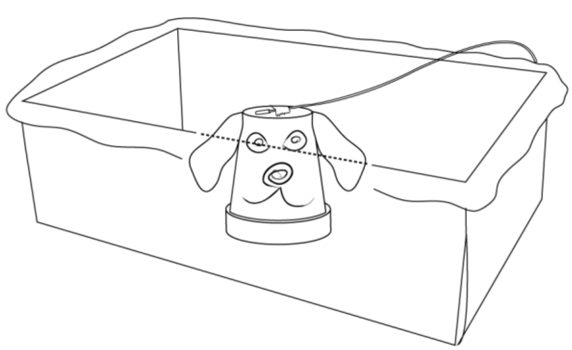
In this section, the students make a shoe box model car and paper cup passenger. The students place the model in the sun and measure the temperature for 5 minutes.

9. ☐ Show the students a sample shoe box model car and paper cup passenger. Explain to the students that they will be making their own model car and passenger.

10. ☐ Direct students to line all five of the inside surfaces of a shoe box with black paper. Have the students secure the paper in place using glue or tape.

11. ☐ Have the students make a paper cup passenger using an inverted paper cup, yarn, cotton balls, markers, and other craft supplies. Let the students decide if the passenger in their model car is a child or a pet.

12. ☐ Have the students place the paper cup passenger in the middle of the paper-lined shoe box and tape the tip of the temperature sensor to the top of their passenger, as shown in the graphic below.



13. ☐ Tell the students that this is their model of a car with a pet or child riding inside. Ask the students the following questions:

    Q Which part of the model represents the car?

    Q Which part of the model represents the pet or child?

14. ☐ Have students draw a picture of their model and label the car, the passenger, and the temperature sensor, on the student response sheet under student response number 3.

15. ☐ Explain to the students that they will use their model of a car with a passenger to determine if their prediction, about how the temperature inside a parked car compares to the temperature of the air outside the car, is correct.

16. ☐ Have each students place their shoe box model with passenger and temperature sensor outside in the sun (or indoor where sunlight shines through a window).

17. ☐ Guide the students through the following steps to record a run of temperature data:

    a. Start a new experiment on the data collection system.

    b. Connect the temperature sensor to the data collection system.

    c. Display the temperature data in a graph with Temperature on the *y*-axis and Time on the *x*-axis.

    d. Begin data recording.

    e. Adjust the scale of the graph to clearly see the temperature data.

    f. After five minutes, stop data recording.

18. ☐ Have the students move their data collection system and model car back inside. The model car needs to cool back to room temperature before it is used again in the Tell Me More section.

Explain It

In this section, help your students analyze the data they have recorded.

19. ☐ Have the students look at their graphs of Temperature versus Time that they just recorded. Ask the following questions to help the students understand their graphs.

    Q What happened to the temperature over the five minutes of data collection?

    Q After five minutes, how did the temperature inside the car model compare to today's temperature outside the car?

20. ☐ Have the students determine the temperature in their model car after it had been in the sun for five minutes. Direct the students to write this temperature down in student response number 4.

21. ☐ Have the students write what they learned by doing this activity as their conclusion in student response number 5.

22. ☐ Have students brainstorm why the temperature inside a car is hotter when it sits in the sun. Make a list on the board of the students' reasons.

    Students should suggest that the light and heat from the sun warm the inside of the car. Students may suggest that when a car is parked, no breeze is able to blow through the windows, so the heat is trapped inside the car even if the windows are partially rolled down. Students may also suggest that dark colored cars or cars with dark colored interiors get even hotter than light colored cars.

23. ☐ Ask students to describe and list some things people do to help keep a parked car cool on a warm, sunny day. Make a list on the board of the students' ideas.

Students may suggest any of the following: park in the shade, put up sunshades in the windshield, leave the windows open, tint the windows, cover the seats with a cloth to keep the sunlight off them, or turn on the air conditioning.

24. ☐ Go over the following vocabulary words with your students. Relate each of the vocabulary words to the model car activity the students just completed.

Temperature	A measure of hot and cold
Temperature sensor	An electronic tool that is used to measure temperature
Absorb	To take in light and heat energy and trap or keep it; the opposite of reflect
Reflect	To let light energy bounce off a surface; the opposite of absorb
Light	Energy from the sun that we can see as brightness
Heat	Energy from the sun that we feel as warmth

Tell Me More

In this part of the activity students predict what will happen if their model car is covered with plastic food wrap, to model a car with closed windows, and then left in the sun for five minutes. They then test their prediction.

25. ☐ Ask the students to think about whether a car with open, partially open, or closed windows gets hottest when it is parked in the sun.

26. ☐ Have students record their predictions on the student response sheet by circling their best choice under student response number 6.

27. ☐ Ask the students whether the first set of data they recorded in their model car represented the windows of the car being open or closed?

The students should explain that the first set of data represented a car with the windows open. This is because air was able to easily flow in and out of their model car.

28. ☐ Discuss with the students how they could change their model car to represent a car with its windows closed. Make sure that the students understand that windows prevent air from moving into and out of the car, but still allow sunlight to come in. In this activity, the students will cover their model cars with food wrap to represent a car with closed window.

29. ☐ Direct the students cover the top of the shoe box car model with plastic food wrap. If necessary, have the students tape the plastic wrap to hold it in place.

30. ☐ Have each student place their covered shoe box model with passenger and temperature sensor outside in the sun (or indoor where sunlight shines through a window).

31. ☐ Have the students record a run of temperature data for the covered model car on the same graph that they recorded their temperature data with the open model car.

    a. Have the students make sure that their graph is still displayed on the data collection system.

    b. Have the students begin data recording.

    c. After five minutes, stop data recording.

32. ☐ Have the students copy both runs of Temperature versus Time data that they recorded on the student response sheet under student response number 7.

Sum It Up

In this section, help your students analyze the data they recorded and draw conclusions about what they have learned in this activity.

33. ☐ Have the students look at their graphs of Temperature versus Time that they just recorded. Ask the following questions to help the students understand their graphs.

    Q What happened to the temperature inside the covered model car as it sat in the sun for five minutes?

    Q Did it get hotter in the covered model car or in the open model car? How do you know?

34. ☐ Give the students some time to analyze their own results and establish a conclusion. Have the students record their conclusion on the student response sheet under student response number 8.

35. ☐ Have students brainstorm why the temperature inside the closed model car became hotter than the temperature in the open model car.

    Students should suggest that the light and heat from the sun warm the inside of both model cars, however the heated air is allowed to move out of the open model car, but is trapped inside the closed model car.

36. ☐ Review what the students have learned by having them answer the following questions:

    Q How does the temperature inside a parked car compare to the temperature of the air outside the car?

    Q Do you think the temperature inside the car will be greater if the car windows are open or closed?

Further Investigations

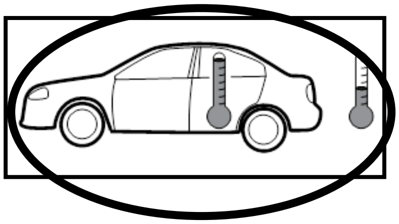
Put a mobile data collection system into your car with the windows closed on a sunny day. Record the change in temperature over one or two hours. Retrieve the system and project the results for students to see, discuss, and interpret in a class discussion.

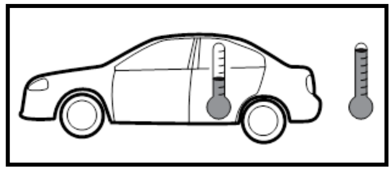
Compare the temperature changes inside two similar cars at the same time, one car with the windows open and the other with the windows closed. Ask student to identify other variables they might test experimentally, such as cars of different colors, sizes, or with tinting on the windows. Carry out as many investigations as time and access permit.

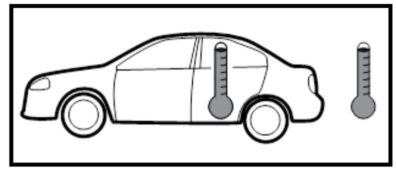
1. What is today's temperature?_

25° C

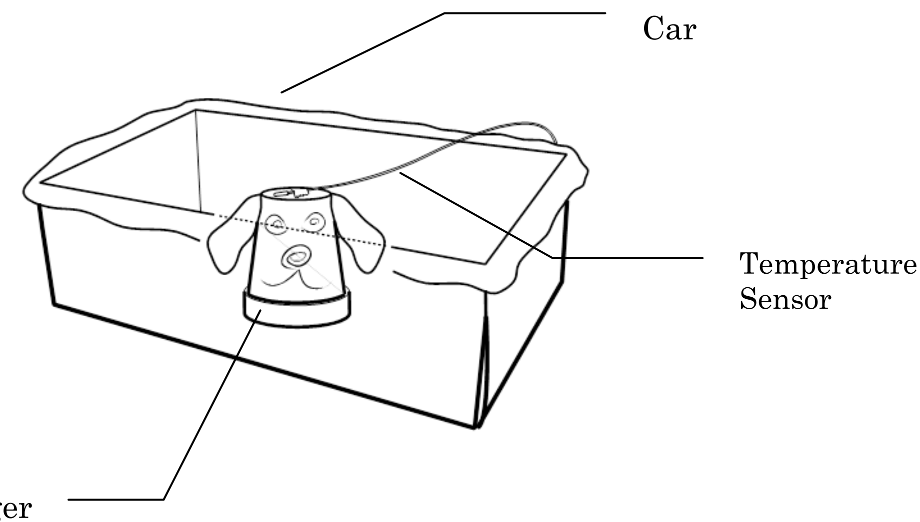
2. Circle the picture that you think best shows how much hotter it will get inside a car than outside on a sunny day.







3. Draw your model car and passenger. Label the parts.



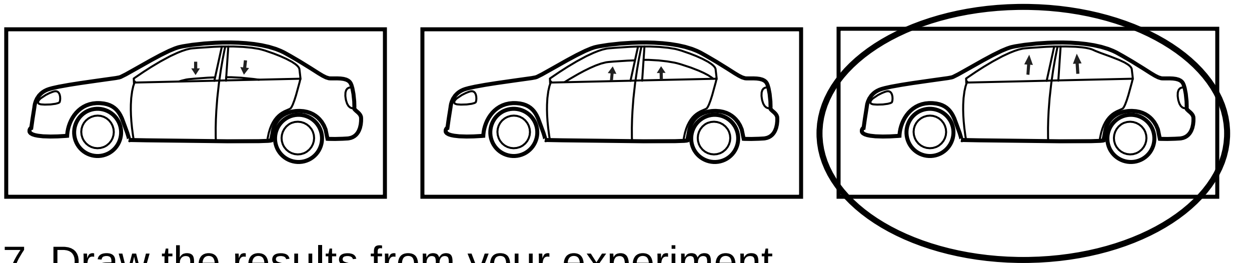
4. What is the temperature inside the model car after it had been in the sun for five minutes?

36° C

5. Conclusion:

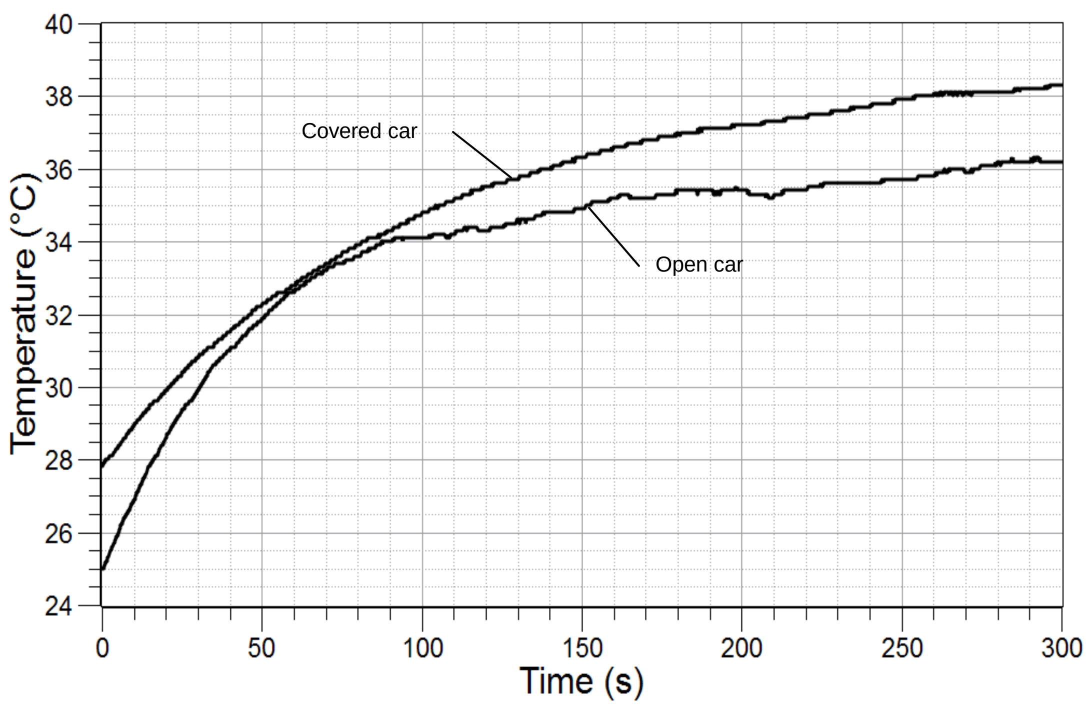
The temperature inside a car is hotter than outside a car.

6. Circle the picture that you think best shows which car will get hottest on a sunny day.



7. Draw the results from your experiment.

Model Cars in the Sun



8. Conclusions:

A car with the windows closed gets hotter than a car with the windows open.

14. Observing Clouds

Recommended Grade Levels: 2 - 3

Objectives

Students learn that clouds in the sky have properties that can be observed and described. They associate cloud formation with specific weather conditions such as temperature and humidity.

Procedural Overview

To understand this content, students:

- Identify types of clouds in the sky using standard pictures of clouds
- Use a compass and learn direction
- Monitor temperature and humidity for three days
- Relate changes in weather to the formation of clouds

Time Requirement

Teacher Preparation	15 – 20 minutes
Get Started	30 – 40 minutes
Let's Explore	30 minutes
Explain It	30 minutes
Tell Me More	15 – 20 minutes per day for three days
Sum It Up	15 minutes

Materials

For teacher demonstration:

- ☐ Mobile data collection system
- ☐ Weather sensor
- ☐ Glass canning jar, 1-quart
- ☐ Posters or pictures of cloud types, in color[1]
- ☐ Turkey baster
- ☐ Sponge
- ☐ Plastic wrap and rubber band
- ☐ Wooden stick matches
- ☐ Ice, 50 mL
- ☐ Hot water, 20 mL

[1] Alternatively, print out a large copy of the Cloud Types graphic included in the Background section.

For each student or group:

- ☐ Mobile data collection system
- ☐ Weather sensor
- ☐ Paper fastener (brad)
- ☐ Weather Journal handout1

- ☐ Cloud Types handout[1]
- ☐ PASCO Cloud Finder handout[1]
- ☐ Scissors
- ☐ Glue
- ☐ Tagboard or card stock, 14 cm x 14 cm
- ☐ Compass
- ☐ Ribbon, 12-15 cm long

[1]Refer to the Preparation section for assembling these handouts

Activity at a Glance

Get Started

- ☐ Make a cloud in a bottle.
- ☐ Raise questions about clouds and observe the conditions that made the cloud form in the bottle.
- ☐ Using the glass with ice water and the glass with room temperature water, introduce the concepts of condensation and evaporation.

Let's Explore

- ☐ Discuss the different types of clouds and the characteristics of clouds.
- ☐ Have students construct a "Cloud Finder" and take them outside so they can use it to help identify cloud types in the sky.
- ☐ Have students learn to illustrate the amount of the sky covered by clouds.
- ☐ Help students use a ribbon to determine the direction of the wind and compare it to the movement of the clouds.

Explain It

- ☐ Have students describe the weather for the day and the types of clouds visible.
- ☐ Students predict the weather conditions that would bring clouds.
- ☐ Review the following vocabulary with the students: water vapor, condensation, evaporation, humidity, relative humidity, precipitation, stratus, cumulus, cirrus, altostratus, nimbostratus, cumulonimbus.

Tell Me More

- ☐ Demonstrate the concepts of humidity and relative humidity.
- ☐ Have students examine the parts of the weather sensor and discuss the features it measures.
- ☐ Students measure and record the temperature and humidity of the air for three days. They also record the sky conditions and the cloud types for the same period.
- ☐ Have students examine their data to see if it supports their predictions.

Sum It Up

- ☐ Students analyze their data to see how their weather conditions support the formation of clouds.
- ☐ Students complete the student response sheet.

Safety

Add these important safety measures to your normal classroom procedures:

- Do not look at the sun at any time. Permanent eye damage can result.
- Use caution working with scissors.
- Do not go outside to log clouds or make entries in the Weather Journal in extreme weather conditions.

Preparation

These are the materials and equipment to set up prior to the activity.

- Prepare copies of the following handouts for each student or group of students. There are several Student response shets needed in this lab. Be sure to prepare copies of the following:
- Cloud Types
- Multiple choice
- Make a large print of the diagram entitled Cloud Types to display on the wall, or project it using any system you may have in place. Alternatively, you may use any cloud poster you already have at hand. A large color illustration of cloud types will be useful in all of your discussions during this activity.
- Before beginning the activity, place two clear glasses on your desk top. Fill the first glass with ice and top it off with cold water. Fill the second glass with room temperature or tepid water (and no ice).
- For the humidity demonstration in the Let's Explore section, determine the amount of water that should be in the turkey baster to saturate the sponge. (If any more water is added to the sponge, the sponge won't be able to absorb it and water will start dripping from the sponge.)
- Prepare your data collection system in advance to model its use for students when carrying out the Tell Me More section:

    1. Start a new experiment on the data collection system.
    2. Connect the weather sensor.
    3. Display temperature in a digits display and relative humidity in a digits display.
    4. Temperature is displayed in units of degrees Celsius. Optionally, change the units to degrees Fahrenheit.
    5. You can change the precision of the digits display if you want to remove the tenths (decimal) place.

Note: Set up as many data collection systems as you have groups of students who will be going outside together to gather weather data.

Background

Why Clouds Form

Depending on the temperature of the air, Earth's atmosphere can hold water in all its phases (gas, liquid, and solid). As a gas, water molecules have the most energy and form a vapor. When air pressure decreases or the air temperature reaches the dew point, the air becomes saturated and water vapor will condense into tiny, liquid water droplets and form clouds. If the droplets get large enough to form precipitation, the air temperature determines if it comes down as rain, snow, sleet or hail.

Water changes from a gas—water vapor—to a liquid through the process of condensation. To "condense" means to go from the gaseous phase to the liquid phase. Water vapor in the air condenses into droplets of water on the surface of a cold window. Water gets into the air through the process of evaporation. In this case, water molecules are energized by heat when sunlight shines on surfaces of lakes or wet fields. The energized water molecules break free of the surface and become airborne. Water molecules in clouds can also evaporate into the air.

Air at different temperatures can hold different amounts of water vapor. Warm air can hold more water vapor than cold air. The amount of water vapor in the air is called humidity. If air at a certain temperature is holding as much water as it can possibly hold, we say that it is “saturated." "Relative humidity" indicates how saturated the air is at that temperature: 50% relative humidity means that the air is only half full of the total amount of water vapor that it could hold. One hundred percent humidity means that the air is completely full of water vapor, so if the temperature should drop, it would rain!

Clouds form when the relative humidity goes up and the temperature drops, usually as a result of pressure changes. In this activity, we will leave the pressure changes out of the picture.

The first step to cloud formation is to saturate the air, that is, to get the air to hold as many water molecules as it can possibly hold at that temperature. If the temperature drops so the air can no longer hold as much water, the water vapor will condense on any solid particulate material floating in the air and form clouds. Air temperature can drop when it is lifted to higher elevations, but the most common cause for air temperature to drop is a change in air pressure. As air expands and pressure decreases, the air cools. This causes an adiabatic temperature change (heat does not enter or leave the system) and clouds will form if the air is moist enough.

To determine if clouds will form, air can be monitored for temperature and humidity. Falling temperature, rising humidity, or a change in wind could lead to the formation of clouds.

Naming Cloud Types

Clouds form at any elevation in the sky, but certain types of clouds tend to form at particular elevations. Clouds generally form from 2,000 meters to 20,000 meters, but can form all the way to the ground in the case of fog.

There are three main types of clouds, so named for their general shape. Sheet-like clouds are called "stratus." They form a blanket that covers the sky and exist at low elevations. Cumulus clouds look like the puffy white clouds of storybooks, and form at low to medium elevations. The term "cumulus" is applied to any cloud that is densely packed and fairly finite in shape. The third cloud type is the "cirrus" cloud, a thin, wispy-looking cloud that resembles horses' tails blowing in the wind. Cirrus clouds form only at the highest elevations. Some cumulus clouds build vertically to surprising heights; these dangerous clouds are full of static electricity and are associated with lightning, rain, hail, and tornadoes.

Certain prefixes are used to describe cloud types. The prefix "alto-" means that the cloud forms at a middle elevation, around 4,000 meters. The prefix "nimbo-" means that the cloud has enough water vapor to form precipitation. A "nimbostratus" cloud is a low, sky-covering rain cloud. An "altostratus" cloud is a mid-elevation sky-covering stratus cloud. A "cumulonimbus" cloud is a towering cumulus cloud that brings rain. Cloud names are also combined, as in "altocumulus," "stratocumulus" or "cirrostratus." The second part of the name describes the basic cloud form; the first part indicates the approximate elevation.

Cumulonimbus clouds are huge; they start at 2,000 meters and rise to 6,000 meters or more. Since their tops are high enough to be caught in high-elevation wind bands, the tops of these clouds usually stream out in one direction, forming an anvil-shaped top. The bottoms of these clouds are very dark, and rain and lightning are associated with them. They are the most dangerous clouds.

Observing Clouds

In this investigation, students initially observe and describe the making of a cloud in a bottle to observe the conditions that cause clouds to form. Students next observe the changing patterns of clouds. Finally, students record in their weather journals daily observable weather conditions: the type of clouds, the wind direction, and the air temperature, for three days (not necessarily consecutive days).

When students are looking at clouds, direct them to use the following characteristics in their descriptions:

- ***Shape:*** There are two different shapes or forms of clouds. They are either "heaped" (cumulus) or "sheeted" (stratus). The dense, huge masses of varying heights are called cumulus clouds. The low, horizontal sheets of layered, lifted fog are called stratus clouds. Clouds that are both heaped and spread out in layers are called stratocumulus clouds because they are like both stratus and cumulus clouds.

- ***Color:*** When the color changes from a fluffy white to a dark cloud, the word nimbus is added to the beginning or ending of the cloud form. For example, a dark cumulus cloud with a dark base that is threatening to rain or hail is called a cumulonimbus cloud. A dark gray horizontal stratus cloud that is threatening to snow, rain, or drizzle is called a nimbostratus cloud.

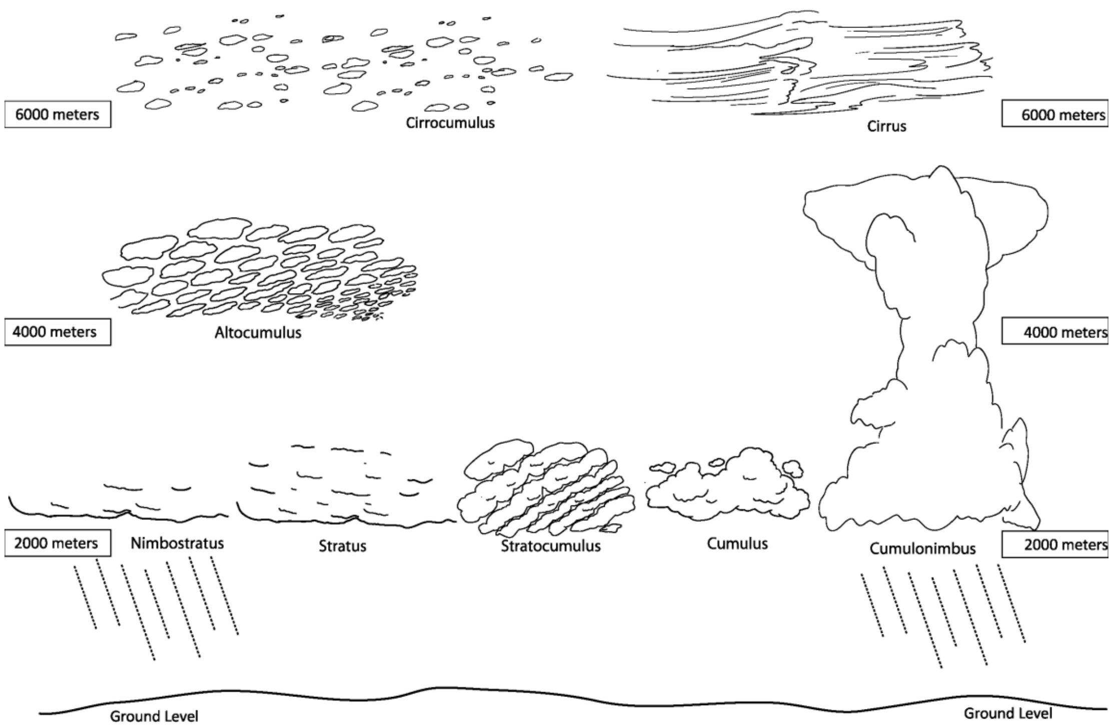
- ***Height:*** The altitude above the ground can also describe clouds. Usually clouds are classified as low, medium, or high. Towering layered clouds that may extend to over 20,000 meters in height form a separate category called vertical clouds. Vertical clouds that have strong updrafts of air are associated with sometimes dangerous precipitation, winds, storms, and even tornadoes. There can be very strong rain and hail from these clouds.

- ***Low:*** Clouds that range in height from 0 to 2000 meters are classified as low clouds. Fog is a cloud that forms at ground level. Stratus clouds are usually low clouds. Cumulus clouds and stratocumulus clouds can also be low.

- ***Medium:*** Clouds that range in height from 2000 to 5000 meters are classified as medium height clouds. Often the prefix "alto-" is used to indicate a specific medium height cloud. Altocumulus and altostratus are two examples.

- ***High:*** Clouds whose bases are above 5000 meters are classified as high clouds. Cirrus clouds are high level clouds that develop in filaments (strands) or wispy patches at extremely high elevation. Often the prefix "cirro-" is used to indicate a high cloud. Cirrocumulus clouds have a spotty appearance created by the many small patches. These clouds are so high and the air so cold that when water vapor condenses, it forms tiny ice crystals instead of water droplets.

- "Contrails" are clouds created by water vapor condensing into ice crystals on the small particles from the exhaust of planes that fly at high altitudes.



Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

- Why do clouds form?

Get Started

1. ☐ Ask for a volunteer to draw a picture of a cloud. Discuss with the class if this agrees with how they each picture clouds in their imagination.

2. ☐ Ask students to list all the questions they have about clouds. Record these questions so they are available to refer to while conducting the investigation.

3. ☐ Ask students in what kinds of weather they have seen clouds form.

   Students will notice kinds of weather in which the air has some water vapor in it.

4. ☐ Ask students if they have seen clouds form at different times of day or in different seasons of the year?

   Students may answer that there are clouds at any time of day, in all seasons. Students can describe how clouds vary throughout the seasons.

Condensation and Evaporation

5. ☐ Introduce the concept of condensation. By now the glass you set on your desk at the start of this lab has produced moisture on the outside of the glass and is "sweating".

6. ☐ Ask students, "What has formed on the outside of the glass of ice water?"

   Drops of water formed on the outside of the glass. The moisture may be a thin film of tiny water droplets, or there may even be drops large enough to collect and roll down to the bottom of the glass.

7. ☐ Tell students that this is called condensation. Ask them where they think the water came from.

   Students may think it came from inside the glass, and that somehow it "leaked" through the glass. But if you have them think about all the glasses they ever filled and drank from, they will quickly realize that glasses don't really leak. The water had to have come from somewhere else. Explain that it came out of the air. This process of water vapor in the air becoming water droplets on the glass is called "condensation."

8. ☐ Have students think about temperature. Which was colder, the ice water in the glass or the air in the room?

Students will know that the ice water in the glass was colder than the air in the room. Emphasize that there is a big difference in the coldness of the glass and the warmth of the air.

9. ☐ Ask students, "Did the other glass 'sweat'?"

Students should notice that the glass with room temperature water did not "sweat".

10. ☐ Tell students to think about temperature. Is there a big difference or a small difference between the temperature of the glass with no condensation and the air temperature?

The glass with the room temperature water feels about as warm as the air feels. Invite students to feel and compare the temperature of the two glasses.

Teacher Tip: If your class is familiar and comfortable using their data collection systems, you could measure the air temperature and then measure the water temperatures, but a qualitative comparison is enough for this demonstration.

11. ☐ Ask students, "Would the condensation happen if the water in the glass is warm and the air is also warm? Why or why not?"

Lead students to understand that temperature is the major factor affecting the amount of invisible moisture air can hold at any given time. Cooler air cannot hold as much water in the gaseous form as warmer air. The ice water in the glass lowers the temperature of the air around the glass, making the water vapor in that air come out of the air and condense on the sides of the glass.

12. ☐ To sum this up, ask students, "Tell me where the water on the outside of the glass came from and what made it condense on the cold glass."

Students need to state that the *water came out of the air* when the cold glass *cooled the air*.

Make a Cloud in a Bottle

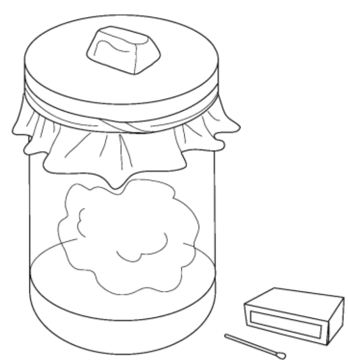
13. ☐ To focus on this process and address some of the students' questions that have been raised, demonstrate the formation of a cloud in a bottle. In this demonstration, you

    a. Place hot water (40 °C to 80 °C) in a small glass bottle.

    b. Light a match and blow it out near the top of the container, allowing the smoke to drift into the container.

    c. Cap the container with a clear plastic sheet and a rubber band.

    d. Put an ice cube on top. (See the illustration.)



14. ☐ Students will see the formation of a cloud in the bottle. Ask them to discuss the conditions that cause the cloud to form.

If they need help, guide students to name the following conditions: the hot water, the smoke, and the ice to cool the air.

15. ☐ Ask students the following:

- Why is the hot water important?

  Hot water puts water vapor into the air. If they don't realize this, remind them of the steam they see above a hot tub or spa, or from a warm pool on a very cold day, or even above their bath water or a hot cup of coffee. This process of a liquid transforming into a gas is called *evaporation*.

- Why is the smoke important?

  The smoke puts particles into the air; the particles provide a surface for the water vapor to condense on. This is also a hard concept, but have them recall that the cold glass provided the surface for the water in the air. Condensation always has to happen on a surface. Smoke particles are extremely small, but still they provide a surface on which the water can collect.

- Why is the ice important?

  The ice chills the air in the top of the jar. Point out that there has to be a temperature drop in the air for condensation to happen.

16. ☐ To clarify the concepts of evaporation and condensation, ask students, "How does the warm water get into the air?"

Warm water has more energy than cold water, and will evaporate more quickly than cold water. The water on the surface of the warm water *evaporates* into the air, like steam rising from a hot tub of water (visible because the warm water condenses in the cooler air above).

17. ☐ To find out if the warm water warms the air above it,

a. Replace the water in the jar with hot water and place a temperature sensor into the bottle above the water.

b. Display the data on a graph, and record the temperature of the air as it warms.

Teacher Tip: Display the data on a computer projection system. If this is not possible, help all students to watch the display as the temperature increases.

18. ☐ Have your students think about what happens to warm air inside a house, and what happens to smoke from a fire.

Warm air, like warm smoke from a fire, rises and cold air sinks. Similarly, the warm air rises inside the bottle and the colder air up at the top sinks. In this way the air circulates inside the bottle.

19. ☐ Ask students what they think the ice cube does to the air inside the bottle.

The ice cools the air at the top of the bottle.

Teacher Tip: Let students know that this process of air circulation is happening all the time in the atmosphere around us. Air picks up moisture from the earth's surface—oceans, lakes, streams and other sources of moisture. Warmer air carrying this water goes to higher altitudes where it becomes cooler. The water can condense out of the air to form a cloud.

20. ☐ Have students predict the weather conditions necessary for clouds to form. Keep a record of these predictions to compare with the weather observations they will make.

Let's Explore

21. ☐ Have students complete the "Cloud Types" section of the student response sheet. Display any posters or photos of clouds you may have.

Cloud Types

22. ☐ Ask students to describe features of the clouds on the Cloud Types picture (see Background section) or on any of your cloud-types posters or pictures you have assembled. Listen for them to use the terms “shape,” “color,” and “height.” They should use these characteristics to describe clouds.

- ***Shape:*** point out that the shape of the cloud helps us to name it.
- ***Color:*** the darker the cloud, the more likely it is that precipitation will fall from it.
- ***Height:*** discuss the relative heights of clouds. Compare their heights to familiar things, such as helicopter height (low clouds) and passenger jet heights (high clouds).

23. ☐ Have students fill out the Cloud Types portion of the student response sheet in class or as a homework assignment. The questions provide students with a place to practice the vocabulary for naming clouds.

24. ☐ Have students create a "Cloud Finder" to help them recognize cloud types. The Cloud Finder gives them a tool for observing clouds in the sky. Make materials available for the class.

- Materials for the Cloud Finder are as follows: PASCO Cloud Finder handout, brass brad, scissors, card stock, glue.

Direct students to do the following:

a. Cut out the two circles that make up the Cloud Finder.

b. Cut out the two windows on the top part.

c. Glue the bottom part to a piece of card stock for rigidity.

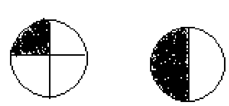
d. Trim around the circle.

e. Attach the top circle to the bottom circle with the brass brad.

Sky Cover

25. ☐ Point out that clouds can cover the whole visible sky, or just parts of the sky.

26. ☐ Discuss and agree on how much of the sky is covered by clouds. You may use relative terms such as “barely covered” or “mostly covered,” or you can use fractions or percents. Another way to model sky coverage is to draw a small circle and color in the circle to represent the amount of the sky covered by clouds. The first image below shows a sky that is ¼ covered by clouds, or 25%. The other shows a sky half covered by clouds, or 50%.



27. ☐ Take the class outside and have them stand with their backs to the sun. Use the Cloud Finder to identify current cloud types.

Note: Caution students never to look directly at the sun.

28. ☐ At the same time, have students notice if there is a wind, if there is a wetness to the air, and if the clouds are moving fast or slow.

Q In what direction are these clouds moving?

Wind Direction

29. ☐ To determine wind direction, make sure students are familiar with the use of a compass.

30. ☐ While holding a ribbon in one hand, students should hold a compass in the palm of their other hand.

31. ☐ Students should turn their bodies to face north, the same direction as the compass needle is pointing.

32. ☐ Students can match the direction the ribbon is blowing with the compass. For example, they might notice that their ribbon is blowing toward the east.

33. ☐ Explain to students that wind is blowing "from" a direction instead of "toward" a direction. If the ribbon is pointing toward the east, then that is a west wind. It is blowing "from" the west.

Explain It

34. ☐ Back in the classroom, review the conditions that were necessary for the cloud to form in the bottle:

    a. Water vapor in the air: there must be some water vapor in the air to begin with.

    b. Particles in the atmosphere: there must be dust or smoke or exhaust in the air for the water vapor to condense on.

    c. Cooling temperature: the ice cube cooled the warm air inside the bottle. Cool air holds less water vapor than warm air.

35. ☐ Review condensation and evaporation. Evaporation is how water changes from a liquid to a gas. Condensation is how water changes from a gas into a liquid. Model them as opposites.

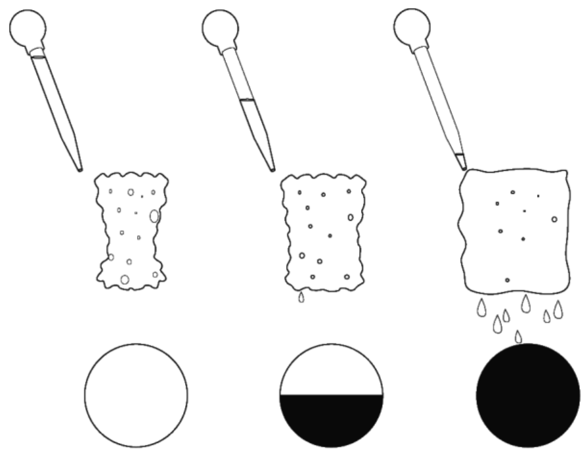
Humidity

36. ☐ Evaporation adds water vapor to the air. The amount of water vapor in the air is called "humidity." Relative humidity is the percentage of water vapor in the air compared to how much water vapor the air can hold at that temperature.

Teacher Tip: Humidity can be compared to a gas tank. If the tank is half full, it is 50% full. If it is three-quarters full, it is 75% full. A full tank of gas is 100% full. Relative humidity is measured similarly. If the air is half full of water vapor, the relative humidity is 50%. The higher the relative humidity, the more likely clouds will form. The closer relative humidity gets to 100%, the more likely rain will come out of the clouds.

37. ☐ Another way to demonstrate percent humidity and precipitation is to use a sponge. In this comparison, think of the sponge as representing the air. The turkey baster is holding 100% of the water that the sponge could possibly hold. When the turkey baster is empty, the sponge is 100% full and is saturated.

Add water to the sponge with the turkey baster, a little at a time. After each addition, lift up the sponge to show that it is not yet dripping because it is not yet full.



- When the turkey baster is half empty and the sponge is half full, compare the situation to the air being at 50% humidity.
- When the turkey baster is nearly empty and the sponge is just about to start dripping, compare to the air being at 100% humidity.
- If the sponge is squeezed, or if you continue to add more water, the sponge will start dripping. This is like the air being cooled and starting to rain.

38. ☐ In your investigations of properties of clouds, cloud formations, and weather conditions, students learned some new scientific ideas and terms. It is important to be able to discuss results using these words and terms correctly.

Take this opportunity to discuss with the students the meaning of the following terms in their own words using what they have learned from the activity.

➤ Vocabulary table with definitions for the teacher

Water vapor	Water in its gaseous state
Condensation	Energy reduction phase change of water from gas to liquid
Evaporation	Energy increase phase change of water from liquid to gas
Humidity	The amount of water vapor in the air
Relative humidity	Comparison of current air humidity to saturated air humidity
Precipitation	Water droplets that have grown large enough to fall to Earth as rain, hail, or snow
Stratus	Wide, low, sky-covering sheets of clouds
Cumulus	Dense mounded lumpy clouds at varying elevation
Cirrus	Thin, high, wispy clouds made of ice crystals
Altostratus	Stratus clouds occurring at medium elevation
Nimbostratus	Low stratus clouds from which rain is falling
Cumulonimbus	Towering cumulus clouds, unstable; associated with rain, hail, lightning

Tell Me More

This part of the lab can be done as a teacher demonstration or by groups of students. Students will need their Cloud Finders, their Weather Journal, their mobile data collection systems, and a pencil.

39. ☐ With students grouped, give each group of students their data collection systems with the weather sensor attached, and a digits display of temperature and relative humidity. (These should already be set up, as directed in the Preparation section.) Point out the slotted top of the weather sensor, and the tips of the probes visible inside. These are the sensor tips that measure the temperature and humidity of the air.

40. ☐ Allow students some time to practice starting and stopping runs of data, and moving around the room to determine where the warmest or coolest locations are located. This will ensure that they are familiar with the device before you go outside.

41. ☐ Help students choose two times during the day to observe the sky and record the temperature and relative humidity. Students will collect data twice a day for three days. Suggestions for collecting this data include:

    - Students may be grouped and this data collected in a center with the supervision of a parent helper, aide, or older student helper.
    - This data may be collected as a whole class instruction.

Note: Remember that students must be supervised when they leave the classroom to record this data and make observations.

Teacher Tip: The observation days do not have to be consecutive. Recording data twice a day allows students to see how the weather conditions change during the day and how those changes can produce clouds. Recording data three times a day could help reveal this relationship more quickly.

42. ☐ Have students gather their Cloud Finder, pen, Weather Journal, and data collection system to take outside for each monitoring session.

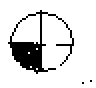
43. ☐ Once the students are outside, direct them to start collecting data.

44. ☐ When the data stabilizes, have them stop recording data.

45. ☐ Students record the temperature and relative humidity in their journals.

46. ☐ Students use their Cloud Finder to name the types of clouds, describe their shape, color and relative height. They draw a symbol showing the amount of sky cover, and comment on any precipitation.

➢ Weather Journal

Condition	Day 1: A.M.	Day 1: *P.M.*	Day 2: *A.M.*	Day 2: *P.M.*	Day 3: *A.M.*	Day 3: *P.M.*
Time of day	9:00 AM	2:30 PM	9:00 AM	2:30 PM	9:00 AM	2:30 PM
Temperature	78 °F	Answers vary throughout				
Relative humidity	56%					
Sky cover						
Wind direction	from the west					
Precipitation	None					
Cloud Description						
Shape	thin and wispy					
Color	white					
Height	very high					
Cloud type	cirrus					

Sum It Up

47. ☐ Restate the driving question, "Why do clouds form?" Explain that clues to the answer lie in the collected data.

48. ☐ First consider temperature. Ask these questions:

    - Was the temperature increasing or decreasing throughout the day?
    - Where the clouds were forming, what was the temperature probably doing?

    If the temperature was increasing, warm air was probably rising in the afternoon, moving water vapor up into higher elevations. If temperature was decreasing, clouds may have been blowing into the area and conditions for clouds would be present even at low elevations. Students should know that the temperature must have been decreasing at the elevation of the clouds.

49. ☐ Next, consider relative humidity. Ask these questions:

    - How was the relative humidity changing?
    - How do our observations support our predictions about how clouds form?

    If relative humidity is low, clouds are less likely to be seen. As it increases, clouds form and could lead to precipitation. Students should list the increases in humidity, the changes in temperature, and the height of clouds where the temperature is probably decreasing. Students should know that clouds form at the places in the sky where water vapor is condensing to microscopically small water droplets and that water will condense when the air is cooled.

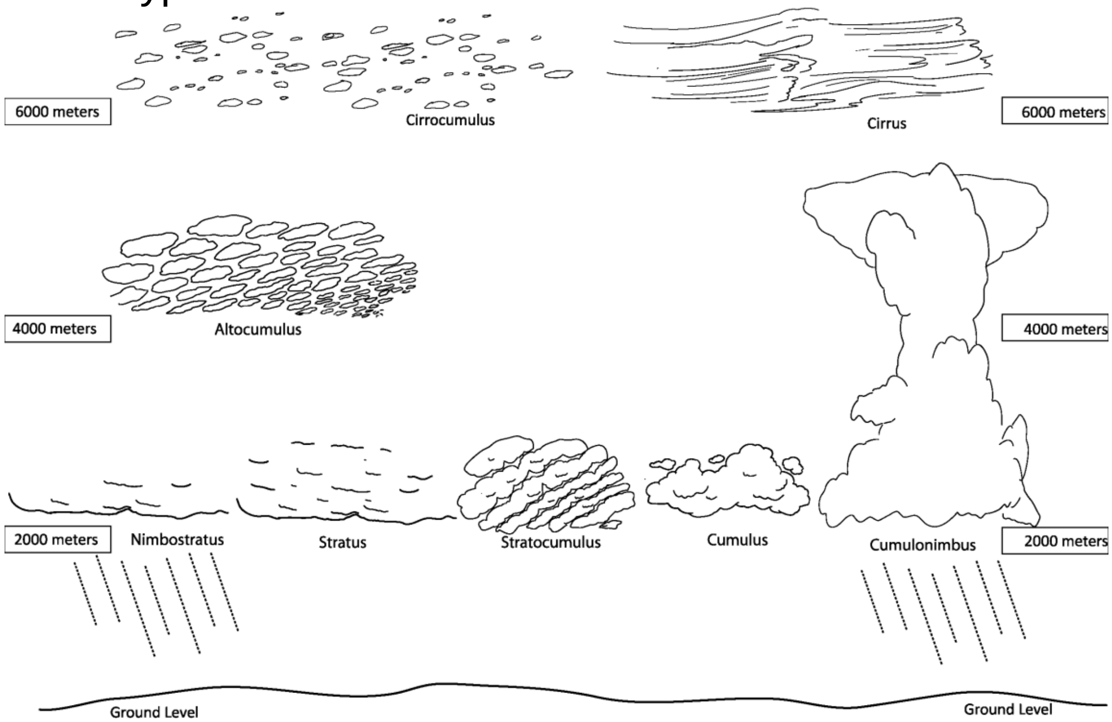
50. ☐ Have students complete the Multiple choice and Cloud Identifications sections of the Student response sheet.

Further Investigations

Have students revisit their Weather Journals in different seasons. Design a weather journal booklet that is large, strong, and permanently located in the classroom with a dedicated data collection device. Encourage students to gather data on any day and at any time. This could become such a popular activity that you may need to set up a rotation system for gathering the daily weather data.

After a period of a month, graph the data. You can have students graph just the highest and the lowest data for the month, or they can average the data and graph the average for the month. This will get more and more interesting as the seasons change.

Cloud types



Use the pictures above to answer the following questions:

1. Stratus clouds look like

 a wide flat blanket.____

2. Cumulus clouds look like

_ fluffy white and gray cotton balls, sometimes stacked or piled up. ________________

3. Cirrus clouds look like

_ thin wispy streaks very high, maybe even like horses' tails blowing in the wind. ____

4. What word part means "rain"?

_"Nimbus" or "nimbo-" means rain. _________________________________

5. What word part means "middle height"?

_"Alto-" means middle height. ____________________________________

Multiple Choice (darken the circle of the correct answer)

1. Clouds form when the temperature of the air]

    Ⓐ **Gets colder**

    Ⓑ Gets warmer

    Ⓒ Stays the same

2. If the clouds are 100% full of water,

    Ⓐ It will not rain

    Ⓑ **Rain is likely**

    Ⓒ Rain will occur with or without clouds

3. Clouds form because of

    Ⓐ Evaporation

    Ⓑ **Condensation**

    Ⓒ Precipitation

4. The air also contains

    Ⓐ Water vapor

    Ⓑ Dust

    Ⓒ **Both water vapor and dust**

5. Clouds are made of

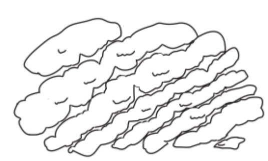
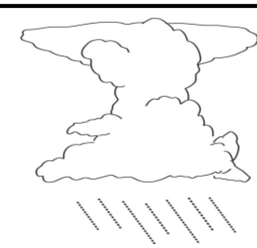
    Ⓐ Cotton balls

    Ⓑ Water vapor

    Ⓒ **Tiny water droplets**

Identify the types of clouds below.

Word Bank: Altocumulus, cirrus, cumulonimbus, cumulus, nimbostratus, stratocumulus

			
Cirrus	Cumulus	Stratus	Cumulonimbus

15. Can Plants Survive without Light and Water?

Recommended Grade Levels: 2 - 3

Objectives

Students determine that plants need both light and water to survive. They also learn that plants have adaptations to help them survive.

Procedural Overview

To understand this content, students:

- Compare the characteristics of animals and plants that make them alive
- Identify the basic needs of plants that will enable them to survive
- Recognize adaptations of plant leaves and roots that help plants acquire sunlight and water
- Identify sunlight as the source of energy for plants to photosynthesize
- Design and carry out an experiment to test if plants need both water and sunlight to survive

Time Requirement

Teacher Preparation	30 minutes to ½ day
Get Started	15 minutes
Let's Explore	20 minutes
Explain It	15 minutes
Tell Me More	15-20 minutes per day for 5 days
Sum It Up	15 minutes

Materials

For teacher demonstration:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Potted plants (8), young plants, all the same kind[1]
- ☐ Roots of plants, a variety[2]
- ☐ Leaves of plants, a variety[3]
- ☐ Growing light (optional)[4]
- ☐ Markers
- ☐ Ruler

[1] Herbs such as mint, or flower plants such as impatiens work well for this because they are non-toxic. Check with Poison Control websites for a list of non-toxic plants.

[2] Uproot some weeds and bring in some root vegetables with stems and leaves attached, such as carrot and beet.

[3] Collect a variety of leaves from plants with different textures: hairy, waxy, succulent, needle and broadleaf.

[4] A fluorescent light works best, but any light will do.

For each student group:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Ruler

Activity at a Glance

Get Started

- ☐ Engage students by talking about the things they can do that make them alive. These are the characteristics of all living things.
- ☐ Help students to differentiate between animals and plants.

Let's Explore

- ☐ Students compare the different kinds of roots and discuss their purpose.
- ☐ Students compare the different kinds of leaves and discuss their purpose.
- ☐ Show students the light sensor and demonstrate its use.

Explain It

- ☐ Link the needs of plants (nutrients, water, sunlight, air) to plants' structural parts.
- ☐ Guide students to plan the set up of their investigation.
- ☐ Review the following vocabulary with the students: characteristic, adaptation, chlorophyll, photosynthesis, and light.

Tell Me More

- ☐ Guide students to determine how they will conduct the experiment.
- ☐ Determine how students will water the plants, measure the plants, and move through the stations.
- ☐ Run the test over several days to see the effect of the test on the condition of the plants.

Sum It Up

- ☐ Determine the best growing conditions for plants from this test.
- ☐ Propose a follow-up experiment to answer any further question concerning how much light and water plants need.

Safety

Add these important safety measures to your normal class procedures:

- Always wash your hands with soap and water after handling plants or soil.

Preparation

These are the materials and equipment to set up prior to the activity.

- This lab should be conducted while you have a good amount of daily sunshine coming in your classroom window. If you need to conduct the lab during the cloudy months, you will have to change the goals and directions of the activity.

- Carefully uproot one small plant of any type (a weed will do) and rinse the roots clean of soil. Try to keep the roots intact. Wrap the roots in a wet paper towel to keep them from drying out. Obtain one carrot and one beet with its leaves intact so students can see the whole plant. Any other root plant or tuber like potato or iris corms would be good to include if you want to talk about tubers.

- Collect a large variety of leaves from different kinds of plants. Find leaves of light green and dark green, needles and broadleaves, hairy, waxy, fuzzy, ribbed, thickened and smooth.

- Prepare a location on your windowsill for four plants. Provide a power strip or extension cord if a power source is far away. If you do not have a windowsill in your room, you will want to set up an artificial light above a table. Obtain a growing light from a garden store and mount it on a rack to shine down on the table surface. Make sure it is located high enough from the plants to keep them from burning. Alternatively, a shop light will also work.

- Students will keep a Journal (#7 in the student response sheet) for a period of 5 days to monitor the effect of light and water on the growth of plants.

- A word about measurement: in this lab students need to measure their plants to “quantify” how the light is affecting their growth. If your students are not ready to use a ruler, you can use Unifix® cubes or graph paper. Cut strips of graph paper and glue them onto a piece of tag board. Students count how many squares high their plants are and estimate to the nearest whole square.

- Set up the data collection system to display for the Let’s Explore portion of the activity.

  1. Start a new experiment on your data collection system.

  2. Connect the light sensor to the data collection system.

  3. Display the data in a digits display.

Background

Plants need nutrients, water, air and sunlight to grow. Plants derive their nutritional needs from minerals in the soil or the water they live in. In kindergarten, students learn about the basic needs of plants. Roots take up water and nutrients from the soil; special xylem cells transport the nutrients and water to the leaves, where, in the presence of sunlight and chlorophyll, the plant makes simple sugars which are then transported to the rest of the plant by phloem cells. In this activity, students investigate the necessity of light and water for the survival of the plant.

Adaptations

Since plants are found in almost every type of environment on this planet, the basic needs of plants are met in a huge variety of ways, and plants have developed a wide range of adaptations to allow them to fully utilize light and water resources wherever they grow. Thickened leaves, lack of leaves, silvered leaves, thickened bark, waxy coatings on leaves, and hairy leaves are all adaptations that plants have evolved to moderate the amount of light they receive or to conserve water. Thickened roots, taproots and fibrous roots, tubers and corms are all adaptations of plants to maximize water absorption and conservation.

Growing Toward the Light

Hormones in the apical meristem, or growing tip, of seedlings cause the seedling to grow toward a light source. Experiments have been done to place seedlings in a variety of dark locations and watch the plant grow around corners or under barriers to reach the light source. A simple example of this is when house plants become unbalanced if they are not rotated in their position, so that all sides of the plant get sunny exposure every few days.

Lack of Sunlight and Water

Plants need sunlight and water to conduct photosynthesis, which provides the plant with the energy that it needs to grow and fruit. Visible signs of insufficient light include paleness of color, especially in the leaves, even whitening of the plant; weakening and thinning of plant tissues; and elongation of young stems so that the plant cannot maintain its upright structure. Visible signs of insufficient water include withering, brown dry edges on leaves, and lack of strength in the stems.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

- What do plants require to stay alive?

Get Started

In this part of the activity, students review the characteristics of living things and their needs for survival. Then they become acquainted with plant adaptations.

1. ☐ Have a discussion with your students about how we know if something is alive.

   Q Tell me as many things about yourself as you can that would prove to me that you are alive.

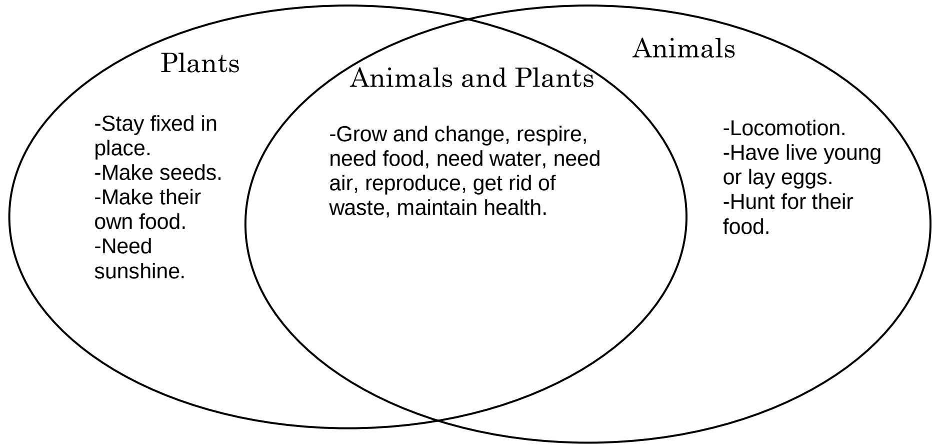
   Q Are these things also true of plants?

2. ☐ Make a list of proof-of-living things that plants and animals share in common.

   Characteristics known to 2nd and 3rd graders include these: living things need food, water and air; living things grow and change; living things make more of themselves (reproduce), eliminate wastes, and need to rest.

3. ☐ Explain to students that these features that are common to all living things are called characteristics.

4. ☐ Draw a Venn diagram on the board and discuss what characteristics plants and animals have in common, and what characteristics they have separately.



5. ☐ Direct students to response 1 on their student response sheet.

Let's Explore

6. ☐ Focus on the needs of plants only. Break off a stem from one of your plants and let students examine inside the stem to see that it is wet.

   Q Where did the water come from?

   Q If the plant did not get this water, what would happen to it?

7. ☐ Show the uprooted plant's roots. Show how small and delicate they are in a young plant.

   - Discuss how the roots anchor plants to the ground.
   - Discuss the main purpose of roots—to draw water and nutrients out of the soil.

8. ☐ Discuss how a carrot and a potato are adaptations of plant roots. Show the whole carrot plant.

9. ☐ Show students the eight test plants. Use one of your sample plants to explain how plants make food in this way:

   Q Do you see the parts of the plant that are green, even the stem?

   Q Do you know that the green coloration in the plant is called chlorophyll?

   Q What part of a plant is not green?

   Q Only the green part of the plant can make food, which is a simple sugar. Do you know the name of the process for a plant to make sugar? (photosynthesis)

10. ☐ Name plants that we eat that taste sort of sweet. This will help students think of the sugar that the plant makes and stores inside its tissues.

    Teacher Tip: If students name sweet foods such as apples and oranges, help them see that the sugar made in the green leaves is transported to all other parts of the plant, especially the fruit, but also the roots (carrots are sweet).

    Students may think of celery, lettuce, and other fruits and vegetables.

11. ☐ Compare the leaves of the example plants.

    Students will observe differences in thickness of leaves, width of leaves, and texture of leaves.

12. ☐ Discuss the purpose of all these adaptations:

    Q Why would a plant have a waxy leaf?

    Q What would a thickened leaf do for the plant?

    Q What would a plant want with a hairy leaf?

13. ☐ Discuss what part of the plants take in air.

    Students may not know this, but the underside of a leaf contains the stoma, or breathing cells, for plants.

14. ☐ Ask students why, when leaves are so important for plants, some plants have very skinny leaves and other plants like cactus have spines instead of leaves?

    Students may suggest that plants have different needs, depending on where they live and how they grow. Needle type leaves are an adaptation, as are broadleaved plants. In some cases, the shape and structure of the leaf prevents the plant from drying out.

15. ☐ Identify sunlight as the source of the sun's energy that helps plants produce food and grow.

16. ☐ Introduce the light sensor as a tool to measure how much sunlight plants are receiving, and demonstrate its use.

    a. The light sensor should already be connected to your data collection system and the measurement should be displayed in digits.

    b. Start data recording.

    c. Show students how the measurement is greater when the sensor is pointed toward light sources and less when it is pointed away from light sources.

    d. Pass the data collection system and sensor to students and encourage them to point the sensor in different directions so that they can become familiar with how it is measuring the brightness of light.

    e. Explain that the brightness of light is measured in units called "lux," just as their weight is measured in units called pounds or kilograms and time is measured in seconds or hours.

17. ☐ Direct students to responses 2 and 3 on their student response sheet.

Explain It

In this part of the activity, students focus on the basic needs of plants and determine ways to test those basic needs, particularly light.

18. ☐ Write the four basic needs of plants on the board (water, sunlight, nutrients, air).

19. ☐ Begin a discussion of each of the four basic needs of plants.

    Q How do we know if plants really need sunlight to survive?

    Q How do we know if plants need water?

    Q Why do plants need nutrients? (Relate this to students' own need for proteins, calcium from milk or other sources, and vitamins.)

    Q Why do plants need air? (Relate this to their need for air.)

20. ☐ Lead students through a simple discussion of how they could set up a test to see if plants really need these things to survive.

    - Explain that a test needs to have two groups of plants: one that gets the normal condition and one that gets the test condition.

21. ☐ Explain to students that since both light and water are critical for the plant to make food, we will focus our test on these two needs only.

22. ☐ Even though we need to test two possible plant requirements, we should still test one requirement at a time. Here is an arrangement to share with your students:

	Sunlight	**No Sunlight**
Water	Plant in sunlight and given normal water	Plant in darkness and given normal water
No Water	Plant in sunlight but not given water	Plant in darkness but not given water

23. ☐ Explain to students that they will have to measure the amount of light and water the plants get. They can use the light sensor to measure the amount of light the plants get, and a tablespoon or 50-mL beaker to measure the amount of water they give the plants.

24. ☐ Ask students to name two locations for the test plants:

    Q Where can we put the plants that we want to get sunlight?

    Q Where can we put plants that we want to remove from sunlight? Remember that they still must have the same amount of air as the plants in the sunlight.

25. ☐ Review the following vocabulary words with your students.

➢ Vocabulary and definitions

Characteristic	A feature of a living thing that describes a basic quality
Adaptation	A change in structure that allows a living thing to survive better in its habitat
Photosynthesis	The process within plants that enables them to make sugar from carbon dioxide and water in the presence of sunlight
Chlorophyll	The green pigment in plant tissues that absorbs light to aide photosynthesis
Light	Energy from the sun for plants to photosynthesize

26. ☐ Have students complete responses 4 and 5 on their student response sheet.

Tell Me More

In this part of the activity, students will conduct an experiment to determine if plants need both light and water to survive.

27. ☐ Explain to students that there will be four groups of plants as described above:

- There will be two locations, one in the light and one not in the light.
- At each location there will be two groups of plants: one gets water and the other gets no water.
- There will be two plants in each group, in case one of the plants should break or die due to some unforeseen disaster.

28. ☐ To develop the students' understanding of how they will conduct the experiment, ask students:

Q How much water will we give all the watered plants? Record that amount (2 tablespoons or 20 mL per day) on the student response sheet.

Q <u>How can we label the plants that will get water and the plants that won't get water?</u>

Q What is the best way to measure if a plant is getting the necessary sunlight it needs to survive?

Q What other observations can we make about the overall health of the plants?

29. ☐ Demonstrate how to measure the height of the plant. Point out that students should not touch the plants while measuring their height. Their ruler or measuring stick will have

to touch the surface of the soil, but they don't have to pull on the plant. That could break the stem.

30. ☐ Have students predict how much growth they will see in the four different groups of plants, and which group will do the best and the worst. Direct students to write their predictions on student response sheet under response 6.

31. ☐ Set out the plants in the predetermined locations. Label each plant for ease in identifying them.

    a. Of the four plants that are in the light, two of them will have water also, and two of them will have no water. Label them clearly.

    b. Of the four plants in the darkness, two of them will have water and two of them will have no water. Label them clearly.

32. ☐ Determine a system for students to measure each plant and record their data in their Journal (response 7 on the student response sheet).

    a. Plants can be measured any time during the day, but only measured once per day.

    b. Each student should be consistent in the time he or she chooses to measure, and try to choose the same time each day.

    c. Each group should measure the amount of light at a consistent time each day.

    Teacher Tip: See the Preparation section for information on creating a Journal for each of the student groups.

33. ☐ Discuss with students why it is important to be consistent when they measure the light and the height of the plant.

    Choose the same time of day to gather data for the sake of consistency. Scientists want to eliminate unintended effects by keeping all variables consistent.

34. ☐ Determine a system for students to take turns watering the plants each day. Post a schedule for this in a visible place.

35. ☐ Guide student groups through the process of using their data collection system and light sensor to gather data in a digits display:

    a. Start a new experiment on the data collection system.

    b. Connect the light sensor to the data collection system.

    c. Display the data in a digits display.

    Note: The light sensor has three buttons for selecting the range of light depending on the conditions. Students may need to choose the sunlight setting for the window and then switch to the light bulb or candle setting for the darker location.

36. ☐ Allow time for students to move to each of the two locations to measure the amount of light that is available. Guide them through steps to record a run of data.

37. ☐ Students will want to toggle back and forth to see their previous run of data. Guide them to select the run they want to look at.

38. ☐ This experiment can continue for several days or until your students see enough of a difference to draw a conclusion.

  a. Continue to have students measure, water, monitor the light, and record their data in their Journals each day.

  b. Encourage students to make good qualitative observations. Model some of your own, observations such as, “The edges of these plants are curling and turning brown.”

39. ☐ Students complete their Journals (response 7 in the student response sheets) each day the experiment is in progress.

Note: The student response sheet Journal is set up to record 5 days’ worth of data. If you would like the experiment to run longer, please print out more of these pages for your students.

Sum It Up

40. ☐ Guide students to compare their data:

Q Are your light measurements consistent with other groups’ light measurements?

Q Are the heights you measured consistent with others’ measurements?

Q Which group of plants had the tallest growth?

Q Which group of plants looks the greenest?

Q Which group of plants looks the worst?

Q Did your results match your predictions? Please explain.

Q If we continued this experiment for 5 more days, what would we find?

Q Do plants need both water and light to survive, or can they get by without one or the other?

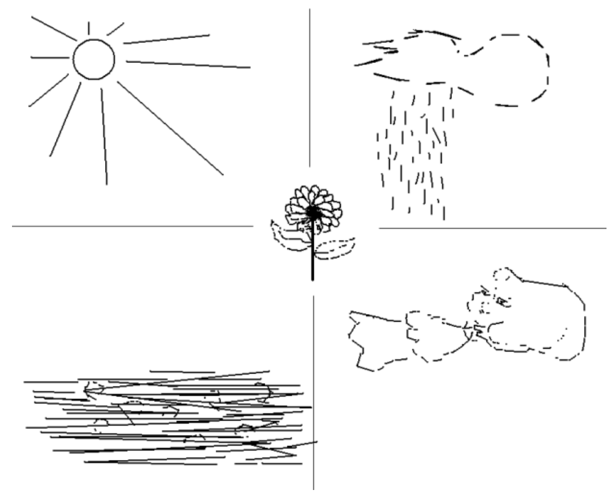
Q What do plants require to stay alive?

41. ☐ Ask students to answer response 8 on their student response sheet.

Further Investigations

The best way to extend this investigation is to let students redesign the experiment. They will have other places to put their plants, and other parameters to control. Some students will want to find a different source of light to investigate, or use light with an intensity between sunshine and darkness. Other students may want to vary the amount of water or have plants grow in water only with no soil.

To cement the idea that plants have four basic needs for survival, you can ask students to illustrate the four needs on a sheet of paper as a homework assignment. Tell them to fold a paper into quarters. In each of the four corners, illustrate and label the four basic needs of plants: light, air (wind), soil (for nutrients), and water (rain or a hose). They can remember this by the acronym LAWN (light, air, water, nutrients).



1. What characteristics tell me that plants are alive?

Plants can grow and change, can make their own food, can take in water and need air, can reproduce and eliminate waste, and can maintain their strength and health. Plants need rest too.

2. Describe how you will use the light sensor.

I will use the light sensor to find out how much light the plants are getting. I will point it at the window where the plants are sitting and take a run of data in a digits display. Then I will point it into the space of darkness where the other plants are sitting and take another run of data. Then I will record the data and turn my light sensor off.

3. What are the units of measurement called for light?

LUX

4. What are the four basic needs of all plants?

a. water	b. sunlight
c. soil for nutrients	d. air for carbon dioxide

5. Draw lines from each vocabulary word to its description.

Photosynthesis	Changes in the plant that help it to survive better, like waxy leaves or thicker roots
Chlorophyll	The process for a plant to make sugar
Adaptation	Main features of living things, like breathing and eating
Characteristic	Green pigment in plants that aid them in making sugar

6. Predict:

a. Which group of plants do you think will grow the best?

The group that gets both water and sunlight.

b. Which group of plants will grow the least?

The group that gets neither water nor sunlight.

c. How much growth do you predict you will see in the four groups?

Condition	Prediction
Plants in sun and water (#1,2)	Possible answer: These will grow 6 in.
Plants in sun but no water (#3,4)	Possible answer: These will grow 2 in.
Plants in darkness with water (#5,6)	Possible answer: These will grow 4 in.
Plants in darkness with no water (#7,8)	Possible answer: These will not grow at all

7. Gather Data (Journal)

Date:______________			Time:____________
Plant	Height (cm)	Light (lx)	Observations
1	4 cm	529	plant looks healthy and strong
2	5 cm	529	plant looks healthy and strong
3	3 cm	529	plant looks healthy and strong
4	4 cm	529	plant looks healthy and strong
5	4 cm	10	plant looks healthy and strong
6	5 cm	10	plant looks healthy and strong
7	3 cm	10	plant looks healthy and strong
8	4 cm	10	plant looks healthy and strong

Teacher Note: Make five copies of #7 from the Student Response Sheet for each student group.

8. Can plants survive without water or sunlight?

No, not for long

Grades 4-5

16. Temperature and Change

Recommended Grade Levels: 4 – 5

Objectives

Students determine the effect of temperature on the time it takes for changes to occur. Through this activity, students:

- Review the difference between a physical change and a chemical reaction
- Identify independent, dependent, and controlled variables in an experiment
- Interpret data displayed in a graph

Procedural Overview

To understand this content, students:

- Time how long it takes a sugar cube to dissolve in three different temperatures of water
- Time how long it takes an antacid tablet to react with three different temperatures of vinegar
- Analyze the data to determine the effect of temperature on the time it takes for a change to occur

Time Requirement

Teacher Preparation	20 minutes
Pre-Activity Discussion	30 minutes
Get Started	15 minutes
Let's Explore	30 minutes
Explain It	30 minutes
Tell Me More	40 minutes
Sum It Up	15 minutes

Materials

For teacher preparation and demonstration:

Preparation

- ☐ Bucket to hold ice water
- ☐ Ice
- ☐ Water
- ☐ Heat source (microwave or hot plate)
- ☐ Thermos®
- ☐ Balance

Demonstration

- ☐ Data collection system
- ☐ Projection system
- ☐ Temperature sensor
- ☐ Wooden block[2]
- ☐ Ice cube (2), small[1]
- ☐ Tape
- ☐ Balance

[1]The ice cubes should weigh about 0.5 g or less. Very small crushed ice will be about this size.

[2]Exact size doesn't matter; block needs to be big enough for an ice cube to sit on as it melts.

For each student group:

Let's Explore

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Beaker, 250-mL
- ☐ Stir rod
- ☐ Tape
- ☐ Sugar cube (3)
- ☐ Water, room temperature, 200 mL
- ☐ Water, cold, 200 mL
- ☐ Water, hot, 200 mL

Tell Me More

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Beaker (2), 250-mL
- ☐ Beaker, 600-mL
- ☐ Stir rod
- ☐ Tape
- ☐ Antacid tablet piece (3), ~ 0.5 g[1]
- ☐ Vinegar, room temperature, 200 mL
- ☐ Vinegar, hot, 100 mL
- ☐ Ice, 300 mL
- ☐ Water, ~100 mL

[1]TUMS™ or any other antacid tablet with calcium carbonate as the main ingredient

Activity at a Glance

Get Started

- ☐ Students brainstorm examples of materials that dissolve in water and materials that do not dissolve in water.
- ☐ They describe a method that could be used to determine how long it takes a material to dissolve in water.

Let's Explore

- ☐ Students time how long it takes a sugar cube to dissolve in cold water.
- ☐ They predict whether it will take a sugar cube more time, less time, or the same amount of time to dissolve in room temperature water and hot water.
- ☐ They test their predictions by timing how long it takes a sugar cube to dissolve in room temperature water and in hot water.

Explain It

- ☐ Students explain the effect temperature had on the time it took a sugar cube to dissolve in water.
- ☐ They identify the independent, dependent, and controlled variables in the sugar cube experiment.
- ☐ They predict the effect temperature will have on the time it takes a chemical reaction to occur.
- ☐ They define the following terms: temperature, temperature sensor, dissolve, physical change, react, chemical change, independent variable, dependent variable, and controlled variable.

Tell Me More

- ☐ Students time how long it takes a piece of an antacid tablet to react with vinegar at room temperature.
- ☐ They predict the time it will take for an antacid tablet piece to react with hot vinegar and cold vinegar.
- ☐ They test their predictions by timing how long it takes the antacid to react with hot vinegar and cold vinegar.

Sum It Up

- ☐ Students describe the overall effect that temperature had on the time it took the antacid to react with vinegar.
- ☐ They summarize the general trend that temperature has on the time it takes for changes to occur.

Safety

Add these important safety measures to your normal classroom procedures:

- Wear safety goggles
- Do not eat or drink any of the lab materials
- Be careful when using hot liquids

Preparation

These are the materials and equipment to set up prior to the activity.

- Set up your data collection system for measuring temperature during the demonstration.

    1. Start a new activity on the data collection system.
    2. Connect the temperature sensor to the data collection system.
    3. Display Temperature on the *y*-axis of a graph with Time on the *x*-axis.

Let's Explore

- Prepare a station where students can get cold water (~5 °C or cooler). To do this, fill a bucket with a mixture of ice and water. Have a supply of ice and water nearby to adjust the temperature as needed.

- Prepare a station where students can get hot water (~45 °C). To do this heat water and then keep it in a thermos for the students to access.

- Prepare an area to clean and dry the beakers. The beakers will need to be cleaned between each trial.

Tell Me More

- Split antacid tablets into pieces that are approximately 0.5 g (about ¼ to ½ of a tablet). Cut enough tablets so that each student group has 3 pieces that are of equal mass.
- In cold vinegar it may take 10 minutes or longer for antacid pieces larger than 0.5 g to dissolve. This portion of the lab will take the longest, so test how long this reaction takes to have a better idea of how long it will take the students to perform the activity.
- If you want to shorten the activity, consider skipping the cold portion and just having the students perform the reaction in room temperature water and hot water.
- Prepare a system for heating vinegar. The "hot" vinegar should be maintained at about 45 ˚C.
- Prepare an area to clean and dry the beakers. They will need to be cleaned between each trial.

Background

Temperature and Change

Temperature is a measure of hotness and coldness. More specifically, temperature is the average kinetic energy of molecules. In general, changes occur more quickly in hotter conditions. This is because hot materials have more energy and can therefore break the forces holding materials together more quickly. Both physical changes and chemical changes tend to occur faster in hotter conditions.

Physical Change and Chemical Reactions

Changes that matter can undergo are generally classified as physical changes or chemical reactions (also called chemical changes). A physical change occurs when a substance's physical appearance changes, but there is no change in the substance's chemical composition. An example of a physical change is sugar dissolving in water. The sugar breaks up into tiny pieces that can no longer be seen, but it is still sugar. There is no new substance formed.

A chemical reaction occurs when one or more new chemical substances are produced. In this activity an antacid tablet reacts with vinegar. When the antacid tablet and vinegar react a gas, seen as bubbles, is formed. This new material, with properties different than either the antacid or the vinegar is evidence that a chemical reaction has occurred. The main ingredient in the antacid tablet is calcium carbonate. The calcium carbonate reacts with vinegar (acetic acid) to form carbon dioxide gas, water, and calcium acetate.

Pre-Activity Discussion

1. Ask the student the following questions:

   Q Does temperature effect the time it takes an ice cube to melt?

   Q Will an ice cube melt faster on a student's hand or on a wooden block? Why?

Q How can we determine if our prediction is correct?

2. Set up a data collection system to be projected in front of the students.

   a. Start a new experiment on the data collection system.

   b. Connect a temperature sensor to your data collection system.

   c. Create a graph of Temperature (˚C) on the *y*-axis versus Time (s) on the *x*-axis.

3. Record a run of data as a student volunteer allows the ice to melt in her hand by following the steps below:

   a. Tape a temperature sensor to the wrist of the student volunteer.

   b. Place a small piece of ice (~0.5 g or smaller) in the open palm of the student volunteer's hand.

   Teacher Tip: Make sure you know the exact mass of the ice cube. You will need another ice cube with the exact same mass in the trial.

   c. Start recording data.

   d. As the water melts, place a paper towel next to the ice cube to soak up the melted water.

   e. As the ice cube is melting, discuss the experimental set up with your students.

   Q What is the temperature of the student volunteer's hand?

   Q How long have we been collecting data?

   Q When will we stop data collection? Why?

   Q What will the graph tell us?

   f. When the ice has completely melted, stop data recording data.

4. Determine how long it took for the ice cube to melt and the temperature at which it was melting.

   The ice cube took 243 s to melt and was melting at 32 ˚C (the temperature of the hand of the student volunteer).

5. Discuss with the students what a graph of ice melting at a cooler temperature would look like compared to the graph they just collected.

   Q If we melt another ice cube with the same weight at room temperature (instead of body temperature) will it take more time, less time, or the same amount of time to melt?

   Q If the ice takes more time to melt, what will it look like on this graph?

   Q If the ice takes less time to melt, what will it look like on this graph?

6. Record a run of data as an ice cube melts on a wooden block:

   a. Tape a temperature sensor to the side of the wooden block.

   b. Place a small piece of ice, the same weight as in the first trial, on the wooden block.

   c. Start recording data.

   d. As the water melts, place a paper towel next to the ice cube to soak up the melted water.

   e. As the ice cube is melting, review with the students the variables being used in this experiment.

      Q What is an independent variable in an experiment?

      Q What is the independent variable in this experiment?

      Q What is a dependent variable in an experiment?

      Q What is the dependent variable in this experiment?

      Q What are some variables we controlled in this experiment?

   f. When the ice has completely melted, stop data recording data.

7. Determine how long it took for the ice cube to melt and the temperature at which it was melting.

   The ice cube took 700 s to melt and was melting at 24 ˚C (the temperature of the wooden block).

8. Discuss the results with the students:

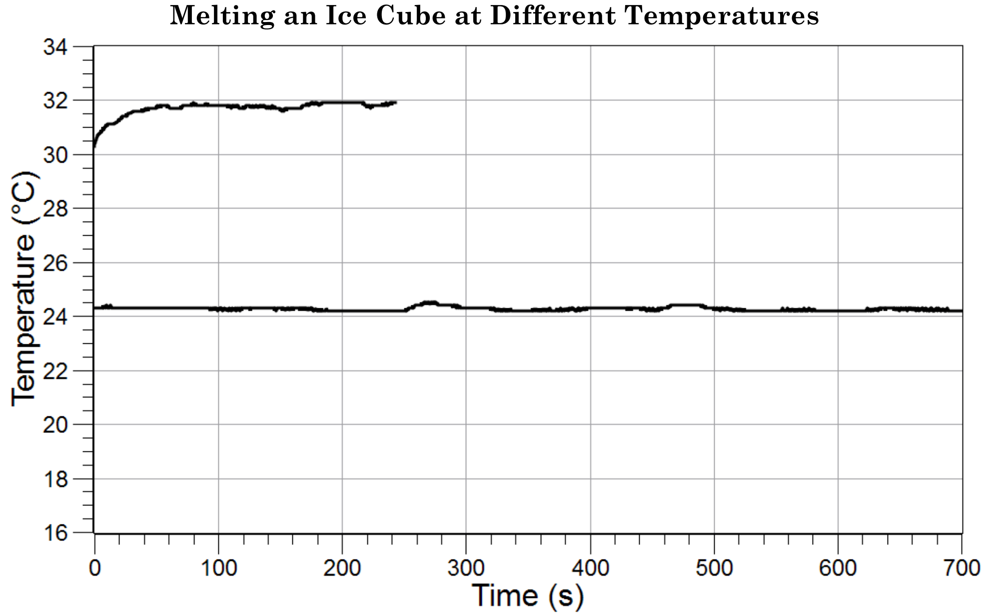
   Q Were our predictions correct?

   Q How did temperature affect the time it took an ice cube to melt?

   Q Can you think of a way to melt the ice cube faster? Why would this work?

9. Explain to the students that they will be completing several lab activities that further explore how temperature affects the time it takes for a reaction to occur.

Sample Data



Driving Question

- What effect does temperature have on the time it takes a change to occur?

Variables

Independent Variable

- The independent variable is the temperature at which the change is allowed to occur.

Dependent Variables

- The dependent variable is the time it takes for the change to occur.

Controlled Variables

- The controlled variables are: the amount of materials used, constant stirring during the change, size and shape of the container in which the change occurs, pressure at which the change occurs, and the same temperature sensor is used.

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

In this section you will brainstorm what you know already know about dissolving one substance in another.

1. ☐ List four materials that dissolve in water.

Materials that dissolve in water include sugar, tea, coffee, salt, soup mixes (bouillon cubes), and powdered drink mixes.

2. ☐ List four materials that do not dissolve in water.

   Materials that do not dissolve in water include black pepper, wax, spoon, and rocks.

3. ☐ Describe how a material changes when it dissolves in water.

   When a material dissolves it breaks into tiny pieces that are so small that they cannot be seen. These tiny pieces mix with the water completely so that the water and the solid particles look like one substance.

4. ☐ Suggest a method for determining how long it takes a material to dissolve.

   Start a stopwatch when you put a spoonful of a solid material into a glass of water. When all the material has dissolved, stop the watch.

5. ☐ Discuss with your group members whether it possible to change the amount of time it takes a material to dissolve.

Let's Explore

In this part of the activity you will use your data collection system to time how long it takes a sugar cube to dissolve in cold water, room temperature water, and hot water.

6. ☐ Start a new experiment on the data collection system.

7. ☐ Connect a temperature sensor to your data collection system.

8. ☐ Create a graph of Temperature (˚C) on the y-axis versus Time (s) on the x-axis.

9. ☐ Fill a 250-mL beaker with 200 mL of cold water.

10. ☐ Place the temperature sensor in the beaker so that the tip of the sensor is at the bottom of the beaker.

    Note: If necessary, tape the sensor in place so that it does not come out of the beaker.

11. ☐ Place the sugar cube in the water and immediately start recording data.

12. ☐ Constantly stir the sugar cube and the water until all of the sugar has dissolved.

13. ☐ When all of the sugar has dissolved, stop recording data.

14. ☐ How did you decide when all of the sugar had dissolved?

    The sugar had completely dissolved when none of the grains of sugar could be seen.

15. ☐ Use the graph on your data collection system to determine how long it took for the sugar cube to dissolve and the temperature of the water. Record these values in Table 1. � (9.1)

➢ Table 1: Time and temperature data collected while dissolving sugar cubes in water

Water	**Temperature (˚C)**	**Time to Dissolve (s)**
Cold water	4	148
Room temperature water	19	87
Hot water	51	37

16. ☐ Clean and dry your beaker according to your teacher's instructions.

17. ☐ Do you think a sugar cube will take the same amount of time, less time, or more time to dissolve in room temperature water?

    The sugar cube should dissolve in less time because the temperature is warmer.

18. ☐ Repeat the steps above this time using room temperature water. Collect this run of data on the same graph as the cold water.

19. ☐ Fill in the data you collected with room temperature water in Table 1 above.

20. ☐ Was your prediction correct? Explain.

    Yes, the prediction was correct. The sugar cube dissolved faster.

21. ☐ How much time do you think it will take the sugar cube to dissolve in hot water? Explain your thinking.

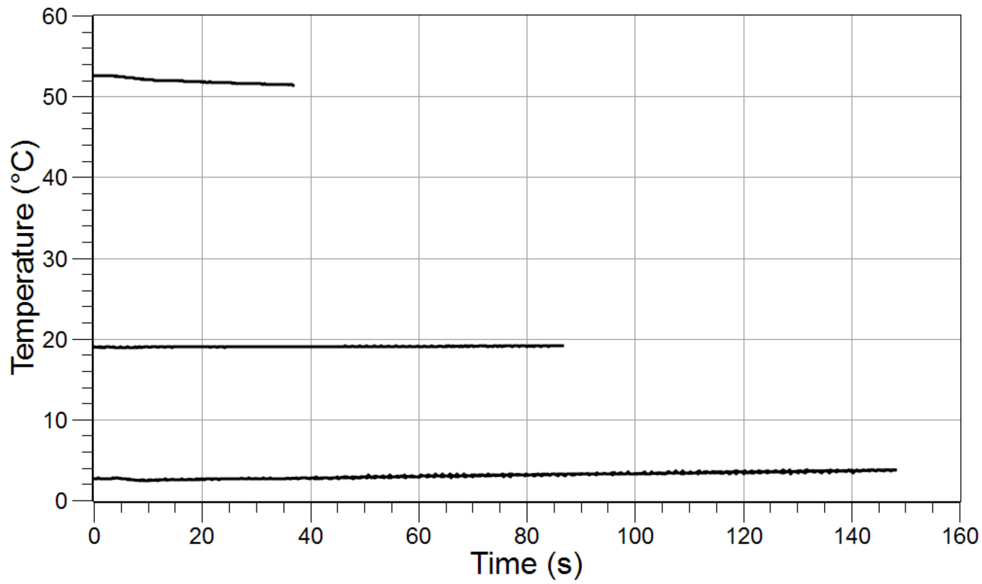
    The sugar cube should dissolve in even less time than the room temperature. Based on the data, it appears that sugar dissolves faster when the water is warmer.

22. ☐ Repeat the steps above this time using hot water. Collect this run of data on the same graph as the cold water and room temperature water.

23. ☐ Fill in the data you collected with hot water in Table 1 above.

24. ☐ Sketch a graph of the Temperature (°C) versus Time (s) data you collected on the axes below. Include all three runs of data.

Time of Dissolving for a Sugar Cube in Different Temperatures of Water



Explain It

In this section you will explain what the data you collected when dissolving a sugar cube in different temperature water means.

25. ☐ What temperature water dissolved the sugar cube the fastest? How do you know?

The hot water dissolved the sugar cube the fastest. The graph shows that the hottest water (51 ˚C) took the least amount of time to dissolve (37 s).

26. ☐ What temperature water dissolved the sugar cube the slowest? How do you know?

The cold water dissolved the sugar cube the slowest. The graph shows that the coldest water (4 ˚C) took the most amount of time to dissolve (148 s).

27. ☐ Describe the overall effect that temperature had on the time it took a sugar cube to dissolve in water?

Increasing the temperature of the water causes the sugar cube to dissolve faster.

28. ☐ What was the independent variable in this experiment? How do you know?

The independent variable was the temperature of the water. This is because the experimenter purposely changed the temperature of the water.

29. ☐ What was the dependent variable in this experiment? How do you know?

The dependent variable was the time it took for the sugar cube to dissolve. This is the variable that was measured.

30. ☐ What variables were controlled?

Controlled variables included the amount of sugar, the amount of water, stirring was constant in each trial, and the method of data collection.

31. ☐ Is dissolving a sugar cube in water a physical change or a chemical reaction? How do you know?

Dissolving a sugar cube in water is a physical change. No new substance (with different properties) was formed and therefore a chemical reaction did not occur. The sugar just broke up into pieces and mixed with the water.

32. ☐ How do you think temperature will affect the time it takes a chemical reaction to occur? Why?

An increase in temperature will probably cause a chemical reaction to occur faster because an increase in temperature causes a physical change (dissolving) to occur faster.

33. ☐ As you have been investigating the effect temperature has on the time it takes a change to occur you have been learning some new scientific ideas. These ideas have their own terms. In science it is important to be able to discuss your results using these words and terms correctly.

Write the meaning of the following terms in your own words using what you have learned from the activity.

- Vocabulary and definitions

Temperature	A measure of how hot and cold.
Temperature sensor	An instrument that measures temperature.
Dissolve	When a solid material mixes with a liquid material by breaking into pieces so small that they can no longer be seen.
Physical change	A change in which no new substance is formed.
React	Combine together chemically to form one or more new materials.
Chemical reaction	A change in which one or more new substances are formed.
Independent variable	The variable that the experimenter purposely changed.
Dependent variable	The variable that is measured in an experiment.
Controlled variable	Variables that are held constant in an experiment.

Tell Me More

In this part of the activity you will use your data collection system to time how long it takes a antacid tablet to react with cold vinegar, room temperature vinegar, and hot vinegar.

34. ☐ Start a new experiment on the data collection system.

35. ☐ Connect a temperature sensor to your data collection system.

36. ☐ Create a graph of Temperature (˚C) on the *y*-axis versus Time (s) on the *x*-axis.

37. ☐ Create an ice-bath:

    a. Fill a 600-mL beaker halfway full with ice.

    b. Add ~100 mL of water to the ice in the 600-mL beaker.

38. ☐ Fill a 250-mL beaker with 100 mL of room temperature vinegar and label this beaker "cold vinegar".

39. ☐ Carefully place the "cold vinegar" beaker into the ice-bath.

40. ☐ Set the ice-bath with the "cold vinegar" beaker of in it aside to allow the vinegar to become cold.

41. ☐ Fill a second 250-mL beaker with 100 mL of room temperature vinegar and label this beaker "room temperature vinegar".

42. ☐ Place the temperature sensor in the "room temperature vinegar" beaker so that the tip of the sensor is at the bottom of the beaker.

    Note: If necessary, tape the sensor in place so that it does not come out of the beaker.

43. ☐ Place one piece of the antacid tablet in the "room temperature vinegar" beaker and immediately start recording data.

44. ☐ Observe the antacid reacting with the vinegar for one minute (60 seconds).

45. ☐ After one minute, constantly stir the antacid and the vinegar until all of the antacid has reacted.

46. ☐ When the antacid tablet piece has completely reacted with the vinegar, stop recording data.

47. ☐ How did you decide when the antacid had completely reacted?

    The antacid had completely reacted when the antacid could no longer be seen and bubbles had stopped forming.

48. ☐ Using the graph on your data collection system, determine how long it took for the antacid tablet piece to react with the vinegar and the exact temperature of the vinegar. Record these values in the room temperature row of Table 2.

➢ Table 2: Time and temperature data collected while reacting antacid with vinegar

Vinegar	Temperature (°C)	Time to Dissolve (s)
Cold vinegar	5	600
Room temperature vinegar	23	298
Hot vinegar	51	242

49. ☐ Clean and dry your beaker according to your teacher's instructions.

50. ☐ Do you think a piece of an antacid tablet will take the same amount of time, less time, or more time to dissolve in hot vinegar?

    The antacid tablet will react with the vinegar in less time because the temperature is warmer.

51. ☐ Repeat the steps above this time using hot water.

    ■ Collect this run of data on the same graph as the room temperature vinegar.

    ■ Observe the reaction for the first minute (60 seconds) and then stir constantly.

52. ☐ Fill in the data you collected with hot vinegar in Table 2 above.

53. ☐ Was your prediction correct? Explain.

    Yes, the prediction was correct. The antacid tablet reacted faster in the warm vinegar.

54. ☐ How much time do you think it will take the antacid tablet piece to react in cold vinegar? Explain your thinking.

    The antacid tablet piece should take a lot longer to react with the cold vinegar than with the room temperature or the hot vinegar. Based on the data, it appears that the antacid tablet pieces react faster when the vinegar is warmer. Since we are cooling down the vinegar, the reaction should take longer.

55. ☐ Repeat the steps above this time using vinegar in the beaker that has been cooling in the ice-bath labeled "cold vinegar".

    ■ Keep the beaker of "cold vinegar" in the ice-bath throughout the reaction so that the vinegar stays cold.

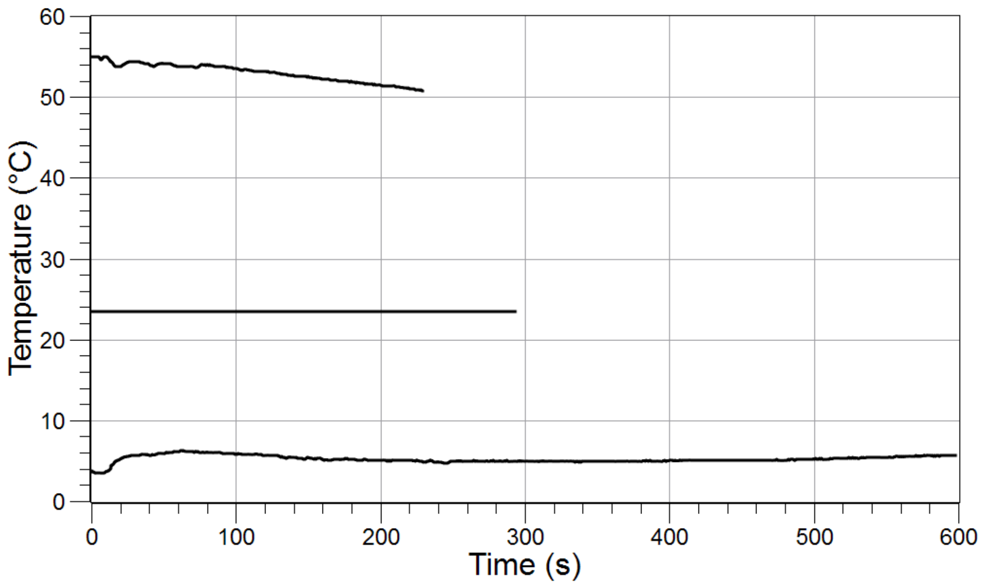
    ■ Collect this run of data on the same graph as the room temperature vinegar.

    ■ Observe the reaction for the first minute (60 seconds) and then stir constantly.

56. ☐ Fill in the data you collected with cold water in Table 2 above.

57. ☐ Sketch a graph of the Temperature (˚C) versus Time (s) data you collected on the axes below. Include all three runs of data.

Reaction Time for an Antacid Tablet Piece in Different Temperatures of Vinegar



Sum It Up

Summarize what you have learned through this activity by answering the following questions.

58. ☐ What temperature vinegar reacted with the antacid the fastest? How do you know?

The hot vinegar reacted with the antacid the fastest. The graph shows that the hottest water (51 ˚C) took the least amount of time to react (240 s).

59. ☐ Describe the overall effect that temperature had on the time it took the antacid to react with the vinegar.

Increasing the temperature of the vinegar caused the reaction to occur more quickly and decreasing the temperature of the vinegar caused the reaction to occur more slowly.

60. ☐ What were the independent, dependent, and controlled variables in the experiment done to determine the effect of temperature on the time it took for antacid to react with vinegar?

➢ Table 3: Variables in the antacid and vinegar experiment

Independent Variable	Dependent Variable	Controlled Variables
Temperature of the vinegar	Time it took the reaction to occur	Amount of vinegar, amount of antacid, stirring after one minutes, data collection method

62. ☐ What effect does temperature have on the time it takes for changes to occur? Is it different for physical changes and chemical reactions?

Increasing temperature causes changes to occur more quickly and decreasing temperature causes changes to occur more slowly. It is not different for physical changes or chemical reactions. It appears that both types of changes are affected by temperature the same way.

Assessment

True or False

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

___T___ 1. Temperature will affect how quickly salt dissolves in water.

___F___ 2. A chemical reaction cannot be speeded up by increasing the temperature.

___F___ 3. Dissolving sugar in water is a chemical reaction.

___F___ 4. Sugar will dissolve more quickly in a cold glass of lemonade than in a hot cup of tea.

___T___ 5. A nail will rust more quickly in hot weather than in cool weather.

Further Investigations

Investigate the effect of particle size on time it takes a change to occur. This can be done by timing how long it takes a whole antacid tablet to react with vinegar, compared to an antacid tablet broken into pieces and a crushed antacid tablet.

Determine the effect of stirring on the time it takes a substance to dissolve. Have the students time how long it takes a spoonful of sugar to dissolve with stirring and without stirring.

17. The Water Cycle

Recommended Grade Levels: 4 – 5

Objectives

Students determine that water, which covers the majority of Earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle."

Procedural Overview

To understand this content, students:

- Build a water cycle tower model out of 2-liter soda bottles.
- Measure the relative humidity of the atmosphere in the model when ice cubes are added.
- Measure the change in relative humidity inside the model as it is heated for five minutes with a lamp.
- Analyze graphical information and draw conclusions based on evidence.

Time Requirement

Teacher Preparation	20 - 30 minutes
Pre-Activity Discussion	10 - 15 minutes
Get Started	10 – 15 minutes
Let's Explore	20 – 30 minutes
Explain It	15 – 20 minutes
Tell Me More	10 – 15 minutes
Sum It Up	10 – 15 minutes

Materials

For teacher demonstration:

- ☐ Data collection system
- ☐ Weather sensor
- ☐ Sensor extension cable
- ☐ Scissors
- ☐ Razor blade or sharp knife
- ☐ Assembled water cycle tower[1]
- ☐ Ice cubes, ~350 mL
- ☐ Transparent packing tape
- ☐ Permanent marker, black or dark color

[1]To assemble the water cycle tower refer to the Preparation section. The construction includes (3) clean 2-L bottles, the transparent packing tape, and the sharp cutting.

For each student group:

- ☐ Data collection system
- ☐ Weather sensor
- ☐ Sensor extension cable
- ☐ Utility lamp with clip (with a 60 W or 75 W incandescent bulb)
- ☐ Scissors
- ☐ Clean 2-L soda bottles (3)
- ☐ Ice cubes, ~350 mL
- ☐ Transparent packing tape, ~1 m
- ☐ Meter stick

Activity at a Glance

Get Started

- ☐ Students discuss within the group all of the places where water is found on Earth.
- ☐ Students discuss how many different ways water can exist.
- ☐ Students predict what will happen to some ice cubes when they are placed in a container with a lamp shining on them.

Let's Explore

- ☐ Build a model water cycle tower.

Explain It

- ☐ Students use their water cycle tower to investigate the processes involved in the water cycle.
- ☐ Students graph changes in relative humidity as ice begins to melt in the water cycle tower.
- ☐ Students identify the states of matter and the changes in matter taking place in the tower.
- ☐ Students begin to define the following terms: ice, vapor, liquid, evaporation, condensation, precipitation, transportation, relative humidity, and atmosphere.

Tell Me More

- ☐ Students investigate what will happen to the relative humidity in the water cycle tower if heat energy is added to the system.
- ☐ Test predictions by shining a utility lamp on the ice cubes in the bottom of the water cycle tower.

Sum It Up

- ☐ Students analyze data and examine evidence to draw conclusions about the water cycle and the processes involved in the water cycle.

Safety

Follow all standard classroom practices.

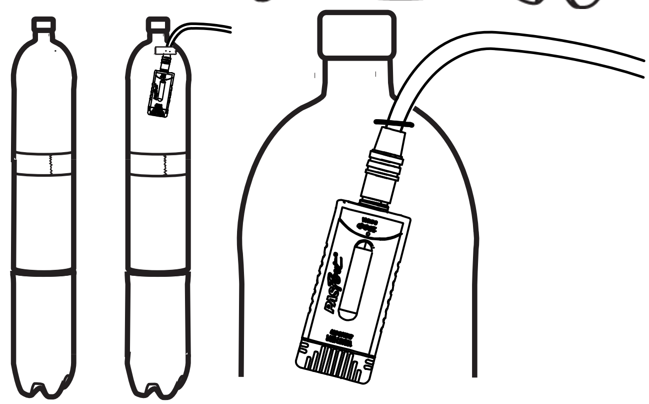
Preparation

These are the materials and equipment to set up prior to the activity.

- Follow these steps to prepare a water cycle tower:

    1. Use the razor blade or sharp knife to cut the three soda bottles as shown in the diagram below:

    2. Use the cut bottles to form one tall tube with a bottom and top, as shown in the diagram below:



    3. Tape the upper two sections of soda bottles together with transparent packing tape. Leave the bottom section un-taped so you can pull it apart to add ice.

    4. Make a slit just below the neck of the top section. The slit should be just wide enough to accommodate the sensor extension cable connected to the weather sensor.

    5. Adjust the height of the weather sensor so it hangs as close to the top of the soda bottle as possible.

    6. Apply a small strip of transparent packing tape over the sensor extension cable and slit to seal the slit and secure the sensor.

    7. Place the cap on top of the soda bottle.

- Ahead of time, remove the labels from all soda bottles and use the razor blade or sharp knife to make cuts in the soda bottles students will be using. Make each cut long enough that the students can get the scissors inside the bottle and continue the cut all the way around the bottle.

- You can use the permanent marker to draw the line for students to cut if this would be helpful for your students.

- Make the slit in the top the soda bottles where students will insert the weather sensor. Show students that it is easier to insert the sensor extension cable through the slit and connect the weather sensor afterword than trying to push the sensor box itself through the slit.

- Students may need your assistance in setting up the tower with the weather sensor cable coming out of it after they have added the ice and taped the section to seal it. Some towers may not be symmetrical, or may be prone to tipping over. Students need to locate their towers near an electrical outlet where they can plug in their utility lamp.

- Set up the data collection system.

1. Begin a new experiment on the data collection system.

2. Connect the weather sensor to the data collection system using the sensor extension cable.

3. Display the relative humidity data in a graph with Relative Humidity on the *y*-axis and Time on the *x*-axis.

4. Change the periodic sampling rate to take a measurement every 5 seconds.

Background

The Water Cycle

The constant, continuous circulation of water between the atmosphere and the Earth's surface and crust is known as the water cycle. Scientists often refer to it as the hydrologic cycle, and the places where water exists as the hydrosphere. Fresh water represents 2.5% of Earth's water. Fresh water may be found on Earth's surface in rivers, streams, lakes, wetlands, snow and ice, and glaciers. Fresh water may also be found under the surface as ground water, and in the atmosphere as water vapor. Salt water makes up 97.5% of Earth's water, and is found in oceans and seas.

Evaporation of surface water, condensation of the water to form clouds, and precipitation back to Earth's surface all occur continuously. Winds in the atmosphere transport water vapor and clouds from one location to another.

What happens to water that falls on land?

Water that falls on land is known as precipitation. It can take the form of rain, snow, sleet, or hail. Once it falls, it can flow into the ocean via streams and rivers. This is called runoff. Precipitation can seep into the ground where it becomes part of the ground water. Ground water flows along and through bedrock, eventually arriving back at the ocean — but this trip can take groundwater decades, centuries, or even longer. Precipitation can also evaporate back into the atmosphere, from the land or from plants' leaves when they transpire.

States of Matter

Water is a unique substance in that we encounter it in our daily experiences in all three of the states, or phases, of matter that exist commonly on Earth: solid, liquid, and gas. Solid water, or ice, has a crystalline structure in which the molecules are locked into a rigid, orderly pattern. This fact is responsible for the characteristic six-sided patterns of snowflakes. Solid water is also less dense than liquid water, which allows ice to float on the surface of lakes and ponds, and icebergs to float only partially submerged in the ocean. Solid water has a definite volume and a definite shape.

Water in the liquid state has a definite volume, but does not have a definite shape. Liquid water takes the shape of the container it is in. The molecules of the liquid water are free to move around and slide easily past one another. They have more kinetic energy than do the molecules of solid water.

Water in the gas or vapor state contains more energetic molecules than solid or liquid water. They lack definite volume and shape, and will expand to fill any space available to them. Water vapor is actually invisible to our eyes. Steam is the name given to water vapor produced by boiling water that has begun to condense back into the liquid phase.

Changes in States of Matter

When enough energy is added to solid ice, the bonds that hold the crystalline structure together begin to break and the ice starts to undergo the process of melting. Melting results in solid water turning into liquid water. If more energy is added, the molecules of liquid water begin to evaporate. They leave the surface of the water and enter the gas state. Each of these changes also can occur in reverse. If water in the gas or vapor state loses energy, it condenses and turns back into a liquid. If more energy is then removed from the liquid water, it freezes and turns back into a solid.

On the Celsius temperature scale, water freezes or melts at zero degrees and boils or condenses at 100 degrees at sea level. On the Fahrenheit temperature scale, these points correspond to 32 degrees for melting or freezing, and to 212 degrees for boiling or condensing. Which process occurs depends upon whether energy is being added to or removed from the water.

Water Cycle Tower Model

The atmosphere surrounding the Earth extends many kilometers above the surface. Air rises because it is warmed at the surface and is less dense than cooler air. As it rises, it cools and the moisture in it condenses into tiny droplets of water or tiny crystals of ice. Once the condensed water is heavy enough, it can fall back to Earth's surface as precipitation. In this investigation, a water cycle tower is used to create a model of a column of air over a point on the Earth’s surface. The water cycle tower, equipped with a weather sensor, allows water vapor to rise to the top where the sensor can measure the relative humidity.

Pre-Activity Discussion

Start the discussion with the question:

What is the water cycle?

- When the dinosaurs lived and roamed the Earth, the water they drank is the very same water available to us now. The water available on Earth is relatively constant, and it has been recycled countless times. The process of recycling water and moving it around is called the water cycle.

- Earth's atmosphere helps water move all around our planet. Water is moved through the sky to lakes, rivers, and land. Water moves from the land back to the ocean and sky. The process is continuous.

You may want to elaborate on the question by asking students to break it into sub-questions about the water cycle and the states of matter of water.

Q How does water get from the sky to the land?

Q How does water get from the land back to the ocean?

Q What states or phases of water are you familiar with?

Q How is water stored in or on the Earth?

Q What happens to ice when it is heated?

Q What happens to water when it is heated?

Q What happens to steam or water vapor when it cools?

Q What happens to water when it cools?

- Tell students that they will be building a model to explore the various parts of the water cycle. In science, a model is an object or system that in some way resembles its real counterpart. Often scientists make models, picking and choosing what aspects are most important to include in the model.

- Show students the water cycle tower you have assembled and explain that they will be building their own system to model the water cycle.

Driving Question

- What is the water cycle?

Variables

Independent Variable

- Heat is added to the system to determine the effect of heat on the water content of the air in the column.

Dependent Variables

- The dependent variable is relative humidity as it changes over time.

Controlled Variables

- Controlled variables are the isolated column of air and the addition of a fixed quantity of ice.

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

Have you ever made a paper airplane or played with a toy car or doll? These are models which in some way resemble their real counterparts. Have you ever used a flight simulator? This is a model made to help people learn how to fly an aircraft. Often scientists make models, picking and choosing what aspects are most important to include in the model.

1. ☐ Discuss with the members of your group all of the places where water is found on Earth. Make a list. Be prepared to share with the rest of the class.

   Student lists should include some or all of the following: Water is found on Earth in oceans, seas, lakes, rivers, in the ground, and in the atmosphere in clouds or precipitation.

2. ☐ How many different ways can water exist? Make a list in your group of all the different forms of water. Be prepared to share your list with the rest of the class.

   Student lists should include some or all of the following: Water can be solid in the form of ice, snow, frost, or hail. Water can be in liquid form as rain, mist, or stored surface water. Water can be in the gas or vapor form as clouds, water vapor with droplets too small to see, fog, or steam.

3. ☐ Predict what will happen to some ice cubes when they are placed in a container with a lamp shining on them.

   Students should suggest that the ice cubes will begin to melt, and some of the solid water will turn to liquid and perhaps to vapor.

Let's Explore

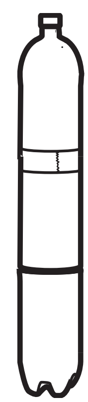
In this part of the activity you will build a model water cycle tower. You will build this model out of parts from three 2-liter plastic soda bottles. You will join the parts together and seal the connections with clear packing tape. The bottom section of the tower will be left unsealed so you can add ice for the next part of the activity.

4. ☐ Your teacher has already made cuts in your soda bottles. Use scissors, and these cuts, to cut the top and bottom off one of your soda bottles.

5. ☐ Cut just the bottom off the second soda bottle. This bottle needs to have its cap on.

   Teacher Tip: As students work, ask them to think about why the model is as tall as it is. Would just a single soda bottle make a good model? Why or why not?

6. ☐ Cut just the top off the third soda bottle.



7. ☐ Join the open cylinder to the bottle that has its bottom removed, as shown in the graphic to the right.

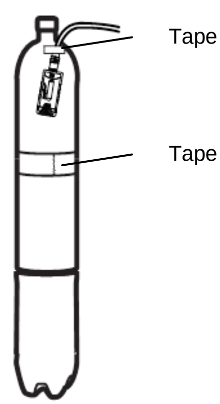
8. ☐ Tape these two sections together with packing tape.

9. ☐ Put the sensor extension cable through the slit in the top of the bottle.

10. ☐ Connect the weather sensor to the sensor extension cable.

11. ☐ Adjust the amount of cable so that the weather sensor just barely hangs down into the tower, as shown in the graphic to the right.

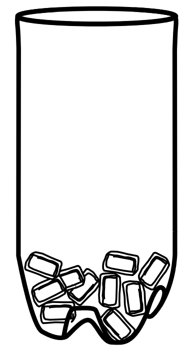
12. ☐ Tape the slit with the weather sensor cable closed. This will hold the sensor in place and seal up the opening.



Explain It

Now that you have built your water cycle tower model, it is time to use it to investigate the processes involved in the water cycle.

13. ☐ Place 300 mL of ice cubes in the bottom of the tower, as shown in the graphic to the right.



14. ☐ Join the top and bottom sections of the water cycle tower, and seal them with packing tape.

15. ☐ Why is it important for this model to be sealed? What do the ice cubes represent in this model?

    It is important for this model to be sealed so that none of the water is lost to the outside. The ice cubes inside the model represents all the water on Earth that is involved in the water cycle.

16. ☐ Your tower may need to be supported so it does not fall over. You can lean it against a chair, a desk, or the wall if necessary.

17. ☐ Begin a new experiment on the data collection system.

18. ☐ Connect the weather sensor to the data collection system with the sensor extension cable.

19. ☐ Display the relative humidity data in a graph with Relative Humidity on the *y*-axis and Time on the *x*-axis.

20. ☐ Change the periodic sampling rate to take a measurement every 5 seconds.

21. ☐ Begin data recording.

22. ☐ After two minutes stop data recording.

23. ☐ Review the relative humidity data. You may need to adjust the scale of the graph to see all of the data. What was the relative humidity in the water cycle tower?

    Relative Humidity: 24 %

24. ☐ In your investigation of the water cycle, you are learning some new scientific ideas and terms. It is important to be able to discuss your results using these words and terms correctly. Take this opportunity to investigate the meanings of these new terms.

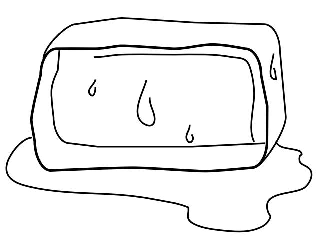
Write the meaning of the following terms in your own words using what you are learning from the lab.

- Vocabulary and definitions

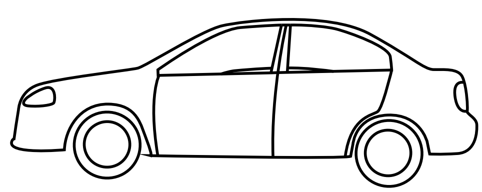
Ice	Water in its solid form
Vapor	Gas form of water or other substance
Liquid	State of matter with no definite shape, but a definite volume
Evaporation	Changing from the liquid to the vapor state when heat energy is added
Condensation	Changing from the vapor to the liquid state when heat energy is removed
Precipitation	Rain, snow, sleet, hail or any form of water that falls from clouds in the sky
Transportation	Moving around, from one place to another
Relative humidity	The amount of water vapor in the air, compared to the amount the air could hold at that temperature
Atmosphere	The layer of gas surrounding Earth, held in place by gravity

25. ☐ Illustrate two terms of your choice in the spaces below.

Word: Ice.



Word: Transportation.



Tell Me More

What will happen to the relative humidity in your water cycle tower if heat energy is added to the system?

26. ☐ Position the utility lamp so that the light shines directly on the ice cubes in the bottom of your water cycle tower. The lamp should be about 25 cm from the ice cubes.

27. ☐ Turn the lamp on.

    Teacher Tip: As an alternative to using the lamp, you may have students collect data in their water cycle tower models outdoors on a sunny or warm day. You may also use a container of hot water under the bottom of the model to provide heat energy. However, this is visually more abstract for students, so you will need to help them make the connection between the heating element and the sun's role in heating Earth's surface.

28. ☐ Begin data recording.

29. ☐ The model you have made includes a tall, closed container with ice cubes and a light bulb. Which part of this model represents the sun's light and heat energy falling on the Earth?

    The lamp represents the sun's light and heat energy.

30. ☐ Which part of the model represents water stored on Earth's surface?

    The ice represents the water stored on Earth's surface.

31. ☐ Which part of the model represents Earth's atmosphere?

    The air in the soda bottles represents Earth's atmosphere.

32. ☐ After 5 minutes, turn off the lamp. Stop data recording.

33. ☐ Carefully observe the ice in the bottom of your water cycle tower. What changes do you notice?

    Students should observe that the ice is beginning to melt. They should be able to notice some liquid water beginning to pool in the bottom of the bottle.

34. ☐ Look at your graph of relative humidity data. You may need to adjust the scale of the graph to see all of your data. What do you notice about the relative humidity?

    Students should be able to see an increase in the relative humidity.

    Teacher Tip: As students look at their relative humidity data, some groups may discover that the humidity in their model increased and then began to decrease. Relative humidity is the ratio of the amount of vapor in the air compared to the amount of water the air can hold at a given temperature. Because warmer air can hold more water than cooler air can, it is relatively less humid. This will be reflected in the data.

35. ☐ Relative humidity is a measure of how much water vapor is in the air compared to how much the air could hold at that particular temperature. Where does the water vapor in your model come from?

The water vapor comes from the ice. Although some of the water molecules go directly from solid to vapor form, some of the vapor comes from the liquid water that formed when the ice began to melt.

36. ☐ What process has happened in your model for there to be more water vapor in the air?

Melting of the solid ice into liquid, and then evaporation of the liquid water into vapor has happened in the model.

Sum It Up

37. ☐ What states or phases of water can you observe in your water cycle tower?

We can observe solid water in the form of ice, and also liquid water in the bottom of our tower.

38. ☐ Based on your relative humidity data, what evidence do you see that water vapor is also present in your water cycle tower?

Answers will vary. One student group answered as follows: Our graph of relative humidity shows that the humidity has gone up from 24% to about 50%. This means that there is more water vapor in the air in our tower.

39. ☐ What would happen to the liquid water and the water vapor in your water cycle tower if the model were put into a freezer for several hours?

All of the water would change to the solid state and become ice again.

40. ☐ Suppose you did put your model into the freezer. What would happen if you then took it out after several hours and placed it in the sun for several hours on a warm day?

The ice in the tower would melt, and much of the liquid water would turn to vapor or steam. The model would contain only liquid and vapor.

41. ☐ How many times could this process be repeated if you kept the model closed and sealed?

This process could be repeated indefinitely as long as the system is closed.

42. ☐ How does the water get transported or moved around in your water cycle tower?

Melting of ice allows water to roll "downhill" to the bottom of the bottle, and evaporation allows water to move up into the top of the bottle. If enough water were to condense on the sides of the bottle, gravity would pull it down as well.

43. ☐ What is another term used when water is transported from one place to another through phase changes, ends up where it started, and begins these changes over again?

A water cycle.

Assessment

Key Term Challenge

Fill in the blanks from the list of randomly ordered words.

evaporation	melting	freezing	precipitation
transportation	gas	condensation	sun

1. The process that changes liquid water into solid ice is _____freezing_____.

2. _____Evaporation_____ is how liquid water on Earth's surface becomes water vapor in the sky.

3. The _____sun_____ provides the energy needed on Earth's surface for plants to grow and water to move through the water cycle.

4. When _____melting_____ happens, solid forms of water such as ice and snow turn into liquid again.

5. Rain, snow, hail, and sleet are all types of _____precipitation_____ .

6. _____Condensation_____ is the process that turns water vapor back into liquid water when it becomes cool enough.

7. Water in the _____gas_____ state is also called water vapor.

8. The water cycle is the process of _____transportation_____ that continuously moves water all around Earth.

Further Investigations

Have your students track the relative humidity of the outside air over several days at the same time they write down their observations of the weather, including how the moisture level of the air feels. Help them relate their observations to the reading of relative humidity they record.

18. Conductor or Not?

Recommended Grade Levels: 4 – 5

Objectives

Students recognize that all materials have certain physical properties, including the ease with which they can conduct electricity.

Procedural Overview

To understand this content, students:

- Build an electrical circuit tester from materials provided
- Use their circuit tester to test which materials are conductors and which are insulators
- Use a voltage sensor to test the voltage drop across their circuit

Time Requirement

Teacher Preparation	20 - 30 minutes
Pre-Activity Discussion	5 - 10 minutes
Get Started	10 minutes
Let's Explore	10 - 15 minutes
Explain It	10 - 15 minutes
Tell Me More	10 - 15 minutes
Sum It Up	5 - 10 minutes

Materials

For teacher demonstration:

- ☐ Data collection system
- ☐ Voltage sensor
- ☐ AA-cell battery fully charged
- ☐ Holiday mini-light bulb (non-LED) with wire ends stripped
- ☐ Alligator clips, 2
- ☐ Wire, 20 cm, with stripped ends, 2
- ☐ Masking tape, ~30 cm
- ☐ Paper clip
- ☐ Penny
- ☐ Plastic spoon
- ☐ Eraser
- ☐ Piece of chalk
- ☐ Clay

Activity at a Glance

Get Started

- ☐ Discuss students' prior experience with conducting and insulating materials, and review the parts of an electric circuit.
- ☐ Test the voltage across a AA-cell battery.

Let's Explore

- ☐ Construct an electric circuit tester using wire, alligator clips, a holiday mini-light and one AA-cell battery.

Explain It

- ☐ Vocabulary terms are introduced; students complete definitions.

Tell Me More

- ☐ Predict voltage across the circuit for each material to be tested.
- ☐ Use the voltage sensor to test the predictions.

Sum It Up

- ☐ Students analyze their data and examine their evidence to draw conclusions about what materials are conductors.

Safety

Add these important safety measures to your normal class procedures:

- Do not connect the terminals of the battery directly with a wire. This may cause a short circuit and become hot enough to burn you.

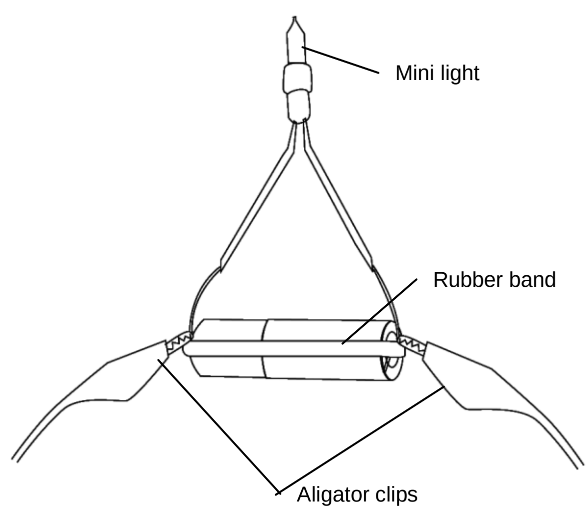
Preparation

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

- Cut lengths of wire for student groups. Strip the ends of the wires of their insulation, exposing 1-2 cm (~0.5-1 in.) of wire on each end. This will allow students enough room to attach alligator clips and to tape the wires to the battery terminals.

- Obtain a strand of holiday mini-lights and cut the individual lights apart. Leave the projecting wires as long as possible. Strip about 1 cm (~0.5 in.) of insulation from each end of each wire.

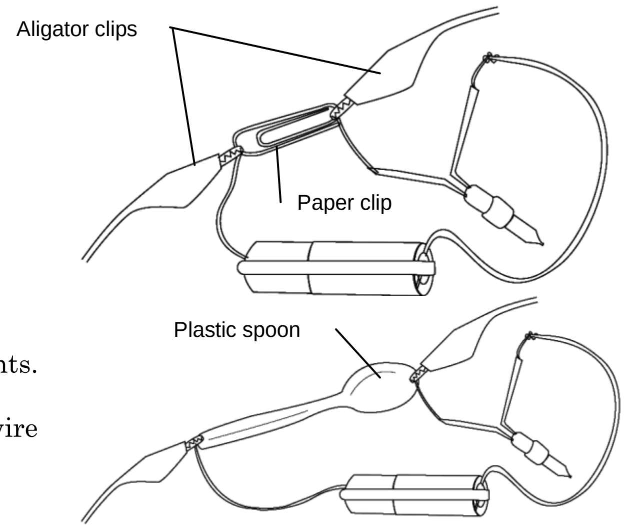
- Use only the batteries described in the materials section. Larger batteries may heat up the bulbs too much, which could be dangerous.



Review with students as necessary the steps for using the data collection system and the voltage sensor.

- Provide a collection of materials for students to test. This may include plastic, wooden and metal utensils, aluminum and steel paper clips, pencil lead and erasers, aluminum foil, plastic wrap or wax paper, etc.

- Students are asked to work in teams and suggest a list of materials that they can test with their circuit tester. Once the list is approved, the students should connect them in series as part of the circuit. Additional wire and tape may be needed.



- Check to see if any additional items appear on the students' proposed lists and approve materials based on availability and set-up based on safety.

- Notice that in order to test the voltage across the item, the voltage sensor is clipped to either end as shown above with the conducting paper clip. In this case the bulb lights.

- In the case above, tape is used to connect the wire to the insulating spoon. Since plastic is an insulator, the bulb does not light.

Background

Conductors versus Insulators

Materials that permit charges to move freely, such as copper, aluminum, or silver, are classified as electrical conductors. Nearly all metals are good conductors of electricity because they permit movement of electric charges. Materials that do not allow for the free movement of charges are classified as electrical insulators. Such materials include glass, plastic, rubber, and silk. A few materials, most notably silicon and germanium, can have properties of both conductors and insulators, and are known as semiconductors. These materials are used in a wide variety of electronics.

What Is Electric Charge?

If you have ever done laundry or torn the plastic wrapper off a package and had it cling stubbornly to your hand, then you are familiar with electric charge, in the form of static electricity. Electric charge is a property of matter, in the same sense that mass, density, color, and temperature are properties of matter. Electric charge arises from the nature of atoms themselves. Atoms are the building blocks of matter. An atom of aluminum has all of the properties of aluminum; it is the smallest "piece" of aluminum that can exist. However, an atom is made up of smaller particles: the positively charged proton, the neutral neutron, and the negatively charged electron. The protons and neutrons are tightly bound in the nucleus of the atom, and under ordinary circumstances they remain there and never move. They are not mobile. Electrons, on the other hand, can become mobile under certain circumstances. Ordinary atoms have equal numbers of positive protons and negative electrons, so on the whole they are electrically neutral. However, if a few electrons migrate away from their atoms, the balance is upset and the region missing its electrons is now positively charged. The region inhabited by the migrating electrons becomes negatively charged. It is this charge imbalance that is responsible for "static cling."

Voltage and the Voltage Sensor

As you know, opposite charges attract one another while like charges repel. When a negatively charged electron is separated from the positively charged nucleus of its atom, or when two electrons are pushed together, work is done on them. Since work transfers energy, the electrons gain what is called electrostatic potential energy. The amount of electrostatic potential energy available for an electron at a given location is called voltage.

To conceptualize voltage, imagine electrons as water and voltage as elevation or altitude above the ground. You know how water behaves - it seeks the lowest elevation when it flows, and when water falls from a great height it is carrying more energy than when it falls from a lower elevation. In nature it is a general law that matter wants to inhabit a position of lowest potential energy. Like water that wants to flow downhill to lower its gravitational potential energy, charge wants to flow to lower its electrostatic potential energy.

The voltage sensor measures voltages from -10 volts to +10 volts. The red lead is the positive lead; the black lead is negative. When the leads of the voltage sensor are connected to the terminals of a battery, the voltage measured will be approximately equal to the stated voltage on the battery. For example, if you touch the black lead to the negative end and the red lead to the positive end of a 1.5-volt AA battery, you will measure 1.5 volts across the terminals of the battery. If you reverse the voltage sensor leads (touch the red lead to the negative terminal and touch the black lead to the positive terminal), you will measure –1.5 volts across the battery.

Pre-Activity Discussion

Start the discussion with the question:

Q What does it mean to conduct electricity?

Q What causes charges to move?

Q What is carrying the electrical charge inside a wire?

Have students think about everyday items that conduct or prevent electrical energy from moving through a circuit.

Driving Question

- What can conduct electricity?

Variables

Independent Variable

- An independent variable is the variable changed by the scientist or experimenter. In this activity the independent variable is the conducting or insulating material.

Dependent Variables

- A dependent variable is what you measure after you set or change the independent variable. The dependent variable in this activity is the voltage across the conducting or insulating material.

Controlled Variables

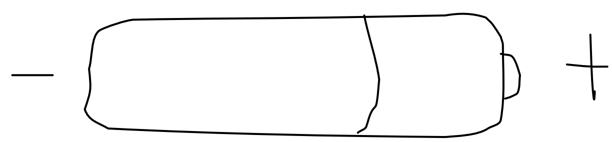
- In this activity the controlled variables are the voltage supplied by the battery and the voltage needed to light the holiday mini-light.

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

1. ☐ A battery can push electric charge like a pump can push water through a hose. The strength of a battery's pumping ability is called voltage. Obtain a AA-cell battery from your teacher. Draw a picture of the battery below.



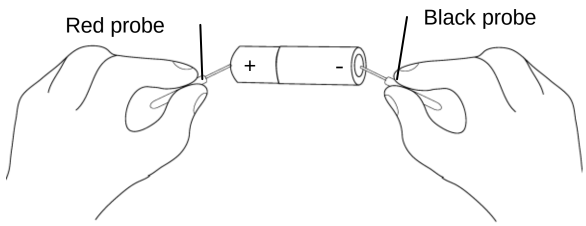
2. ☐ Use your voltage sensor to measure the voltage across the battery as shown in the picture below.

   a. Start a new experiment on the data collection system.

   b. Connect the voltage sensor to your data collection system.

   c. Display voltage in a digits display.

   Note: Make sure to connect the red end of the sensor to the positive end (+) of the battery and the black end of the sensor to the negative end (–) of the battery.



   d. Monitor live voltage data.

   Battery voltage = 1.53 V

3. ☐ What do you think happens to the strength (voltage) of a battery with use? Explain why you think this. Be prepared to share your ideas with the class.

The strength of the battery will decrease (the voltage will go down) as the battery is used. This is because some of the electrical energy is converted to heat and light.

Let's Explore

In this investigation, you will build a circuit tester with a holiday light.

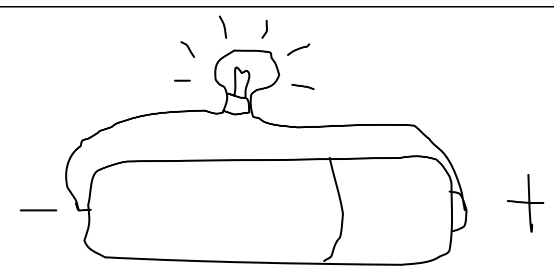
4. ☐ You can use a battery to light a holiday bulb in a complete circuit. A circuit is a complete loop that allows electrical charge to flow. Where do you have to connect the bulb to the battery to make it light?

Teacher Tip: A clump of clay can be used under the wire to position the ends of the wire on the battery terminals. However, when making multiple connections and using a voltage sensor, circuits may require multiple hands or the addition of tape to keep them connected.

The ends of the wire need to be connected to the terminals of the battery.

5. ☐ Draw a picture of your setup showing the connections.

➢ Drawing of circuit tester setup



6. ☐ Obtain a holiday bulb from your teacher. Make it light by connecting it to your battery. This setup will become your circuit tester.

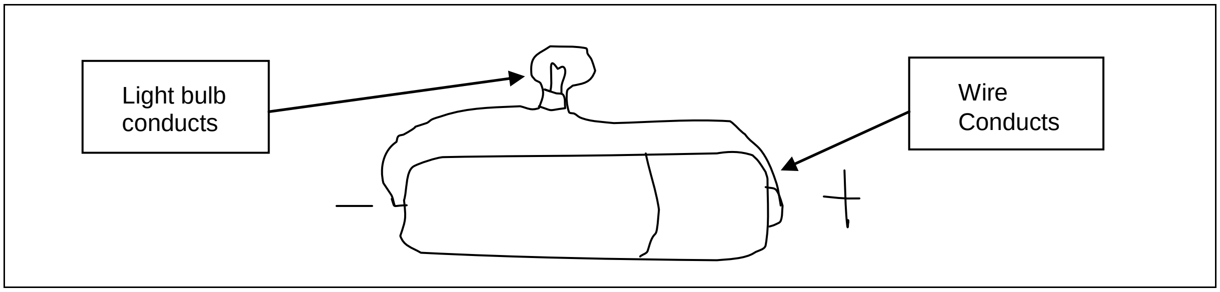
Explain It

7. ☐ Look closely at a holiday bulb. What conducts electrical charge and what does not conduct electrical charge? Draw a picture of the wires and the bulb, and label what conducts and what does not.

Teacher Tip: Students may not be familiar with the term "filament." A filament in a light bulb is a very fine wire that conducts electricity but with more resistance to the flow of current than the surrounding wire in the circuit. The word filament comes from the Latin word meaning "thread." A light bulb filament in an electric circuit is somewhat analogous to a thread connecting two pieces of much thicker rope.

The wire and the light bulb filament conduct. The tape or rubber band and the coating on the wire do not conduct.

➢ Drawing of what conducts and what does not



8. ☐ Things that do not conduct electrical charge are called insulators. Think about items and appliances in your house. Why are insulators necessary? Be prepared to share your thoughts with the class.

Answers will vary. Students should suggest that appliances such as refrigerators, toasters, washing machines, dryers, hair dryers, televisions, and computers need insulators to keep the electricity "inside" them. Students may suggest that without insulators, such appliances could give electric shocks.

9. ☐ In your investigation of what can conduct electricity you learned some new scientific ideas and terms. It is important to be able to discuss your results using these words and terms correctly.

Write the meaning of the following terms in your own words using what you have learned from the lab.

➢ Vocabulary and definitions

Electric circuit	A looped path for electricity to flow through, from one end of a battery to the other (higher potential to lower potential)
Electric conductor	A material which allows electrical charge to flow
Electric insulator	A material which prevents electrical charge from flowing
Switch	A way of opening and closing an electric circuit
Light bulb	Part of an electric circuit that changes electrical energy to light and heat energy
Voltage	The strength of a battery's ability to move electrical charge through a circuit (a potential difference between two points.)

Tell Me More

10. ☐ Some materials conduct electrical charge well and some do not. A conductor is a material that allows electrical charge to easily flow through it. Work with your group to list some possible conductors.

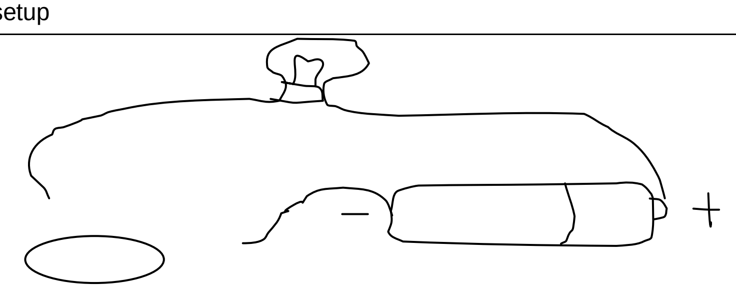
Answers will vary. Students may suggest wires, paper clips, coins, aluminum foil, metal objects, keys, nails.

11. ☐ Below is a list of some suggested materials. Predict which materials are conductors and which are not. Add any additional materials with your teacher's approval.

Material	**"Conductor" or "Not a conductor"**
Penny	Conductor
Paper clip	Conductor
Plastic spoon	Not a conductor
Rubber band	Not a conductor
Eraser	Not a conductor
Chalk	Not a Conductor
Answers will vary	Answers will vary
Answers will vary	Answers will vary
Answers will vary	Answers will vary

12. ☐ Using your circuit tester (AA cell battery and a holiday bulb) can you come up with a way to test whether or not the above materials conduct electrical charge? Make a drawing and describe the setup you are going to use and how it will work.

Drawing of setup



Answers will vary. One student group answered as follows: We will make a circuit that has a place in the loop to put each thing we are testing. We will first test the penny. Then we will take the penny out of the circuit and test the paper clip.

13. ☐ Now use your circuit tester. Check the box for each material that DOES conduct electricity. Use the last boxes to list any additional materials you plan to test.

- ☐ Penny
- ☐ Paper clip
- ☐ Plastic spoon
- ☐ Rubber band
- ☐ Eraser
- ☐ Chalk

- ☐
- ☐
- ☐

14. ☐ Use your voltage sensor to measure the voltage across each item while using the circuit tester. Record the voltages below. Use the last blank spaces to list the names and voltages of any additional materials you plan to test.

Voltage across the penny = 1.4 V

Voltage across the paper clip = 1.4 V

Voltage across the plastic spoon = 0 V

Voltage across the rubber band = 0 V

Voltage across the eraser = 0 V

Voltage across the chalk = 0 V

Voltage across the ________________ = ____________ V

Voltage across the ________________ = ____________ V

Voltage across the ________________ = ____________ V

Sum It Up

15. ☐ What can conduct electricity?

Answers will vary, but students should see that metals tend to be conductors and materials like plastic, rubber or glass tend to be insulators.

16. ☐ Look back to the list of materials you tested. Are some of them conductors? How do you know?

The penny and the paper clip are conductors. Electricity could pass through them and light the bulb. The voltage was 1.4 volts.

17. ☐ Look back to the list of materials you tested. Are some of them insulators? How do you know?

The plastic spoon, the rubber band, the eraser, and the chalk are insulators. Electricity could not pass through them because the bulb did not light. The voltage was 0 volts.

Assessment

Multiple Choice

Fill in the bubble to the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. A good conductor of electricity is

   Ⓐ Rubber

   Ⓑ **Metal**

   Ⓒ Plastic

2. What happens when an insulator is tested in the circuit tester created in this lab?

   Ⓐ **The circuit tester's bulb does not light.**

   Ⓑ The circuit tester's bulb lights dimly.

   Ⓒ The circuit tester's bulb lights brightly.

3. When a conductor is tested in a circuit tester, what happens to the bulb?

   Ⓐ The circuit tester's bulb does not light**.**

   Ⓑ The circuit tester's bulb flickers and goes out.

   Ⓒ **The circuit tester's bulb lights.**

True or False

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

___T___ 1. Electricity can pass through materials that are conductors.

___F___ 2. All materials are conductors.

___F___ 3. A piece of check and a paper clip are both conductors.

Further Investigations

Ask students to bring in items from home that they can test with their circuit testers.

Make a list of common household objects and discuss whether they are conductors or insulators.

19. Electric Circuits

Recommended Grade Levels: 4 – 5

Objectives

Students establish a fundamental understanding that:

- Electric circuits require a complete loop through which an electric current can flow
- Two light bulbs in a parallel circuit will be brighter than two light bulbs in a series circuit
- The voltage applied to a light bulb is related to the brightness of the bulb

Procedural Overview

To understand this content, students:

- Build simple series and parallel circuits using AA-cell batteries and light bulbs
- Compare the brightness of two bulbs in a simple series circuit to the brightness of two bulbs in a simple parallel circuit
- Measure the voltage being applied to the light bulbs in each circuit
- Relate the brightness of the light in their circuits to the voltage and the type of circuit

Time Requirement

Teacher Preparation	20 minutes
Pre-Activity Discussion	15 – 20 minutes
Get Started	10 minutes
Let's Explore	15 - 20 minutes
Explain It	20 - 30 minutes
Tell Me More	15 - 25 minutes
Sum It Up	25 - 35 minutes

Materials

- ☐ Data collection system
- ☐ Voltage sensor
- ☐ AA-cell battery (2)
- ☐ Miniature holiday light bulbs with stripped wire ends (2)
- ☐ Masking tape, ~30 cm
- ☐ Wide rubber band[1]
- ☐ Alligator clip or other pieces of wire with stripped ends (2)

[1] The rubber bands used to hold together bunches of produce work well.

Activity at a Glance

Get Started

- ☐ Students choose which of two diagrams will allow electric current to flow and cause a light bulb to light.
- ☐ Students discuss different types of circuits they are familiar with in their homes.

Let's Explore

- ☐ Students build a small series circuit using two AA batteries, alligator clip leads, and a holiday miniature light bulb.

Explain It

- ☐ Students predict what will happen when a second light bulb is added to their circuit.
- ☐ Students test their prediction by adding a second light.
- ☐ Students begin defining vocabulary terms electric circuit, electrical conductor, parallel circuit, series circuit, and voltage.

Tell Me More

- ☐ Students build either a series or a parallel circuit.
- ☐ Students compare the brightness of the bulbs in their circuit with the brightness of the bulbs in the type of circuit built by another group.

Sum It Up

- ☐ Students measure the voltage across the batteries and the bulbs in their circuit.
- ☐ Students compare voltages with the values measured by a group that built a different type of circuit.
- ☐ Students examine evidence to draw conclusions about the arrangement of circuit elements and brightness of bulbs in the circuit.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

- Cut lengths of wire for student groups. Strip the ends of the wires of their insulation, exposing 3 to 5 cm (1 to 2 in.) of wire on each end. This will allow students room enough to attach alligator clips as well as to tape the wires to the battery terminals.
- Cut the individual miniature lights apart. Leave the connecting wires as long as possible. Strip about 3 cm (1 in.) of insulation from each end of each wire.
- Use only the batteries described in the materials section. Larger batteries may heat up the bulbs too much, which could be dangerous.

- Review with students, as necessary, the steps for using the data collection system and the voltage sensor.
- Set up the data collection system to display voltage in a digits display:
  1. Start a new experiment on the data collection system.
  2. Connect the voltage sensor to your data collection system.
  3. Create a digits display of voltage.

Background

Voltage and the Voltage Sensor

Voltage is defined as the measure of electrostatic potential energy given to an amount of charge by a charge producer. In a circuit, this potential energy is often converted to work done by the charges to do things like light a bulb, turn a fan, or heat a resistor. Think of charges as the electrons from an atom, free from the atom's nucleus (free electrons), and think of charge producers as anything that produces an amount of excessive free electrons. Everyday charge producers include things like batteries and generators.

Before the charges from a charge producer can do work, they must be part of a complete circuit (closed loop) where they are free to move from one potential energy state to a lower potential energy state in a uniform flow known as an electric current. Voltage and current are closely related, but it is most important to note that without voltage there can be no current in a circuit. When work is done by the charges in a circuit, the current may not change but the voltage does, generally decreasing as potential energy from the charges is converted to work.

At its most basic, an electric circuit contains a power source (charge producer), such as a battery, connecting wires, a switch to open and close the circuit, and a load or resistor such as a light bulb. The switch may be as simple as touching the ends of two wires together to allow electric current to flow, or holding the two ends apart so current cannot flow. The load or resistor in the electric circuit consumes the power that the charges provide in the form of work done.

Series versus Parallel Circuits

When discussing these two types of circuits the term "current loop" must first be defined. A current loop is a complete (closed) current-conducting loop through which current flows from one battery terminal (+) to the other (–). A simple circuit with bulbs in series has only one loop through which current flows. In a parallel circuit, current flows through more than one loop.

In a series circuit containing several light bulbs, the current flows through each bulb. If one of the bulbs burns out (its filament is broken), the circuit is no longer closed, and the current stops flowing through the circuit. As a result, all of the bulbs go out.

A circuit containing three bulbs connected in parallel has three current loops. If one of the bulbs in a parallel circuit burns out, the current still flows through another part of the circuit, through another loop. If the bulb in the middle burns out, the first and last bulbs stay lit because they each form a closed loop for the current to flow from the positive battery terminal to the negative battery terminal.

Pre-Activity Discussion

- Talk briefly with students about charge and how it is produced and stored. Many different objects and processes are used every day to produce charge, like a turning generator or a solar panel on a house. However, without a way to store charge all the work that is done to produce the charge may be for nothing. This is why there are things like batteries that can store charges and save them for use in other systems like electric circuits.

  Q What are some examples of things that use electric circuits?

  Q Can you name some of the important parts of an electric circuit?

- Voltage can be a difficult concept for younger students to understand; however, for this activity students need only understand that voltage is a measurement of the relative strength of a battery and how many charges are stored within, and that a higher voltage applied to a light bulb will cause the bulb to be brighter.

- Explain that a circuit can be very complex, like those in a computer or a cell phone and use many small pieces of electronics. Or a circuit can be very simple, like a string of holiday lights which are just light bulbs and wires. Ask students why wires are used in circuits instead of things like shoelaces or plastic pipes. Students may respond by saying that the wires are responsible for carrying electricity to the light bulbs, and that electricity cannot go through things like shoelaces. If a student hasn't already mentioned them, remind students about the terms, "conductor," and "insulator:"

  Q What is an example of a material or item that is an electric conductor?

  Q What is an example of a material or item that is an electric insulator?

- Students will need to understand how current is established and that it flows from the positive terminal on a battery to the negative terminal. This lends itself to an important discussion about the continuity of a circuit and how a circuit must form a closed loop, through any circuit components, from one end of a battery to the other, and that circuits come in two general forms: parallel and series, both of which will be explored experimentally.

  Series: a circuit where all of the components are connected in one closed path (loop).

  Parallel: a circuit where the components are connected such that multiple paths are formed for current to flow through (multiple loops).

- The last important topic is power consumption by circuit components. Students will have a basic understanding that electricity is responsible for turning the lights on in their house. Many may not know that the light from the bulbs is a byproduct of the charges moving *through* the bulb in a complete circuit. As charges move through electric components in circuits such as light bulbs, hair dryers, toasters, or remote controlled cars the components are activated by converting energy from the moving charges into other forms of energy like heat or light.

Driving Questions

- How is the brightness of two light bulbs in a series circuit different than the brightness of two bulbs in a parallel circuit,

- How is the brightness of the bulbs related to voltage?

Variables

Independent Variable

- An independent variable is the variable changed by the scientist or experimenter. In this activity the independent variable is the type of circuit configuration used and the number of bulbs used in each configuration.

Dependent Variables

- A dependent variable is what you measure after you set or change the independent variable. The dependent variable in this activity is the brightness of the bulb(s) in each circuit and the measured voltage being applied to each bulb.

Controlled Variables

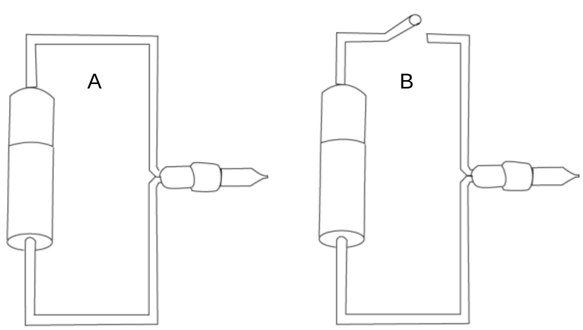
- In this activity the controlled variable is the voltage supplied by the batteries.

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

1. ☐ Look at the setups below. Circle the one that will light the bulb.



2. ☐ Explain your choice. Be prepared to share your ideas with the class.

   A is a complete loop while B is not.

3. ☐ A "circuit" is a complete loop of wire that allows electric current to flow from the positive (+) side of a battery to the negative (–) side. What would you have to do to setup "B" above to make electric current flow?

   Close the loop by connecting the broken section of wire.

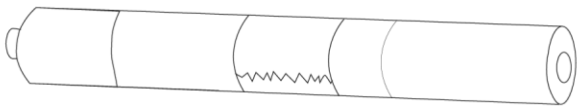
4. ☐ Electric circuits can be made in different ways to do many things. Things that you use every day often use electricity to do more than light a single light bulb. Can you think of something that has more than one light bulb?

   A computer uses electricity and circuits.

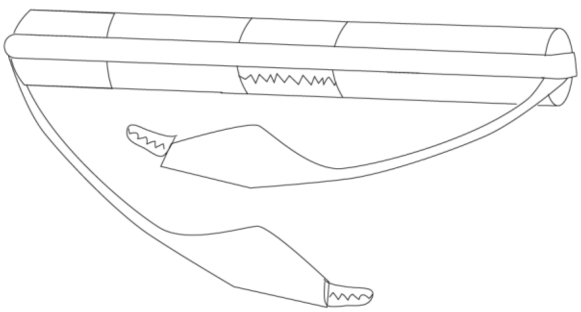
Let's Explore

In this part of the investigation, you will build different types of electric circuits.

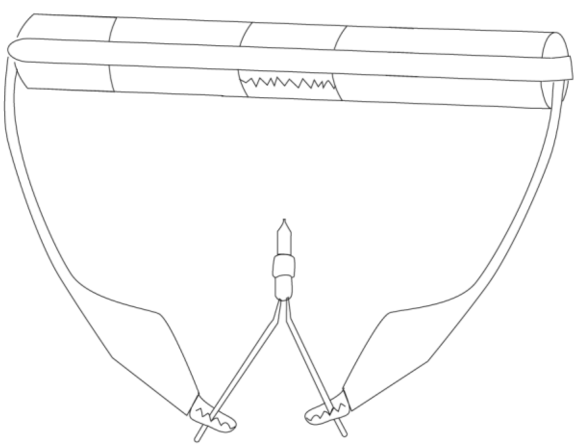
5. ☐ Connect the two AA cell batteries together using tape as shown below. The positive (+) end of one battery needs to connect to the negative (–) end of the other battery. Make sure you push the batteries together so that they are touching each other.



6. ☐ Connect the alligator clips using a rubber band to hold the wires against the ends of the batteries, as shown below. Make sure you have a good connection between the wires and your batteries.



7. ☐ Clip the alligator clips to a bulb.



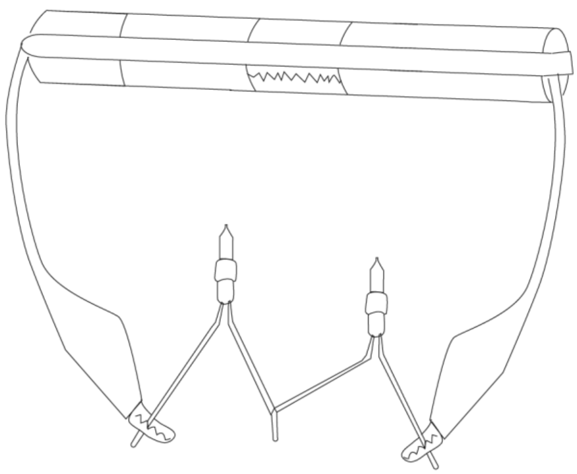
8. ☐ Look at the brightness of the bulb. Draw the brightness of the bulb. If it is very bright, draw a lot of light coming from the bulb. If it is dim, draw only a little light.

➢ Brightness of the bulb

Student drawings will vary, but should show that the light is bright.

Explain It

9. ☐ If you use two bulbs as shown in the picture below, what do you think would happen to the brightness of the bulbs? Darken the circle of the choice you think will happen.



Ⓐ The will be brighter

Ⓑ **They will be less bright**

Ⓒ They will be the same brightness

10. ☐ Add the second bulb as shown in the picture above and look at the bulb brightness.

11. ☐ Draw the brightness of the bulbs. If they are very bright, draw a lot of light coming from the bulbs. If they are dim, draw only a little light.

➢ Brightness of the two bulbs

Student drawings will vary. Students should show that the two bulbs are less bright than the previous example.

12. ☐ How did the brightness of each of the bulbs in the two-bulb circuit compare with the brightness of the one-bulb circuit?

Students should observe that each bulb in the two-bulb circuit is less bright than the bulb in the one-bulb circuit.

13. ☐ In your investigation of an electric circuit you learned some new scientific ideas and terms. It is important to be able to discuss your results using these words and terms correctly.

Write the meaning of the following terms in your own words using what you have learned from the activity.

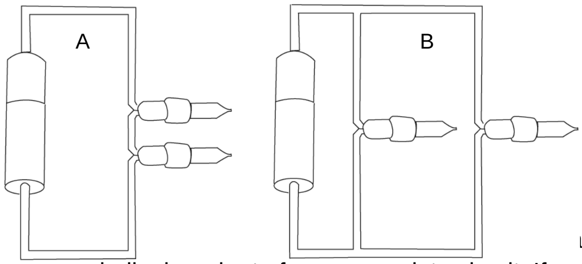
➢ Vocabulary and definitions

Electric circuit	A network that has a closed loop, giving a return path for the current; it contains a source, a load (resistor), connecting wires, and a switch
Electric conductor	A material allowing the movement of electric charges and current flow.
Parallel circuit	A circuit where two or more circuit components are connected like the rungs of a ladder; a parallel circuit provides the same voltage across all its components
Series circuit	A circuit where two or more circuit components are connected end to end like a daisy chain; a series circuit is a single path for electric current through all of its components
Voltage	The amount of electric potential energy given to charges moving through a circuit; one AA battery gives charges of about 1.5 volts

Tell Me More

Are there different ways to connect a circuit?

14. ☐ Two different circuits, each with two light bulbs, are shown below (labeled A and B). Describe some differences in the two circuits. Be prepared to share your findings with the class.



t in circuit A the electricity must pass through both light bulbs in order to form a complete circuit. If one of the bulbs is burned out (if its filament is not intact) then the circuit will not be complete and neither bulb will light. Students may point out that in circuit B one of the light bulbs may be burned out and the other bulb can still light because there is still a complete path or circuit for the electricity to flow through.

15. ☐ When bulbs are attached in one loop of wire it is called a "series circuit." Circuit A is an example of a series circuit. When bulbs are connected in separate loops of wire it is called a "parallel circuit." Circuit B is an example of a parallel circuit. Which circuit is like the one you have been using? Why?

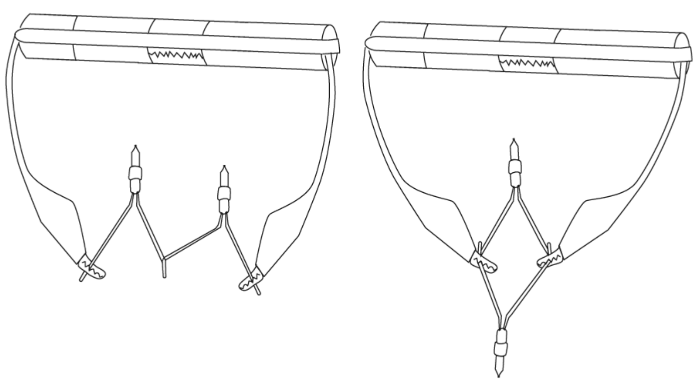
Students have been using a series circuit up to this point.

16. ☐ As a class, you are going to compare series circuits with parallel circuits. Ask your teacher which type of circuit your group should build and circle the circuit type you are building below.

- Our group is building a series circuit.
- Our group is building a parallel circuit.

17. ☐ Build your series or parallel circuit as shown in the pictures below.

Series　　　　Parallel



18. ☐ Get together with another group that is building a different type of circuit. Look at the brightness of the light bulbs in a series circuit and in a parallel circuit. Are the bulbs in each circuit the same brightness? If not, which circuit has brighter bulbs? Be prepared to share your results with the class

The bulbs in the parallel circuit are brighter

Sum It Up

Now you are going to measure voltages in your circuit. If you have been working with a parallel circuit, continue with the directions below for measuring voltage in a parallel circuit. If you have been working with a series circuit, skip down to the directions for measuring voltage in a series circuit below.

Measuring Voltage in a Parallel Circuit

19. ☐ Using the data collection system and voltage sensor, measure and record the voltage across the two batteries.

    Set up the data collection system to display voltage in a digits display:

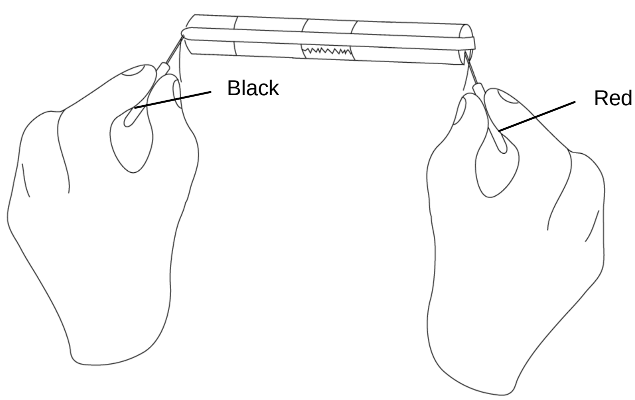
    a. Start a new experiment on the data collection system.

    b. Connect the voltage sensor to your data collection system.

    c. Create a digits display of voltage.

    d. Touch the red banana plug from the voltage sensor to the positive (+) side of the battery, and the black banana plug from the voltage sensor to the negative (–) side as shown.

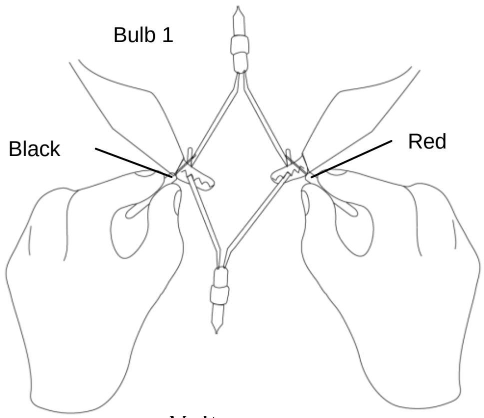
    e. Hold the banana plugs in place, and then begin recording a run of data.



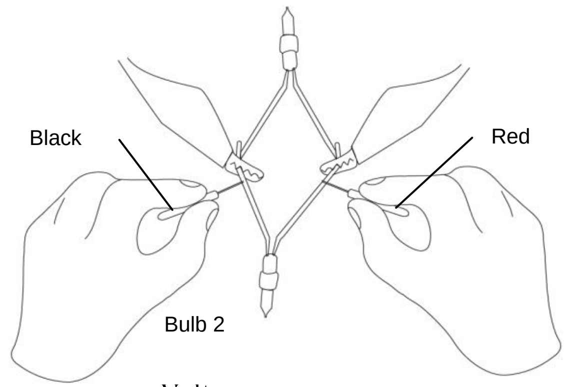
    f. Write down your battery voltage here:

       Battery Voltage: 3.05 volts

20. ☐ Now measure the voltage across each holiday bulb as shown below and record the values in the boxes below.



Voltage: 2.52 volts



Voltage: 2.54 volts

21. ☐ Compare the voltages across the batteries and the bulbs. What do you notice about the voltages?

    Answers will vary. One student group answered as follows: The voltage of our batteries was 3.05 volts, and we noticed that each bulb had 2.5 volts across it. Each bulb had the same voltage across it.

Measuring Voltage in a Series Circuit

22. ☐ Using the data collection system and voltage sensor, measure and record the voltage across the two batteries.

    Set up the data collection system to display voltage in a digits display:

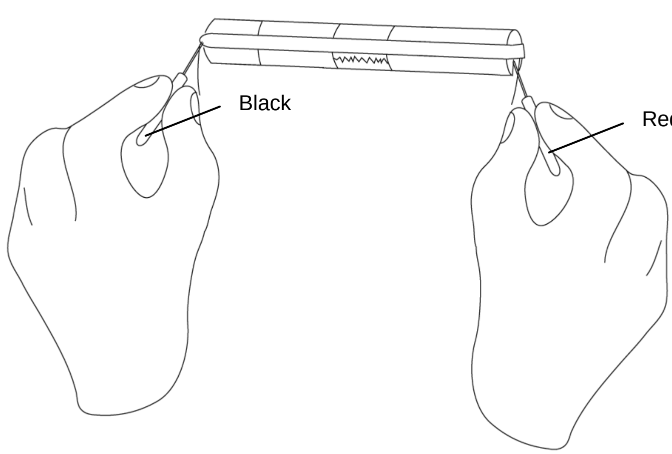
    a. Start a new experiment on the data collection system.

    b. Connect the voltage sensor to your data collection system.

    c. Create a digits display of voltage.

    d. Touch the red banana plug from the voltage sensor to the positive (+) side of the battery, and the black banana plug from the voltage sensor to the negative (–) side as shown.

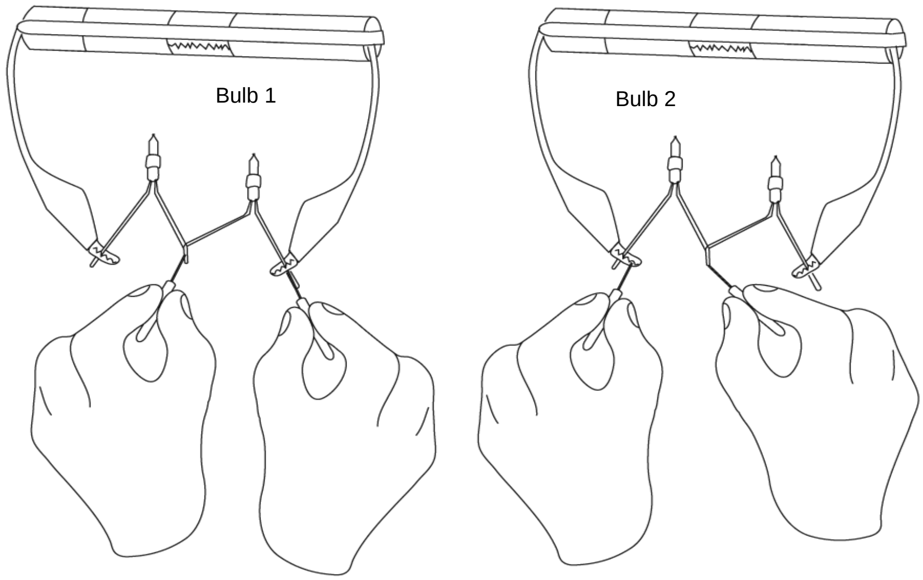
    e. Hold the banana plugs in place, and then record a run of data.



    f. Write down your battery voltage here:

Battery Voltage: 3.05 volts

23. ☐ Now measure the voltage across each holiday bulb as shown and record the values in the boxes below.



Bulb 1 Voltage: 1.55 volts

Bulb 2 Voltage: 1.26 volts

24. ☐ Compare the voltages across the batteries and the bulbs. What do you notice about the voltages?

Answers will vary. One student group answered as follows: The voltage of our batteries was 3.05 volts. The first bulb had 1.55 volts across it, but the second bulb only had 1.26 volts across it.

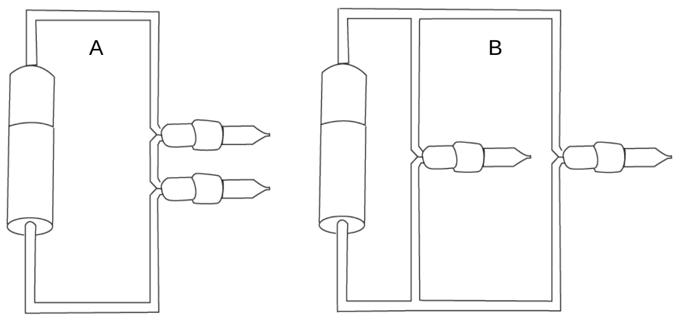
25. ☐ Get together with another group that measured voltage on a different type of circuit. Do the voltages look the same for each type of circuit? Explain. Be prepared to share your results with the class.

Answers will vary. One student group answered as follows: We found out that in the parallel circuit each bulb had about the same voltage drop. It was about 0.5 volts for each bulb because the battery was 3.05 volts and each bulb was about 2.5 volts. In the series circuit the battery was 3.05 volts also, but the voltage drop across both bulbs was 2.8 volts. This was not shared equally between the bulbs. The first bulb had a drop of 1.55 volts, and the second one had a drop of 1.26 volts.

26. ☐ How do the voltages measured compare with the brightness of the holiday bulbs in series and parallel circuits? Be prepared to share your results with the class.

Answers will vary. One student group answered as follows: The voltages measured across the bulbs in the parallel circuits were higher. The voltages measured across the bulbs in the series circuit were not as high as the parallel circuit. The bulbs in the parallel circuit were brighter than the bulbs in the series circuit.

27. ☐ Darken the circle of the choice for the circuit below that will light the holiday bulbs the brightest if each of the AA batteries is new.



Ⓐ Circuit A

Ⓑ **Circuit B**

28. ☐ Suppose you had two AA-cell batteries and two holiday bulbs and you wanted to make as much light as possible with a circuit. How would you make your circuit? Describe your design in words below.

Students should describe a parallel circuit with two batteries connected, and the two bulbs wired like rungs of a ladder. They should describe each bulb as having its own path for electricity to complete the circuit.

29. ☐ Make a drawing below, with labels, of your circuit.

➢ Our circuit that makes as much light as possible

Drawings will vary. Students should show two batteries connected, with the bulbs wired in parallel.

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. A complete path for charges to move from one terminal of a battery to the other is called

   Ⓐ A wire

   Ⓑ **A current loop**

   Ⓒ An electric loop

2. We used the ________________ to measure the voltage across the holiday light bulbs.

   Ⓐ Voltage sensor

   Ⓑ **Resistor**

   Ⓒ Alligator clips

Key Term Challenge

Fill in the blanks from the list of randomly ordered.

switch	connecting wires	battery	series
parallel	light bulb	voltage	charges

1. A ______parallel___________ circuit has separate paths for electric current to flow through, while a _______series___________ circuit has only one path for the electric current to flow through.

2. A circuit can be opened and closed with a __________switch_________ .

3. To construct an electric circuit, use _______connecting wires________, a __battery____and a light bulb______to make a loop or path for the electric current to flow through.

4. The ________voltage__________ sensor measures how strong a battery is.

5. A battery is the source of the __________charges_________ in the circuits we made in this activity.

Further Investigations

Investigate whether it is possible to use a different charge producer in students' series or parallel circuits. Have students try using a solar panel or a hand-crank generator as the charge producer for each circuit.

Provide students with red or green light emitting diodes (LEDs) to use as circuit elements. An LED allows electric current to travel in one direction only. Use the LED to test the direction of current in each circuit.

20. What Is an Electromagnet?

Recommended Grade Levels: 4 – 5

Objectives

Students learn how to build an electromagnet. They also:

- Understand that electric energy from a battery in a circuit can produce magnetic effects
- Can predict what will happen if they increase the number of coils around the nail or batteries in the circuit

Procedural Overview

To understand this content, students

- Construct a simple electromagnet and observe its behavior when the circuit is open and closed
- Observe the strength of the electromagnet after changing the voltage across it or number of coils around it

Time Requirement

Teacher Preparation	20 - 30 minutes
Pre-Activity Discussion	15 minutes
Get Started	10 minutes
Let's Explore	30 minutes
Explain It	20 minutes
Tell Me More	20 minutes
Sum It Up	15 minutes

Materials

- ☐ Data collection system
- ☐ Voltage sensor
- ☐ AA-cell battery (2)
- ☐ Paper clip (10 to 15)
- ☐ Alligator clip (2)
- ☐ Scissors
- ☐ Masking tape, ~20 cm
- ☐ Large iron nail, 3 to 4 inches long
- ☐ Insulated bell wire, 22 to 26 gauge, 1 m with ends stripped of insulation for 5 cm

Activity at a Glance

Get Started

- ☐ Students list different uses for magnets.
- ☐ Students describe the properties of magnets and discuss how they know if an object is magnetic or nonmagnetic.

Let's Explore

- ☐ Students construct an electromagnet using a length of insulated wire, an iron nail, and one or two AA batteries.
- ☐ To prepare for measuring the voltage, they connect the leads of the voltage sensor to their circuit on either side of the battery.

Explain It

- ☐ Students use their electromagnets to find the relationship between open and closed circuits, electricity, and magnetism (only when electricity is flowing in a closed circuit is magnetism produced).
- ☐ This section highlights the difference between open and closed circuits.
- ☐ Vocabulary words: circuit, electromagnet, switch, magnetic, and coil

Tell Me More

- ☐ Students investigate ways to increase the strength of their electromagnets, possibly by adding another battery or by adding more turns of wire to the coil, or both.

Sum It Up

- ☐ Students analyze the results of the activity and answer the driving question,

Safety

Add these important safety measures to your normal classroom procedures:

- Do not connect the terminals of the battery directly with a wire. This will cause a short circuit and the battery and wire may become hot enough to burn you.
- Use caution when working with sharp objects.

Preparation

These are the materials and equipment to set up prior to the activity.

- Cut lengths of wire for each student group. Cut wire can be wound around an index card or your hand to facilitate its storage until student use.
- Strip the insulation from the ends of wires students will use.
- Set up the data collection system to demonstrate how to obtain the voltage.

  1. Set up a digits display of temperature:

a. Start a new experiment on the data collection system.

b. Connect the voltage sensor to your data collection system.

c. Monitor live data.

d. Display voltage in a meter display.

2. If possible, connect the data collection system to your classroom projection system.

Background

A straight current-carrying wire produces a magnetic field encircling the length of the wire. When that current-carrying wire is wound into coils forming a solenoid, the magnetic field inside and outside the solenoid changes in strength and becomes more uniform, resembling the magnetic field of a bar magnet. Placing a substance like iron inside the solenoid also affects the magnetic field strength, inducing a magnetic field inside the iron and adding to the field strength from the solenoid.

The result is a stronger electromagnet whose magnetic field strength is dependent on the amount of current flowing through the solenoid coils, the number of turns in the coil, and the magnetic properties of the substance inside the solenoid core. Iron, although naturally un-magnetized, proves to be a very strong magnet when in the presence of an external magnetic field.

Pre-Activity Discussion

1. Ask students to list different uses for magnets. Have them describe the properties of magnets and discuss how they know if an object is magnetic or nonmagnetic. You might elaborate on the question by asking students to break it into sub-questions, such as:

   Q How many shapes and sizes do magnets come in?

   Q What happens when two magnets are placed near one another?

   Q Are magnets attracted to all materials or just to some?

   Q Is a magnet always magnetic or are there times when it "loses" its magnetism?

   Q What are the parts of an electric circuit?

Teacher Tip: To answer these questions, ask the students to think about toys they have played with that use magnets or magnetism. Some toys use both the attraction and repulsion of magnets, while others depend on the magnets sticking together. Ask students to discuss the different types of refrigerator magnets they have seen, as well as what kinds of surfaces these will stick to.

2. Demonstrate the use of the data collection system for measuring voltage.

Driving Question

Can electricity create a magnet?

Variables

Independent Variable

- Both the number of batteries used and the number of turns of wire around the iron nail are the independent variables.

Dependent Variables

- The number of paper clips the electromagnet attracts is the dependent variable.

Controlled Variables

- The type of core in the coil is our controlled variable in this experiment. Different core materials in an electromagnet will change its strength. In this experiment the same nail will be used as the solenoid core throughout all trials.

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

1. ☐ What are some different uses for magnets? What are some examples of toys or devices that use magnets?

   We use magnets to attach papers and other things to metallic surfaces. Compasses use magnetic needles to seek north. Magnets can be used to pick up small objects such as dropped sewing pins and needles. Some devices that use magnets include electric can openers, electric motors and generators (which are used in many other devices). Toys such as wooden trains and building sets use magnets to connect or hook parts together.

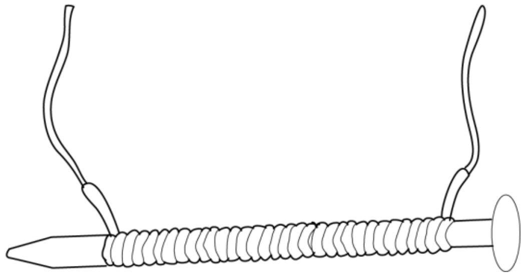
2. ☐ What are the parts of an electric circuit?

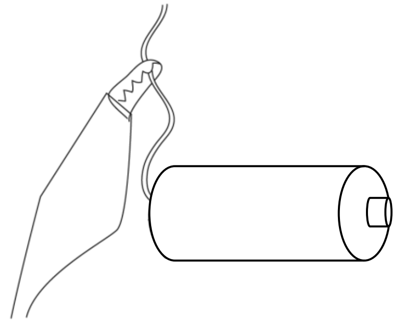
   An electric circuit has a source of energy (a battery), connecting wires, a load or resistance of some type, and a switch.

Let's Explore

In this part of the activity you will construct an electromagnet using a nail, a long piece of wire, and one AA battery.

3. ☐ While keeping about 10 cm of wire free on the starting end, begin winding your long wire neatly in a coil around the nail. Leave about 40 cm of wire free on the other end. Try to make the turns of wire in your coil as close together as possible, and as neat as possible, as shown in the illustration below.





Teacher Tip: Make sure that enough insulation has been removed from each end of the wire (about 5 cm or 2 in.) to allow for room for the voltage lead alligator clips to be connected to the wire on each side of the battery.

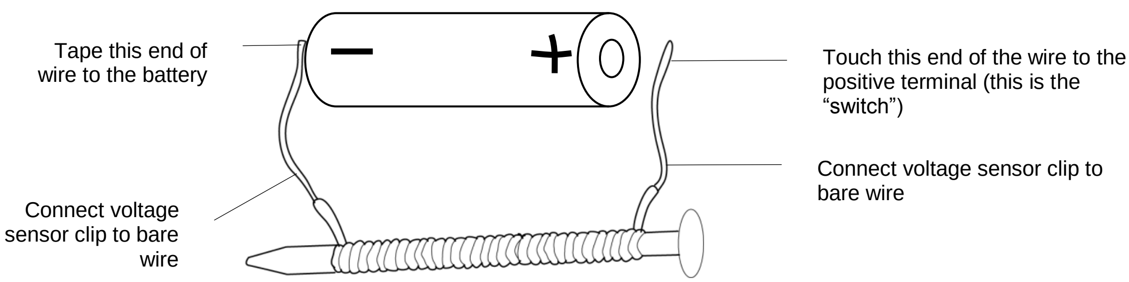
4. ☐ Start a new experiment on the data collection system.

5. ☐ Connect a voltage sensor to the data collection system.

6. ☐ Display voltage in a meter display.

7. ☐ Use a piece of tape to connect one end of the wire coil to the negative end of the battery.

8. ☐ Use an alligator clip adapter to connect the black lead from the voltage sensor to the bare part of the coiled wire where it connects to the battery.



9. ☐ Use an alligator clip adapter to connect the red lead clip of the voltage sensor to the other end of the coiled wire.

   Note: You will touch this wire to the positive end of the battery to close the circuit. This is your circuit's switch.

10. ☐ Monitor live voltage data.

11. ☐ Touch the wire to the positive end of the battery and place the pointed tip of the nail near some paper clips.

12. ☐ Are the paper clips attracted to the nail? Can you pick up a paper clip from the table?

   Students should be able to attract and pick up one or more paper clips to the tip of the nail.

Explain It

13. ☐ Open and close the switch in your electromagnet circuit. As you do, observe the change in voltage across the circuit.

14. ☐ How does the voltage change when the switch is open and closed?

Answers will vary. One student group answered as follows: When the switch is open the voltage is zero volts. When the switch is closed the voltage is 1.3 volts.

15. ☐ How does the electromagnet's ability to attract paper clips change when the switch is opened and closed?

Answers will vary. One student group answered as follows: When the switch is open, the electromagnet will not pick up any paper clips. When the switch is closed it will pick up three paper clips.

16. ☐ In your investigation of electricity and magnetism you learned some new scientific ideas and terms. It is important to be able to discuss your results using these words and terms correctly.

Write the meaning of the following terms using what you have learned from the lab.

Vocabulary and definitions

Circuit	A path for electricity to flow through. It consists of a source, a load, wires, and a switch.
Electromagnet	A magnet made of a coil of wire that is magnetized only when electricity flows through it
Switch	A way of opening and closing a circuit
Magnetic	Able to be attracted by a magnet
Coil	Wire that has been wound into many loops

Tell Me More

17. ☐ What would happen to the strength of your electromagnet if you connected it to two batteries? How would the voltage of your circuit change if you used two batteries instead of one? Write your prediction in the space below.

Teacher Tip: Focus attention on the students' predictions without telling students the right answer.

Answers will vary. One student group answered as follows: We think our magnet will be stronger with two batteries. We think we will measure higher voltage with two batteries than with one.

18. ☐ Connect a second battery to your circuit. Use tape to hold the negative end of the second battery to the positive end of the first battery.

Teacher Tip: When students are ready to connect their batteries together, show them how to use tape to join the positive terminal of one battery to the negative terminal of the second battery. Tape the batteries down to the desk to prevent them from rolling while students are measuring their voltages.

19. ☐ Try your electromagnet by closing the switch. See how many paper clips your electromagnet can pick up. How does this compare to your electromagnet with only one battery in the circuit?

    Students should be able to attract and pick up about twice as many paper clips with their electromagnet.

20. ☐ Monitor live voltage data.

21. ☐ Open and close the switch in your electromagnet circuit. As you do, observe the change in voltage across the circuit.

22. ☐ How does the voltage change when the switch is open and when it is closed?

    Students should measure twice the voltage with two batteries in their circuit.

23. ☐ Besides using additional batteries, can you think of any other way to increase the strength of your electromagnet? Write your idea below.

    Winding more turns of wire in the coil around the nail will increase the strength of the electromagnet.

24. ☐ Try your idea for increasing the strength of your electromagnet. What was the result?

    More turns in the coil result in a stronger electromagnet.

Sum It Up

25. ☐ How did the number of batteries used affect the strength of your electromagnet?

    The more batteries are used, the stronger the electromagnet is.

26. ☐ Can electricity make a magnet?

    Yes, electricity flowing through wire wrapped around an iron nail turns the nail into a magnet.

27. ☐ If you needed to build an electromagnet that could pick up a heavy, metal object such as a car, would it be better to design it with fewer or with more turns of wire in its coil?

    It would be better to design such an electromagnet with more turns of wire.

28. ☐ An electromagnet is part of an electric circuit. What evidence did you have from the voltage sensor that the electromagnet works only when the circuit is closed?

    Answers will vary. One student group answered as follows: When our circuit's switch was open and electricity could not flow in the circuit, the voltage was zero and our electromagnet stopped working. We know it stopped working because it dropped the paper clips.

29. ☐ Can you turn off the magnetism of an electromagnet? If so, how can this be done?

    To turn off the magnetism in an electromagnet, you open the switch (open the circuit).

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. A magnet made of a coil of wire with electricity flowing through the coil is called a/an

   Ⓐ Permanent magnet

   Ⓑ **Electromagnet**

   Ⓒ Refrigerator magnet

2. When the voltage is zero there is

   Ⓐ **An open switch in the circuit with the electromagnet**

   Ⓑ A closed switch in the circuit with the electromagnet

   Ⓒ Two closed switches in the circuit

True or False

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

___T___ 1. A circuit contains a source of electricity, connecting wires, a load, and a switch.

___F___ 2. A coil of wire always makes magnetism, even when no electricity flows in the coil.

Key Term Challenge

Fill in the blanks from the list of randomly ordered words.

switch	wires	load	coil
source	flow	conductor	insulator

1. A ___conductor___ is a material through which electricity can easily flow.

2. When electricity flows through a ___coil___ of wire, an electromagnet is formed.

3. The ___switch___ of an electric circuit must be closed in order for electricity to flow.

21. Determining Sound Levels

Recommended Grade Levels: 4 – 5

Objectives

Students learn that sound is produced by vibrating objects, that sound travels from a source through air, solids, and liquids, and its loudness depends on the size of its vibrations.

Procedural Overview

To understand this content, students:

- Build a simple drum and use it to make vibrations that can be seen
- Make sounds with objects and measure the sound levels with a sound sensor
- Examine evidence and data to draw conclusions that relate vibrations to sound levels

Time Requirement

Teacher Preparation	10 - 15 minutes
Pre-Activity Discussion	15 minutes
Get Started	15 - 20 minutes
Let's Explore	10 minutes
Explain It	10 - 15 minutes
Tell Me More	10 minutes
Sum It Up	15 minutes

Materials

- ☐ Data collection system
- ☐ Sound level sensor
- ☐ Tin can, open at both ends
- ☐ Pliers (teacher use only)
- ☐ Can opener (teacher use only)
- ☐ Rubber band (2–3)
- ☐ Balloon, cut open to make a drumhead
- ☐ Water, ~300 mL
- ☐ Scissors
- ☐ Paper clip
- ☐ Square plastic food storage container
- ☐ Paper or plastic cup, 350-mL (12-oz)
- ☐ Notebook or copy paper (3–4 sheets)
- ☐ Drinking straw
- ☐ Paper towel (2-3 sheets)

Activity at a Glance

Get Started

- ☐ Students build a drum using a tin can (open at both ends), a balloon, and a rubber band.
- ☐ They investigate the vibrations of the drumhead and how the sound intensity is related to the size of the vibrations, as students try to make a paper clip "jump" off the drumhead.
- ☐ Students predict which objects will make sound by vibrating.

Let's Explore

- ☐ Students make sound with a sheet of paper, a cup of water and a straw, a pair of stretched rubber bands, and with a balloon drum. They record the intensity of each sound with the sound level sensor.
- ☐ Students examine sound data and identify which sounds were the loudest.
- ☐ Students describe sound data and consider how the objects vibrated to make the sounds.

Explain It

- ☐ Students make vibrations that produce sounds that last for several seconds.
- ☐ Review the following vocabulary with the students: vibration, sound level sensor, decibels, loudness, and sound.

Tell Me More

- ☐ Students study the structure of a human ear and how we hear with our ears open and covered.
- ☐ Students use cupped hands around the ears to make "deer ears" and practice using the deer ears to amplify sounds.

Sum It Up

- ☐ Students discuss observations and results in order to draw conclusions about making and hearing sound.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

- Use a can opener to remove the tops and bottoms from tin cans as necessary. If you have asked students to bring cans from home, check to be sure the cans are open at both ends.

  Note: In all cases, make sure there are no sharp metal pieces protruding from the rim. Use the pliers to flatten or remove any sharp areas.

- Cut the necks off the balloons for students. Try stretching a balloon tautly over a tin can to see how this works so you can demonstrate this step for your students. It is possible that students will not need to use a rubber band to hold the balloon in place as a drumhead if the balloon fits tightly over the can.

- Make one balloon drum ahead of time to show students.
- Set up the data collection system

  Begin a new experiment on the data collection system.

  Connect the sound level sensor to the data collection system.

  Begin data recording.

Background

The Making and Hearing of Sound

The way in which sounds travel through air (pressure variations) is less important at this age than the fundamental idea that sounds are regular vibrations. Something must be moving back and forth in a regular way to make a continuous sound. The faster it vibrates (the greater the frequency), the higher the pitch of the sound, while the larger the vibration (the greater the amplitude), the louder the sound. The more energy that is put into each vibration, the louder the sound.

Humans hear sound when our ears convert air vibrations into nerve signals that travel to the brain. Sound vibrations travel down the ear canal and cause the eardrum to vibrate. The eardrum is a thin membrane connected to tiny bones that transmit the vibrations at the eardrum to the auditory nerves that send the signal onto the brain. Things that vibrate within our range of hearing (30 to 15,000 vibrations per second, or hertz Hz) and transmit that vibration to the air around them make sounds that we can hear.

Vocal cords moving back and forth cause pressure variations in the air. These pressure variations travel in the air and make the ear drum move when they arrive there. Young students may not understand pressure, although they may have noticed that sounds travel through solid things and through water. A way to describe it more simply is to say that the vibrations cause disturbances in the air as well as in solids or liquids. These disturbances travel through the medium and cause a disturbance when they arrive at something that can vibrate, such as the surface of a drum.

Students at this age often learn about sound in the context of musical instruments and how the different types of instruments work to produce sound. It is important for students to have experiences with sound and making sound that are generalized and not limited only to this context. In this activity, two of the items used to make sound are models of musical instruments (the balloon drum and the stretched rubber bands). The other two items are unrelated to musical instruments and do not model musical sounds (the cup of water and the sheet of paper). This will help students see vibrations and sound in a larger context.

The Sound Level Sensor and Decibels

The sound level sensor displays measurements in units called decibels, and abbreviated dBA. The “A” in the abbreviation indicates that this is the “A-weighted” scale or system. Decibels are an expression of the relative loudness of sounds in air as perceived by the human ear. In the A-weighted system, a correction is made at low frequencies because the human ear is less sensitive below about 1000 Hz than it is at higher frequencies.

Decibels are defined in terms of power per unit of surface area, on a scale where zero decibels is just at the threshold of human hearing, up to the threshold of pain, which is considered to be between 120–140 dB.

The following table gives some sound levels for a variety of situations.

Sound	Decibels (dBA)
Threshold of human hearing	0
Rustling leaves	10
Whisper	10 to 20
Very soft music	30
Classroom	35
Average home	40 to 60
Conversation	60 to 70
Heavy street traffic	70 to 80
Vacuum cleaner	75 to 85
Hair dryer	85 to 90
Chain saw	100 to 110
Ambulance siren	150
Rocket engine	200

Pre-Activity Discussion

Begin by asking students how they make sounds (they use their vocal cords and breath), how they hear sounds (eardrums), and how the sound gets from one to the other (vibrations that travel through the air). Students cannot observe their vocal cords and eardrums directly, but they can build a comprehensible model of each.

You might elaborate on the question by asking students sub-questions, such as:

- Can you feel the vibrations coming from your voice?
- How do you think the vibrations get from your mouth to the eardrum?

Show students a balloon drum and a stretched rubber band. Explain to the students that the balloon drum and the stretched rubber band are models of the eardrum and the vocal cords.

Students can observe that the tightening of rubber bands changes the sound, as it does with vocal cords. They can observe that the stretched balloon vibrates in response to sounds, and can make something move that touches it (a paper clip), as does the eardrum. Make sure that all of the students locate their vocal cords and feel them vibrating.

Share with students that a scale has been developed to measure the loudness of different sounds. The loudness of a sound is measured in units called decibels (dBA). A sound with the intensity level of 0 decibels is so soft that it cannot be heard. Thunder has an intensity of 120 decibels. Sounds with intensities louder than 120 decibels can actually cause pain to humans.

Driving Question

- How do we make sounds and how do we hear sounds?

Variables

Independent Variable

- The amount of energy added, and therefore the size of vibration (the amplitude) of the medium, is the independent variable throughout this activity.

  Teacher Tip: The particular object being vibrated (balloon, rubber band, paper, water) may be mistaken for the independent variable. However, since each of these objects ultimately causes pressure variations or vibrations in the air, this is not an independent variable, strictly speaking. Each vibrated object is essentially a new experiment in which the same phenomenon is being tested.

Dependent Variables

- In this activity the dependent variable is the sound intensity level, or loudness of sound produced by vibrating various objects.

Controlled Variables

- In this activity the distance of the sound-producing object from the sound sensor is controlled.

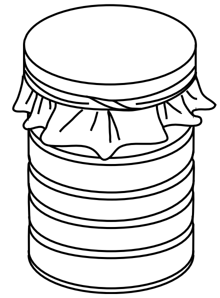
Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

Sounds come from things that vibrate. A vibration is something moving back and forth in a regular way. Some things vibrate and make sounds that we can hear. All musical instruments have some part of them that vibrates and makes the musical sound. You can see how sounds are vibrations by building a model.

1. ☐ Build a balloon drum by stretching a balloon over one end of a tin can that has both ends open as shown above. Stretch the balloon tight and hold it in place by putting a rubber band around the edge if necessary.



2. ☐ Talk into the open bottom of the tin can while touching the balloon.

   What does your voice do to the stretched balloon?

   Students should observe that the sound of their voice causes the balloon to vibrate.

   Can you feel the vibrations coming from your voice?

   Answers will vary.

   How do you think the vibrations get from your mouth to the drum?

   The vibrations travel through the air.

3. ☐ Talk into the open bottom of the tin can after placing a paper clip on the drumhead. Can you make the paper clip move? Can you make the paper clip jump off the drum?

   Students should be able to make the paper clip move and jump off the drum by speaking louder, as necessary.

   Teacher Tip: Make sure that every student has a chance to use his or her voice to make a paper clip bounce around on the balloon drum.

4. ☐ Your voice makes the drumhead vibrate up and down. These vibrations are very fast, and they make sounds that we can hear. How do you think the sound of your voice moves the paper clip?

   The vibrations caused by students' voices travel through the air to reach the balloon drumhead, which vibrates in response. The paper clip is moved along with the drumhead.

5. ☐ Predict which objects will make a sound by vibrating. Record your prediction in the table below by writing "yes" or "no" in the appropriate column. Be prepared to explain your answers.

➢Predictions

Objects That Make a Sound	**Will Sound Be Made by Vibrations?**
Sheet of paper	yes
Water in a cup	yes
Rubber band	yes
Balloon drum (from Get Started)	yes

6. ☐ For each of the items listed in the table above, think about how it can be used to make a sound. Will it make a short and quick sound only, or can it be used to make a longer,

drawn out sound that lasts for several seconds? Discuss your ideas with the members of your group. Be prepared to share your ideas with the rest of the class.

Answers will vary. Students may suggest that the paper may be crumpled, torn, held taut and tapped like a drum, or rolled into a tube and tapped or blown into. The water may be sloshed, stirred with the straw, or air may be bubbled into the water through the straw. The rubber band may be plucked, snapped, or stretched over a container and plucked. Some students may suggest that the rubber band may be scraped or rubbed, similar to a violin string. The balloon drum may be tapped or the balloon may be rubbed.

Let's Explore

7. ☐ Start a new experiment on the data collection system.

8. ☐ Connect a sound level sensor to the data collection system.

9. ☐ Display the data in a graph display with Sound Level on the y-axis and Time on the x-axis.

   Teacher Tip: You may want to review with the students the units in which sound intensity is measured. A scale has been developed to measure the loudness of different sounds. The loudness of a sound is measured in units called decibels (dBA). A sound with the intensity level of 0 decibels is so soft that it cannot be heard. Thunder can have an intensity of 120 decibels. Sounds with intensities louder than 120 decibels can actually cause pain to humans.

10. ☐ Begin data recording.

11. ☐ Use a sheet of paper to make sound for 30 seconds. Be sure to hold the paper near the sound sensor as you make sounds. Try as many different ways to make sound with one sheet of paper as you can think of.

12. ☐ Stop data recording.

13. ☐ What was the maximum sound level you were able to record?

    Maximum sound level: 86 dBA

14. ☐ Fill a paper or plastic cup about half full with water, and place a straw into the water.

15. ☐ Begin data recording.

16. ☐ Use the straw and the cup of water to make sound for 30 seconds. Be sure to hold the cup near the sound sensor as you make sounds. Try as many different ways to make sound with the cup of water as you can think of, but be careful that you do not make sound with your voice.

17. ☐ Stop data recording.

18. ☐ What was the maximum sound level you were able to record?

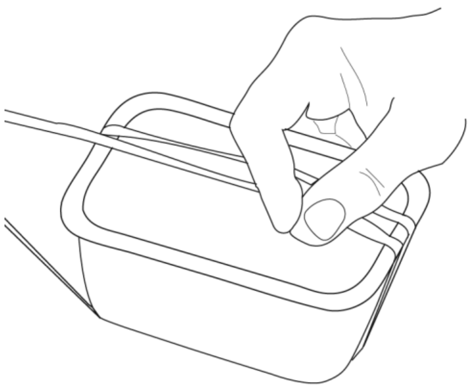
Maximum sound level: 84 dBA

Why was it important not to make sound with your voice?

It is important not to use your voice to make sound because that is not what is being tested. We are trying to measure the sound level of running, bubbling, or dripping water only.

19. ☐ Stretch two rubber bands around a plastic food container, as shown in the illustration below.

Note: Make sure the rubber bands are far enough apart so you can touch one without disturbing the other.



20. ☐ If you have data runs on your graph display, you may choose to hide them.

21. ☐ Begin data recording.

22. ☐ Use the rubber bands to make repeated, quick sounds for 30 seconds. Be sure to hold the stretched rubber bands near the sound sensor as you make sounds.

23. ☐ Stop data recording.

24. ☐ Describe how you made the sounds you just recorded.

Answers will vary. Students should describe plucking, tapping, snapping, or “twanging” the rubber bands either individually or both at the same time.

25. ☐ Begin data recording.

26. ☐ Use the balloon drum to make repeated, quick sounds for 30 seconds. Be sure to hold the drumhead near the sound sensor as you make sounds. Be careful to avoid breaking or tearing the balloon drumhead.

Teacher Tip: Students may have difficulty working carefully enough, and may pop or tear the balloons. Have replacement balloons ready ahead of time in case of breakage.

27. ☐ Stop data recording.

28. ☐ Review your data. You may need to show hidden runs of data, or adjust the scale of the graph. Describe what your sounds look like on the graph.

Answers will vary. Students should observe that the short sounds they produced with their objects resulted in spikes or peaks in their data.

29. ☐ You recorded sound level data for several sounds. Which of the sounds were made by vibrating objects? Which of the objects disturbed the air and caused the air to vibrate?

All of the sounds were made by vibrating objects. All of the objects disturbed the air, causing it to vibrate. Students may have difficulty recognizing that vibrations were produced by the paper and the water in the cup.

Explain It

In this part of the activity you will use the rubber bands, the balloon drum, and a sheet of paper to make sounds that last for several seconds.

30. ☐ Review with your group members your ideas about how the rubber bands, the balloon drum, and a sheet of paper can be used to make sound that lasts for several seconds.

31. ☐ When you have decided how to make sound with the objects, begin data recording.

32. ☐ Use the rubber bands to make long, drawn out sounds for 30 seconds. Be sure to hold the rubber bands near the sound sensor as you make these sounds.

33. ☐ Stop data recording.

34. ☐ Begin data recording.

35. ☐ Use the balloon drum to make long, drawn out sounds for 30 seconds. Be sure to hold the drum near the sound sensor as you make these sounds.

36. ☐ Stop data recording.

37. ☐ In your investigation of how we make and hear sounds, you learned some new scientific ideas. These ideas have their own terms. In science it is important to be able to discuss your results using these words and terms correctly.

Write the meaning of the following terms in your own words using what you have learned from the activity.

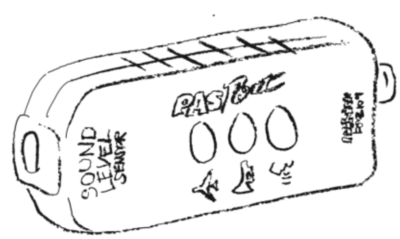
➢ Vocabulary and definitions

Vibration	Movement that happens rhythmically and steadily back and forth in a regular way
Sound level sensor	Tool used to measure the loudness or intensity of a sound
Decibels	The unit that describes the intensity of sound
Loudness	The amount of volume or intensity of a sound
Sound	A vibration that disturbs the air and our ear drums so our brain can perceive it

38. ☐ Illustrate two terms of your choice in the spaces below.

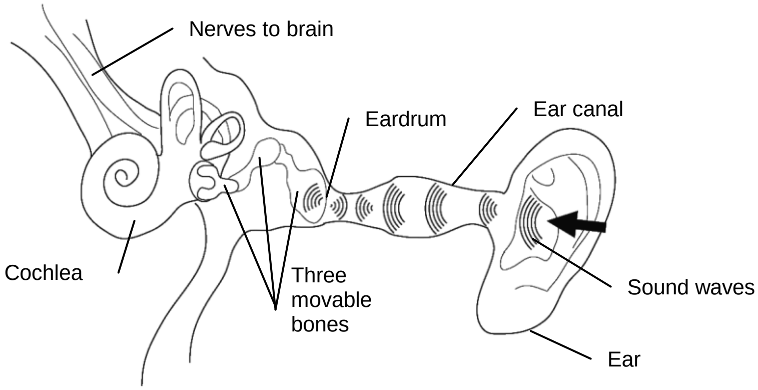
➢ Word: Vibration.

➢ Word: Sound level sensor.



Tell Me More

39. ☐ Your eardrum is a piece of skin just like a stretched balloon. It vibrates when sounds reach your ear. Bones that touch the eardrum carry the vibrations to your inner ear, where they are detected and translated into signals to the brain. Here is a diagram of the ear.



- Why are sounds not as loud when you cover your ears?

Sounds are not as loud when we cover our ears because our hands absorb most of the vibrations before they get to our ear drums.

40. ☐ Cup your hands behind your ears. What do you notice about the sounds you hear with your hands cupped behind your ears, compared to what you hear normally? Why do you think this is the case?

Students should be able to observe that they perceive sounds as being louder when they cup their hands around their ears. This is the case because more air is funneled toward our ear canals, so larger vibrations reach our ear drums.

41. ☐ Imagine yourself as a deer, grazing for your meal in the forest or in a field. You need to be constantly alert for any sounds of danger. Fortunately, nature has equipped you with large ears which you can swivel around to help you hear sounds from all directions.

Experiment with your "deer ears" as follows:

- Use your cupped hands to point your deer ears behind you.
- Point one deer ear in front of you and one behind you.
- Slowly turn in a circle with your deer ears pointing in front of you.

42 ☐ What did you hear? Describe your "deer hearing" results.

Answers will vary. Students should notice a marked amplification of sound intensity in the direction they pointed their cupped hands and ears ("deer ears").

Sum It Up

43. ☐ Imagine that you are sitting in a large room with many people, and it is supposed to be very quiet. Then, from across the room, you hear the faint sound of a piece of candy being unwrapped. Who ever is unwrapping the candy must not want to be noticed, because he tries to do it as quietly as possible.

Describe this sound using the words "intensity" and "vibration" in your description.

Answers will vary. One student group answered as follows: The candy wrapper makes a soft rustling sound with a low sound intensity. The paper or plastic candy wrapper caused a vibration in the air. It was a small vibration but enough to reach our ears.

44 ☐ Which of the objects in your prediction in the Get Started section of the activity caused vibrations that traveled through the air and into your ears where it vibrated your ear drums?

All of the objects caused vibrations that traveled through the air and caused our eardrums to vibrate.

45. ☐ Which of the objects most resembles a musical instrument? Which instrument does it resemble?

Students should suggest that the balloon drum or the rubber bands most resemble musical instruments. The balloon drum is literally a miniature drum. The stretched rubber bands resemble guitar strings (a guitar).

46. ☐ Which of the objects least resembles a musical instrument? Explain why you think this.

Answers will vary. Students should suggest that the paper least resembles a musical instrument. Possible explanations may include: No instruments make use of crumpling or tearing to make sound, the paper itself gets "used up" or ruined and can't be used over again for repeated trials.

47. ☐ How do we make sounds?

We make sounds by causing something to vibrate.

48. ☐ How do we hear sounds?

We hear sounds when a vibrating object causes our ear drum to vibrate. This happens when the air in our ear canal has vibrations transmitted to it.

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. A vibration is a

Ⓐ **Regular, repeated back and forth motion**

Ⓑ Random motion

Ⓒ Repeated but unpredictable motion

Ⓓ Back and forth motion that happens once

2. We used the ____________________ to measure the sound level made by crumpling paper and blowing into water with a straw.

Ⓐ **Sound level sensor**

Ⓑ Vibrations

Ⓒ Deer ears

Ⓓ Decibels

3. The intensity of sound, or its loudness, is measured in units called

   Ⓐ Vibrations

   Ⓑ Disturbances

   Ⓒ **Decibels**

   Ⓓ Intensities

4. We hear sound when

   Ⓐ Vibrations are not allowed to reach our ear drums

   Ⓑ **Vibrations are able to reach our ear drums**

   Ⓒ Sound levels are below zero decibels

   Ⓓ There are no vibrations of any kind

5. Which of the following has measurements in order from quietest to loudest?

   Ⓐ 50 decibels, 25 decibels, 100 decibels

   Ⓑ 100 decibels, 33 decibels, 71 decibels

   Ⓒ 80 decibels, 15 decibels, 0 decibels

   Ⓓ **3 decibels, 40 decibels, 80 decibels**

6. Suppose you measure two sounds with a data collection system, and find the level of one sound to be 5 decibels and the level of the second sound to be 75 decibels. Which of the following may be true?

   Ⓐ The first sound could be a dog barking loudly, and the second sound could be a leaf falling from a tree

   Ⓑ The first sound could be a leaf falling from a tree and the second sound could be a whispering voice.

   Ⓒ The first sound could be a hair dryer and the second sound could be a whispering voice.

   Ⓓ **The first sound could be a leaf falling from a tree and the second sound could be a hair dryer**.

Further Investigations

If there are any musicians in the class, have them demonstrate their instruments. Measure the range of sound levels of the instrument and show the graph of the sounds with the sound level sensor.

Have students research which occupations have hearing damage or hearing loss as an occupational hazard. How are workers protected from hearing damage? What is the intensity of the sound to which the employees are exposed?

Some studies show that personal music systems can lead to hearing damage. Have students test their music players with the sound level sensor. Do the students listen to music at a level that could promote hearing damage?

22. Keeping Warm

Recommended Grade Levels: 4 – 5

Objectives

Students determine that:

- All materials have certain physical properties including the ease with which they conduct heat.
- Different clothing materials have different conducting or insulating properties.
- Clothing works as an insulator between the body and the cooler surrounding air.

Procedural Overview

To understand this content, students:

- Classify clothing or fabrics according to the type of fiber with which they are made
- Measure the temperature change in a cup of hot water exposed to the air for five minutes
- Design and implement an insulated covering for a test tube of hot water
- Measure the temperature change in a control test tube and in an insulated test tube of hot water, each for three minutes

Time Requirement

■ Teacher Preparation	10 minutes (not including time to gather clothing items)
■ Pre-Activity Discussion	10 - 15 minutes
■ Get Started	10 minutes
■ Let's Explore	10 minutes
■ Explain It	10 - 15 minutes
■ Tell Me More	15 - 20 minutes
■ Sum It Up	15 minutes

Materials

For teacher demonstration:

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Variety of clothing items[1]
- ☐ Projection system

[1]For a list of suggested fabrics and materials see the Preparation section.

For each student group:

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Cup with hot water
- ☐ Cup with cold water
- ☐ Tape (optional)
- ☐ Rubber band (optional)
- ☐ Test tubes (2)
- ☐ Test tube rack
- ☐ Hot water to fill test tubes (~500 mL)
- ☐ Funnel
- ☐ Insulating clothing materials such as cotton, Polartec®, and wool
- ☐ Paper towels (2-3)

Activity at a Glance

Get Started

- ☐ Examine and observe a variety of fabrics and distinguish between natural fibers such as cotton and wool, and man-made fibers such as polyester, nylon, or acrylic.
- ☐ Predict which type of fabric or material will best prevent heat loss from a test tube of hot water into the surrounding air.

Let's Explore

- ☐ Measure and record the temperature of the air in the room, cold tap water, and hot tap water.
- ☐ Compare temperature values mathematically by subtracting smaller values from larger values.

Explain It

- ☐ Measure the decrease in temperature in a cup of hot water that is in contact with the surrounding, cooler, air.
- ☐ Begin defining vocabulary terms: temperature sensor, insulate, heat, natural fiber, synthetic fiber, control, and variable.

Tell Me More

- ☐ Measure the change in temperature of hot water in the control test tube for a period of three minutes.
- ☐ Design an insulated covering for a test tube. Fit the test tube with the insulation.
- ☐ Measure the change in temperature in hot water in the insulated test tube for a period of three minutes.

Sum It Up

- ☐ Analyze results of temperature data both within the group and among all the groups in class.
- ☐ Draw conclusions based on class discussion and results.

Safety

Add these important safety measures to your normal class procedures.

- Do not use water hotter than 40 °C (105 °F). Burns could result.

Preparation

These are the materials and equipment to set up prior to the activity.

1. Gather a wide variety of fabrics or clothing items that are used as insulating layers. Try to obtain articles of wool, synthetic fleece such as PolarTec, real or synthetic fur, down, cotton, and polyester or acrylic fibers. Also, obtain a mitten and a glove. If you do not have access to these types of clothing, obtain photographs of these items for students to examine.

2. Set up the data collection system and your classroom projection system so that you can project for students a graph display with Temperature on the *y*-axis and Time on the *x*-axis.

3. Set up the data collection system to display a graph of Temperature versus Time:

    a. Start a new experiment on the data collection system.

    b. Connect the temperature sensor to your data collection system.

    .c. Create a graph display of Temperature on the *y*-axis versus Time on the *x*-axis.

    d. Temperature is displayed in units of degrees Celsius. Optionally, change the units to degrees Fahrenheit.

    e. Practice recording runs of data and hiding runs of data.

Background

Clothing in the Arctic

Among some of the peoples in the Arctic, clothing is traditionally made of sealskin and caribou hide, and trimmed with animal fur. The words parka, anorak, and kamik (boots), come from these cultures. The clothing in this climate must protect people from blizzards and temperatures as low as -60 degrees Celsius. Present-day Arctic dwellers also wear clothing made of modern, high-tech materials to protect them from wind and extreme cold.

An insulating object such as a jacket does not produce its own heat, which many students at this age mistakenly believe. Instead, clothing insulates the body by preventing heat from flowing easily away from it and into the surrounding, cooler environment.

Conduction of Heat

Conduction is the transfer of thermal energy through matter by molecular activity. Molecules transfer the energy through collisions from one to the next. The thermal energy tends to move from a region of higher temperature to a region of lower temperature.

Some substances conduct thermal energy much better than others. Metals tend to be good conductors of thermal energy. Because of the space between particles, air is a poor conductor. It is this fact that makes trapped air such a good insulator in clothing fibers. The fibers and fabrics we typically associate with warmth, such as down, wool, and fleece, all trap microscopic pockets of air within themselves.

Some materials that are poor conductors of heat, and therefore are good insulators, lose this property when they become wet. This is because the small areas of trapped air become filled with water, and water is a better conductor of heat than air is. To think of this in another way, imagine how air at 25 °C (77 °F) "feels" to your exposed skin, compared to water at the same temperature. The water "feels" colder, because it conducts heat away from your body more efficiently than does the air.

Human Body Temperature

The human body has the capability of regulating its core temperature via several feedback mechanisms. But all parts of the body are not at the same temperature. People commonly refer to the temperature measured orally as the typical body temperature. As the table shows, the temperature of the body varies, depending on where it is measured.

➢ Typical temperatures of different parts of the human body

Body Area	Temperature (°C)	Temperature (°F)
Body organs	40.6	105
Mouth	37.0	98.6
Armpit	36.5	97.7
Forehead	34.5	94.1
Hand	33.0	91.4
Fingers	32.0	89.6

Even though the temperatures vary around the body, the core temperature stays within a tight range through thermoregulation. Thermoregulation is the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different.

This process is one aspect of homeostasis: a dynamic state of stability between an animal's internal environment and its external environment. The hypothalamus, located in the brain, regulates the body temperature (as well as hunger, thirst, fatigue, and anger).

Pre-Activity Discussion

- Show students a variety of clothing articles that are made of different fabrics. You might assemble a variety of items used for layering such as a fleece jacket, cap, or scarf; a wool sweater, sock, or glove, a down vest or jacket, and a base layer made of a synthetic fiber.

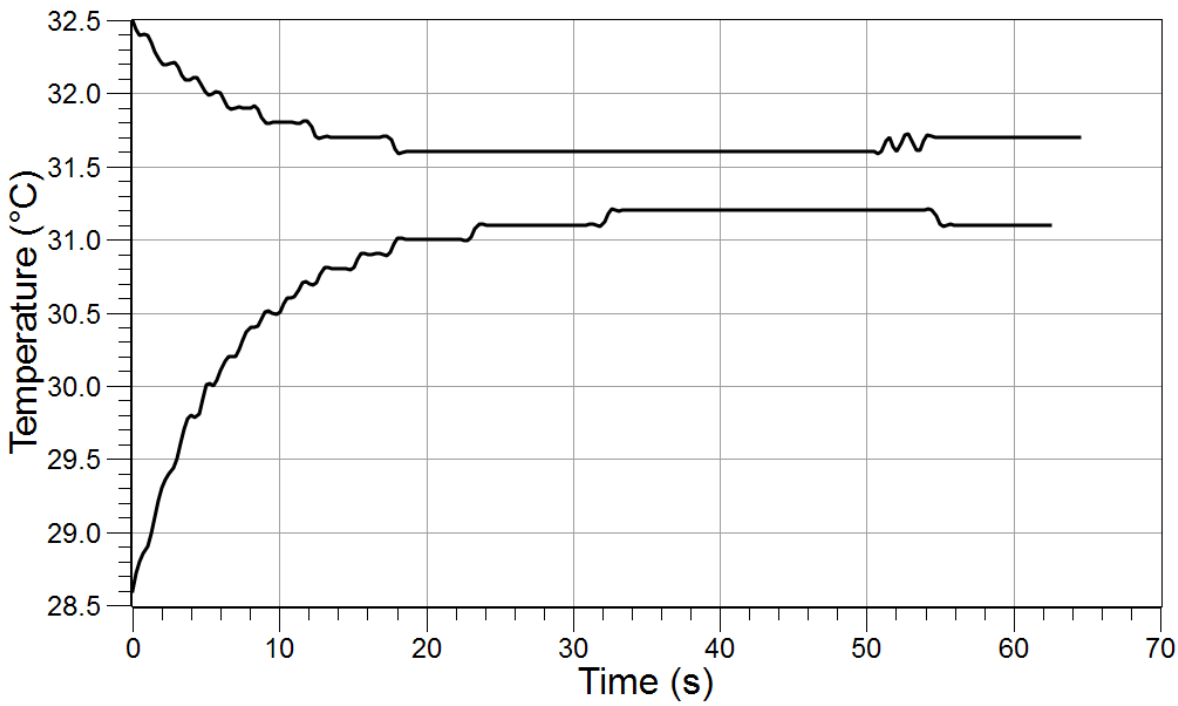
- Tell students that high-tech clothing designers do their best to make products that protect us from the elements. They develop materials that keep us warm and dry in the winter. They do this by adding insulation to clothing to slow down the flow of heat away from the body.

- Ask a student volunteer to help you demonstrate for the class how skin temperature varies depending on whether it is exposed to air or under clothing.

  1. While projecting the graph of temperature versus time on your data collection system, have the student volunteer place the tip of the temperature sensor on the bare skin his or her arm. Allow the temperature reading to stabilize. This may take between 20 and 40 seconds.

  2. Next have the same student volunteer place the tip of the temperature sensor in contact with the skin under the sleeve. Use the same location on the opposite arm. Allow the temperature reading to stabilize.

- Lead the class in a discussion that compares the results of the skin temperature found on bare skin to the temperature found on skin covered by clothing. For the sample data shown below, the skin temperature on the bare skin was 31.2 °C, and the skin temperature under clothing at the same location on the opposite arm was 31.6 °C. In both cases, for the sample data, the tip of the temperature sensor was taped to the skin with a small strip of adhesive tape, in order to keep the sensor in contact with the skin.



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Driving Question

- Are some materials better-suited for warm clothing than other materials?

Variables

Independent Variable

- In this activity the independent variable is the type of material used to insulate the test tube of hot water.

Dependent Variables

- The dependent variable in this activity is the temperature change measured in the insulated test tubes of hot water.

Controlled Variables

- The controlled variables are the test tube size, shape and material; the volume of water contained in each test tube, and the length of time the temperature of each sample of water is measured.

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

Clothing designers are always trying to invent new materials to protect us from the cold. You will test some of these materials to see how well they work.

1. ☐ Carefully observe the materials and items of clothing your teacher has shown you. Discuss among your group which of these items are made from natural fibers, and which are made from synthetic fibers.

   Teacher Tip: Show students how to read the labels inside clothing to learn about the type of fiber or material the clothing is made of.

   Classify the clothing or fabric samples into two groups according to whether their fibers are natural or synthetic.

   Answers will vary. Students should classify wool, down, cotton, or linen materials as natural fibers. They should classify others as human-made fibers. If materials are made of a blend, students may classify them as both or either.

2. ☐ Predict which of the fabric or clothing items will be best at keeping a test tube of hot water from losing heat. Be prepared to explain your thinking.

   Answers will vary. The fabric or clothing material that traps more air within its fibers will generally provide the most insulation and prevent loss of heat the best.

Let's Explore

In this part of the activity you will use the temperature sensor to measure the temperature of the air in the room, the temperature of cold water from the faucet, and the temperature of hot water from the faucet.

3. ☐ Start a new experiment on the data collection system.

4. ☐ Connect a temperature sensor to the data collection system.

5. ☐ Display your data in a graph display with Temperature on the *y*-axis and Time on the *x*-axis.

6. ☐ Start data recording.

7. ☐ Hold the temperature sensor in the air to measure the air temperature. Continue recording until the temperature reading stabilizes.

8. ☐ Stop data recording. Write the air temperature in data Table 1 below.

Teacher Tip: Remind students that when they write their data in the table below, they need to use the stabilized value, which will occur between 20 to 40 seconds after they begin data recording.

➢ Table 1: Temperature data

Sample Tested	Temperature (°C)
Air in the classroom	18.5
Cold water	16.9
Hot water	32.7

9. ☐ Get a cup of cold water from the sink or faucet.

10. ☐ Place the temperature sensor into the cup of cold water.

11. ☐ Start data recording.

12. ☐ Continue recording until the temperature reading stabilizes.

13. ☐ Stop data recording. Write the cold water temperature in data Table 1 above.

14. ☐ Get a cup of hot water from the sink or faucet.

15. ☐ Place the temperature sensor into the cup of hot water.

16. ☐ Start data recording.

17. ☐ Continue recording until the temperature reading stabilizes.

18. ☐ Stop data recording. Write the hot temperature in data Table 1 above. Set aside your cup of hot water for the next part of the activity.

19. ☐ Examine the temperature data in Table 1. What is the difference in temperature between the cold water and the air temperature in the room?

Answers will vary. For the sample data, the difference is 18.5 °C – 16.9 °C = 1.6 °C.

Teacher Tip: Review with your students that in order to find a difference between two values, they must subtract the smaller value from the larger value.

What is the difference in temperature between the cold water and the hot water?

Answers will vary. For the sample data, the difference is 32.7 °C – 16.9 °C = 15.8 °C.

Explain It

What happens to your hot water as time goes by? Does the paper cup keep the water hot or does the water lose some of its heat to the air around it? What does this tell us about the cup's ability to insulate against heat loss?

20. ☐ Place the temperature sensor back into your cup of hot water.

21. ☐ You may choose to hide the data you have already recorded.

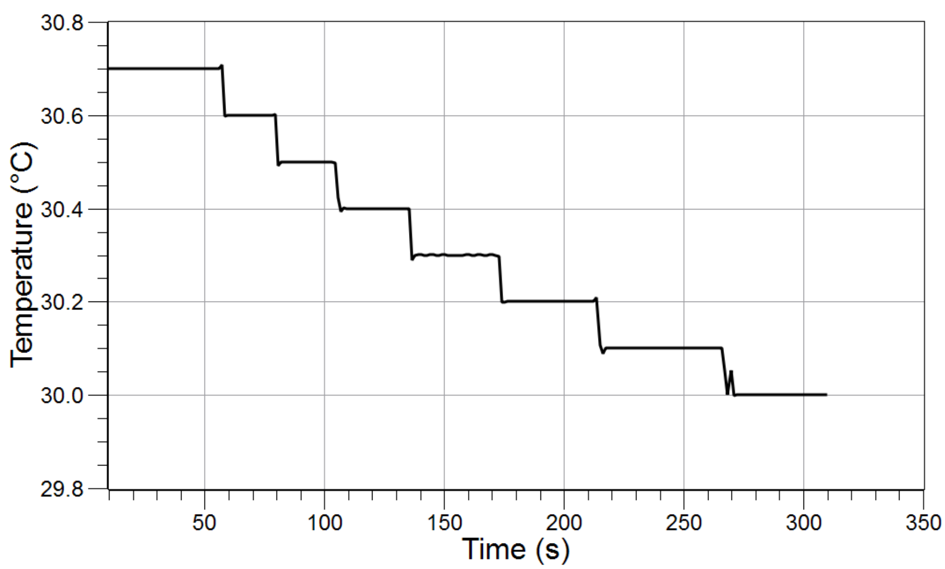
22. ☐ Begin data recording.

23. ☐ Continue recording temperature data for five minutes. You may want to adjust the scale of your graph as you record this data so you can more clearly see any change in temperature.

24. ☐ After five minutes, stop data recording.

25. ☐ Examine your temperature data. Did the temperature of the hot water change during the five minutes? If so, by how many degrees did it change?

Answers will vary. For the sample data below the temperature changed by 0.7 °C.



26. ☐ Look back at your temperature data from the Table 1 in the Let's Explore section. How much did the temperature of the hot water in the cup change from when you first measured it until you stopped recording data at the end of the five minutes?

Answers will vary. For the sample data the temperature change was 32.7 °C – 30.0 °C = 2.7 °C.

27. ☐ Has the cup insulated the hot water or allowed some heat to flow into the surrounding air? Use evidence from your data and observations to support your statement.

The cup has not completely insulated the hot water, because it has lost some of its heat. For the sample data, the temperature has decreased by 2.7 °C, which means that heat flowed from the water which was at a higher temperature to the surroundings which are at a lower temperature.

Tell Me More

In this part of the activity you will design a covering for a test tube that will insulate the hot water inside the tube. You will try to minimize the heat loss from the insulated test tube, so that the water in the tube stays as warm as possible for three minutes. Later, you will compare your results with those of other groups in class.

Your control will be a non-insulated test tube of the same type that is filled with the same volume of hot water as your insulated test tube.

28. ☐ Fill one of your test tubes to the top with hot water from the faucet. Use a funnel if necessary. If any water spilled on the outside of the tube, be sure to dry it.

29. ☐ Place the temperature sensor into the middle of the test tube. Keep the tip away from the sides of the tube. This test tube is the control.

30. ☐ Begin data recording.

31. ☐ Continue recording temperature data for three minutes. Observe the graph as the water cools. You may want to adjust the scale of your graph as you record this data so you can more clearly see any change in temperature.

32. ☐ After three minutes, stop data recording.

33. ☐ Discuss with the members of your group which type of material you think will make the best choice for insulation.

34. ☐ After deciding which material your group will use to insulate the test tube, describe the material and write an explanation for why you chose this particular material.

    Answers will vary. One student group answered as follows: We decided to use a wool sock. We chose it because the wool sock is thick and tightly woven out of yarn. The test tube can be put into the sock so the surrounding air cannot get inside and cool the water.

35. ☐ Figure out how you will cover the test tube with the insulation. Depending on your materials, you may need to use tape or a rubber band to hold the insulation in place. You will need to be able to cover the test tube first, and then fill it with hot water.

36. ☐ Insulate the test tube and fill it to the top with hot water, using the funnel if necessary.

37. ☐ Place the temperature sensor into the middle of the tube. Keep the tip away from the sides of the test tube.

38. ☐ Begin data recording.

39. ☐ Continue recording temperature data for three minutes. Observe the graph as the water cools. You may want to adjust the scale of your graph as you record this data so you can more clearly see any change in temperature.

40. ☐ After three minutes, stop data recording.

41. ☐ Save your experiment.

42. ☐ As you have been investigating what makes some clothing warmer than others you learned some new scientific ideas. It is important to be able to discuss your results using these words and terms correctly.

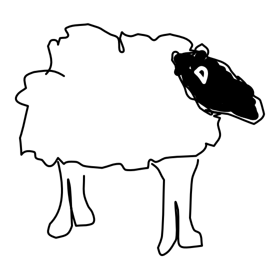
Write the meaning of the following terms in your own words using what you have learned from the activity.

➢ Vocabulary and definitions

Temperature sensor	Tool or instrument used to measure the temperature of an object or substance
Insulate	To prevent loss of heat
Heat	Energy that we feel as warmth
Natural fiber	A type of fiber that comes from nature, such as wool (from sheep), or cotton (from a plant)
Synthetic fiber	A type of fiber made by prople, such as fleece, polyester, nylon, or acrylic
Control	Any factor or condition that is held the same throughout an experiment
Variable	Any factor or condition that is allowed to change in an experiment

43. ☐ Illustrate two terms of your choice in the spaces below.

➢ Word: Natural fiber.

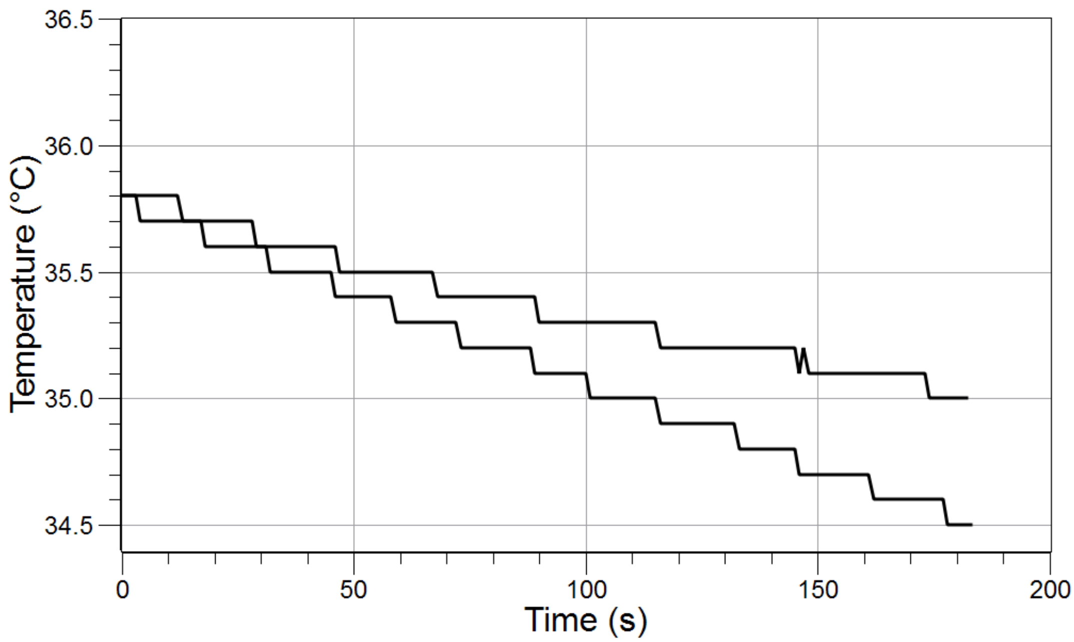


➢ Word: Insulate.

Sum It Up

44. ☐ Review your temperature data for the two test tubes. How much did the temperature change in the control (non-insulated) test tube?

Answers will vary. For the sample data shown below the temperature changed from 35.8 °C to 34.5 °C, which is a change of 1.3 °C.



45. ☐ How much did the temperature change in the insulated test tube?

Answers will vary. For the sample data shown above, the temperature changed from 35.8 °C to 35.0 °C, which is a change of 0.8 °C.

46. ☐ Check the results of other groups in your class. For the insulated test tube what was the biggest change in temperature measured in the class?

Answers will vary.

What material or fabric did this group use to insulate their test tube?

Answers will vary. Generally the material that incorporates the most microscopic air spaces within the fibers will provide the best insulation, while the material with the least microscopic air spaces within the fibers will conduct heat most efficiently and therefore be a poor insulator.

47. ☐ After comparing the results of all the groups for the temperature changes in the insulated test tubes, discuss in your own group how the prediction you made in the Get Started section compares to your experimental results. Summarize your discussion.

Answers will vary depending on students' predictions.

48.☐ If you want to dress to be outdoors in a very cold climate and need your clothing to prevent heat being transferred away from your body, which of the materials tested in your class would you want your clothing to be made of?

Answers will vary depending on materials available for students to test. Possible answers include wool, Polar fleece®, down-filled, or thick flannel materials.

49.☐ The air in the room is cooler than the hot water in your test tube. What will eventually happen to the temperature of the hot water if it is allowed to sit out in the room until tomorrow? If you measured the air temperature and the temperature of the water in your test tube tomorrow, what would you expect to find?

After enough time passes, the temperature of the water will be the same as the temperature of the air in the room.

50.☐ Why is some clothing warmer than others?

Answer will vary. Clothing that traps air within its fibers is a better insulator, and prevents the transfer of heat more effectively. The fibers used to make fabric and clothing vary in the way they trap air and also in their own ability to conduct heat.

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. When a material has a lower temperature after five minutes than it had at the start, it

Ⓐ **Has lost heat**

Ⓑ Is well insulated

Ⓒ Has gained heat

2. A material that is a good insulator

Ⓐ Allows heat to flow through it easily

Ⓑ **Prevents heat from flowing through it easily**

Ⓒ Is also a good conductor of heat

3. The following pairs of beginning and ending temperatures were taken in three different containers of hot water. Which pair of temperatures shows that the container was insulated?

Ⓐ Beginning temperature: 36 °C, ending temperature: 29 °C

Ⓑ Beginning temperature: 32 °C, ending temperature: 29 °C

Ⓒ **Beginning temperature: 32 °C, ending temperature: 31 °C**

True or False

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

___T___ 1. Some materials are better than others at allowing heat to flow through them.

___F___ 2. All materials used for warm clothing are made of natural fibers.

Further Investigations

Have students repeat the investigation, with the insulating materials wet. Do all of the materials fail to provide insulation when they are wet, or do some retain the ability to insulate while wet? What importance does this have in our daily lives? Is cotton clothing, for example, the best choice to keep us warm if we might get wet? Or is there another material that would keep us warm even when it got wet? Have students plan a "trip" to a cold, damp climate, supporting their clothing choices with evidence from the experiment.

Have students research traditional clothing worn by Arctic inhabitants. What properties of the clothing materials make them a good choice for their use in warm clothing? Are there drawbacks associated with the use of these materials? If so, what are some of the drawbacks?

Provide students with microscopes and slides of goose down, wool fibers, cotton fibers, and synthetic fibers. Allow students the time to observe these objects at the microscopic level with a focus on how these fibers are able to trap air.

23. Heating Land and Water

Recommended Grade Levels: 4 – 5

Objectives

Students understand that light can be reflected or absorbed by an object. Light from the sun interacts differently with land than it interacts with water.

Procedural Overview

To understand this content, students:

- Heat samples of water and sand with a lamp while recording the change in temperature as each sample is heated
- Determine a property of some materials that allows them to heat up faster than other materials
- Use evidence from the activity and research to draw conclusions about water's influence on a region's climate

Time Requirement

Teacher Preparation	5-10 minutes
Pre-Activity Discussion	10-15 minutes
Get Started	10-15 minutes
Let's Explore	30 minutes
Explain It	15 minutes
Tell Me More	30 minutes
Sum It Up	15 minutes (Could be assigned for homework)

Materials

- [ ] Data collection system
- [ ] Temperature sensor
- [ ] Meteorology records on the Internet
- [ ] Utility lamp with clip, 75 W, 100 W, or sunlamp
- [ ] Table or stool to clamp lamp
- [ ] Petri dish (2)[1]
- [ ] World map or globe
- [ ] Scissors
- [ ] Meter stick
- [ ] Dry sand (40-50 mL) and other materials[2]
- [ ] Room temperature water, 40-50 mL
- [ ] Construction paper, skin-tone[3]

[1]A small shallow dish or jar lid may be used in place of a Petri dish.

[2] Other materials for the Tell Me More section include grass, dirt, foil, waxed paper, wood, chocolate, milk, material, glass, ground charcoal, paint, or any other materials you have in your classroom that would provide a variety of textures and surfaces and would also fit inside the Petri dishes.

[3] A piece 8 cm x 12 cm (3 in. x 5 in.) is sufficient

Activity at a Glance

Get Started

- ☐ Work in groups to generate a list of surfaces that reflect the sun's energy and surfaces that absorb the sun's energy.
- ☐ Predict how the temperature will vary in their water and sand samples while they are being heated.

Let's Explore

- ☐ Use a heating lamp to heat samples of sand and water, and measure the results with a temperature sensor.

Explain It

- ☐ Compare the results of their tests.
- ☐ Relate reflectivity of materials to albedo.
- ☐ Begin defining vocabulary terms: albedo, absorption, atmosphere, reflection, light, heat.

Tell Me More

- ☐ Choose from a variety of new materials to identify the property which makes materials have a high albedo.
- ☐ Test the new material and compare the results to those of water and sand.

Sum It Up

- ☐ Draw conclusions about the properties that make sand heat up faster than water
- ☐ Relate this test to the location of places on Earth that experience very hot or cool temperatures to see if the causes of high albedo in the test also apply to the properties of high albedo for large water and land bodies.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

- Arrange for incandescent lamps to be plugged in for each student group. Students need to be able to position their samples of water and sand so that the surface of each sample is 40 cm below the incandescent bulb of the lamp.
- Ensure that student groups have access to world maps or globes, as well as to the Internet. You may want to have students open their Internet browsers and go to a particular location; if so, write the name of the website on the board for students to see.
- Set up the data collection system

  1. Begin a new experiment on the data collection system.

2. Connect the temperature sensor to the data collection system.

Background

Heating Land and Water

This investigation starts by focusing on the amount of heat absorption that occurs from sunlight reaching the earth. The results are strongly related to the cover ecosystem (for example, grasslands, land, and water) and how much light is absorbed or reflected back by a surface. Scientists use the term albedo to define the percentage of solar energy reflected back by a surface.

White or light colored materials have a high albedo because the color white reflects all colored light energy and absorbs none. Sunlight falling on a white snowy surface is strongly reflected back into space. This results in very little heating of the surface and the lower atmosphere.

Dark colored materials have a lower albedo because black color absorbs all colored light energy and reflects none. Sunlight falling on dark farm soil or black pavement is strongly absorbed. This results in a large amount of heating of the surface and the lower atmosphere.

Absorption and reflection are not simply dependent on color. For example, white sand and white snow have very different albedos. There are several reasons why water warms (and cools) more slowly than land. One reason is that the sunlight penetrates deeper into the water. Another reason is that, since water is a fluid, it can spread the heat more evenly within itself. Still another reason is that water has a higher specific heat capacity than most other substances, which means that it needs more energy to raise its temperature than most other substances need. Finally, some of the energy from the water is used to evaporate water from the surface. Thus, less of the energy is used to heat the water.

Pre-Activity Discussion

- Before focusing on the different temperatures around the planet, begin with a general discussion of the impact of sunlight on the earth. Have the students think about how heat from sunlight contributes to the overall temperature on earth and changes in seasons. Start by asking the following question:

  Q When during the day does the sun feel the hottest?

  Q When during the seasons is the sun the hottest?

  Q What is similar about the position of the sun in both of the above conditions?

  Q When it is hot outside, what kinds of surfaces would you rather walk or stand on?

- The following discussion will help set the stage for how surfaces heat up and cool off differently. Ask students to consider the different temperatures for water (ocean, lake, rivers) and land (sand or rocks) on a sunny day.

- Discuss the difference between absorbing and reflecting. Ask students to come up with strategies for the following questions. Their answers should focus on temperature:

  Q How will you know if a material is absorbing more energy than it is reflecting?

Q How will you know if a material is reflecting more energy than it is absorbing?

Driving Question

- How do the different properties of Earth's surfaces, including sand and water, affect the temperature of the surfaces?

Variables

Independent Variable

- The material (water or sand) being exposed to heat and light energy from the incandescent lamp is the independent variable.

Dependent Variables

- The changes in temperatures of the materials being exposed to the lamp are the dependent variables.

Controlled Variables

- In this experiment the controlled variables are the volume of material, the type of container, the depth to which the containers are filled, the depth at which the temperature is measured, the surface area of exposed material the distance from the incandescent lamp, and the duration for which the materials are exposed to the lamp.

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

In this activity, you will investigate different heating and cooling characteristics of water and land.

1. ☐ Discuss with your group members and come up with a list of surfaces found on Earth that absorb sunlight more than they reflect it. Write your list below.

   Answers will vary. Students may suggest natural surfaces such as sand, rock, and soil, and synthetic surfaces such as concrete and asphalt. Students may suggest clothing items with dark colors or thicker textures.

2. ☐ Discuss with your group members and come up with a list of surfaces found on Earth that reflect sunlight more than they absorb it. Write your list below.

   Answers will vary. Students may suggest natural surfaces such as water, ice, and snow, and synthetic surfaces such as white or light-colored buildings. Students may suggest clothing items with light colors or smooth textures.

3. ☐ Now think about the beach, river, or lake shore on a hot, sunny day. Think about standing barefoot on the dry sand, and then think about dipping your toes into the water.

Predict which will be warmer on a sunny day: the sandy shore or the water. Be prepared to share your reasoning with the class.

Students should predict that the sandy shore will be warmer than the water on a sunny day. Those students who have experienced the beach will recall that the sand can get hot enough to be uncomfortable to walk barefooted in, even while the water remains cold.

4. ☐ Predict how the temperature of water and of sand will differ while being heated by a lamp.

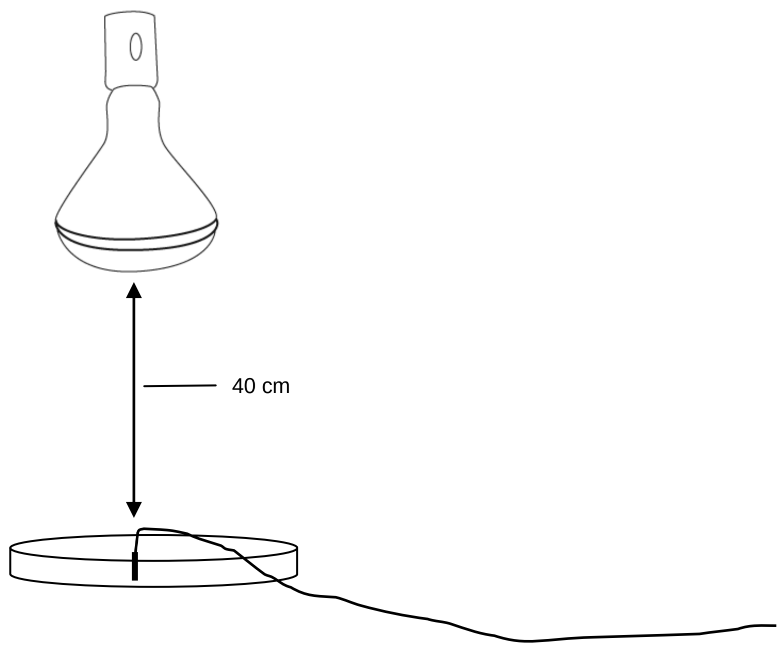
   The sand will heat up faster than the water.

Let's Explore

5. ☐ Obtain two shallow Petri dishes, sand and water.

6. ☐ Place 50 mL of water in a Petri dish or small bowl.

7. ☐ Position the Petri dish below a lamp mounted 40 cm above the dish as shown in the diagram below.



8. ☐ Measure the tip of your temperature sensor and note how far 6 mm is from the tip of the sensor. This will be as deep as you will push the sensor into either the water or the sand.

9. ☐ Start a new experiment on the data collection system.

10. ☐ Connect the temperature sensor to the data collection system.

11. ☐ Display the data in a graph with Temperature on the *y*-axis and Time on the *x*-axis.

12. ☐ Change the periodic sampling rate to measure temperature every 10 seconds.

13. ☐ Place the temperature sensor approximately 6 mm down into the water (the tip of the fast response temperature probe) and turn the lamp on.

14. ☐ Immediately start data recording.

15. ☐ Write the starting temperature in Table 1 while heating the water with the lamp.

16. ☐ After 5 minutes, stop data recording and turn off the lamp.

17. ☐ Write the final temperature in Table 1.

➢Table 1: Temperature of the Water

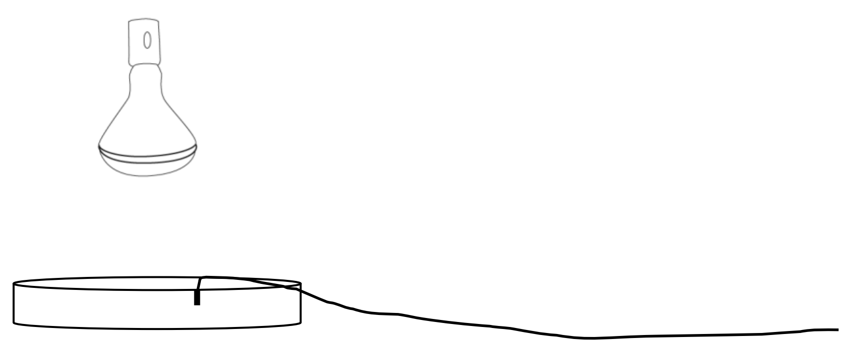
Condition	Temperature (°C)
Starting temperature of water	24.5
Final temperature of water	26.4

18. ☐ How much was the difference between the starting and final temperatures?

Difference in temperature of water: 1.9 °C

19. ☐ Replace the Petri dish of water with a Petri dish of sand as shown in the diagram below.

Note: Make sure you fill the Petri dish with sand to the same level as you did with water.



20. ☐ Place the temperature sensor approximately 6 mm down into the sand (the tip of the fast response temperature probe) and turn the lamp on.

21. ☐ Immediately start data recording.

22. ☐ Write the starting temperature in Table 2 while heating the sand with the lamp.

23. ☐ After 5 minutes, stop data recording and turn off the lamp.

24. ☐ Write the final temperature in Table 2.

➢Table 2: Temperature of the Sand

Condition	Temperature (°C)
Starting temperature of sand	25.4
Final temperature of sand	30.0

25. ☐ What was the difference between the starting and final temperatures?

Difference in temperature of sand: ______4.6________°C

Explain It

26. ☐ How did the temperature changes compare for the dish of water and the dish of sand?

The temperature changed more in the sand in five minutes than it did in the water.

27. ☐ How do these results match your prediction?

These results match my prediction; the water is slower to heat up than the sand.

28. ☐ In this activity you have been working with a model of water and land. What part of the model represents the ocean or a lake? What part of the model represents the land?

The water in the dish represents the ocean. The sand in the dish represents the land.

29. ☐ In this experimental setup, which variables have you controlled?

In this experimental setup we controlled the amount of material, the type of container, the material's surface area, the distance the material is from the heating lamp, the depth of the temperature sensor in the material, and the length of time the material is heated.

30. ☐ Which variable are you testing?

We are testing how the two different materials heat up.

31. ☐ Within your group, list three different properties of water and sand that could possibly account for why they heated up differently. What is different about water and sand?

Answers include the following: solid vs. liquid; wet vs. dry; all one thing vs. individual grains; colored vs. colorless; bumpy vs. smooth. Your students may even come up with more!

32. ☐ Albedo is the ability of a material to reflect light. Which material, sand or water, do you think has a higher albedo?

Water has a higher albedo than sand. This is partly due to the granularity of the sand, but also to the mineral properties of the sand so that sand will absorb more sunlight than water and water will reflect more.

33. ☐ In your investigations of how oceans and lakes influence a region's climate you learned some new scientific ideas. These ideas have their own terms. In science it is important to be able to discuss your results using these words and terms correctly.

Write the meaning of the following terms in your own words using what you have learned from the activity.

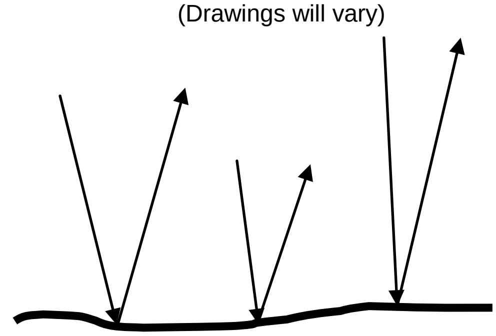
Albedo	The property of reflectance of a material; the proportion of incident light that is reflected by a material
Absorption	Taking in heat and light energy from the sun's rays that strike a surface; the opposite of reflection
Atmosphere	The layer of air above the Earth's surface made up of different gases, held in place by gravity
Reflection	To return a ray of light back toward its source; the opposite of absorption
Light	Energy from the sun that we see as brightness
Heat	Energy from the sun that we feel as warmth

34. ☐ Illustrate two terms of your choice in the spaces below.

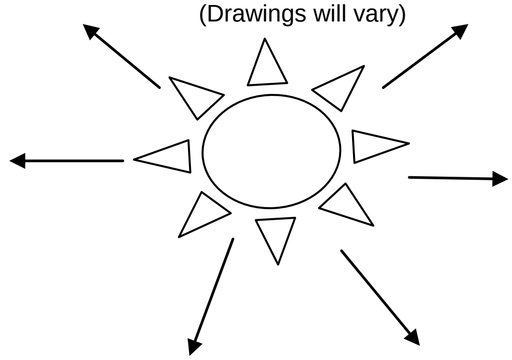
➢ Word: Reflection

➢ Word: Heat

(Drawings will vary)



(Drawings will vary)



Tell Me More

In this section, you will investigate how a variety of different materials absorb or reflect heat energy from a heat source.

35. ☐ You have observed how the sun heats up sand and water differently. Look back at the properties your group listed in the Explain It section above and choose the one property you think best explains why the sand heats up faster than the water. List it here.

Answers will vary. Students might choose wet and dry, for example.

36. ☐ The property you listed in the previous question becomes the independent variable, and how quickly the material heats up is the dependent variable. Now you will have to test your prediction. Write a testable question here that includes the dependent and independent variables for your prediction.

Guide students to refine their testable question in the form of, "How does *this* (the independent variable they want to test) affect *that* (how quickly the material will heat up)?" Example: How does the wetness of a material affect how quickly it will heat up or cool down when exposed to heat?

37. ☐ Gather the materials you would like to test from the resources your teacher has assembled.

Note: Tell your teacher your testable question before you begin.

Teacher Tip: Examples of materials you could offer students for testing are listed as a footnote in the Materials List. If you discuss the above questions in class on one day, students could bring materials in from home the next day.

38. ☐ List your materials here: (see list of possible materials in the footnote under Materials section)

Teacher Tip: To save time, limit the number of materials offered as choices.

39. ☐ Place the material you will test into the empty Petri dish to the same level that the sand and water were placed originally.

40. ☐ Place the temperature sensor approximately 6 mm down into the test material and turn the lamp on.

41. ☐ Immediately start data recording.

42. ☐ Write the starting temperature in Table 3 while heating the test material with the lamp.

43. ☐ After 5 minutes, stop data recording and turn off the lamp. Write the final temperature in Table 3. Temperatures will vary depending on materials tested.

➢Table 3: Temperature of the test material

Condition	Temperature (°C)
Starting temperature of Test Material 1	
Final temperature of Test Material 1	

44. ☐ What was the difference between the starting and final temperatures?

Difference in temperature of Test Material 1: (temperature difference) (°C)

45. ☐ If time allows and your teacher encourages it, you may want to test other materials. If you do, construct another table to hold those data in the space provided below.

Sum It Up

46. ☐ How did the temperature change for your test materials compare to the temperature changes for the water and the sand?

    Answers will vary. Students will probably find that wetter materials heat more slowly than drier materials.

47. ☐ Did your findings support your prediction? What did you learn?

    Answers will vary. Students may end up with another question rather than an easy answer. You may want to explain that this is how research proceeds, with one question leading to another question. Students have learned that water and wet things heat up more slowly than do dry things and sand.

48. ☐ Rank your test material with the sand and the water. Put the material with the highest albedo first, and on down to the material with the lowest albedo last.

    Answers will vary, but all lists will probably start with water.

49. ☐ If the sun shines equally on a city next to a large body of water and another city next to a desert, which would get hotter during the day? Explain.

    The city near the desert would get hotter during the day, because it is more like the sand heating up in our experiment than the water.

50. ☐ Do you think that shores and beaches store energy from the sun differently than oceans and lakes store the energy? Explain your reasoning. Be prepared to share your thoughts with the class.

    Answers will vary. One student group answered as follows: We think that oceans and beaches do store the sun's energy differently. We think this because the sand gets warm faster than the water so it has more time to absorb more heat than water does. Water does not heat up as fast as sand.

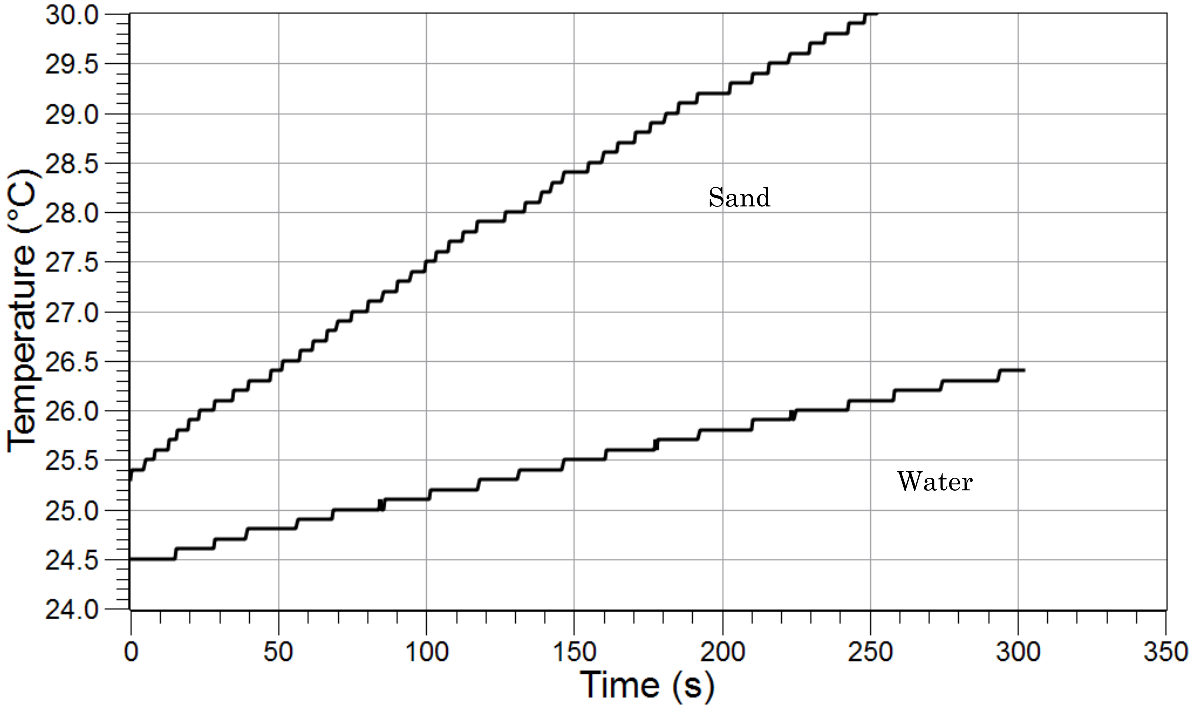
51. ☐ How could oceans and lakes influence a region's climate?

    Oceans and lakes contain water. Water heats up more slowly than land does. Regions or cities located near oceans or lakes may not get as hot as regions located far from bodies of water.

52. ☐ Using the map or globe, locate two cities at the same latitude that may have different climates based on how near they are to an ocean. Which cities or regions did you find? Explain why you chose these two places as examples.

    Answers will vary. One student group answered as follows: We picked Sydney and Alice Springs in Australia. Sydney is located on the coastline of the Tasman Sea. Alice Springs is right in the middle of the continent. Alice Springs is far from the sea, and it gets very hot there.

Sample Data



Temperature (°C)
30.0
29.5
29.0
28.5
28.0
27.5
27.0
26.5
26.0
25.5
25.0
24.5
24.0
Sand
Water
0
50
100
150
200
250
300
350
Time (s)

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. Energy from the sun can be

   Ⓐ **Absorbed or reflected**

   Ⓑ Only absorbed

   Ⓒ Only reflected

2. We used the ________________ to determine how much heat energy the water and sand absorbed during our experiment.

   Ⓐ **Temperature sensor**

   Ⓑ Incandescent lamp

   Ⓒ Meter stick

3. Materials with a high albedo would also be materials that

   Ⓐ Absorb most of the light

   Ⓑ **Are highly reflective**

   Ⓒ Heat up really fast

4. The variable that we are testing in an experiment is called the

   Ⓐ Dependent variable

   Ⓑ **Independent variable**

   Ⓒ Control

Key Term Challenge

Fill in the blanks from the list of randomly ordered.

reflection	absorption	atmosphere	heat
light	energy	snow	dark

1. A surface that reflects much of the sun's light is ____snow____.

2. A ____dark____ surface such as sand or soil is able to absorb more energy from the sun than a shiny surface.

3. ____Absorption____ occurs when the sun's energy is kept or trapped by a material.

4. ____Reflection____ occurs when the sun's energy bounces off a material and travels back in the direction it came from.

5. The Earth's ____atmosphere____ is a layer of gases, held in place by gravity, that absorb energy from the sun.

6. ____Heat____ is the sun's energy we feel as warmth.

7. ____Light____ is the sun's energy we see as brightness.

8. The sun provides the ____energy____ necessary to maintain the temperature of the Earth.

Further Investigations

Have students obtain a map or globe and work with group members to predict the coldest location in the world. They can use the Internet to research the location predicted as the coldest place on Earth. It may be helpful to conduct a search for this location's meteorology records. Relate this location to findings from the lab activity. Students should be prepared to share their thoughts with the class.

24. Chemical Reactions

Recommended Grade Levels: 4 – 5

Objectives

Students learn to recognize chemical reactions. Through this activity, students:

- Learn that when two (or more) materials chemically react, a new substance is formed
- Explain that a new substance has properties different from the original materials
- Explain that materials can be mixed together without chemically reacting

Procedural Overview

To understand this content, students:

- Observe the properties of matter before and after mixing different materials
- Identify clues that can be used to determine whether or not a new substance has formed
- Use a temperature sensor to measure the change in temperature as two substances chemically react

Time Requirement

Teacher Preparation	15 minutes (does not include shopping for materials)
Pre-Activity Discussion	20 minutes
Get Started	20 minutes
Let's Explore	30-40 minutes
Explain It	15-20 minutes
Tell Me More	30-40 minutes
Sum It Up	15 minutes

Materials

For teacher demonstration:

- ☐ Beaker half full of water (2)1
- ☐ Stir rod
- ☐ Plastic spoon
- ☐ Effervescent antacid tablet[2]
- ☐ Table salt, 5 g (1 spoonful)
- ☐ Balance (optional)

[1]Any size will work.

[2]Alka-Seltzer® tablets work well, or any other effervescent antacid tablet that contains both citric acid and sodium bicarbonate.

For each student group:

Get Started

- ☐ Sugar cube
- ☐ Beaker half full of water[1]
- ☐ Steel wool1,[2]
- ☐ Beaker of air1,[3]
- ☐ Cracker on a paper towel
- ☐ Bowl[4]

Let's Explore – Part 2

- ☐ Paper towel
- ☐ Tincture of iodine, 15 drops[2]
- ☐ Cracker
- ☐ Sugar cube
- ☐ Cheese1
- ☐ Notebook paper[1]
- ☐ Potato slice[1]

Let's Explore – Part 1

- ☐ Balance (optional)
- ☐ Water, 200 mL
- ☐ Beaker (2), 250-mL
- ☐ Beaker, 50-mL
- ☐ Stir rod
- ☐ Plastic spoon
- ☐ Tape
- ☐ Sugar, 5 g (1 spoonful)
- ☐ Alum, 5 g (1 spoonful)[2]
- ☐ Ammonia, about 30 mL (6 spoonfuls)[2,5]

Tell Me More

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Beaker (2), 250-mL
- ☐ Beaker, 50-mL
- ☐ Stir rod
- ☐ Plastic spoon
- ☐ Tape
- ☐ Paper towels, several
- ☐ Steel wool, 2 pieces of ~ 1 g each[2]
- ☐ Vinegar, ~ 75 mL[6]
- ☐ Baking soda, ~ 2 g (¼ spoonful)

[1]The exact amount or size is unimportant as these materials will be used for observation purposes only.
[2]Refer to the Preparation section for information on where this item can be purchased.
[3]Label an empty beaker "air" so that students learn that an empty beaker really is full of air.
[4]The bowl needs to be large enough to hold all the water in the beaker.
[5]Use a bottle of clear household ammonia used for cleaning.
[6]Use distilled white vinegar that has 4 to 8% acidity.

Activity at a Glance

Get Started

- ☐ Describe the properties of a sugar cube, water, steel wool, air, and a cracker.
- ☐ Change matter so that some of the properties change, but that the type of matter stays the same.

Let's Explore

- ☐ Mix water with sugar, water with alum, alum water with ammonia, and sugar water with ammonia and record the properties of the starting materials and ending materials.
- ☐ Mix tincture of iodine with a variety of materials (cracker, sugar cube, cheese, notebook paper, and a potato slice) and identify what materials the tincture of iodine reacts with.

Explain It

- ☐ Begin defining the terms properties, chemical reaction, mixture, and physical change.
- ☐ Explain how to identify whether or not a chemical reaction occurs when two materials are combined.
- ☐ Predict whether or not there is a temperature change associated with chemical reactions.
- ☐ Define the following terms: properties, chemical reaction, mixture, physical change.

Tell Me More

- ☐ Measure the temperature change as air is combined with steel wool (that has been cleaned).
- ☐ Measure the temperature change as baking soda and vinegar are combined.

Sum It Up

- ☐ Explain how you know if a chemical reaction has occurred when two materials are combined.
- ☐ Explain how temperature changes when materials chemically react.

Safety

Add these important safety measures to your normal classroom procedures:

- Wear safety goggles.
- Do not eat or drink any of the lab materials.
- Wash your hands immediately after finishing the activity.
- Ammonia is an irritant with strong fumes. Do not breathe the fumes!

Preparation

These are the materials and equipment to set up prior to the activity.

- The materials needed for this lab can be purchased at the following store:

Alum	Found in the spice aisle of most grocery stores.
Ammonia	Found in the cleaning section of most grocery stores.
Tincture of iodine	Found in the first aid aisle of most grocery stores.
Steel wool	Found in hardware stores. Do not buy the steel wool soap pads.

- For the Get Started activity, label an empty beaker “air” for each student group.
- Prepare a cleaning station for the students. The students will need to clean and dry their beakers and spoons to reuse them throughout the activity.
- Set up the data collection system
    1. Begin a new experiment on the data collection system.
    2. Connect the temperature sensor to the data collection system.

Background

Chemical Reactions

Matter constantly undergoes change. These changes can be classified as either physical changes or chemical reactions (also called chemical changes). A physical change occurs when a substance's physical appearance changes, but there is no change in the substance's chemical composition. Ice melting is a physical change because the ice has changed from a solid state to a liquid state, but its chemical composition, H_2O, remains the same. A chemical reaction occurs when one or more new chemical substances are produced. Rusting is an example of a chemical reaction because iron (steel wool) reacts with oxygen in the air to form a new chemical substance, rust (iron(III) oxide).

At the upper elementary school level students should understand that a chemical reaction causes a new substance to be formed. Students should be able to recognize a new substance because it has properties that are different than the starting materials. This can be difficult because some properties of materials also change when a physical change occurs. Therefore it is important that students observe how properties of materials change during both physical changes and chemical reactions.

Properties of Materials—Extensive and Intensive Properties

Properties of a material are the characteristics that are used to describe the material, and are important when identifying substances. For example, a substance that melts at 0 ˚C and boils at 100 ˚C might very well be water, especially if that substance is a clear, colorless, odorless liquid at room temperature. Boiling point, melting point, color, and odor are all examples of properties. Intensive properties are those that are independent of how much of the substance is being measured. All water, from a small amount contained in a glass to a large amount contained in a swimming pool or a fresh water lake, freezes at 0˚C and boils at 100˚C.

Some properties, however, depend on the amount of substance present. An extensive property changes as the amount of the material being measured changes. Weight and volume are both examples of extensive properties. The water in a glass takes up less space and is not as heavy as the water in a swimming pool even though both contain the substance. In this activity the terms intensive property and extensive property are not introduced, but the concept behind them is used.

Physical and Chemical Properties

Properties can also be divided into physical and chemical properties. Physical properties are properties that can be readily observed without chemically changing the material. Examples of physical properties include color, shape, odor, taste, size, luster and melting point. Chemical properties, on the other hand, describe how the material reacts with other substances. Examples of chemical properties include the ability to burn, the ability to react with water, or the ability to react with an acid.

Chemical reactions need to be understood before a student can understand the difference between chemical and physical properties. This activity introduces the students to several types of chemical reactions and can provide the many examples that can be used to later teach the difference between physical and chemical properties.

Chemical Reactions in this Activity

Let's Explore

Part 1

Mixing alum water with ammonia is a chemical reaction. Alum is a chemical compound that contains aluminum. Ammonia used in cleaning compounds is a dilute solution of ammonia hydroxide. The reaction between alum and ammonia forms a white insoluble gel called aluminum hydroxide.

Part 2

Tincture of iodine is a solution that contains potassium iodide, elemental iodine, ethanol, and water. Tincture of iodine reacts with starch to form a dark blue/black compound. This is a common test to determine if a material contains starch.

Tell Me More

Steel Wool and Air

Steel wool is made up of iron and is coated with a protective coating. When the protective coating is removed using vinegar, iron reacts with oxygen in the air to form rust which is iron(III) oxide.

Vinegar and Baking Soda

Distilled vinegar used in cooking is a dilute solution of acetic acid. Baking soda is a chemical compound called sodium hydrogen carbonate (or sodium bicarbonate). Acetic acid and sodium hydrogen carbonate react to form carbon dioxide gas, water, and sodium acetate (which is dissolved in the water).

Pre-Activity Discussion

Demonstration

1. Discuss with your students the importance of describing the properties of materials. Make sure they understand that properties are used to identify materials and to differentiate materials from one another. Review the different types of physical descriptions such as size, weight, texture, color, and state of matter.

   Q Describe the properties of table salt.

   Q Describe the properties of water.

   Q Describe the properties of an effervescent tablet.

   Q How is the effervescent tablet similar to salt?

   Q How is the effervescent tablet different than salt?

2. Explain to the students that some properties of matter (such as size, amount, and shape) can change without changing the type of material.

a. Break the effervescent tablet in two pieces.

Q Have any properties of the effervescent tablet changed?

Q Is the effervescent tablet still made of the same material?

b. Take one grain of table salt and separate it from a pile of table salt.

Q Are the properties of this one grain of salt different than this pile of table salt?

Q Is this grain of salt still salt? What properties are the same?

Q If the grain of salt is blown into the air can you see it? Is it still salt?

3. Discuss with the students what happens when two materials are mixed together. Help them start to understand that sometimes two substances react with each other to form a new substance with new properties and other times two substances simply mix together (the two materials keep their same properties but they spread out among one another and occupy the same area.

   a. Place half of the effervescent tablet into a beaker of water and discuss with your students that a new substance, a gas (which forms bubbles), has properties that are different than either the effervescent tablet or the water.

   Q What do you observe as the effervescent tablet is combined with the water?

   Q What state of matter causes bubbles?

   Q Where did the gas come from? Did the effervescent tablet or the water contain gas? Is the gas a new substance?

   Q Did a chemical reaction occur or did the particles just mix in the same area?

   b. Place a spoonful of salt in the other beaker of water and discuss what happens with your students. Help the students understand that as the salt dissolves it is breaking up into tiny pieces, smaller even than one single grain. Although it is hard to see it is still in the beaker. It still tastes salty. Therefore no chemical reaction has taken place; the salt and the water have just spread out in the same area.

   Q What do you observe as the salt is added to the water?

   Q Is there a new substance formed? What properties does it have?

   Q Did a chemical reaction occur or did the particles just mix in the same area?

4. Explain to your students that they will be exploring the properties of materials and how to use the properties of materials to determine if a chemical reaction has occurred when two materials are combined.

Driving Question

- When you combine two materials, how do you know if a chemical reaction has occurred?

Variables

Note: This lab includes many small experiments and does not focus on one overall experiment with one independent variable. The table below lists several of the small experiments that the students are exploring and their corresponding variables.

Section of the Lab	Independent Variable	Dependent Variable	Controlled Variables
Let's Explore (Part 1)	Type of material to mix with water (sugar and alum)	Visual change in properties	Amount of water Amount of sugar/alum added Temperature of materials
Let's Explore (Part 1)	Types of material to mix with ammonia (sugar water and alum water)	Visual change in properties	Amount of sugar water/alum water Amount of ammonia Temperature of materials
Let's Explore (Part 2)	Type of material to react with iodine	Visual change in properties (color)	Amount of tincture of Iodine added Temperature
Tell Me More	Types of materials that are being reacted	Temperature	Initial temperature of the starting materials (room temperature)

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

In this section, you will observe properties of different materials and explore what properties change when a material is physically changed.

1. ☐ Carefully observe each material listed in Table 1 below. Record at least three properties for each material.

Table 1: Properties of various materials

Material	Properties (description of the material)	State of Matter (solid, liquid, or gas)
Sugar cube	White, hard, crystalline, sweet	Solid
Water	Clear, colorless, odorless	Liquid
Steel wool	Silver, metal, shiny, rough	Solid
Air	Colorless, clear, odorless, tasteless	Gas
Cracker	Brown, rough, square	Solid

2. ☐ Record the state of matter for each material in Table 1 above.

3. ☐ Break the cracker in half and then answer the following questions:

   a. What properties of the cracker changed?

      The size and the shape of the cracker changed.

   b. What properties of the cracker stayed the same?

      The color (brown), the texture (rough), and the state of matter (solid) all stayed the same.

   c. Has a new material been formed?

      A new material has not been formed. Even though the cracker was broken, the pieces are still crackers.

4. ☐ Pour the water into a bowl and then answer the following questions:

   a. What properties of the water changed?

      The shape of the water changed.

   b. What properties of the water stayed the same?

      The water is still clear, colorless, and odorless. The water is also still in the liquid form.

   c. Has a new material been formed?

A new material has not been formed. Even though the shape of the water changed, it is still water.

5. ☐ How could you change the sugar cube so that you still have sugar? What properties would stay the same? What properties would change?

   The sugar cube could be crushed. The sugar would still be white, hard, crystalline, and sweet, but the shape would be different. The sugar cube could also be added to water. The sugar would still be sweet, but the pieces of the sugar would be so small that the color, shape, and particle pieces would all be too small to see. Other answers may also be correct.

6. ☐ Is the following statement true or false? Explain your reasoning.

   Materials can be changed so that some of their properties change, but that the material itself may stay the same. When this occurs it is called a physical change.

   True. When the cracker was broken the size and shape of the cracker changed, but the cracker pieces are still crackers. This is an example of a physical change.

Let's Explore

Part 1

In this part, you will mix different materials to determine if any of the materials chemically react with each other.

7. ☐ Pour approximately 100 mL of water into a clean 250-mL beaker.

8. ☐ Add approximately 5 grams (1 spoonful) of sugar to a dry, clean 50-mL beaker.

9. ☐ Observe the water and sugar in their beakers and record at least three properties of each in Table 2.

Table 2: Properties of water, sugar, and water plus sugar

Material	Properties (description of the material)
Water	Clear, colorless, odorless, liquid
Sugar	White, hard, crystalline, sweet, solid
Water + sugar	Clear, colorless, odorless, the sugar has dissolved

10. ☐ Pour the sugar into the water and stir for 2 to 3 minutes.

11. ☐ Describe the properties of the water and the sugar together and record your description in Table 2.

12. ☐ Label the beaker “sugar water” and set it aside to use later in this activity.

13. ☐ Pour approximately 100 mL of water into a second, clean, 250-mL beaker.

14. ☐ Add approximately 5 grams (1 spoonful) of alum to a dry, clean, 50-mL beaker.

Teacher Tip: The students will need to clean and dry the 50-mL beaker to reuse it throughout the activity.

15. ☐ Observe the water and alum and record at least three properties of each in Table 3.

Table 3: Properties of water, alum, and water + alum

Material	Properties (description of the material)
Water	Clear, colorless, odorless, liquid
Alum	White, hard, crystalline, solid
Water + alum	Clear, colorless, odorless, the alum has dissolved

16. ☐ Pour the alum into the water and stir for 2 to 3 minutes.

17. ☐ Describe the properties of the water and the alum together and record your description in Table 3.

18. ☐ Label the beaker "alum water."

19. ☐ Add approximately 15 mL (3 spoonfuls) of ammonia to a dry, clean 50-mL beaker.

CAUTION: Ammonia has strong fumes; do not breathe the fumes!

20. ☐ Observe the alum water and the ammonia and record at least three properties of each in Table 4.

Table 4: Properties of alum water, ammonia, and alum water + ammonia

Material	Properties (description of the material)
Alum water	Clear, colorless, odorless, liquid
Ammonia	Clear, colorless, strong smell, liquid
Alum water + ammonia	White solid material floating in a clear colorless liquid

21. ☐ Pour the ammonia into the alum water.

22. ☐ Describe the properties of the alum water and ammonia together and record your description in Table 4.

23. ☐ Add approximately 15 mL (3 spoonfuls) of ammonia to a dry, clean 50-mL beaker.

24. ☐ Observe the sugar water and the ammonia and record at least three properties of each in Table 5.

Table 5: Properties of sugar water, ammonia, and sugar water + ammonia

Material	Properties (description of the material)
Sugar water	Clear, colorless, odorless, liquid
Ammonia	Clear, colorless, strong smell, liquid
Sugar water + ammonia	Clear, colorless, slight smell, liquid

25. ☐ Pour the ammonia into the alum water.

26. ☐ Describe the properties of the sugar water and ammonia together and record your description in Table 5.

27. ☐ Look over your results and determine whether or not any of the materials you mixed together chemically reacted.

Hint: When a chemical reaction occurs, a new material is formed. This new material has properties different from the starting materials.

Table 6: Evidence of materials reacting chemically

Materials Combined Together	Chemical Reaction Or Mixture	Evidence
Water + sugar	Mixture	There were no new substances formed. All of the properties of the water + sugar were the same as the water, the sugar, or an expected combination of the two.
Water + alum	Mixture	There were no new substances formed. All of the properties of the water + alum were the same as the water, the alum, or an expected combination of the two.
Alum water + ammonia	Chemical reaction	A new solid white material was formed. This substance had properties that were different than the water, the ammonia, or an expected combination of the two. You would not expect two clear liquids to combine to form a white solid.
Sugar water + ammonia	Mixture	There were no new substances formed. All of the properties of the sugar water + ammonia were the same as the sugar water, the ammonia, or an expected combination of the two.

Part 2

In this part, you will determine what materials chemically react with tincture of iodine and provide evidence to support your decision.

28. ☐ Get a bottle of tincture of iodine and open it and describe at least three properties of the tincture of iodine. **Hint**: Observe the tincture of iodine on the applicator stick that comes in the bottle.

    The tincture of iodine is a brown, clear, liquid.

29. ☐ Place a cracker, a sugar cube, a piece of cheese, a piece of notebook paper, and a slice of a raw potato on a paper towel.

30. ☐ Record at least three observations of each material in Table 7.

Table 7: Tincture of iodine test

Materials	Properties (description of the material)	Properties of the Material Mixed with Tincture of Iodine
Cracker	Brown, rough, square, solid	Tincture of iodine spot turns dark blue/black
Sugar cube	White, hard, crystalline, sweet, solid	Tincture of iodine spot turns the sugar a light brown color
Cheese	Orange, opaque, soft, solid	Tincture of iodine spot is clear, and brown on top of the cheese
Notebook paper	White, thin, solid	Tincture of iodine spot turns dark blue/black
Potato slice	Yellow, solid, round, opaque characteristic odor	Tincture of iodine spot turns dark blue/black

31. ☐ Place 2 to 3 drops of tincture of iodine on each of the materials.

32. ☐ Which of the materials chemically reacted with the tincture of iodine? Explain your reasoning.

    The cracker, notebook paper, and potato chemically reacted with the tincture of iodine. In each of these cases, a new dark blue/black material was appeared. This was a new material because neither the tincture of iodine nor any of the materials started with a dark blue/black color.

33. ☐ Which of the materials did not chemically react with the tincture of iodine? Explain your reasoning.

    The sugar cube and the cheese did not react chemically with the tincture of iodine. When the tincture of iodine was placed on the sugar cube and the cheese it remained the same clear, brown color that it started with. Although the sugar turned brown, this was an expected color change because when you mix a brown color with a white color a light brown color is expected.

Explain It

In this section, you will review vocabulary and concepts that you have learned so far in this activity and you will use this information to make predictions about other aspects of chemical reactions.

34. ☐ In your investigation of whether or not a chemical reaction occurs when you combine two materials you learned some new scientific ideas and terms. It is important to be able to discuss results using these words and terms correctly.

    Write the meaning of the following terms in your own words using what you have learned from the activity.

Table 8: Vocabulary and definitions

Properties (of a material)	A description of what a material looks like such as color, shape, texture, state of matter, smell, and taste.
Chemical reaction	When two or more things are combined and a new material, with properties that are different from those of the original materials, is formed.
Mixture	Two or more materials that are in the area together. For example a salad is a mixture of lettuce, tomatoes, and carrots.
Physical change	Things that are done to materials that cause some of their properties to change, but remain the same chemical substance. Physical changes include mixing, dissolving, phase changes (boiling, freezing, condensing, and evaporating), tearing, cutting, and more.

35. ☐ What clues suggest that a chemical reaction has occurred? Give at least two examples from the activities you have performed.

    A new material must be formed when a chemical reaction has occurred. This new material must have properties that are different from the starting materials. In part 1 of Let's Explore, a white solid was formed when two clear liquids were mixed. This unexpected formation of a solid is one clue that a chemical reaction has occurred. In part 2 of Let's Explore, an unexpected color change occurred (brown tincture of iodine turned dark blue/black when it reacted with certain materials).

36. ☐ When two materials are combined together does a chemical reaction always occur? Explain your thinking.

    No. When two materials are mixed together sometimes a chemical reaction occurs and a new substance forms. Other times the two materials just occupy the same area and a mixture is formed.

37. ☐ Do all materials respond the same way when they are mixed with tincture of iodine?

    No. Some materials chemically react with tincture of iodine and other materials do not.

38. ☐ Did alum water and sugar water respond the same way when they were mixed with ammonia?

   No. Alum water chemically reacted with ammonia, but sugar water just formed a mixture with ammonia.

39. ☐ When two substances chemically react, do you think there is there a change in temperature? Is the temperature of the newly formed substance the same as the starting materials, lower than the starting materials, or the same as the starting materials? Explain your thinking.

   This is a prediction question so the answers will vary. The correct answer is that the chemical reactions often involve a change in energy, but not always. The temperature of the newly formed products can be the same as, lower than, or greater than the starting materials. It depends on the materials being reacted. In general, a change in energy may suggest that a new substance is being formed but this clue needs to be accompanied by another piece of evidence indicating that a new substance has formed.

Tell Me More

In this activity, you will determine whether or not chemical reactions involve change in temperature. You will also practice identifying clues that indicate a chemical reaction has occurred.

Steel Wool and Air

40. ☐ Start a new experiment on the data collection system.

41. ☐ Connect a temperature sensor to your data collection system.

42. ☐ Display a graph of Temperature (˚C) on the *y*-axis versus Time (s) on the *x*-axis.

43. ☐ Label a dry, clean 250-mL beaker "air" (in this experiment you will be reacting steel wool with air which is all around you including inside the beaker).

44. ☐ Place the tip of the temperature sensor so that it hangs about 1 cm above the bottom of the beaker. **Note:** If necessary, use a piece of tape to keep the temperature sensor in place.

45. ☐ Stretch a piece of steel wool (~2 g) apart so that there are lots of open spaces that you can see through.

46. ☐ Observe the steel wool and air and record at least three properties of each in Table 9.

➢ Table 9: Properties of air, steel wool, and air + steel wool

Material	**Properties (description of the material)**
Air	Clear, colorless, odorless, gas
Steel wool	Metallic, gray, shiny, solid
Steel wool + air	Brownish-orange, dull, rusty, solid

47. ☐ Label a second 250-mL beaker "vinegar."

48. ☐ Pour approximately 75 mL of vinegar into the beaker labeled "vinegar."

49. ☐ Place the stretched out piece of steel wool into the vinegar.

50. ☐ Allow the steel wool to soak in the vinegar for at least 1 minute. Use a stir rod to make sure that all the steel wool is beneath the vinegar.

    Note: The vinegar is being used to clean the steel wool by removing a protective covering.

51. ☐ Begin recording temperature data of the air inside the beaker.

52. ☐ Remove the steel wool from the beaker of vinegar and squeeze out all the vinegar.

53. ☐ Stretch apart the steel wool and quickly, but thoroughly dry the steel wool with paper towels.

54. ☐ Add the steel wool to the bottom of the beaker labeled "air" so that it covers the tip of the temperature sensor.

55. ☐ Adjust the scale of a graph so that you can see the changes taking place.

56. ☐ When the temperature stabilizes (after 1 to 2 minutes) stop recording data.

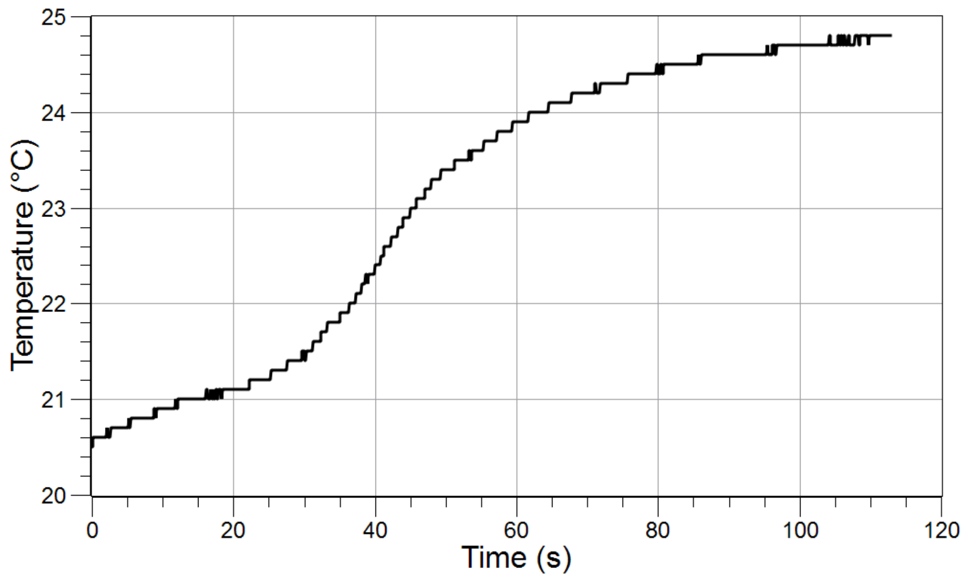
57. ☐ Remove the steel wool from the beaker labeled "air" and set it beside a second, unused piece of steel wool. Record your observations of the steel wool + air in Table 9 above.

58. ☐ Did a chemical reaction occur between the steel wool and the air? How do you know?

    A new brownish-orange substance was formed on the steel wool. The formation of a new substance means that a chemical reaction occurred. A brown-orange color was not one of the original properties of either the steel wool or the air.

59. ☐ Sketch a copy of your Temperature (°C) versus Time (s) graph on the axes provided below.

Temperature Change as Steel Wool Reacts with Air



60. ☐ Was there a temperature change as the air and steel wool reacted? If so, was heat released by the chemical reaction or absorbed?

Yes, the temperature increased. This means that the reaction between steel wool and air released heat.

Vinegar and Baking Soda

61. ☐ Make sure that your data collection system is still on and a graph of Temperature (°C) versus Time (s) is displayed.

62. ☐ Make sure there is at least 30 mL of vinegar still in the beaker labeled "vinegar" (more is okay).

63. ☐ Place approximately 2 g (¼ spoonful) of baking soda in a dry, clean 50-mL beaker.

64. ☐ Observe the vinegar and baking soda and record at least three properties of each in Table 10.

Table 10: Properties of vinegar, baking soda, and vinegar + baking soda

Material	Properties (description of the material)
Vinegar	Clear, colorless, strong odor, liquid
Baking soda	White, powder, solid, opaque
Vinegar + baking soda	Bubbles, clear liquid, foamy bubbles

65. ☐ Place the temperature sensor in the vinegar so that the tip of the temperature sensor is completely underneath the vinegar.

Note: Use a piece of tape to keep the temperature sensor in place.

66. ☐ Start data recording.

67. ☐ Add the baking soda to the vinegar.

68. ☐ When the temperature stabilizes (after about 1 to 2 minutes) stop recording data.

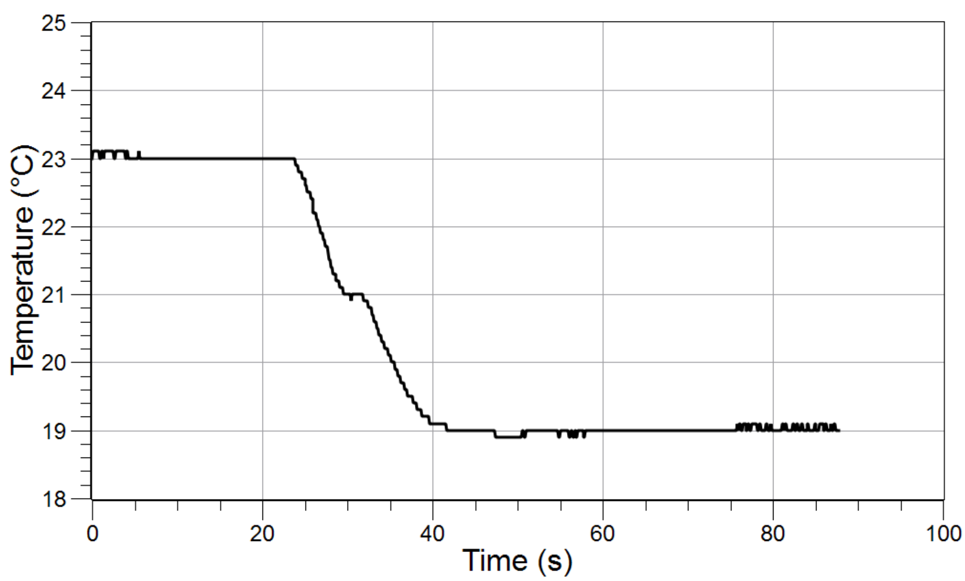
69. ☐ Record your observations of vinegar + baking soda in Table 10 above.

70. ☐ Did a chemical reaction occur between the vinegar and baking soda? How do you know?

Yes a chemical reaction did occur because a new substance, a gas was produced. Neither vinegar nor baking soda is made up of gases so the gas was a new and unexpected material.

71. ☐ Sketch a copy of your Temperature (˚C) versus Time (s) graph for the reaction between vinegar and baking soda on the on the axes provided below.

Temperature Change as Vinegar reacts with Baking Soda



72. ☐ Was there a temperature change as the vinegar and baking soda reacted? If so, was heat released or absorbed by the chemical reaction?

Yes, the temperature decreased. This means that the reaction between vinegar and baking soda absorbed heat from the surroundings making the surroundings colder.

Sum It Up

Summarize what you have learned through this activity by answering the following questions.

73. ☐ When you combine two materials, how do you know if a chemical reaction has occurred?

   A chemical reaction has occurred if a new material is formed. A new material will have properties that are different than the original materials.

74. ☐ Table 11 has a list of observations a student made when combining two materials together. Help the student decide whether a chemical reaction has occurred or not. If a chemical reaction has occurred write "Chemical reaction" in the space provided. If not, write "Mixture" in the space provided.

Table 11: Observations suggesting a chemical reaction or mixture

Observations	Chemical Reaction or Mixture
A gas formed when two clear liquids were mixed.	Chemical reaction
A light red liquid is formed when a red solid combines with a clear liquid.	Mixture
A white solid forms when two clear liquids were combined.	Chemical reaction
A purple liquid is formed when a red liquid and a blue liquid are combined.	Mixture
A clear liquid is observed after a white solid is added to a clear liquid.	Mixture

75. ☐ Do temperature changes occur during a chemical reaction? Explain your thinking.

   A chemical reaction may cause a change in temperature. Sometimes chemical reactions release energy (the new materials are hotter) and sometimes chemical reactions absorb energy (cause the new materials to be colder).

76. ☐ List four clues you can look for to determine whether or not a chemical reaction has occurred.

   An unexpected color change, the formation of a solid when two liquids are mixed, the formation of a gas, and a change in temperature.

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. To make sweet tea you add sugar to tea. This is an example of a

   Ⓐ Chemical reaction

   Ⓑ Physical change

   Ⓒ Both a physical change and a chemical reaction

   Ⓓ No change has taken place

2. A chemical reaction will always

   Ⓐ Release heat (cause an increase in temperature)

   Ⓑ Form a gas

   Ⓒ Form a new material

   Ⓓ Involve a color change

3. Which of the following changes involves a chemical reaction?

   Ⓐ Tearing a paper into two pieces

   Ⓑ Mixing table salt and water

   Ⓒ Using a paper towel to soak up water

   Ⓓ Burning a log

4. When two materials are mixed

   Ⓐ A chemical reaction will always occur

   Ⓑ A physical change will always occur

   Ⓑ Either a physical change or a chemical reaction may occur

   Ⓓ Neither a physical change nor a chemical reaction will occur

Further Investigations

Investigate other types of physical changes such as phase changes and explore how they are similar to and different than chemical reactions.

Have the students explore the difference between dissolving (two substances mixing) and melting (one material gaining heat).

Have the students repeat the reaction between alum water and ammonia and have them take the temperature as the reaction occurs. This will help the students understand that not all chemical changes involve chemical reactions.

Explore the changes involved during combustion (burning). Have the students list the changes they observe a candle as it is burning and then have the students decide if the changes are chemical reactions or physical changes.

Investigate how physical properties of each individual material in a mixture may be used to separate mixtures.

25. Weather Station

Recommended Grade Levels: 4 – 5

Objectives

Students know that weather is a complex system that changes in measurable ways and can be monitored with simple instruments. Through this investigation, students use inquiry methods to predict, measure, evaluate, and share weather data.

Procedural Overview

To understand this content, students:

- Design and build a weather station
- Use a weather sensor to measure temperature, dew point, humidity and atmospheric pressure over a period of time
- Analyze graphs of the weather data to see if there is a correlation to observable weather conditions

Time Requirement

Teacher Preparation	2 hours or as needed
Pre-Activity Discussion	30 minutes
Get Started	20 minutes (Could be assigned for homework)
Let's Explore	30 minutes
Explain It	15 minutes
Tell Me More	20 minutes each day for 5 days
Sum It Up	30 minutes

Materials

For teacher demonstration:

- ☐ Computer with Internet weather websites, bookmarked
- ☐ Computer overhead projection system
- ☐ Grounded outdoor extension cord
- ☐ Clouds poster
- ☐ Weather maps
- ☐ Utility knife

For each student group:

- ☐ Mobile data collection system
- ☐ Weather sensor
- ☐ Sensor extension cable
- ☐ USB flash drive
- ☐ Weather Journal[1]
- ☐ White plastic milk container with lid, 1.89 liter (½ gallon)
- ☐ Index card cut to 2 cm x 6 cm
- ☐ 3-meter wooden stake
- ☐ Hammer
- ☐ Duct tape
- ☐ Masking tape
- ☐ Plastic utility tub
- ☐ Brick
- ☐ String, 1 meter

[1]Refer to the Preparation section for printing the Weather Journal.

Activity at a Glance

Get Started

- ☐ Brainstorm the way we could monitor the weather and what we would need to make a weather prediction.

Let's Explore

- ☐ Build a weather station.
- ☐ Put the weather station outside and gather data briefly.
- ☐ Record information about the actual observed conditions.

Explain It

- ☐ Look at data from the four weather variables and explain how each variable influences the weather.
- ☐ Define vocabulary terms: temperature, dew point, relative humidity, and barometric pressure.

Tell Me More

- ☐ Put the station back outside for five days and gather new data.
- ☐ Analyze the graphs to find patterns and draw conclusions about how each of the four factors influences the weather we observed during the same time period.

Sum It Up

- ☐ Use the patterns to make some generalized statements about how weather forms and changes. Make a forecast.

Safety

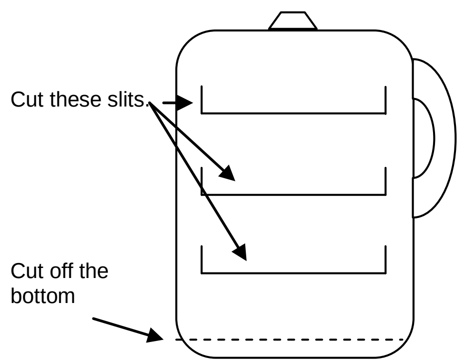
Add these important safety measures to your normal outdoor class procedures:

- Electrical extension cords must be grounded and certified for outdoor use.
- Do not allow the data collection system to get wet in sprinklers or rain.

Preparation

These are the materials and equipment to set up prior to the activity.

- Bookmark weather sites on the Internet or gather weather reports from newspapers.
- If you have a classroom projection system, prepare to display your computer screen on the projection system.
- Print copies of the Weather Journal handout for your students. Make as many copies as you will need for the number of days students will be watching the weather.
- A Stevenson screen is constructed by the students to protect the sensors from direct sunlight and rain while allowing for free air circulation. You may decide to prepare the containers in advance. If so, direct students to skip certain steps as they proceed through the lab. Here is what you need to know, whether you prepare the container or your students do it:



The milk container needs to be white to minimize solar radiation effects. A colored station may heat up more than the surrounding environment, giving inflated temperature readings. Save the lid for each container.

The vents in the screen are meant to allow for good air flow through the screen but prevent precipitation from falling into the container. Students can use scissors to cut this, but will need you to give them a starting hole with a craft knife. Draw the slats on the sides of the container with a permanent ink pen, or provide your students with a template or the measurements. Make each slat as wide as each side and about 2 to 3 cm high. See diagram. Tell students not to cut the vent off completely; only the bottom and sides of the vent is cut.

- Mount the post: The weather station is mounted on a post at a height of 1 m to 2 m above ground level and 10 times farther away from any object, tree or wall than it is high (in other words, out in the open.) Determine the number of posts you will need; more than one weather station could be placed on the same post as long as they do not interfere with each other. Set the post deeply enough in the ground to hold the weather station even in windy conditions. It may need to be within extension cord distance to a power supply.

Data can be gathered in a variety of ways. Because the data collection system (DCS) can run out of battery life or get "bogged down" with too much data, follow one of the tips below:

- Set the DCS to collect data once per half hour, but stop data collection after 24 hours and start a new run. Do this each day until your five days are complete. The separate runs will save memory. This is the way the activity is developed for the student, but you can change it according to your particular needs.

- Use two separate data collection systems and alternate them daily, recharging the unused one while the other collects data.
- Use a battery powered DCS that is fully charged. If the battery power is strong, the device can gather data at one- or two-hour intervals for five days nonstop.
- Use a battery powered DCS but set it to manually collect data. Send students out to the station at predetermined times to collect data.
- Plug in the DCS with an extension cord and run it continuously, selecting to gather data once every hour. You won't run out of power, but the device still may have a limit for how much data it can store per run.
- All the variables can be assembled in a table, or each variable can be displayed in a graph. You can also use both a table and graphs.

Background

We live in an ocean of air which surrounds our planet and is constantly in motion due to its uneven heating and the rotation of the planet. Our atmosphere consists of 78% nitrogen gas, 21% oxygen gas, 1% a mixture of other gases and water vapor. Suspended in the air are solid particulates of dust, residue from the combustion of fossil fuels, smoke from burning and forest fires, and ash from volcanism. For people, the most important parts of the atmosphere are the oxygen content and the water vapor, which makes life on this planet possible.

Cloud formation

Air picks up moisture from the Earth's surface: oceans, lakes, streams and other sources of moisture. Warmer air, carrying this water vapor, goes to higher altitudes where it cools. Cooler air cannot hold as much water vapor as warm air, so the water vapor is squeezed out of the air.

Water can condense out of the air onto dust particles to form a cloud. The various cloud types come from variations in the temperature of the air, the way the air is moving, the air's altitude, and moisture content. For example, a stratus cloud, which is long and thin, often forms when a layer of warm air comes in contact with a layer of cool air, creating a layer-like cloud. Cumulus clouds, which appear more like cotton-balls, form when a volume of moist air moves upward and cools, creating a more billowing appearance. Cirrus clouds form only at the highest altitudes, where the water droplets freeze and form ice crystals.

Causes of air movement

The direction of high altitude winds can be observed from watching the motion of clouds. Generally speaking, weather moves from west to east in the United States. This is the product of two phenomena: differential heating of the Earth's surface, and the Coriolis Effect.

The equator is warm and the poles are cooler because the sun is more directly overhead at the equator than it is at the poles. As a result, the Earth's surface gets hotter at the equator than at the poles, and radiates more heat into the air, which heats and stays hot. Hot air has a lot of energy, and expands, becoming less dense than the cooler air above it. The hot air rises and cooler air gets drawn into the space it leaves behind. The result of this is that there is a circulation of air going up at the equator, and moving outwards toward the poles, cooling and finally sinking back down, and moving back towards the equator. This is known as a convective current.

The second phenomenon is called the Coriolis Effect. The speed of the earth's rotation is essentially zero at the poles, as is the air above the poles. The equator is moving very fast, as is the air above the equator. You can envision a merry-go-round. On the outside edge (equator), it is going very fast. Near the center (pole or axis), it is moving more slowly. When you combine these two phenomena, you have warm air rising at the equator and moving towards the poles. This air has a lot of west to east velocity as it rises up, and as it moves towards the poles, it is going faster than the Earth's surface below. This creates a high altitude wind (jet stream) going from west to east.

Factors that influence weather

Temperature

Knowing why air shifts around does not explain why we have different kinds of weather. For that, we need to consider what influences changes in the air. The first factor is temperature. The differential heating causes large masses of air to have a definite temperature. Air masses are known as hot or cold air masses.

Water Vapor and Humidity

The second factor is the amount of water vapor in the air at any given height or temperature. This is known as humidity. Warm air can hold more water vapor than cold air, because there is more space for the water molecules to fit into the air. Relative humidity is the amount of water vapor in the air compared to the possible total amount of water vapor that the same air could hold at that temperature. Relative humidity is reported as a percent. If the air is at 100% relative humidity, the air at that temperature is completely saturated and is holding as much water vapor as it possibly can hold. The closer the relative humidity is to being saturated, the more likely it is to rain.

Dew Point

The third factor is another way to look at temperature called the dew point. The dew point temperature is the temperature to which a mass of air would have to cool in order to reach saturation. Think of a sponge holding an amount of water. Gently squeeze the sponge, making it take up less space, and water will come out of the sponge. The same is true for a mass of air. If it cools, the air molecules move closer together, and squeeze the water molecules out of it. When air cools to its dew point, water vapor will condense onto any nearby solid. That's why the ground, your car, your sleeping bag can get covered in dew during the colder nighttime hours.

Air Pressure

The fourth factor related to weather is air pressure. When more air piles up in a location, it weighs more. This is high pressure. If there is more air pressing down on the Earth in a given location, it will serve to squeeze water vapor out of the air, or at least prevent water vapor from accumulating in the air. The opposite is true for low pressure. Low pressure means that there is less air in a given place, so the air can expand and potentially hold more water vapor. Because more water vapor can lead to more cloud cover, low pressure systems are associated with cloudy, even rainy days, and high pressure systems are associated with clear, fair days.

Pre-Activity Discussion

How can we gather and use weather data to make a weather forecast?

- A computer with Internet access and the ability to project the screen for the whole class to see is necessary for this part of the lab. (Alternately, you can use weather reports from newspapers.)

- Bookmark weather sites that show a map of the country and Doppler radar images. Also bookmark various sites that show weather reports for individual cities. Ask the students the following series of questions that can help focus the discussion on weather features.

1. In examining the images of Doppler radar, what does the map reveal?

   The map shows clumps of cloudy weather systems across the country.

2. What is the radar "seeing"?

   The radar is "seeing" clouds. The radio waves are bouncing off the water molecules.

3. What is happening in the areas where no clouds are shown?

   In these areas there are no clouds, so there is nothing for the radio waves to bounce off except the ground.

4. What do the different colors mean on a Doppler image?

   The different colors represent more or less dense clouds. The denser the cloud, the more water it is holding.

5. What can you NOT tell from a Doppler image?

   The image does not tell you the temperature of the air mass, nor the atmospheric pressure.

6. Looking at the weather report for our city, what weather conditions are being reported?

   The weather report consists of temperature, relative humidity, dew point, wind direction and speed, cloud cover, precipitation, and atmospheric pressure. It may also give the amount and type of particulates in the air, such as pollens, and report on the general healthiness of the air for asthma sufferers.

7. How do you think these conditions are being measured?

   There must be sensors outside at determined locations. The sensors include a thermometer, barometer (for pressure), hygrometer (for humidity) and other specialized devices for analyzing the particulates.

- Review the basic cloud types, stratus, cumulus and cirrus. You may want to have a cloud poster to hang in your classroom if your students have not learned about cloud types in a previous grade.

1. Is the best way to tell a stratus cloud from a cumulus cloud?

   A stratus cloud covers most or all of the sky. A cumulus cloud is more compact and looks like the puffy clouds illustrated in storybooks.

2. What is the best way to identify a cirrus cloud?

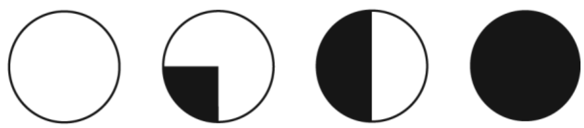
   Cirrus clouds look wispy, thin and streaky, and are extremely high in the sky.

3. Which clouds are likely to bring precipitation?

   Both stratus and cumulus clouds can bring precipitation if they are loaded with enough water.

- Teach your students a strategy for estimating the amount of the sky that is covered in clouds. The usual strategy is to use a pie graph. Color in the circle in proportion to the amount of sky coverage.

  1. What would a sky coverage symbol look like for a sky that was half covered in clouds? One-fourth covered in clouds? Half covered in clouds? All covered in clouds?



Driving Question

- How can we gather and use weather data to make a weather forecast?

Variables

Independent Variable

- The only variable we will control is the amount of time we run the experiment.

Dependent Variables

- The variables that will change over time, and depending on the location, include temperature, relative humidity, dew point, and barometric pressure.

Controlled Variables

- The variables we will keep from changing are the height of the weather station from the ground and the position of the sensor inside the weather station.

Activity with Answer Key and Teacher Tips

Get Started

Teacher Tip: This section could be assigned for homework after you have done the Pre-Activity Discussion and before the students begin Let's Explore.

In these activities, you will build and use a weather station to measure temperature, relative humidity, and barometric pressure over 5 to 10 days. In addition you will journal weather conditions during the same time.

1. ☐ Why do we study the weather?

   Students will say that we study the weather so that we can predict what the weather will be doing in the next few days. We want to know if the weather will affect our plans.

2. ☐ What other name do we give a weather prediction?

   Weather predictions are also called weather forecasts.

3. ☐ Meteorologists study the weather by recording and analyzing data. The term "weather" refers to the atmospheric conditions around us at any given time. Make a list of different types of atmospheric conditions that affect weather. Remember that a clear day is weather, too. In fact, most meteorologists would call clear days the best kind of weather!

   Answers will vary. Students may suggest temperature, moisture, the presence of clouds, precipitation and wind speed as examples of atmospheric conditions that affect weather. They may need help in remembering that air pressure or air pollutants are also studied, as is the direction the wind is blowing from.

4. ☐ Based on your list of atmospheric conditions, what types of measurements would be best for us to measure?

   Answers will vary. Students may suggest measuring the temperature, moisture, dew point, barometric pressure and wind speed.

5. ☐ Here is a picture of a weather station called a Stevenson screen. How do you think it is being used to measure weather features?

   Answers will vary. Students may suggest that the sensors are inside the box. The louvers on the sides of the box allow air to circulate inside where the sensors are located, but the sensors are protected from rain and sun.

Source: Wikimedia Commons

6. ☐ What in the picture gives us clues about how to place a weather station?

   The weather station has to be out in the open, away from buildings and trees. It has to be raised up off the ground. The instruments have to be protected from the weather, but still able to measure it. It may have a solar cell for power.

7. ☐ List the weather measurements you would like to gather in order to make a prediction about the weather.

   Students will list temperature, humidity, dew point, wind speed and direction, atmospheric pressure.

8. ☐ Aside from the measurements, what other factors can be observed to let us know as much as possible about the weather?

   Students will name clouds, amount of sky cover, and type and amount of precipitation.

Let's Explore

9. ☐ Examine the equipment that is available for you to measure weather data. Use the table to list the equipment you will use, and explain what each part is for.

Equipment for Measuring Weather Data	Purpose
Weather sensor	Measures temperature, relative humidity, atmospheric pressure, and dew point
Extension cable	Attaches the sensor to the data collection system
Data collection system	Records all the weather data in table or graph
Extension cord	Provides power to the data collection system

10. ☐ Available for your use is a plastic milk container and a plastic utility tub. Describe how you will use these materials to properly house the weather sensor and data collection system (DCS).

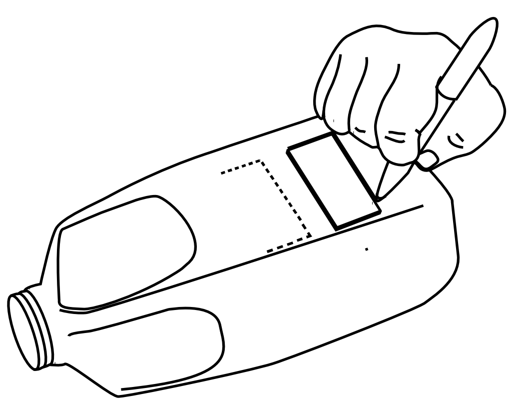
    Teacher Tip: Make this activity more open inquiry by allowing students to creatively design their own station and gather their own materials. This will extend the length of the lab an extra day or two.

    Students should describe how they will remove the bottom from the milk container and cut slits in the sides for aeration. The weather sensor will be suspended inside the milk container and the top securely covered to prevent leakage. The DCS will be placed on a brick or block so it is up off the ground, and covered with the plastic utility tub. More bricks could be placed on the overturned tub to prevent it from blowing away. Designs can vary as long as all equipment is protected.

11. ☐ Get a white plastic milk container and lid from your teacher. Remove the bottom with your scissors.

    Note: This will let you place the sensor inside, and will provide extra ventilation.

12. ☐ Use a 3 cm x 6 cm template cut from an index card to trace two shutters on each side of the container.



13. ☐ Ask your teacher to get each vent started for you by punching a small hole in a corner of the vents you drew. Then you can cut the vents with your scissors.

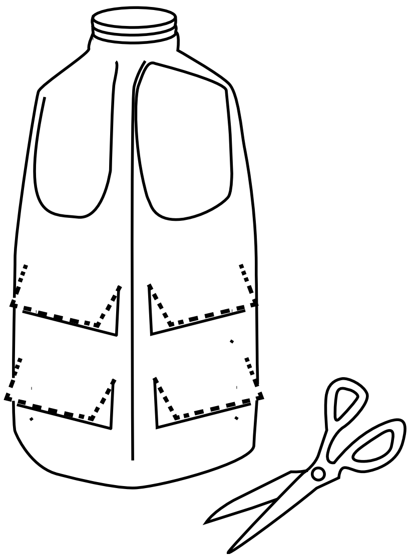
Note: Do not cut the top of the vent! Cut the sides and bottom only so that a flap can be lifted to ventilate your weather station. Cut two vents on all sides of the container. (See diagram A.)

14. ☐ Tape a piece of string securely to both sides of the bottom of weather sensor.

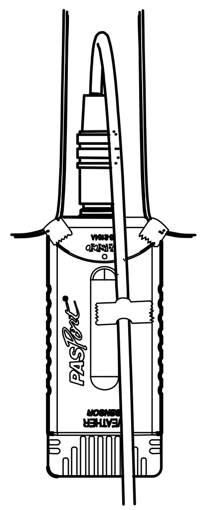
15. ☐ Plug the sensor extension cable into the bottom of the weather sensor.

16. ☐ Hold the weather sensor by the string and allow the cable to fall down the back of the sensor. Tape it to the back of the sensor.

A.



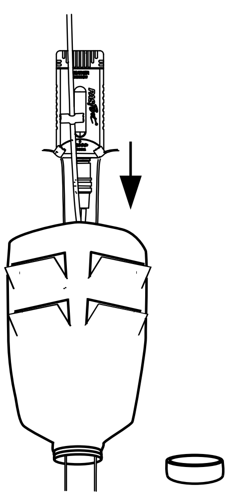
B.

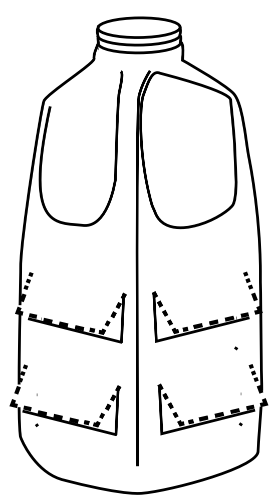


Note: At this point, the slotted end of the sensor should be hanging downward. (See diagram B above.)

17. ☐ Draw the string up through the opening on the top of the container and secure the string in place with the lid.

Note: Suspend the weather sensor inside the container in such a way that it does not touch the sides of the container and is fully enclosed inside the container, not hanging out.





18. ☐ Compare your weather station to the professional Stevenson screen shown at the beginning of the activity. How does the design of your weather station benefit your experiment?

    Answers will vary. Students should say that their weather station must protect the weather sensor from rain or other precipitation, while still allowing air to circulate inside the screen.

19. ☐ Start a new experiment on the data collection system.

20. ☐ Connect the sensor extension cable to your data collection system.

21. ☐ Display temperature, relative humidity, dew point and barometric pressure in a table.

22. ☐ Change the sampling rate to once every 15 seconds.

23. ☐ Take your mobile DCS and Weather Station outside, away from buildings. Bring a copy of your weather journal and a pencil with you.

Teacher Tip: Use the one page handout at the end of this activity entitled "Weather Journal" for both the practice session and the data collection during the week.

24. ☐ Start recording data. After 2 minutes, stop recording data.

25. ☐ Notice if there are clouds, how much of the sky is covered in clouds, if there is a wind and what direction it is coming from, and if there is any precipitation. Record these things in your weather journal.

Explain It

26. ☐ Return to your classroom and examine the data to see how the temperature and humidity support your experience of what the weather is currently doing in your area.

    a. Did the temperature feel as if it was about what the sensor measured?

    Hopefully, students will have some experience with estimating the daily temperature. This is an opportunity to compare the Celsius scale with Fahrenheit scale.

    b. Was it cloudy? If so, was the relative humidity high?

    If it is cloudy, students will see that the relative humidity will be fairly high. If it is clear, the relative humidity will be lower.

    c. If it looks like it is going to rain, was the temperature very close to the dew point with a high humidity?

    The air temperature should be close to the dew point.

    d. If the sky is free of clouds, is the barometric pressure high?

    If the sky is clear, the barometric pressure should be rising. Even slight changes are significant.

27. ☐ How does the temperature affect the weather?

Warming air rises and carries humidity up to heights where the air temperature is cooler. The warm air cools and clouds form.

28. ☐ How does relative humidity affect the weather?

The higher the relative humidity, the more saturated is the air with water vapor. This makes it possible for clouds to form and precipitation to happen.

29. ☐ How does dew point affect the weather?

When temperature and dew point are equal, water will condense out of the clouds and come down as precipitation or form on the ground as dew.

30. ☐ How does barometric pressure affect weather?

When the pressure is rising, skies generally clear. When the pressure is falling, skies generally cloud up.

31. ☐ In your investigation of weather you learned some new scientific ideas and terms. It is important to be able to discuss results using these words and terms correctly.

Write the meaning of the following terms in your own words using what you have learned from the activity.

➢ Vocabulary and definitions

Temperature	A measure of the amount of heat present in the air as compared to a standard scale
Dew point	The air temperature at which water will condense and dew will form. The saturation temperature.
Relative humidity	A comparison of the amount of water in the air as compared to the total amount of water that air at that temperature could possibly hold.
Barometric pressure	The pressure of the air in a given area which is related to the weight of the air mass

Tell Me More

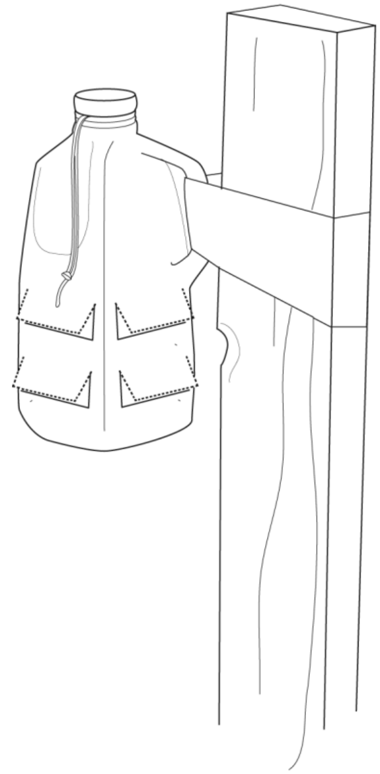
In this part of the activity, you will set up your mobile data collection system outside and prepare to take weather data for 5 days.

32. ☐ Start a new experiment on the data collection system.

33. ☐ Connect the sensor extension cable to your data collection system.

34. ☐ Display temperature, relative humidity, dew point and barometric pressure in a table.

35. ☐ If your teacher recommends it, display each variable in a graph.



36. ☐ Change the sampling rate to once every 30 minutes.

37. ☐ Before you go outside, consider how you will place your DCS so that it is protected from any water (including sprinklers). How will you protect it?

Students should think of a way to raise the DCS off the ground and keep it dry. The utility tub in the materials list is one item that can be put to use, but they may also want a concrete block, a chair, step ladder, or other materials. Review their plan and materials before they set out their DCS.

38. ☐ You are now ready to set up your weather station! Take all your materials out to your post (follow your teacher's directions for selecting the location). Tape the milk container with the sensor to the post as shown in the picture. Mount your DCS in a waterproof system of your own design.

39. ☐ Start recording data.

40. ☐ On Day 2, return to your DCS and stop recording data.

41. ☐ Record the cloud types, wind direction, amount of sky cover, and precipitation (if any) in your Weather Journal.

42. ☐ Save your experiment and name it Day 1 Weather Data.

43. ☐ Record the cloud types, wind direction, amount of sky cover, and precipitation (if any) in your Weather Journal.

44. ☐ Follow your teacher's direction if you want to look at yesterday's data.

Teacher Tip: At this point, students can bring their DCS into the classroom and examine their data before returning it to the weather station and starting a new run of data for the next 24 hours.

45. ☐ Start a new experiment by repeating the set up procedure from the previous day.

46. ☐ Record a new run of data without changing any of the settings. You will repeat this process for the rest of the week.

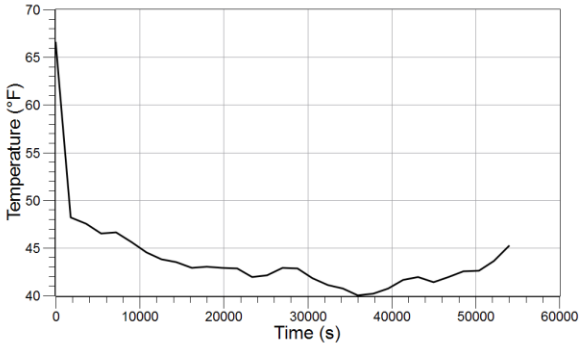
Sum It Up

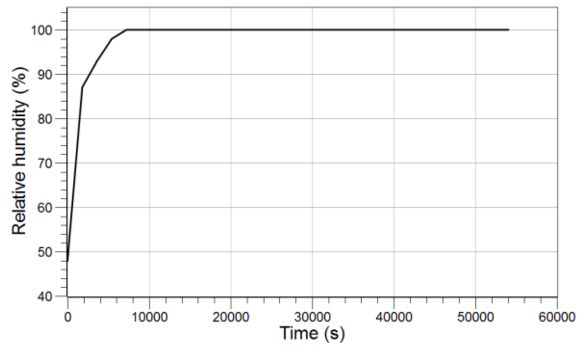
47. ☐ In the table below, summarize your observations and your data.

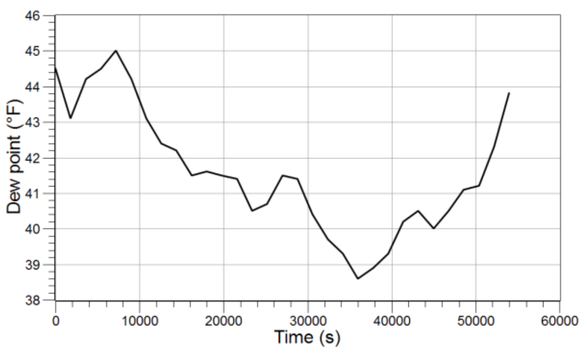
Note: If you did not observe any of the following conditions, write N/A (not applicable).

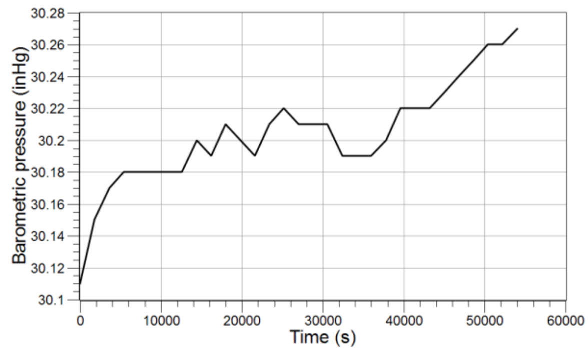
Weather Condition	Day 1	Day 2	Day 3	Day 4	Day 5
Cloud Types	Stratus	Stratus	Fog	Stratus	Stratus
Sky Cover	100%	50%	100%	100%	75%
Wind	1 mph (0.447 m/s)	6.9 mph (3.08 m/s)	0	0	10.4 mph (4.64 m/s)
Precipitation	0	0	0	0	0
Temperature	28 ^{o}F (-2.2 ^{o}C)	33 ^{o}F (5.5 ^{o}C)	30 ^{o}F (-1.1 ^{o}C)	32^{o} F (0 ^{o}C)	30 ^{o}F (-1.1 C)
Dew Point	25 ^{o}F (-3.9 ^{o}C)	29 ^{o}F (-1.7 ^{o}C)	29 ^{o}F (-1.7 ^{o}C)	28 ^{o}F (-2.2 ^{o}C)	18 ^{o}F (-7.8 ^{o}C)
Relative Humi dity	88%	82%	96%	85%	61%
Barometric Press ure	30.23 in. (102.7 kPa)	30.21 in. (102.3 kPa)	30.1 in. (101.9 kPa)	30.01 in. (101.6 kPa)	30.17 in. (102.6 kPa)

48. ☐ Below are four blank graphs. Draw the trend for your temperature, dew points, relative humidity and barometric pressure over the five day period.









49. ☐ What happened to the barometric pressure as the temperature changed?

Students will notice that as temperatures increased the pressure increased.

Teacher Tip: Refine these questions to fit the weather your class experienced.

50. ☐ What was the relationship between temperature and the sky cover (cloudiness)?

Answers will vary, but cooling temperatures are associated with increased sky cover.

51. ☐ What was the relationship between the relative humidity and the presence of clouds?

Answers will vary, but increased humidity is associated with cloudiness.

52. ☐ What was the relationship between the amount of clouds and any change in barometric pressure?

Answers will vary, but increased barometric pressure is associated with clearing skies.

53. ☐ If it rained during your study, what happened to the temperature?

Cooling temperatures are associated with precipitation. Students would observe that it rained during this period. The dew point was higher than the temperature, and humidity was at 100%.

54. ☐ Now that you have recorded and examined weather data for a period of time, can you use that data to make a forecast for tomorrow's weather? Think about the trend of the atmospheric pressure, the temperature, and the cloud cover. What would happen if pressure is falling and clouds are increasing? What could happen if pressure is rising and clouds are shrinking?

Student answers will vary. If pressure is falling and clouds are increasing, the weather could turn to rain. If pressure is rising and clouds are shrinking, you could be in for a nice day. If the trends in their data have not varied much, they can predict that tomorrow's weather will be the same as today's weather.

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. Throughout a 24-hour cycle, the greatest change in temperature is due to

Ⓐ Increased cloudiness

Ⓑ A drop in barometric pressure

Ⓒ Wind conditions

Ⓓ **The day/night cycle of the Earth**

2. Clouds will dry up and disappear if

Ⓐ **Pressure rises**

Ⓑ Temperatures fall

Ⓒ Relative humidity remains the same

Ⓓ Temperature matches the dew point

3. Winds in our area tend to blow from the (Answers will vary)

Ⓐ North

Ⓑ South

Ⓒ East

Ⓓ **West (answers will vary)**

4. In general, if temperatures fall, cloudiness will _________ and humidity will __________.

Ⓐ Decrease, decrease

Ⓑ Decrease, increase

Ⓒ Increase, decrease

Ⓓ **Increase, increase**

5. If it is going to rain, the humidity has to be at ____________ and the temperature will match the ___________.

Ⓐ 75%, humidity

Ⓑ 80%, dew point

Ⓒ **100%, dew point**

Ⓓ 100%, barometric pressure

Further Investigations

The best way to extend this investigation, particularly to continue to develop the relationships between temperature, relative humidity and what the sky looks like, is to conduct a long term study of the weather over a period of weeks or even months. For such an endeavor, you'll want to construct a more permanent weather station at your school site.

A graph of temperature over many months reveals a shift in the high temperature and low temperature data, which is interesting in comparison with the shift in seasons.

Consider sharing and comparing your data with another class in another town, particularly one that is located in another climate zone.

Once students are comfortable with reading the trends and interpreting the conditions, encourage weather predictions. Compare predictions to weather channel predictions, and keep a record of your class accuracy compared to media accuracy.

26. Dew and Frost

Recommended Grade Levels: 4 - 5

Objectives

In this investigation, students use models to discover and simulate the weather conditions responsible for the formation of dew and frost.

Procedural Overview

To understand this content, students:

- Create dew and frost on the outside of a beaker and measure their temperatures
- Duplicate dew and frost formation conditions inside a terrarium and measure the dew point

Time Requirement

Teacher Preparation	Will vary depending on materials at hand
Pre-Activity Discussion	20-30 minutes
Get Started	30 minutes
Let's Explore	30 minutes
Explain It	15-20 minutes (Could be assigned for homework)
Tell Me More	30 minutes
Sum It Up	10 minutes (Could be assigned for homework)

Materials

For each student group:

- ☐ Data collection system
- ☐ Fast response temperature sensor
- ☐ Weather sensor
- ☐ Beaker, 250-mL [1]
- ☐ Stirring stick or spoon
- ☐ Crushed ice, 180 mL
- ☐ Water, distilled, 125 mL[2]
- ☐ Salt, 20 mL
- ☐ Rubber band
- ☐ Tape

[1]Any glass jar or plastic cup of that size will do.

[2]Distilled water is not chlorinated and has few if any salts that could affect your results.

For each soda bottle terrarium:

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Potting soil, 500 mL
- ☐ Gravel, vermiculite or perlite, 200 mL
- ☐ Large bowl to mix the soil
- ☐ Soda bottle, clear, cleaned, 2-L, with a hole punched in the lid[1]
- ☐ Small plants of the same variety , 3
- ☐ Pie pan or small bucket
- ☐ Water, warm, 100 mL
- ☐ Dry ice, one block, broken up[2]
- ☐ Tongs for handling the dry ice
- ☐ Plastic storage bag, gallon sized, re-sealable, with holes punched in the bag

[1] Drill or pound a hole in the top of the soda bottle lid in advance for the temperature sensor to fit through. See Preparation section.

[2] Students should not handle the dry ice. Teacher should use tongs. See Safety section for more information.

Activity at a Glance

Get Started

- ☐ Take the temperature of the air and the beaker.
- ☐ Explore the temperature of the beaker when ice water is inside the beaker and dew forms on the outside of the beaker.

Let's Explore

- ☐ Add salt to the ice water and monitor the temperature of the outside of the beaker until frost forms.

Explain It

- ☐ Interpret and explain the similarities and differences in the formation of dew and frost.
- ☐ Define the following terms: condensation, dew, dew point, evaporation, frost, temperature, humidity, relative humidity, and precipitation.

Tell Me More

- ☐ Prepare the soda bottle terrarium and monitor the temperature of the soil until dew forms.
- ☐ Place the terrarium in a “nest” of dry ice and monitor the temperature of the soil until frost forms.

Sum It Up

- ☐ Relate the formation of dew and frost inside the terrarium to the beaker activity.
- ☐ Draw conclusions.

Safety

Add these important safety measures to your normal class procedures:

- ■ Always use gloves or tongs when handling dry ice. Never place dry ice in a sealed container or sealed plastic bag without air holes. The container will burst.
- ■ Do not place dry ice in the closed soda bottle.

Preparation

These are the materials and equipment to set up prior to the activity.

- Terrarium construction

    1. For the Tell Me More section, you may want to set up the terrarium in advance so that the plants have a chance to become established. However, this is not necessary to do the experiment.

    2. If each group of students will be assembling its own terrarium, gather the soda bottles in advance, clean them and remove the labels. Pound or drill holes in the caps for the temperature sensor to fit through. Use a nail and a hammer to make the holes in advance for your students or use an electric drill.

    3. Additionally, you will have to get a flat of small plants, a bag of potting soil and a bag of soil amendment such as vermiculite or perlite, gravel or sand. Keep a gallon of distilled water on hand to water the plants.

- Keep ice in the freezer or ice chest until just before use. For the second part of the experiment, obtain the dry ice on the day you will use it. To break it into chunks, place the block into a paper bag, place the bag on the floor, and hit it with a hammer. Do this just as you are ready to use it.

- Handle the dry ice with tongs and perforate the bag so that it won't burst. The dry ice goes into the perforated bag. You will direct the students to nest the soda bottle terrarium down into the center of the bag of dry ice so that the ice in the bag surrounds the soil in the bottle. Take care that students do not handle the dry ice by hand!

- Set up the data collection system.

    1. Begin a new experiment.

    2. Connect the temperature sensor to your data collection system.

    3. Display temperature in a digits display.

Background

Evaporation and condensation

Water gets into the air through the process of evaporation. The sun's radiant energy is transferred to the surface of bodies of water, where water molecules gradually become energized enough that they break free from the surface and become water vapor, a gas. The point at which water molecules break their hydrogen bonds and become a gas can be measured with a temperature sensor.

Similarly, as water vapor cools and loses energy, the molecules reform their hydrogen bonds and become a liquid in the process called condensation. Therefore, the processes of evaporation and condensation are complimentary: they are like two sides of the same coin. Looked at from the perspective of the gain or loss of heat energy, evaporation is the gain in heat energy and condensation is the loss of heat energy.

Humidity and precipitation

The measure of the amount of water vapor in the air is called humidity. Absolute humidity is a measure of the actual amount of water vapor in the air, in grams of water per cubic meter of air at a given temperature. The temperature of the air is important, because gases are very sensitive to heat energy. As gases heat up, the molecules expand, which means that the molecules spread out from each other. (They spread out because their more energetic movement makes them take up more space.) Air that warms and expands can hold more water vapor than air that is cooler and denser. So we always talk about humidity as related to a particular temperature.

Relative humidity is a more useful way to think of humidity. Relative humidity is a comparison between the actual amount of water vapor in the air at a given temperature, and the possible amount of water vapor that could be held in that air at that same temperature. Air at 50% relative humidity means that it is holding half of the water vapor that it could hold at that temperature. Think of it as 50% full. Air that is 100% saturated would mean that the air, at that temperature, could not hold any more water vapor than it is currently holding.

Saturation means that the air is full of water vapor. If the air temperature falls, the air contracts, and squeezes some of the water vapor out of it. Precipitation occurs. Humidity and temperature are the most important variables in determining precipitation. You can have saturated air and no rain, as long as the temperature remains constant.

Water vapor condenses on solid particles. These can be microscopic dust particles or smoke in the air, in which case clouds will form. Water vapor can also condense on the ground, grass, or objects like cars and patio furniture. When this happens, we call the water that forms "dew". The temperature at which dew will form is called the dew point. Dew is liquid water and is another form of precipitation. If the temperature is below the freezing point of water at ground level, water vapor will form frost instead of dew. The process is still called condensation.

Pre-Activity Discussion

This discussion focuses on precipitation and the processes of evaporation and condensation. Use the following line of questions to discuss these two concepts:

Q What kinds of precipitation are you familiar with?

Q What happens to rain when it freezes?

Q What makes hail different from snow?

Q Is there a certain temperature at which rain changes to hail?

Q Where does precipitation come from?

Q What puts water vapor into the air to begin with?

Q What is the process called that puts water vapor into the air?

- You may need to develop the concept of evaporation more completely. Leaving a pie pan of water on a windowsill for a few days, or boiling a pan of water on a hot plate can develop the concept for students who may not have much experience with evaporation.

- Start a new experiment with your data collection system. Plug in a weather sensor and monitor the relative humidity of the air. (Normal classroom air with air conditioning should be around 50% humidity. After boiling pans of water, you will see this number go up.) You can display this data on an overhead computer display system for the whole class to see. Use this line of questioning:

Q With this weather sensor, I am measuring the humidity in the air. What do you think humidity is?

- Depending on your students' familiarity with percents, you may need to explore with them the concept of 50% humidity or 75% humidity. Discuss the meaning of relative humidity and saturation. See the Background for these concepts.

Q Water vapor gets into the air through evaporation, and comes out of the air as precipitation. What is the process called that allows water vapor in the air to become a liquid again on any solid surface?

- To develop the concept of condensation, have a glass of ice water sitting on your desk. Water vapor in the air will condense on the glass and drip down onto the desk top. Make sure that students do not think that water is leaking out of the sides of the glass! The water that condenses on the outside of the glass comes from the air.

Q Can water in the air become a liquid in any other way besides rain and snow?

Q Where have you seen dew form?

Q Have you seen anything else form on lawns or cars?

Q When during the year do you see dew form?

Q What are daytime and nighttime temperatures like at this time of year?

Q How does this help dew to form?

Q When during the year do you see frost form?

Q What are daytime and nighttime temperatures like at this time of year?

Q How does this help frost to form?

Driving Question

- Under what conditions will dew and frost form?

Variables

Independent Variable

- The independent variable in this activity will be the additive to the water (ice, or salt and ice).

Dependent Variables

- The temperature of the water is the dependent variable. The temperature is subject to the substances (ice, or salt and ice) added to the water.

- A secondary dependent variable will be the formation of dew or frost as the cold beaker cools the air next to the surface of the beaker.

Controlled Variables

- Variables to be controlled include the distance of the temperature sensor to the beaker, the size of the beaker or glass, the amount of ice you add. As long as everyone agrees about these variables, the results will be comparable.

Activity with Answer Key and Teacher Tips

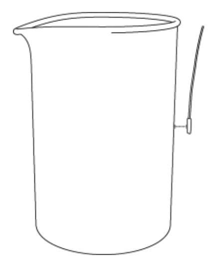
After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

1. ☐ In this activity, you will use a data collection system including an electronic temperature sensor to measure changing air temperatures and investigate the weather conditions required for dew and frost to form. A temperature sensor is a kind of thermometer.

2. ☐ In addition to the data collection system and temperature sensor, you will need to get a 250-mL beaker, about 125 mL (4 oz.) of distilled water, 180 mL (6 oz.) crushed ice, about 20 mL (3 tsp.) of salt, a spoon and a rubber band from your teacher.

3. ☐ Start a new experiment on the data collection system.



4. ☐ Connect a temperature sensor.

5. ☐ Display temperature in a digits display.

6. ☐ Hold the temperature sensor approximately 1 cm from the outside of the beaker.

7. ☐ Measure the air temperature by recording a run of data.

8. ☐ When the temperature stops changing, record the temperature in the top row of Table 1 below.

9. ☐ Delete the previous run of data.

10. ☐ Hold the temperature sensor against the outside of the beaker. Measure the outside surface temperature by recording a run of data. When the temperature stops changing, record the outside surface temperature of the beaker in Table 1 below.

11. ☐ Delete the previous run of data.

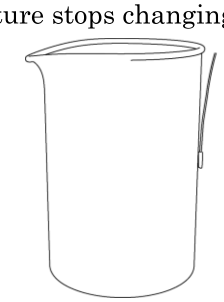


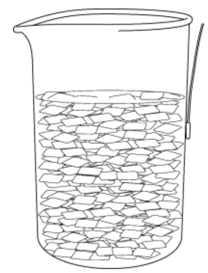
Table 1: Air temperature and the temperature of the outside surface of a beaker

Measurement	Temperature (°C)
Air temperature 1 cm away from the beaker	24.6
Outside surface of the beaker	24.6

12. ☐ What do you notice about the air temperature and the temperature of the outside surface of the beaker?

    Answers will vary, however students should say the temperatures are the same, or they are very close.

13. ☐ Set up to display data in a graph.



14. ☐ Fill the beaker 3/4 full with crushed ice and then add 125 ml of distilled water. Wipe the outside of the beaker with a paper towel to remove any moisture that has started to form.

15. ☐ Place the temperature sensor against the outside of the beaker and use a rubber band to hold it in place.

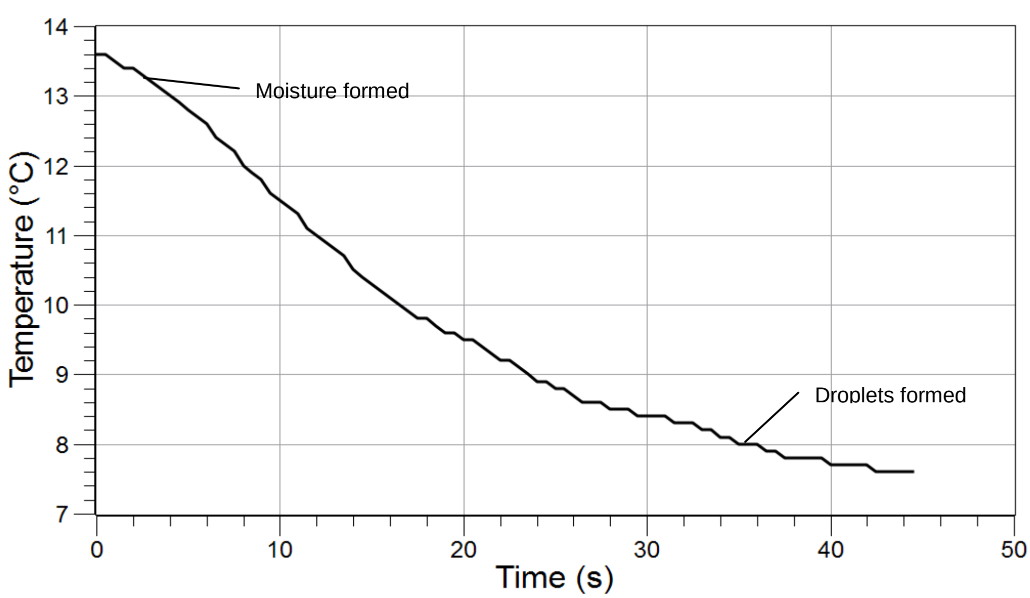
16. ☐ Record a run of data and stir the ice water while continuing to record data until water droplets begin to form on the outside of the beaker.

17. ☐ Stop recording data.

18. ☐ Adjust the scale of the graph to be able to properly view the data.

19. ☐ Save the graph and name it "Temperature Graph of Dew Forming".

20. ☐ Sketch a copy of your graphed data on the blank graph below.



21. ☐ Label on the graph the point at which you first observed moisture forming on the outside of the beaker.

22. ☐ Delete the previous run of data.

23. ☐ Where did the water come from that formed water droplets on the outside surface of the beaker?

Answers will vary at this point. Students may say the water came from inside the beaker. If so, point out that the bottle is not leaking of its own accord. Glasses don't leak! Refer back to the discussion at the beginning of the lab. The water droplets formed from water vapor in the air that condensed when it contacted the cooler surface of the breaker.

24. ☐ Why were there no water droplets forming on the outside of the beaker before water and ice were added to the bottle?

Answers will vary at this point. Students should notice the temperature of the air around the beaker and the surface temperature of the beaker was about the same.

25. ☐ Consider the "Temperature Graph of Dew Forming." What weather conditions were necessary for "dew" to form on the outside of the beaker? Explain.

The temperature of the beaker had to be cooler than the surrounding air and there had to be water vapor in the air. The cooler surface of the beaker removed heat energy from the air. When the air next to the beaker cooled, water condensed out of it and beaded up on the cold surface of the beaker.

26. ☐ Delete the previous run of data.

Let's Explore

27. ☐ Why is salt sprinkled on icy sidewalks to help clear the sidewalk? What does the addition of salt do to the water?

Most students will not understand why we use salt on icy sidewalks. Explain that salt is used because it dissolves easily in the water's surface. Once something is mixed into the water, it is harder for the water to freeze *at the freezing point of water*. The temperature of the water will have to go lower before the water will freeze. So if the air temperature remains the same, the ice will melt. This is because the salt takes up space among the water molecules, so the water has to use more energy to freeze into its crystalline structure. Therefore, it will have to go to a lower temperature before it freezes.

28. ☐ We want to get frost to form on the beaker, not dew. What will have to be true for the temperature of the surface for frost to form?

The temperature will have to be lower on the surface of the beaker for frost to form than it was for the dew to form.

29. ☐ Predict what the temperature of the beaker's surface will be in order for frost to form.

Answers will vary, but students may know that water freezes at 0 °C

30. ☐ Explain why the addition of salt to the beaker of water will help the water cool to your predicted temperature.

Salt lowers the freezing point of water. Another way to think of this is that salt water stays liquid at the same temperature where plain water freezes.

31. ☐ Add 3 tablespoons of salt to the beaker containing ice and distilled water.

32. ☐ Stir the beaker vigorously for 10 seconds to help the salt dissolve.

33. ☐ Add more ice to replace any that may have melted. Dry the outside of the beaker with a paper towel.

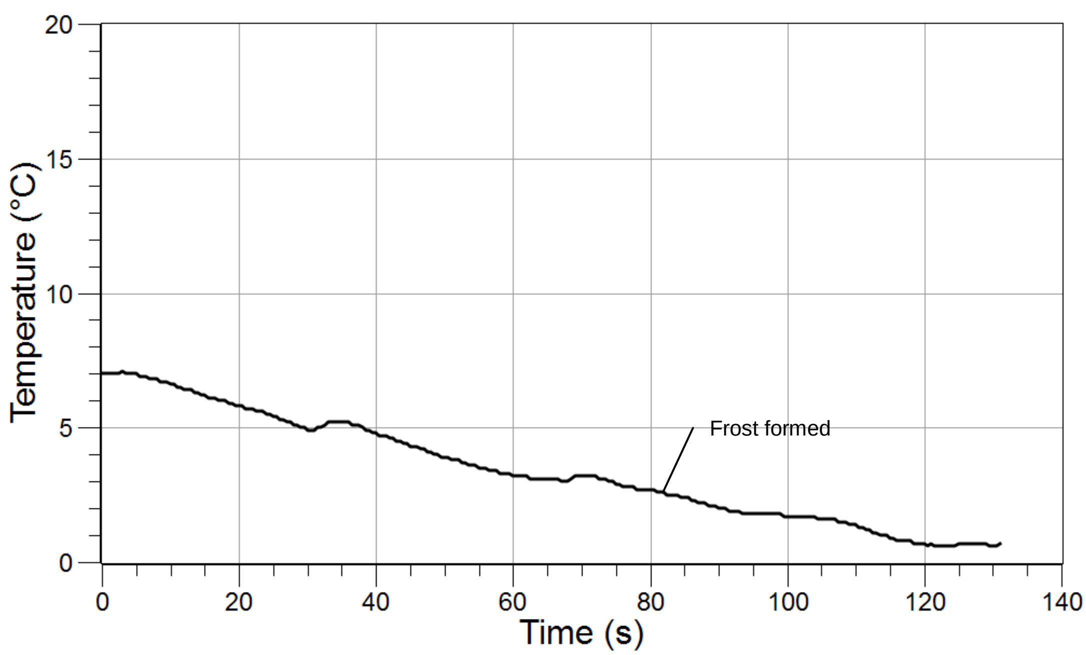
34. ☐ Ensure that the temperature sensor is still held in place with the rubber band to the outside surface of the beaker.

35. ☐ Start recording data while stirring constantly and continue recording until frost begins to form on the outside of the beaker.

36. ☐ Scratch lightly with your fingernail on the outside of the beaker to tell exactly when the "frost" has formed.

37. ☐ Stop recording data. Adjust the scale of the graph to be able to properly view the data.

38. ☐ Save the graph and name it "Temperature Graph of Frost Forming".



39. ☐ Carefully observe the temperature at which frost begins to form on the outside of the beaker and label it on the graph. How does this compare to your prediction? Explain.

The frost started to form at a higher temperature than the predicted temperature of 0 °C, probably because the air temperature and the glass temperature are interacting so it is a complex system.

40. ☐ Delete the previous run of data.

Explain It

Teacher Tip: This section can be assigned for homework.

41. ☐ What weather conditions have to exist for dew and frost to form?

    The surface temperature must be lower than the air temperature and there must be water vapor in the air. For frost to form, the surface temperature must drop to at least 0º C.

42. ☐ At what temperature does frost form?

    Frost forms at or very close to 0 ºC.

43. ☐ In our model, what parts of the Earth and the environment might the surface of the beaker represent?

    It might represent the surface of tree leaves, blades of grass or the surfaces of objects such as soil, rocks and twigs that are close to the ground where dew and frost can form.

44. ☐ If the cold beaker is a model of the Earth's surface where dew and frost can form, what is missing to make it a better model? How can this model be improved?

    Our model did not show living and non-living parts of the Earth on which dew and frost form or how it affects them. To improve the model, build one that includes elements of the Earth's surface, such as soil, rocks and plants. Wind is also not accounted for. In this model, humidity is assumed to be constant.

45. ☐ In your investigation of the formation of dew and frost you learned some new scientific ideas and terms. It is important to be able to discuss your results using these words and terms correctly.

    Write the meaning of the following terms in your own words using what you have learned from the activity.

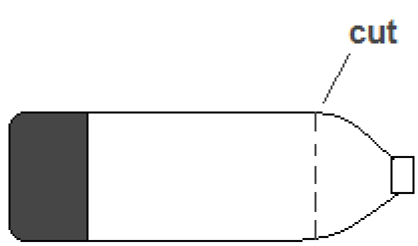
➢ Vocabulary and Definitions

Condensation	Process where water vapor changes to liquid water due to a loss of heat energy
Dew	Form of precipitation where water vapor in the air condenses on a cooler surface due to loss of heat energy
Dew point	Temperature at which dew forms
Evaporation	Process where liquid water changes to water vapor due to heating
Frost	Form of precipitation where water vapor in the air condenses and freezes on a cooler surface
<u>Temperature</u>	A measure of the amount of heat energy in something compared to a standard scale
Humidity	A measurement of the amount of water vapor present in the air
<u>Relative humidity</u>	Comparison between the actual humidity level and the saturated humidity level
Precipitation	Water vapor in the atmosphere that condenses and falls back to the Earth as dew, rain, frost, snow, sleet, hail or fog

Tell Me More

Teacher Tip: The next two sections of this lab can be run as a whole class experiment to extend the concepts of this activity.

46. ☐ We will improve our model to better show how dew and frost form on surfaces by including living and non-living materials found on the Earth's surface. You will need a 2-liter plastic soda bottle.

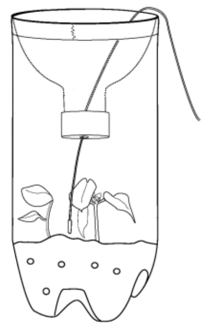


47. ☐ Draw a line around the bottle with a permanent marker where the curve of the bottle meets the straight sides and use a pair of sharp scissors to cut the top part off of the plastic soda bottle. Retain the lid and set the top aside.

48. ☐ Prepare a soil mixture of potting soil and soil amendments. Fill the bottom of the soda bottle terrarium to a depth of 10 cm with the soil mixture and gently tamp it down.

49. ☐ Plant three small plants of the same type in the soil mixture in the bottom of the bottle and carefully add 100 ml of warm water to the soil.

➢ Top turned upside down and taped to the bottom of the bottle



50. ☐ Ensure that the lid of the soda bottle has a hole poked in it just large enough for the temperature sensor to fit through. Turn the top part of the soda bottle upside down and tape it inside the bottom part of the bottle so the cap is pointing towards the soil.

Note: Make sure the top of the bottle is sealed to the bottom of the bottle with tape all the way around.

51. ☐ Start a new experiment on the data collection system.

52. ☐ Connect a temperature sensor.

53. ☐ Display temperature in a digits display.

54. ☐ Place the temperature sensor inside the bottle through the opening in the cap to measure the air temperature inside the bottle, and record a run of data.

Note: Make sure the sensor does not touch the sides or the soil.

55. ☐ When the temperature stops changing, record the air temperature inside of the soda bottle in Table 2 below.

56. ☐ Delete the previous run of data.

57. ☐ Place the temperature sensor through the opening of the bottle cap and touch it to the surface of the soil.

58. ☐ Measure the temperature of the surface of the soil by recording a run of data.

Note: Make sure the sensor stays in contact with the surface of the soil the entire time.

59. ☐ When the temperature stops changing, record the temperature of the surface of the soil in Table 2 below.

60. ☐ Delete the previous run of data.

➢ Table 2: Air and Soil Surface Temperatures in ºC

Measurement	Temperature (°C)
Air temperature inside the bottle	27.6
Soil surface temperature	29.6

61. ☐ Allow the temperature sensor to rest on the top surface of the soil mixture.

62. ☐ Fill a gallon-sized plastic re-sealable bag with chips of dry ice.

63. ☐ Working in a pie pan, place the soda bottle model on top of the bag with the dry ice pieces wrapped around the bottom and sides of the soil area of the bottle.

64. ☐ Record a run of data.

65. ☐ Continue recording until dew forms on the surface of the soil, the sides of the bottle or the leaves of the plants. Record the temperature for the dew formation in Table 3 below.

66. ☐ Raise the temperature sensor up off the soil and record the temperature of the air. Record this in Table 3. Delete the previous run of data.

67. ☐ Record a run of data and continue recording until the "dew" begins to change into frost on the surface of the soil, the sides of the bottle or the leaves of the plants.

68. ☐ Record the temperature at which dew becomes frost in Table 3 below.

➢ Table 3: Temperature when dew and frost form

Measurement	Temperature (°C)
Temperature of the soil when dew forms	20.2
Temperature of the air after dew formed	24.5
Temperature of the soil when frost forms	0.0

69. ☐ Delete the previous run of data.

Sum It Up

70. ☐ Where did the water come from that formed dew and frost on the surface of the soil, the sides of the bottle or the leaves of the plants?

    Some of the warm water in the soil became water vapor in the air inside the soda bottle.

71. ☐ What caused the water vapor in the air to form dew and then frost on the surfaces of the living and non-living parts of the soda bottle model?

    The dry ice caused the surfaces of the living and non-living parts of the model to cool. The water vapor in the air cooled and condensed forming dew and then frost when the temperature of the surfaces cooled to 0 °C.

72. ☐ How is the formation of dew and frost on the beaker similar to the formation of dew and frost in the terrarium?

    The formation of dew and frost in both cases happens in a similar way. The dew and frost form from water vapor in the air. The air cools, the water vapor condenses out of it onto the solid surfaces.

73. ☐ What is different about the formation of dew and frost in the terrarium compared to the beaker?

    In the beaker activity, the air *outside* the beaker is being cooled. The water vapor comes from air *outside the system*. In the terrarium, the water vapor is *inside the system*. Water evaporates out of the soil, cools and condenses out of the air onto the leaves, soil surface and inside the chamber.

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. For dew to form, the surface temperature of the Earth must be cooler than the air above it and there must be

   Ⓐ No water vapor in the air

   Ⓑ A river or an ocean nearby

   Ⓒ **Water vapor in the air**

   Ⓓ Rain falling

2. For frost to form, the surface temperature of the soil must be

   Ⓐ No water vapor in the air

   Ⓑ **At or below 0º C**

   Ⓒ 100 0º C

   Ⓓ Warmer than the temperature of the air above the surface

True or False

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

_____T_____1. Humidity and temperature are the two most important variables for precipitation to form.

_____T_____2. Dew and frost are a form of precipitation.

_____F_____3. The independent variable in this experiment is the temperature of the water.

Key Term Challenge

Fill in the blanks from the list of randomly ordered.

precipitation	evaporation	condensation	humidity
dew	dew point	frost	temperature

1. The temperature at which dew will form is called the _____dew point_____.

2. The process that causes water to lose energy as it forms a liquid on surfaces is called _____condensation_____.

3. A measure of the amount of water vapor in the air is called _____humidity_____.

4. _____Frost_____ forms when condensation happens at the freezing point of water.

5. Water vapor gets into the air through the process of _____evaporation_____.

Further Investigations

Students can test the temperature of the air and the temperature of the soil simultaneously by using two temperature sensors and setting up two graphs on the data collection system. While collecting data, place the terrarium in a sunny location, in a refrigerator, or in a dark location. Let the soil get very dry and repeat the experiment. Add more plants and repeat the experiment. Remove all the plants and repeat the experiment.

To address the question of what effect the type of plants may have on the formation of dew or frost, use very different kinds of plants in several terrariums at once. Types include grasses, succulents, broadleaf plants and mosses.

27. Microclimates

Recommended Grade Levels: 4 - 5

Objectives

Students observe that air temperature and humidity are affected by the type of structures, soil and plants in a given area.

Procedural Overview

To understand these concepts, students:

- Measure air temperature and humidity in a variety of locations around the school grounds
- Compare the temperature and humidity of various locations and determine the reason for variation

Time Requirement

Teacher Preparation	30 minutes (longer if you choose to make a terrarium)
Pre-Activity Discussion	30 minutes
Get Started	10-15 minutes
Let's Explore	20 minutes
Explain It	10-15 minutes (Could be assigned for homework)
Tell Me More	30 minutes
Sum It Up	10 minutes (Could be assigned for homework)

Materials

For teacher demonstration:

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Weather sensor
- ☐ Ecochamber or terrarium or house plants[1]

[1]Any environments that will provide a unique habitat will do.

For each student group:

- ☐ Mobile data collection system
- ☐ Weather sensor
- ☐ Notebook and pencil

Activity at a Glance

Get Started

- ☐ Students make predictions about locations they will find microclimates in.

Let's Explore

- ☐ Students explore the variation in air temperature and humidity inside the classroom.
- ☐ They record the environmental conditions.

Explain It

- ☐ Students analyze the data to see if there is a relationship between the data and recorded observations.
- ☐ Review the following vocabulary with the students: climate, weather, microclimate, variable, and control.

Tell Me More

- ☐ Students apply observations of the indoor environment, and travel around outside locations on their campus to examine different microclimates.

Sum It Up

- ☐ Students use their data and observations to determine what factors influence the creation of a microclimate.

Safety

Add these important safety measures to your normal outdoor class procedures:

- Metal surfaces can burn your skin when they are exposed to the sun for extended periods of time. Take care when measuring the temperature around metal objects.

Preparation

Set up these materials and equipment prior to the activity.

- If you do not already have a classroom terrarium or ecochamber you can set one up now. Terrariums can also be used in the “Dew and Frost” and the Greenhouse activities. PASCO has a multipurpose EcoChamber™, which can be used for this activity. You can also repurpose an old aquarium, or make an ecochamber out of 2-L soda bottles. If you do not want to go to such lengths, you can purchase a house plant or borrow one from a colleague’s classroom.

- Prepare to send students out onto the school grounds to find microclimates. Scout out some possible locations that will provide them with a variety of data. Give students clear directions about where they should not go to collect data. Make sure that your data collection systems are fully charged.

- Practice setting up a table on your data collection system that has a column for user-entered text data and a column for temperature. This is described in Tech Tip 5.2.1. Note that the first value you touch in the Measurements List will be the first column in your table. Practice removing the time column from the table if you do not want it.

- Set up your data collection system for measuring temperature.

  1. Start a new activity on the data collection system.

  2. Connect the temperature sensor to the data collection system.

3. Display Temperature on the *y*-axis of a graph with Time on the *x*-axis.

Background

Air temperature depends on many things, primarily the radiant energy of the sun and its ability to heat the Earth's surface. Once the surface absorbs energy, it radiates it back into the atmosphere in the form of long infrared waves of electromagnetic energy. We call this "heat".

Materials have the ability to absorb and then radiate heat energy back into the atmosphere at different rates. Materials that contain water absorb heat energy more slowly and also lose the heat energy back to the air more slowly than materials without water molecules. This is because water has a high specific heat index compared to most other materials. You have experienced this when you have walked barefoot on a wet sidewalk compared to a dry sidewalk, or wet sand compared to dry sand. In the summertime you would always choose to walk barefoot across a lawn rather than a driveway. This is because the lawn contains much more water than the concrete or asphalt.

Dirt contains more water than most manmade surfaces we use, such as concrete or asphalt. The water content in dirt keeps its temperature lower than the surface of the asphalt playground. Consequently, the air temperature above a dirt field, the school baseball diamond or parkway will be cooler than the air temperature above the asphalt playground, parking lot, or concrete patio.

Microclimates

A microclimate refers to a small location whose climate is controlled by a specific set of factors that are similar to those that control large-scale climates. Climate implies a long term *pattern* that is repeatable from year to year and recognizable for a particular geographic area, whereas weather refers to daily changes in temperature and humidity that result in weather conditions that we experience at any given moment. Therefore a microclimate would be a location with a *pattern* of temperature and/or humidity that could be expected in a small area, dependent on the environmental conditions.

Other physical conditions that affect microclimates include the exposure to prevailing winds, southern or northern exposure to the sun, the presence or absence of trees or overgrowth; proximity to water, proximity to manmade structures. The greatest limiting factor in a microclimate is the shape or size of the area. Usually this determines the temperature and humidity because of the limitation to air mixing with the larger environment.

Technically, the term microclimate applies to habitats outdoors, and not necessarily small places within classrooms and buildings, but we borrow the term for this application.

Pre-Activity Discussion

- Start by placing a terrarium, or a single potted plant (or many potted plants) on your desk or in a location the class can view. Ask students the following questions:

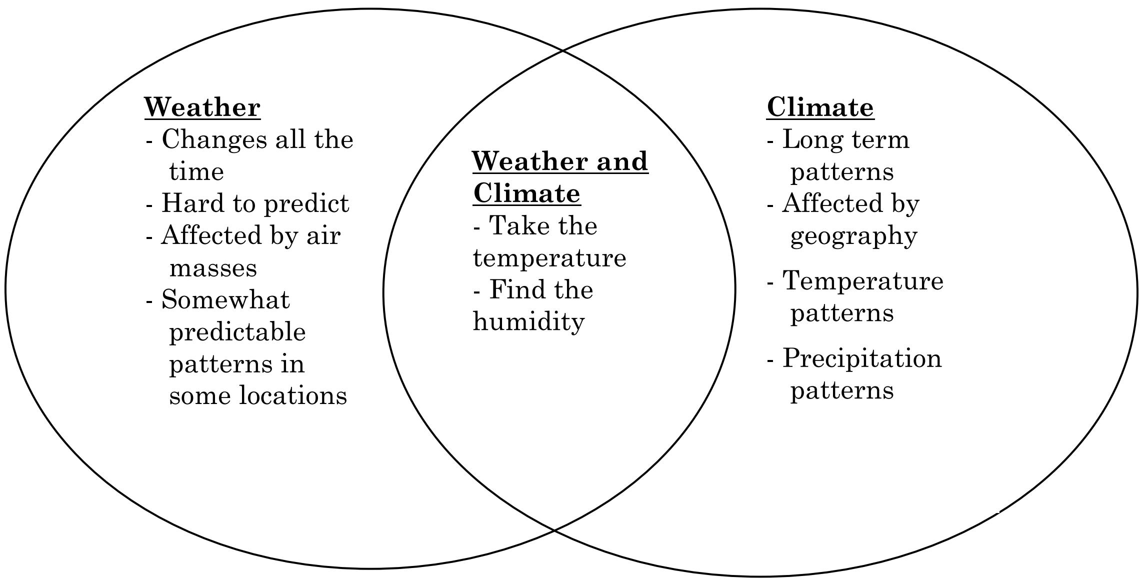
  Q Did you ever play under the bushes in your yard, with action figures or toys, and imagine other worlds under the plants?

  Note: (Literature Connection: Gulliver's Travels, or any story with very small characters who live under the shrubbery.)

Q What makes it so nice to play under the shrubbery or in the culverts?

Q Could we call these little environments "microclimates?" What would that imply?

- Discuss the similarities and differences between the words "weather" and "climate". Have students organize these points in a Venn diagram such as the one below.



- Point out that in a microclimate, you can examine the weather and the geography that affect the pattern of weather, as in a mini-climate.

- Discuss the elements of weather that could be measured in a microclimate. Focus the discussion on the measurement of temperature and humidity, because both of these measurements are taken and used to classify weather and climate.

Driving Question

- Will some locations have a different temperature and humidity than the surrounding area?

Variables

Independent Variable

- The independent variable will be the location of the microclimate.

Dependent Variables

- There are two dependent variables in this activity: temperature and humidity.

Controlled Variables

- The variables that will have to be controlled, but are difficult to control, include the kind of weather during the experimental day. Gather all your data on the same day, at the same time, if possible to avoid extreme fluctuations in environmental conditions.

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

1. ☐ In general, does this classroom have a “climate”?

   Students will talk about the general temperature in the room which is probably controlled by a thermostat. This is called “climate control”. If the classroom relies on fresh air, the climate in the classroom is more directly tied to the outside air.

2. ☐ Discuss with your classmates the measurable variables of climate for your classroom and record your conclusions.

   Air temperature and humidity are the two most obvious variables to measure.

3. ☐ What are the dependent and independent variables?

   Temperature and humidity are the dependent variables. The changing locations are the independent variable.

4. ☐ Make predictions about how the air temperature and humidity vary in your classroom. List at least one place (or more) in the classroom that will have its own microclimate.

   Student predictions will vary. Develop the idea that a microclimate is a small place with a unique temperature and humidity based on some physical feature which limits air flow.

5. ☐ For any microclimate you have listed in your prediction, describe the physical feature that will cause it to vary in temperature and/or humidity.

   Guide students to see the connection to physical features that limit the easy flow of air in the room, such as a bookshelf that juts out into the room, a coat room wall, a corner near the floor far removed from air ducts, inside an enclosure, and behind computers.

Let's Explore

6. ☐ Obtain a mobile data collection system and start a new experiment.

7. ☐ Connect a weather sensor and monitor live data.

8. ☐ Measure the temperature of the air at your desk. Record it in Table 1 below. Is this a microclimate? Explain.

   The area around student desks is not technically a microclimate; air probably circulates freely around their desks. Students will know that the climate around their desks is more truly the actual classroom climate, rather than a microclimate, which would vary from the normal climate.

9. ☐ In scientific terms, would the air temperature of the room be considered a variable or a controlled variable in this experiment? Explain.

The normal air temperature would be considered the control against which other temperatures will be compared. This is because it is a standard, and there is nothing different about it that would make it vary.

10. ☐ Move to an area that you think you will find a microclimate in. Observe the air temperature and humidity. Record the location and the values in Table 1.

➢ Table 1: Classroom Microclimates

Location	Temperature (°C)	Relative Humidity (%)
The air in the classroom	26.0	36
Under the plants in the terrarium	26.5	38
(Student locations will vary)	(data will vary)	(data will vary)

11. ☐ In the space below, draw a picture of one microclimate from your investigation. Include the features that make it a microclimate. Label those features.

➢ Microclimate in the Classroom

Explain It

12. ☐ What was the difference in temperature and humidity between your microclimate and the classroom climate?

Students will list differences in the temperature and humidity. There will probably be very little difference between the microclimate and the classroom climate.

13. ☐ Were these big differences or small differences? What does this tell you about changes that can produce microclimates?

    Students may say that the changes were smaller than they expected. This could mean that even small changes can produce microclimates, or it could mean that within a controlled climate environment you really don't have microclimates.

14. ☐ What physical features helped create changes in temperature or humidity?

    Students will list the physical characteristics of the microclimate that caused its temperature to be different from the air temperature of the classroom, such as pools of sunshine through a window and ventilation to the outside.

15. ☐ You will be going outside to measure the air temperature in places that you think could be microclimates. Predict where you think you will find a microclimate around your school yard.

    Student predictions will vary.

16. ☐ In your investigation of what controls temperature in a microclimate you learned some new scientific ideas and terms. It is important to be able to discuss your results using these words and terms correctly.

    Write the meaning of the following terms in your own words using what you have learned from the activity.

➢ Vocabulary and definitions

Climate	Long term average temperature and humidity patterns for a region
Weather	Daily variations in temperature, humidity, wind, cloud cover and precipitation for a locality
Microclimate	Unique temperature and humidity patterns for a small area limited by some physical feature
Variable	Factor that affects or is affected by a condition in the experimental design
Control	Factor that is the standard against which other factors that vary can be compared

Tell Me More

In this section you will go outside and measure air temperatures of various microclimates.

17. ☐ Start a new experiment on your data collection system. If it is not already connected, plug in a weather sensor.

18. ☐ Create a new display with temperature and humidity in a table.

19. ☐ Change the sampling option to manual sampling.

20. ☐ In Table 2 below, list the locations you think you will observe microclimates in. These will be your destinations.

21. ☐ Discuss with your partners what other factors you will observe at each location that will give you clues to the uniqueness of the microclimate. Physical features should be the first one. Fill in the top row of Table 2 below with these factors.

    Students will look for the presence or absence of small organisms such as bugs; they can describe the moisture of the area (this can be qualitatively measured with tissues); they can record wind conditions and amount of shade.

22. ☐ Follow your teacher's directions for travelling around your school grounds in search of microclimates.

23. ☐ When you arrive at your chosen location, record a set of manually sampled data.

24. ☐ Complete Table 2 below for recording your observations.

    Teacher Tip: Encourage students to determine their own list of factors to observe; they may choose other factors than this model, depending on how they define a microclimate. If they cannot print their table from their data collection system, have them add a column to Table 2 for temperature and humidity.

➢ Table 2: Sample Observations

Location	**Physical Features and Organisms Present**	**Amount of Shade**	**Wind or Air Movement**	***Humidity***	**Temperature**
Open space					

25. ☐ Save your experiment and print your table from your data collection system or transfer your data to the final columns of Table 2 above.

Sum It Up

In this part of the activity you will analyze your data and observations and draw conclusions about the factors that define a microclimate.

26. ☐ What happened to the temperature when the amount of moisture increased?

    Moist areas should help to moderate the temperatures. Students will find that moist areas tend to have a lower temperature, due to evaporative cooling.

27. ☐ In what ways did the closeness of structures such as walls affect the temperature and humidity?

    If the wall is reflecting light and is close by, the air temperature will be much hotter. If the structure is creating shade, the area may be cooler.

28. ☐ Did the color of the ground or pavement have an effect on the temperature?

    Students will notice that black asphalt gets hotter than concrete.

29. ☐ Did the color of the ground or pavement have an effect on the humidity?

    Students notice that dark pavement gets very hot and is consequently very dry. Almost anything over pavement is dry.

30. ☐ Draw conclusions: What factors affect the temperature and humidity in a microclimate?

    Answers will vary but should include structures, exposure (including wind and shade) and moisture.

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. Which statement below best describes a microclimate?

   Ⓐ the temperature of the air

   Ⓑ **small area where the climate differs from the surrounding area**

   Ⓒ similar to an ecosystem

   Ⓓ the weather in a given place

2. What variables can we use to determine microclimates?

   Ⓐ temperature

   Ⓑ humidity

   Ⓒ barometric pressure

   Ⓓ **both A and B**

3. In an experiment the _______________ is the factor against which the changing dependent variable gets compared. It is like a standard.

   Ⓐ temperature

   Ⓑ wind speed

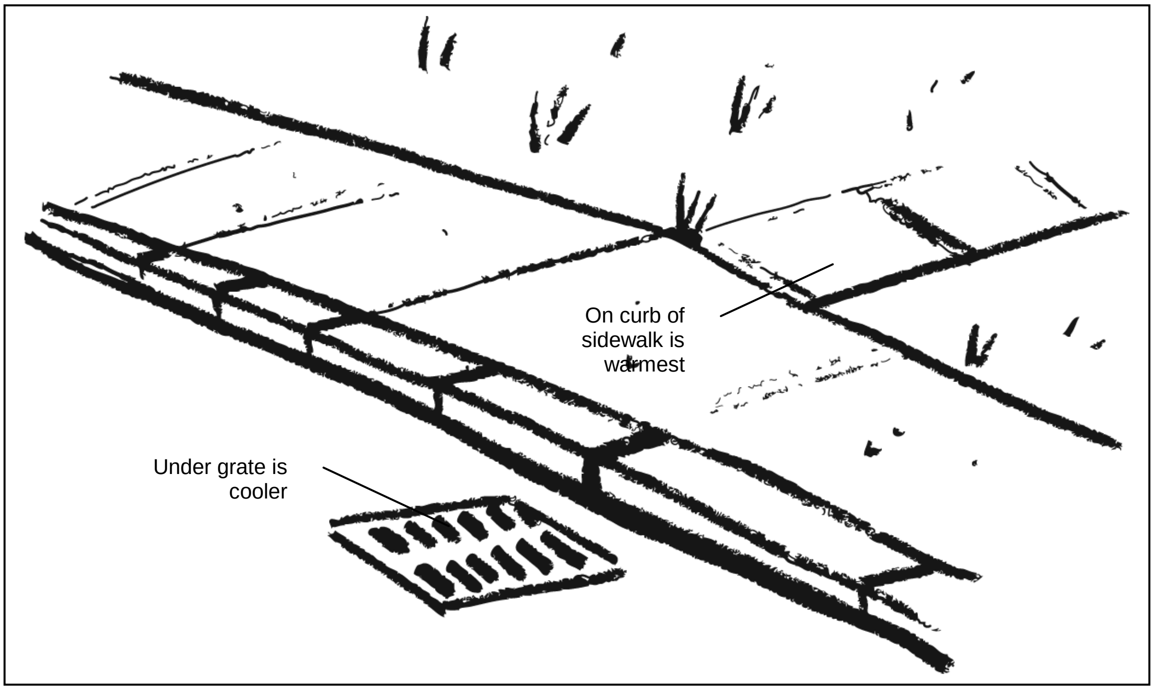
   Ⓒ independent variable

   Ⓓ **control**

Illustration

In the space below, draw a picture of an area exhibiting a microclimate and label the key parts. On the lines below your picture, explain what makes the scene a microclimate.

➢ Area of a Microclimate



Explanation:

Answers will vary. One student group answered as follows: We found that the air inside the drainage grate was cooler than any place above the ground. The sidewalk and curb were the warmest.

Further Investigations

Take your class on a field trip to a city or regional park, wetland or wildlife habitat. Bring along your mobile data collection systems and explore microclimates in these more natural settings.

Send a mobile data collection system home with students to explore microclimates in their own back yards.

28. How a Greenhouse Works: Light

Recommended Grade Levels: 4 - 5

Objectives

- Students investigate how light intensity or brightness depends on the angle at which the sun's light strikes the surface of the ground and how this changes throughout the day.
- Students determine that changing the transparency of a greenhouse covering material affects light intensity and determine what translucent materials support the photosynthesis process.

Procedural Overview

To understand this content, students:

- Change the angle at which light strikes a model greenhouse and measure its intensity
- Control the intensity of the light by changing the transparency of the greenhouse covering material

Time Requirement

Teacher Preparation	15 minutes
Pre-Activity Discussion	15 minutes
Get Started	15 minutes
Let's Explore	50 minutes
Explain It	30 minutes
Tell Me More	30 minutes
Sum It Up	20 minutes

Materials

For teacher demonstration:

- ☐ Classroom terrarium[1]

[1]Optional: Refer to the Preparation section for construction ideas.

For each student group:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Reflector lamp or desk lamp with 60-watt incandescent light bulb
- ☐ Shoebox or cardboard box of comparable size
- ☐ White legal size typing paper, white butcher paper or white bulletin board paper
- ☐ Clear or transparent plastic wrap
- ☐ Wax paper
- ☐ Glad Press 'N Seal® Wrap
- ☐ Any other translucent materials[1]
- ☐ Scissors
- ☐ Protractor
- ☐ Pencil
- ☐ Transparent adhesive tape
- ☐ Metric ruler and a meter stick

[1] You can provide a variety of translucent materials for students to choose from, or you can control their choices. Other suggestions include parchment paper, paper towels, or sheer material.

Activity at a Glance

Get Started

- ☐ Discuss the usefulness of greenhouses and where they are found.
- ☐ Discuss construction materials and how we could model a greenhouse.

Let's Explore

- ☐ Build a model greenhouse.
- ☐ Explore how light intensity or brightness depends on the angle at which the sun's light strikes the surface of the ground and how this changes throughout the day.
- ☐ Practice measuring reflected light with the light sensor.

Explain It

- ☐ Explain that sunlight is necessary for the growth of plants.
- ☐ Discuss the process of photosynthesis and how it allows plants to make their own food.
- ☐ Review the following vocabulary with the students: transparent, translucent, opaque, greenhouse, intensity, lux, diffuse, transmit, independent variable, dependent variable, controlled variable.

Tell Me More

- ☐ Repeat the investigation using different covering materials that filter the amount of light.

Sum It Up

- ☐ Draw conclusions about the angle of the sun’s light and the material used as a covering to create the best light conditions in the model greenhouse.
- ☐ Complete the Assessment section if needed.

Safety

Add these important safety measures to your normal classroom procedures:

- Do not touch the bulb of the desk lamp or the bulb/reflector of the reflector lamp. Severe burns may result.
- Do not look directly at a light bulb. It can hurt your eyes.
- Always turn off a reflector lamp and allow it to cool before you set it down on the desk top; it could burn the top of the desk.

Preparation

These are the materials and equipment to set up prior to the activity.

- If you do not have a classroom terrarium established in your classroom, this would be a good time to develop one. You can use a commercially developed tank such as the PASCO EcoChamber, or you can repurpose an old fish tank. Clear 2-L soda bottles also work well as terrariums. You will need good potting soil, some soil amendment that encourages good drainage, a variety of plants, and an external light source such as a sunny window or a lamp.
- The hardest thing for your students to control in this lab will be the distance of the lamp from the surface of their model greenhouse. If the lamp is a utility work lamp with a clamp, you can set up ring stands and clamps for them to hang the lamps at fixed heights. If ring stands are not available, provide the lamp holder with a meter stick so that they can measure the distance.

Background

Greenhouses

Greenhouses have always been used to provide a warm, well-lit habitat for seedlings to start growing in the late winter and early spring. The very simplest type would be the use of a glass jar inverted over the top of a plant cut back to its base. As soon as the snow melts around the jar, the plant can start to grow. Commercial growers use elaborate large greenhouses to start seeds, while backyard gardeners erect small, closet-sized greenhouses. The one thing any greenhouse must have is a covering of translucent material and a means of controlling the temperature and humidity.

Sunlight is necessary

Plants need sunlight to grow, and students have tested this in other activities throughout various grade levels. However, it is less clear that seeds and seedlings have a similar dependency on the sun. In the early spring, when solar intensity increases and the ground begins to warm, seed sprout. The sun’s energy enables the tiny seedling to grow and to begin the process of photosynthesis. If these conditions can be duplicated in a greenhouse, you need not wait for the change in seasons to sprout seeds.

Sunlight intensity varies throughout the day, and throughout the seasons. Light intensity is measured in units called lux, similar to the way sound intensity is measured with decibels. The industry standard for light intensity is in lux, and the scale ranges from very small (1.5K lux) for candle power to a larger range for lamp power (15K lux) to very large for sunlight (150K lux).

Glazing

In a greenhouse, the clear or translucent walls that let in light are termed "glazing." The glazing promotes an environment with lots of light. Clear glazing, such as the clear plastic used to cover the roof of students' greenhouses, is transparent. It allows most of the light to pass through and enter the greenhouse. Glazing made of transparent material can cause plants to be burned. Translucent materials allow some of the sun's light to pass through and cause the light to be diffused or scattered evenly throughout the greenhouse. Diffused light is better for all types of plants to successfully carry on the process of photosynthesis. Opaque materials block out all the sun's light and are good for providing shade.

Pre-Activity Discussion

- Begin the discussion by asking students to recall what they know about greenhouses, what they are made of and why they are called "greenhouses." Then use effective questioning to guide students to recall what plants need in order to survive and grow. Focus on the need for light and how greenhouses are designed to meet this need. To develop these ideas, ask the following questions:

  Q Where have you seen greenhouses?

  Q What is the purpose of a greenhouse?

  Q What is true about the walls and roof of greenhouses, in general? Explain.

- Show a piece of clear glass and some other samples of transparent and translucent materials such as a plastic light cover and a piece of clear colored plastic report cover. Discuss the terms transparent, translucent, transmit, and opaque.

  Q What other needs of plants must be met by the design of a greenhouse?

- Explain that in this activity students will build a model greenhouse that is only meant to be used to test light intensity and later, heat. The other factors that are controlled in a greenhouse will not be tested here.

Driving Question

- How does the angle of the sun’s light affect the intensity of light that can be absorbed by plants in a greenhouse?

Variables

- List the factors that vary in a greenhouse. Students will include the amount of sunlight, the temperature, the amount of water, and other factors such as location and soil. All of these factors can be controlled and so they are variables. Go back to the driving question now and review it to determine which variables to keep for this activity.

Independent Variable

- The angle of the lamp, and therefore the angle at which radiant light strikes the surface, will be the independent variable in the first part of this activity.

- The translucent materials used in the second part of the activity become the new independent variables.

Dependent Variables

- The light sensor will measure the intensity of the light. The intensity of the light is the dependent variable. It depends on the angle at which the lamp is positioned. In part two of this activity, the type of material that the greenhouse is made of will be the dependent variable.

Controlled Variables

- Since no water, soil or air changes will occur, these variables are controlled.

- The distance of the light source from the model greenhouse must be controlled, even as the angle of incidence changes. The closer the light source is to the model, the greater will be the intensity. Therefore, a group decision should be made about the distance of the lamp to the box and how to control it. The recommended distance is 40 cm.

- The position of the model greenhouse in relation to the position of the lamp should be discussed. The lamp can either move from side to side across the model, or from front to back. All should agree on how they will move the lamp across the model.

Activity with Answer Key and Teacher Tips

After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

1. ☐ What materials will you use to build your greenhouse?

   Students will list their cardboard box or shoebox; plastic wrap or other translucent material; tape.

2. ☐ Do these materials allow you to create a complete greenhouse? Explain.

   Students will explain that in this experiment they can only test the way the light varies inside their greenhouse. They will not actually be building a complete greenhouse.

3. ☐ How do you think the conditions inside your greenhouse will differ from the conditions outside? Think about different times of day and different seasons.

   Answers will vary. Students know that inside the model greenhouse the temperature will be warmer because it is a confined space and there is no exchange of air with the outside.

4. ☐ Obtain a data collection system from your teacher and start a new experiment.

5. ☐ Connect a light sensor to the data collection system

   If your sensor has different settings, select the light bulb setting.

6. ☐ Display light intensity in lux in a digits display. Lux is the unit of measure for light intensity. We use this term to compare one light measurement to another.

Let's Explore

7. ☐ Point the light sensor at the overhead lights in your classroom and begin collecting data. When the values stop changing, stop recording data and record the intensity of the overhead lights.

   Teacher Tip: Answers will vary but all students will notice that in the digits display the value jumps around. 0.4 lux to 30.0 lux depending on the light source and the distance from the light source. Explain that this is due to the sensitivity of the equipment and that students should try to capture the best value possible. Practice this until students feel comfortable measuring light intensity and agree on values for their classroom.

8. ☐ Obtain a shoebox to use as your greenhouse model.

   a. Lay the shoebox on a piece of white paper and carefully trace the shoebox on the paper.

   b. Cut the white paper along the lines you just traced.

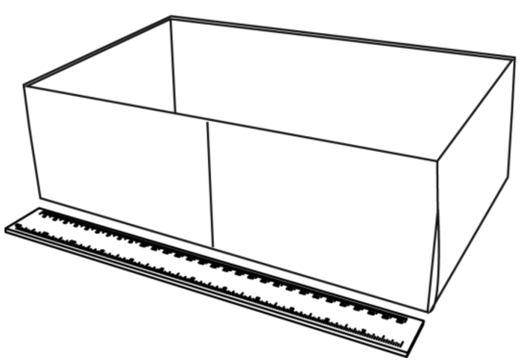
   c. Place the sheet of paper in the bottom of the box. Tape it down so it lies flat.

9. ☐ What is the purpose of the white paper, inside and on the bottom of the box?

   The purpose of the white paper is to bounce off as much light as possible to be detected by the light sensor. White reflects light more completely than any other color.

10. ☐ Measure the length of one of the longer sides of the shoebox with the metric ruler. Find the midpoint and draw a line from the top of the box to the bottom dividing it into two equal halves.

➢ Diagram 1: Shoebox with a line drawn at midpoint from top to bottom



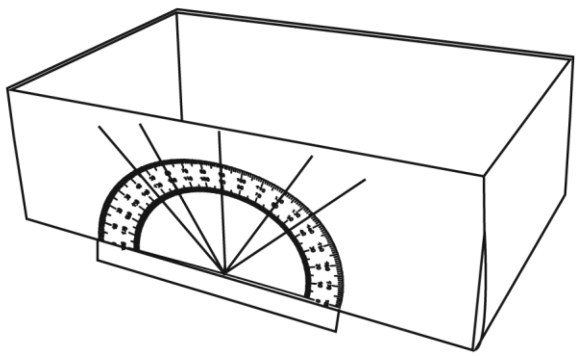
11. ☐ Align the protractor with the bottom edge of the shoebox and the line you just drew.

    a. Mark dots at 45°, 60°, 120° and 135°.

    b. Draw a line connecting each dot to the bottom of the line at the midpoint and label each new line as in Diagram 3.

    c. Label the line down the middle of the box 90°. These lines represent the angle of the sun's light as it enters the greenhouse and changes position throughout the day as the Earth rotates.

➢ Diagram 2: Shoebox with lines drawn and labeled at 45°, 60°, 90°, 120° and 135°



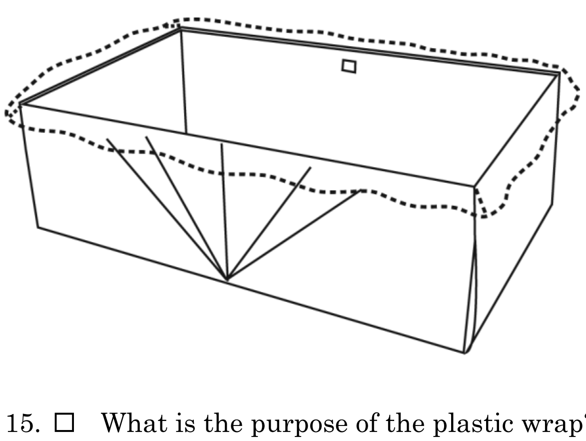
12. ☐ On the side of the shoebox opposite the angle measurements, cut a 1-cm square hole for the light sensor, approximately 1 cm from the top edge of the box, centered on that side. See Diagram 4.

13. ☐ What is the purpose of the lines you drew on the side of the box?

    The purpose of these lines is to help align the light so position of the light will be a controlled variable.

14. ☐ Cover the top of the shoebox with transparent plastic wrap and tape it in place. Be sure you do not cover the hole for the light sensor. Now it is a finished model.

Diagram 3: Model greenhouse with 1 cm square light sensor hole, covered with transparent plastic wrap



15. ☐ What is the purpose of the plastic wrap?

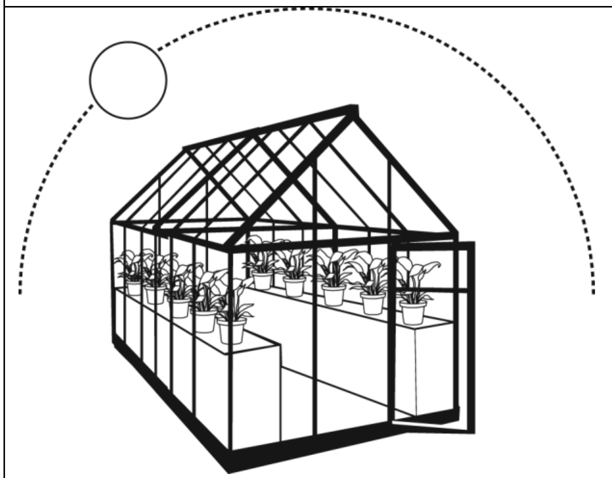
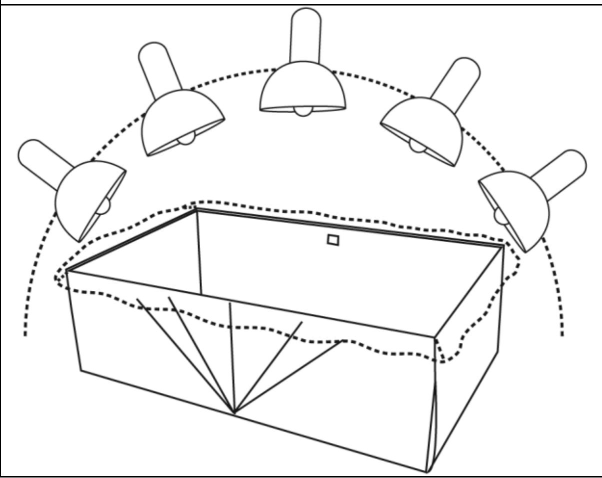
    The clear plastic wrap is supposed to represent the glass walls and roof of a real greenhouse. You need a translucent material to allow sunlight to shine through.

16. ☐ What does it mean to “transmit” light?

To transmit light means that light can be conveyed through a material that is transparent or translucent. To transmit means to cross through.

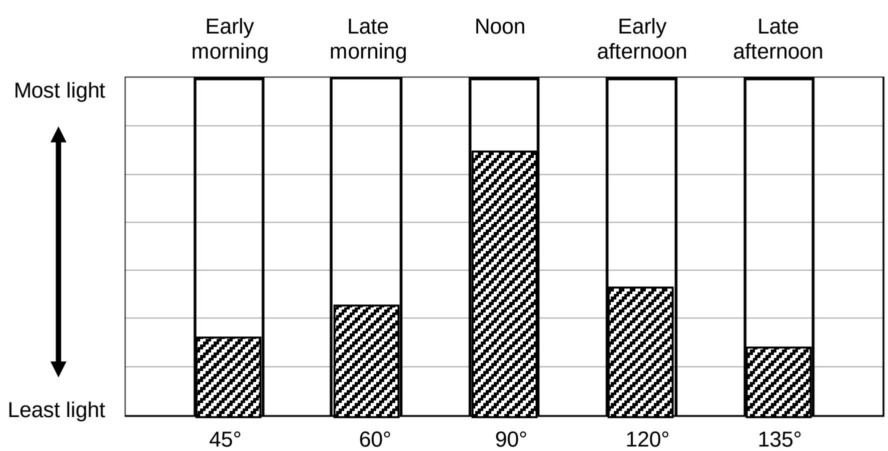
17. ☐ You will investigate light intensity in your model greenhouse, using the lamp to model the sun at five different positions during the day, represented by different angles. Shown below, in Diagram 5, is a drawing of a real greenhouse and the sun. In Diagram 6 is a drawing of your model greenhouse and a lamp modeling five different positions of the sun during the day.

Remember, the sun does not actually move across the sky. As the Earth rotates, it makes it appear to us that the sun is moving.

➢ Diagram 4: Greenhouse and sun at different positions during the day	➢ Diagram 5: Greenhouse model and lamp used to model the sun in five different positions during the day
	

18. ☐ Before using the light sensor to collect data, predict how you think the sun's light intensity will change as the sun's position and angle of its light rays change during the day. Draw and shade a bar graph showing your prediction.

➢ Graph 1: Predicted light intensity for five different positions of the sun during the day



Note: Student predictions will vary.

19. ☐ Now, use the data collection system to check your predictions. Push the light sensor's tip through the hole in the side of the model and point it towards the fold on the paper in the bottom of the model. One person must hold this steady throughout the experiment.

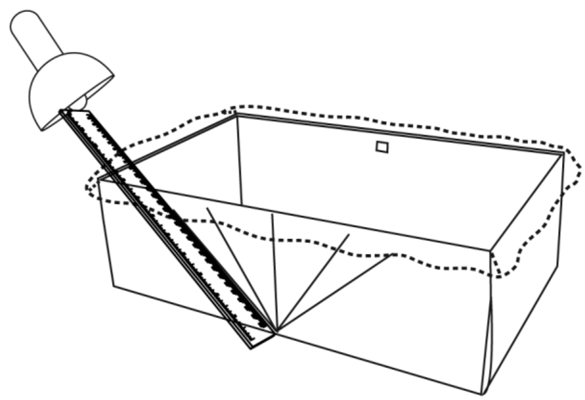
20. ☐ Now have another partner turn on the lamp and hold it above the model about 40 cm from the bottom of the model.

21. ☐ Why is it important to keep the lamp at the same distance from the bottom of the model?

    You have to control all other variables except the ones you are testing. Height must be controlled.

22. ☐ Use a metric ruler and the lines you made on the outside of the model to help angle the lamp so it is shining on the inside of the model at a 45° angle. The bulb should line up with the ruler.

➢ Diagram 6: Use a metric ruler to help angle the lamp and measure the distance from the lamp to the top of the box



23. ☐ Record a run of data. Copy each light intensity measurement in the chart below.

24. ☐ Move the lamp to each of the other four modeled positions of the sun, taking care to maintain a consistent distance to the model. Record the light intensity.

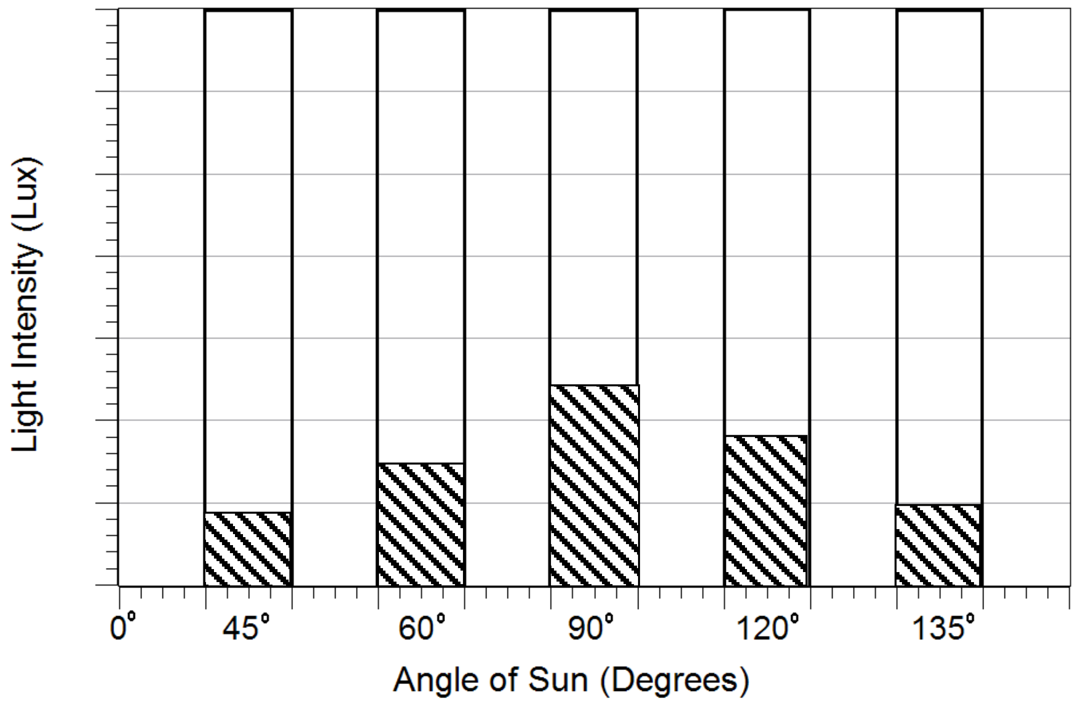
Table 1: Data for modeled positions of the sun

Angle	Light intensity in Lux
45°	87.22
60°	147.08
90°	245.55
120°	180.33
135°	98.99

25. ☐ Transfer your results from the table to the bar graph below.

Graph 2: Bar graph of measured light intensities

➢ Light intensity comparison of the sun's positions during the day



26. ☐ Were your results the same as, similar to, or completely different from your predictions?

Answers will vary.

Explain It

27. ☐ Look at your bar graph and explain how the angle of the light affected the intensity of the light.

Students will explain that as the light became more perpendicular to the surface of the box, the intensity increased.

28. ☐ Compare your findings to the position of the sun during the day. When during the day could you expect sunlight to be most intense?

Students will relate the 90° point to midday, or noon and shortly thereafter.

29. ☐ Throughout the year, the sun's path across the sky shifts in relation to the seasons. In winter, the sun's path is lower in the sky than in the summer. How would that affect the sunlight intensity?

Students should infer that a sun that is lower in the sky will be less intense than a sun that is higher in the sky. That is why it is hotter in the summer than in the winter.

30. ☐ You covered your box with clear plastic wrap so that light could be transmitted through the wrap and into the box. Clear plastic wrap is transparent, meaning that light can pass through the material without any change in intensity. Would the same be true of waxed paper? Explain.

You cannot see clearly through waxed paper but you can see clearly through plastic wrap. Therefore, waxed paper is not transparent.

31. ☐ Look up the following terms and write their definitions. Then give some examples of a material that fits each definition.

➢ Vocabulary and Definitions

Word	Definition	Examples
Transparent	light intensity passes through this material unchanged	clear plastic wrap, window glass
Translucent	light passes through but is scattered so the image is blurred	waxed paper, stained glass, frosted glass, many plastics
Opaque	light is completely blocked and cannot be transmitted through this material	black plastic garbage bags, sheets of wood

32. ☐ In your investigation of how the angle of the sun's light affects the intensity of the light as it falls on your greenhouse, you learned some new scientific ideas. These ideas have their own terms. In science it is important to be able to discuss your results using these words and terms correctly.

Write the meaning of the following terms in your own words using what you have learned from the lab.

➢ Vocabulary and Definitions

Word	Definition
Greenhouse	A building constructed for growing plants
Intensity	Amount of energy or strength
Lux	Unit used to measure the intensity of light
Diffuse	To scatter or spread out evenly
Independent variable	The condition or event or quantity that you change in an investigation
Dependent variable	The variable that is affected by the change in the independent variable
Controlled variables	Those factors that you hold constant so that they don't accidentally affect your results

Tell Me More

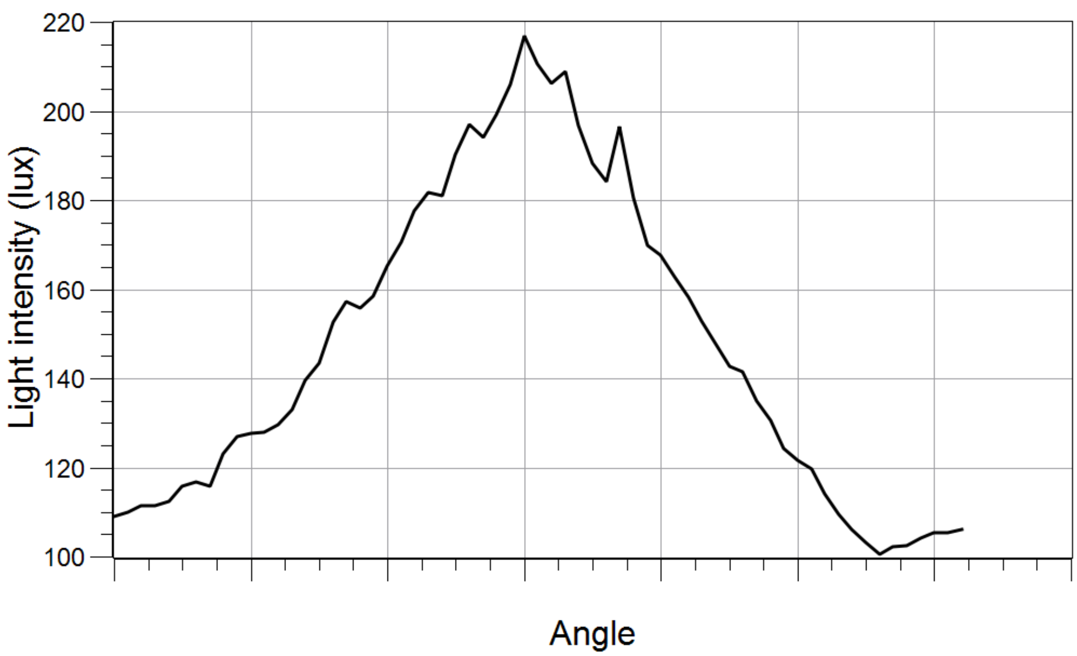
33. ☐ Let's model this data in another way. Close your previous experiment on your data collection system without saving and start a new experiment with the light sensor plugged in.

34. ☐ Display your data in a graph.

35. ☐ Turn on the lamp and place your light sensor in the hole on the side of the box.

36. ☐ Begin recording data. Starting with the lamp at about the 45° point, move the lamp slowly and smoothly across the "sky", keeping a constant distance from the box as much as possible. Stop recording data when you reach the other side.

37. ☐ On the blank graph below, sketch the shape of your curve. This will serve as your control for the next part of this activity.



Data should appear as a rough bell-shaped curve, with the highest point at 90 degrees.

38. ☐ Plants in greenhouses grow best when the light is scattered, or diffused, throughout the greenhouse. Materials used to cover the greenhouse have different properties. Glass is transparent and allows most of the sunlight to pass through. However, this can cause plants to burn. Translucent materials work better because they scatter the light.

39. ☐ Select three translucent but not transparent materials from those supplied by your teacher. Predict the ability of these materials to transmit light. Word it in such a way that you say how each material will affect the light intensity.

Student answers will vary; accept all answers as this is their hypothesis, as long as they are written as an if/then statement.

40. ☐ Test the three different materials to determine which material is best to use as a covering for your greenhouse.

    a. Cover your greenhouse with a sheet of one of the materials and tape it down.

    b. Insert the light sensor into the hole and point it towards the crease in the middle of the shoebox.

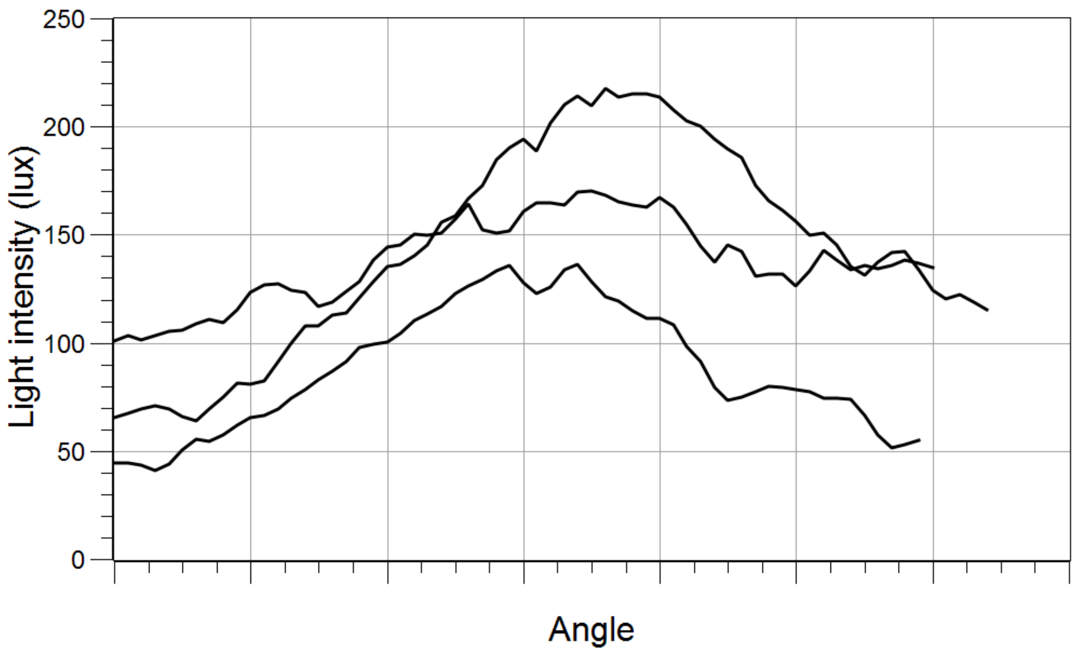
    c. Turn on the lamp.

    d. Start recording data and move the lamp across the "sky" in the same way you did for the clear wrap covering.

    e. Stop recording data and replace the covering material with the next choice.

    f. Repeat the test for both of the remaining coverings, making a new run of data for each covering.

41. ☐ Copy each line, including the one for the control, onto the graph below and label each line. Alternatively, print out a copy of your graph from your data collection system.



Answers vary depending on the materials used. Materials that allow less light through them will have curves corresponding to lower light intensities.

Sum It Up

42. ☐ If a material diffuses light very well, will the light intensity be higher or lower? Would this be good for plants?

Light intensity will be lower if the material diffuses light very well. This would be good for plants, because direct intense sunlight can burn them.

43. ☐ Looking at the graphs of these materials, compared to the graph of the effect of clear plastic wrap, how did the shapes of the lines change?

Students will describe the shapes of the lines. In general, they will see that the clear plastic wrap has a steep and tall curve. Translucent materials that scatter light better than clear plastic wrap will not have curves that go as tall as the clear material, but the curves may rise faster to height at both ends of the curve. This can tell your students that more light is available to plants earlier in the day than with a clear material, and the light is more evenly distributed throughout the day.

44. ☐ Recall the driving question for the first part of this activity.

How does the angle of the sun's light affect the level of light intensity that can be absorbed by plants in a greenhouse?

Rewrite the driving question to match the second part of the activity that you just completed.

How do different materials affect the level of light intensity in a greenhouse?

45. ☐ What is the independent variable in this second part of the activity?

The independent variable is the type of translucent materials used in the covering of the greenhouse.

46. ☐ Write a paragraph that summarizes what you have learned from this activity that answers the driving question and includes what you learned about materials that also scatter light.

Answers will vary. The early morning light and the late afternoon light have a lower light intensity than the midday light. Clear transparent material allows the most intense light to pass through, but translucent materials scatter the light better and make it less damaging to plants. Scattered light is less intense during midday, but maintains its intensity longer than unfiltered light.

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. Which material below will allow almost all of the sun's light to pass through?

Ⓐ Translucent plastic

Ⓑ **Transparent glass**

Ⓒ Opaque white plastic

Ⓓ Translucent white paper

2. To convey across or through a barrier is to

   Ⓐ **Transmit**

   Ⓑ Transport

   Ⓒ Transduct

   Ⓓ Transpire

3. Another word for scattered light or light that is spread out is

   Ⓐ Transmitted

   Ⓑ Intensity

   Ⓒ **Diffused**

   Ⓓ Translucent

4. The intensity of light is also the ____________ of the light.

   Ⓐ Amount of energy

   Ⓑ Strength

   Ⓒ **Both A and B are correct**

   Ⓓ None of the above

5. Light is most intense at what time of day?

   Ⓐ Early morning

   Ⓑ Late afternoon

   Ⓒ **Midday**

   Ⓓ Late morning

Further Investigations

For an interesting investigation, change the position of the light sensor to investigate the light intensity at either end of the "greenhouse" as the sun moves across the "sky" throughout the day. Reposition the sensor to either end of the box by cutting another hole for the sensor's tip near the end on the side of the box and rerun the tests.

In this activity, you moved the lamp across the greenhouse from end to end. How would the curves change if you moved the lamp from side to side? The orientation of the box to the "sun" would be interesting to explore.

Build a model greenhouse with transparent sides as well as the top. Test clear transparent material compared to translucent material on the walls and top.

29. How a Greenhouse Works: Heat

Recommended Grade Levels: 4 - 5

Objectives

- Students measure the heat generated in a model greenhouse by altering the types of material that light passes through.
- Students investigate if using a heating pad instead of a light source will alter the temperature in the greenhouse.

Procedural Overview

To understand this content, students:

- Investigate the temperature changes in a closed greenhouse
- Compare the effects of a change in the transparency of the covering materials in the temperature of the air
- Compare the effects of a change in the heat delivery mechanism to the greenhouse

Time Requirement

Teacher Preparation	15 minutes
Pre-Activity Discussion	15 minutes
Get Started	15 minutes
Let's Explore	30 minutes
Explain It	20 minutes
Tell Me More	30 minutes
Sum It Up	15 minutes

Materials

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Greenhouse models from the "How a Greenhouse Works: Light" activity
- ☐ Light source such as a swivel desk lamp or reflector lamp with a 60-watt incandescent bulb
- ☐ Electric heating pad
- ☐ Scissors
- ☐ Metric ruler or meter stick
- ☐ Adhesive tape
- ☐ Clear plastic wrap
- ☐ Wax paper

Activity at a Glance

Get Started

- ☐ Students monitor the temperature in their greenhouse model with no covering.
- ☐ Place the clear plastic covering on the greenhouse and retest the temperature.

Let's Explore

- ☐ Change the translucency of the covering materials and retest the temperature.

Explain It

- ☐ Explain how the air is heated in all examples.
- ☐ Review the following vocabulary with the students: greenhouse, radiant energy, heat, temperature, transmit, and independent variable.

Tell Me More

- ☐ Change the source of heat to an electric heating pad and compare the results.

Sum It Up

- ☐ Determine the best heat transfer mechanism for the greenhouse.

Safety

Add these important safety measures to your normal classroom procedures:

- Do not touch the bulb of the desk lamp. Severe burns may result.
- Do not look directly at a light bulb. It can hurt your eyes

Preparation

These are the materials and equipment to set up prior to the activity.

- Make sure that students have their model greenhouses from the activity entitled "How a Greenhouse Works: Light." If your students did not complete that activity, they will have to build the model greenhouses before beginning this one. See the directions for building this model in the section entitled "Let's Explore" in "How a Greenhouse Works: Light."

- Place a temperature sensor inside your classroom ecochamber or greenhouse. Monitor the temperature over a period of 24 hours to see how the temperature changes throughout the day and night, when there is a living system in operation.

Background

The sun heats the Earth by radiation, conduction and convection. Radiant energy transmitted through space from the sun is absorbed by Earth's surfaces which then conducts heat into the air. Therefore, most of the air is warmed by heat from the surface through conduction and then convection.

Heat is necessary for plant growth. Seeds germinate and grow when soil warms up after the cold of winter. Too much heat will cause tender seedlings to dehydrate and wither, and not enough heat will prevent seeds from germinating. Mature plants also are sensitive to changes in temperature and grow most vigorously within a narrow range of temperatures. Planting times and harvest times are temperature-dependent. Therefore greenhouses that control the temperature can actually speed up plant growth.

In greenhouses, several methods are used to control and moderate heat, including ventilation, diffusion, shading, and passive storage. For ventilation, hinged walls and roof panels can be opened or closed to moderate the air temperature. Glazed glass or colored plastic sheeting diffuse the light, scattering it and moderating the light and heat simultaneously.

Green mesh netting is also used within the greenhouse to further shade delicate seedlings. Passive storage of heat includes the use of water drums, which absorb the sun's energy during the day and radiate the heat into the room during the night. In some places, geothermal activity is used to pump hot water through the floors which is very effective at heating the greenhouse.

Pre-Activity Discussion

- Use the following series of questions to establish how the sun's energy gets transferred to the earth and becomes warm air.

  Q What kinds of energy come from the sun?

  Q Does heat come from the sun to our planet?

  Q Is space hot or cold?

  Q Why do we talk about the coldness of space? Why do astronauts have to wear spacesuits with heaters in them?

- Establish the idea that the sun's energy travels to Earth in the form of electromagnetic energy. The atmosphere blocks some of this energy, but a lot of sunlight, including visible light and ultraviolet light (invisible), passes through the atmosphere and falls on the Earth's surface.

- Space is cold, even though sunlight passes through space to Earth. There are only a very few particles floating around in space, but they do absorb solar energy. You can take the temperature of space: it's only about –270 °C, or 3 Kelvin! That's cold!

- Ask students where they have been that gets really hot in the sunshine. They may think of standing or working in sunny locations surrounded by hot pavement or buildings. Connect their ideas to the fact that matter absorbs sunlight and then conducts heat back out into the air to heat the air.

  Q How does light energy from the sun become warm air on Earth?

- When sunlight passes through the atmosphere of Earth, a little bit of the energy is absorbed by the air and the air warms up. But most of the light is absorbed by the ground. The ground then gets hot and heats the air directly above the ground by conduction. Through conduction, the air above the ground warms up. When air warms up, convection currents develop because hot air rises and cold air sinks. So it is this secondary heat that warms the atmosphere for the most part.

- This would be the time to review radiation, conduction, and convection in this process if these terms are in your curriculum. The sun transfers energy to Earth by radiation. The Earth absorbs the energy. The energy is conducted into the air directly above the surface, which conducts the energy further away from the surface. Convection currents develop, and the hot air mixes with the cold air higher up.

- Water has a high specific heat and takes time to warm up; water once warmed takes time to give up its heat to the environment. A high humidity inside the greenhouse will allow more heat energy to be absorbed and maintained.

Driving Question

- What conditions are necessary to maintain a moderate temperature inside a greenhouse?

Variables

Independent Variable, Part 1

- Test different materials to cover your greenhouse, such as clear plastic wrap, waxed paper, bubble wrap, parchment paper, or butcher paper.

Independent Variable, Part 2

- Replace the overhead lamp with an electric heating pad to see if heat from below affects the temperature differently than heat from above.

Dependent Variables

- The temperature of the air inside the greenhouse is the dependent variable.

Controlled Variables

- The distance from the lamp to the greenhouse model must be controlled. Use a meter stick to measure carefully.

- Since no water, soil or air changes will occur, these variables are controlled.

Activity with Answer Key and Teacher Tips

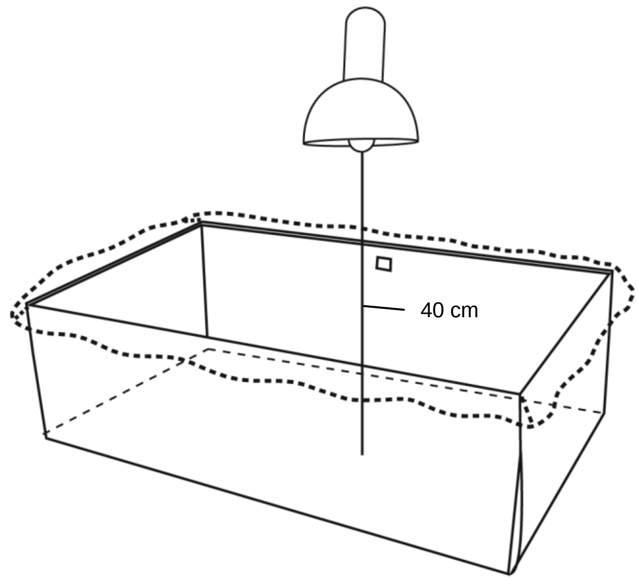
After you complete a step or answer a question, place a check mark in the box (☐) next to that step.

Get Started

1. ☐ Retrieve your model greenhouse from the previous lab on greenhouses and light.

2. ☐ Place the lamp you used for the other lab above the model greenhouse.

3. ☐ Use a meter stick to position the lamp so it is about 40 cm above the floor of the model and pointing directly down at the greenhouse as shown below.



4. ☐ In this activity, you are investigating how heat in the model greenhouse is affected by changes to the covering material on the box. What is the independent variable?

   The independent variable will be the materials used as coverings on the model.

5. ☐ What tool will you use to measure the dependent variable?

   The dependent variable will be the heat in the model, so we will use the temperature sensor to measure heat.

6. ☐ Start a new experiment on the data collection system.

7. ☐ Connect a temperature sensor to the data collection system.

8. ☐ Display temperature in a digits display.

9. ☐ Should you vary the position of the lamp in this experiment? Explain your answer.

   Students should not vary the position of the lamp because the only factor we are going to vary is the type of material covering the model.

10. ☐ Turn on the lamp and make sure that it is shining directly down on the bottom of the model.

    Note: You do not need any paper on the bottom of the model, and no covering material is needed yet.

11. ☐ You are to explore what is happening to the temperature inside the model with the lamp shining into it. Push the temperature sensor through the hole in the side of the greenhouse model so the tip of the sensor hovers just above the floor of the greenhouse.

12. ☐ Start recording data.

13. ☐ Wait until the temperature stops changing, and record the temperature of the floor of the greenhouse and the air just above it in °C in Table 1.

14. ☐ Stop recording data.

15. ☐ Record your observations in Table 1.

➢ Table 1: Greenhouse temperatures, uncovered, with white paper floor

Temperature Sensor Location	Temperature (°C)	My Observations
Just above the floor of the greenhouse model	23.6	If I left the sensor in longer, the temperature would continue to increase.
At other locations, such as the middle or near the top of the model	23.6	If the temperature went up in the middle of the model, it also went up at the bottom.

16. ☐ Now that you have explored the temperature in the model, what else has to be controlled in this experiment?

    Students will realize that the *amount of time* must be controlled because the longer the lamp is left on, the hotter the air in the model will become. They also need to control *where they place the sensor*, and place it in the same location every time.

Let's Explore

17. ☐ You know what the temperature is inside the model when there is no covering. Make a prediction about how the temperature will change with a covering on the model.

18. ☐ Select clear plastic wrap and three other translucent materials to use in covering your greenhouse model. Predict how each covering will affect the temperature in Table 2.

Table 2: Predictions for temperatures using different materials.

Material for Covering	Predicted Temperature	My Reason
Clear plastic wrap	Hotter than with no covering, so maybe 30°C	I think it will be hotter because no fresh air can get into the box.
Other materials such as wax paper, bubble wrap, or parchment paper	Answers will vary.	Reasons will vary.
Other materials such as wax paper, bubble wrap, or parchment paper	Answers will vary.	Reasons will vary.
Other materials such as wax paper, bubble wrap, or parchment paper	Answers will vary.	Reasons will vary.

19. ☐ Since you now know that you have to control the amount of time, we will add these rules for taking each measurement:

a. Make sure that the inside of the model is as cool as room temperature before you start each run.

b. After you apply a covering, let the model warm up for 2 minutes.

c. After you insert the temperature sensor, record the temperature for 2 additional minutes.

20. ☐ Start by applying the clear plastic wrap to your model, taping it down.

Steps for testing the covering materials

21. ☐ Turn on the lamp and let it sit for 2 minutes.

22. ☐ Place the temperature sensor inside the model near the bottom.

23. ☐ Record a run of data in the digits display.

24. ☐ Stop recording data after 2 minutes.

25. ☐ Record this result in Table 3.

26. ☐ Remove the plastic wrap and cool your model down to room temperature by blowing into it or waving it in the air.

27. ☐ Why is it necessary that you air out the model after each test?

    If the starting temperature changes, then the ending temperatures cannot be compared side by side.

28. ☐ Replace the clear plastic wrap with any of the other materials your teacher has provided.

29. ☐ Repeat the "Steps for testing the covering materials" for all materials you are suppose to test.

➢ Table 3: Actual temperatures resulting from different covering materials

Material for Covering	Actual Temperature	My Observations
Clear plastic wrap	26.0	The temperature continued to climb steadily during the entire minute.
Waxed paper (example)	25.2.	The temperature rose faster than with plastic wrap.
Bubble wrap (example)	26.1	The temperature behaved the same way it did for the others.
Other material		

Explain It

In this part of the activity, you will define the terms that have come up so far and explain what is happening in your model.

Teacher Tip: This entire section could be assigned for homework.

30. ☐ Did the clear plastic wrap have any effect on the temperature in the model?

    Students will note that the temperature of the air in the model was warmer than the temperature without a covering.

31. ☐ What is your explanation for this change in temperature?

    Since the covering prohibits the air from mixing with the room, it will be warmer than air that mixes with the room.

32. ☐ Explain your results for the other materials you chose.

    Student answers will vary. The distance of the lamp to the box does makes a difference, so if your students have differing results, point them to an examination of their experimental design. There are no right or wrong answers here.

    In general, you could predict that the more the light is diffused by the covering, the cooler the temperature inside the model will be. However, this model is far from perfect and those results may not occur.

    In this answer, your students' explanations need to match their results and be plausible for their experimental design.

33. ☐ In your investigation of how different coverings affect the air temperature inside your greenhouse, you learned some new scientific ideas. These ideas have their own terms. In science it is important to be able to discuss your results using these words and terms correctly.

    Write the meaning of the following terms in your own words using what you have learned from the lab.

➢ Vocabulary and definitions

Word	Definition
Greenhouse	a building constructed for growing plants
Radiant energy	energy transferred from the sun to Earth
Heat	energy transferred from particle to particle
Temperature	a measure of the amount of heat transferred, compared to a standard
Transmit	allowing to pass through
Independent variable	the condition or event or quantity that you change in an investigation
Dependent variable	the variable that gets affected by the change in the independent variable

Tell Me More

In this part of the activity, you will change the heat source to a heating pad to see if it makes a difference in the internal temperature of the model.

Teacher Tip: This part of the activity could be run as a whole class demonstration if you only have one heating pad. Alternately, this part of the activity could be assigned as an out-of-class experiment.

Teacher Tip: Students may want to explore other alternative heating sources, such as hot water bottles or radiators. Make sure that their methods leave no possibility of fire danger.

34. ☐ Now explore what is happening to the temperature inside the model with the heating pad warming it. If you change the heat source to a heating pad, how will that change the driving question? What is the independent variable now?

    The lamp was a controlled variable, not the independent or dependent variable. So if we change the lamp to a heating pad, we can still run the same experiment and have the same driving question.

35. ☐ Remove the lamp.

36. ☐ Plug in a heating pad and place it underneath your greenhouse model.

37. ☐ Start a new experiment on the data collection system.

38. ☐ Connect a temperature sensor to the data collection system.

39. ☐ Display temperature in a digits display.

40. ☐ Turn on the heating pad and set it to the highest setting. Let it heat up to its highest temperature. It should take approximately 5 minutes.

41. ☐ You should not have a cover on the greenhouse yet. Place the greenhouse model on the heating pad. Let the heating pad warm the greenhouse model for 2 full minutes.

42. ☐ Make a prediction: how will the heating pad change the way the greenhouse warms, using the same materials as we did in the first experiment?

    Answers will vary: accept all predictions.

43. ☐ Push the temperature sensor through the hole in the side of the greenhouse model so the tip of the sensor hovers just above the floor of the greenhouse. (Do not let the sensor touch the bottom!)

44. ☐ Start recording data.

45. ☐ Wait for 2 minutes, (the temperature will change rapidly at first, then will level off) and stop recording data.

46. ☐ Write the temperature in °C in Table 4.

47. ☐ Lift the model off the heating pad and allow it to cool completely.

    Teacher Tip: If you have a small electric fan, this could be used to quickly cool the bottoms of the models before the students try the next trial.

48. ☐ Repeat your tests for the different materials used before and record your results in Table 4. Remember to cool your model before starting each new test.

➢ Table 4: Greenhouse temperatures, uncovered, with white paper floor

Material for Covering	Actual Temperature	My Observations
No covering	24.5	I let it heat up for several minutes.
Clear plastic wrap	29.3	The temperature continued to climb steadily during the entire minute.
Waxed paper (example)	30.7	The temperature rose faster than with plastic wrap.
Bubble wrap (example)	29.5	The temperature behaved the same way it did for the others.
Other material		

Sum It Up

49. ☐ How did the temperatures with the heating pad compare overall to the temperatures with the lamp?

Answers will vary. In these examples, the heating pad warmed the air above the bottom more efficiently than the lamp.

50. ☐ Did the change in covering materials affect the temperature differently when using the heating pad compared to the lamp?

Answers will vary. In these examples, the waxed paper worked slightly better with the heating pad than it did with the lamp.

51. ☐ Overall, which covering material makes the greenhouse model the warmest, regardless of heating source?

Answers will vary. In these examples, all covering materials worked equally well at warming the air temperature with both methods.

52. ☐ What conditions are necessary to maintain a moderate temperature inside a greenhouse?

A light source or radiant heating is needed to warm a greenhouse. However, a greenhouse can continue to heat to very high temperatures that could kill plants. Ventilation and fans can help moderate the temperature inside a greenhouse. Translucent material that makes up the walls and ceiling of the greenhouse can allow different amounts of light into the greenhouse.

Assessment

Multiple Choice

Darken the circle of the best answer to each of the questions below. Be prepared to give the reasons for your choices.

1. When using the lamp as a heat source, why did you measure the temperature close to the bottom of the model?

Ⓐ Because hot air sinks.

Ⓑ Because hot air rises.

Ⓒ **Because light energy is absorbed by the bottom, then the bottom gives off heat.**

Ⓓ Because heat is absorbed by the bottom and reflects itself.

2. Why did you measure the temperature inside the model without any covering on the model?

Ⓐ **You want to have a standard temperature to compare changes to later.**

Ⓑ You want to know what the air temperature is in the classroom.

Ⓒ “No covering” is the first independent variable.

Ⓓ “No covering” is the first dependent variable.

3. When temperatures continued to climb inside the model, which solution did we use?

   Ⓐ We put slits in the top of the covering to ventilate the model.

   Ⓑ We cooled the model in between tests.

   Ⓒ We limited the amount of time we collected temperature data.

   Ⓓ **We both cooled the model between tests and limited the time for collecting data.**

4. Translucent coverings keep the model cooler than transparent coverings because

   Ⓐ **Less light energy gets through translucent materials than transparent materials.**

   Ⓑ Translucent materials absorb more energy than transparent ones.

   Ⓒ Less light gets through transparent materials than translucent ones.

5. Which of the following statements is true?

   Ⓐ **Heat builds up continually in a greenhouse unless you ventilate it.**

   Ⓑ Heat builds up then levels off inside a closed greenhouse.

   Ⓒ Light energy cannot be changed into heat energy in a greenhouse.

Further Investigations

In your classroom greenhouse, students may want to alter the heat source. Put the greenhouse on the radiator or on a heating pad for a week and watch the internal temperature around the plants and the temperature of the soil. See if the plants need more or less watering than without the change in heat source.

Remove the lamp from this experiment and put the model greenhouse outside in the sunshine. Repeat the covering tests using only direct sunlight. Control the amount of time you leave the model in the sun.

Line the bottom of the model greenhouse with black construction paper and repeat the experiment to see if you can maximize the amount of light the bottom can absorb from the lamp.