EARTH SCIENCE 1

An introductory course in getting to know our planet better through the eyes of a scientist. Students get to build a homemade weather station, complete with cloud tracker and hair hygrometer for measuring the Earth's atmosphere. Students also learn about convention currents, liquid crystals, air pressure, and how sunlight, water, and wind can be used as sources of energy.

Created by Aurora Lipper, Supercharged Science

www.SuperchargedScience.com

This curriculum is aligned with the California State Standards and STEM for Science.

TABLE OF CONTENTS

Introduction

Greetings and welcome to the study of Earth Science. This unit was created by a mechanical engineer, university instructor, airplane pilot, astronomer, robot-builder and real rocket scientist… me! I have the happy opportunity to teach you everything I know about earth science over the next set of lessons. I promise to give you my best stuff so you can take it and run with it… or fly!

Studying Earth Science draws on the knowledge of certain areas of physics, chemistry and biology. To get the most out of these labs, there are really only a couple of things to keep in mind, which you'll learn about as you work through this set of experiments. Since we are all here to have fun and learn something new, this shouldn't be too hard.

One of the best things you can do as the student is to cultivate your curiosity about things. *Why did that move? How did that spin? What's really going on here?*

This unit on Earth Science is chock-full of demonstrations and experiments for two big reasons. First, they're fun. But more importantly, the reason we do experiments in science is to hone your observational skills. Science experiments really speak for themselves much better than I can ever put into words or show you on a video. And I'm going to hit you with a lot of these science demonstrations and experiments to help you develop your observing techniques.

Scientists not only learn to observe what's going on in the experiment, but they also learn how to observe what their experiment is telling them, which is found by looking at your data. It's not enough to invent some new kind of experiment if you don't know how it will perform when the conditions change a bit, like on Mars. We're going to learn how to predict what we think will happen, design experiments that will test this idea, and look over the results we got to figure out where to go from there. Science is a process, it's a way of thinking, and we're going to get plenty of practice at it.

Good luck with this Earth Science unit!

For the Parent/Teacher:
Educational Goals for Earth Science 1

Earth Science encompasses a huge area of scientific study, from weather and atmosphere to rocks and energy, and much more! In this first unit of Earth Science, we're going to learn about the dynamic phenomena of weather by building our own weather and tracking station, discover how the atmosphere uses wind, water, and sunlight to create weather, and the basic thermodynamics and fluid mechanics behind it all.

Here are the scientific concepts:

- Weather can be observed, measured and described using scientific instruments.
- How to use simple tools (e.g., thermometer, wind vane) to measure weather conditions and record changes from day to day and over the seasons.
- The weather changes from day to day, but trends in temperature or of rain (or snow) tend to be predictable during a season.
- The sun warms the land, air, and water.
- Energy from the sun reaches the Earth through radiation.
- The color of a material will affect how much energy is absorbed and reflected by the object. Dark objects absorb more energy than lighter objects; lighter objects reflect more energy than darker objects.
- Water can be purified through coagulation, sedimentation, and filtration, or by distilling.
- Sub-cooling is when substances are cooled below their freezing point while still in a liquid state. In order to turn into a solid, the substance must heat up to its freezing temperature first before turning into a solid.
- Higher pressure always pushes.
- Air isn't invisible or a vacuum. It takes space, and we can record pressure, temperature, and volume measurements for air.
- Atmospheric pressure is 14.7 psi, or 1 atm.
- For air, when there's a decrease in volume, both temperature and pressure increases. When volume increases, temperature and volume decrease.

By the end of the labs in this unit, students will be able to:

- How to measure the amount of energy the sun produces.
- Build and test a device that uses wind as an energy source.
- Design an experiment to demonstrate how water can use used to store energy.
- How to record data and interpret results.
- How to measure rainfall, wind speed, temperature, and atmospheric pressure.
- Demonstrate how air pressure influences an object in relation to moving air.
- Understand how the sun's energy can be used in a variety of ways to meet the needs of daily life.
- Measure and estimate the weight, length and volume of objects.
- Formulate and justify predictions based on cause-and-effect relationships.
- Conduct multiple trials to test a prediction and draw conclusions about the relationships between predictions and results.
- Construct and interpret graphs from measurements.
- Follow a set of written instructions for a scientific investigation.

Master Materials List for All Labs

This is a brief list of the materials that you will need to do *all* of the activities, experiments and projects in this unit. The set of materials listed below is just for one lab group. If you have a class of 10 lab groups, you'll need to get 10 sets of the materials listed below. Most materials are reusable.

- Activated carbon (check a fish store)
- Alum (spice)
- Balloons (5)
- Black paint or spray (flat)
- Black piece of paper
- Bowl
- Business card or index card
- Chemistry glassware , basic set (CE-KIT01) from www.hometrainingtools.com or similar
- Cheesecloth
- Clay
- Cotton balls (2)
- Diaper Genie refill package
- Disposable cups (4)
- Disposable pie tin (2)
- Drill bits and drill
- Duct tape, masking tape
- Electric fan
- Film canister or soup can
- Food dye (red and blue)
- Funnel
- Garbage bag
- Glass jars (3)
- Glasses for water (2, identical)
- Gloves
- Goggles
- Hair dryer (hand held)
- Highlighter (silver) OR aluminum foil
- Hole punch
- Ketchup packet
- Lighter (with adult help)
- Lime (calcium hydroxide,
- Marker
- Measuring cups
- Measuring spoons
- Medicine dropper or syringe without needle
- Newspaper
- Paintbrush
- Paper
- Paper clips
- Pencil with eraser on top
- Pepper
- Ping pong ball
- Pinwheel
- Popsicle sticks (2)
- Rubbing alcohol
- Ruler
- Salt
- Sand (clean)
- Scissors
- Shoe box
- Soda bottle (two liter)
- Soda cans (3, empty)
- Sodium acetate (CH-NAACET) from www.hometrainingtools.com OR get it from a reusable hand-warmer like (HEA-400) from www.teachersource.com
- Stopwatch
- Straws (25)
- String (about 4 feet long)
- Sunprint paper (SPP-40) from www.teachersource.com
- Tacks or pins
- Tape
- Liquid crystal sheet (LC-2530B) from www.teachersource.com
- Thermometer
- Water bottles
- Wire screen

Lab Safety

Goggles: These should be worn when working with chemicals, heat, fire, or projectiles. These protect your eyes from chemical splatter, explosions, and tiny fast-moving objects aimed at the eyes. If you wear glasses, you can find goggles that fit over them. Don't substitute eyeglasses for goggles, because of the lack of side protection. Eyeglasses don't provide this important side eye protection.

Clean up Messes: Your lab area should be neat, organized, and spotless before you start, during your experiment, and when you leave. Scientists waste more time hunting for lost papers, pieces of an experiment, and trying to reposition sensitive equipment… all of which could have easily been avoided had they been taught organizational skills from the start.

Dispose of Poisons: If a poisonous substance was used, created, or produced during your experiment, you must follow the proper handling procedures for disposal. You'll find details for this in the experiments as needed.

Special Notes on Batteries: Do not use alkaline batteries with your experiments. Find the super-cheap kind of batteries (usually labeled "Heavy Duty" or "Super Heavy Duty") because these types of batteries have a carbon-zinc core, which does not contain the acid that alkaline batteries have. This means when you wire up circuits incorrectly (which you should expect to do because you are learning), the circuits will not overheat or leak. If you use alkaline batteries (like Energizer and Duracell) and your students short a circuit, their wires and components will get super-hot and leak acid, which is very dangerous.

No Eating or Drinking in the Lab: All foods and drinks are banned from your classroom during science experimentation. When you eat or drink, you run the very real risk of ingesting part of your experiment. For electricity and magnetism labs, always wash your hands after the lab is over to rinse off the lead from the electrical components.

No Horse Play: When you goof around, accidents happen, which means chemicals spill, circuits short, and all kinds of hazards can occur that you weren't expecting. Never throw anything to another person and be careful where you put your hands – it could be in the middle of a sensitive experiment, especially with magnetism and electricity. You don't want to run the risk of getting shocked or electrified when it's not part of your experiment.

Fire: If you think there's a fire in the room (even if you're not sure), let your teacher know right away. If they are not around (they always should be), smother the fire with a fire blanket or use a fire extinguisher and send someone to find an adult. Stop, drop, and roll!

Questions: If you're not sure about something stop and ask, no matter what it's about. If you don't know how to properly handle a chemical, do part of an experiment, ask! If you're not comfortable doing part of the experiment, then don't do it.

Introduction to Creating
A Homemade Weather Station

Note: If you're a teacher, set out different weather instruments as samples for students to move from station to station. If you're a parent or student, skip this lesson and come back to it after you've made your various weather instruments.

Overview: Keeping track of the weather is important for many reasons! What was the weather like today? Do you need a coat or a swimsuit? Will your flowers freeze tonight? We'll learn how scientists use different instruments while making some for ourselves.

What to Learn: These experiments help us learn how weather can be observed, measured, and even predicted.

Materials

- Weather instrument samples
- Pencil
- Data worksheet

Lab Time

1. Each of the instruments should be set up in stations around the room. Go to the first instrument.
2. For this instrument, we want to know what it measures. Let's use the thermometer as an example. We will record what the instrument is, what it measures, and then take a reading outside.
3. This might sound basic, but don't forget to put your units in! Is that thermometer reading in Celsius, Fahrenheit, Rankine, or Kelvin?
4. Go outside and take a reading using your instrument. Make sure to let each member of your group have a try so that you get an accurate measurement of the weather.
5. Think now: why is it important for us to know about this particular piece of data? This is what weather observation and data collection is all about! Next time you rag on the meteorologist for being wrong, maybe you'll give him or her a little slack for all they have to keep track of!

Weather Stations Data Table

Item/Object	What is it for?	Weather reading
1.		
2.		
3.		
4.		
5.		
6.		

Reading

Being able to predict tomorrow's weather is one of the most challenging and frequently requested information. Do you need a coat tomorrow? Will soccer practice be canceled? Will the crops freeze tonight? You get the point.

Scientists use different instruments to record the current weather conditions, like temperature, barometric pressure, wind speed, humidity, etc. The real work comes in when they spend time looking over their data over days, months, even years and search for patterns.

By understanding how the atmosphere moves and changes, scientists can guess on what it will do tomorrow based on what it's done in the past. Even with our massive super-computers today, people are still required to make certain calculations and decisions as to which set of math equations best fit, or model what the weather's currently doing. Maybe one day computers will be able to do this, but we're just not there yet now.

We're going to build our own homemade weather station and start keeping track of weather right in your own home town. By keeping a written record (even if it's just pen marks on the wall), you'll be able to see how the weather changes and even predict what it will do, once you get the hang of the pattern in your local area. For example, if you live in Florida, what happens to the pressure before the daily afternoon thunderstorm? Or if you live in the deserts of Arizona, what does a sudden increase in humidity tell you?

One of the greatest leaps in meteorology was using numbers to predict the flow of the atmosphere. The math equations needed for these are very complicated . The equations are fluid mechanics equations, which are currently unsolvable, meaning that we can only guess at the answer and never get an exact answer. Even today's most powerful computers cannot solve these complex equations! The best they can do is make a guess at the solution and then adjust it until it fits well enough in a given range.

Weather stations around the world work together to report the current weather every hour. These stations can be land-based, mounted on buoys in the ocean, or launched on radiosondes (an instrument carried by balloon to different levels in the atmosphere which uses radio signals to transmit what it measures). Pilots in airplanes also give weather reports en route to their destination, which get recorded and added to the database of weather knowledge. Long story short: weather is hard to predict, and it's constantly changing so it's difficult to keep up with.

Exercises Answer the questions below:

1. Write the name of an instrument that measures the temperature of the air.

2. Describe the weather outside today.

3. What is the name of someone who studies the weather?
    a. Oncologist
    b. Herpitologist
    c. Climatologist
    d. Meteorologist
    e. Asteroidologist

Lesson #1: Anemometer

Overview: Today you'll make your very own wind speed indicator, also known as an anemometer.

What to Learn: This experiment helps us learn how to measure and observe important aspects of our planet's weather patterns.

Materials

- Four lightweight cups
- Two sticks or popsicle sticks
- Tape or hot glue
- Tack or pin
- Pencil with eraser on top
- Block of foam (optional)

Lab Time

1. Make an X with the popsicle sticks. Hot glue these sticks together, and also hot glue a cup to each end of the stick.
2. This part is tricky: find the center of gravity by balancing your sticks on the pointy end of the pencil. Once you can balance it, make a note of this point on the sticks. Run your tack through this point.
3. Insert the tack end to the top of the pencil's eraser.
4. Test your anemometer to make sure it moves by blowing on it. If it doesn't, this means there is too much friction and you need to wiggle your tack until it does.
5. Mount your anemometer into a block of foam with your pencil if needed. Go outside to check the wind speed, and record your data in the worksheet. Continue recording your data over a period of days, so that we can build a comprehensive catalog of data on the weather.

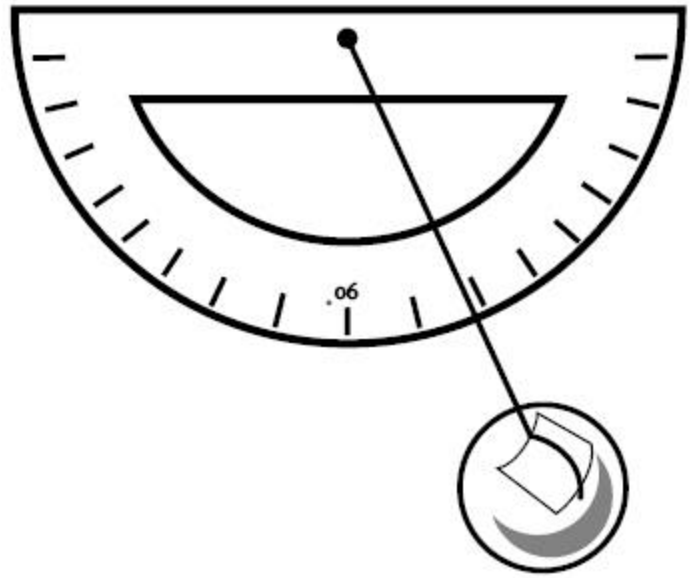
Bonus Experiment Idea:

Most weather stations have anemometers to measure wind speed or wind pressure. The kind of anemometer we're going to make is the same one invented back in 1846 that measures wind speed. Most anemometers use three cups, which is not only more accurate but also responds to wind gusts more quickly than a four-cup model.

The quickest anemometer to make is to attach the end of a string (about 12″ long) to a ping pong ball. Suspend the string in the wind, like from a fan or hair dryer (use the 'cool' setting). Since the ball is so lightweight, it's quite responsive to wind speed.

Add a protractor flipped upside down (so you can measure the angle of the string). Use the measurements below to figure out the wind speed. For example, mark the 90^{o} angle with "0 mph". This is your ping pong ball at rest in no wind. Use the numbers below to make the rest:

Angle	Wind Speed
degrees	*mph*
90	0
80	8
70	12
60	15
50	18
40	21
30	26
20	33



Anemometer Data Table

Time/Date	Degrees on Protractor	Wind speed *(mph)*

Reading

Some anemometers also have an aerovane attached, which enables scientists to get both speed and direction information. It looks like an airplane without wings – with a propeller at the front and a vane at the back.

Other anemometers don't have any moving parts – instead they measure the resistance of a very short, thin piece of tungsten wire. (Resistance is how much a substance resists the flow of electrical current. Copper has a low electrical resistance, whereas rubber has a very high resistance.) Resistance changes with the material's temperature, so the tungsten wire is heated and placed in the airflow. The wind flowing over the wire cools it down and increases the resistance of the wire, and scientists can figure out the wind speed.

Scientists also use sonic anemometers, which use ultrasonic waves to detect wind speed. The great thing about sonic anemometers is that they can measure speed in all three directions, which is great for studying wind that is not all moving in the same direction (like gusts and hurricanes).

Sonic anemometers send a sound wave from one side to the other and measure the time it takes to travel. Which means that these can also be used as thermometers, as temperature will also change the speed of sound. Since there are no moving parts, you'll find these types of anemometers in harsh conditions, like on a buoy or in the desert, where salt disintegrates and dust gets in the way of the cup-style anemometer. The big drawback to sonic anemometers is water (like dew or rain): if the transducers get wet, it changes the speed of sound and gives an error in the reading.

Exercises Answer the questions below:

1. An anemometer is one scientific instrument that measures the weather. Which one is also an instrument that measures the weather?
    a. Spectrometer
    b. Barometer
    c. Bathometer
    d. Inclinometer
2. What is important about measuring wind speed?

3. Which instrument measures humidity?
    a. Thermometer
    b. Barometer
    c. Hygrometer
    d. Rain Gauge

Lesson #2: Barometer

Overview: A barometer is a very useful tool for scientists to use when they attempt to predict the weather. We'll make one today and learn more about the importance of measuring the earth's atmospheric pressure.

What to Learn: This lab helps us understand different ways to measure the earth's weather.

Materials

- Balloon
- Straw or stick
- Water glass or clean jar
- Index card
- Tape
- Scissors

Lab Time

1. Cut the neck off the balloon with your scissors. Throw this little bit away.
2. Stretch the remaining balloon over the lip of the jar or glass and secure it tight, wrapping the edges down the sides of the glass.
3. Place your stick on top of the balloon and secure it in place with some tape.
4. Point the barometer's stick at a wall and use your index card. Mark it with a pencil or marker with today's date. Record the differences in pressure/location on your worksheet.

Barometer Data Table

Date (Fill out one measurement per day)	Difference in Pressure (mm on wall)

Reading

A barometer uses either a gas (like air) or a liquid (like water or mercury) to measure pressure of the atmosphere. Scientists use barometers a lot when they predict the weather, because it's usually a very accurate way to predict quick changes in the weather. Barometers have been around for centuries – the first one was in the 1640s!

At any given moment, you can tell how high you are above sea level by measure the pressure of the air. If you measure the pressure at sea level using a barometer, and then go up a thousand feet in an airplane, it will always indicate exactly 3.6 kPa lower than it did at sea level.

Scientists measure pressure in "kPa" which stands for "kilo-Pascals". The standard pressure is 101.3 kPa at sea level, and 97.7 kPa 1,000 feet above sea level. In fact, every thousand feet you go up, pressure decreases by 4%. In airplanes, pilots use this fact to tell how high they are. For 2,000 feet, the standard pressure will be 94.2 kPa. However, if you're in a low front, the sea level pressure reading might be 99.8 kPa, but 1000 feet up it will always read 3.6 kPa lower, or 96.2 kPa.

At standard pressure, depending on the kind of barometer you have, you'll find they all read one of these: 101.3 kPa; 760 mmHg (millimeters of mercury, or "torr"); 29.92 inHg (inches of mercury); 14.7 psi (pounds per square inch); 1013.25 millibars/hectopascal. They are all different unit systems that all say the same thing. Just like you can have 1 dollar or four quarters or ten dimes or 20 nickels or a hundred pennies, it's still the same thing.

Have you ever wondered why does water boil differently at sea level than it does on a mountain top? It has to do with pressure! It takes longer to cook food at high altitude because water boils at a lower temperature. Water boils at 212^{o}F at standard atmospheric pressure. But at elevations higher than 3,500 feet, the boiling point of water is decreased.

The boiling point is defined when the temperature of the vapor pressure is equal to the atmospheric pressure. Think of vapor pressure as the pressure made by the water molecules hitting the inside of the container above the liquid level. But since the saucepan of water is not sealed, but rather open to the atmosphere, the vapor simply expands to the atmosphere and equals out. Since the pressure is lower on a mountaintop than at sea level, this pressure is lower, and hence the boiling point is lowered as well.

Exercises Answer the questions below:

1. What is one unit of measuring pressure?

2. True or False: As you go higher in the air, pressure increases.
   a. True
   b. False
3. True or False: Changes in pressure are good indicators of quick changes in the weather.
   a. True
   b. False
4. What are two other scientific instruments that measure weather?
   a.
   b.

Lesson #3: Hygrometer

Overview: Welcome! Today we'll learn about the water vapor in the air and how scientists measure it. This is called humidity. Together, we'll make an instrument that measures the changes in the air's humidity using some of our own hair!

What to Learn: Today you'll learn more about an important attribute of the weather that scientist study: humidity. You'll see how they can track the changes in the atmosphere over time, and you'll do this for yourself in today's experiment when you construct your own!

Materials (per lab group)

- Single hair
- Index card
- Cardboard
- Tack
- Tape
- Weight (Coin is preferable, such as a dime or quarter)
- Scissors
- Ruler

Lab Time

1. Find the person in your group with the best hair to use for the experiment.
2. Use the scissors to cut an arrow out of the index card. Then, cut a piece of cardboard that is wide for the index card to fit.
3. Tape the weight to the pointed end of the index card, and secure the other side to the cardboard using a tack. The arrow needs to be able to move on the cardboard, so make sure not to push the tack too far in.
4. Use the scissors to cut a notch in the top right side of the cardboard. Put one end of the hair into the notch and wrap it around to the other side. Secure the hair in the notch with tape.
5. Tape the other side of the hair to the end of the arrow (you can wrap it around a few times to make sure it stays). Make sure it is stretched tight.
6. Cut another piece of paper to use to record each day's measurement, and tape it to the side of the cardboard. Make your first mark where the arrow is pointing.
7. Designate someone in your group to be the data recorder. After there are two measurements, use a ruler to measure the differences between one day and the next in your data log. Look closely to make sure you are measuring in millimeters. Each day, record the difference between the day's measurement and the previous one.

Hygrometer Measurements Log

Basic Data

Color:

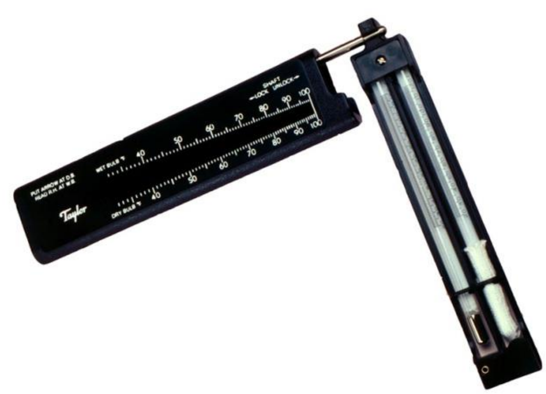
Age of Hair:

Type (Curly, Wavy, or Straight):

Day	Date	Difference from previous day (measure in mm)
1	DD/MM/YY	0
2		
3		
4		
5		
6		
7		
8		

Reading

Hygrometers measure how much water is in the air, called humidity. If it's raining, it's 100% humidity. Deserts and arid climates have low humidity and dry skin. Humidity is very hard to measure accurately, but scientists have figured out ways to measure how much moisture is absorbed by measuring the change in temperature (as with a sling psychrometer), pressure, or change in electrical resistance (most common).



The dewpoint is the temperature when moist air hits the water vapor saturation point. If the temperature goes below this point, the water in the air will condense and you have fog. Pilots look for temperature and dewpoint in their weather reports to tell them if the airport is clear, or if it"s going to be 'socked in'. If the temperature stays above the dewpoint, then the airport will be clear enough to land by sight. However, if the temperature falls below the dewpoint, then they need to land by instruments, and this takes preparation ahead of time.

A sling psychrometer uses two thermometers (image above), side by side. By keeping one thermometer wet and the other dry, you can figure out the humidity using a humidity chart. The psychrometer works because it measures wet-bulb and dry-bulb temperatures by slinging the thermometers around your head. While this sounds like an odd thing to do, there's a little sock on the bottom end of one of the thermometers, which gets dipped in water. When air flows over the wet sock, it measures the evaporation temperature, which is lower than the ambient temperature, measured by the dry thermometer.

Scientists use the difference between these two to figure out the relative humidity. For example, when there's no difference between the two, it's raining (which is 100% humidity). But when there's a 9^{o}C temperature difference between wet and dry bulb, the relative humidity is 44%. If there's 18^{o}C difference, then it's only 5% humidity.

You can even make your own by taping two identical thermometers to cardboard, leaving the ends exposed to the air. Wrap a wet piece of cloth or tissue around the end of one and use a fan to blow across both to see the temperature difference!

Among the most precise are chilled mirror dew point hygrometers, which uses a chilled mirror to detect condensation on the mirror's surface. The mirror's temperature is controlled to match the evaporation and condensation points of the water, and scientists use this temperature to figure out the humidity.

We're going to make a very simple hygrometer so you get the hand of how humidity can change daily. Be sure to check this instrument right before it rains. This is a good instrument to read once a day and log it in your weather data book

Exercises Answer the questions below:

1. Why should we compare two hygrometers if we are using two different types of hair?

2. After observing your results for a few days, which variable has the biggest effect on the humidity reading from the class hygrometer readings? Hair color? Texture? Age?

Lesson #4: Thermometer

Overview Thermometers are useful ways of measuring how much energy something has. Since our fingers detect heat flow, not temperature (more on this later), we need a scientific instrument to help us determine the temperature of objects.

Suggested Time 30-45 minutes

Objectives Temperature is a way of talking about, measuring, and comparing the thermal energy of objects. There are three different kinds of scales to measure temperature.

Materials (per lab group)

- Thermometer (a real one, so you can calibrate yours with it)
- Marker
- Paper
- Water
- Rubbing alcohol
- Clear plastic container, like a water bottle
- Straw
- Clay
- Food coloring
- Drill with adult help

Lab Time

1. Drill a hole through the center of your cap. The hole should be slightly larger than the diameter of your straw.
2. Insert the straw part way through the hole in the cap.
3. Make an air-tight seal using the clay or the hot glue gun at the top of the cap. Test the seal by trying to blow into the straw. If the seal is tight, you won't be able to blow in.
4. Fill your bottle halfway with rubbing alcohol, adding a couple of drops of food coloring.
5. Fill the bottle the rest of the way with water.
6. Add a little water so that it comes partway up the straw above the cap.
7. Make a mark (using a marker) where the line is.
8. Place the bottle next to the wall and tape a sheet of paper to the wall behind the thermometer.
9. Write on the paper the date, time, and make a line right where the level of the water in the straw is. Look at a calibrated thermometer to get a reading of the temperature and write this number next to your line.
10. Continue to make marks throughout the day as the level of the water changes. You will get a scale on the paper as you continue to work through this experiment.
11. Part of your data log is now on the wall. Use the data table below to help you keep track of how much your thermometer readings changed.

Thermometer Measurements Log

Date & Time	Calibrated Thermometer Reading (This is not the one you made, but the real one from the store.)	Change from Previous Reading
		n/a

Reading

I want you to imagine a desk, the kind you'd find in a typical classroom. You know the kind I mean – the wood desk is attached on the side to the chair part? So, now which is colder: the wood table or the metal legs? Quick – tell me! Which is colder: the metal screws in the desk or the plastic seat?

That's right… neither! They are ALL at the same temperature. What temperature is that?

Room temperature! Right? You didn't just pull the metal legs out of a freezer or stick the wood desk part in the oven… they've both been sitting there in the same classroom, with the same temperature air circulating around it, inside a building and out of sunlight. There's nothing that makes the legs a different temperature than the wood, right?

But then why does metal usually feel colder than wood or plastic when in this case, they are ALL at the same room temperature? Tell the person next to you.

The metal will feel colder because heat flows away from your skin faster into the metal than the wood.

That effect is called "heat capacity"! We'll talk more about that in a moment, but this is why scientists had to invent the thermometer, because the human body isn't designed to detect temperature. The human body can detect only heat flow. And they are two different things.

Notice that I said the wood and metal parts are at the same temperature, even if they don't feel like that to your body.

So, what is temperature? Temperature is a way of talking about, measuring, and comparing the thermal energy of objects. Now there are three different kinds of scales to measure temperature.

There's the Fahrenheit scale, Celsius, and Kelvin. Now Kelvin is the absolute scale for Celsius. You get from Celsius to Kelvin by adding 273.

For example, if it's zero degrees Celsius, it's 273 K. Notice I didn't say degrees Kelvin. It's just plain old Kelvin when you say it. So if something is at 2 degrees Celsius, it's how many Kelvin? That's right – it's 275 Kelvin. Good! So 2 deg C is the same as 275 K. It's like saying something is four quarters or one dollar. They are two different units to mean the same exact thing.

Now to get from Fahrenheit to Celsius, you've got to do a complicated equation with fractions, so for now, just know that when something's a zero degrees Celsius, it's 32 degrees F.

There is a fourth temperature scale, Rankine (Ran-kin), which is the absolute scale for Fahrenheit, is the one you'll learn about in college. You add about 460 to the Fahrenheit number, so if something is two degrees F, then its 462 degrees Rankine. So if something is 4 degrees F, how much is it in Rankine? That's right: 464 degrees R.

With so many temperature scales, you can see how engineers and scientists have to be careful about which one they're using so they don't get mixed up. Do you see all those temperature numbers on the slide? Those are all from the same thermometer, meaning that they are all the same temperature, just in different scales. Can you see how the number zero is a lot different than 491? It's really important to always put your units at the end of the number.

First invented in the 1600s, thermometers measure temperature using a sensor (the bulb tip) and a scale. Temperature is a way of talking about, measuring, and comparing the thermal energy of objects. We use three different kinds of scales to measure temperature. Fahrenheit, Celsius, and Kelvin. (The fourth, Rankine, which is the absolute scale for Fahrenheit, is the one you'll learn about in college.)

Mr. Fahrenheit, way back when (18th century) created a scale using a mercury thermometer to measure temperature. He marked 0° as the temperature ice melts in a tub of salt. (Ice melts at lower temperatures when it sits in salt. This is why we salt our driveways to get rid of ice). To standardize the higher point of his scale, he used the body temperature of his wife, 96°.

As you can tell, this wasn't the most precise or useful measuring device. I can just imagine Mr. Fahrenheit, "Hmmm, something cold…something cold. I got it! Ice in salt. Good, okay there's zero, excellent. Now, for something hot. Ummm, my wife! She always feels warm. Perfect, 96°. " I hope he never tried to make a thermometer when she had a fever.

Just kidding, I'm sure he was very precise and careful, but it does seem kind of weird. Over time, the scale was made more precise and today body temperature is usually around 98.6°F.

Later, (still 18th century) Mr. Celsius came along and created his scale. He decided that he was going to use water as his standard. He chose the temperature that water freezes at as his 0° mark. He chose the temperature that water boils at as his 100° mark. From there, he put in 100 evenly spaced lines and a thermometer was born.

Last but not least Mr. Kelvin came along and wanted to create another scale. He said, I want my zero to be ZERO! So he chose absolute zero to be the zero on his scale.

Absolute zero is the theoretical temperature where molecules and atoms stop moving. They do not vibrate, jiggle or anything at absolute zero. In Celsius, absolute zero is -273 ° C. In Fahrenheit, absolute zero is -459°F (or 0°R). It doesn't get colder than that!

As you can see, creating the temperature scales was really rather arbitrary:

"I think 0° is when water freezes with salt."
"I think it's just when water freezes."
"Oh, yea, well I think it's when atoms stop!"

Many of our measuring systems started rather arbitrarily and then, due to standardization over time, became the systems we use today. So that's how temperature is measured, but what is temperature measuring?

Temperature is measuring thermal energy which is how fast the molecules in something are vibrating and moving. The higher the temperature something has, the faster the molecules are moving. Water at 34°F has molecules moving much more slowly than water at 150°F. Temperature is really a molecular speedometer.

Exercises Answer the questions below:

1. What is the boiling temperature of water in Celsius and Fahrenheit?

2. What is temperature really measuring?

3. What is the temperature in the deepest, coldest reaches of space?

Lesson #5: Rain Gauge

Overview: We're making a simple but effective means to measure rainfall and continue our quest to collect all kinds of data on the weather.

What to Learn: This lesson helps us understand how weather changes daily, but how specifically precipitation may be very predictable during certain seasons.

Materials

- Two water bottles
- Scissors
- Rainy Day
- Funnel
- Tape

Lab Time

1. Place your funnel in the bottle, and secure it in place with some tape. If you don't have a funnel, you can cut the top off the water bottle and flip the cut off portion upside down. Secure this end with tape.
2. Wait until the next rainy day and check your rain gauge. Is there water in it? Check the newspaper for the amount of water that fell. Make a mark on your bottle and record this measurement. Now your rain gauge is calibrated!
3. Record rainfall each time it rains on the worksheet.

Rain Gauge Data Table

Date	Reading

Calibrated to:

Reading

Rain gauges are not just used by meteorologists. Geologists, hydrologists, biologists, and all kinds of other scientists keep track of localized rainfall to augment their own data. This can help us keep track of trends of moisture during the seasons of a particular watershed, for example. This is especially helpful in the drier western states, where much of the economy depends on this rainfall to provide for its crops and municipal needs. Biologists can get the jump on a particular migratory path of an animal community, or know when to look for certain species that depend on seasonal pools of rainwater to breed.

Also known as an udometer, pluviometer or ombrometer, or just plain old 'rain cup', this device will let you know how much water came down from the skies. Folks around the world have been known to use bowls to record rainfall and used to estimate how many crops they would grow and thus how much tax to collect.

These devices reports in "millimeters of rain" or ""centimeters of rain" or even inches of rain". Sometimes a weather station will collect the rain and send in a sample for testing levels of pollutants.

While collecting rain may seem simple and straightforward, it does have its challenges! Imagine trying to collect rainfall in high wind areas, like during a hurricane. There are other problems, like trying to detect tiny amounts of rainfall, which either stick to the side of the container or evaporate before they can be read on the instrument. And what happens if it rains and *then* the temperature drops below freezing, before you've had a chance to read your gauge? Rain gauges can also get clogged by snow, leaves, and bugs, not to mention used as a water source for birds.

So what's a scientist to do? Press onward, like all great scientists! And invent a type of rain gauge that will work for your area. We're going to make a standard cylinder-type rain gauge, but I am sure you can figure out how to modify it into a weighing precipitation type (where you weigh the amount in the bottle instead of reading a scale on the side), or a tipping bucket type (where a funnel channels the rain to a see-saw that tips when it gets full with a set amount of water), or even a buried-pit bucket (to keep the animals out).

Exercises Answer the questions below:

1. What is one other scientist that might use a rain gauge?

2. What is most appropriate for your area to measure rainfall in? Millimeters, centimeters, or inches?

3. What is one thing we need to look out for to make sure our rain gauge keeps functioning well?

Lesson #6: Cloud Tracker

Overview: If you look up in the sky you may notice a few things. If it is a clear day, you won't see any clouds. But you may look up and see some beautiful formations overhead. Today you'll make an instrument that can measure the amount of clouds overhead in a given time so you don't crook your neck looking up all day!

What to Learn: This lesson gets us thinking about how we observe and measure the weather. The scientists who do this sort of thing are called meteorologists. For this unit, you'll become a meteorologist yourself!

Materials

- Sun print paper or other paper sensitive to light
- Film canister or soup can
- Drill with drill bit
- Scissors
- Sunlight

Lab Time

1. Dim the lights and close the shades. You are going to work with light-sensitive paper, and you need it to be dark so you don't expose it to light before you're ready.
2. Take the sun print paper, and make sure to *open the paper away from exposure to light*.
3. Put a hole in the side of your container (soup can or film canister). Trim the paper so that it will fit into the container.
4. Insert the paper with the blue (or receptive) side facing the hole on the opposite side of the container. Close the container.
6. Take your container outside and make sure that it is placed facing the sky, in a south direction if you live in the northern hemisphere.
7. After a set amount of time, take your paper out and observe the streaks. Do you see any gaps? That is where clouds blocked the sun from making a mark on your paper. Record the observations in the worksheet.

Cloud Tracker Observations

Draw your cloud tracker's streaks after 3 hours

Draw your cloud tracker's streaks after 1 day

Were there times when the sky was cloudy? How can you tell? Write your answer below.

Reading

One of the most remarkable images of our planet has always been how dynamic the atmosphere is a photo of the Earth taken from space usually shows swirling masses of white wispy clouds, circling and moving constantly. So what are these graceful puffs that can both frustrate astronomers and excite photographers simultaneously?

Clouds are frozen ice crystals or white liquid water that you can see with your eyes. Scientists who study clouds go into a field of science called *nephology*, which is a specialized area of meteorology. Clouds don't have to be made up of water – they can be any visible puff and can have all three states of matter (solid, liquid, and gas) existing within the cloud formation. For example, Jupiter has two cloud decks: the upper are water clouds, and the lower deck are ammonia clouds.

Nephology is a special term for the study of clouds—a particular branch of the broader field of meteorology. This lesson will allow the kids to become miniature nephologists themselves. Clouds represent a particular part of the earth's water cycle, and can take various forms all dependent upon a variety of atmospheric conditions in a particular location. We all know of the towering thunderstorm clouds called *cumulonimbus*, or "thunderheads" with their anvil-shaped tops and tendency to develop into tornadoes or hail-inducing storms. We can even recognize the puffball *cumulus* clouds that litter our desktop wallpapers. But there are other, more fantastic types of clouds, like the saucer-shaped *lenticular* clouds.

Yet clouds, at their very simplest level, are collections of frozen water vapor crystals that are suspended in the air. Today, the lesson will help you gain an appreciation for the unique weather they experience and help them attune to the daily patterns of the atmosphere in a way that enhances their observation skills.

The paper from a sun print kit has a very special coating that makes the paper react to light. Most sun print kits use set of light-sensitive chemicals such as potassium ferricyanide and ferric ammonium citrate to make a cyanotype solution. The paper changes color when exposed to UV light. First off, expose the paper to different colors and see which changes the paper the most over a set amount of time. What do you notice?

The last step of this chemical process is to 'set' the reaction by washing it in plain water – this keeps the image on the paper so it doesn't all disappear when you hang it on the wall. After the paper dries, the area exposed to UV light turns blue, and everything shaded turns white.

You can use sun print paper to test how well your sunblock works – just smear your favorite sunscreen over a sheet (or put a couple dabs of each kind) and see how well the paper stays protected: if it turns white, the light is getting through. If it stays blue, the sunscreen blocked the light!

Exercises Answer the questions below:

1. What is the science called that investigates the weather and patterns of the Earth's atmosphere?
    f. Zoology
    g. Biology
    h. Meteorology
    i. Nephology

2. What are clouds made of?
    j. Nitrogen
    k. Water
    l. Oxygen
    m. Irridium

3. What form of water exists in clouds
    n. Water vapor
    o. Liquid water
    p. Frozen water

Lesson #7: Sensing Temperature

Overview: Today you'll use your fingers to show how scientists measure one of the most important pieces of data to keep track of when it comes to weather—the temperature!

What to Learn: You'll learn why meteorologists care about the temperature, and how we record this data.

Materials

- 3 glasses
- 1 Celsius/Fahrenheit thermometer
- 1 clock with second hand
- Hot water
- Cold water
- Ice cubes (optional)
- Room-temperature water

Lab Time

1. Place the three glasses in front of you on a table. They should be in a row: left, middle and right.
2. Put hot water from the faucet into the first glass on your right. Pour very cold water from the tap into the far left glass. You can even add a couple of ice cubes if you have them available. Finally, fill the glass that is in the middle with room temperature water.
3. Now use your right hand to hold on to the glass on the right with hot water. Really spread out your fingers and wrap them around the glass. Do the same thing with your left hand and the glass filled with cold water. Be sure to check the clock and leave your hands on the glasses for exactly one minute.
4. After one minute, take your hands and put them both on the middle glass. (You may need to stack one on top of the other if your glasses are narrow). Note the temperature you feel with each hand: *hot, cold,* or *medium.* You can use the thermometer to record the actual water temperature.
5. Now repeat steps 1-4. This time, switch the hot and cold glasses so that you are holding the hot water with your left hand and the cold water with your right hand. Compare these results with your initial results. Do both hands respond in a similar way or is one more sensitive that the other?

Sensing Temperature Data

For sixty seconds, each hand is placed around each glass. Data records the temperature according to feeling after 1 minute.

Glass	**Right Hand** (after 1 min)	**Left Hand** (after 1 min)	**Temperature** (during)
Hot			
Cold			
Room Temperature			

Does the temperature of the middle glass feel *warmer*, *cooler*, or the *same* when you touch it with your hand that was holding the warm glass?

What does your hand that was touching the cold glass feel when it touches the middle glass?

What do you feel when both hands are on the middle glass?

Why do you think your hands are not the best instruments for determining temperature?

Reading

Today's experiment uses the hands to mimic how a thermometer helps tell the changes in temperature. Meteorologists always record this piece of data and use it to track weather changes throughout the day and year. More recently, average yearly temperatures for certain locations have been recorded with more attention due to concerns about global climate change. One of the implications of climate change is that the average temperature may rise in certain areas by a measure of degrees. While this may not sound like such a big deal to us, it may have drastic consequences throughout the year for crops, water supply, and the local ecosystem which is adapted to a specific temperature range.

Your hands are designed to adapt to temperature. Touching the warm glass relaxes the muscles of your hands, increases circulation, and enhances flexibility. When your hand touches the cold glass the cells on your skin's surface begin to contract to minimize loss of heat and your hand becomes less flexible. Then, when you grab the middle can your hands get a bit confused. Relatively speaking, the middle glass feels warmer to the hand that was holding the cold glass and it feels cooler to the hand that was holding the warm one. The hands are still feeling the temperature, but your brain gets confused.

What we are doing with our fingers is getting a sense of the temperature of the water. Scientists care about temperature because this is one of the biggest things that varies and can determine the conditions of a particular location around the world. Do you ever look at the newspaper to check on today's weather? You'll notice that often the first piece of data mentioned is the temperature! We use Fahrenheit to measure temperature in the USA, but other countries use Celsius. This is why the temperature reading often comes in two numbers, separated by a slash.

Did you notice the temperature change today? Often, in temperate climates, we experience greater temperature changes than in tropical climates, where the weather conditions are more constant. This has to do with the amount of water in the air, the sunlight, and other factors.

Exercises: Answer the questions below:

1. What is the unit of measurement for temperature here in the USA?
    a. Newtons
    b. Joules
    c. Fahrenheit
    d. Celsius
2. What is another unit of measurement used for temperature?
    a. Fahrenheit
    b. Celsius
    c. Joules
    d. Newtons
3. Write the abbreviations for Fahrenheit and Celsius below:

Lesson #8: Soaking Up Rays

Overview: If you've ever been outside on a sunny day, you may notice that your clothes can either help you stay warm or heat you up quite a bit! But why? Today's experiment will help you answer this question.

What to Learn: This lab will help you understand how the sun interacts with the earth in the form of radiation

Materials

- Ice cubes (use small pieces that will melt in a few minutes on the sidewalk)
- White piece of paper
- Black piece of paper
- Sunlight

Lab Time

1. Put the sheet of white paper on a sunny part of the sidewalk.
2. Right next to it, place the sheet of black paper.
3. Put an ice cube in the middle of each sheet of paper.
4. Wait and watch.
5. Record all observations in the worksheet

Soaking Up Rays Observations

Time in sun	Ice Cube on White	Ice Cube on Black
Still around after 30 seconds?	Yes or No	Yes or No
1 minute?		
1 minute, 30 seconds?		
2 minutes?		
2 minutes, 30 seconds?		
3 minutes?		
3 minutes, 30 seconds?		
4 minutes?		

Reading

There are three ways to transfer heat: by conduction (two objects touching), by convection (one of the objects is a fluid like water or air), and radiation (this doesn't need to be touching like conduction and convection – in fact, the sun's energy gets to us via radiation). Heat is transferred by radiation easier to something dark colored then it is to something light colored and so the black paper increased in temperature more than the white paper.

Heat is transferred by radiation through electromagnetic waves. The word "radiation" means to spread out from a central spot, whether it's heat, light, sound, rays, or spokes on a wheel. There's a spot of origin, and heat by radiation means that the energy started from a central spot, and is moving to the space around it. The energy is carried by electromagnetic waves, so it doesn't need to move through a medium the way sound waves do. This means that radiation can travel through a vacuum, like space.

Energy is vibrating particles that can move by waves over distances right? Well, if those vibrating particles hit something and cause those particles to vibrate (causing them to move faster/increasing their temperature) then heat is being transferred by waves. The type of electromagnetic waves that transfer heat are invisible to the eye, but if you use special cameras, you can see the infra-red waves. The Sun transfers heat to the Earth through radiation. The hotter the object is, the more it radiates. The sun radiates more energy than a cup of coffee.

If you hold your hand near (not touching) an incandescent light bulb until you can feel heat on your hand, you'll be able to understand how light can travel like a wave. This type of heat transfer is called radiation. This is not a bad kind of radiation like you get from x-rays. It's infra-red radiation. Heat was transferred from the light bulb to your hand. The energy from the light bulb resonated the molecules in your hand. Since the molecules in your hand are now moving faster, they have increased in temperature. Heat has been transferred! In fact, an incandescent light bulb gives off more energy in heat than it does in light, so they aren't very energy efficient.

Exercises Answer the questions below:

1. How does radiation travel?
    a. As a beam
    b. As a wave
    c. As a molecule
2. Which color reflects more light?
    a. White
    b. Black
3. Which color absorbs more light?
    a. White
    b. Black
4. If you are wearing a white shirt, will you feel warmer than if you are wearing a black shirt?

Lesson #9: Liquid Crystals

Overview: This lab uses liquid crystal thermal sheets to record temperatures so that we can "see" radiation at work.

What to Learn: You'll learn about the ways that the sun affects our Earth and its air, water, and land. We'll use the liquid crystals in our special sheets in lab today to see this happen, and discover why.

Materials

- Hands
- Thermal paper (liquid crystal sheets)
- Incandescent bulb or sunlight
- Silver highlighter or aluminum foil

Lab Time

1. Color half of the backside of the thermal paper (the side that doesn't change color) with the highlighter (or cover half of it with foil).
2. Hold it in a position where you can easily see the color-changing side while keeping the light source on the backside.
3. Record your observations on the worksheet.

Liquid Crystals Observations

1. Which side of the sheet changes color?

2. Is there a difference between the white and the black halves?

3. Draw a zoomed in view of the sheet when it is under sunlight.

Reading

Today we're going to "see" radiation at work. Radiation is the name given to the type of energy that is given off by the sun. **Radiation** is most commonly experienced by us as visible light, but is also present as radio waves, X-rays, microwaves, and infrared.

To see radiation at work, we're using a thermal sheet. The liquid crystal sheet is temperature-sensitive. When the sheet received heat from the bulb, the temperature goes up and changes color. The plastic sheets remain black except for the temperature range in which they display a series of colors that reflect the actual temperature of the crystal.

Why do liquid crystals change color with temperature? Your liquid crystal sheet is not just one sheet, but a stack of several sheets that are slightly offset from each other. The distance between each layer changes as the sheet warms up – the hotter the temperature, the closer the stacks twist together. The color they emit depends on the distance between the sheets.

The molecules that make up the sheets are long and thin, like hot dogs. When the sheets are cooler, these molecules move around less and don't twist up as much, which corresponds to reflecting back a redder light. When the temperature rises, the molecules move around more and twist together, and they reflect a bluer light. When the liquid crystal sheet is black, all the light is absorbed (no light gets reflected).

When we talk about solar energy, we usually are referring to radiation in the form of visible light, radio waves, microwaves, X-rays, gamma rays, infrared, and ultraviolet. These various forms of radiation are present on the electromagnetic spectrum, which represent the various wavelengths at which radiation is present. Some objects in our universe emit a variety of these types of energy, which is why we use more than just big visual telescopes to gaze into the extremities of space. We use radio telescopes to collect radio signals from distant stars, nebulae, and galaxies.

Exercises: Answer the questions below:

1. What type of energy does the sun emit?
    a. Echolocation
    b. Kinetic
    c. Potential
    d. Radiation
2. Write down one type of radiation:

3. When are the molecules in your crystal sheet more movable?
    a. When the sheet is warm
    b. When the sheet is not warm

Lesson #10: How Much Energy Does the Sun Produce?

Overview: Today you'll harness the power of the sun in the palm of your hand. Well, not exactly. But today you'll create an experiment to measure just what kind of energy we're dealing with and depend on for daily life.

What to Learn: This experiment should demonstrate how influential the sun is on our earth, from its natural atmosphere dynamics to its energy usage and history.

Materials

- Water
- Disposable pie tin
- Paint brush
- Measuring cups
- Stopwatch
- Newspaper
- Black paint or spray (flat, not glossy)

Lab Time

1. Go outside and spread out a sheet of newspaper. Place an aluminum pie pan on the newspaper.
2. Carefully bend one spot on the edge of the pie pan to make a spout shape. This will allow you to more easily pour water out of the pan. Have an adult help you paint the inside of the aluminum pie pan. You can use a brush and a can of paint or spray paint. Be sure not to get the paint on anything except the disposable pie pan and the newspaper. After painting, set the pie pan where the paint can dry overnight.
3. You will need to do the rest of this experiment on a warm, sunny day. You do not want the pie pan to be in the shade. Set the aluminum pie pan in a warm, sunny spot. The sun will need to constantly shine on the pie pan. The black color of the pie pan allows it to absorb, rather than reflect, solar energy. You will need to begin the experiment about 11:00 A.M., so the solar heating will be done when the sun is high in the sky.
4. Add exactly one cup of water to the pie pan. Wait four hours while the sun is shining on the pan of water. After exactly four hours of sunshine, carefully pour the remaining water from the pie pan into a one-half or one-fourth measuring cup. Use these measuring cups to estimate the amount of remaining water to the nearest one-eighth of a cup.
5. Record your observations and data on the worksheet in the space provided.

Sun Energy Data Table

Time	Water remaining (mL)
4 hours	
8 hours	
24 hours	
36 hours	
48 hours	

Is the amount of water left less than when you began the experiment? How much water was left over after 4 hours?

Reading

Without the sun, there would be no life on Earth. The sun warms the earth, generates wind, and carries water into the air to produce rain and snow. The energy of the sun provides sunlight for all the plant life on our planet, and through plants provides energy for all animals.

The sun is like a giant furnace in which hydrogen nuclei (atoms without electrons) are constantly smashed together to form helium nuclei. This process is called nuclear fusion. In this process, 3.6 billion kilograms (8 billion pounds) of matter are converted to pure energy every second. The temperature in the sun exceeds 15 million degrees.

Nuclear fusion is one kind of energy. Other forms of energy include: mechanical energy, heat, electrical energy, chemical energy, and light. Mechanical energy is the energy of organized motion, such as a turning wheel. Heat is the energy of random motion, such as a cup of hot water. Electrical energy is the energy of moving charged particles or electrons, such as a current in a wire. Chemical energy is the energy stored in bonds that hold atoms together. Light is any form of electromagnetic waves, such as X rays, microwaves, radio waves, ultraviolet light, or visible light.

Energy can be converted from one from to another. For example, the nuclear energy of the sun is converted to light, which goes through space to the earth. Solar collectors of mirrors can be used to focus some of that light to heat water to steam. This steam can be used to turn a turbine, which can power a generator to produce electricity.

Most of our energy needs are met by burning fossil fuels such as coal, oil, gasoline, and natural gas. The chemical energy stored in these substances is released by burning these fuels. When fossil fuels burn, they combine with oxygen in the air and produce heat and light.

Tremendous amounts of renewable energy are available. For example, the solar energy that falls on just the road surfaces in the United States is equal to the entire energy needs of the country. Although there are sufficient amounts of renewable energy, we must improve our methods of collecting, concentrating, and converting renewable energy into useful forms.

Scientists use the unit of joule as a measure of energy. However, you may find it helpful to think in units of dietary calories instead of joules. One dietary calorie is equal to 4,184 joules of energy. One cup of breakfast cereal with one-half cup of milk would have about 240 dietary calories, or approximately 1,000,000 joules of energy. Although the earth receives only a tiny portion of the total energy output of the sun, the earth has a constant supply of 173 million billion (173,000,000,000,000,000) watts of solar power. A watt is a unit of power equal to a joule of energy used per second. For comparison, a typical light bulb to run a lamp in your home might require 100 watts of power. A million watts could supply the energy needs of about 500 average American homes.

Use the table below to determine the solar energy required to evaporate a certain amount of water. The amount of water remaining in the pan will allow you to determine how much energy was used, how much power was used, and the amount of power per area.

Your results will probably be in the middle range of this table. For example, if one-half of your water evaporated, then the water remaining would be one-half cup. Thus, the energy used to evaporate this water would be 289,000 joules of energy. This energy would give a power of 20 watts, and a power per area of 800 watts per square meter (watts / meter^2).

Solar Energy Required to Evaporate Water				
Water Remaining (cup)	Water Evaporated (cup)	Energy Used (joules)	Power Used (watts)	Power per Area (watts / meter^{2})
1	0	0	0	0
7/8	1/8	72,250	5	200
3/4	1/4	144,500	10	400
5/8	3/8	216,750	15	600
1/2	1/2	289,000	20	800
3/8	5/8	361,250	25	1000
1/4	3/4	433,500	30	1200
1/8	7/8	505,750	35	1400
0	1	578,000	40	1600

The following procedure was used to generate the numbers in the Table. It is known that it takes 578,000 joules of energy to evaporate one cup of water. This known energy per cup is multiplied by the fraction of a cup that was evaporated. This gives the solar energy used to evaporate the water in the pie pan. The energy is divided by the number of seconds in four hours (14,400 seconds). This gives the power of the solar energy striking the pie pan, since a watt is equal to a joule per second. Finally, the power (in watts) is divided by the surface area of the pie pan (0.025 square meters) to give the power per area.

When the sun is overhead, the intensity of solar energy can be as much as 1,000 watts per square meter. If all of this energy could be converted to electricity, one square meter of sunshine would be enough to run ten 100-watt light bulbs. However, our current solar cells that convert sunlight to electricity are able to change only about 15 percent of the light to electricity.

You can see from this experiment that there is tremendous energy available from our sun. Most of this energy warms our planet or is reflected back into space. Among other things, the remaining portion of energy powers our water cycle, producing rain and snow, or provides plants with the energy they need to live.

Scientists and engineers are learning more about trapping solar energy and converting it to useful power. It has been estimated that all forms of potentially available renewable energy (wind, water, biomass, and direct solar) have an energy equivalent to 80 trillion barrels of oil. In other words, one year of renewable solar energy is 5,000 times greater than the current yearly energy needs of the United States. In comparison, it has been estimated that all the remaining coal, oil, natural gas, and other potential nonrenewable energy reserves of the United States are equal to about 8 trillion barrels of oil.

Exercises Answer the questions below:

1. Name two types of renewable energy that we can use on earth:
   a.
   b.
2. Which process contributes to the energy generated in the sun's core?
   a. Nuclear fission
   b. Nuclear fusion
   c. Hydrogeneration
   d. Heliumization
3. What is the unit used to measure energy?
   a. Newton
   b. STP
   c. Joule
   d. Calorie
4. What is a joule?

5. True or false: most of our energy needs are met by renewable sources.
   a. True
   b. False

Lesson #11: Can Wind be Used as a Source of Energy?

Overview: Today you get construct a own windmill and use it to collect objects under its own power. In the process you'll learn important concepts about energy and the growing importance of renewable resources like wind power.

What to Learn: Pay attention to how the sun allows wind to form, and the importance of wind in our future's energy needs and consumption.

Materials

- Pinwheel (can be purchased or made from construction paper)
- Paper clips
- Tape
- Small shoe box (children's size)
- Electric fan
- Lightweight string (about 4 feet long)
- Plastic straw (longer than the width of the shoe box)
- Hole punch

Lab Time

1. Use a hole punch to punch holes in the opposite sides across the width of the cardboard shoe box. Use the narrow sides of the box so the two holes are less than 6 inches (15 centimeters) apart. Make sure the holes are directly opposite each other. Place a plastic straw through the holes. Enlarge the holes if you need to.
2. Use the blades from a pinwheel or cut and fold a square piece of construction paper into the shape of a pinwheel. Attach the blades to one end of the straw.
3. Partially unfold a small paper clip and insert it into the larger end of the straw. Push the straightened end of the paper clip through the center of the pinwheel. Bend this end of the paper clip and tape it to the outside of the pinwheel.
4. Set the fan on a table or countertop. Hold the shoebox so that the pinwheel is free to turn. Have an adult plug in and turn on the fan. Move the windmill box to direct the breeze from the fan toward the blades of the pinwheel. Move the box until you find the best angel of the fan to the pinwheel so that the blades turn freely.
5. Turn off the fan. Tape one end of the string to the side of the straw with no pinwheel just outside the box, and wrap the string around the straw a few times. Tie the other end of the string to a paper clip. Attach five other paper clips to the paper clip tied to the string. Allow the string to hang down so that the paper clips on the end of the string rest on the floor.
6. Now, you will test to see if your windmill can convert wind power to do work and lift the paper clips off the ground. Turn on the fan and hold the box where you did before to make the pinwheel turn. Record all your observations and data in the worksheet.

Wind Energy Observations

1. Does the windmill turn the straw?

2. Does the string wrap around the straw as the straw turns?

3. What happens to the paper clips?

4. How is energy being converted by your windmill?

Reading

The United States has large reserves of coal, natural gas, and crude oil which is used to make gasoline. However, the United States uses the energy of millions of barrels of crude oil every day, and it must import about half its crude oil from other countries.

Burning fossil fuels (oil, coal, gasoline, and natural gas) produces carbon dioxide gas. Carbon dioxide is one of the main greenhouse gases that may contribute to global warming. In addition, burning coal and gasoline can produce pollution molecules that contribute to smog and acid rain.

Using renewable energy-such as solar, wind, water, biomass, and geothermal-could help reduce pollution, prevent global warming, and decrease acid rain. Nuclear energy also has these advantages, but it requires storing radioactive wastes generated by nuclear power plants. Currently, renewable energy produces only a small part of the energy needs of the

United States. However, as technology improves, renewable energy should become less expensive and more common.

Hydropower (water power) is the least expensive way to produce I electricity. The sun causes water to evaporate. The evaporated water falls to the earth as rain or snow and fills lakes. Hydropower uses water stored in lakes behind dams. As water flows through a dam, the falling water turns turbines that run generators to produce electricity.

Currently, geothermal energy (heat inside the earth), biomass (energy from plants), solar energy (light from concentrated sunlight), and wind are being used to generate electricity. For example, in California there are more than sixteen thousand (16,000) wind turbines that generate enough power to supply a city the size of San Francisco with electricity.

In addition to producing more energy, we can also help meet our energy needs through conservation. Conservation means using less energy and using it more efficiently.

One way to store the energy produced by a windmill is to lift a weight. When the weight is allowed to fall, work can be produced. Weights in a grandfather clock are used to store energy and can run a clock for a week or longer. A windmill's energy can be used to pump water to a storage area at a higher elevation. Later, this water can be allowed to fall through a turbine which turns a generator and produces electricity.

Electricity can also be produced directly from wind power. The shaft, or rod to which the windmill blades are attached, can be used to turn a generator. A generator or dynamo is used to convert mechanical energy into electrical energy. Power conversion units can change the direct current that wind generates to an alternating current. The alternating current can be fed directly into utility lines and used in our homes.

The sun is the original source of wind power. Without the sun to heat the earth, there would be no wind. The energy of the sun heats the earth, but all parts of the earth are not at the same temperature. These differences in temperature are responsible for global and local patterns of wind. For example, during the day a constant wind blows from the sea toward the land along coastal regions. Air above the hotter land rises and cooler, heavier air above the ocean moves in to take its place.

The power of the wind can be harnessed to do work. For at least 4,000 years, the wind has been used to move sailing ships. The wind has enough power to move ships across oceans and around the world.

For at least 1,000 years, windmills have been used for pumping water and turning stones to grind grain. Millions of windmills have been used on the plains of America, Africa, and Australia to pump water from deep wells for livestock and humans.

In this century, windmills or wind engines have been used to generate electricity. Over 15,000 wind engines were installed in California in the 1980s. These wind engines have the capability to produce up to 1.5 billion watts of electricity. In California in 1987, wind was used to produce as much electricity as the city of San Francisco uses in an entire year.

Exercises Answer the questions below:

1. Name three sources of renewable energy:
    a.
    b.
    c.
2. What does the sun have to do with wind?

3. Name three examples of wind power in historical or current usage:
    a.
    b.
    c.

Lesson #12: Can Water be Used to Store Energy?

Overview: Our sun can be used for all kinds of things. In our world that is suffering from an energy crisis, we need to be more proactive to address these needs. Did you know that large bodies of water are used to store heat? Find out how today!

What to Learn: This lab will allow us to see how water interacts with the heat energy of the sun. Remember the key terms we've learned so far: conduction, convection, etc. What type of heat transfer do we observe here?

Materials

- Paper cups
- Measuring cups
- Hot water
- Watch or clock
- Sink
- Refrigerator (with freezer compartment)
- Thermometer

Lab Time

1. Turn on the hot water faucet and wait until the water is hot. Be careful not to burn yourself!
2. Add ¼ cup of hot water to the first paper cup, and 1 cup water to the second paper cup.
3. Place both cups in the freezer compartment of the refrigerator. Be sure to label your cups!
4. Check the water after 30 minutes. Record your data in the worksheet, taking the temperature of each cup and seeing if the water has frozen.
5. Return to the freezer and check the temperature again after 45 minutes. Record your data.
6. Keep checking the cups at fifteen minute intervals until one has frozen. Record your data in the sheet.

Water Energy Data Table

Time (minutes)	Temperature (Cup 1)	Temperature (Cup 2)	Frozen? (Cup 1)	Frozen? (Cup 2)
0				
30				
45				
60				
75				

What conclusions can you draw about the relationship between the water's amount and its ability to store energy?

Reading

Temperature is a measure of the average hotness of an object. The hotter an object is, the higher its temperature. As the temperature is raised, the atoms and molecules in an object move faster. The molecules in hot water move faster than the molecules in cold water. Remember that the heat energy stored in an object depends on both the temperature and the amount of the substance. A smaller amount of water will have less heat energy than a larger amount of water at the same temperature.

Increasing the temperature of a large body of water is one way to store heat energy for later use. A large container filled with salt water, called brine, may be used to absorb heat energy during the day when it is warm. This energy will be held in the salt water until the night when it is cooler. This stored heat energy can be released at night to warm a house or building. This is one way to store the sun's heat energy until it is needed.

The sun's rays interact with the earth in a number of different ways, and scientists are getting more creative in their attempts to harness the energy abundant that comes down to influence the surface. Solar ponds are large bodies of water that can store heat during the daytime and release it during the evening to be used by some nearby area. They involve placing a layer of fresh water atop salt water, which remains heavier and sinks to the bottom. The fresh water insulates the bottom layer of water and can retain quite a bit of heat.

In a fresh water pond, as the water on the bottom is heated from sunlight, the hot water becomes lighter and rises to the top of the pond. This convection or movement of hot water to the top tends to carry away excess heat. However, in a salt water pond, there is no convection so heat is trapped. In Israel a series of salt water, solar ponds were developed around the Dead Sea. The heat stored in these solar ponds has been used to run turbines and generate electricity.

For another example of water storing large amounts of heat energy, consider the city of San Francisco. It lies at the end of a peninsula, surrounded on three sides by water. If you've ever visited the city during the summer, you'll be surprised by how cold it can get! This is because the water absorbs a large amount of the energy from the sun, leaving the landmass colder than the continental inland. This is why the city of Oakland across the bay can be experiencing completely different weather just a few miles away.

Lesson

Exercises Answer the questions below:

1. What type of heat transfer is at work in a solar pond?
    a. Kinetic
    b. Conduction
    c. Potential
    d. Convection
    e. Radiation
2. What units do we use to measure energy?
    a. Kilowatts
    b. Joules
    c. Newtons
    d. Kilowatt-hours
3. Draw a diagram of a solar pond in the space below:

Lesson #13: Water Purification

Overview Today it's all about swamp muck science! Can you take a batch of yucky, mucky ooze and transform it into clean water? Do you think you can turn your dad's coffee back into clear water? You bet!

What to Learn You will see that you can use a whole bunch of different filtering tricks to separate out what you want from what you don't want.

Materials

- "swamp muck" (water, coffee, and coffee grounds)
- sand (clean sand, from the hardware store)
- alum (found in the grocery or drug store) (MSDS)
- lime (found in gardening store) (MSDS)
- clear water
- carbon (found in a fish store—used to clean tanks) (MSDS)
- cheese cloth
- 3 clear containers, such as jars
- Erlenmeyer flask or other container
- funnel
- medicine dropper or syringe dropper
- 2 cotton balls
- measuring spoons (1/4 and 1/2)
- paper towels
- disposable light stick (optional)

Lab Time

1. Aeration:
    a. Pour swamp muck into cup #1. This aerates the sample, allowing trapped gases to be released.
2. Coagulation:
    a. To the swamp muck sample in cup #1, add ½ teaspoon alum (aluminum sulfate) and ¼ teaspoon lime (calcium hydroxide). CAUTION: Lime is a hazardous chemical. Use gloves and eye protection! Alum collects small dirt particles, forming larger, sticky particles called floc.
3. Sedimentation:
    a. Stir; allow to sit for 10 minutes. The larger floc particles will settle to the bottom of the cup.
4. While waiting for sedimentation, prepare the following:
    a. Cup #2: clean water
    b. Cup #3: empty. The sample will be poured into it later
    c. Erlenmeyer flask or other containter: clear water and small scoop of carbon. Use a rubber band to attach cheesecloth over the mouth of the container. Swirl to mix.
5. Make the filter:
    a. Fluff 2 cotton balls as much as possible. Stuff into funnel.
    b. Put funnel in Cup #3 (empty cup) and pour carbon water over cotton balls. Run the dripped-out water back through the funnel a few times, making cotton balls as dark as possible.

    c. Add a layer of sand on top of the cotton balls. It should cover the balls entirely and come right up to the top of the funnel.
    d. Using a dropper, add clean water from cup #2 to get the filter saturated and ready to filter.
6. Filtration:
    a. Without disturbing the sample, notice where the floc is (the dark, solid layer at the bottom). The larger particles have already been filtered out without using a filter!
    b. Using a dropper, take a sample from the layer above the floc (closer to the top of the container) and drip it into the funnel. Observe your clean water!
    c. Continue this process until the liquid starts to turn pale, indicating the filter is saturated and can't filter out any more particles.
7. To make a "radioactive" sample:
    a. Shake a light stick until it glows
    b. Cut open, pour material into filter. This allows you to observe where the swamp muck got stuck.
8. Invert the funnel over four layers of paper towels. Observe where coffee grounds and light stick material is located.

Water Purification Data Table

Action	**Observations** *(How did it work? Why was it important?)*
Pouring swamp muck into cup	
Adding alum	
Allowing swamp muck to sit for 10 minutes	
Using cotton balls in the funnel	
Adding carbon water to the cotton balls	
Putting sand on top of the cotton balls	
Putting glow stick material in the filter	

Reading

Ever wonder how the water draining down your sink gets clean again? Think about it: The water you use to clean your dishes is the same water that runs through the toilet. There is only one water pipe to the house, and that source provides water for the dishwasher, tub, sink, washing machine, toilet, fish tank, and water filter on the front of your fridge. And, there's only one drain from your house, too! How can you be sure what's in the water you're using?

This experiment will not only turn coffee back into clear water, but the swamp muck from the back yard as well! Sand, alum, carbon, cheese cloth, and cotton balls act as filters to get different materials out of the muck so the result is clean, clear water.

Exercises Answer the questions below:

1. What are the five stages of filtration?

2. What was the purpose of alum in this experiment?

3. Where were the coffee grounds located?

4. Why did the cotton balls need to be as dark as possible?

Lesson #14: Desalination

This is a BONUS LAB that you can do as a demonstration to your students, or if you already have a chemistry set you can pull it out and use the glassware to set up your own desalination plant.

Overview: Put on your goggles and rubber gloves: we're doing some serious chemical handling today. The question today is: how do you separate salt from salt water? Let's find out!

What to Learn: This experiment lets us deal with one of the most common substances on the earth's surface: salt. In fact, we're seeing how to handle the majority of the salt around us, since the oceans cover almost 75% of the Earth's surface! That's a lot of salt water.

Materials

- Goggles
- Gloves
- Jar or glass
- 2 90^{o} glass tubes
- Chemistry stand
- Rubber tubing
- Test tube clamp
- Erlenmeyer flask
- One-hole rubber stopper
- Wire screen
- Alcohol burner
- Lighter
- Test tube
- Water
- Saltwater
- Heating rod

Lab Time

1. Follow the instructions CAREFULLY. We'll be dealing with a very hot system and need to practice good lab safety. You'll want to set up your chemistry apparatus first. After your apparatus has been approved by an adult, proceed with the experiment.
2. Put the salt water in your Erlenmeyer flask attached via clamp to a chemistry stand. You'll place this above a wire mesh and stationed above the alcohol burner. Make sure the flask is stoppered with a rubber stopper. Your tubing will travel from the stopper into the other jar. With the help of an adult, turn on the burner and boil the contents of the flask for a few minutes.
3. Watch out for when the water begins to flow back into the tube. When this happens, lift the tubing out of the jar. Put it aside.
4. Check if there is any salt left over in your water: take it and place it into a test tube and proceed to boil the water until it is gone. Is there any salt left over when the water is gone?
5. Leave the apparatus set up until it is cool, at least five minutes.

Desalination Observations:

1. What is going on when the burner is placed under the Erlenmeyer flask?

2. How do you know that all the salt has been removed from the water?

Reading

Lewis and Clark did this same experiment when they reached the Oregon coast in 1805. Men from the expedition traveled fifteen miles south of the fort they had built at the mouth of the Columbia River to where Seaside, Oregon now thrives. In 1805, however, it was just men from the fort and Indians. They built an oven of rocks. For six weeks, they processed 1,400 gallons of seawater, boiling the water off to gain 28 gallons of salt. Lewis and Clark National Historic Park commemorates the struggles of the expedition. (The reconstructed fort is also there to visit.) It is Fort Clatsop National Memorial, and is quite an experience to go through the fort. Lewis and Clark went to great lengths to obtain salt. The men had been complaining that fish without salt had become something to avoid.

Salt is important to us as well. It is a condiment, an addition to food that brings out the food's natural flavor. Besides its food value, salt is used as a food preservative. It destroys bacteria in food by removing moisture from their "bodies" and killing them. Salt is also present in the majority of the Earth's surface because the majority of the Earth's surface is water in the oceans.

Sodium chloride, table salt, NaCl – it all means the same thing: salt. If NaCl is broken down into its component elements, the elements don't act like our friend salt. Its components are sodium and chlorine.

Sodium is a highly reactive alkali metal, element #11 on the periodic table. It is exothermic in water, which means that is gives of heat as it reacts with water. Small pieces tossed into water will react with it. The sodium particles give off heat that melts them into round balls. The sodium particles bounce and scurry around the surface at a high rate of speed. If you ever get the chance to observe this, do it. The reaction continues until the sodium is gone. Sodium, as it reacts with the water, changes chemically into sodium hydroxide. These cool things that sodium does are also dangerous. Sodium and sodium hydroxide are caustic…they are so pH basic that they will burn you.

Chlorine is a halogen, group 17, element #17. Chlorine is used in bleach, disinfectants, and in swimming pool maintenance. It seems that anywhere you want to remove color or life, chlorine is your element. Chlorine is known as bleach at home. **Never, never, drink it or breathe its fumes.**

Look out for the hot flask and other glassware. Allow everything to cool before cleaning.

When done heating, move the rubber tubing out of the water. There is a difference in pressure between the heated glassware and the water bath. That difference in pressure will cause the water to enter the tubing and cool water will flow into the hot glassware and could cause catastrophic damage to the glassware. **Never…Never!….drink the results of an experiment.** I know that plain old water is supposed to be in the test tube, but follow the experiment's safety guidelines. You've had other stuff in that test tube, too.

Here's what's going on in this experiment: That flask of saltwater will start to boil, and water vapor will leave the flask and travel to the test tube. There is no chemical change occurring in this experiment, but a physical one. A physical change involves a change in state (melting, freezing, vaporization, condensation, sublimation). Physical changes are things like crushing a can, melting an ice cube, breaking a bottle, or boiling saltwater until there is nothing left but salt and steam.

Cleanup: Clean everything thoroughly after you are finished with the lab. After cleaning with soap and water, rinse thoroughly. Chemists use the rule of "three" in cleaning glassware and tools. After washing, chemists rinse out all visible soap and then rinse three times more.

Storage: Place cleaned tools and glassware in their respective storage places.

Disposal: Liquids can be washed down the drain

Exercises Answer the questions below:

1. What is the chemical name for table salt?
    a. Potassium chloride
    b. Sodium hydroxide
    c. Sodium chloride
    d. Potassium hydroxide
2. Where is the majority of the earth's salt found?
    a. Underground
    b. The Ocean
    c. In the atmosphere
    d. In the earth's mantle and core
3. Who were the explorers who first did this experiment in the 1800s?
    a. Roald Amudsen
    b. Sir Edmund Hillary
    c. Lewis and Clark
    d. Captain Cook

Lesson #15: Instant Ice

Overview: Did you know that in some clouds there is water that has been cooled below the level of freezing, and yet it doesn't turn into ice? How can this happen? We'll do a little experiment today to find out.

What to Learn: This experiment helps us understand some of the important phenomena present in our earth's weather, as well as the interaction of water with these occurrences.

Materials

- Water
- Glass
- Bowl
- Ice
- Salt
- Sodium acetate
- Disposable pie tin
- Rubber gloves
- Scissors

Lab Time

1. Place your ice (should be crushed) in the bowl.
2. Fill your glass with water, and put the glass into the bowl. The level of ice should be higher than the level of the water in the glass.
3. Put salt all around the edge of the bowl.
4. If you have a refrigerator handy, place the bowl in the fridge overnight, or at least for two hours to thoroughly cool the water.
5. Take your water out of the ice, and put a piece of ice into the water. Record your observations on the worksheet. What do you see?

Instant Ice Observations

Describe the water before you placed the ice into it, and after cooling.

Once you dropped the water in, what happened? Draw a picture below.

6. Now we're going to work with the sodium acetate.
7. Put on your rubber gloves, and keep them on for the remainder of lab time today. The sodium acetate exists now in a supercooled state, so it needs to be activated. That is what the little metal disc is for. Flex the disc, and observe what happens. What do you feel?
8. We want one of the crystals inside. Use scissors to open the packet, and grab one of the crystals. Place it in the disposable pan.
9. Take a packet of liquid sodium acetate, and cut off the corner of the packet so you can pour the liquid in a thin stream. Pour it over your crystal and record your observations, including what you feel.
10. To return the chemical back to the state we found it in, wrap the packet in a dish towel and then place the whole thing into boiling water, which an adult should set up. This will make sure the pack turns back into a liquid.

Hot Ice Observations

When you flex the disc initially, what happens? What do you feel?

Write what happens when you pour the supercooled liquid over the seed crystal? Draw your finished ice sculpture below:

What happens to the heat energy during this experiment? Is Heat given off or absorbed as the liquid freezes into a solid?

Reading

Supercooling a liquid is a really neat way of keeping the liquid a liquid below the freezing temperature. Normally, when you decrease the temperature of water below 32°F, it turns into ice. But if you do it gently and slowly enough, it will stay a liquid, albeit a really *cold* one!

In nature, you'll find supercooled water drops in freezing rain and also inside cumulus clouds. Pilots that fly through these clouds need to pay careful attention, as ice can instantly form on the instrument ports causing the instruments to fail. More dangerous is when it forms on the wings, changing the shape of the wing and causing the wing to stop producing lift. Most planes have de-icing capabilities, but the pilot still needs to turn it on.

We're going to supercool water, and then disturb it to watch the crystals grow right before our eyes! While we're only going to supercool it a couple of degrees, scientists can actually supercool water to below -43°F!

Don't mix up the idea of supercooling with "freezing point depression". Supercooling is when you keep the solution a liquid below the freezing temperature (where it normally turns into a solid) *without* adding anything to the solution. "Freezing point depression" is when you lay salt on the roads to melt the snow – you are lowering the freezing point by adding something, so the solution has a lower freezing point than the pure solvent.

Supercooling is also use in mechanical parts of refrigerators as well.

A supercooled liquid is a liquid that you slowly and carefully bring down the temperature below the normal freezing point and still have it be a liquid. Since the temperature is now ***below*** the freezing point, if you disturb the solution, it will need to heat up in order to go back up to the freezing point in order to turn into a solid. When this happens, the solution gives off heat as it freezes. So instead of cold ice, you have hot ice. Weird, isn't it?

Sodium acetate is a colorless salt used making rubber, dying clothing, and neutralizing sulfuric acid (the acid found in car batteries) spills. It's also commonly available in heating packs, since the liquid-solid process is completely reversible – you can melt the solid back into a liquid and do this experiment over and over again!

The crystals melt at 136°F (58°C), so you can pop this in a saucepan of boiling water (wrap it in a towel first so you don't melt the bag) for about 10 minutes to liquefy the crystals.

You have seen this stuff before – when you combined baking soda and vinegar in a cup, the white stuff at the bottom of the cup left over from the reaction is sodium acetate. (No white stuff? Then it's mixed in solution with the water. If you heat the solution and boil off all the water, you'll find white crystals in the bottom of your pan.) The bubbles released from the baking soda-vinegar reaction are carbon dioxide.

To recap: Supercooled liquids refer to liquids cooled below their freezing point without becoming a solid. This has to do with the physical structure of their molecules interacting around a "seed crystal" or nucleus which allows for a larger crystal structure to grow. In the layers of cumulus and other clouds, these nuclei don't exist, allowing supercooled water to exist inside. This can fall to the earth as freezing rain, or instantly crystallize when an aircraft wing flies through, for example. The aircraft wing provides such a nucleic structure for the water to crystallize onto. Generally, it's a good idea to avoid flying straight through a turbulent storm cloud.

Exercises Answer the questions below:

1. Where can we find supercooled liquids naturally? Name two places:
    a.
    b.
2. What most frequently determines the phase of water in the earth's atmosphere?
    a. Pressure
    b. Power
    c. Temperature
    d. Moisture
3. Name one commercial application of supercooling:

4. What is one hazard of finding this supercooled liquid in nature?

5. What is it called when fog freezes, or when any other gas changes directly into a solid?
    a. Hoarfrost
    b. Sublimation
    c. Aeration
    d. Liquifaction

6. What is the most important factor for getting a supercooled liquid to freeze?
    e. Temperature
    f. Pressure
    g. Needs a crystal surface
    h. Needs a pure liquid

Lesson #16: Making Clouds

Overview: Did you ever think you could make it rain indoors? Why or why not? Today you'll be able to wow your friends and family as you create weather without ever leaving your classroom!

What to Learn: Water is an important part of our Earth and daily lives. This lab will show you how water moves through the air as it condenses and forms clouds from vapor, which then continues to cycle through the water cycle as precipitation and other forms.

Materials

- Glass of ice water
- Glass of hot water
- Towel
- Adult help

<u>Optional materials for Part 2:</u>

- 2 L soda bottle with cap
- Rubbing alcohol
- Bicycle pump
- Car tire valve (get one at a tire repair shop)

Lab Time

1. Make sure to follow all instructions for today's lab. Read carefully through the directions before beginning, and when appropriate, ask an adult on hand to help.
2. Fill one glass half full of ice water, and the other full of very hot water.
3. Place the cold glass directly on top of the other glass and wait several minutes. Record your observations on the worksheet below.
4. If the seal holds between the glasses, a rain cloud will form, and it might actually rain inside the glass! To make a better seal, you can use a damp towel.

Indoor Rain Cloud Observations:

What happened when you placed the cold glass on top of the other glass?

Why did this happen? Explain as best you can. Draw a picture of the glasses to help explain.

Part 2: (Optional)

5. Place the empty 2L bottle in the refrigerator overnight. Make sure your bottle is labeled so that you can find it when we continue tomorrow.
6. Get an adult to light a match and drop it into the bottle. Immediately screw the cap on, and watch what happens.
7. Squeeze the sides of the bottle and then release. What do you see? Record this and other observations on your worksheet.

Bottled Clouds Observations:

How many times can you repeat this?

Does it matter what size the bottle is?

What if you don't chill the bottle?

What if you freeze the bottle instead?

Reading

Try filling up a glass with cold water. After a moment, ask the kids to tell you what is going on at the side of the glass. Where did the water come from? Why is this happening? It's all about condensation, and is a key part of the cycle that moves around the earth and sustains life: water!

Water exists in many forms around the earth. What is the main source of water on the planet? We talked last week about the oceans. Usually we can't use this because it is too salty. Our bodies would reject it. In some countries where there is not enough fresh water to find, like Saudi Arabia, they rely on the process of desalination to make all their usable water.

The majority of the fresh water in the earth is locked up in the ice caps on the Earth's poles. Other places we find fresh water, usually less than one percent of the whole earth's water, is in the springs, lakes, and rivers of the planet.

The key determining factor for water on our planet is *temperature*. Depending on climate, elevation, and local weather patterns, we see water exist in its different forms. Can you name some examples around us?

Invisible water vapor is all around us, all the time, but they normally don't stick together. When you squeezed the sides of the bottle, you increased the pressure and squeezed the molecules together. Releasing the bottle decreases the pressure, which causes the temperature to drop. When it cools inside, the water molecules stick to the smoke molecules, making a visible cloud inside your bottle.

Did you know that most drops of water actually form around a dust particle? Up in the sky, clouds come together when water vapor condenses into liquid water drops or ice crystals. The clouds form when warm air rises and the pressure is reduced (as you go up in altitude). The clouds form at the spot where the temperature drops below the dew point.

Today you may observe some science magic happening. The water in the glass will condense into a rain cloud because the heat influences the water nearby. This creates a state change in the water: it will evaporate from the cold liquid and then **condense** into a cloud. Condensation refers to the state change from gas into liquid, and is present in cloud formation as well as the sides of your beverage glass. Basically, the heat difference will influence the molecules of water in the air and cause them to cluster together on some surface: a particle of dust as in a cloud, or the sides of your glass.

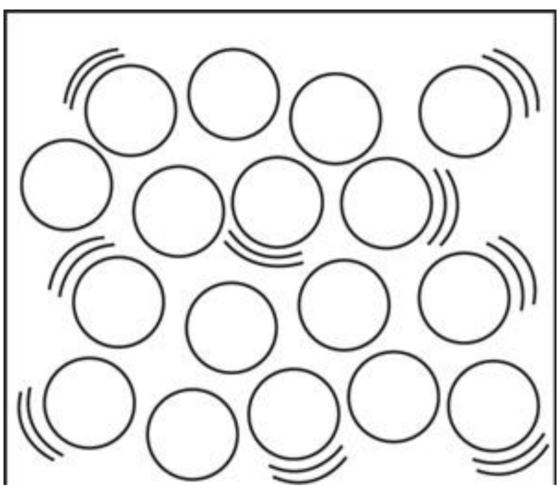
For the second part of the experiment, you can substitute rubbing alcohol and a bicycle pump for the matches to make a more solid-looking cloud. Swirl a bit of rubbing alcohol around inside the bottle, just enough to coat the insides, and then pour it out. Cap your bottle with a rubber stopper fitted with a needle valve (so the valve is poking out of the bottle), and apply your pump. Increase the pressure inside the bottle (keep a firm hand on the stopper or you'll wind up firing it at someone) with a few strokes and pull out the stopper quickly. You should see a cloud form inside. The alcohol works better than water because it evaporates faster than water does, which means it moves from liquid to vapor more easily (and vividly) than regular old water.

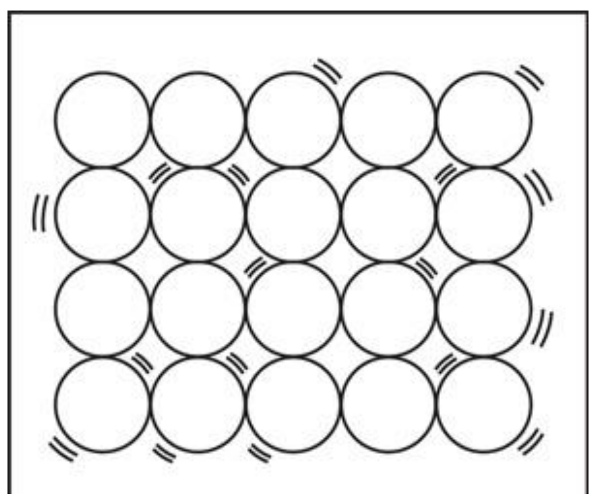
Exercises Answer the questions below:

1. Name one example of water on the earth's surface as it occurs naturally as a solid, liquid, and gas.
    a. Solid:
    b. Liquid:
    c. Gas:
2. What determines how water exists in nature as solid, liquid, or gas?
    a. Pressure
    b. Elevation
    c. Temperature
    d. Latitude and Longitude
3. When water becomes a liquid from a gas, what is this called?

4. Where can we find an example of this happening in nature?

5. What is the dew point?
    a. When moist air condenses into fog
    b. When fog evaporates into the air
    c. When water freezes
    d. When water no longer stays in solid form and melts
6. Circle the picture that represents molecules of water under greater pressure:





7. When pressure increases, what happens to temperature?
    e. It increases
    f. It decreases
    g. Nothing
8. When pressure increases in your bottle, do you see clouds?
    h. Yes
    i. No

Lesson #17: Can Fish Drown?

Overview: Turns out fish don't "breathe" water, but use their gills to filter the oxygen out of the water. But what happens when we remove the oxygen? How does this normally happen in nature?

What to Learn: This lesson helps us understand the properties of the fresh water on our planet's surface. What is so special about fresh water? What do we observe through this experiment in particular?

Materials

- test tube clamp
- test tube
- lighter (with adult help)
- alcohol burner or votive candle
- right-angle glass tube inserted into a single-hole stopper
- regular tap water

Note: If you don't have a chemistry glassware set, simply watch the video experiment and proceed with the questions.

Lab Time

1. Use a gentle twisting motion to move the glass tubing through the stopper. Twist until the stopper is about halfway up the tube.
2. Fill the test tube almost full of tap water. Press the stopper onto the top of the test tube until you see some water coming up into the smaller glass tube.
3. Clamp your test tube, and check that there are no pockets of air in the tube.
4. Get an adult to light the burner, and then move the test tube over the heat source so that it gets heated evenly. Make sure the water does not boil.
5. Watch for bubbles inside your test tube. Where did these come from? Record your observations on the worksheet. More air can dissolve in cold water than hot water. What do we see happening to this air? This clues us into how fish need the conditions of the water to remain fairly dynamic, since the water needs to have its air replaced.
6. Extinguish the flame and allow your tube to cool. Clean the tube if necessary to remove any buildup of material.

Can Fish Drown? Observations

How long did it take for the water to form bubbles? Record your data in minutes.

Write down what you see happening inside your test tube as you apply heat.

Why is this happening?

Reading

The vast majority of the fresh water is locked up in the caps on either pole: in sea ice in the Arctic, or in the large ice sheets on Antarctica. Next, there is water available in the ground. Far smaller are the percentages of water in lakes and rivers (around .0072 percent). This means that fresh water is a precious commodity. It also explains why some nations where water is scarce resort to using chemical and physical means to remove the salt from the water. Salt water accounts for 96.5% of all water on the planet. Lake Baikal, in Russia, is the world's deepest lake, and is so deep that it accounts for almost 20% of all the fresh water available on the surface of our planet!

If you've ever owned a fish tank, you know that you need a filter with a pump. Other than cleaning out the fish poop, why else do you need a filter? (Hint: think about a glass of water next to your bed. Does it taste different the next day?)

There's tiny air bubbles trapped inside the water, and you can see this when you boil a pot of water on the stove. The experimental setup shown in the video illustrates how a completely sealed tube of water can be heated… and then bubbles come out one end BEFORE the water reaches a boiling point. The tiny bubbles smoosh together to form a larger bubble, showing you that air is dissolved in the water.

The filter pump in your fish tank 'aerates' the water. The simple act of letting water dribble like a waterfall is usually enough to mix air back in. Which is why flowing rivers and streams are popular with fish – all that fresh air getting mixed in must feel good! The constant movement of the river replaces any air lost and the fish stay happy (and breathing). Does it make sense that fish can't live in stagnant or boiled water?

You don't need the fancy equipment show in this video to do this experiment… it just looks a lot cooler. You can do this experiment with a pot of water on your stove and watch for the tiny bubbles before the water reaches 212^{o}F.

Exercises Answer the questions below:

1. Where is most of the world's water located?
    a. Rivers
    b. Lake Baikal
    c. Oceans
    d. Ice Caps
2. How much fresh water can we find in rivers and lakes?
    a. Less than 10%
    b. Less than 1%
    c. Less than 1/100th of 1%
    d. Greater than 10%
3. How does air get replaced in a river or lake?

4. Can fish drown? How?

Lesson #18: Convection Currents

Overview: Convection is a little difficult to understand, so we'll use a simple experiment that allows us to visualize this important concept that influences so much of our world.

What to Learn: You'll connect what we do in lab today with the grand patterns of climate and the earth's relationship to the sun? But how? That's what you'll want to focus on today.

Materials:

- A stove
- Pepper
- Heating source
- Adult help
- Ice cubes
- Food coloring (optional)

Lab Time

1. Fill the pot about half way with water.
2. Put about a teaspoon of pepper into the water
3. Put the pot on the stove and turn on the stove (be careful please).
4. Watch as the water increases in temperature. You should see the pepper moving. The pepper is moving due to the convection currents. If you look carefully you many notice pepper rising and falling.
5. Put an ice cube into the water and see what happens. You should see the pepper at the top of the water move towards the ice cube and then sink to the bottom of the pot as it is carried by the convection currents.
6. Just for fun, put another ice cube into the water, but this time drop a bit of food coloring on the ice cube. You should see the food coloring sink quickly to the bottom and spread out as it is carried by the convection currents.

Convection Currents Observations:

Draw a diagram, labeled, that shows the movement of heat in the pot at the climax of this experiment. Label pepper, ice, and the stove.

Reading

Every time I'm served a hot bowl of soup or a cup of coffee with cream I love to sit and watch the convection currents. You may look a little silly staring at your soup but give it a try sometime!

Convection is a little more difficult to understand than conduction. Heat is transferred by convection by moving currents of a gas or a liquid. Hot air rises and cold air sinks. It turns out, that hot liquid rises and cold liquid sinks as well.

Room heaters generally work by convection. The heater heats up the air next to it which makes the air rise. As the air rises it pulls more air in to take its place which then heats up that air and makes it rise as well. As the air get close to the ceiling it may cool. The cooler air sinks to the ground and gets pulled back near the heat source. There it heats up again and rises back up.

This movement of heating and cooling air is convection and it can eventually heat an entire room or a pot of soup. This experiment should allow you to see convection currents.

Our Earth displays convection currents. Since our planet is not heated evenly (ask our neighbors in Australia what it is like this time of year) heat will flow around the planet in different ways. This affects climate in some parts of the world, and ultimately determines things like seasons, precipitation, and thus the local vegetation and resources that we find.

Hot water rising in some areas of the pot and cold water sinking in other areas of the pot carried the pepper and food coloring throughout the pot. This rising and sinking transferred heat through all the water causing the water in the pot to increase in temperature.

Heat was transferred from the flame of the stove to the water by convection. More accurately, heat was transferred from the flame of the stove to the metal of the pot by conduction and then from the metal of the pot throughout the water through convection.

Exercises Answer the questions below:

1. What type of heating is caused by direct contact?
    a. Convection
    b. Conduction
    c. Transfer
    d. Asymmetrical heat
2. What type of heating is caused by heat flow or molecular movement?
    a. Convection
    b. Conduction
    c. Transfer
    d. Asymmetrical heat
3. Name two examples of convection:
    a.
    b.

Lesson #19: Food Dye Currents

Overview: Today you'll use some food coloring to turn a bottle of water into a simulator for a heat current.

What to Learn: This experiment shows you the important processes that allow life to sustain on our planet. Where does this happen, you ask? And how? That's what we'll dive into today as we talk about heat currents and the definition of convection.

Materials

- Two bottles of water
- Food coloring
- Bathtub or sink
- Business card or index card
- Stopwatch

Lab Time

1. Put about the same amount of water into two bowls. One bowl should be filled with hot water from the tap. If you're careful, you can put it in the microwave to heat it up but please don't hurt yourself. The other bowl should have cold water in it. If you're using water bottles, pour the hot and cold water into each bottle.
2. Let both bowls sit for a little bit (a minute or so) so that the water can come to rest.
3. Put food coloring in both bowls (or bottles) and watch carefully. Start your stopwatch as soon as the dye is added. Record the time that it takes for the dye to completely distribute through each bottle. The food coloring should have spread around faster in the hot water bowl than in the cold water bowl. Can you see why? Remember that both bowls are filled with millions and millions of molecules. The food coloring is also bunches of molecules. Imagine that the molecules from the water and the molecules from the food coloring are crashing into one another like the beans on the plate. If one bowl has a higher temperature than the other, does one bowl have faster moving molecules? Yes, the higher temperature means a higher thermal energy. So the bowl with the warmer water has faster moving molecules, which crash more and harder with the food coloring molecules, spreading them faster around the bowl.

Food Dye Currents Data Table

Bottle	Time for Dye to disperse (seconds)
Hot Water	
Cold Water	

Reading

When something feels hot to you, the molecules in that something are moving very fast. When something feels cool to you, the molecules in that object aren't moving quite so fast. Believe it or not, your body perceives how fast molecules are moving by how hot or cold something feels. Your body has a variety of antennae to detect energy. Your eyes perceive certain frequencies of electromagnetic waves as light. Your ears perceive certain frequencies of longitudinal waves as sound. Your skin, mouth and tongue can perceive thermal energy as hot or cold. What a magnificent energy-sensing instrument you are!

In today's experiment, imagine that the molecules from the water and the molecules from the food coloring are crashing into one another like the beans on the plate. If one bowl has a higher temperature than the other, does one bowl have faster moving molecules? Yes, the higher temperature means a higher thermal energy. So the bowl with the warmer water has faster moving molecules, which crash more and harder with the food coloring molecules, spreading them faster around the bowl.

The type of current that is created is called a convection current, which is different than conduction, which happens when one hot object touches another. Where is the most important place that convection happens? The sun! As atoms are fused together they release tons of energy that we feel even here. This energy cycles in the star between the hot core and the cooler surface.

The sun is a giant reactor of nuclear fusion. The molecules of hydrogen are fused into one molecule of hydrogen, which releases a tremendous amount of energy. When this happens, the energy travels from the hyperactive core of the star to the outer layers, which collapse and cycle back into the interior. This creates a massive convection current whose energy cycles in massive "belts" deep within the body of the star.

All life on earth owes its existence to the energy given from the sun, which allows water to transition between its phases, influences the weather patterns and atmosphere, and provides energy for our plants and animals to survive.

Exercises: Answer the questions below:

1. Name two types of heat transfer:

2. Where does convection happen?
    a. A Radiator
    b. Hot Plate
    c. Tea Kettle
    d. The Sun
3. True or False: When an object heats up, its molecules move slower.
    a. True
    b. False

Lesson #20: Streaming Water

Overview: I know I am a full-fledged grown-up, but this experiment still amazes me, and I am not quite sure why. Maybe because it's part magic, part science, and it's got just the right mix of both to instill curiosity.

What to Learn: Higher pressure always pushes, once again! We're going to use this idea to stop a flow of water.

Materials

- Bottles of water
- Outdoor area
- Tack or nail to make holes in the bottle

Lab Time

1. This experiment is best done outdoors, or in a tank or a large bathtub.
2. Grab your water bottle and tack and poke several holes into the lower half the water bottle.
3. Fill up your water bottle and cap it tightly.
4. Lift the bottle up and untwist the cap. Water should come streaming out.
5. Close the cap and the water streams should stop.
6. Open the cap and when the water streams out again, can you "pinch" two streams together using your fingers?
7. Record your data below.

Streaming Water Data Table

Trial	Observations

Reading

As the water streams out, the water level in the bottle moves downward. Notice how the space for air increases in the top of the bottle as the water line moves down. (The air comes in through the mouth of the bottle.) When you cap on the bottle, there's no place for air to enter the bottle. The water line wants to move down, but since there's no incoming air to equalize the pressure, the flow of water through the holes stops. Technically speaking, there's a small decrease in pressure in the air pocket in the top of the bottle and therefore the air outside the bottle has a higher pressure that keeps the water in the bottle. *Higher pressure pushes!*

Exercises: Answer the questions below:

1. Why does the water stop in this experiment?

2. What holds the two streams of water together when you pinch them?

3. Does temperature of the water matter in this experiment? If so, how does it change the experiment?

Lesson #21: Air Takes Space

Overview: We're going to show how increasing air pressure can displace water to show how air takes up space.

What to Learn: When air pressure increases, the volume also wants to increase. The more air you blow in a balloon, the bigger the balloon gets. This experiment will show you that air really is something, albeit invisible.

Materials

- Water
- Bathtub or sink or tank
- Tube or straw
- Clear cup or glass jar

Lab Time

1. Plunge one cup underwater so it fills completely with water.
2. While the cup is underwater, point its mouth downward.
3. Insert one end of the tubing or straw into the cup and blow hard into the other end. The water is forced out of the cup!
4. While the cup is still underwater, invert one cup (mouth downwards) and plunge it into the tub so that air gets trapped inside the cup.
5. Place the second cup in the water so it fills with water.
6. Invert the water-filled cup while underwater and position it above the first cup so when you tilt the first cup to release the air bubbles, they get trapped inside the second cup.
7. Here you see that air takes space, because in both variations of this experiment the air forced the water out of the cups.

Reading

You're playing with one of the first methods of underwater breathing developed for scuba divers hundreds of years ago. Back then, scientists would invert a very large clear, bell-shaped jar over a diver standing on a platform, then lower the whole thing into the water. Everyone thought this was a great idea, until the diver ran out of breathable air!

Exercises: Answer the questions below:
1. What is the pressure of air in the atmosphere?

2. Why do air bubbles float to the surface of the water?

3. What states of matter are present in this experiment?

Lesson #22: Sneaky Bottles

Overview: How much space does air take up? Is it different in certain places rather than others? Find out the answers to these important questions in today's lesson

What to Learn: This experiment helps us focus on one particular property of the atmosphere: pressure. We'll learn how pressure plays a role at different layers of our atmosphere.

Materials

- 2 Balloons
- Tack
- 2 Water bottles

Lab Time

1. Take your balloon and poke it into a water bottle with your finger. You'll want to stretch its neck over the opening of your water bottle from the inside, so don't let go of the balloon!
2. Repeat with the other bottle. Once both are in place, Poke several small holes into the bottom of one of your bottles. Be sure to label each bottle accordingly.
3. Put your mouth to each bottle, and try to inflate each balloon. What happens? Record your observations in the worksheet.

Sneaky Bottles Observations

Which bottle is easier to inflate? What happens when you try to inflate each bottle?

Why does one bottle inflate and not another? Where is the region of higher pressure in the case of each bottle? Draw and label in the space below:

Reading

You can begin class by talking about the experiences of somebody cooking on top of Mount Everest, versus somebody cooking while near the ground. Cooking times vary because there is a difference in the atmosphere between both places. There are many factors at play, but we are focusing on one particularly important factor today: the fact that air exerts pressure on the earth at all places, and in all directions.

We can test this simply by holding our hands out and whooshing them through the air. Can you feel the air moving out of the way when you move it left? How about right? What about up and down? Yes, it is the same, although influenced more by gravity in the vertical level. Turns out that air is a fluid, and so behaves in some particular ways. Just like another fluid, water, it exerts pressure on objects suspended within it. When you go to the bottom of a pool, do you experience more water pressure than at the top? What do you think?

So, taking this principle to the pressure of the air, do we experience more pressure at lower elevations than at higher elevation? Yes, at lower elevations, we are subject to more atmospheric pressure, since there is more of the atmosphere on top of us! Today's experiment will reinforce the concept that air takes up space and behaves in particular ways.

Scientists measure pressure for its applications and principles relating to chemistry, thermodynamics, and natural phenomena like weather. When we measure barometric pressure, we look out for systems of air that interact to produce severe weather. It turns out that the fluid dynamics of air is intricately related to a set of standard physical principles. We'll visually explore this today as we look at the space that "empty" air actually takes up.

Exercises Answer the questions below:

1. What is one property of the earth's atmosphere that is influenced by pressure?
    a. Mercury level
    b. Temperature
    c. Weather patterns
    d. Changes in weather
2. True or False: If you go higher into the atmosphere, the pressure increases.
    a. True
    b. False
3. Pressure is experienced equally in:
    a. A Vertical direction
    b. All directions
    c. Lateral directions (on the sides)
    d. No directions

Lesson #23: Fountain Bottle

Overview: Today you'll be working in the splash zone as we learn about high pressure.

What to Learn: Students will learn that higher pressure always pushes, even if you're building up pressure inside a water bottle.

Materials

- Plastic bottle (water or soda bottles work)
- A straw
- Clay
- Water
- Drill with drill bit about the size of your straw
- Ruler
- Stopwatch

Lab Time

1. Fill the bottle with water about ¾ full, leaving at least 2 inches of air at the top.
2. Drill a hole in the cap that is slightly smaller than your straw.
3. Thread the straw into the cap partway and seal it with the clay.
4. Make sure the straw is submerged in the water.
5. Take a deep breath.
6. Blow into the straw, completely emptying your lungs. You want to stuff as much air into the bottle as possible.
7. Watch the bubbles and pay attention to the sides of the bottle. How do they feel?
8. Remove your face and watch what happens!
9. Complete the exercise and worksheet, and clean up any mess you've made in the process.

Fountain Bottle Observations

Draw a picture of the experiment and label the areas of higher and lower air pressure:

Fountain Bottle Data Table

Trial Number	How much water? *(measure in inches or cm)*	How long did you exhale for?	How high did the water go?

Reading

When you blow air into the bottle, the air pressure increases inside the bottle. When the pressure is released, the bottle pushes down on the water, which shoves the water up the straw.

Exercises Answer the questions below:

1. Where is the higher pressure in this experiment?
2. Did you increase the pressure of the water or the air?
3. How can you modify this experiment to make the water shoot up even higher?

Lesson #24: Ping Pong Funnel

Overview: This lab, if you understand it, will help you understand why airplanes fly without flapping their wings. This experiment, like airplane wings, generates and makes effective use of a difference in air pressure.

What to Learn: Higher pressure always pushes. The higher pressure in this experiment is the air surrounding the top of the ball. The air below the ball is at a lower pressure because it's moving faster to get around the ball. This difference in pressure is what makes the ball stay in the funnel, and what gives airplane wings their lift.

Materials

- Ping Pong ball
- Funnel

Lab Time

1. Before you start, write your predictions on the worksheet. What do you predict will happen to the ping pong ball when you blow on it?
2. Place a ping pong ball inside your funnel.
3. Stick the funnel between your lips with the top towards the ceiling. Try as hard as you can to force the ball out of the funnel.
4. Record all observations on the worksheet.

Ping Pong Funnel Observations

What do you predict will happen when you blow on the ping pong ball?

What did you observe about the ping pong ball?

Draw a picture of the experiment and label the areas of higher and lower air pressure:

Reading

Take a piece of construction paper and hold it to your lips. Ask the kids what they think might happen if you blow. Blow underneath the paper first. It flies upward! Ask the kids what they think might happen if you blow on the top surface of the paper. It should also fly upward! How can this happen? This helps us explain how an airplane can fly.

When you have a higher pressure, it will always push. When you blow on the paper, you create a lower pressure than the rest of the air around the paper. The higher pressure on the other side pushes on the paper, causing it to fly upwards. Cool, huh? This is demonstrated as Bernoulli's principle. It states: A fast moving fluid will create lower pressure, as we're about to find out.

The earth's atmosphere exerts a specific pressure, proportional to the temperature and distance from the surface. Scientists use a standardized unit, called Standard Temperature and Pressure, when they do their measurements. They are often interested in the ways that the atmosphere behaves because differences in pressure can indicate increased wind speeds, storms developing, or changing precipitation.

Bernoulli's principle demonstrates that an increasing speed will result in a lower pressure in a fluid. For air, this is important to explain how an airplane's wings create lift, especially when its shape allows one column of air to travel faster than the other. Since the curve of an airfoil forces air to move farther over the top surface, it will travel slower than the air underneath. This speed difference creates an area of lower pressure underneath the wing, which allows the airplane to climb into the air.

Exercises Answer the questions below:

1. Which other measurement is pressure related to?
    a. Elevation
    b. Temperature
    c. Oxygenation
    d. pH
2. As you go higher off the ground, does the pressure increase or decrease?
    a. Increase
    b. Decrease
3. True or False: Air is one example of a fluid.
    a. True
    b. False
4. True or False: As a fluid increases in speed, its pressure increases.
    a. True
    b. False

Lesson #25: Diaper Wind Bag

Overview: This is one of those really neat magic tricks that seem to defy reason when you first see it, because it looks so impossible. Once you understand how air pressure differences work, then you'll be able to mystify your friends like a pro.

What to Learn: This experiment helps us understand pressure and its relationship to the atmosphere, especially something called Bernoulli's principle. Higher pressure always pushes, and air moving at a higher velocity has a decreased air pressure compared to the non-moving air. This means you have a pressure difference in the area of the fast-moving air.

Materials

- Diaper Genie refill, or large plastic bags.
- Scissors
- Stopwatch
- Ruler

Lab Time

1. Cut an 8-foot long section from the diaper genie bag. Seal one end of the bag by gathering the end and tying it off.
2. Find the other end of the diaper genie and blow into the end of the bag. Can you fill it with one breath?
3. We want to try this again, but first, squeeze all the air out. Have a partner hold the bag out, being careful not to let any air in. Try to blow again, but hold the bag about 8 inches away from your face. Record your observations in the worksheet.
4. Tie off the end quickly before the air can escape.

Diaper Wind Bag Observations

Trial Number	How Long Did you Exhale For?	Distance Bag Opening from your Mouth

Reading

When air behaves as a fluid, it is important to pay attention to how its speed creates areas of higher or lower pressure. How does this influence the weather? How does this influence how we construct things like airplanes or Formula 1 racing cars? Spend some time reminding the kids about these kinds of questions and concepts, and then jump right into the experiment.

Today's experiment demonstrates the dynamics of airflow in some unique ways. While the experiment itself is relatively straightforward, it's important to understand the science behind it all.

When you blow air out of your mouth, a pocket of lower air pressure forms in front of your face. The stronger you blow, the lower the air pressure pocket. The air surrounding this lower pressure region is now at a higher pressure than the surrounding air, which causes things to shift and move. When you blow into the bag (keeping the bag a few inches from your face), you build a lower pressure area at the mouth of the bag, and the surrounding air rushes forward and into the bag.

Exercises Answer the questions below:

1. How is pressure related to temperature?
    a. No relationship
    b. As pressure increases, temperature decreases
    c. As pressure decreases, temperature stays the same
    d. As pressure increases, temperature increases
    e. None of the above
2. How is pressure related to the elevation of an object above the ground?

3. How is pressure related to the speed of a fluid?

4. What is the law above called?
    a. Newton's second law
    b. Bernoulli's Principle
    c. Pascal's wager
    d. Relativity Theory

Lesson #26: Magic Water Glass Trick

Overview: This experiment is another fine example of how higher pressure always pushes. This is one that will wow the students, and is relatively simple and easy to do anywhere.

What to Learn: This lesson will teach you the importance of pressure in our atmosphere and how it relates to objects. You'll also learn how the earth's atmosphere exerts a pressure on the ground, evenly experienced in all directions.

Materials

- Glass
- Index card
- Water
- Ruler

Lab Time

1. Fill a glass one-third full of water from the tap. Cover the rim of the glass with an index card.
2. Make sure you remain over the sink for this part. Quickly invert the glass and remove your hand from the index card. Viola!
3. Answer the questions on this worksheet and make your observations

Magic Water Glass Observations

Draw a diagram of the experiment and label the higher and lower regions of pressure:

Now add arrows to your diagram above that show the weight of the water (the arrow for weight is pointing downwards) and the force of the air holding the card in place (which way will this one point?).

Magic Water Glass Data Table

Trial Number	Amount of Water *(measured in inches or cm)*	Time Inverted 'til the Card Buckled	Observations

Reading

This experiment demonstrates the same principles as the previous experiment, so you can do a quick review of atmospheric pressure, why it is important to study, how scientists measure it, and what its implications are for weather. You can get into some more specific chemistry with the kids when you explain how Pressure is directly related to the temperature experienced by an object. You increase the pressure, the temperature increases.

Atmospheric air pressure is pushing on all sides of both the glass and the card, so the card "defies gravity" and "sticks" to the bottom of the glass. Recall that higher pressure pushes and when you have a difference in pressure, things move. This same pressure difference causes storms, winds, and the index card to stay in place.

Where's the pressure difference in this trick? At the opening of the glass! The water inside the glass weighs a pound at best, and, depending on the size of the opening of the glass, the air pressure is exerting 15-30 pounds upward on the bottom of the card. Guess who wins? Tip, when you get good at this experiment, try doing it over a friend's head!

Exercises Answer the questions below:

1. Where does an object experience the greatest pressure?
    a. Bottom of the Marianas Trench
    b. Top of Mount Everest
    c. Ocean Surface
    d. 10,000 feet altitude
2. How is Pressure related to Temperature?

3. What is an instrument that scientists use to measure the pressure in the atmosphere?
    a. Anemometer
    b. Hygrometer
    c. Barometer
    d. Inclinometer
4. True or False: The pressure is greater on the bottom (dry side) of the index card than on the wet side.
    a. True
    b. False

Lesson #27: Hot Air Balloon

Overview: Air behaves differently depending on the temperature it's at. Sometimes it floats, sometimes it sinks, sometimes it speeds across the land, and other times it just hangs around doing nothing. You can see this in weather patterns, but can also take advantage of it for hot air balloons.

What to Learn: This experiment helps illustrate the different properties of air, temperature, pressure, and how they interact in ways that we can see all the time around us.

Materials

- Lightweight plastic garbage bag
- Duct tape, masking tape
- Hand-held hair dryer
- Cold, calm morning
- Ruler
- Stopwatch

Lab Time

1. Shake out a garbage bag to its maximum capacity. Using duct or masking tape, reduce the opening until it is almost-closed leaving only a small hole the size of the hair dryer nozzle.
2. Use the hair dryer to inflate the bag, heating the air inside, but make sure you don't melt the bag! When the air is at its warmest, release your hold on the bag while at the same time you switch off the hair dryer. The bag should float upwards and stay there for a while.
3. Record your observations on the worksheet below.

Hot Air Balloon Observations

Draw a diagram of your hot air balloon experiment, clearly labeling the hot and cold air.

Hot Air Balloon Observations

Trial Number	Time Length to Heat Air inside the Balloon	How High Did the Balloon Travel?	How Long Did It Remain Aloft?

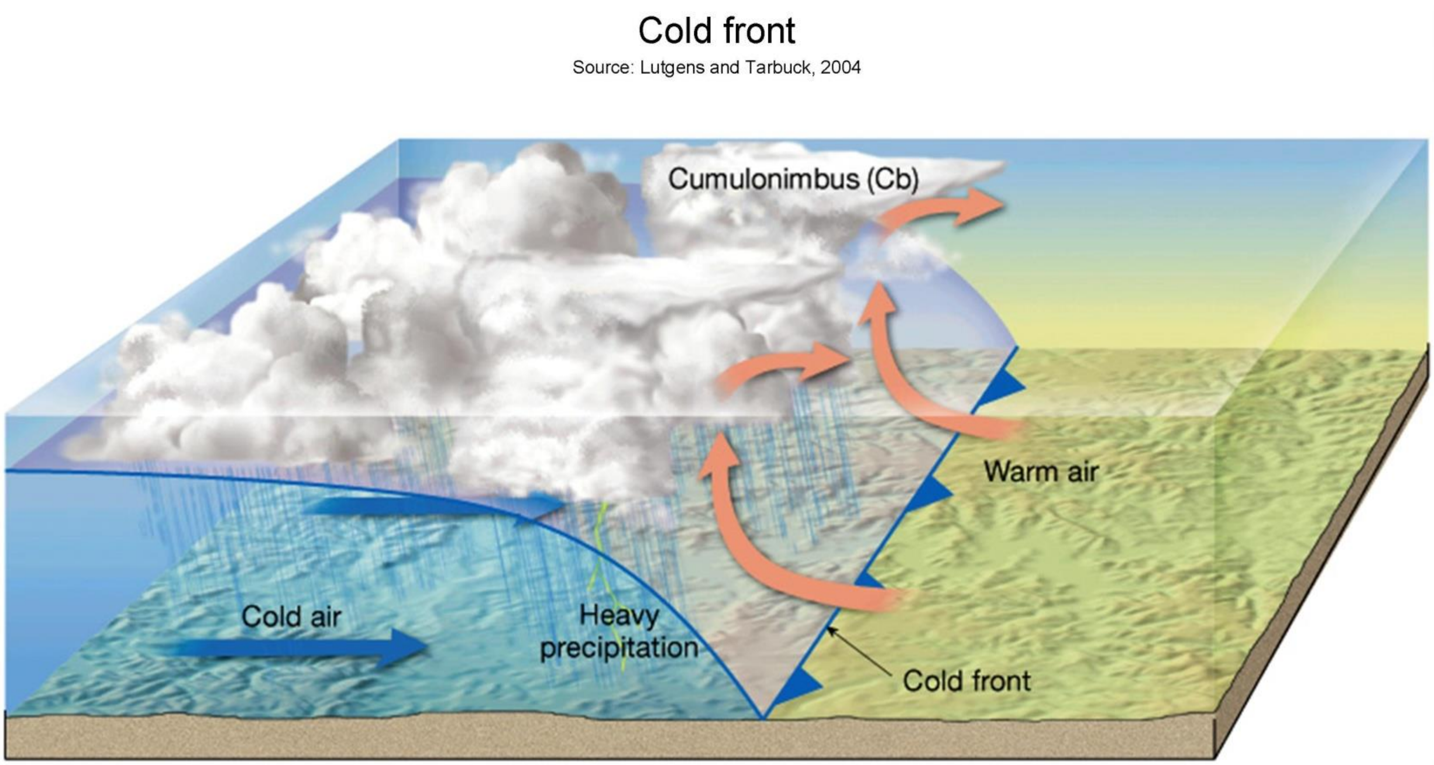
We can observe the heat difference in weather patterns. Warmer air rises and colder air sinks, which is why a cold front will shove air out of the way much more quickly than an advancing warm front. As this air gets shoved out of the way, the great amount of turbulence can create some dramatic weather, including thunderstorms, lightning, and lots of rain. A warm front will produce a mellow shower, if any weather at all.

As for Hot Air Balloons, there are several places around the world where these take flight in massive and spectacular fashion. One of the most famous is in Albuquerque, New Mexico, where every September hundreds of these take flight over the Rio Grande Valley. The flights usually begin early in the morning, when the cool air makes it easier for these colorful creations to get airborne.

The most important concept relating to why warmer air rises and colder air sinks happens at the molecular level. When matter is heated, its atoms get excited and move around more quickly. In a gas, this tends to make it spread out more. When it cools, it gets denser and will sink below the atoms that are more prone to move around. This same concept can be seen demonstrated with liquids when you can stratify hotter and cooler liquids.

For this experiment: The greater the temperature difference between the hot air inside the garbage bag versus the cold, still air, the faster the bag rises. The only other thing to watch for is that you've taped the mouth of the garbage bag securely so the hot air doesn't seep out. Be sure the opening you leave is only the diameter of your hair dryer's nozzle.

This diagram should be helpful to illustrate the dynamics at work with warm and cold air interacting:



Exercises Answer the questions below:

1. Which type of air will rise? Why?

2. Situation: You notice from your collection of scientific instruments that the pressure is rapidly increasing, but somehow the temperature is decreasing in that area as well. What could be happening?
    a. A warm front advancing
    b. A cold front advancing
    c. A tornado
    d. Your instruments are clearly broken; the above situation is impossible
3. Where is there more likely to be extreme weather:
    a. Warm front
    b. Cold front
    c. No front
4. True or False: Pressure is an indicator for slow, stable changes in weather.
    a. True
    b. False

Lesson #28: Soda Can Trick

Overview: Today in lab we explore the relationship between air pressure and air movement.

What to Learn: This simple experiment will help us understand the concepts behind air pressure in the earth's atmosphere, how it is experienced by objects, and how it decreases with altitude.

Materials

- 25 straws
- 2 empty soda cans
- Stopwatch
- Ruler

Lab Time

1. Unwrap the straws if needed.
2. Make a bed of straws on the table, with the straws parallel to each other.
3. Place two soda cans on the straws about an inch apart
4. Lower your face so that your nose is between the cans
5. Blow even and strong at the space between in the cans.
6. Did the cans move? If not, try again!
7. Record your observations in the worksheet.

Soda Can Observations

Where is the area of greater pressure? Draw a diagram of your experiment, labeling the lower and higher pressure regions.

Soda Can Data Table

Trial Number	Distance Cans Initially Apart	Time Length *(from when you started to blow until the cans clinked together)*

Reading

When air moves, the air pressure decreases. This creates a lower air pressure pocket right between the cans relative to the surrounding air. Because higher pressure pushes, the cans clink together. Just remember – whenever there's a difference in pressure, the higher pressure pushes.

This lab reinforces the principles behind the previous experiments in air pressure. Higher pressure always pushes. Ask your students to identify the higher and lower air pressure regions as you demonstrate this lab.

Exercises Answer the questions below:

1. What principle describes how pressure behaves in a moving fluid?
    a. Boyle's Law
    b. Pascal's Wager
    c. Bernoulli's Principle
    d. High-Pressure Hypothesis
2. A higher pressure will ________ an object.
    a. Push on
    b. Pull on
    c. Have no effect on
3. An object experiences pressure in the Earth's atmosphere in which direction more?
4. If an object is higher in altitude above the earth, it experiences which pressure in relationship to an object at sea level?

Lesson #29: Genie in a bottle

Overview: This is another great way to visualize why hot air balloons rise on cool mornings. Warmer air rises above cooler air, but since air is invisible to the human eye no matter what temperature it's at, it can be hard to understand what's going on. This experiment will help you learn about changes in density and how they are related to temperature.

What to Learn: This experiment illustrates the connection to pressure and temperature on objects in our atmosphere.

Materials

- Two glasses (identical)
- Hot Water
- Cold Water
- Red and Blue Food Dye
- Index card large enough to cover the glasses
- Stopwatch
- Thermometer

Lab Time

1. Fill two identical water glasses to the brim: one with hot water, the other with cold water.
2. Put a few drops of blue dye in the cold water, a few drops of red dye in the hot water.
3. Place the index card over the mouth of the cold water and invert the glass over the glass of hot water. Line up the openings of both glasses, and slowly remove the card.
4. Record all observations in the worksheet

Genie in a Bottle Observations

How does this relate to the Hot Air Balloon we made in the last lesson?

What would happen if the warm water was placed underneath the cold water? What color would we get?

Genie in a Bottle Observations

Trial Number	Temperature of Hot Water Initially	Temperature of Cold Water Initially	How Long Did It Take to Mix? *(Use your best judgment here)*

Reading

Imagine a glass of hot water and a glass of cold water sitting on a table, side by side. Now imagine you have a way to count the number of water molecules in each glass. Which glass has more water molecules?

The glass of cold water has *way* more molecules.

Why? The cold water is denser than the hot water. Warmer stuff tends to rise because it's less dense than colder stuff and that's why the hot air balloon in experiment 36 floated up to the sky.

Clouds form as warm air carrying moisture rises within cooler air. As the warm, wet air rises, it cools and begins to condense, releasing energy that keeps the air warmer than its surroundings. Therefore, it continues to rise. Sometimes, in places like Florida, this process continues long enough for thunderclouds to form. Let's do an experiment to better visualize this idea.

For this experiment, always invert the cold glass over the hot glass using an index card to hold the cold water in until you've aligned both glasses. You can also substitute soda bottles for water glasses and slide a washer between the two bottles to decrease the flow rate between the bottles so the effect lasts longer.

Exercises Answer the questions below:

1. Which atoms are likely to be under greater pressure:
   a. Cooler atoms
   b. Hotter atoms
   c. Metallic atoms
   d. Gas atoms
2. Fill in the blank: If air moves more quickly over a surface, that surface will experience _______________ pressure than others.
3. The above principle explains how we travel by which popular means?

Lesson #30: Cartesian Diver

Overview: How does a submarine work? One minute they are resting on top of the ocean, and the next they're diving below the surface at a constant rate. Submarines can do this over and over again. This lab explores how submarines do this repeatedly by using pressure and volume.

What to Learn: The submarine has tanks that can be filled with water if it needs to dive, or air if it needs to float (though usually it's a combination).

Materials

- Large 2L soda bottle of water
- Smaller water bottle
- Test tube (or medicine dropper)
- Ketchup packet
- Ruler

Lab Time

1. Fill the large soda bottle most the way with water.
2. Fill the small water bottle with water also. This is how you'll add small drops of water to the large bottle, which will have your diver in it.
3. Use the small bottle to fill your test tube partway with water. You want the right ratio of air-to-water so that the test tube floats between the top and bottom of the water bottle, and sits right in the middle.
4. If the test tube is still sticking out of your bottle when you place it in, there's too much air.
5. If the test tube sank all the way to the bottom, there's too much air.
6. Make the test tube hover inverted in the soda bottle. Your test tube will have both water and air inside.
7. Add more water to the large bottle until it spills out the top and overflows.
8. Put the cap on, and water should s[pill out. You don't want any air bubbles inside the bottle.
9. Squeeze the bottle… your test tube should sink!
10. Release it – does it float back up?
11. Now remove the test tube from the bottle.
12. Place a packet of ketchup into a cup of water…does it float or sink? Find a packet that floats and place it in the large soda bottle. Add more water (like you did for the test tube) so it overflows, and cap it.
13. Squeeze the bottle… your ketchup should sink!
14. Release it – does it float back up?

Cartesian Diver Data Table

Trial	Amount of Water *(measure in cm or inches)*	Did it Sink to bottom, Float to the Top, or Hover?

Reading

Rene Descartes (1596-1650) was a French scientist and mathematician who used this same experiment show people about buoyancy. By squeezing the bottle, the test tube (diver) sinks and when released, the test tube surfaces. You can add hooks, rocks, and more to your set up to make this into a buoyancy experiment!

Why does the test tube sink? The test tube sinks because the when you squeeze the bottle, you increase the pressure of the water and this forces water up into the test tube, which then compresses the air inside the tube. When this happens, it adds enough mass to cause it to sink. Releasing the squeeze on the bottle means that you decrease the pressure and the water is forced back out of the tube.

Exercises: Answer the questions below:

1. When the diver sinks, what's going on?

2. If you used hot water, how does this change the experiment?

3. What happens if you try this with a ketchup packet instead of a test tube?

Lesson #31: Squished Soda Can

Overview: When energy is added to water, the temperature (or thermal energy) of the water increases. The liquid water is turned into steam, which fills a fixed volume. When the steam is suddenly cooled, the temperature and pressure decrease, and the volume decreases, collapsing the fixed volume into a tighter space.

What to Learn: This lab shows how the pressure, volume, and temperature of an ideal gas, like air, are related.

Materials

- Empty soda can
- Tongs
- Bowl of ice water
- Room temperature water
- Tablespoon measure
- Stove or burner with adult help

Lab Time

1. Prepare an ice bath by putting about ½" of ice water in a shallow dish.
2. With an adult, place a few tablespoons of water in an empty soda can.
3. Place the can upright in a skillet on the stove to heat the water.
4. When the can emits a thin trickle of steam, grab the can with tongs and quickly invert it into the ice dish. CRACK!

Squished Soda Can Data Table

Trial Number	Amount of Water	Did it Collapse the Can?

Reading

An average can of soda at room temperature measures 55 psi before you ever crack it open. (In comparison, most car tires run on 35 psi, so that gives you an idea how much pressure there is inside the can!) If you heat a sealed can of soda, you'll run the pressure over 80 psi before the can ruptures. Adding energy (heat) to a system (can of soda) causes a pressure increase. It also causes a volume increase (kaboom!). How about trying a safer variation of this experiment using water, an *open* can, and implosion instead of explosion?

For this experiment: The air in the can was heated and expanded. When you cool it quickly by taking it off the stove and placing it in the ice water, the air cools down inside and shrinks, creating a lower pressure inside the can. Because the surrounding air outside of the can is now higher, it pushes on all sides of the can and crushes it.

The trick to making this work is that the can needs to be full of hot *steam*, which is why you only want to use a tablespoon or two of water in the bottom of the can. It's alright if a bit of water is still at the bottom of the can when you flip it into the ice bath. In fact, there should be some water remaining or you'll superheat the steam and eventually melt the can. You want enough water in the ice bath to completely submerge the top of the can.

Always use tongs when handling the heated can and make sure you completely submerge the top of the can in the icy water. The water needs to seal the hole in the top of the can so the steam doesn't escape. Be prepared for a good, loud *CRACK!* when you get it right.

Exercises: Answer the questions below:

1. Which type of heat transfer is being used to heat the can?

2. Why does the can collapse?

3. True or False: When temperature increases, pressure decreases.

Lesson #32: Squished Balloon

Overview: This is such a classic experiment, and can be done with a peeled hardboiled egg instead of a balloon. Students will notice how an egg (or balloon) doesn't fit into a bottle, but using the science of ideal gas and pressure changes, it will easily pop through.

What to Learn: This lab allows us to explore differences in pressure, and how it relates to volume. We also get to look at how fire consumes oxygen to decrease pressure.

Materials

- Glass bottle, like a flask or a milk bottle
- Paper
- Matches with adult help
- Balloon (only partway blown up so it's a little bigger than the bottle's opening) or an egg (or both!)
- Stopwatch

Lab Time

1. Blow up the balloon partway so that it's too big to fit into the bottle. If you're using an egg, peel the shell off.
2. Cut a strip from your paper to be about an inch wide, about 6-8 inches long.
3. Ask your adult helper to light the end of your paper.
4. While the paper is burning, stock it into the neck of the bottle, all the way down to the bottom.
5. Set the balloon on top of the bottle. What happened to the flame and the balloon?
6. If you've used an egg, it's impressive to get it back out by doing it this way: lift invert the bottle and blow as much air as you can into it, keeping the egg against the neck of the bottle. When you stop blowing, hold the bottle in place for about 10 seconds, until the egg pops out (seemingly on its own!)
7. You can repeat this experiment with a water balloon, but just make sure that the balloon is filled so that it doesn't fit into the bottle by itself.

Squished Balloon Data Table

Trial Number	Time Flame was Lit *(seconds)*	Observation

Reading

In today's experiment, the air molecules are getting heated up and expanding in the bottle when the flame is lit. When the flame goes out, the molecules move closer together as they cool off, which creates a lower pressure inside the bottle. The flame also consumes the oxygen in the bottle and generates other types of gases, while also adds to the decrease of pressure in the bottle.

The flame in the bottle needs oxygen, which it quickly runs out of when you seal the top of the bottle by placing an egg or balloon on top. When the flame goes out, the air in the bottle cool down and move closer together, forming a lower region of pressure, called a partial vacuum. If the balloon wasn't capping the bottle, air would come rushing inside when the air pressure decreases. The higher pressure is on the outside of the balloon, which pushes the balloon into the bottle.

Exercises: Answer the questions below:

1. What are three things required for fire to occur?

2. Does the balloon get sucked into or pushed into the jar?

3. Where is the higher pressure in this experiment?

Earth Science 1 Evaluation

Student Worksheet

Overview Today you're going to take two different tests: the quiz and the lab practical. You're going to take the written quiz first, and the lab practical at the end of this lab. The lab practical isn't a paper test – it's is where you get to show your teacher that you know how to do something.

Lab Test & Homework

1. Your teacher will ask you to share how much you understand about earth science. Since science is so much more than just reading a book or circling the right answer, this is an important part of the test to find out what you really understand.
2. While you are waiting to show how much of this stuff you already know, you get to choose which homework assignment you want to complete. The assignment is due tomorrow, and half the credit is for creativity and the other half is for content, so really let your imagination fly as you work through it. Choose one:
   a. Write a short story or skit about weather from the perspective of the air or water vapor. You'll read this aloud to your class.
   b. Make a poster that teaches the main concepts of weather. When you're finished, you'll use it to teach to a class to younger students and demonstrate the principles that you've learned.
   c. Write and perform a poem or song about sub-cooling. This will be performed for your class.

Earth Science 1 Quiz

Name____

1. How does radiation travel?
   a. As a beam
   b. As a wave
   c. as a molecule

2. Where does most of the energy on earth come from?
   a. Underground
   b. The Sun
   c. The Oceans

3. What is one way that we use energy from the sun?

4. Which instrument measures humidity?
   a. Thermometer
   b. Barometer
   c. Hygrometer
   d. Rain Gauge

5. What is the unit of measurement for temperature here in the USA?
   a. Newtons
   b. Joules
   c. Fahrenheit
   d. Celsius

6. What is another unit of measurement used for temperature?
   a. Fahrenheit
   b. Celsius
   c. Joules
   d. Newtons

7. What is the science called that investigates the weather and patterns of the Earth's atmosphere?
   a. Zoology
   b. Biology
   c. Meteorology
   d. Nephology

8. What are clouds made of?
   a. Nitrogen
   b. Water
   c. Oxygen
   d. Irridium

9. What form of water exists in clouds
   a. Water vapor
   b. Liquid water
   c. Frozen water

10. What is the name of someone who studies the weather?
    a. Oncologist
    b. Herpitologist
    c. Climatologist
    d. Meteorologist
    e. Asteroidologist

11. What is the type of energy that comes from the sun?
    a. Potential
    b. Kinetic
    c. Electronic
    d. Radiation

12. What principle describes how pressure behaves in a moving fluid?
    a. Avogadro's Principle
    b. Bernoulli's Principle
    c. Boyle's Law
    d. Pascal's Wager

13. A higher pressure will ________ an object.

14. An object experiences pressure in the Earth's atmosphere in which direction more?
    a. Upwards
    b. Downwards
    c. Equally in all directions

15. If an object is higher in altitude above the earth, it experiences which pressure in relationship to an object at sea level?
    a. Greater Pressure
    b. Less Pressure
    c. Equal Pressure

Earth Science 1 Lab Practical

Student Worksheet

This is your chance to show how much you have picked up on important key concepts, and if there are any holes. You also will be working on a homework assignment as you do this test individually with a teacher.

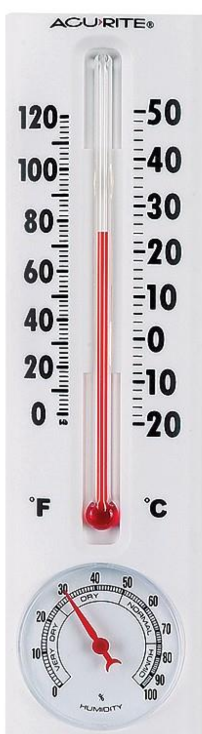
Materials:

- Two balloons, each with a string attached
- Ping pong ball
- Sheet of paper

Lab Practical:

1. Design an experiment using the materials provided to demonstrate how higher pressure always pushes.

2. For following instruments pictured below:
    a. What is the temperature in ^{o}C and ^{o}F?
    b. What temperature water will freeze at?
    c. The thing on the right is a barometer, a lot like the one we made in our experiments. The water inside is sealed, but the water in the pipe is open to the atmosphere. When does the water travel up the pipe, when the atmospheric pressure is increasing or decreasing?
    d. Does the barometer indicate calm or stormy weather is coming soon?



Answers to Exercises

Introduction: Homemade Weather Station

1. Write the name of an instrument that measures the temperature of the air. (Thermometer)
2. Describe the weather outside today. (Answer varies.)
3. What is the name of someone who studies the weather? (Meteorologist)

Lesson 1: Anemometer

1. An anemometer is one scientific instrument that measures the weather. Which one is also an instrument that measures the weather? (Barometer)
2. What is important about measuring wind speed? (Can indicate stormy weather, changing winds, severe weather, etc.)
3. Which instrument measures humidity? (Hygrometer)

Lesson 2: Barometer

1. What is one unit of measuring pressure? (millibars, torr, kilopascals, inches Mercury)
2. True or False: As you go higher in the air, pressure increases. (False)
3. True or False: Changes in pressure are good indicators of quick changes in the weather. (True)
4. What are two other scientific instruments that measure weather? (Thermometer, anemometer, hygrometer, rain gauge). What do they measure? (Temperature, windspeed, humidity, rainfall)

Lesson 3: Hygrometer

1. Why should we compare two hygrometers if we are using two different types of hair? (Not all hair is the same when responding to moisture, and some types of hair change with humidity more than others.)
2. After observing your results for a few days, which variable has the biggest effect on the humidity reading? Hair color? Texture? Age? (Texture should have the biggest effect: curly hair should show more changes daily than by color)

Lesson 4: Thermometer

1. What is the boiling temperature of water in Celsius and Fahrenheit? (100^{o}C, or 212^{o}F)
2. What is temperature really measuring? (The speed of molecules, of the thermal energy of the molecules.)
3. What is the temperature in the deepest, coldest reaches of space? (Near 0 Kelvin.)

Lesson 5: Rain Gauge

1. What is one other scientist that might use a rain gauge? (Biologist, Geologist, Hydrologist)
2. What is most appropriate for your area to measure rainfall in? Millimeters, centimeters, or inches? (Drier to wetter climates)
3. What is one thing we need to look out for to make sure our rain gauge keeps functioning well (make sure it doesn't get blocked by debris)

Lesson 6: Cloud Tracker

1. What is the science called that investigates the weather and patterns of the Earth's atmosphere? (Meteorology)
2. What are clouds made of? (Frozen crystals of water)
3. What form of water exists in clouds (Water vapor)

Lesson 7: Sensing Temperature

1. What is the unit of measurement for temperature here in the USA? (Fahrenheit)
2. What is another unit of measurement used for temperature? (Celsius)
3. Write the abbreviations for Fahrenheit and Celsius below: (F, C with degree symbol)

Lesson 8: Soaking Up Rays

1. How does radiation travel? (As a wave)
2. Which color reflects more light? (White)
3. Which color absorbs more light? (Black)
4. If you are wearing a white shirt, will you feel warmer than if you are wearing a black shirt? (No)

Lesson 9: Liquid Crystals

1. What type of energy does the sun emit? (Radiation)
2. Write down one type of radiation (Visible light, x-rays, etc.)
3. When are the molecules in your crystal sheet more movable? (When the sheet is warm) Why? (The sun heats up the molecules and transfers its energy to them)

Lesson 10: How much energy does the sun produce?

1. Name two types of renewable energy that we can use on earth: (wind, hydropower, solar, geothermal)
2. Which process contributes to the energy generated in the sun's core? (Nuclear fusion)
3. What is the unit used to measure energy? (Joule)
4. What is a joule, exactly? (the amount of energy required to move one Newton force 1 meter)
5. True or false: most of our energy needs are met by renewable sources. (False)

Lesson 11: Can wind be used as a source of energy?

1. Name three sources of renewable energy: (Solar, hydropower, biomass, wind, geothermal)
2. What does the sun have to do with wind? (Creates areas of higher and lower pressure air by heating them, which makes the air move as wind)
3. Name three examples of wind power in historical or current usage: (Windmills, sailing, electricity)

Lesson 12: Can water be used to store energy?

1. What type of heat transfer is at work in a solar pond? (Convection)
2. What units do we use to measure energy? (Joules)
3. Draw a diagram of a solar pond in the space below: (Should show salt water on bottom, layer of fresh water, and heat stored in the upper layer by the sun's rays from above)

Lesson 13: Water Purification

1. What are the five stages of filtration? (Aeration, coagulation, sedimentation, filtration, disinfection.)
2. What was the purpose of alum in this experiment? (It aided in the coagulation stage, where small bits of dirt stuck to the alum)
3. Where were the coffee grounds located? (In the sand)
4. Why did the cotton balls need to be as dark as possible? (The more carbon, the more efficient the filter will be in filtering out unwanted particles).

Lesson 14: Desalination

1. What is the chemical name for table salt? (Sodium chloride)
2. Where is the majority of the earth's salt found? (The oceans)
3. Who were the explorers who first did this experiment in the 1800s? (Lewis and Clark)

Lesson 15: Instant Ice

1. Where can we find supercooled liquids naturally? Name two places: (Clouds, freezing rain)
2. What most frequently determines the phase of water in the earth's atmosphere? (Temperature)
3. Name one commercial application of supercooling (refrigeration)
4. What is one hazard of finding this supercooled liquid in nature? (Aircraft problems)
5. What is it called when fog freezes, or when any other gas changes directly into a solid? (Sublimation)
6. What is the most important factor for getting a supercooled liquid to freeze (needs a seed nucleus or crystal to allow it to crystallize)

Lesson 16: Making Clouds

1. Name one example of water on the earth's surface as it occurs naturally as a solid, liquid, and gas. (Solid=polar ice, glacier, etc. Liquid=rivers, lakes, oceans. Gas=clouds, etc.)
2. What determines how water exists in nature as solid, liquid, or gas? (Temperature)
3. When water becomes a liquid from a gas, what is this called? (Condensation)
4. Where can we find an example of this happening in nature? (Clouds and rain)
5. What is the dewpoint? (The temperature that moist air will turn to fog)
6. Circle the picture that represents molecules of water under greater pressure (should be closer together)
7. When pressure increases, what happens to temperature? (It increases)
8. When pressure increases in your bottle, do you see clouds? (No, they will not form)

Lesson 17: Can Fish Drown?

1. Where is most of the world's water located? (Oceans)
2. How much fresh water can we find in rivers and lakes? (Less than 1/100th of a percent)
3. How does air get replaced in a river or lake? (The movement of the water allows air to be cycled in)
4. Can fish drown? How? (If the water becomes stagnant and no oxygen is replaced, the fish will drown)

Lesson 18: Convection Currents

1. What type of heating is caused by direct contact? (Conduction)
2. What type of heating is caused by heat flow or molecular movement? (Convection)
3. Name two examples of convection: (Radiator heating, weather patterns, coffee cooling, etc.)

Lesson 19: Food Dye Currents

1. Name two types of heat transfer: (Conduction and Convection)
2. Where does convection happen? (The sun)
3. True or False: When an object heats up, its molecules move slower. (False)

Lesson 20: Streaming Water

1. Why does the water stop in this experiment? (As the water streams out, the water level in the bottle moves downward. The water line wants to move down, but since there's no incoming air to equalize the pressure, the flow of water through the holes stops. There's a small decrease in pressure in the air pocket in the top of the bottle and therefore the air outside the bottle has a higher pressure that keeps the water in the bottle. Higher pressure pushes!)
2. What holds the two streams of water together when you pinch them? (Surface tension)
3. Does temperature of the water matter in this experiment? If so, how does it change the experiment? (Not much.)

Lesson 21; Air Takes Space

1. What is the pressure of air in the atmosphere? (14.7 psi, 101.3kPa, or 1 atm)
2. Why do air bubbles float to the surface of the water? (Gaseous air is less dense than liquid water.)
3. What states of matter are present in this experiment? (Air is a gas, water is a liquid, and the cup is a solid.)

Lesson 22: Sneaky Bottles

1. What is one property of the earth's atmosphere that is influenced by pressure? (Changes in Weather)
2. True or False: If you go higher into the atmosphere, the pressure increases. (False)
3. Pressure is experienced equally in: (all directions)

Lesson 23: Fountain Bottle

1. Where is the higher pressure in this experiment? (Inside the bottle)
2. Did you increase the pressure of the water or the air? (Air)
3. How can you modify this experiment to make the water shoot up even higher? (Answers vary, but look for solutions that involve getting more air into the bottle or decreasing the volume of the bottle as it shoots up.)

Lesson 24: Ping Pong Funnel

1. Which other measurement is pressure related to? (Temperature)
2. As you go higher off the ground, does the pressure increase or decrease? (Decrease)
3. True or false: Air is one example of a fluid (True).
4. True or false: As a fluid increases in speed, its pressure increases (False).

Lesson 25: Diaper Wind Bag

1. How is pressure related to temperature? (Temperature increases as pressure increases)
2. How is pressure related to the elevation of an object above the ground? (Pressure decreases as elevation increases)
3. How is pressure related to the speed of a fluid? (Pressure decreases as airspeed increases)
4. What is the law above called? (Bernoulli's Law)

Lesson 26: Magic Water Glass Trick

1. Where does an object experience the greatest pressure? (Bottom of the Marianas Trench)
2. How is Pressure related to Temperature? (As pressure increases, temperature increases)
3. What is an instrument that scientists use to measure the pressure in the atmosphere? (Barometer)
4. True or False: The pressure is greater on the bottom (dry side) of the index card than on the wet side. (True)

Lesson 27: Hot Air Balloon

1. Which type of air will rise? (Warm air)
2. Situation: You notice from your collection of scientific instruments that the pressure is rapidly increasing, but somehow the temperature is decreasing in that area as well. What could be happening? (An advancing cold front)
3. Where is there more likely to be extreme weather (Cold front).
4. True or False: Pressure is an indicator for slow, stable changes in weather. (False)

Lesson 28: Soda Can Trick

1. What principle describes how pressure behaves in a moving fluid? (Bernoulli's principle)
2. A higher pressure will ________ an object. (Push on)
3. An object experiences pressure in the Earth's atmosphere in which direction more? (Equally in all directions)
4. If an object is higher in altitude above the earth, it experiences which pressure in relationship to an object at sea level? (Less pressure)

Lesson 29: Genie in a bottle

1. Which atoms are likely to be under greater pressure (Hotter atoms)
2. Fill in the blank: If air moves more quickly over a surface, that surface will experience ______________ pressure than others. (Lower)
3. The above principle explains: (Why airplanes fly)

Lesson 30: Cartesian Driver

1. When the diver sinks, what's going on? (The test tube sinks because the when you squeeze the bottle, you increase the pressure of the water and this forces water up into the test tube, which then compresses the air inside the tube. When this happens, it adds enough mass to cause it to sink.)
2. If you used hot water, how does this change the experiment? (A cup of warm water takes up more space than a cup of cold water, so the amount of water you need in the diver will change.)
3. What happens if you try this with a ketchup packet instead of a test tube? (If the ketchup packet sinks when placed in the bottle, it means that the pressure in the packet isn't enough keep the packet floating, so it won't work for this experiment. For ketchup packets that float, it works the same way as the test tube. The bubble in the packet gets compressed and squished into a smaller space, and the packet becomes denser than water so it sinks.)

Lesson 31: Squished Soda Can

1. Which type of heat transfer is being used to heat the can? (Conduction)
2. Why does the can collapse? (The air in the can was heated and expanded. When you cool it quickly by taking it off the stove and placing it in the ice water, the air cools down inside and shrinks, creating a lower pressure inside the can. Because the surrounding air outside of the can is now higher, it pushes on all sides of the can and crushes it.)
3. True or False: When temperature increases, pressure decreases. (False)

Lesson 32: Squished Balloon

1. What are three things required for fire to occur? (Oxygen, fuel, and a spark)
2. Does the balloon get sucked into or pushed into the jar? (Pushed by higher pressure.)
3. Where is the higher pressure in this experiment? (On the outside of the balloon.)

Vocabulary for the Unit

Condensation – when a gas forms into a liquid while suspended in the air, usually on some surface such as a beverage glass.

Crystal – a group of rigid molecules arranged in a regular, repeating pattern. They are the basic units for mineral structures, and are classified according to their chemical makeup and physical properties.

Electromagnetic spectrum – how the light emitted in the universe is categorized according to energy and wavelength. Includes radio waves, microwaves, ultraviolet, infrared, visible, x-rays, and gamma radiation.

Dewpoint – the temperature that moist air will saturate and condense into fog.

Meteorology – the field of study investigating the weather and conditions of earth's atmosphere on a local, regional, and continental scale, usually over a shorter period of time.

Nephology – a type of meteorology that deals with the study of clouds in the Earth's atmosphere

Radiation – energy given off by the sun, in the form of radio waves, microwaves, X-rays, and visible light, for example.