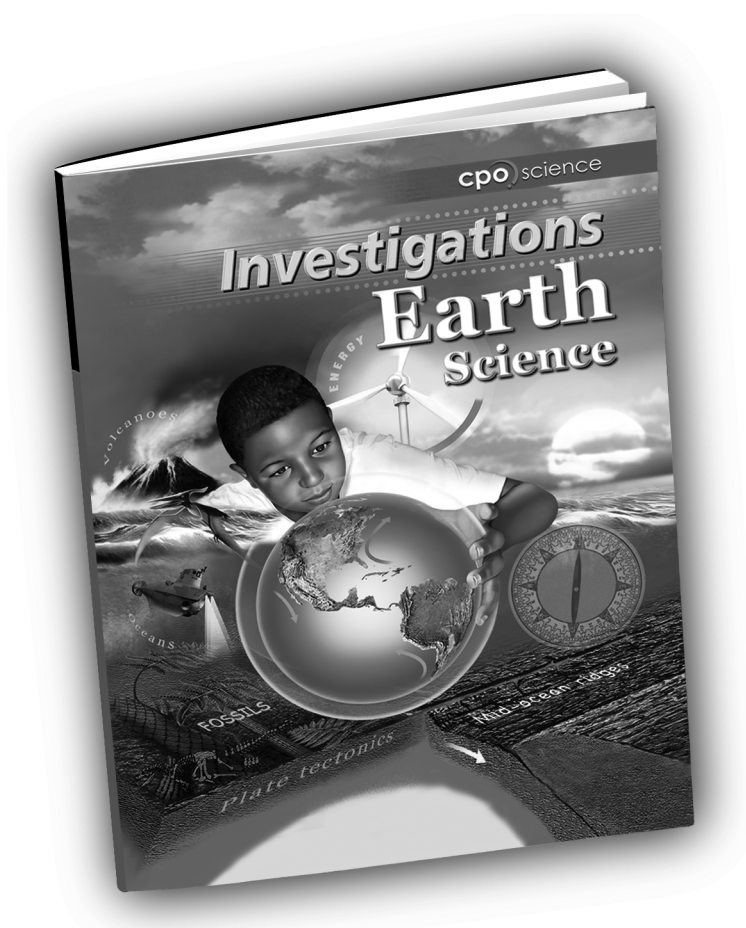


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How to Read an Investigation

Investigation title

Investigation number

Key question for the Investigation

Steps
Proceed in order

Getting ready to do the Investigation

Investigation procedures, equipment setup, and data collection

Data table

Questions you will answer

Investigation 4A The Water Cycle

How is a model of the water cycle in your classroom like the Earth's water cycle?

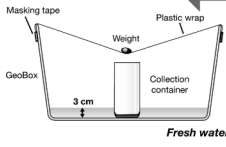
Earth has large quantities of water. The Sun's energy evaporates water from Earth's surface into the atmosphere. This water is then recycled as it cools and condenses into clouds and then precipitates back to the ground as rain, sleet, or snow. The processes of evaporation and condensation are very important in the water cycle. In this investigation, you will learn how to build and observe a model of the water cycle in your classroom.

Materials

- Water (preferably bottled water)
- Beaker to use for pouring water
- Table salt
- Balance
- 2 GeoBoxes
- 2 collection containers (shorter than height of GeoBox)
- 2 weights
- Plastic wrap
- Masking tape
- Metric ruler

1. Setting up

1. Pour fresh water to the 3-centimeter mark in one GeoBox and pour salt water up to the 3-centimeter mark in the other GeoBox. The salt water will be approximately as salty as ocean water.
2. Put a collection container that is shorter than the height of the GeoBoxes in the middle of each of the GeoBoxes. A drinking glass works well for this purpose.
3. Cover the GeoBoxes with plastic wrap. Do not stretch the wrap tightly. Seal the edges using masking tape all the way around box rim.
4. Place a weight in the middle of the plastic wrap on each GeoBox so the lowest part of the plastic wrap is centered over the drinking glass.



Fresh water

Photo or illustration that helps in understanding the Investigation

2. Doing the experiment

1. Place the GeoBoxes in a warm, sunny window so solar still allows you to collect pure water as this is done in the investigation.
2. Check the GeoBoxes periodically.

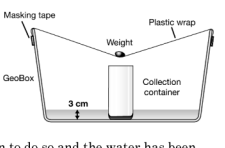
3. Record your observations and what you think is happening inside the GeoBoxes in Table 1.

Table 1: Observations

Day	Fresh water GeoBox		Salt Water GeoBox	
	Observation	What you think is happening	Observation	What you think is happening
1				
2				
3				
4				

3. Thinking about what you observed

- a. What happened to the fresh water level in the first GeoBox?
- b. What happened to the salt water level in the second GeoBox?
- c. What happened to the water level inside the collection containers in each box?
- d. Where is evaporation happening inside the GeoBoxes?
- e. Where is condensation happening inside the GeoBoxes?
- f. How did water get into the collection containers?
- g. How do you think what you observed happening in the GeoBoxes relates to the water cycle?
- h. You will find a water cycle diagram in Chapter 4 of your textbook. Compare this diagram to what took place in the GeoBoxes. Label the diagram below to show where each stage of the water cycle is taking place inside the GeoBox.
- i. Describe a situation where a solar still would be useful for obtaining fresh water.
- j. With teacher supervision only, test the water in the collection containers. If you have permission to do so and the water has been collected in fresh plastic cups, you may taste the water. If not, allow the collected water in each collection container to evaporate. If the water is fresh, you will not see any salt crystals when all the water has evaporated.



NOTE: You will answer all questions and fill-in data on separate fill-in answer sheets



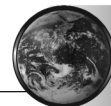
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1A Measuring Flow Rate

How can we measure the rate at which water is flowing?

Science is a process that lets us try to answer questions about the world. Scientists study things often by measuring them. In this investigation, you will measure the flow rate of water from a bucket. Once you have measured the water flowing out of the bucket and calculated the flow rate, you will learn how to organize the information you have collected.

Materials

- Stream table stage
- Bucket with spigot
- Displacement tank
- Stopwatch
- Water
- Simple calculator
- Graph paper

1 Setting up

1. Turn the spigot on the bucket to the closed position. Then, fill the bucket with water up to the fill line.
2. Put the bucket on the stream table stage with the displacement tank underneath the spigot of the bucket. The displacement tank will be used to collect the water.

Safety Note: Do not stand on the stage! This piece of equipment can only support up to a mass of 10 kilograms.

2 Collecting data

In this part of the investigation, you will measure the volume of water (in milliliters) flowing out of the bucket in 20-second intervals.

1. One partner will use the stopwatch to time 20 seconds. Another partner will open, and then close the spigot when 20 seconds have elapsed. (Always open the spigot to the mark for each trial during this investigation).
2. Measure and record the amount of water (in mL) collected by the displacement tank in the second column of Table 1. Make sure the displacement tank is flat on the table when you read and record the amount in the data table.
3. Empty the displacement tank back into the bucket. Make sure the water level is back up to the original fill line.
4. Repeat the process for Trial 2 and Trial 3. Remember to fill the bucket up to the fill line before starting the next trial to make up for any spilled water.



Table 1: Volume when spigot is turned to the notch

Trial	Volume of water (mL)	Time (seconds)
1		
2		
3		

3 Using your measurements

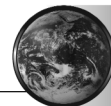
1. Flow rate is the term used to describe an amount of water flowing during a specific time period. For this investigation, we will use units of mL/sec to describe the flow rate of the bucket. Calculate the flow rate for each of the three intervals and fill in the second column of Table 2. Flow rate is calculated by dividing the milliliters collected by the time in seconds.
2. Once you have calculated the three flow rates in mL/sec, average them and record your answer in Table 2.

Table 2: Flow rate when spigot is turned to the notch

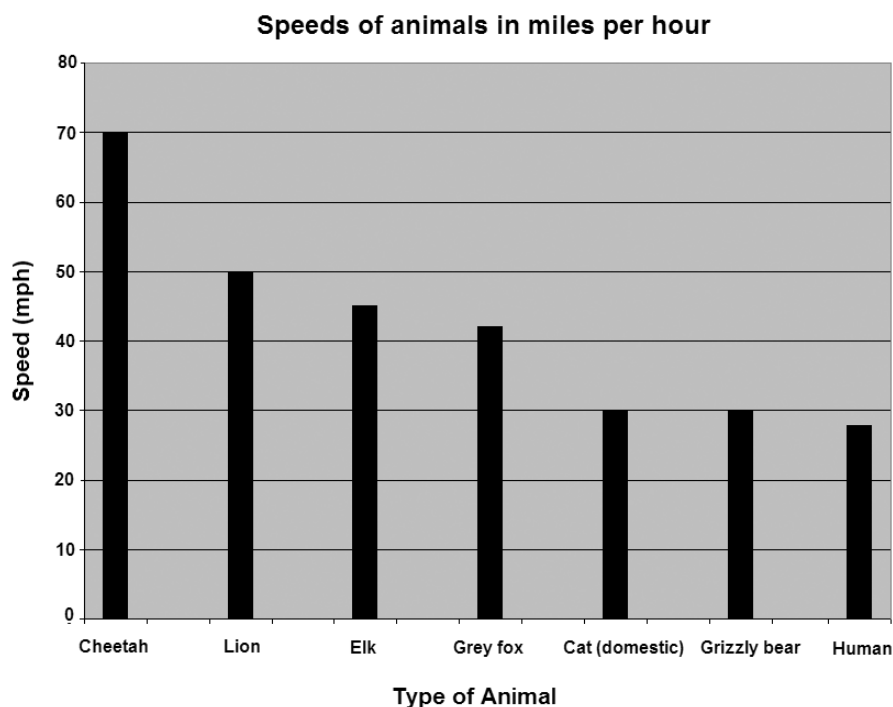
Trial	Flow rate (mL/sec)
1	
2	
3	
Average flow rate $(1 + 2 + 3) \div 3$	

4 Thinking about what you observed

- a. Flow rate describes how fast or slow water is flowing. Speed is also a rate. It is often used in units of miles per hour to describe how fast or slow objects like cars, comets, or even particles of light are moving. What are some other rates that you know?



- b. A bar graph is a useful tool for organizing information. Look at the bar graph below. It shows the top speeds at which different animals can travel.



Make a bar graph of the flow rates from the objects in Table 3. Be sure to label each vertical bar on your bar graph.

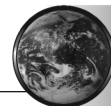
Table 3: Flow rates of common objects

Object	Flow rate (mL/sec)
drinking fountain	40
bathroom faucet	60
kitchen faucet	140
super-efficient shower head	160
garden hose	220
non-efficient shower head	410

- c. Where does your bucket fit onto the flow rate graph? Draw it in on your flow rate graph.
- d. Was the flow rate similar or very different for each of your 3 trials? Why do you think that was?
- e. Do you think the flow rate is the same no matter how much water is in the bucket?
- f. What would you do to test your idea (your answer to question e)?

5 Try it at home

- a.** Find a measuring cup, or another container of known volume and measure the amount of water that flows into it at 20-second intervals.
- b.** Before you perform this water flow activity, think of a use for the water you will collect. Watering plants, boiling food like rice or pasta, or even drinking are all good uses.
- c.** Make a data table and calculate the flow rate of your faucets, shower heads, garden hose, or other water dispensing devices. How do they compare to Table 3 values?
- d.** Make a bar graph with the data you were able to collect at home.
- e.** How does your data collected at home compare to the data you collected in school?



1B Observation, Question, and Hypothesis

Is the flow rate constant no matter how much water is in the bucket?

In the last investigation, you observed the flow rate of the bucket by measuring the volume of water that flowed out of the bucket during three 20-second intervals. For each trial, you started with the same amount of water in the bucket, so the flow rate was similar for each trial.

In this investigation, you will answer the key question after you state a *hypothesis*. You will collect new data and learn how to organize this data in the form of a graph.

Materials

- Stream table stage
- Bucket with spigot
- Bucket without spigot
- Displacement tank
- Stopwatch
- Water
- Simple calculator
- Graph paper

1 Getting started

In the last investigation, you made some observations and found that the flow rate of water emptying out of the bucket was very close to being constant for each of your three trials. You filled the bucket up to the fill line at the top of the bucket with water, so each trial had the same amount of water. But what if we didn't keep filling it back up? What if we let all the water run out of the bucket?

2 Setting up

1. Turn the spigot on the bucket to the closed position. Then, fill the bucket half-way with water.
2. Put the bucket on the stream table stage. Place the second bucket under the spigot of the water-filled bucket on the stage.

Safety note: Do not stand on the stage! This piece of equipment can only support up to a mass of 10 kilograms.



3 Making observations

In this part of the investigation, you will observe the flow of the water as it empties out of the bucket. You won't measure the flow, but you and the other members of your team will watch the flow of the water. Try and be specific with your observations. Use these questions to guide your observations.

1. Is the flow rate getting faster as the bucket empties?
2. Is the flow rate getting slower as the bucket empties?
3. In this part of the investigation, you are collecting *qualitative* data. What would you need to do to collect *quantitative* data?

4 Thinking about what you observed

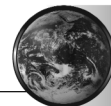
Now that you have observed the water emptying out of the bucket, it is time to form a hypothesis based on the key question.

- a. Make a prediction based on the key question: ***Is the flow rate constant no matter how much water is in the bucket?***
- b. How do you think the flow rate will change?
 - Will the flow rate increase and let more water out for each 20-second interval as the bucket empties?
 - Will the flow rate decrease and let less water out for each 20-second interval as the bucket empties?
 - Will the flow rate remain constant for each 20-second interval as the bucket empties?
 - Will the flow rate increase for some intervals and decrease with others as the bucket empties with no obvious pattern that we can see?
- c. Combine your answers to questions a and b. This will be your hypothesis. State if you think the flow rate will change. If you think it will change, say how it will change.

5 Testing your hypothesis by doing an experiment

To test your hypothesis, you will measure the volume of water that flows out of the bucket for each 20-second interval until the bucket is empty. You will then calculate the flow rate during each of the 20-second intervals. From this data, you will decide if your hypothesis was correct or not.

1. Turn the spigot on the bucket to the closed position. Then, fill the bucket up to the fill line with water.
2. Put the bucket on the stream table stage. Place the displacement tank under the spigot of the bucket.
3. One partner will use the stopwatch to time 20 seconds. Another partner will open, and then close the spigot when 20 seconds have elapsed. (Always open the spigot to the mark for each trial during this investigation).



4. Measure and record the amount of water (in mL) collected by the displacement tank in the second column of Table 1. Make sure the displacement tank is flat on the table when you read and record the volume in the data table.
5. Remember, do not pour the collected water back into the bucket on the stage. Pour the water into the collection bucket provided by your teacher.
6. Repeat the 20-second intervals until the bucket is empty, or no more water flows out of the spigot.

Note: Copy this data table into your notebook or on a separate piece of paper. You may not need all 12 interval rows on the data table.

Table 1: Volume when spigot is turned to the notch

Interval	Volume of water (mL)	Time (seconds)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

6 Using your measurements

1. Once you have completed your measurements, use your data to calculate the flow rate for each interval.
2. Record the values in Table 2.

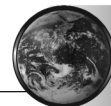
Table 2: Flow rate when spigot is turned to the notch

Interval	Flow rate (mL/sec)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

7 Making a graph

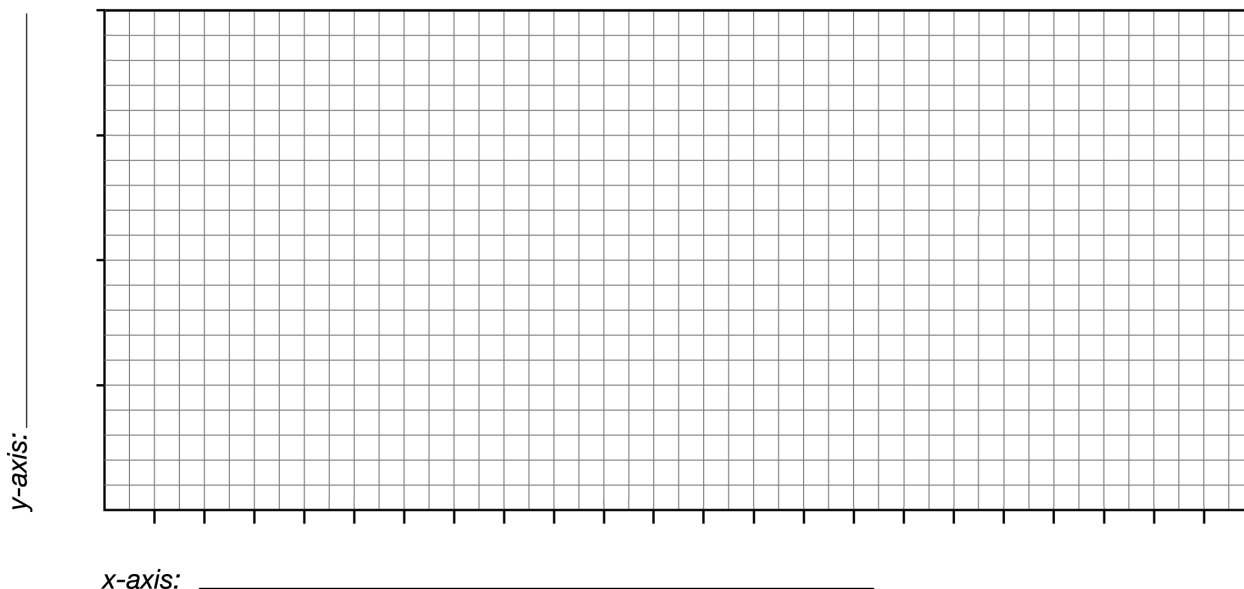
You have collected data. Now you need to interpret this data. One way to interpret data is to make a picture of it. A graph is a picture of data. It can help you identify patterns, trends, or other important information that may help to verify a hypothesis or make a prediction. A graph compares two types of information.

1. The two types of data in this investigation are flow rate and the interval number. You are going to make a graph of flow rate versus interval number.



2. There are many kinds of graphs. Each is useful in certain situations. You are going to use a bar graph for this investigation. A bar graph is useful to indicate specific amounts of things, like flow rate at different time intervals.
3. On the graph below, plot your data. You will put the flow rate on the y -axis, and the interval number on the x -axis. Draw each bar so that it is two squares wide. The height of each bar equals the flow rate for one interval.
4. Color in all the bars the same color with a pencil, pen, or colored pencil.

Title: _____



8 Analyzing your data

- a. Was your hypothesis correct? The answer to this question is known as your conclusion. Write a short paragraph to answer this question. Use your graph to help you answer this question.
- b. Compare your data with the data collected by other lab groups. Did the data from the other lab groups support your hypothesis?
- c. Did you find it easier to understand your data in number form on your data tables, or in picture form on your graph?
- d. How can you make data presented in a table easier to understand? How can you make data presented in a graph easier to understand?
- e. What condition was kept constant during each interval?
- f. What condition changed and was not kept constant for each interval?

2A SI Units

How can you become more familiar with SI units?

Measuring is an important part of understanding our world. It helps us answer questions like: How much do I need? How far do we still have left to drive? Is it cooked all the way? To make communicating easier, scientists around the globe have agreed to use the *Metric System*. In 1960, the name “Metric System” was changed to “the International System of Units” or “SI Units” for short. In this investigation, you will become familiar with SI Units.

Materials

- Triple beam or electronic balance
- 1 cup of sand, 1 cup of soil, and 1 cup of gravel in paper cups
- Variety of everyday objects: paperclips, pennies, dimes, etc.
- Meter stick and trundle wheel
- Thermometer
- 3 cups of water at different temperatures

1 Stop and think

- a. How often in your daily life do you use measurements or products that require measurements? List at least three things you have done where it was necessary for you to use a measurement in either length, mass, volume, or temperature. For example: I took my temperature when I was sick.
- b. SI units are used in science. Predict why scientists have agreed to use SI units such as centimeters, meters, and kilometers instead of the English system of inches, feet, and yards.
- c. Teachers always tell you to include units, such as grams or centimeters, when writing your answers. Why is it so important to include units?

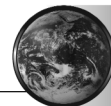
2 Doing the activity

A. Measuring and estimating different masses

1. When estimating, it is important to have a point of reference. In other words, if you are familiar with an object that has a particular measurement, then it is easier to make estimates by using your object of reference as a comparison. For example, if you know that an average large paperclip's mass is one gram, then when you think about the mass of other objects, you can always compare their mass to the mass of the reference object, the paperclip.
2. Knowing that a paperclip is one gram, what other everyday objects might have a similar mass? List at least three possible objects in Table 1. Then determine if you are correct by measuring the mass of each object. Record your results in Table 1.

Table 1: Objects estimated to measure 1 gram

Object	Actual mass
large paperclip	1 g



Object	Actual mass

- Measure the mass of an empty cup, and record your measurements in Table 2.
- Collect a cup containing the pre-measured amount of sand. Feel the mass in your hand. Using the paperclip as your reference point of one gram, estimate the mass of the sand in grams, including the cup. Record your estimate in Table 2.
- Measure the mass of the cup of sand in grams, including the cup, and record your results in Table 2.
- You measured the mass of the cup while the sand was in it, so how do you know the mass of the sand? If you subtract the mass of the empty cup from the measured mass of the cup with the sand in it, you are left with the mass of the sand.

$$\text{Mass of cup with sand in it} - \text{Mass of empty cup} = \text{Mass of sand in cup}$$

- Record the actual mass of the sand you calculated from step 6 in Table 2.
- Calculate the difference between your estimated mass and the actual mass in Table 2.
- Repeat steps 3 - 8 for the cup of clay, soil, gravel, and water.

Table 2: Estimated and actual mass of different materials

Material	Mass of empty cup	Estimated mass of material	Mass of cup with material in it	Actual mass of material	Difference between actual mass and estimated mass
sand					
soil					
gravel					
water					

B. Measuring and estimating distances and areas

1. Again, it is important to create a point of reference. You are probably already familiar with the length of a meter stick. If not, your teacher will hold one up for you to see. Look around the room. In Table 3, list at least three objects you predict will be about one meter in length, then record the actual measurement in meters, in Table 3.

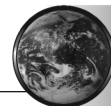
Table 3: Objects estimated to measure 1 meter in length

Object	Actual length
1.	
2.	
3.	

2. Your teacher has set up three pre-measured spaces for you labeled space A, B, and C. Using a meter stick, or other object of your choice, as a reference point, estimate the length of each space and record the data in Table 4.

Table 4: Estimates and measurements of length and width of each space

Space	Estimated length	Actual length	Difference between actual and estimated length	Estimated width	Actual width	Difference between actual and estimated width
A						
B						
C						



Area is a calculation of the length times the width. Using either the trundle wheel or the meter stick, measure the actual space and record your measurements in Table 5.

Table 5: Estimates and calculations of area of each space

Space	Estimated length x width (from Table 4)	Estimated area	Actual length x width (from Table 4)	Actual area	Difference between estimated and actual area
A					
B					
C					

C. Estimating and measuring temperature

1. Room temperature is usually between 20° to 25° Celsius. This is equivalent to 68° to 77° Fahrenheit, the more common temperature scale used in the U.S. However, as scientists, we will stick to SI units and use Celsius. So let's use room temperature as our reference point.
2. Collect a cup of water from your teacher. This will be Cup A. In Table 5, using room temperature of 20°- 25° C as a reference point, estimate the temperature of the water. Then use the thermometer to measure and record the actual temperature.
3. Repeat step 2 for the other two cups of water.

Table 6: Estimates and Measurements, in Celsius, of each cup of water

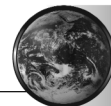
Cup of water	Estimated temperature	Actual temperature	Difference between actual and estimated temperature
A			
B			
C			

3 Thinking about what you observed

- a. Which was the easiest to estimate: mass, length, area, or temperature? Explain why.
- b. Why do you think it is helpful to practice using SI units?
- c. What are the benefits of using SI units over the English system?
- d. The U.S. is one of the only countries to still use the standard system of units in everyday use. What do you think would be necessary to help the U.S. change to using SI units as their primary system instead of the English system?
- e. All scientists use measurements. List at least three scientists and the measurements they would take. You can use any type of scientist such as a scientist who studies life, stars, chemistry, atoms, weather, etc. For example, a biologist would measure the body temperature of animals.

4 Exploring on your own

- a. How familiar are adults in the U.S. with SI units? Create a survey to answer this question. After getting approval from your teacher, conduct the survey, and report your findings using a graph as a visual.
- b. Volume is another unit of measurement. Design an experiment to determine how familiar you are with metric units of volume. After getting approval from your teacher, conduct your experiment.
- c. Create an outline for a board game to help fellow students learn the SI units measuring system. After you get your teacher's approval, create your board game.



2B Modeling a River

Which variables affect the formation of a river?

When an experiment is done, usually one variable is tested to see how it affects another variable. In this investigation, you will learn about variables. You will manipulate variables in an experiment that uses a stream table.

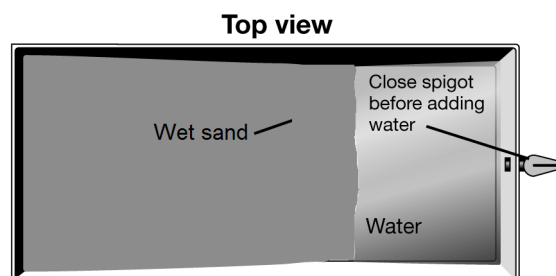
A stream table is a model of a river system. You cannot easily change variables that affect a real river. You can for a model river in a stream table! What variables might you be able to change? You will find out in this investigation!

Materials

- Stream table stage
- Stream table
- Bucket with spigot
- Bucket without spigot
- Displacement tank
- Stopwatch
- Water
- Simple calculator

1 Setting up

1. Fill the top 2/3 of the stream table with sand. Pour some water onto the sand and mix it all up so it is completely wet. The sand should fill the tray up so it reaches just about 2 centimeters below the edge of the tray.
2. Smooth the surface of the sand out as much as you can so it is nice and flat.
3. Place the stream table on one of the rungs of the stand.
4. Move the spigot on the bucket to the closed position. Then, fill this bucket with water. Place it on top of the stage with the spigot pointing over the distribution trough that channels the water into the stream table.
5. Place the empty bucket (the one without the spigot) below the spigot of the stream table to catch water that will run out of the tray once water starts to run into the table.
6. Make sure the spigot on the stream table is in the closed position.



2 Looking at a system

What is a system? A system is a group of objects and the variables that affect those objects. We'll be looking at the stream table as a system. Examine the stream table set up with your group and answer the following questions;

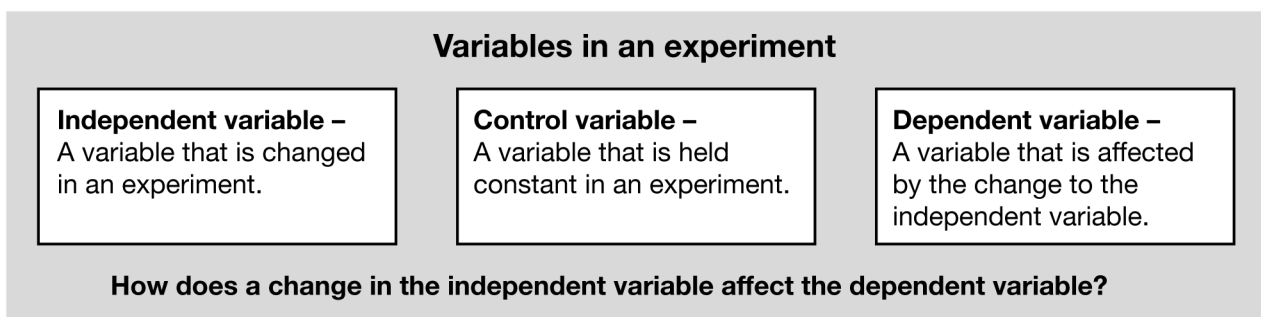
- a. What are the objects that make up the stream table?
- b. What are the variables that affect the objects in the system?
- c. What are some variables that probably do not affect the system?

3 Doing the activity

1. Look at the lists of variables that affect the objects in the stream table system you made in part 2.
2. With your group, observe how these variables affect the process of making a stream, and the final effects on the sand in the tray.
3. Make sure your spigot at the bottom of the sand tray is closed. Place the bucket without the spigot under the spigot on the sand tray.
4. Open the spigot on the bucket that is holding the water and let the water flow into the trough, and down onto the stream table.
5. Carefully observe what happens as the water flows onto the sand and down the tray. Make notes of your observations with your group.
6. Close the spigot when your observations are over.
7. If water gets to the point where it may spill over, open the spigot on the tray and drain some water in the bucket below the spigot.

4 More about variables

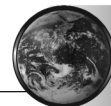
Variables are factors that affect a system. In Part 2 you listed variables that affected the stream table system. In Part 3, you made observations. You watched what happened, and made notes about how you and your group thought the variables affected the system. In an experiment, the investigator usually wants to see how one variable affects the system. Variables in an experiment can be categorized into independent variables, control variables, and dependent variables. These different types of variables are explained below.



5 Posing a scientific question—an inference

Every experiment begins with a question:

- How large is Earth?
- How fast do mountains grow?



- What is the best fertilizer for roses?
- How old is this glacier?

Asking questions helps to focus on what we want to know. Once we find out what it really is that we want to know, we consider the possibilities based on what we have observed. Then, we make a prediction about what we think is true. In science, this is called a hypothesis. The purpose of an experiment is to test if a hypothesis is true.

1. Examine your list of variables you made in part 2, and your observations you made in part 3.
2. With your group, look at your list of variables and decide on a question that involves the formation of a stream in your tray and how changing one of those variables will change the stream.
3. There should be a cause and effect relationship between the variable and its effect on the system. For example; Does making an object heavier make it fall to the ground faster when it is dropped?
4. What is your group's question?

6 Hypothesis and variables

Once you have your question formed, it is time to make a hypothesis—what do you and your group think will happen to your dependent variable when you change your independent variable. Your hypothesis is a possible answer to this question.

Table 1: Your hypothesis, variables, and experiment

What is your question?	
What is your hypothesis?	
What is your independent variable?	
What are your control variables?	
What is your dependent variable?	

7 Designing your experiment

It is time to plan what you will do to test your hypothesis. This is what designing an experiment is all about. Answer the questions below and present your proposal to your teacher for final approval.

- a. What are you going to change about your independent variable?

- b. How will you measure and record this change? (Hint: make a data table)
- c. What are you going to measure concerning your dependent variable?
- d. How will you measure and record any change?
- e. What will you do to ensure your control variables remain the same?
- f. What is the procedure for your experiment?
- g. How will you know if your hypothesis is correct or not?

8 Setting up and performing your experiment

Once you have approval from your teacher, carefully follow your group's plan and perform your experiment. Be sure to take notes about observations, things you may or should have done differently, or things you did well as your experiment is underway. Good luck!

9 Evaluating your data

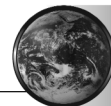
- a. Was your experiment able to answer your question?
- b. Did this experiment lead you to think of any other scientific questions? What are they?
- c. What would you have done differently next time you design and perform an experiment?
- d. What was successful that you would try again in your next experiment?
- e. Can you present your data graphically, or in some other way that would help you to communicate your findings?

10 Conclusions

- a. Was your hypothesis correct?
- b. If not, can you tell why it was not correct?
- c. Did you make any interesting observations that were not part of the original experiment?

11 Presenting your findings

As time permits, gather your data together, make any graphs, charts, or diagrams that would be helpful, and present your findings to your class as a group. All members should have some part in the presentation. Write up a report that summarizes your experience.



3A Convection in Earth's Atmosphere

How is convection responsible for the movement of air through the atmosphere?

If you have ever seen a hot air balloon in the sky, you may have asked yourself a few questions: “How does the balloon rise up?” or “How does it sink back to the ground?” In a hot air balloon, a flame is ignited inside the balloon to warm the air, causing it to become less dense. The less dense air in the balloon causes it to take flight. When the flame is allowed to go out, the air inside the balloon cools off and becomes denser so the balloon sinks back toward the ground. In this investigation, you will explore how convection moves air from one place to another, forming winds.

Materials

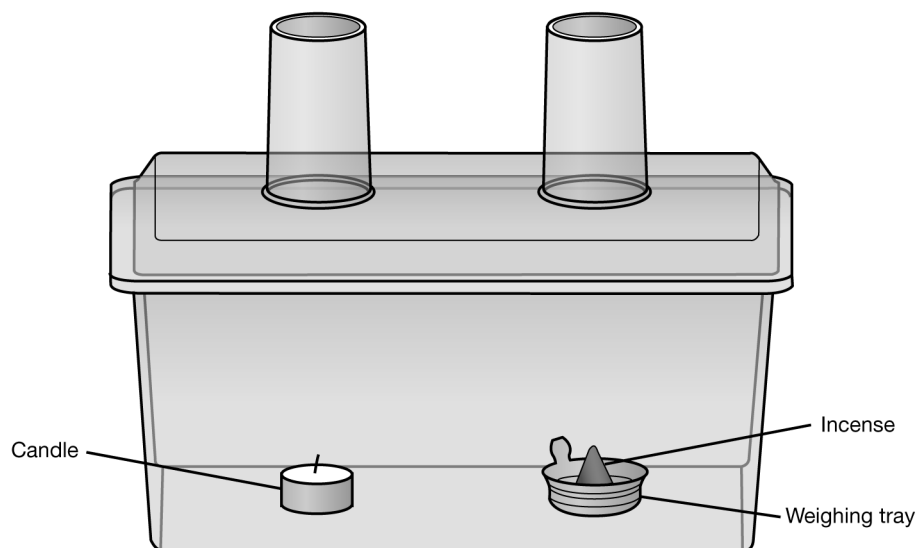
- GeoBox (to be used as a convection chamber)
- Candle
- Long fireplace matches
- Safety goggles
- Incense
- Aluminum weighing dish
- A small piece of cardboard

WARNING — This lab contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

1 Setting up and making observations

Safety tip: Use caution when working with an open flame. Long hair should be tied back. Loose or bulky outer layers of clothing should be removed.

1. Gather the materials listed above. Remove the lid of the GeoBox
2. Carefully place the candle into the GeoBox so that it will be under one of the two chimneys that are on the lid. Put the incense in the weighing tray and place it in the GeoBox so that it will be under the other chimney. See the diagram below.
3. Carefully, light the candle. Place the lid back onto the box.
4. Place your hand over the chimney above the candle. What do you feel with your hand?
5. Remove the lid from the GeoBox, and light the incense. Place the lid back on, and observe what you see inside the box.



6. Observe what is happening inside the box and chimneys for several minutes. Sketch your observations.

2 Stop and think

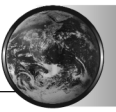
- a. Define convection. Where is the air rising and sinking in the box/convection chamber?
- b. Describe the movement of the smoke inside the box. Be sure to describe the movement of smoke in the two chimneys as well.
- c. What is the purpose of the smoke from the burning incense?
- d. Based on your sketch in part 1 and your answers to these questions (a - c), make a diagram that illustrates how convection is taking place in the GeoBox. Draw and label where air is rising, sinking, becoming less dense, and becoming more dense.

3 Further exploration

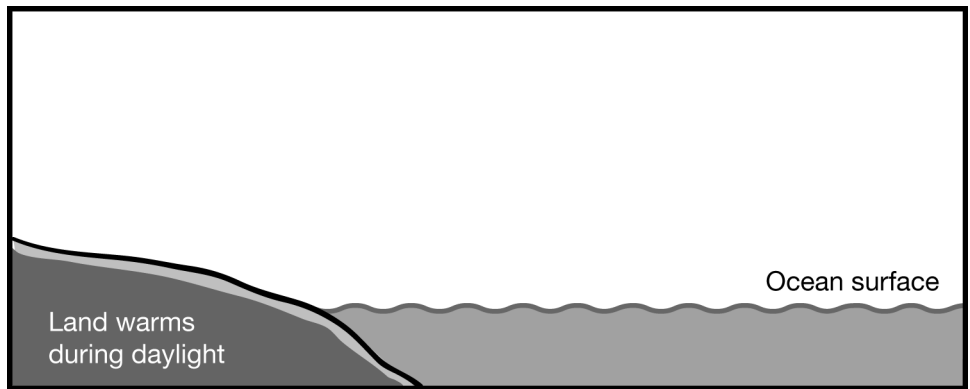
1. Carefully place your fingers inside the two chimneys. Take note of what you feel. Is the air rising or sinking in each of the chimneys?
Safety note: Your fingers will be at a safe distance from the candle when you place your fingers in the chimneys. However, it is always a good idea to work carefully around heat sources especially candles!
2. Cover the chimney above the candle with the piece of cardboard. Observe what happens to the movement of the air inside the GeoBox.
3. Now, cover the chimney above the burning incense with the piece of cardboard. Observe what happens to the movement of the air inside the GeoBox.

4 Thinking about what you observed

- a. Describe the motion of the air in the GeoBox above the candle. Be sure to describe the change in density of the air and whether or not air is rising or sinking.
- b. Describe the motion of the air in the box above the incense. Be sure to describe the change in density of the air and whether air is rising or sinking.
- c. Why is the air rising in the chimney above the candle? Why is the air sinking in the chimney above the incense?
- d. Describe how the air is moving between the candle and the incense. How can you explain this movement in terms of convection?
- e. Think about what you observed inside the GeoBox. Explain how convection currents in the atmosphere form and how they are related to wind.

**5 Exploring on your own**

- a. A sea breeze is a type of wind that is commonly found along coastal areas during daytime hours. During the day, the sand of a beach absorbs more heat than the ocean, causing it to become warmer. This causes



a wind known as a sea breeze to flow from the ocean to the land. Using arrows, draw how convection currents would form in the situation in the picture. Label the sea breeze, the location where air becomes less dense, and the location where the air becomes denser.

- b. A land breeze is a type of wind that is commonly found along coastal areas during the night time. During the night the ocean tends to retain more heat than the sand on the beach. This causes the ocean



temperature to typically become warmer than the sand on the beach. This temperature difference causes convection currents to form and winds to blow from the beach out to the ocean. Using arrows, draw how convection currents would form in this situation. Label the land breeze, the location where air becomes less dense, and the location where air becomes denser.

3B Density

Why do some objects float in water, while others sink?

Density is an important earth science concept. Understanding density is useful for understanding weather systems and plate tectonics. So, what is density?

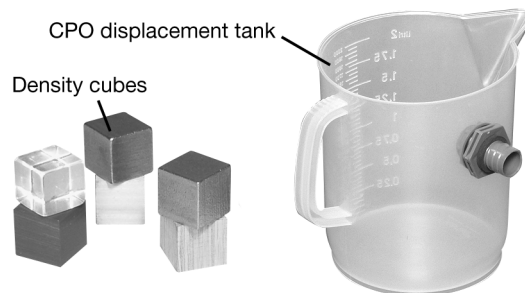
Density is the ratio of mass to volume. It is a property of solids, liquids, and gases. In this investigation, you will determine the densities of cubes made of different materials. Based on the density of each cube, you will predict and test whether they float or sink in water.

Materials

- Displacement tank
- Density cubes (steel, wood, aluminum, copper, PVC)
- A digital balance or a triple beam balance
- Metric ruler
- 100-milliliter graduated cylinder
- A 250-milliliter beaker
- Water
- Paper towels
- Disposable cup
- Simple calculator

1 Setting up

1. Your setup should include density cubes (steel, wood, aluminum, copper, and PVC), a balance, a metric ruler, and a displacement tank.
2. Examine and hold each cube, and predict whether it will sink or float in water. Record your predictions in Table 1.

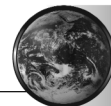


2 Stop and think

Table 1: Density Table

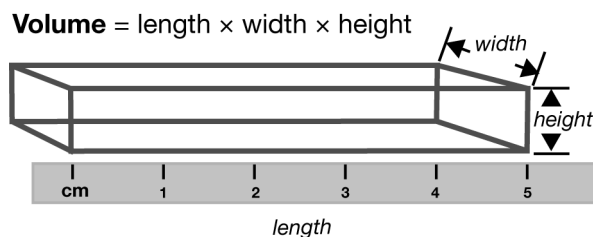
Material of solid cube	Prediction (Sink or Float?)	Mass (g)	Volume (cm ³)	Density (g/cm ³)	Results (Sink or Float?)
Steel					
Wood					
Aluminum					
Copper					
PVC					

- a. Consider the cubes. How is each cube similar? Different?
- b. What factors will determine whether the cube will float or sink in water?
- c. What is density? How does the density of a solid cube (g/cm³) relate to the density of water (g/mL)?



3 Doing the experiment

1. Use a balance to determine the mass of the steel cube, and record in Table 1.
2. Determine the volume of the steel cube and record it in Table 1.
Note: To find the volume of a regularly-shaped object, measure the length, width, and height of the object, and multiply these dimensions.



3. Calculate the density of the steel cube. Divide the mass by the volume:
Density (g/cm^3) = mass (g) / volume (cm^3). Record the density values in Table 1.
4. Repeat steps 1-4 using the other cubes.

$$\text{Density (g/cm}^3\text{)} \longrightarrow D = \frac{m}{V} \quad \begin{array}{l} \longleftarrow \text{Mass (g)} \\ \longleftarrow \text{Volume (cm}^3\text{)} \end{array}$$

5. Find the volume of each cube using the displacement tank.
 - Place a disposable cup under the spout to catch the overflow of water.
 - Fill the tank with water until it just begins to run out of the spout. The volume of water in the tank will be approximately 1,400 mL.
 - When the water stops, remove the cup and place a dry beaker under the spout.
 - When you place your object in the tank, water will flow out of the spout. As soon as the water stops flowing, pour the water from the beaker into a graduated cylinder to measure the volume of water. This volume is equal to the volume of your object.



4 Thinking about what you observed

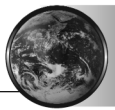
- Describe how to find the density of a regularly-shaped object like a solid cube.
- Explain why these cubes have similar volumes but different masses.
- Explain why these cubes have different densities.
- Do you notice any correlation (pattern) between the density of an object and its ability to sink or float?
- As a geologist, how would you determine the densities of different rocks found in a field?
- Did you observe a difference in the depth in which an object floated or the rate in which the object sunk in the water? Explain your answer.

5 Further exploration—Finding the density of an irregularly-shaped object

- With your group, select a few objects that are irregularly-shaped. List the objects in Table 2. Record the data you collect in steps 2 through 6 in Table 2.
- Predict whether the objects will sink or float in water.
- Find the mass of each object.
- Use the displacement tank to find the volume of each object.
- Use the mass and volume information to calculate the density of each object.
- Record the results of your test in the last column of Table 2.
- Write a short paragraph describing your results. State whether or not your predictions were correct.

Table 2: Density Table

Object	Prediction (Sink or Float?)	Mass (g)	Volume (cm ³)	Density (g/cm ³)	Results (Sink or Float?)



4A The Water Cycle

How is a model of the water cycle in your classroom like Earth's water cycle?

Earth has large quantities of water. The Sun's energy evaporates water from Earth's surface into the atmosphere. This water is then recycled as it cools and condenses into clouds and then precipitates back to the ground as rain, sleet, or snow. The processes of evaporation and condensation are very important in the water cycle.

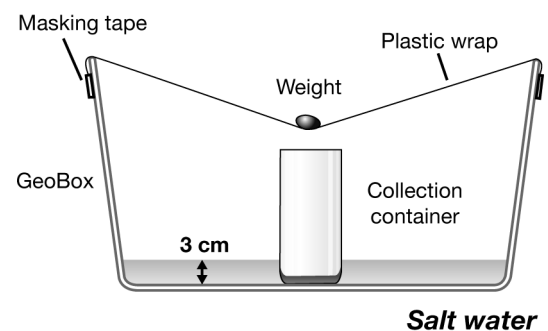
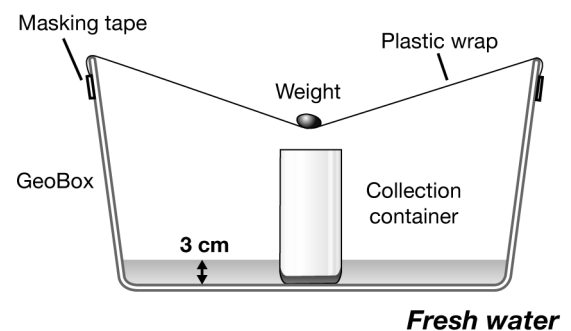
In this investigation, you will learn how to build and observe a model of the water cycle in your classroom.

Materials

- Water (preferably bottled water)
- Beaker to use for pouring water
- Table salt
- Balance
- 2 GeoBoxes
- 2 collection containers (shorter than height of GeoBox)
- 2 weights
- Plastic wrap
- Masking tape
- Metric ruler

1 Setting up

1. Pour fresh water to the 3-centimeter mark in one GeoBox and pour salt water up to the 3-centimeter mark in the other GeoBox. The salt water will be approximately as salty as ocean water.
2. Put a collection container that is shorter than the height of the GeoBoxes in the middle of each of the GeoBoxes. A drinking glass works well for this purpose.
3. Cover the GeoBoxes with plastic wrap. Do not stretch the wrap tightly. Seal the edges using masking tape all the way around box rim.
4. Place a weight in the middle of the plastic wrap on each GeoBox so the lowest part of the plastic wrap is centered over the drinking glass.



2 Doing the experiment

1. Place the GeoBoxes in a warm, sunny window. You have now made a *solar still*. A solar still allows you to collect pure water using the Sun's energy. You will see how this is done in the investigation.
2. Check the GeoBoxes periodically.

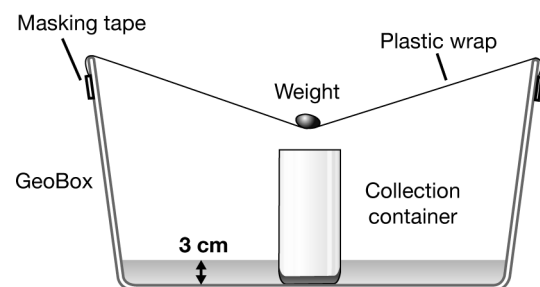
3. Record your observations and what you think is happening inside the GeoBoxes in Table 1.

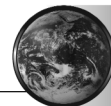
Table 1: Observations

Day	Fresh water GeoBox		Salt water GeoBox	
	Observation	What you think is happening	Observation	What you think is happening
1				
2				
3				
4				

3 Thinking about what you observed

- What happened to the fresh water level in the first GeoBox?
- What happened to the salt water level in the second GeoBox?
- What happened to the water level inside the collection containers in each box?
- Where is evaporation happening inside the GeoBoxes?
- Where is condensation happening inside the GeoBoxes?
- How did water get into the collection containers?
- How do you think what you observed happening in the GeoBoxes relates to the water cycle?
- You will find a water cycle diagram in Chapter 4 of your textbook. Compare this diagram to what took place in the GeoBoxes. Draw this diagram at the right and label where each stage of the water cycle is taking place inside the GeoBox.
- Describe a situation where a solar still would be useful for obtaining fresh water.
- With teacher supervision only, test the water in the collection containers. If you have permission to do so and the water has been collected in fresh plastic cups, you may taste the water. If not, allow the collected water in each collection container to evaporate. If the water is fresh, you will not see any salt crystals when all the water has evaporated.





4B Water in Earth's Atmosphere

How can we measure water content in the atmosphere?

When water evaporates from Earth's surface, the atmosphere temporarily stores that moisture, until it precipitates back down to the land and oceans. This is all part of the water cycle.

Relative humidity is a measure of how much water vapor is in the air compared to the maximum amount the air can hold at a certain temperature. Relative humidity is expressed as a percent. When the air is saturated, it has one hundred percent relative humidity. When the air holds half the humidity that it could potentially hold at a certain temperature, it has a relative humidity of fifty percent. When the relative humidity is high, it feels “sticky.”


In this investigation, you will determine some factors that influence evaporation and use a device called a sling psychrometer to indirectly measure relative humidity in the atmosphere.

Materials


- Sling psychrometer
- Relative humidity chart
- Stopwatch
- Graph paper
- Water in a wide-mouth container
- Vaporizer or humidifier
- Simple calculator

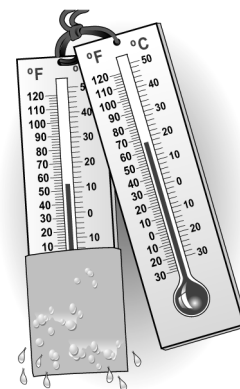
1 Doing the experiment

1. Place the felt-covered bulb in room temperature water until the felt is thoroughly wet. Place the two thermometers back-to-back. Slip a rubber band over them to hold them together.
2. Slide the string through the holes in the thermometer backing and tie off the end. Your sling psychrometer is now assembled.
3. Take the sling psychrometer to an open, spacious area in your classroom or another indoor location. Gently swing the psychrometer in front of you in a circular pattern for three minutes.

 **Safety Tip:** Be sure to provide enough space so that your classmates will not be struck by the swinging thermometers.

4. Record the temperature of the wet-bulb and the dry-bulb thermometers in Table 1. Your teacher will give you a version of this table to write on.
5. Record the difference between the two temperatures.
6. Repeat steps 1-3 in another location. If you are outside and precipitation is falling, choose a covered porch, walkway, or pavilion.
7. Repeat steps 1-3 in a room in which a vaporizer or humidifier has been operating for at least 30 minutes.

 **Safety Tip:** The steam from a vaporizer can cause serious burns. Do not put your hands or face near the steam vent.



8. Share the data you collected with your classmates. In the remaining rows of the table, record data collected in three additional locations by other lab groups.

Table 1: Sling psychrometer data

Location description	Dry bulb temperature (°C)	Wet bulb temperature (°C)	Temperature difference (°C)

2 Analyzing your data

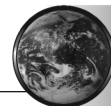
- Which was generally higher, the wet bulb temperature or the dry bulb temperature?
- Give a reason for the temperature difference between the thermometers.
- In which location did you find the greatest temperature difference between the two thermometers? Which location had the smallest difference?
- What environmental factors seem to be connected to large temperature differences between the two thermometers? What factors seem to be connected to small temperature differences?
- How might the temperature difference at each location be related to the water content of the atmosphere at each location?

3 Finding relative humidity

Relative humidity is a term that you may have heard mentioned on your local weather report. It is a measure of the actual water content of the air compared to the potential amount that could be in the air at that temperature and pressure. If the relative humidity is 100%, water added to the atmosphere condenses right back out again. Days with high relative humidity feel “sticky” because perspiration can’t easily evaporate from your skin to cool you.

Use your data from the experiment to determine the relative humidity in each location tested.

- Obtain a relative humidity chart from your teacher. On the left-hand column of the chart, find the dry-bulb reading for your first measurement.
- Find the difference between the dry- and wet-bulb readings at the top of the chart.



3. Find the box where the two readings cross. The number in the box tells you the relative humidity at this location. Record the relative humidity in Table 2.
4. Repeat steps 1-3 for each location measured.

Table 2: Relative humidity for each location tested

Location	Relative humidity (%)

4 Analyzing your results

- a. Make a bar graph which shows the relative humidity of the locations tested, in order from lowest to highest. On each bar, print the dry bulb temperature at each location.
- b. Does your graph show a relationship between dry bulb temperature (the temperature of the atmosphere) and the relative humidity? Using what you know about water content in the atmosphere, explain why or why not.
- c. Challenge: It takes specialized equipment to directly measure water content in the atmosphere. This equipment tells how many grams of water are present in a cubic meter of air—a measurement called absolute humidity. If the relative humidity was 100% in two cities, but one had a dry bulb temperature of 16°C and the other was at 32°C, would their absolute humidity be the same? Why or why not?

5A The Atmosphere

Can you measure atmospheric pressure?

The atmosphere is often referred to as an “ocean of air.” As weather systems interact in the troposphere, atmospheric pressure varies slightly above and below the average 1013.25 millibars at sea level. These slight changes in atmospheric pressure are one of the most useful measurements for weather prediction. How are these pressure changes measured? In this investigation, you will build your own atmospheric pressure gauge.

Materials

- Wide-mouth glass jar
- Permanent marker
- Yellow (wood) glue
- Approximately 0.5 meters string
- Plastic grocery bag
- Broom straw or coffee stirrer
- Cellophane tape and duct tape
- Three index cards
- Scissors
- Shoe box
- Ruler and/or protractor
- Weather tools set

Optional materials

- Small mirror
- Laser pointer

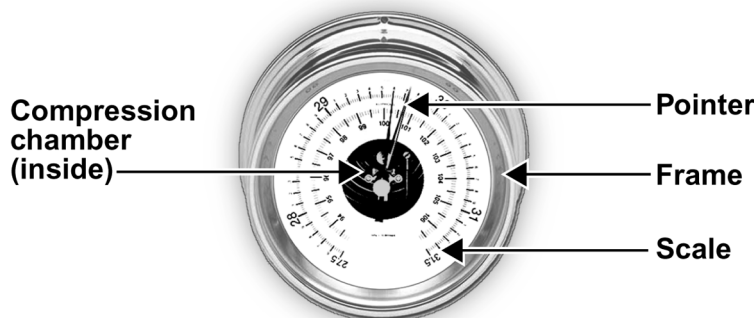
1 Parts of an aneroid barometer

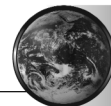
How does an aneroid barometer work? An aneroid barometer consists of a sealed canister of air (the compression chamber) with a flexible top called a *tympanum*. The tympanum is pressed inward when atmospheric pressure increases. It bulges outward as the atmospheric pressure decreases. A pointer is used to measure these movements of the tympanum.

To build a reliable barometer, you will:

- Make a compression chamber to observe changes in atmospheric pressure.
- Construct a pointer that amplifies tiny changes and shows them on a scale.
- Contain the compression chamber in a sturdy frame so that you can move your barometer around and take readings that are consistent.
- Calibrate your barometer so that its readings are accurate even if it undergoes temperature changes.

Parts of an Aneroid Barometer



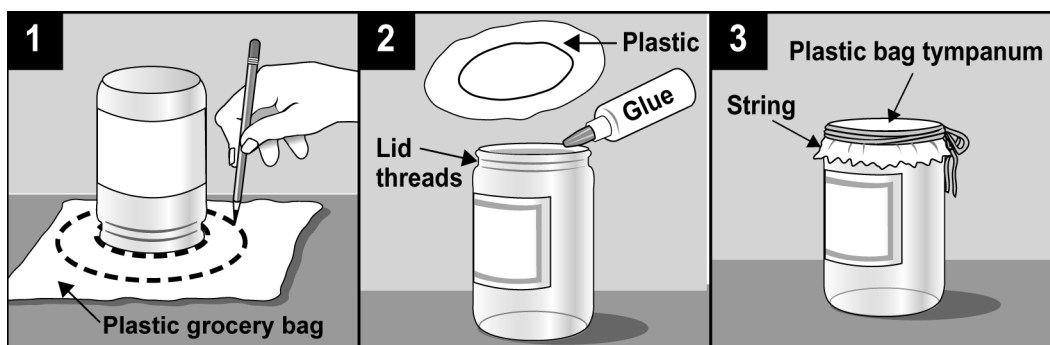


- a. A compression chamber must be airtight yet flexible so that you can measure changes in volume of the gas it contains. With your group, brainstorm materials you could use for a compression chamber.
- b. How will you measure your compression chamber's changes in volume?

2 Building the compression chamber

Your compression chamber must be rigid except for the tympanum. The rigid part is where you will attach a frame and where you will pick it up.

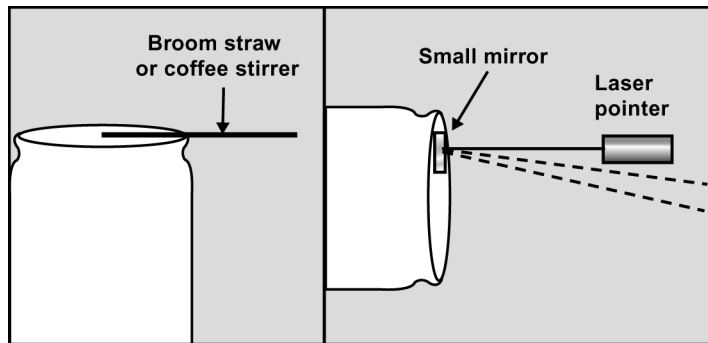
A wide-mouth glass jar will make a good compression chamber. The size of the jar affects the amount of movement of the tympanum. A large mayonnaise jar and a peanut butter jar have similar sized openings, but the larger volume of the mayonnaise jar will cause larger movements of the tympanum. You will form the tympanum by sealing a piece of plastic grocery bag over the mouth of the jar.



1. Cut the grocery bag in half so that you have a flat piece of plastic to spread out on your work space.
2. Place the jar upside down on an area of the plastic that is free of even the smallest holes. Use a permanent marker to trace an outline of the mouth of the jar on the plastic.
3. Remove the jar. Draw a larger circle around the first circle. Your new circle should be 6 centimeters larger in diameter than the first.
4. Cut out the larger circle with scissors.
5. Apply a generous amount of glue to the lid threads of the jar.
6. Center the plastic circle over the jar. Wind several tight turns of string around the jar's lid threads, making sure the plastic fits tightly over the jar.
7. Tie off the string. When the glue dries, cut away the excess plastic.

3 Constructing the pointer

The pointer has two purposes. It makes the small movements of the tympanum visible, and it allows those movements to be recorded as a number. Here are some suggestions:



Study the pictures above. They may spark further ideas among your group. Choose one method to try.

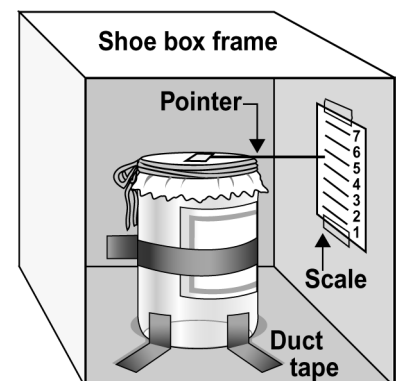
- Write out a step-by-step procedure for constructing your pointer.
- As you construct the pointer, you may encounter unexpected issues that may require you to modify your procedure. When finished, revise the steps you listed in Part 3a to reflect your final procedure.
- Test your mechanism by gently pushing on the tympanum with your finger. Could you see the pointer's movement? If not, devise a method to increase the distance moved by the pointer. Record any final changes made to your procedure.

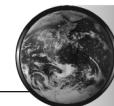
4 Attaching a frame and scale

The frame must allow the barometer to be moved without disturbing the pointer. The frame also supports the pointer scale. The frame must be sturdy so that the positions of the pointer and scale cannot change. Movement between the pointer and the scale will cause enormous errors.

A sturdy box makes a good frame. The compression chamber with attached pointer must fit easily inside the frame. The pointer should almost touch one of the walls of the box.

- Attach the compression chamber to the frame. The position of the compression chamber inside the frame should not change even if the frame is moved from one location to another.
- Create a scale to help you measure the movement of the pointer. Use a pen and a ruler to make a series of evenly-spaced marks on a piece of white paper. Number each mark 1, 2, 3, and so on.
- Slide your scale between the pointer and the wall of your frame. Attach the scale with tape so that you can record movements of the pointer. For example, if the pointer currently points to the space between 4 and 5 on the scale, you would record the atmospheric pressure as 4.5 units.





5 Calibrating your barometer

Changing atmospheric pressure is not the only force that will cause the tympanum to bulge in and out. If your barometer warms up, the air inside will expand and that, too, will make the tympanum bulge out. Similarly, if the barometer cools, the tympanum will bulge inward. You need a way to correct readings for temperature. Commercial barometers do this with a second mechanism inside so that the displayed readings are already adjusted, or compensated, for temperature changes. To keep your barometer from becoming too difficult to build, you will read the temperature from a separate thermometer and use a graph to adjust your barometer readings for changes in temperature.

1. The first step in calibrating your barometer is to make a table of readings over the course of at least one week. Each day, record the temperature in the first column, the pointer reading in the second column, and the reading from the commercial barometer in the last column.

If you find that the temperature varies widely over the course of the week, you may wish to take readings for a second week. Once you have at least three barometer readings at the same temperature you will be able to begin graphing your data.

Table 1: Atmospheric pressure data, Week 1

	Temperature	Scale mark on barometer	Commercial barometer reading
Sample	24°C	3	1031 millibars
Sample	26°C	4	1031 millibars
Day 1			
Day 2			
Day 3			
Day 4			
Day 5			
Day 6			
Day 7			

2. Make a graph to help you convert your barometer readings to millibars. First, rewrite your table, grouping together all readings at one temperature.
3. Label the x -axis of your graph with your pointer scale and the y -axis with the commercial barometer readings. Plot all of the readings *for one temperature* and draw a trend line through the points. Label that line with its temperature. Repeat this process for each group of temperatures. The end result will be a series of trend lines, one for each temperature.
4. After you have taken several sets of readings, you will be able to determine atmospheric pressure using your barometer. Find your pointer scale reading on the x -axis, and then follow that line upward until you meet the trend line for the current temperature. Then read the y -coordinate of that point to find the barometer reading in millibars. Continue to compare your barometer with the commercial one until you can read yours with confidence.

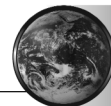
6 Evaluating your design

- a. Use your barometer, thermometer, and graph to measure barometric pressure for an additional week. Record your data, along with data from a commercial barometer, in the table below.

Table 2: Atmospheric pressure data, Week 2

Day	Your barometer reading	Commercial barometer		Day	Your barometer reading	Commercial barometer
1				5		
2				6		
3				7		
4						

- b. What is the maximum difference, in millibars, between your reading and the commercial barometer reading? Calculate the percent error of this reading.
- c. Name two adjustments you could make to increase the accuracy of your barometer.
- d. Look back on your barometer readings for the past week. Can you see a relationship between air pressure and the weather? Do sunny days tend to have high or low pressure? How about rainy days?



5B Heating Land and Water

How does solar radiation affect the heating and cooling of continents and oceans?

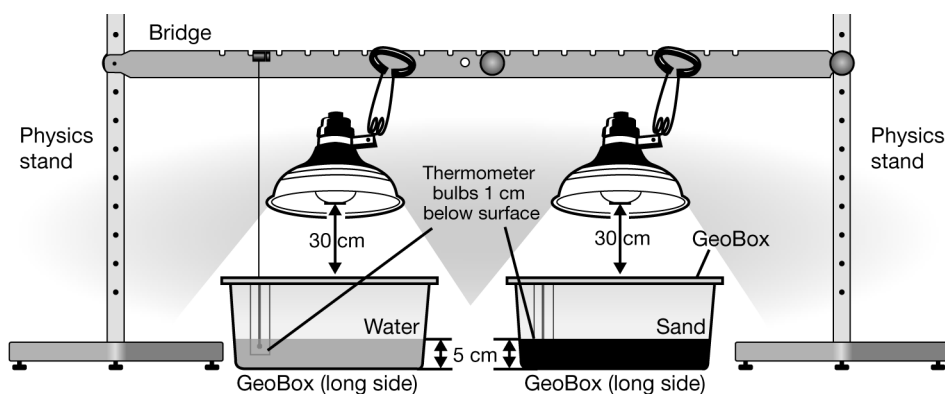
When solar radiation reaches Earth's surface, it is absorbed differently by different surfaces. An important term, which will be useful in explaining the results of this investigation, is specific heat. ***Specific heat*** is the amount of energy needed to raise the temperature of 1 gram of a substance by 1 degree Celsius.

Which has a higher specific heat—the oceans or the land? Having a higher specific heat means that it takes more energy to raise a substance's temperature, but once the substance is warm, it takes longer to cool off. In this investigation, you will find out whether water or land has the higher specific heat, and how that affects local temperatures.

Materials

- 2 GeoBoxes
- 2 Physics stands
- Bridge
- Stopwatch
- a piece of string
- 2 thermometers
- 2 light sources with clips
- Sand (to fill one bin 5 cm deep)
- Water (to fill one bin 5 cm deep)

1 Doing the experiment



1. Set up your materials as shown above. You will need to team up with another lab group in your class to have two physics stands.
2. One tray will contain water and the other will contain sand. Both the water and sand should be added to a depth of 5 centimeters. Each tray will have its own light. Place the lights so that the bottom of the bulbs are about 30 cm directly above the top of their respective trays.
3. Place one thermometer in the sand so that the thermometer bulb is about 1 cm below the surface. Using the piece of string, suspend the other thermometer so that the bulb is about 1 cm below the surface of the water.
4. Wait three minutes. Record the initial temperature of each thermometer in the space provided.
5. Turn the lights on at exactly the same time and use the stopwatch to record temperatures from both thermometers each minute for 10 minutes. Record your data in Table 1.

6. Turn the lights off and continue to record temperatures for an additional 10 minutes. Record your data in Table 1.

Table 1: Time and temperature

	Initial	Heating (light turned on)										Cooling (light turned off)									
Time (minutes)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sand Temp. (°C)																					
Water Temp. (°C)																					

2 Graphing your results

Graph the data, using time as the x -axis variable and temperature as the y -axis variable. Make a key to indicate the curves for sand and water. Don't forget to label your axes, to use units, and to title your graph.

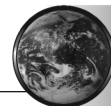
3 Thinking about what you observed

- Which received more heat (radiation) from its lamp, the sand or the water? Or did they receive the same?
- Which material heated up faster?
- Which material cooled down faster?
- Using the term *specific heat*, explain your results.
- Based on your results, which places on Earth would have the smallest/greatest temperature ranges—the land or the sea?

4 Exploring on your own

- Find out which of the world's hemispheres has a higher proportion of water to land and describe how that might influence the temperature variations in the hemispheres.
- Use the term *specific heat* to explain how sea and land breezes work. Also, refer to Section 5.3 of your text to answer this question in terms of convection in the atmosphere.
- Give an explanation for why the temperature range (8 degrees) for Boston, MA (a coastal city) is smaller compared to the temperature range (11 degrees) for Las Vegas, NV (a landlocked city).

	Temperature range for January (°C)	Total degrees in range
Coastal city Boston, MA	- 6 to 2	8
Landlocked city Las Vegas, NV	3 to 14	11



6A Observing the Weather

How can you use weather data to make predictions?

In this investigation, you will go outside to practice your observation skills. You will observe cloud types and use instruments to measure temperature, air pressure, and humidity. You will use the Beaufort wind scale to make observations about wind speed and direction.

In this investigation, you will keep a journal of weather conditions for four weeks. Then you will graph your data and look for patterns in the measurements you recorded.

Materials

- Weather tools set (includes a thermometer, a barometer, and a hygrometer)
- Cloud chart
- Beaufort wind scale
- Compass
- Graph paper
- Blue and pink highlighter pens

1 Setting up

1. Gather the instruments and charts you'll need to collect your weather data.
2. Take a look at the data chart on the next page. Decide as a group which instrument or chart is needed to take each measurement.
3. In your group, pass around each instrument. Discuss the unit you'll use to report each of your measurements. Everyone should practice reading each instrument and chart.
4. Decide on an outdoor location and a time of day to make your measurements.

2 Stop and think

- a. Why is it important to take measurements in the same location every day?
- b. Why is it important to take measurements at the same time every day?
- c. What season are you currently experiencing? Will you have more hours of daylight at the end of this four-week period, or fewer? Do you think the temperatures you measure will be getting warmer, cooler, or staying about the same over the next four weeks?

3 Doing the experiment

1. Assign each person in your group an instrument or chart and one type of data to collect. Rotate after four or five days so that each person has a chance to collect each type of data. Note: Be sure to use the correct units for your measurements.
2. Spend five minutes at the beginning or end of class each day collecting and recording your weather data in the chart on the following page. For percent cloud cover, estimate whether 0%, 25%, 50%, 75%, or 100% of the sky is cloudy.
3. In the notes section, record any precipitation (rain, snow, etc.) that has fallen since last time you took measurements, and whether any precipitation is currently falling.

Table I: Weather data

Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____
Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____
Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____
Notes: _____ _____	Notes: _____ _____	Notes: _____ _____	Notes: _____ _____	Notes: _____ _____
Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____
Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____
Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____
Notes: _____ _____	Notes: _____ _____	Notes: _____ _____	Notes: _____ _____	Notes: _____ _____

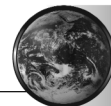


Table I: Weather data

Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____
Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____
Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____
Notes: _____ _____	Notes: _____ _____	Notes: _____ _____	Notes: _____ _____	Notes: _____ _____
Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____
Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____	Temp: _____ Pressure: _____ Humidity: _____ Wind speed and direction: _____ _____
Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____	Cloud type and % sky covered: _____ _____
Notes: _____ _____	Notes: _____ _____	Notes: _____ _____	Notes: _____ _____	Notes: _____ _____

4 Graphing your data

You have collected weather data for four weeks. Making graphs of this data can help you to find patterns that influence the weather in your region. Each member of your team will be responsible for a different graph. Make separate line graphs for temperature, pressure, humidity, wind speed, and percent cloud cover.

1. For each graph, plot the data you collected on the y -axis against time in days on the x -axis. Be sure to include even the days no data was collected. Remember to draw a line or curve of best fit rather than simply connecting the dots on your graph.
2. Using a blue highlighter pen, color in each column of your graph that represents a day where precipitation fell.
3. Label each graph appropriately.

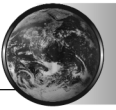
5 Thinking about what you observed

The following questions will help you think like a meteorologist! You will be looking for patterns in your data that could help you recognize when certain weather events are likely to occur.

- a. Examine the blue colored-columns on your five graphs. Is there a pattern to the data on days with precipitation? For example, is the air pressure usually higher or lower on rainy days? Does it tend to snow on the coldest days, or warmer days? Of course, your answers will depend on your season and climate. Just note any data patterns you find in your graphs.
- b. Meteorologists look for patterns to help them predict what will happen in the future. Take a second look at your five graphs. Is there anything that usually happens *before* you get precipitation? For example, does the temperature usually rise, or the wind speed up? Provide specific evidence from your data as you answer these questions.
- c. Look at your cloud cover data. Which type of cloud did you see most often? Mark those days with a pink highlighter. Since the column may already be colored blue, just highlight the number on the x -axis for those days. Do you see any patterns here? Does this type of cloud usually occur with rising or falling pressure, temperature, humidity, or wind speed? Or do the clouds seem to appear randomly?
- d. Go back and look at the prediction you made in part 2c. Was there a relationship between hours of daylight and the temperatures you recorded? Why or why not?

6 Exploring on your own

Watch a local weather forecast. What sorts of evidence does the forecaster use to predict the weather? Which types of data—temperature, pressure, humidity, wind speed, cloud type, or cloud cover—were mentioned in the predictions? Were other types of measurements used as well?



6B Storms

How does Doppler radar work?

"The National Weather Service has just issued a severe thunderstorm warning for the following locations..."

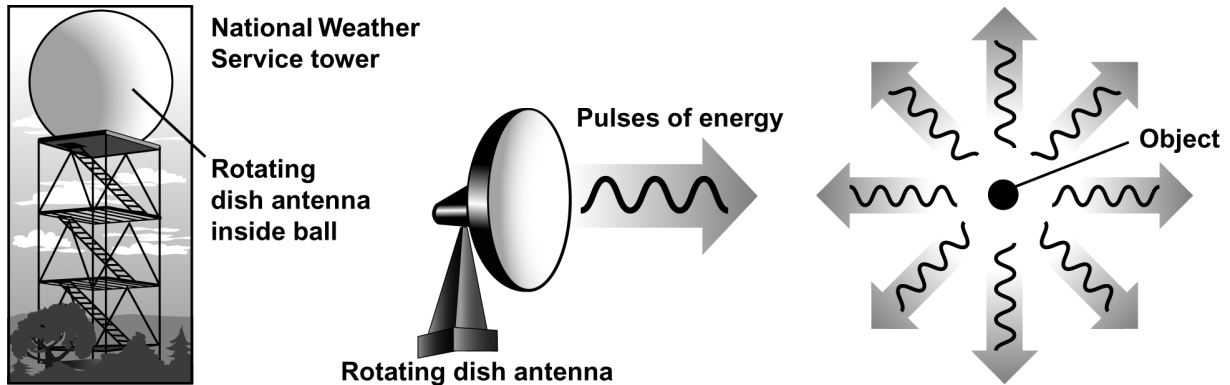
Has a broadcaster ever interrupted your favorite television program with these words? In this investigation, you will learn about one of the important tools the National Weather Service uses to track storms: Doppler radar.

Materials

- Radar image plates (set of six)
- A metric ruler (with millimeter marks)

1 How can we use radar to track precipitation?

You may be familiar with the radar images used by weather forecasters on the news. Did you ever wonder how these images are produced?



The National Weather Service has radar stations located across the United States. At each station there is a tower with what looks like a large soccer ball on top. Inside this protective ball is a 10-meter-diameter rotating dish antenna that sends out pulses of energy. If a pulse of energy strikes an object like a raindrop, the energy is scattered in all directions. A small part of the energy will bounce back to the antenna.

This reflected energy is then received by the radar station during its listening period. This process of sending a signal, listening for any returned signal, then sending the next signal, takes place very fast, up to around 1,300 times each second. Computers analyze the strength of the returned signal and the time it took to travel to the object and back. They use this information to create a color diagram showing the location, amount, and movement of precipitation falling over a region. In this reflectivity mode, four colors are typically used to show the rainfall rate per hour. For example, green may indicate traces of precipitation; yellow, a light rain; orange, heavy rainfall; and red, severe thunderstorms or hail. A color key is usually provided on the radar image.

- Look at Radar Image Plate 1. Over which state is the most intense rain falling?
- Name two states in which mixed precipitation is falling.

2 How can we use radar to detect a tornado?

Doppler radar, developed in 1988, has an advantage over earlier radar systems: It can detect the direction of air movement inside a storm. Doppler radar works by detecting the difference between signals bouncing off raindrops moving away from the antenna and signals bouncing off raindrops moving toward the antenna. In Doppler mode (also called velocity mode), the radar image is presented in two colors: green represents raindrops moving toward the antenna, and red represents raindrops moving away from the antenna. Doppler radar is very useful for locating rotating columns of air within a storm. One feature meteorologists pay close attention to is the appearance of a “J” hook-shape appearing near the back of the storm. This means that air is beginning to circulate in a pattern that often leads to the formation of a tornado.



Central Oklahoma tornado, May 3, 1999

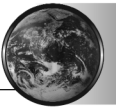
- a. Look at Radar Image Plate 2. Near which interstate highway intersection is a tornado possibly beginning to form?
- b. The National Weather Service issues tornado watch and tornado warning bulletins when certain atmospheric conditions are observed. Use the Internet to find out what each notice means. How does Doppler radar help meteorologists issue these bulletins?

3 Recognizing insects, birds, or airborne debris on a radar image

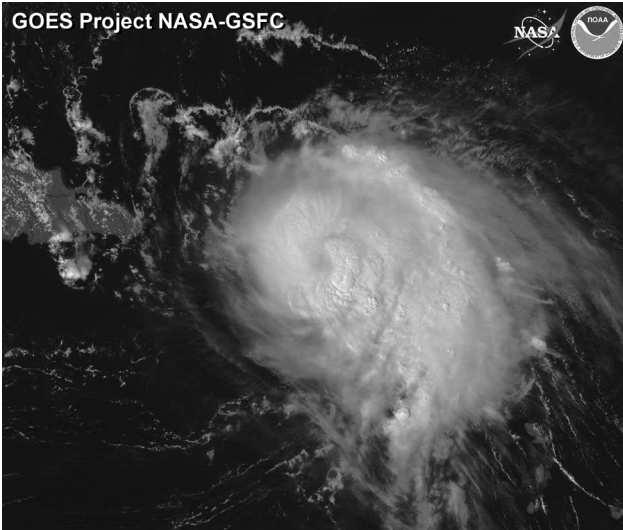
Of course, the pulses of energy sent by the antenna can bounce off things other than raindrops or other forms of precipitation. Interference from objects on the ground can be easily recognized because those objects do not move. However, in the spring and fall, swarms of insects or flocks of migrating birds can show up on radar images. Meteorologists practice looking at images and recognizing the characteristic patterns these creatures create, so that they do not mistake the birds and bugs for rain.

In some cases, the interference is actually important to meteorologists. In Radar Image Plate 3, locate the white spot in the center of a very intense storm. The color white represents an area that is reflecting back a large number of energy pulses—too many pulses to be bouncing off raindrops. These energy pulses are bouncing back from debris in the air thrown there by a tornado. This white area helps meteorologists locate places where the tornado is causing damage.

- a. Near which city is the airborne debris located?
- b. What safety precautions does the National Weather service recommend when conditions like these are observed?



4 How can we use radar to track a hurricane?



Satellite image of Hurricane Georges as it hit Puerto Rico on September 21, 1998.

Hurricane Georges, a category 3 hurricane, struck the island of Puerto Rico on Monday, Sept. 21, 1998. The next six radar images are from the National Weather Service's San Juan headquarters. The radar station is located in the Guavate Forest just south of the city of Cayey. All of the hurricane images are in reflectivity mode, depicting the intensity of the rainfall through a series of colors. The color key to the right of each image tells you that blue indicates light rainfall; green moderate rainfall; and yellow, orange, red, purple, and white indicate increasingly severe rainfall, often accompanied by thunderstorms and hail.

- a. The hurricane's eye is the low-pressure center around which the storm rotates. Inside the eye, winds are calm and skies are blue. Look at Hurricane Image 1. Where is the eye located?
- b. In the afternoon, Georges gathered strength because of the combination of the Caribbean Sea's warmer waters, the demise of some earlier wind shear, and the fact that as the storm moved over open sea between St. Croix and Puerto Rico, the wind circulating around the eye had no resistance from land objects. What evidence can you see in Hurricane Image 2 that the storm is gaining strength?
- c. The National Weather Service reported that Georges made landfall on Puerto Rico at 7 p.m. local time (23:00 GMT). Landfall is defined as the time when the center of the hurricane's eye reaches land. Use the scale printed on Hurricane Image 3 to determine the diameter of the eye when it made landfall.



Airplane entering the eye of Hurricane Georges to take storm measurements. The sky above is clear and sunlight can be seen reflecting off clouds.

- d. As the hurricane moved across Puerto Rico, intense rain and a possible tornado were spawned as the eye wall's heavy thunderstorms interacted with the mountainous terrain. Notice the strong bands of precipitation found in Hurricane Image 4. Why do you suppose it is harder to see the eye in this image?

- e. Just after midnight on the morning of Sept. 22, 1998 (04:01 GMT), the eye of Hurricane Georges began to move off the west coast of Puerto Rico. Using the time stamps on Hurricane Image 3 and Hurricane Image 5, calculate the time it took for Georges to make its way across Puerto Rico.

USGS photo



Hurricane George's high winds tore the roof and exterior walls from this home in Puerto Rico.

Hurricane Georges' travel time (round to the nearest hour): _____

Then, using a ruler and the scale provided on the radar images, calculate the distance from the center of the eye in the third image to the center of the eye in the fifth image.

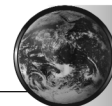
Hurricane Georges' travel distance (round to the nearest km): _____

Divide the distance traveled by the time taken in order to calculate the speed of the hurricane as it moved across the island.

Hurricane Georges' speed (round to the nearest km/hour): _____

- f. By 2:51 a.m. local time (06:51 GMT) the eye of Hurricane Georges was again over water. Use information from Hurricane Image 5 and Hurricane Image 6 to calculate the speed of the storm as it moved off of Puerto Rico. Does the storm appear to be intensifying or dissipating? Explain your answer.

Distance _____ km ÷ **time** _____ hours = **speed** _____ km/hour



7A Global Winds and Ocean Currents

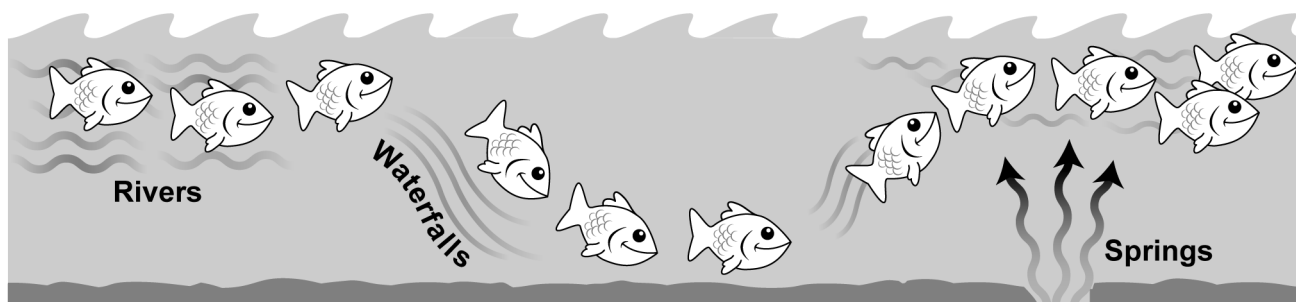
How do temperature and salinity cause ocean layering?

Did you know that there are rivers in the ocean? In some places, there are two rivers running side-by-side—in opposite directions. Now imagine underwater waterfalls and underwater springs. All of these exist in the world's oceans as a result of differences in water temperature and **salinity** (saltiness). How do temperature and salinity differences cause these underwater rivers, waterfalls, and springs? **Density** changes are the key. In this investigation, you will discover how temperature and salinity create currents, underwater waterfalls, and springs in the ocean.

Materials

- A clear plastic cup
- Two foam coffee cups
- Eyedropper
- Pipette with a barrel longer than an eyedropper's
- Salt
- Measuring spoon—teaspoon size
- 10-cm square of single ply cardboard
- Pencil
- Scissors
- 20 staples
- Newspapers
- Cafeteria tray or paper plate
- Source of hot and cold water
- Food coloring: red, green, and blue

The ocean contains:



1 Density and ocean currents

As global winds push ocean currents around the planet, the ocean water undergoes several changes. As the current moves nearer to the equator, the water warms up. As it moves toward the poles, the water cools down. These changes affect the density of ocean water.

When the current moves through a warm area, there is an increase in evaporation. Since evaporation removes fresh water and leaves salt behind, the salinity of the current increases. This increases the current's density. Fresh water is added back to the ocean through melting ice, rivers, and rain. Adding fresh water to the salty ocean water decreases its density.

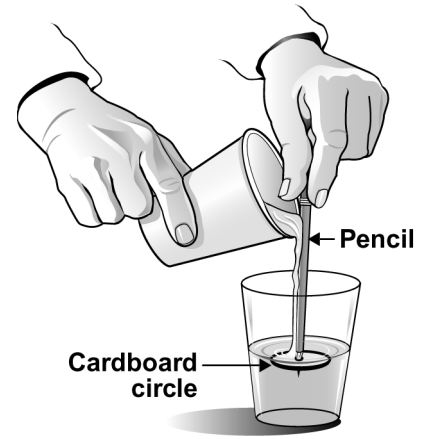
These changes in density cause ocean currents to float and sink at different points in their journeys. In this investigation, you will model underwater rivers, waterfalls, and springs. Then you will use your observations to help you understand the movements of the Atlantic gyre, an ocean current system. You will also discover how these density differences play an enormous role in the life of the world's most important fishing grounds.

- Which do you think is more dense, warm or cold ocean water? Why?
- Explain why dissolved salt increases the density of ocean water.

2 Observing salinity-dependent layering

This investigation requires care and preparation to keep your cleanup quick and easy. Spread newspaper over your work area to catch drips. Keep any water-filled cups over a tray or paper plate. Wipe up any spills before they get tracked around. Discard any water in the bucket provided or in the sink.

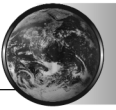
1. Make a pouring stick by cutting a cardboard circle about 4 centimeters in diameter with your scissors. Press the point of a pencil into the center of the disk so that it is stuck firmly onto the pencil.
2. Fill a clear plastic cup half-full with cool water. Add 1 teaspoon of salt to the water. Add 2 drops of green food coloring. Stir until the salt dissolves.
3. Fill a foam cup half-full with cool water.
4. Have a team member hold the pouring stick at its top, near the eraser. Lower the pouring stick into the middle of the clear cup so that the cardboard disk is just under the surface of the green water. Have a second team member hold the lip of the foam cup up to the pouring stick.



5. Tip the foam cup so that the cool water flows slowly down the pouring stick. The first team member must move the pouring stick upward as the second team member pours so that the cardboard disk remains at the surface of the water. Continue to add water until the clear cup is almost full, and then gently remove the pouring stick. You have created two ocean layers, separated by their salinity.
- a. Try slightly tipping the clear plastic cup. Are the layers stable? Do they resist mixing?
 - b. Tear off a small piece of foam cup. Press some staples into the foam, and place it on the surface of the clear water. Remove the foam and add more staples to it, one at a time, until the foam bit sinks. Where did the foam bit end up? Why?
 - c. Explain why the clear water floats over the saline water.

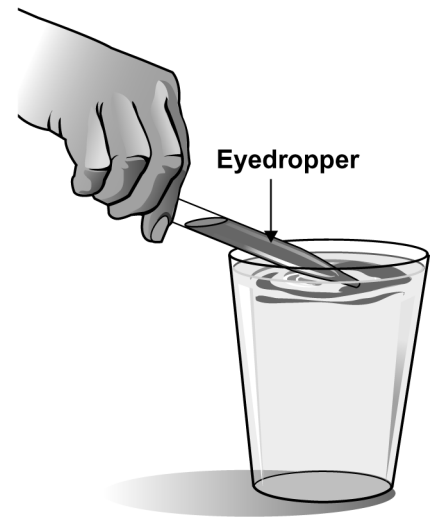
3 Exploring temperature-dependent layering

1. Fill a clear plastic cup half-full with cool water. Add 2 drops of blue food coloring. Stir to mix.
 2. Fill a foam cup almost full from the hot-water source. Add 2 drops of red food coloring. Stir to mix.
 3. Add hot red water to the clear cup using the pouring stick as you did in salinity-dependent layering. You have again created two ocean layers, this time separated by their temperatures.
- a. Try tipping the cup slightly. Are the layers stable? Do they resist mixing?
 - b. Explain why the hot red water floats over the cool blue water.



4 Creating an underwater waterfall

1. Fill a clear plastic cup nearly full with cool water.
 2. Fill a foam cup half-full with hot water. Add a pinch of salt. Add 6 drops of red food coloring. Stir until the salt dissolves.
 3. Place the eyedropper into the hot red water to warm it up. After a minute, fill the dropper barrel with the water.
 4. Hold the dropper so that it lies at a flat angle at the surface of the clear water with the tip just under the surface. Gently squeeze out a layer of hot red water onto the surface of the clear water.
 5. After a short cooling time, the red layer will form little waterfalls that sink through the clear water. They may even form little smoke-ring-like structures as they fall. If this does not happen within a few minutes, add a little more salt to the hot red water, stir, and try again.
- a. Explain why the red water floats at first.
 - b. Explain why the red water eventually sinks.



5 Observing underwater springs

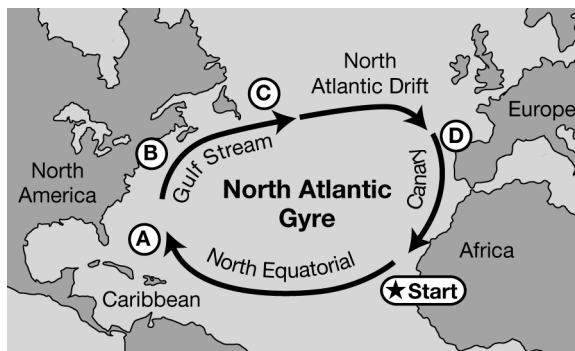
1. Fill a clear cup three-quarters full with cool water. Add a heaping teaspoon of salt to the water. Stir until the salt dissolves.
 2. Fill a foam cup half-full with cool water. Add 6 drops of blue food coloring. Stir to mix.
 3. Fill the eyedropper with cool blue water.
 4. Gently lower the dropper into the salt water so that the tip is near the bottom. Gently squeeze the dropper so that a small stream of blue water is released.
- a. Where did the blue water go? Why?
 - b. In this model, the blue water was less salty than the surrounding water. Think of another difference you could use to create an underwater spring. Write your own procedure, test it, and explain what happened.



6 Applying your knowledge

You can use these experiments to understand the North Atlantic gyre, a system of currents that occupies the North Atlantic Ocean basin. After each description, fill in the experiment that applies (salinity-dependent layering, temperature-dependent layering, underwater waterfall, or underwater springs), and then determine whether the current will float or sink.

We will start with the part of the North Atlantic gyre off the coast of Africa. We will assume that the temperature of the water is cool and its salinity is low. The low salinity is dominant and the current is floating on the surface.



- a. From there, the North Equatorial Current flows westward toward the Caribbean Sea. Then it turns north and becomes the beginning of the Gulf Stream. During this trip along the equator, the intense sun warms the current and evaporates a lot of water. This makes the water both warm and highly saline. The high temperature is dominant.

Experiment: _____ Float or sink: _____

- b. After turning northward, the Gulf Stream flows along the United States' Atlantic Coast. The water is highly saline, but it remains warm. The high temperature remains dominant.

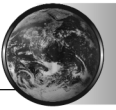
Experiment: _____ Float or sink: _____

- c. As the Gulf Stream leaves the U.S. coast, evaporation is not as great in the cold northern regions, but the cooling effect is very significant. The low temperature is dominant.

Experiment: _____ Float or sink: _____

- d. Now part of the Gulf Stream becomes the North Atlantic Drift. Fresh water from ice melt may mix with these cold waters off the coast of Europe. Lower salinity is dominant.

Experiment: _____ Float or sink: _____



7 Extension: Thermohaline currents and the ocean food chain

Back in the 1960s, it was popularly believed that the key to feeding the world was the bountiful harvest that could be taken from the seas. Today, we are faced with the collapse of fisheries on both sides of the Atlantic. Why has the ocean proven to be such a modest food source?

The food paradox of the oceans is based on the nutrient cycle. For new creatures to grow, the nutrients from the old creatures must be recycled. Unfortunately, when ocean creatures die, they take their nutrients to the deep bottom. The photosynthetic plankton (phytoplankton) that do the recycling must live in the sunlit top-600 feet of ocean, so recyclers and the needed nutrients are hopelessly separated by thousands of feet of ocean unless something can transport the nutrients to the surface.

- a. Two of the biggest fisheries in the world are off the Canary Islands and Peru. Can you explain why?
- b. If global climate change eliminates all ice from the poles, how might this affect ocean currents and world fisheries?

7B Wave Speed

What is the relationship between water depth and wave speed?

In the ocean, most waves are driven by the wind. As long as the wave is in deep water, the water depth does not influence the wave very much. When a wave approaches the shore, however, the speed of the wave changes.

In this investigation, you will collect data to observe how water depth affects wave speed.

Materials

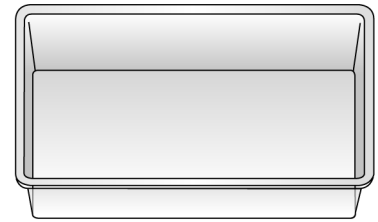
- GeoBox
- 1,000-mL beaker
- Masking tape
- Stopwatch
- Ruler or measuring tape
- Graph paper
- Wooden block

1 Setting up

Gather your materials including the GeoBox. Fill the 1,000-mL beaker with water.

2 Stop and think

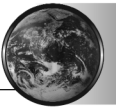
Predict the relationship between wave speed and water depth. Does the wave speed increase or decrease as the water depth increases? Why?



GeoBox

3 Doing the experiment

1. Place water in the GeoBox to a depth of one centimeter.
2. Place the wooden block under one end of the tray. One student will be the “timer,” and the other student will watch the waves.
3. First practice the following, then measure when you are ready. Pull the wooden block out. This will create a wave as the tray falls to the table. The water will “slosh” lengthwise in the tray.
4. As soon as you begin to move the block, start the stopwatch. The person watching the wave will watch it make four round trips. That means back and forth four times. As soon as it finished making the four round trips, stop the stopwatch. Record your data (time) in the table. Repeat for the same depth for two more trials.
5. Once you have made three time measurements for the one-centimeter depth, add water up to the two-centimeter mark.
6. Follow the same procedure and continue increasing water depth until you get as high as you can go (probably around six centimeters).



7. Find the average time for each depth. Then calculate wave speed using the formula below.

$$\text{wave speed} = \frac{\text{total distance traveled}}{\text{average time}}$$

Hint: Be careful when you measure for the total distance traveled—think about how many times the wave goes back and forth.

Table 1: Wave speed at different depths

Depth (cm)	Trial 1 (seconds)	Trial 2 (seconds)	Trial 3 (seconds)	Average (seconds)	Wave speed (cm/sec)
1					
2					
3					
4					
5					
6					

8. Make a graph with depth on the x -axis and wave speed on the y -axis.

4 Thinking about what you observed

- Describe the pattern of the graph.
- Why should there be any change in wave speed?

5 Exploring on your own

- What happens when waves reach the shoreline?
- What is the difference between swells and whitecaps?
- Would waves approach the shore in the same manner if the shoreline was gradual or very steep? Explain.

8A Topographic Mapping

How do you make a topographic map from a 3-dimensional surface?

Topography is the shape of the surface of an area and includes the elevations of land formations like mountains. The topography of a region is represented by a topographic map.

A topographic map is the two-dimensional representation of a three-dimensional land surface. Scientists use these types of maps to understand the effects of geologic processes on Earth's surface. Topographic maps show the difference in elevation through the use of contours. Contour lines connect points of equal elevation. Contour lines are drawn at specific intervals known as the contour interval. Once the contour lines are present, details are added to show land use using standard mapping symbols.

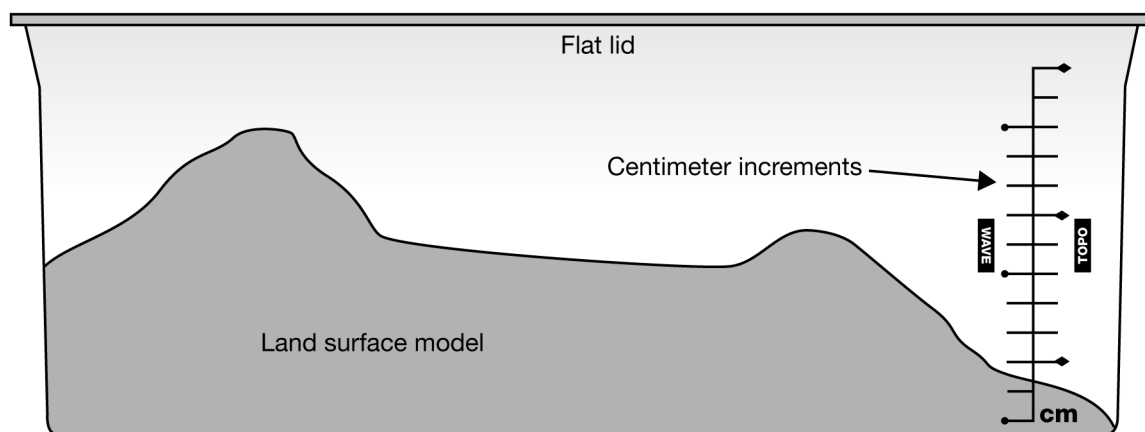
In this investigation, you will use a model land surface to make a contour map.

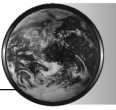
Materials

- GeoBox with the topo form (white land surface model) and topo lid (the flat lid)
- Container to hold water (or use a bucket from the stream table)
- Beaker to transfer water between containers
- Overhead projector markers (thin)
- Pencil
- Colored pencils
- Tracing paper
- Water colored with food coloring
- Metric ruler

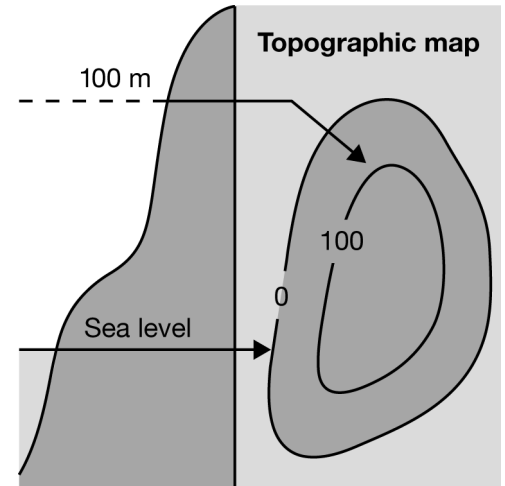
1 Making a topographic map

1. Note that the GeoBox has a sticker on the side. Each mark on this sticker represents one centimeter. Pour water into the GeoBox up to the first centimeter line.
2. Place the topo lid on the GeoBox. Stand over the GeoBox so that you are looking down on the topo form. With the overhead projector marker, first make a boarder for your map by outlining the lid. Then, outline the perimeter of the land surface onto the lid. This will be considered “sea level,” or the 0 meter contour line.
3. Now, using your marker, number each centimeter above sea level. Use the sketch below to help you with this step.
4. Remove the topo lid and add water until the water level reaches the 1-centimeter mark. Replace the lid. Trace the “coastline,” the line along which the water and land meet, onto the lid. All points on this line are 1 cm above sea level. They form a contour line, a line of equal elevation.





5. Add water to the level of the 2-centimeter mark. Replace the lid and again, trace the “coastline.” All points on this line are 2 centimeters above sea level.
6. Continue this procedure until the topo form is covered with water.
7. Now you have a contour map of your land surface. Use the tracing paper to trace what is on the lid. Each partner makes his/her own contour map. The elevation for each contour represents 100 meters. Draw the contours as solid lines. Indicate the elevation as shown in the graphic at right.



2 Labeling your map

1. Each partner will now finish his/her own map, which is now on tracing paper. Add details showing land-use using the USGS topographic map symbols (see next page). Make sure the following features are on your map. With your group or with the whole class, define any terms you do not understand.
 - Geographic north
 - A contour interval
 - A fractional scale
 - A verbal scale
 - A bar scale
 - A river
 - A depression
 - An airport
2. Color in areas on your map where appropriate. Water is shown in blue. Densely populated areas are shown in gray or pink. Wooded areas are in green and open areas in white. Individual buildings are solid black shapes.
3. When your group is finished, write a title on your map. Also, write your name or your group's name on the map.

3 Thinking about what you observed



- a. What is the direction that your river is flowing?
- b. What is the difference in elevation between the start and end of the river?
- c. What is the overall total change in elevation in your map?
- d. What is the highest elevation in your map?
- e. By looking at your map, what area is the steepest? *Remember: Look at the contours to see how close or far away they are from each other.*

4 Exploring on your own



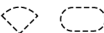

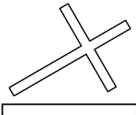
1. Obtain a topographic map of your local area. See if you can find where you live and some of the landmarks around you.
2. Besides scientists, who might be interested in a contour map? Why would it be useful to those people?
3. See if you can find out where the closest benchmark is in your local area. A benchmark is a place where the exact elevation is known. A marker is placed in the ground at that spot. There is an **X** on the marker with the exact elevation inscribed in it. (Hint: Benchmarks are noted on topographic maps.)


Topographic Map Symbols




Boundaries

City	
Small Park	




Buildings and related features

Building	
School	
Athletic field	
Forest headquarters	
Airport	



Well (other than water), windmill or wind generator	
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Picnic area	
Campground	
Winter recreation area	



Contours

Contour line	
Depression	
River mileage marker	





Railroads

Railroad, single track	
Railroad, multiple track	





Rivers, lakes and canals

Perennial river	
Perennial lake/pond	

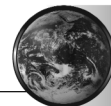
Roads and related features

Primary highway	
Secondary highway	
Trail	
Highway or road with median strip	

Vegetation

Woodland	
Shrubland	
Orchard	
Vineyard	

U.S. Geological Survey used in compiling this information.



8B Bathymetry of the Sea Floor

How can we tell what kinds of features are on the sea floor?

Did you know that about three quarters of the surface of Earth is covered by water? People have used boats and ships to travel all over the oceans for hundreds, if not thousands of years. During most of this time nobody really knew what was beneath the surface of the ocean. Today we have detailed maps of the ocean bottom. Bathymetry is the mapping of the ocean bottom. In this investigation, you will learn how scientists have been able to find out what kinds of features are deep down on the sea floor.

Materials

- Blindfold
- Graph paper
- Colored pencils (red, orange, yellow, green, blue, purple, brown, and black)
- Pencil sharpener
- Side-view depth diagrams A-H

Dolphins use sound waves to navigate, hunt, and visualize their surroundings. They make a series of clicking sounds and wait for the echoes of those sounds to return. This is called echolocation. The direction and volume of the echoes gives the dolphin an idea of what is in their general area. Let's find out what it might be like to be a dolphin and use echolocation.

1 Setting up

1. Clear an area in your classroom that is big enough for everyone in your class to stand in a large circle. You could also use a large open space like a gym, or even a field outside as well.
2. Your teacher will select one person to be the dolphin.
3. Your teacher will select three people to be fish.
4. Your teacher will select two people to be squid.
5. Your teacher will select one person to be a shark.
6. The remaining students will stand in a circle, and gently guide the dolphin back to the middle of the circle if he or she gets to the edge.

2 Doing the activity

1. The dolphin in this activity will wear a blindfold.
2. The dolphin will say "click!" every few seconds. When the dolphin says "click", the fish have to respond by saying "fish", the squid reply by saying "squid", and the shark responds by saying "shark." The replies represent the dolphin's clicks echoing back to the dolphin.
3. The shark swims randomly around the circle. The fish must stay together in a school as they swim around in the circle, by walking together with baby steps. The fishes and the shark must always swim forward at all times. They may not move backwards or stop. The squid can swim around in any direction, stop, and move backwards. The squid and the shark should move at a regular walking speed as they swim around.
4. The dolphin tries to capture his prey, the fish and the squid, and avoid his predator, the shark. The dolphin can stop swimming, but not move backwards.

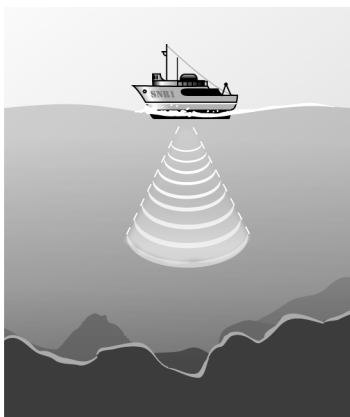
5. The dolphin captures his prey by tagging them lightly when it sounds like they are near, using echolocation.
6. The dolphin must avoid the shark. If the dolphin bumps into the shark, someone else gets to be the dolphin.
7. The game is over when the dolphin catches all the fishes and both squid.

3 Thinking about what you observed

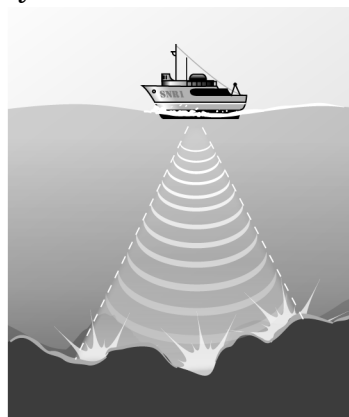
- a. How did the dolphin know where the fishes, squid, and shark were?
- b. When a dolphin makes clicking noises under water, how do you think it can tell the difference between a fish and a shark?
- c. Why do you think scientists call this process echolocation?

4 Man-made echolocation

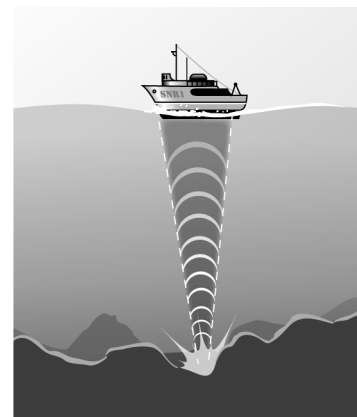
In the early 1900's, scientists and engineers tried to use sound waves to measure the depth of the ocean. Sound travels about 340 m/sec in air. That's pretty fast! But in saltwater it travels even faster, about 1,500 m/sec. Ships carry devices that use sound waves and echoes in a system called SONAR. SONAR devices send out bursts of sound waves, and then listen for the echoes of the sound waves when they bounce back off the bottom of the ocean.



Sound waves
sent down from ship



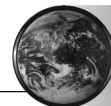
Sound waves
bounce off ocean floor



Sound wave
echo returns to ship

5 Stop and think

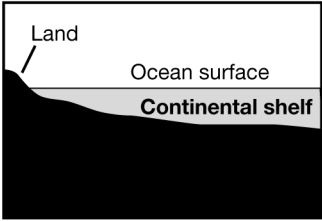
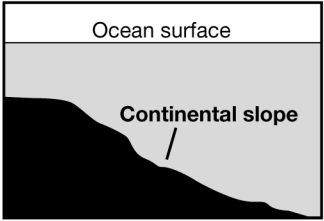
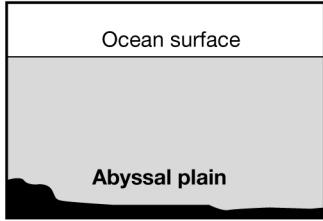
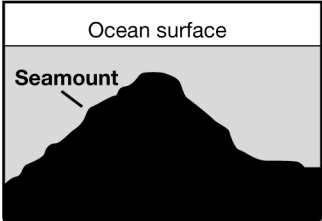
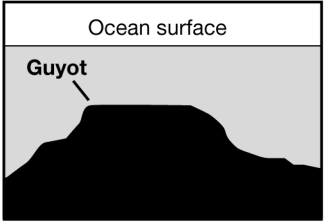
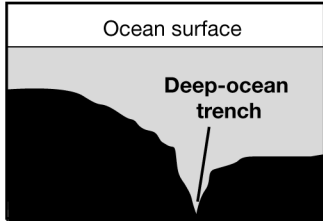
- a. How fast does sound travel through saltwater?
- b. In saltwater, how far would a sound wave travel in 1 second? In 2 seconds? In 3 seconds? How about 10 seconds?
- c. What is the relationship of the depth of the water to the total distance the sound wave travels?
- d. When you find out how far a sound wave has traveled, how can you tell how deep the water is?



6 What's down there?

The use of SONAR has helped identify many different features and regions of the ocean bottom that cannot be seen from the surface. These features have distinctive variations in their shapes and locations.

Table 1: Features and regions of the ocean bottom

<p>Continental shelf</p>  <p>A submerged border of a continent that slopes gradually and extends to a point of steeper descent.</p>	<p>Continental slope</p>  <p>The transitional area between the continental shelf and abyssal plain.</p>	<p>Abyssal plain</p>  <p>The flat, deep ocean floor. It is almost featureless because a thick layer of sediment covers the hills and valleys.</p>
<p>Seamount</p>  <p>A mountain rising from the ocean seafloor that does not reach to the water's surface.</p>	<p>Guyot</p>  <p>A flat topped seamount that shows signs of being above the water's surface in the past.</p>	<p>Deep-ocean trench</p>  <p>A long, narrow depression of the sea floor having steep sides. The deepest part of the ocean.</p>

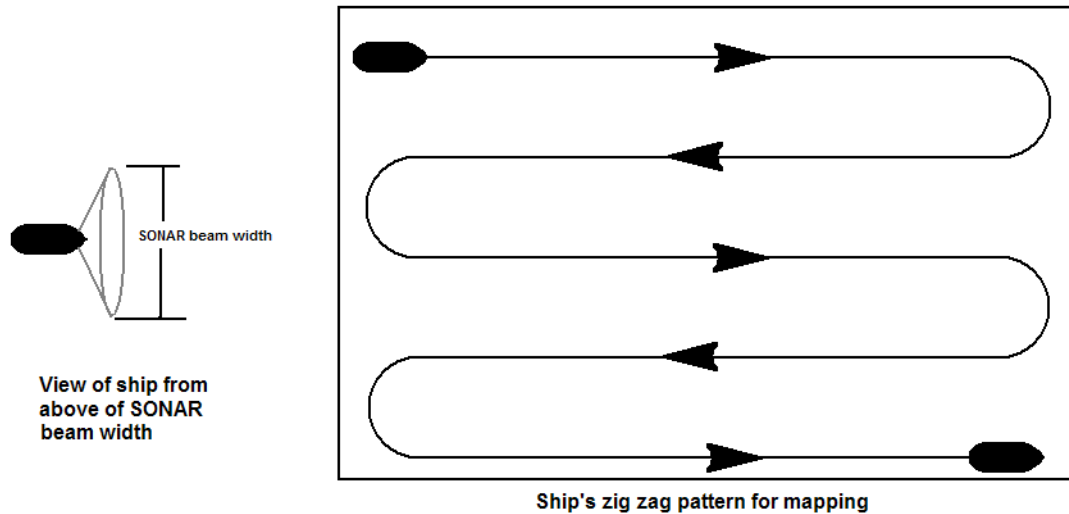
7 Stop and think

- How could you use the information a SONAR system provides to identify the kinds of ocean bottom features and regions in Table 1?
- What is a seamount that rises above the surface of the ocean called?
- What do you think causes the flattened top of a guyot?
- If you were taking SONAR measurements, how would you know that there was a deep-sea trench beneath your ship on the ocean bottom?
- How would you know you were going over a seamount?
- What would happen to your SONAR readings as your ship went from the continental shelf into the continental slope?

8 Mapping the ocean bottom

To make a map of the ocean bottom, ships have to travel back and forth in a zig-zag pattern over large areas and take readings from their SONAR equipment all along the way. The sound waves spread out to the side of the boat, so each pass the boat makes can measure depth and indicate features in a wide swath. The beam's width depends on the kind of SONAR equipment the ship has and the depth of the water.

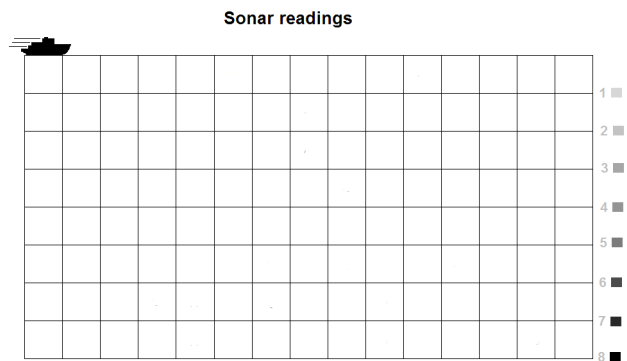
Table 2: Beam width and a zig-zag mapping pattern

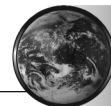


- Why do you think a ship follows a zig-zag pattern?
- How does the width of a ship's SONAR beam affect how many zigs and zags the ship needs to make to get a complete map of an area of the ocean bottom?

9 Readings and depth

- Your group will be in charge of one set of readings made on a SONAR mapping expedition. You will be given one part (a zig or a zag) of the entire map.
- The readings indicate how many seconds a SONAR reading took to return to the ship.
- Your group's task is to create a side view of the terrain under your ship based on the data collected on one pass over part of the whole area.
- Your teacher will give you a side view depth diagram for your group. Each SONAR reading tells you how long the sound took to return to the ship at that location.
- Mark the depth of the water based on how many seconds the SONAR sound wave took to return to the ship.
- The depth will be color coded. Mark each depth according to the color indicated on the depth readout diagram.





10 Making a bathymetric map from your readings

1. Each group will have a completed color coded side view depth diagram.
2. Your class will make a color coded bathymetric map based on the diagrams produced by all groups.
3. Each group will transfer their color coded depth information, from their side view diagram onto the bathymetric map grid, an overhead view of the area.
4. Once all the groups have transferred their color coded depth information, the bathymetric map is complete.

11 Thinking about your observations

- a. What kind of information does your color coded bathymetric map tell you?
- b. The readings on your side view depth diagram indicated how many seconds the SONAR signal took to return to the ship. How would you turn this information into actual depth readings?
- c. Convert each color into the actual depth it represents on your bathymetric map.

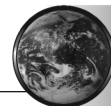
Table 3: Finding the depth of water based on sound travel time

Color	Time sound took to echo off ocean bottom (seconds)	Speed of sound in salt water (m/sec)	Total distance sound traveled (m)	Depth of water (m)
red	1	1500		
orange	2	1500		
yellow	3	1500		
green	4	1500		
blue	5	1500		
purple	6	1500		
brown	7	1500		
black	8	1500		

- d. Using information from part 6 of this investigation, what kind of features can you identify on your color coded bathymetric map?
- e. Use a piece of graph paper to make your own small color coded bathymetric map that shows a seamount, a guyot, and a deep-ocean trench.
- f. **Challenge:** How could you use the information represented by different colors to add contour lines to your bathymetric map?

12 Exploring on your own

- a. What does SONAR actually stand for?
- b. Near the coast we sometimes see the bottom of the ocean. In deep water, how far does visible light penetrate down into the water? What are the different zones associated with light in the ocean?
- c. Research: Who was Marie Tharp and what major project did she help accomplish before anyone else?
- d. Research: What other animals use echolocation?



9A Sedimentary Rocks and Relative Dating

What can sedimentary rock tell us about its age?

Sedimentary rocks are formed from the compaction and cementation of separate particles called sediment.

Sediment can consist of materials such as sand, clay, silt, pebbles, and gravel.

As time passes, sediment that is weathered from rock and/or eroded from the land gets deposited somewhere else. In certain environments, where weathering and erosion are slow, layers of sediment can build up faster than they are removed.

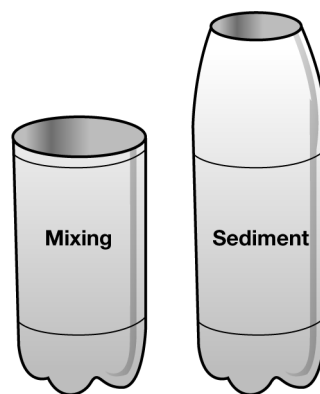
In this investigation, you will model the formation of sedimentary rock, observing how sediment size plays a part in its development, and gain an understanding of how scientists are able to place events in the sequence that they occurred, using these rock layers.

Materials

- Two 1-liter plastic soda bottles (labels removed)
- Scissors
- Permanent marker
- Soil mixture (one part topsoil to one part sand)
- Newspaper
- Beaker
- Metric ruler
- Spoon
- Sedimentary rock samples (sandstone, shale, conglomerate)

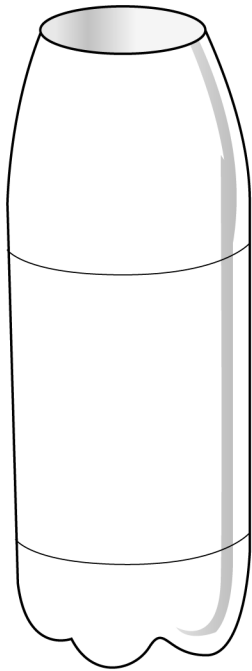
1 Setting up

1. Gather the items needed for this investigation. Cover your work area with newspaper. At the end of the investigation, you can wrap up the newspaper and throw it away to ease your clean-up.
2. Ask your teacher to make a slit in your first plastic bottle just below the bottle's shoulder. Then use your scissors to cut all the way around the bottle. You should have an open cylinder with straight sides. This bottle will be used for mixing.
3. Your teacher should make a slit in the second bottle just above the shoulder. Then use your scissors to cut all the way around this bottle. It will be used for holding your sediments. See the diagram to the right before you cut your bottles.
4. Label the first bottle "mixing" and the second bottle "sediment."
5. Add water to the sediment bottle to a depth of five centimeters.
6. Add the soil mixture to the mixing bottle to a depth of three centimeters.
7. Add water carefully into the mixing bottle and mix it to make a "mud slurry." Add just enough water to make it the thickness of a thick milk shake.
8. Pour your mud slurry into the sediment bottle and mix it into the water.
9. Allow the sediment bottle to stand undisturbed for two minutes or until you can see layers forming.

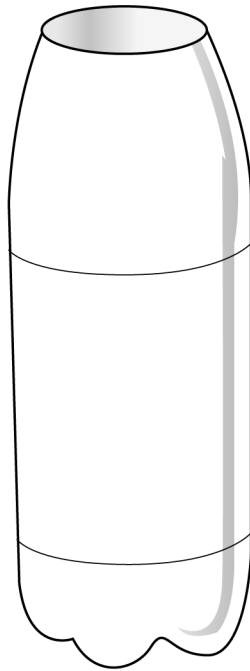


2 Stop and think

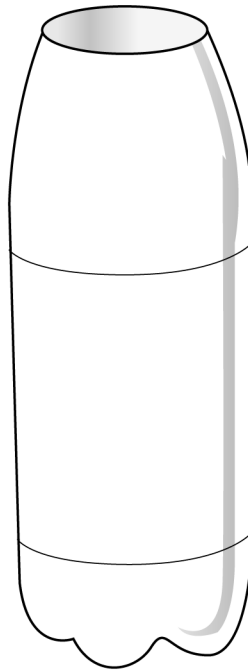
- Once you see layers in the sediment bottle, make a sketch of the layers in the first bottle below, labeled “first slurry.” Be sure to draw and label the following in your diagram: floating debris, fine particles, and coarse particles.
- Where in your bottle did you find the coarsest sediment? Where is the finest sediment?
- Is there a change in color from bottom to top? Explain why or why not?



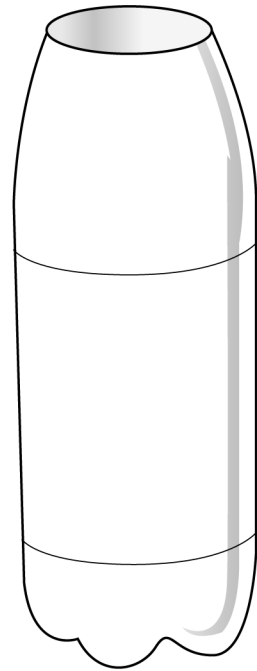
First slurry



Second slurry



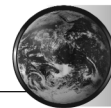
Third slurry



Fourth slurry

3 Doing the experiment

- Now you will be adding more sedimentary layers to your bottle. The procedure is slightly different than the first trial.
- Examine the water level in your sediment bottle. You need only five centimeters of water over the settled slurry. Carefully pour off excess water into a wastewater container.
- Add 1 centimeter of sediment to the mixing bottle. Then, add water until the new mud slurry is much thinner than the first slurry you made.
- Have one of your team members continuously stir the slurry for twenty seconds. Do the next two steps quickly.
- Pull your spoon through the water in the sediment bottle just over the surface of the settled slurry, a little off-center.
- Immediately add the new slurry to the sediment bottle while the water is still swirling.
- After two minutes, sketch the layers you see. Use the bottle diagram labeled “second slurry.” Pay special attention to thickness, sediment size, and the angle in which layers formed (i.e. slanted, straight across, etc.).



8. Repeat steps 2 through 7 until you have added three slurries to the original for a total of four slurries added to the sediment bottle. Stop the process if your sediment bottle gets too full.

4 Thinking about what you observed

- a. Wipe off the sides of your bottle. Carefully examine the sediment in your bottle. Is each slurry you made represented by a distinct layer? If so how many layers do you see?
- b. Are the sedimentary layers in your bottle the same thickness?
- c. Which size sediments settled into the bottle faster: larger or small particles? Explain your answer.
- d. What will happen to your sedimentary layers when the water evaporates?
- e. What kinds of environments would cause sediment layers to be deposited over time on top of each other?

5 Exploring further

- a. Label the sedimentary layers in your sketch from oldest to youngest. How do you think geologists can figure out the age of sedimentary rock layers in areas such as the Grand Canyon?
- b. Do you think the age of the sedimentary rock layers from the Grand Canyon that geologists figure out would be the relative age (the age in reference only to the other rock layers in the area) or absolute age (the exact age)?
- c. What might be a way of figuring out the absolute, or exact age of the rock layers? Hint: what might be embedded in those sedimentary layers that the geologists could use to get an exact date?

6 Exploring on your own

- a. Examine the sedimentary rock samples. Classify these sedimentary rocks according to color, texture, and particle size. What types of particles do you think make up each of the rock samples?
- b. Based on the results of this investigation, where would you expect to find each of these sedimentary rock samples in a river system? Upstream near the source of the river or farther downstream near the mouth of the river?
- c. Go for a “rock walk” around your school or around your home. See if you can find samples of sandstone, shale, or conglomerate in these areas. Collect any other rocks that may seem interesting to you as well. Take these rocks back to your classroom and classify them according to their color, texture, and mineral size.

9B Time and Tree Rings

Do tree rings tell a story?

If you look at the cross-section of a tree, you will see tree rings. Tree rings tell a story about the growing conditions of the tree. The number of rings that a tree has equals its age.

Careful examination of tree rings can give detailed information about the age of a piece of wood and the growing conditions a tree experienced during its life time. Scientists compare tree rings to a catalog of tree ring history to figure out the age of certain wooden objects like old ships, log cabins, and archeological artifacts. In this investigation, you will determine the age and growing conditions of several samples of wood by examining tree rings and tree core samples yourself.

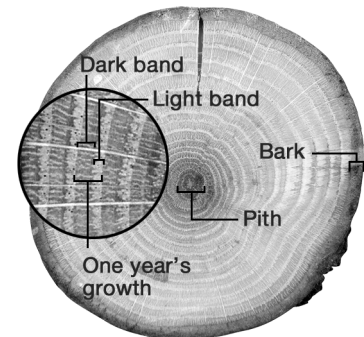
Materials

- Microscope slide of a tree cross-section
- Tree cross section
- 7 paper strips representing tree cores, a set of 4 and a set of 3 (included as a graphic in the lab)
- Two blank pieces of paper
- Graph paper
- Scissors
- Tape
- Ruler
- Colored pencils
- Magnifying lens

1 How do trees grow?

Each year, a tree gets larger by one ring. It is easy to count tree rings because each ring has a light and a dark band.

Tree rings (and the individual light and dark bands) vary in width depending on the growing climate. Wet, warm years allow for more growth than cool, dry years. A wide ring means the tree grew during a wet year. A narrow ring band means the tree grew during a cool, dry year.



- Look at the microscope slide of the tree cross-section. Use the magnifying lens to help you see the details. Write a short paragraph describing what you see.
- You will see small holes in the tree cross-section. What are these holes? Come up with a hypothesis that answers this question.
- Looking at the slide with your eyes, how many tree rings do you see?

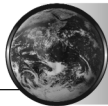
2 Investigating tree rings

1. Tree cross-section:

Now, look at the tree cross-section. Use a magnifying lens to help you see the rings. Notice the width of the bands. Look at the bark and the pith. See if you can figure out the age of the tree. Remember that one ring (one year's growth) includes a light band and a dark band. Discuss what you see with your group. *NOTE: The pith and bark are not counted in determining the age of a sample. The youngest wood is under the bark.*

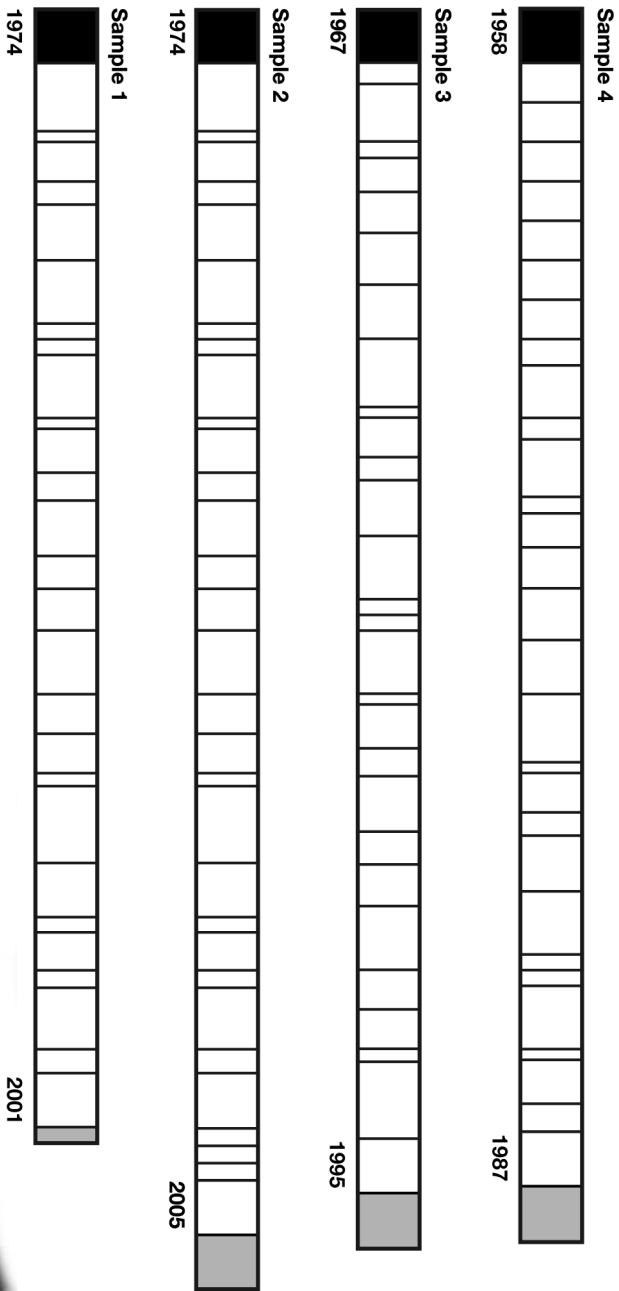
2. Tree cores:

Obtain copies of the four paper strips below and cut them out. The strips represent tree cores from four different trees. The trees are the same species and grew in the same woodland.



Pith (center of tree)

Bark (outside of tree)



- Determine the age of each tree by counting the rings (one ring includes a wide light band and dark line). Record your answers in Table 1.

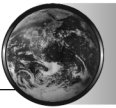
Table 1: Tree core data

Sample	Age of Tree	Year Cut or Cored	Year Growth Began
1			
2			
3			
4			

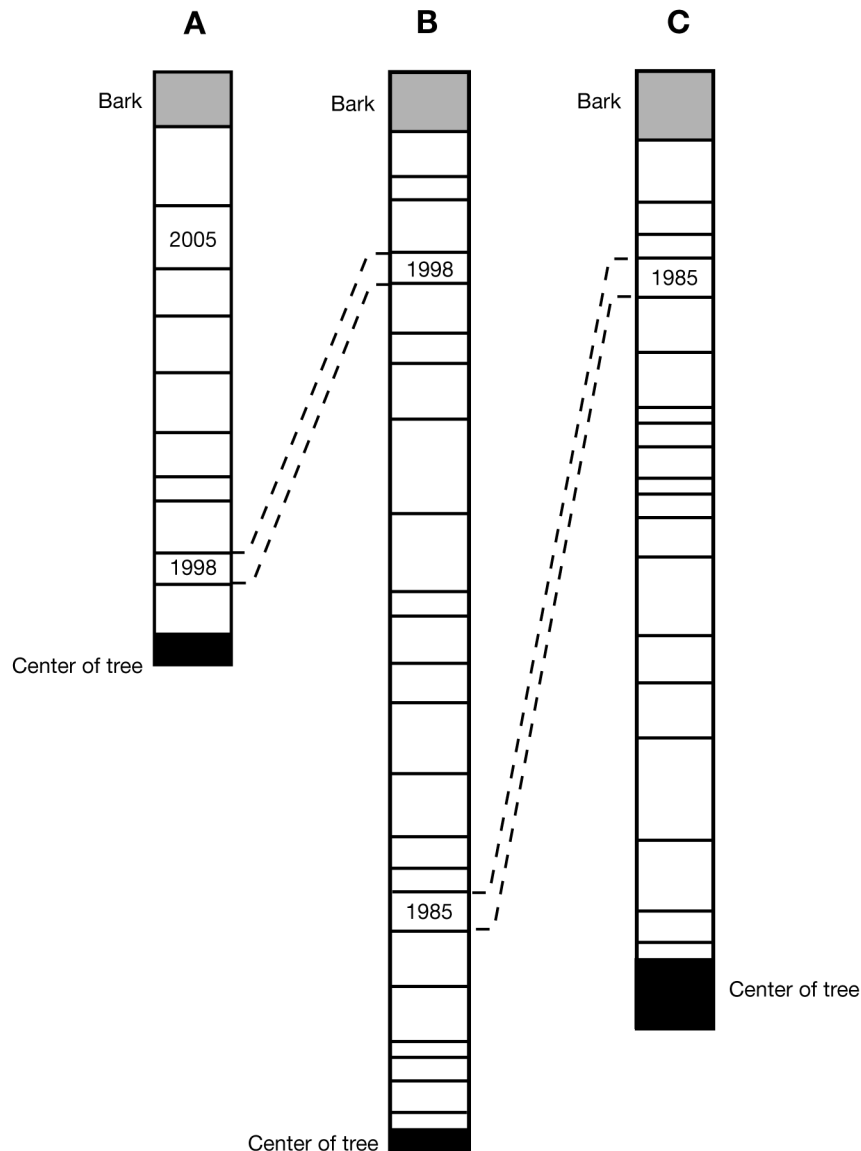
- Look for patterns in the rings. Line up all the samples by matching the patterns before taping them onto a blank piece of paper. Color the overlapping sections so you don't lose track. Figure out the age of each tree and record this information, and the years that the trees began growing and were cut in Table 1.
Note: These matching patterns indicate the trees grew in the same woodland and help prove what the climate was like in the past for that area.
- More tree cores:**
Now look at the three new tree cores (see next page). Write down the age of each core. Then, cut out the paper strips and line them up.
- Use the information for the age of each core to figure out the width of the ring for each year listed below. Two years have already been done for you: 2006 and 2005. Measure the width of each tree ring for each core sample, and record them in Table 2.

Table 2: Tree core data

Year	Tree ring width (mm)	Year	Tree ring width (mm)	Year	Tree ring width (mm)
2006	10 mm	1993		1990	
2005	8 mm	1992		1979	
2004		1991		1978	
2003		1990		1977	
2002		1989		1976	
2001		1988		1975	
2000		1987		1974	
1999		1986		1973	
1998		1985		1972	
1997		1984		1971	
1996		1983		1970	
1995		1982			
1994		1991			



7. Make a graph of this tree core data. Plot the ring-width data (on the y -axis) against time (on the x -axis). One ring includes a wide light band and dark line. Label the graph appropriately.



3 Thinking about what you observed

The set of four ring cores:

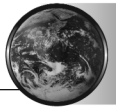
- What kind of growing season existed for the first four cores in 1967? How can you tell?
- If poor tree growth is mainly caused by drought, which years were probably drought years? How can you tell?
- Did this woodland have more years of drought or plentiful rainfall?
- Why might a climatologist be interested in tree ring data from this woodland?

The set of three ring cores:

- a. What does your graph show about the three cores (A, B, and C) and the climate?

4 Exploring on your own

- a. Global warming (caused by an increase of carbon dioxide in the atmosphere) is a current environmental topic that concerns scientists. The result of global warming is an increase in Earth's average temperature. Due to global warming, what differences would you expect to see between tree rings of today and tree rings in the future (100 years from now)?
- b. What factors can influence the growth of trees? List all the factors you can think of.
- c. Trees are like the history books of a forest. But, what other objects in nature can we observe and measure to tell us something about certain environments? You may want to go to an outdoor location to brainstorm answers to this question.
- d. What is a dendrochronologist and what does one do?



10A All Cracked Up

What is a good way to model Earth?

Using **models** is an important practice when studying science. Many of the objects that a scientist would study, such as a planet or a molecule, are much too big or too small to work with by hand. Models can help a scientist solve this problem. Some examples of scale models a scientist might build include shrinking a planet down to the size of a basketball or blowing up a molecule to the size of a tennis ball. These models make objects easier for scientists to conduct their research. Think about a geologist studying plate tectonics and continental drift—two concepts you will learn more about in Chapter 11. The geologist would likely build small scale models of each of Earth's lithospheric plates in order to more easily understand how the movements of the plates affect one another.

Different kinds of scale models serve different purposes. In this activity, you will examine several geologic models of Earth to learn more about some of Earth's important features.

Materials

- Three objects that can serve as models of Earth.
Examples: a ping-pong ball, a baseball, a golf ball, an orange, a basketball, etc.
- Colored pencils for sketching.

1 Procedure

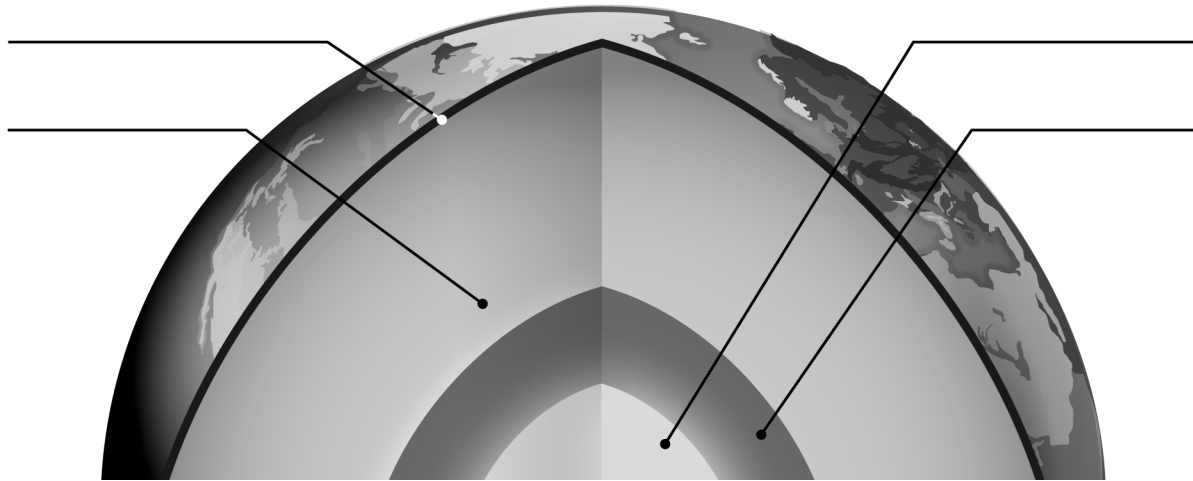
1. You will be shown three different objects that can serve as models for Earth. Make a sketch of each model on a blank piece of paper or in your notebook.
2. Write the name of each object in the first column of Table 1. Then, based on your understanding of Earth, determine each model's strengths and weaknesses. Write your evaluations in Table 1.

Table 1: Evaluating your models

Model	Strengths	Weaknesses

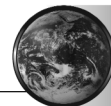
3. Of the three models, which do you feel is the most accurate for modeling the layers of Earth? Which model do you feel is the least accurate? Explain your reasoning behind both answers.
4. Your teacher will now conduct a short demonstration using a hard-boiled egg as a model for the interior of Earth. Record and sketch your observations of the egg model. Be sure to make observations and sketches of both the interior and exterior of the egg.

5. Based on the demonstration, label the layers of Earth in the diagram.



2 Discussion questions

- a. Which layer of the interior of the egg corresponds to which layer of the interior of Earth? What part of Earth does the cracked egg shell model?
- b. What are two strengths and two weaknesses of the cracked egg model?
- c. How do Earth's layers compare in their composition and consistency with the egg layers?
- d. Earth's lithospheric plates move relative to one another, unlike the eggshell sections which do not move at all. In some places plates move apart. In other places, plates come together, and in still others, plates rub sideways against each other.
 - What geologic event might occur where plates rub sideways against each other?
 - What geologic formation might result when two plates collide?
 - What geologic formation might form where two plates move apart?



10B Buoyancy and Mountains

How and why do objects float?

Solid objects float if they are less dense than the liquid in which they are placed. Objects sink if they are more dense than the liquid. You may have noticed that large ships are often made of steel. Ships made of steel float in water, even though steel is much more dense than water. Mountains, embedded in the continental crust, float in the upper mantle of the Earth. So how does a steel boat or a mountain float? The answer is in the concept of apparent density. You will soon discover how and why boats can be made of materials that are denser than water, and how a giant mountain can float.

Materials

- Displacement tank
- 1/2 stick of modeling clay
- Balance
- Disposable cup
- Beakers
- Graduated cylinder
- GeoBox
- Wood mountain blocks
- Metric ruler

Part I - Boats

Have you ever wondered how a boat made out of steel can float? Boats have even been made out of concrete, and they float too. Metal like steel, and materials like concrete are things that people usually are not surprised to see sink when put into water. So why would anybody try to make a boat made out of steel or concrete? Instead of these materials, you will use a piece of clay to investigate how these seemingly “heavy” materials can be used to make a boat that actually floats.

1 The density of clay

Find the density of your stick of clay before you change its shape.

1. Measure the clay's mass. Record it in Table 1.
2. Find the volume of your stick of clay using the displacement method:
 - Place a disposable cup under the displacement tank spout.
 - Fill the tank until water begins to run out of the spout (approx. 1,400 mL).
 - When the water stops flowing, remove the cup and replace it with a dry beaker.
 - Gently place your clay into the tank. Collect the water that runs out of the spout.
 - Quickly remove your clay and dry it with a paper towel. Do not allow water to mix with your clay or it will get very slimy.
 - The volume of the water you collected is equal to the volume of your clay. Use the graduated cylinder to measure the volume and record it in Table 1.



Table 1: Density data for clay

Substance	Mass (g)	Volume (mL)	Density (g/mL)
Clay			

- Calculate the density in g/mL.
- Did your stick of clay sink or float in the displacement tank? Use the density of your stick of clay and the density of water (1.0 g/mL) to explain why.

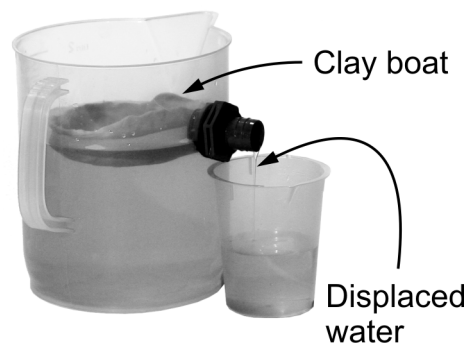
2 Making the clay float

You know that steel can be formed into a shape that floats. Can you do the same thing with clay? For this activity, you must use **ALL** of your clay. Mold it into a shape that you think will float.

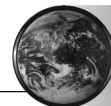
- Fill the container with water until it is about 12 centimeters deep.
- When you are ready to test a shape that you have made, gently place it in the water in the container. If the clay sinks, take it out of the water and dry it off right away.
- When your clay is dry, change the shape of your “boat” and try again.
- When you have successfully made a boat that floats, take it out of the water. Dry it with a paper towel.
- Measure the mass of your boat and record it in Table 2.

3 Why a boat floats

- When a boat floats, it displaces a certain volume of water. Make a prediction: Do you think your boat will displace more water, less water, or the same amount as your stick of clay?
- To find out, first prepare the displacement tank just as you did in step 1.
- Place your clay boat in the water in the displacement tank. Let it float there while the water flows out of the tank.
- Measure the volume of the water displaced by your clay boat. Record this volume in Table 2.
- Use your mass and volume data to calculate the apparent density of your clay boat.

**Table 2: Data for boat**

Mass of boat (g)	Volume of water displaced by the boat	Apparent density of the boat



4 Thinking about what you observed

- Which displaced more water, the stick of clay or the clay boat?
- Assuming the mass of the clay did not change, how do you explain the difference in the volumes displaced by the stick of clay and the clay boat?
- Look at the boat's apparent density. Why is it different than the density of the stick of clay? What other substance has a density very similar to the boat's apparent density?
- Explain why a solid stick of clay sinks but a clay boat can be made to float.
- What would happen if you added "cargo," like pennies, to your boat? Is there a limit to how much mass you can add before the boat sinks? Does the volume of displaced water increase or decrease when the boat gets heavier? Why? Try the experiment.

Part 2 - Earth's crust and mountains

Unlike steel, concrete or clay, Earth's crust is not shaped like a boat. For the most part it is solid, without a hollowed out section like the boat you made, and yet it floats. Beneath Earth's crust is the mantle. The mantle is made of very hot rock.

5 Why Earth's crust floats

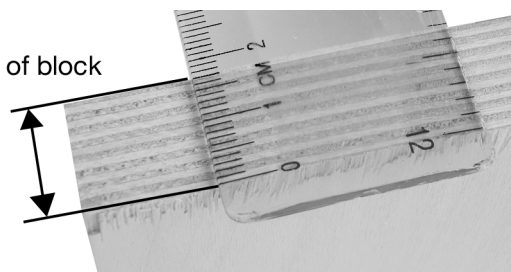
- Based on what you learned in the first part of the investigation, how would you explain why Earth's crust floats on the mantle?
- There are two types of Earth's crust; continental and oceanic. Oceanic crust is on average about 15% more dense than continental crust. How do you think the difference in density would affect how both types of crust float on the mantle?
- What kinds of things would make part of Earth's crust thicker than another part?
- Continental crust is usually much thicker than oceanic crust. Make a prediction; Would being thicker affect how continental crust floats on the mantle compared to oceanic crust? If so, how?

6 Testing your prediction

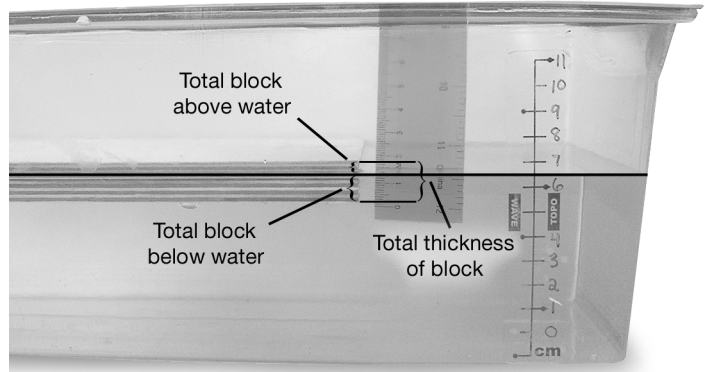
As mountains and mountain chains grow, the part of the crust they are on gets thicker and thicker. We are going to test your prediction of how getting thicker affects how the crust floats on the mantle by watching what happens when we build a mountain.

- Fill the GeoBox with water up to the 5 cm line.
- Measure the thickness of the largest mountain block and record your measurement in Table 3.

Thickness of block



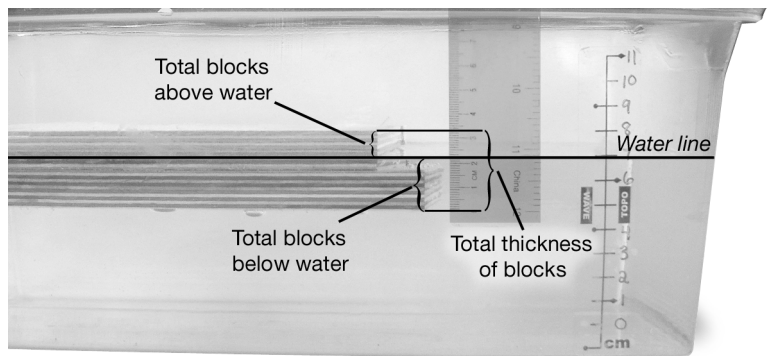
- Place the largest mountain block in the water. This block represents Earth's continental crust.
- Measure how much of the block is above the surface of the water, and how much is below the surface of the water. Record your measurements in Table 3.



- Measure the thickness of the second largest mountain block. Record your measurement in Table 3. Add this measurement to the thickness of the first block and record the total thickness of all blocks in Table 3.

- It's time to start building your mountain. Place the second largest block on top of the block in the water.

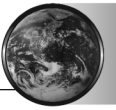
- Measure the total amount of both blocks above the surface of the water, and the total amount of both blocks below the surface.



- Repeat steps 5 -7 until you've measured all the blocks and completed the mountain.

Table 3: Mountain blocks data

Block	Thickness (mm)	Total thickness of all blocks (mm)	Total amount above water (mm)	Total amount below water (mm)
first				
second				
third				
fourth				
fifth				



7 Thinking about what you observed

- a. As the mountain grew taller, did the increase in height equal the thickness of each block you put on?
- b. What happened to the total amount of all blocks underwater as the mountain grew taller?
- c. Did the total amount underwater increase steadily as the mountain grew taller? Why or why not?
- d. How does this activity relate to Earth's crust and mountain building?
- e. Predict what you think happens to the crust as its mountains and mountain chains slowly erode over many years through weathering and erosion? Take your mountain apart one block at a time and see if your prediction is correct.

8 Exploring on your own

- a. How thick on average are oceanic and continental crust?
- b. Where are the thinnest and thickest part of the crust, and how thick are they?
- c. **Research:** Find out the average densities of the mantle, oceanic and continental crust.
- d. **Challenge:** As the thickness of the crust decreases, what do scientists call the process that takes place? What else other than mountains can cause this same process to happen?

11A Plate Tectonics

What is plate tectonics?

Earth’s crust plus the upper mantle forms the *lithosphere*. Earth’s lithosphere is broken in a number of different pieces. How these pieces move and interact is what plate tectonics is all about. In this investigation, you will be an Earth detective and identify lithospheric plates using geologic evidence.

Materials

- Bathymetric map
- Colored pencils
- Pencil

1

Setting up

Part 1: Reading a bathymetric map

1.

Examine your map. A bathymetric map shows what land looks like under a body of water like the ocean.
2.

Find examples of the following features on your bathymetric map: mid-ocean ridges, rises, deep ocean trenches, and mountain ranges. List one example of each from your map in the second column of Table 1.
3.

In the third column of Table 1, list which type of plate boundary, convergent or divergent, is associated with each feature. Note: A rise is like a ridge.
4.

In the fourth column, there are small diagrams showing two plates and the boundary between these. Draw arrows showing how the plates move relative to each other at these boundaries.

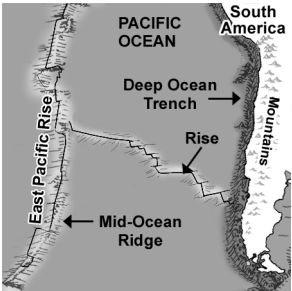


Table 1: Features on a bathymetric map

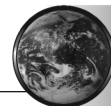
Features	Examples from the map	Kind of plate boundary (convergent or divergent?)	How do the plates at this boundary move?	
mid-ocean ridge			Plate 1	Plate 2
rise			Plate 1	Plate 2
deep ocean trench			Plate 1	Plate 2

Part 2: Starting to find plate boundaries.

1.

Earth has seven to ten large pieces and many small plates. To keep things simple on your map, you will identify seven large plates.
2.

Keep in mind that mid-ocean ridges, rises, deep ocean trenches, and mountain ranges are all geologic features that are formed at tectonic plate boundaries.



- With your pencil, draw a single line along the mid-ocean ridges, rises, deep ocean trenches, and mountain ranges. Draw your lines along the center of each of these features. Your lines represent the boundaries between tectonic plates.

Part 3: Using earthquake activity to find plate boundaries

- Once you have identified all of the mid-ocean ridges, deep ocean trenches, and mountain ranges, you may notice that many of your lines may not connect. Complete the following steps to help fill in some of the missing parts of your plate boundaries.

Table 2: Earthquake data table

	Location	Magnitude		Location	Magnitude
1	Lat 36.3° N, Long 23.4° E	6.8	11	Lat 4.5° S, Long 153.4° E	7.7
2	Lat 32.5° N, Long 104.5° W	4.2	12	Lat 35.0° N, Long 119.0° W	4.7
3	Lat 5.7° S, Long 76.4° W	7.5	13	Lat 36.4° N, Long 140.8° E	6.4
4	Lat 18.8° N, Long 155.4° W	5.2	14	Lat 7.9° N, Long 92.1° E	7.3
5	Lat 34.5° N, Long 73.6° E	7.6	15	Lat 9.6° N, Long 84.2° W	6.4
6	Lat 10.9° N, Long 140.8° E	6.6	16	Lat 51.2° N, Long 179.4° W	6.8
7	Lat 45.1° N, Long 167.2° E	7.2	17	Lat 41.3° N, Long 125.9° W	7.2
8	Lat 2.1° N, Long 97.0° E	8.7	18	Lat 36.3° N, Long 51.6° E	6.3
9	Lat 55.5° N, Long 165.8° E	6.7	19	Lat 49.3° N, Long 128.8° W	6.7
10	Lat 39.8° N, Long 43.8° E	5.2	20	Lat 19.9° S, Long 69.0° W	7.8

- Earthquakes are common along tectonic plate boundaries. The earthquake data table (Table 2) shows the location and magnitude of recent earthquakes around the globe.
- You will be plotting 20 earthquakes according to latitude and longitude. Plot the earthquakes using a colored pencil according to their magnitude. Use this key for your earthquakes, draw this key on your map.
- When you have finished plotting the earthquake data, use your pencil and draw a single line along the earthquake dots. You may find that many of these lines will connect with the lines you drew for mountain ranges, deep-ocean trenches, and mid-ocean ridges. These lines represent the boundaries between tectonic plates.

Key for Earthquake Magnitude

- Magnitude less than 5.0
- ⊙ Magnitude 5.0 to 6.9
- ★ Magnitude 7.0 and above

Part 4: Using volcanic activity to find plate boundaries

1. Once you have plotted your earthquake data, you may find that some of the lines still do not connect. Follow these steps to help fill in some of the missing parts of your plate boundaries.
2. Volcanoes, like earthquake activity, are often found along plate boundaries. The volcano data table (Table 3 below) shows the location of recent volcanic eruptions around the globe.

Table 3: Volcano data table

	Location		Location
1	<i>Lat</i> 59.4° N, <i>Long</i> 153.4° W	7	<i>Lat</i> 35.2° S, <i>Long</i> 70.6° W
2	<i>Lat</i> 12.3° N, <i>Long</i> 93.9° E	8	<i>Lat</i> 19.0° N, <i>Long</i> 98.6° W
3	<i>Lat</i> 1.2° N, <i>Long</i> 77.4° W	9	<i>Lat</i> 16.7° N, <i>Long</i> 62.2° W
4	<i>Lat</i> 5.5° S, <i>Long</i> 150.0° E	10	<i>Lat</i> 46.2° N, <i>Long</i> 122.2° W
5	<i>Lat</i> 19.5° N, <i>Long</i> 155.3° W	11	<i>Lat</i> 54.0° N, <i>Long</i> 159.5° E
6	<i>Lat</i> 16.5° S, <i>Long</i> 168.4° E	12	<i>Lat</i> 14.5° N, <i>Long</i> 90.9° W

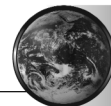
3. You will be plotting volcano activity according to latitude and longitude. Plot the volcanoes using a colored pencil. Use a triangle to represent volcanoes. Include this in your key on your map.
4. When you have finished plotting your volcano data, use your pencil and draw a single line along the triangles. You may find that the lines you draw for the volcanoes will connect with the previous lines you have drawn.

Part 5: Using your evidence to locate Earth's major tectonic plates

1. Using your pencil, continue working on connecting the lines that mark tectonic plate boundaries. Remember you are trying to locate seven major tectonic plates: the American Plate, Eurasian Plate, African Plate, Pacific Plate, Antarctic Plate, Indo-Australian Plate, and the Nazca Plate. Label each of the plates you found.

2 Stop and think

- a. How well do you think you did in accurately locating the seven major tectonic plates? What further evidence would have been helpful in making your map more accurate?
- b. In what areas of your map could you have used more geologic evidence to help locate plate boundaries?
- c. Why is a bathymetric map more useful in this investigation than a regular world map that does not show the ocean floor?



3 Doing the experiment

1. Now that you have come up with a hypothesis of where the seven major tectonic plates are located, your teacher will help you distinguish the actual location of the seven plates.
2. When you have the actual locations of the seven major tectonic plates, use your colored pencils to shade in each of the plates a different color. Be sure you have written the name of each of the seven plates on your map as well.

4 Thinking about what you observed

- a. Find the Himalaya Mountains on your map. These mountains are continuing to grow taller. What does this tell you about the type of plate boundary between the Eurasian plate and the Indo-Australian plate?
- b. The boundary around the Pacific plate is commonly referred to as the “Ring of Fire.” Examine the geologic events along this boundary. Why do you think this boundary has been given this name?
- c. Find the Mid-Atlantic Ridge on your map. The Atlantic Ocean was once much smaller millions of years ago and has been growing in size to present day. What does this tell you about the type of plate boundary that exists at the Mid-Atlantic Ridge?
- d. The boundary between the African Plate and the Eurasian Plate in the Mediterranean Sea is a convergent boundary. Africa is slowly pushing northward towards Europe. What will eventually become of the Mediterranean Sea in the future? Why?
- e. The boundaries between the Eurasian Plate and the Indo-Australian Plate as well as the Nazca Plate and the South American plate are convergent boundaries. What is a major difference in the geologic features and events at these two plate boundaries?
- f. Lithospheric plates move about as fast as your fingernails grow—2.5 cm/year! Your teacher will help you figure out the main directions to move the plates on your map. Using this information and the rate of movement, figure out what Earth will look like in 50 million years!

11B Evidence for Plate Tectonics

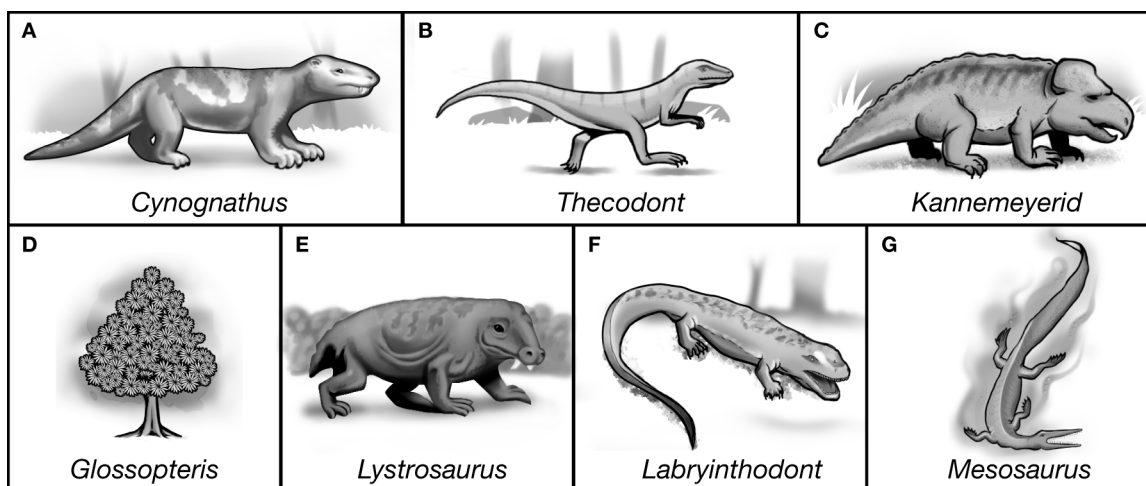
How are fossils useful evidence for continental drift?

Fossils are the remains or evidence of living organisms. Fossils come in different forms, including casts, molds, imprints, amber, and ice. Scientists can learn a great deal about life and the history of Earth using fossils. Fossils are useful evidence for understanding how organisms have evolved over time. They are also used to see how life has changed throughout Earth's history. Fossils have also been used to help scientists understand how the continents appeared millions of years ago. In this investigation, you will use several fossils to try to reconstruct how Earth's landmasses may have appeared approximately 250 million years ago.

Materials

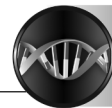
- Bathymetric map
- Fossil data (included in investigation)
- Scissors
- Tape
- A piece of construction paper
- Pen or pencil

1 Setting up



	Fossil name	Locations found
A	Cynognathus	South America, western Africa
B	Thecodont	Europe, eastern North America
C	Kannemeyrid	northern South America, Africa, India, Asia
D	Glossopteris	eastern South America, central Africa, India, Australia
E	Lystrosaurus	Antarctica, southern Africa, India
F	Labryinthodont	Antarctica, central Africa, eastern Asia, Australia
G	Mesosaurus	southern South America, southern Africa

1. Using the information table above, write the letter of each fossil onto the correct locations on your bathymetric map. Note: the locations given in the table are only approximate locations.



2 Stop and think

- a. Which of the fossils from the table were found in Antarctica? Why might this seem strange or unexpected?
- b. Which of the fossils from the table were found both in North America and Asia?
- c. What are some possible ways these organisms could have traveled from continent to continent when they were living?
- d. If these animals and plants were not able to swim across large bodies of water such as oceans or sea, explain how else the pattern of fossil distribution can be explained.

3 Doing the experiment

1. Cut out each of the following continents and landforms from your map: North America, South America, Antarctica, Africa, Europe, Australia, and Asia.
2. Place these continents onto your piece of construction paper.
3. Using the shape of the continents' coastlines and the locations where each type of fossil has been found, reconstruct the world so that all the continents are connected to form a large "supercontinent."
4. When you have completed the previous step tape down the continents to your piece of construction paper in the same positions you arranged them in step 3.

4 Thinking about what you observed

- a. *Glossopteris* is an extinct type of plant referred to as a seed fern. These plants most likely thrived in tropical climates. Do any of the locations where the fossils of the *Glossopteris* have been found seem strange? Explain your answer.
- b. *Thecodont* was a small dinosaur. Where have fossils of this dinosaur been uncovered? Does it seem likely that this animal could have traveled between these two locations? Explain your answer.
- c. How did the fossils of *Cynognathus* help you construct your map?
- d. Where on your new map is Australia? To which continents is it connected? Which fossils did you use to help place Australia? How were they useful?
- e. What other evidence might be useful for connecting the continents together into one giant landmass?

5 Exploring on your own

Pick two of the organisms from the fossil list you used in this investigation. Using your school library or the Internet research this organism. Write a one paragraph summary of what you found about each of these organisms. Your research should include but is not limited to - when it lived, what it ate, how it behaved, its size, and the habitat in which it lived. Include a sketch of your organisms as well.

12A Earthquakes

What conditions affect the timing, duration, and intensity of an earthquake?

Most earthquakes are associated with plate boundaries. This is because the slow movement of the plates against each other causes stress on the rocks at the boundaries to increase. Stress results in the buildup of pressure and stored energy in objects.

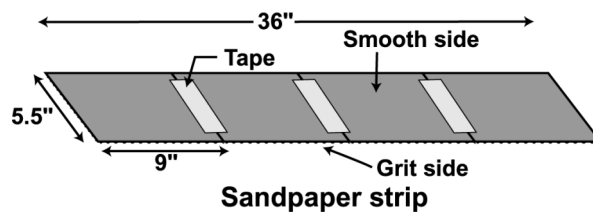
Earthquakes occur when the rocks that are under stress experience a release of pressure and stored energy. In this investigation, you will use simple materials to simulate an earthquake.

Materials

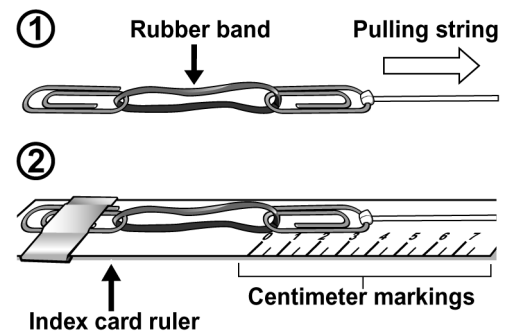
- Safety goggles
- Sandpaper
- Masking tape
- 2 paper clips
- Rubber band
- Kite string
- Index card (2 cm × 12.5 cm long)
- Metric ruler
- Hardcover book with sand paper cover
- Sugar cubes

1 Setting up

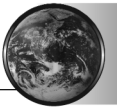
1. Cut two pieces of sandpaper in half. Each half will be 9 x 5.5 inches. Turn the four halves smooth side up and place them short-end-to-short-end. Tape the halves together so that they form a 36-inch strip.



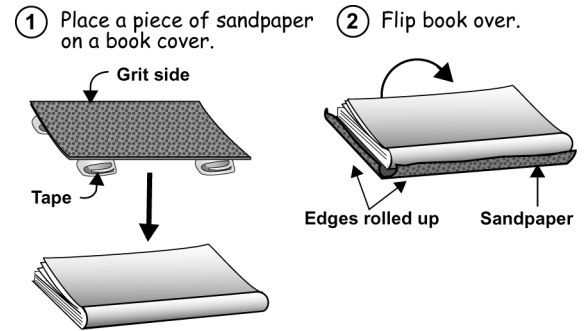
2. Tape the sandpaper strip to your desk so the smooth side is down and the grit is up.
3. Put on safety goggles. Use caution with rubber bands. Do not shoot or overstretch them.
4. Make a strain gauge by hooking two paper clips into a rubber band. Tie a long piece of kite string to one of the paper clips.
5. Now, you will make a paper ruler with a piece of index card that is 2 cm wide by 12.5 cm long. First, place the blank card under the paper clip that is not attached to the string. Tape the card to this paper clip as shown in the diagram. The strain gauge and the paper ruler will move together in the model.



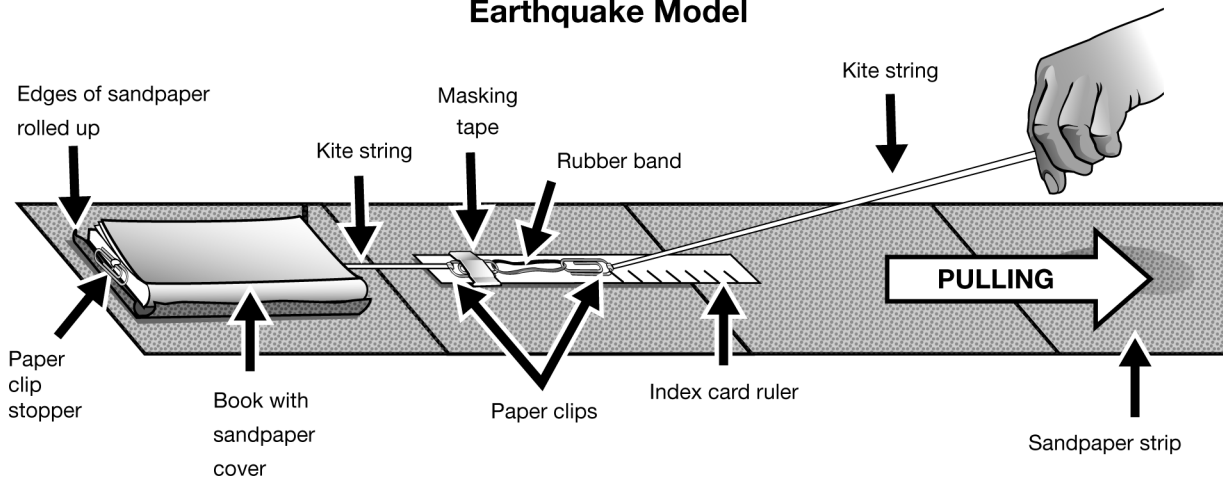
Strain gauge setup



6. Next, starting with zero at the far end of the rubber band, mark off centimeters using a metric ruler until you get to the end of the card. Make your strain gauge look like the diagram. Make sure you have at least 7 centimeters marked on the paper ruler.
7. Using masking tape, attach a piece of sandpaper on the outside of one cover of a book. The sandpaper should be a little larger than the cover. Once the sandpaper is on the book, fold up the overhanging sandpaper.
8. Tie a piece of kite string to the paper clip that is taped to the paper ruler. Then, place this string down the center of a page in the middle of the book. Use a very small piece of tape to hold the string in place on the page. Close the book. Tie the overhanging kite string to another paper clip so that it serves as an anchor to keep the string from pulling through the book. You may want to tape this paper clip to the top of the book with masking tape.
9. Place the book on the sandpaper strip at one end of the sandpaper strip. Make sure your setup matches with the setup of the earthquake model shown in the diagram below.



Earthquake Model



2 Stop and think

The graphic at right shows an earthquake occurring near a fault. Use this graphic to identify how the earthquake model represents an earthquake. Then, fill in Table 1.

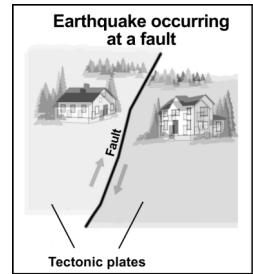


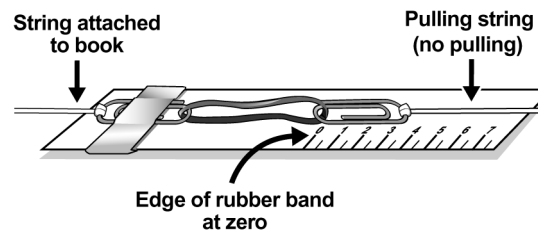
Table 1: Earthquake model

Material in setup	What does it represent?
The book	
The sandpaper strip	
The boundary between the book and the sandpaper	

3 Doing the experiment—working with the model

Safety tip: Wear goggles!

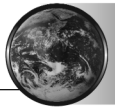
1. Place the book at one end of the sandpaper strip.
2. Gently pull on the string until the book moves a little. If the book does not move straight, move the string inside the book a little off center, and re-tape the string to the page.
3. Make adjustments to the setup as needed until it works well. However, do not pull the book along the sandpaper too many times. Doing this will wear down the sandpaper and change your results.
4. Now, place the book back at the end of the strip, and pull the string until the edge of the rubber band moves from zero on the paper ruler to the 1-centimeter mark. This distance is related to how much stress is in the rubber band.
5. Answer questions **a** and **b** in Part 8: Thinking about what you observed.



4 Doing the experiment—simulating the timing of an earthquake

To simulate an earthquake, you will pull the string until the book suddenly moves along the sandpaper strip. This sudden movement, called a “slip” or a “failure” is the release of stress between the book and the sandpaper. It is also a release of energy.

1. Place the book at the far end of the sandpaper strip.
2. Pull the string slowly and smoothly until the book slips (moves suddenly). Record the stretch just as the book slips. This is the *slip stretch*.
3. Without moving the hand holding the string, record the remaining stretch after the book stops. This is called the *stop stretch*.



- Repeat this process twice. Start with the book at the far end of the sandpaper strip for each trial. Record all data in Table 2. Find the average slip stretch and stop stretch lengths. Then, answer questions **c** and **d** in Part 8.

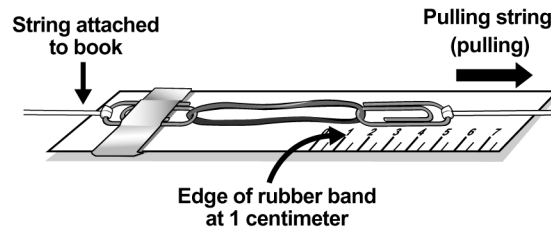


Table 2: Earthquake timing simulation

Trial Number	Length of slip stretch (cm)	Length of stop stretch (cm)
1		
2		
3		
Average		

5 Doing the experiment—simulating the duration of an earthquake

- In this part of the investigation, you will simulate another earthquake. As you did in the previous simulation, pull the thread to move the book. However, when the book slips, continue to pull the thread just hard enough to keep the book moving. Practice your technique.
- When you have perfected your technique, begin collecting data in Table 3. Read the stretch measurement after the book first slips but while the book is still moving. Run three trials, record your data below, and find the average.
- Answer questions **e** and **f** in Part 8.

Table 3: Earthquake duration simulation

Trial number	Length of stretch while the book is moving (cm)
1	
2	
3	
Average	

6 Doing the experiment—simulating the intensity of an earthquake

- You and your group will simulate another earthquake by having team members drum on the tabletop with their fists. Each person should drum on the table with gentle to medium force.
- While drumming is taking place, simulate an earthquake with your model.
- Depending on what you observe in this experiment, record slip and stop stretches or stretches while the book is moving. Record your data in Table 4 and then average your data.
- Answer questions **g-i** in Part 8.

Table 4: Earthquake intensity simulation

Trial number	Length of slip stretch (cm)	Length of stop stretch (cm)	Length of stretch while book is moving (cm)
1			
2			
3			
Average			

7 Doing the experiment—simulating the damage caused by an earthquake

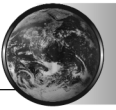
1. Perform each of the experiments with sugar cubes stacked on the book. Place one sugar cube alone, then have stacks of two, three, and four cubes. These stacked sugar cubes represent one-, two-, three-, and four-story building,
2. In the spaces of Table 5, record whether the cubes moved or the stacks fell during each simulation.
3. Answer questions j-1 in Part 8.

Table 5: Earthquake damage simulation

Earthquake experiment	One cube	Two cubes	Three cubes	Four cubes
Timing simulation				
Duration simulation				
Intensity simulation				

8 Thinking about what you observed

- a. Did the book move when the stretch was 1 centimeter?
- b. What does the movement of the book on the sandpaper strip represent in this investigation?
- c. The movement of tectonic plates occurs all the time, but earthquakes do not. Why doesn't plate movement cause continual small earthquakes? Why do earthquakes occur every once in a while? Explain your answer.
- d. Did all of the energy stored in the rubber band release when the book slipped? Do you think an earthquake releases all of the stored energy when it occurs?
- e. How does the data from “timing of an earthquake” compare with the data from “duration of an earthquake”? Why do you think this is?
- f. Earthquakes last longer than a few seconds. They do not simply start and quickly stop. Explain the relatively long duration of earthquakes based on the results of the experiment.
- g. How does the data from “timing of an earthquake” or “duration of an earthquake” compare with the data from “intensity of an earthquake”? Why do you think this is so?



- h. How did the drumming affect the intensity of the “earthquake” in the model?
- i. Do you think one earthquake can cause another earthquake? Explain your answer.
- j. Which sugar-cube building experienced the most damage? Why do you think this happened?
- k. Which experiment resulted in the most damage? Why do you think this happened?
- l. Given the results, suggest one safety tip that would reduce damage to buildings during an earthquake.

9 Exploring on your own

- a. Find out what areas in the United States have the highest seismic risk.
- b. In terms of plate tectonics, what is happening at the San Andreas Fault?
- c. How fast is the plate movement at the San Andreas Fault?

12B Volcanoes

How are volcanoes and plate boundaries related?

Mount Saint Helens in Washington State erupted violently in 1980, sending ash and dust high into Earth's atmosphere. The winds in the atmosphere blew this ash and dust around the world. All active volcanoes erupt and release material like lava, ash, and dust that is very hot and therefore dangerous. Some volcanoes, such as Mount Saint Helens, are especially dangerous because of the sudden, violently explosive nature of their eruptions. Other volcanoes, such as Mauna Loa in Hawaii, are less explosive. Less explosive volcanoes spew lava fountains and streams of melted rock, but in a gentler manner. In this investigation, you will discover key differences between gentle and explosive volcanoes and will discover a pattern in their geographic distribution.

Materials

- Bathymetric map
- Red and blue markers
- Ruler
- Rock samples – basalt, rhyolite, andesite, obsidian, granite samples

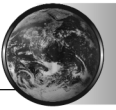
1 The Volcanic Explosivity Index

The Richter scale has been used by geologists for more than 50 years to measure the strength of an earthquake. The Richter scale is a number scale where the higher the number, the stronger the earthquake. Geologists have also used a number scale that describes volcanic eruptions. This number scale is called the Volcanic Explosivity Index, or VEI. The higher the VEI, the more explosive or violent the eruption of a volcano. Explosive eruptions are associated with high plumes of lava and ash escaping from the top of the volcano, such as Mount Saint Helens. Volcanoes with low VEI numbers have gentle eruptions. The plumes of these eruptions are not very high and not as much lava is released when the volcano erupts, such as Kilauea in Hawaii. Table 1 provides a list of volcanoes and their VEI ratings.

Table 1: Examples of volcanoes and VEI ratings

VEI	Plume height	Volume (m ³)	Average time interval between eruptions	Example
0	<100 m	≥ 1000	one day	Kilauea
1	100-1000 m	≥ 10,000	one day	Stromboli
2	1-5 km	≥ 1,000,000	one week	Galeras, 1992
3	3-15 km	≥ 10,000,000	one year	Ruiz, 1985
4	10-25 km	≥ 100,000,000	≥ 10 years	Galunggung, 1982
5	> 25 km	≥ 1,000,000,000	≥ 100 years	Mount St. Helens, 1981
6	> 25 km	≥ 10,000,000,000	≥ 100 years	Krakatoa, 1883
7	> 25 km	≥ 100,000,000,000	≥ 1,000 years	Tambora, 1815
8	> 25 km	≥ 1,000,000,000,000	≥ 10,000 years	Toba, 71,000 years ago

- a. What is the relationship between the VEI and the average time interval between eruptions?



- b. The plume height is the height the erupted material rises from a volcano. What is the relationship between the plume height and the VEI?
- c. What rating does Kilauea in Hawaii have on the VEI? What rating does Mount Saint Helens in Washington state have on the VEI?

2 Connecting volcanoes to plate boundaries

1. Table 2 provides the position by latitude (Lat) and longitude (Long) for eight volcanoes represented by two-letter symbols. The volcanoes in the left-hand group are known to erupt violently. The right-hand group volcanoes are known as gentle or less violent.
2. Plot the locations of all volcanoes on your bathymetric map.
3. Represent each volcano with its two-letter symbol. Represent violent volcanoes with a red marker and gentle volcanoes with a blue marker.

Table 2: Locations of volcanoes

Violent volcanoes		Gentle (less violent) volcanoes	
PN	<i>Lat</i> 15.1° N, <i>Long</i> 120.4° E	MA	<i>Lat</i> 19.5° N, <i>Long</i> 155.5° W
KR	<i>Lat</i> 16.7° S, <i>Long</i> 105.4° E	FE	<i>Lat</i> 0.4 S, <i>Long</i> 91.6 W
KA	<i>Lat</i> 58.3° N, <i>Long</i> 155.0° W	ER	<i>Lat</i> 13.6° N, <i>Long</i> 40. 7° E
BE	<i>Lat</i> 56.1° N, <i>Long</i> 160.7° E	PT	<i>Lat</i> 21.2° S, <i>Long</i> 55.7° E

- a. How do the locations of the two kinds of volcanoes relate to the locations of plate boundaries?
- b. Volcanoes that form near convergent plate boundaries release magma that is viscous. Viscous magma is very thick and gases become trapped inside, building up pressure over time. What types of volcanoes are located near convergent plate boundaries?
- c. Near divergent plate boundaries the magma in volcanoes is not viscous. Magma that is not viscous is not as thick and does not contain as much gas. This causes the magma to flow more easily and with less pressure built up inside. What types of volcanoes are located near divergent plate boundaries?

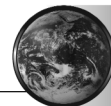
3 Connecting the location of volcanoes to volcanic rock

Table 3 provides information about the magma composition and the type of volcano that you plotted in Part 2. Study the table, and using your map, think about how the magma composition relates to a volcano's location.

Table 3: Type of volcano and magma composition

Volcano	Type	VEI	Volcanic Rock (Magma composition)
Pinatubo (PN)	composite	6	rhyolite
Krakatoa (KR)	composite	7	rhyolite/andesite
Katmai (KA)	complex composite	3	andesite
Bezymianny (BE)	complex composite	2	andesite
Mauna Loa (MA)	shield	0	basalt
Fernandina (FE)	shield	2	basalt
Erta Ale (ER)	shield	2	basalt
Piton de la Fournaise (PT)	shield	1	basalt

- What type of volcanic rock is associated with more explosive eruptions (higher VEI)?
What type of volcanic rock is associated with less explosive eruptions (lower VEI)?
- What is the relationship between the volcanic rock and the type of plate boundary (convergent or divergent)?
- Using your bathymetric map, where do you typically find volcanoes that contain basalt?
Where do you typically find volcanoes that contain rhyolite or andesite?
- Imagine you are asked to investigate a newly discovered volcano to find out whether it will produce a gentle or violent eruption. Develop a research plan for studying the volcano. What evidence will you need to be able to identify the nature of the eruption?
Assume that you can use any resources you need.



13A Mineral Identification

How are minerals identified?

Minerals are the building blocks of rocks. They come in all sizes, shapes, and colors. It is not always easy to identify them just by looking at them. Different types of minerals can look very similar to one another. There are many characteristics that need to be observed to assure the identity of the mineral in hand.

One important way to assist in identification is by assessing the hardness of a mineral. A scientist named Friedrich Mohs established the scale, in 1812, that is still used today to identify mineral hardness. Mohs based his scale on the observable hardness of 10 readily available minerals. Hardness is rated from 1 to 10, with 10 representing the hardest mineral (diamond) and 1 the softest (talc) on the scale.

In this investigation, you will be given several unidentified minerals and use the Mohs hardness scale, along with a few other observable characteristics, to identify the minerals.

Materials

- Copper penny
- Steel nail
- Glass plate
- Plastic bin
- Streak plate
- Mineral ID chart
- Magnet
- HCl (10% solution) in bottle with dropper
- Rocks and Minerals set

1 Setting up

1. Collect a bin full of supplies put together by the teacher.
2. The mineral samples you will be identifying are labeled by letter. For example, you will get mineral A from its place in the classroom, bring it back to your table, and use your supplies to identify its real name.

2 Doing the activity

1. First, identify the color of each sample. Put the information in the appropriate column in Table 2. You will notice that depending on the sample you picked up, others of the same mineral type may be a very different color.
2. Streak each mineral on the streak plate. The streak is the color of a mineral in its powdered form. Note the color of this powder, if any. Not all minerals have streaks. Put a dash in the table if no streak is present.
3. The Mohs hardness scale (Table 1) is an important indicator of hardness. Hardness is the measure of resistance of a mineral to being scratched. The mineral to be identified is rubbed against another mineral of known hardness or a material of known hardness. The scale starts at one and goes to ten. Talc is the softest mineral and is rated at one. Diamond is the hardest mineral and is rated at 10. There are eight other mineral markers in between. Other materials, like glass are also used to identify hardness. Glass has a hardness of 5.5. Use the edge of a mineral. Place the glass flat on the table. Scratch the glass hard with the mineral. Wipe away any powder. If there is a line etched in the glass, then the mineral is harder than 5.5. If there is no line etched in the glass, then the mineral has a hardness less than 5.5. Other indicators are noted below. The goal is to narrow the hardness down to the smallest range possible. For example, the hardness is 2.5-3.5.

Table I: Mohs Hardness scale of minerals and common materials

Mohs hardness scale		Common materials	
#	Mineral	#	Material
1	talc	2.5	finger nail
2	gypsum	3.5	copper penny
3	calcite	5.5	glass
4	fluorite	6.5	steel nail
5	apatite	7	quartz
6	feldspar		
7	quartz		
8	topaz		
9	corundum		
10	diamond		

1. Luster is the appearance of light reflected from the surface of the mineral. A mineral with metallic luster has the appearance of a metal, whereas a non-metallic mineral does not.
2. Cleavage/Fracture: Cleavage is the tendency of a mineral to break along planes of weakness. Some minerals cleave into plates. A mineral has fracture when it does not exhibit this quality.
3. Other Properties: Smell (some mineral powders smell when streaked), taste (a mineral such as halite tastes salty), reactivity with a dilute HCl solution (when a mineral reacts with HCl, it contains calcite), magnetic (only some minerals are magnetic), feel/touch (some minerals are known for their greasy or powdery feel).
4. Once you have identified the properties of the minerals, use the mineral ID chart to figure out the names of the minerals. Take your time. It is easy to make a mistake.

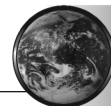


Table 2: Mineral data

Sample	Color	Streak	Hardness	Luster	Cleavage/ fracture	Other properties	Mineral ID
A							
B							
C							
D							
E							
F							
G							
H							
I							
J							
K							
L							

3 Thinking about what you observed

- Why do you think some minerals which have the same name can look so different?
- Is the Mohs hardness scale a reliable way on its own to identify an unknown mineral? Why or why not?
- Do you think the observations you have made on the minerals in this investigation would allow you to properly identify a rock you may find on the ground?

13B Igneous Rocks

How are igneous rocks classified?

Geologists divide rocks into three groups - igneous, metamorphic, and sedimentary - based on how they were formed. Igneous rocks are formed from the cooling of magma or lava either on or below Earth's surface. Many *igneous rocks* consist of mineral crystals. When magma cools, it usually includes the ingredients for more than one kind of mineral. As the magma cools, it begins to form mineral crystals. As the cooling continues, different mineral crystals form. Eventually the last of the cooled magma solidifies, locking all of the crystals in place, forming an igneous rock.

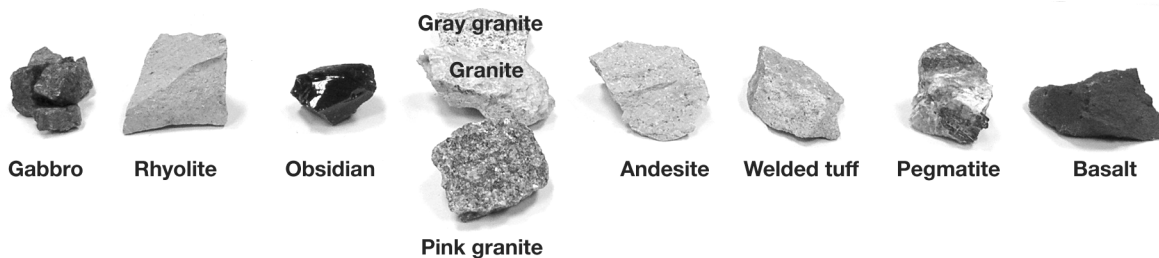
Some igneous rocks do not contain minerals with crystal structures. These rocks are formed when magma cools rapidly on the surface, not allowing the minerals to crystallize. Igneous rocks formed this way are known as volcanic glass. In this investigation you will learn how to classify igneous rocks. You will also determine how crystal size relates to the cooling rate of magma.

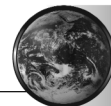
Materials

- Igneous rock samples: gabbro, granite, basalt, andesite, rhyolite, obsidian, welded tuff, pegmatite
- Hand lens
- 2 Small plastic dishes or saucers
- Table salt
- Plastic beverage cup
- Plastic spoon

1 Examining igneous rocks

1. Arrange the igneous rock samples on your table so that they can easily be examined.
2. Rocks are classified based on their texture and color. You will be classifying the rocks on your table based on these properties.
3. Use the hand lens and classify each of the rocks according to its color. Some rocks may have more than one color. Be sure to classify all of the colors you see. Record your observations in Table 1 in part 2.
4. Rocks are also classified based on their texture. Geologists define a rock's texture as the shape, size and pattern of the mineral crystals that make up the rock.
5. Classify each of your rock samples based on its texture. Place a check mark in each of the appropriate columns in Table 1 to classify your rock's texture.





2 Rock classification

Table I: Rock Classification

	TEXTURE							
	Color(s)	Fine Grained	Coarse Grained	Round	Jagged	Flat layers	Wavy	No Visible Grains
Granite samples								
Basalt								
Obsidian								
Andesite								
Rhyolite								
Gabbro								
Pegmatite								
Welded tuff								

3 Stop and think

- Which of the rocks you observed were composed of larger, coarse-grained mineral crystals? Did these rocks have any other properties in common?
- Which of the rocks you observed were composed of smaller, fine-grained crystals or no visible crystals at all? Did these rocks have any other properties in common?
- Based on your observations and what you know about the formation of igneous rocks, which rocks do you think formed from magma that cooled quickly? Which of the rocks may have formed from magma that cooled very slowly?
- Based on your answer to question **c**, predict which rocks may have formed below Earth's surface? Which rocks may have formed on or near the surface?

4 Doing the experiment

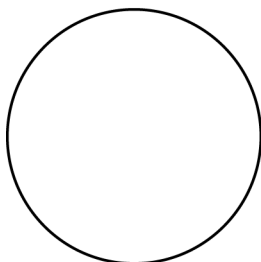
1. Add 4 heaping teaspoons of salt to a plastic beverage cup half-filled with water.
2. Stir this mixture for 1 minute. Not all the salt will dissolve because you have formed a saturated solution. This means the water has dissolved all the salt it can hold.
3. Pour a little of the salt solution into two dishes. Label one dish “warm” and the other “cool.”
4. Place the dish labeled “warm” in a warm place such as over a radiator or near a sunny window. Alternatively, you can use a hair dryer to warm the liquid in this dish until it dries up. Operate the hair dryer on low speed at least 60 cm from the dish. You want to warm the salt water without blasting it out of your dish!
5. Place the dish labeled “cool” away from sources of warmth and light.

Make a prediction:

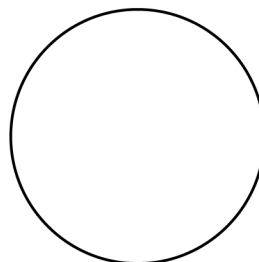
How do you think the crystals will look in each dish after the water has evaporated?

Draw a picture in each of the circles below to illustrate your prediction

How do you think the crystals will look in each dish
after the water has evaporated?



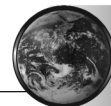
Cool



Warm

NOTE: Crystal growth is slow and will take more than one day.

6. Examine both dishes from time to time for the next few days until all the water has evaporated. You may want to record the temperature at each dish's location.
7. Make a table to record your observations.
8. Record the date, time, and the amount of water left in each dish at each observation. Describe the crystals in each dish. Use relative terms such as *slightly*, *more*, and *most* to record these observations. Measure and record the size of the largest crystal in each dish.
9. When the water has evaporated from one of the dishes, make a final inspection of both dishes. Both dishes will have large and small crystals, but one will have the largest crystals. Usually these largest crystals will form near the edges of the dish.
10. Record your final observations in the table you made in step 7 and 8.



5 Thinking about what you observed

Part 1

- a. Which dish had more time to grow crystals? Which dish contained bigger crystals?
- b. Write a conclusion sentence about the time available for crystals to form and the size of the crystals that form.

Part 2

The size of rock crystals depends on the amount of interaction among the materials in the magma that forms the rock. More time allows more interaction. As a result, slow-growing crystals tend to be bigger than fast-growing crystals. Anything that might slow the cooling of magma will provide that time.

- a. List two natural events or conditions on Earth (other than the methods you used in this investigation) that might slow the cooling of magma.
- b. List two natural events or conditions on Earth that might speed up the cooling of magma.

6 Exploring on your own

- a. Go back to the rock samples you classified earlier in this investigation. Compare the appearance of each sample and look at the observations you made about each rock's texture in Table 1. Based on your work in this part of the investigation, which rocks formed slowly and which rocks formed quickly? Explain your answer to this investigation based on what you learned about crystal growth.
- b. Igneous rocks that form on Earth's surface are *extrusive* and those that form underground are called *intrusive*. Based on your observations of the igneous rocks, which of the rocks are likely to be extrusive? Which are likely to be intrusive? Explain your answer.

14A Water Systems

How does running water shape rivers and the landscape?

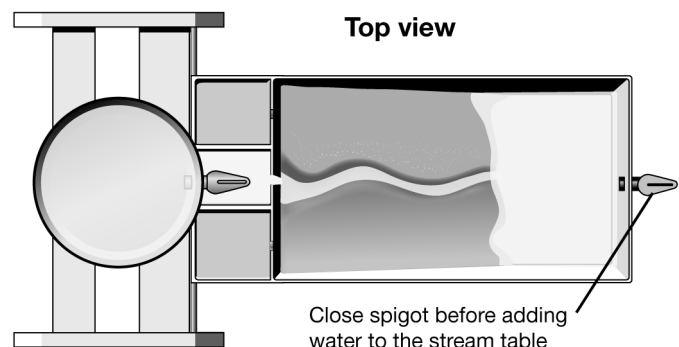
Running water on Earth's surface is a powerful force that shapes the landscape. The power of running water in a river is related to the slope of the river, the shape of the river, and the volume of water flowing in the river. In a river, water erodes sediment from the bottom and sides of the river and moves the sediment farther downstream. In this investigation, you will model how running water moves different sized sediment particles and shapes rivers.

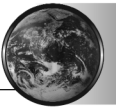
Materials

- Stream table setup (includes stage, two buckets, the table, removable tray, and grit)
- A plastic Petri dish (for collecting grit at each level of the stream table)
- Permanent marker
- Beaker
- Tweezers
- Shovel (optional)

1 Setting up

1. Set up your stream table as shown in the picture at right. Make sure the table is set on the stage's second rung. The bucket on the stage should have a spigot.
2. Using your hands (or a shovel), smooth the sediment (grit) in your stream table so that the bottom third of the table is empty and clear of particles. The bottom third of the table represents the ocean. The sediment should slope from the "ocean" to just under the base of the tray.
3. Use your hands to make a meandering stream channel in your sediment. Dig down only halfway to the bottom of the sediment. Make sure your stream goes all the way to the "empty ocean" in your stream table.
4. Close the drain spigot at the end of the stream table. Place the bucket without the spigot under the drain spigot.
5. Fill the upper bucket with water.
6. Begin **SLOWLY** running water into the top of the river channel. Watch the river gradually fill with water and the sediment particles move downstream. Also note the formation of a delta at the mouth of the stream near your "ocean."





7. Stop the flow of water when your delta has grown into about half of your ocean, or when the water level in the ocean rises too close to the top of the stream table wall.
8. Make sure the lower bucket is lined up with the drainage hole. Open the drain spigot and allow the water to drain from the table into the lower bucket. Observe the general sizes of the particles remaining near the source of the river, the middle, and at the delta.
9. Use a permanent marker to divide a petri dish into 6 equal sections, labeling them from 1 through 6.
10. Using your tweezers, take small samples of the sediment from the following locations and place them in the numbered sections of your petri dish. Use the last page of this investigation to find out what a river delta looks like!
 - **Section 1:** The river source
 - **Section 2:** The end of the stream before the delta
 - **Section 3:** The middle of the delta
 - **Section 4:** The end of the delta
 - **Section 5:** The middle of the ocean bottom
 - **Section 6:** The far end of the ocean bottom



2 Stop and think

Diagram 1: River system

- a. Make a drawing of your river channel, delta, and ocean. Label the following river features: meanders, river source, floodplain, delta, ocean.
- b. Number your diagram showing the location of each of your six sections. For example, label your river source "1." Draw to scale the relative size of the sediment particles found at each location.
- c. How does the size of the particles change as you go from the river source to the far end of the ocean? Why do you think the sediment is sorted this way?
- d. Where was the speed of the water fastest? Where was it the slowest? How can you explain this?

3 Doing the experiment

1. Repeat steps 1 through 10 in the procedure. But this time, change the slope of the stream table so that it is steeper than your first trial.
2. Repeat steps 1 through 10 in the procedure. This time, change the slope of the stream table so that it is not as steep as the first trial.

4 Thinking about what you observed

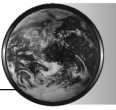
- a. How does increasing the slope of a river affect the rate of erosion by running water?
- b. How does decreasing the slope of a river affect the rate of erosion by running water?
- c. How do you think the width of the river channel affects the erosion of sediment in a river?
- d. Based on your knowledge of sedimentary rocks, where would you likely find samples of conglomerate, sandstone, and shale in a river system?

5 Exploring on your own

1. Use your stream table to model the formation of the following river features. The images on the next page will help you with your work.
2. Your teacher will check off each feature as your team correctly models its formation. Your teacher can ask anyone in your lab group to model and/or describe how the feature forms. Therefore, all members need to be prepared to answer. Your team will earn the most points toward your lab grade if you can demonstrate the knowledge on the first try.

Table 1:

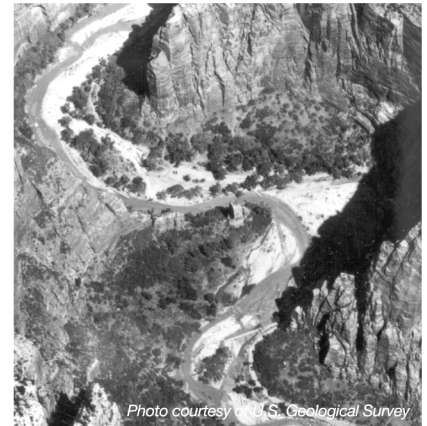
Try 1	Try 2	Try 3	
			v-shaped valley upstream
			meanders
			delta
			floodplain
			alluvial fan
			oxbow lake
			waterfall



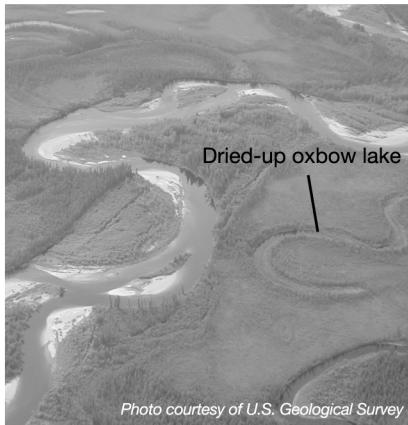
River delta: The mouth of a river that flows into an ocean or lake.



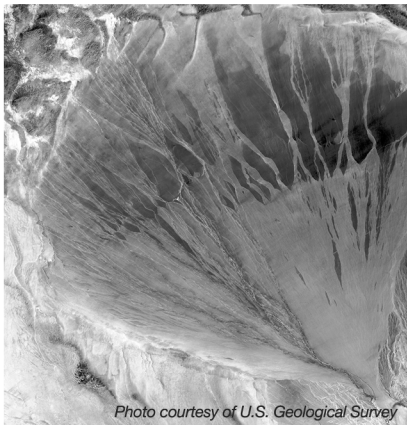
V-shape valley: When a river cuts a mountain it forms a V-shaped valley (a U-shaped valley is formed when a glacier moves through mountains).



Meander: S-shaped curves in a river.



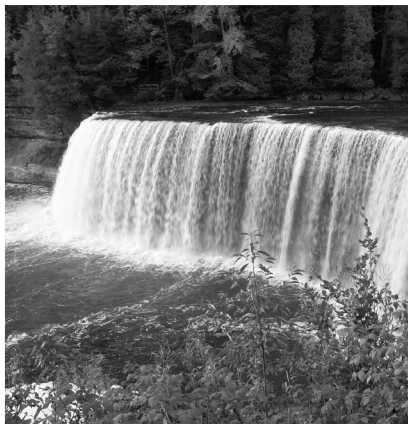
Oxbow lake: A meander that breaks off from the main river channel.



Alluvial fan: A fan-shaped area of sediment caused by a fast-flowing stream slowing down as it flows onto flatter land.



Flood plain: Flat land nearest a river that usually occurs at a distance from the source of the river. A flood plain is very good land for growing plants because the flooding of the river deposits nutrients in the land. However, flood plains are not good places for building because of the flooding.



Waterfall: Falling water that results when a river flows from a high to a low place in its path (such as over a cliff).

14B Human Impacts on Coastal Erosion

How do people living and working in coastal areas affect erosion?

Weathering and erosion by wind, water, and waves constantly changes coastal environments as sediment is transported from one location to another. Coastal erosion increases as wind, water, and waves increase such as during hurricanes. Human-influenced alterations can also cause the rate of erosion of coastal areas to increase at a faster rate than normal. In this investigation, you will explore how the construction of hard structures such as jetties and sea walls can impact coastal areas. In addition to how these alterations impact the shape of our coastlines, you will also explore how building homes on beach areas affects erosion.

Materials

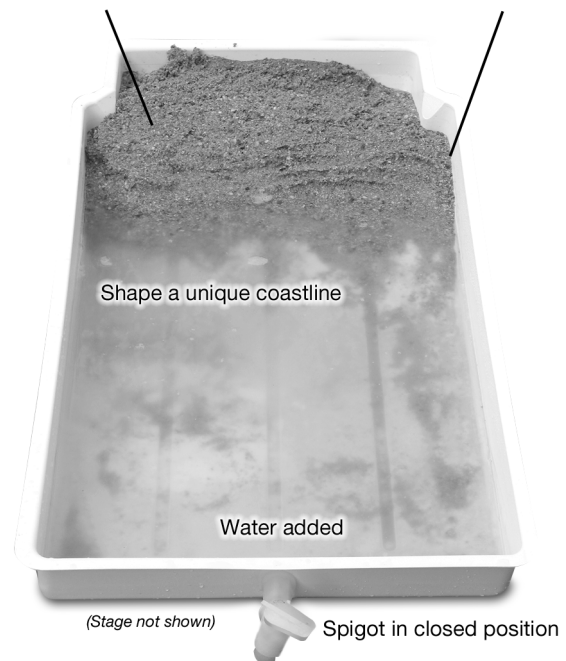
- Stream table with buckets and stage
- Access to water
- Sediment
- Rocks of various sizes
- Sheet of heavy-duty aluminum foil
- Clay
- Toothpicks

1 Setting up

1. Set up your stream table so that it is on the lowest rung of the stand.
2. Fill the top third of the stream table with a layer of sand that is nearly to the top of the stream table's walls.
3. Adjust the spigot at the end of the stream table so that water will not drain from it.
4. Use the buckets and fill the bottom portion of the stream table with water so that it just reaches the sand. Note: The water level should not be more than half the thickness of the sand.
5. Shape out a unique coastline in the stream table using your hands. If necessary wet the sand a bit to help shape your coastline.

Sand added to one third of stream table

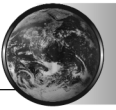
Sand should nearly reach top of edge of stream table



Safety note: Do not stand on the stage! This piece of equipment can only support up to a mass of 10 kilograms.

2 Making predictions

- a. Predict what will happen to your shoreline if you were to create waves in your “ocean.”
- b. How do you think the rate of erosion will change as the amount and size of waves increases?



3 Getting started

1. Draw the shape of your original coastline in Table 1.
2. Use the plastic trough and generate waves in the stream table. Observe and draw the resulting eroded coastline in Table 1.

Table 1: Coastal erosion observations

Sketch and description of coastline before waves	Sketch and description of coastline after waves

4 Jetties

Jetties are structures constructed out of hard materials like boulders or concrete that extend off shorelines out into the water in coastal areas. Humans build jetties to influence weathering and erosion caused by waves. Investigate what happens to a coastline when a jetty is present.

1. Using the rocks, create a wall that extends just above the level of the water and runs parallel to half of your coastline. (Make your jetty about 3-4 cm away from the shoreline.)
2. What do you think will happen to the coastline when you start generating waves? Make a prediction about the coastline behind the jetty, and the coastline not behind the jetty in Table 2.
3. Use the plastic trough and begin generating waves. Watch what happens to the shoreline behind the jetty and also along the coastline that is not behind the jetty. Record your observations in Table 2.
4. Sketch the new eroded shape of the coastline with the model jetty in your stream table in Table 2.

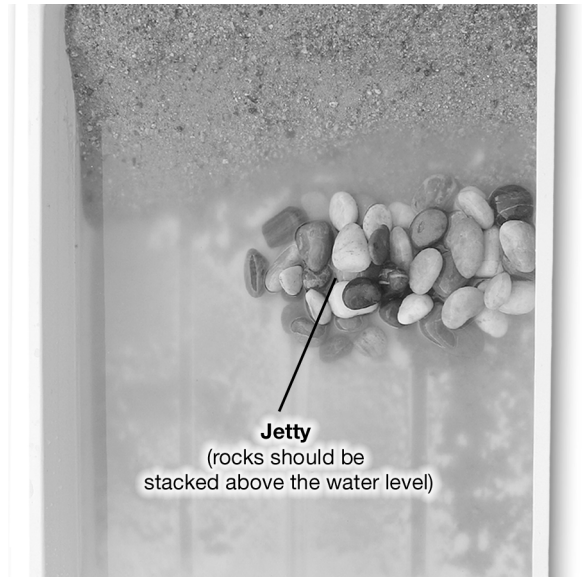
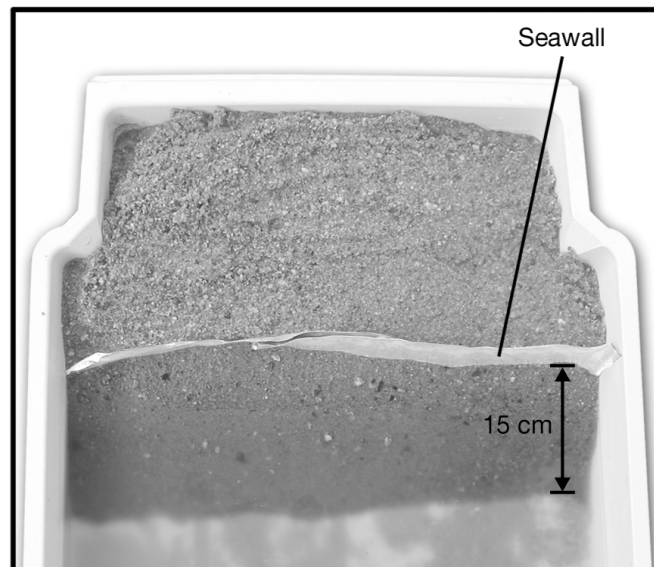


Table 2: Coastal erosion observations with jetty

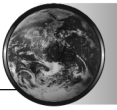
Prediction of what will happen to coastline	Observation of what happens to coastline
Sketch of coastline with jetty before waves	Sketch of coastline with jetty after waves

5 Seawalls

1. Remove your jetty. Refer to your sketch in Table 1 to reshape the coastline as close as possible to the original coastline.
2. The piece of aluminum will serve as your model seawall. Fold it over upon itself several times until your piece is about 10 centimeters tall. Insert the seawall down into the sand so that at least 5 centimeters of aluminum sticks up above the sand. Place the seawall 15 cm from the edge of the water.



3. Make a prediction of what will happen to the part of the coast in front of the seawall and the beach behind the seawall. Record your prediction in Table 3.
4. Use the plastic trough and begin generating waves.
5. Observe and record what happens to the coast in front of the seawall and the beach behind the seawall in Table 3.



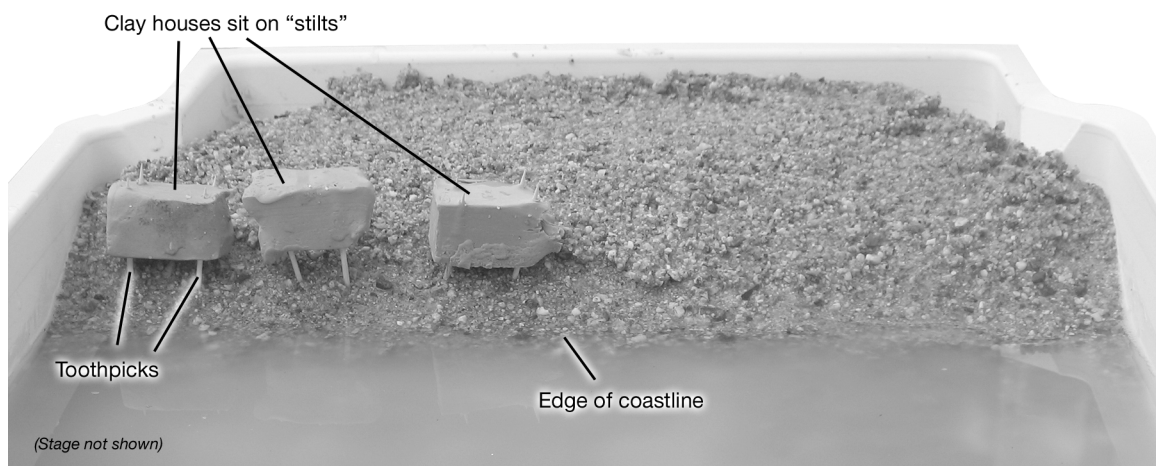
- Sketch the new eroded shape of the coastline with the seawall in your stream table in Table 3.

Table 3: Coastal erosion observations with seawall

Prediction of what will happen to coastline	Observation of what happens to coastline
Sketch of coastline with seawall before waves	Sketch of coastline with seawall after waves

6 Houses

- Remove your seawall. Reshape the coastline as close as possible to the original coastline you shaped.
- Make 2 to 3 miniature houses with the clay. Stick toothpicks in each corner of the bottom of your houses. Insert these “stilt houses” near the edge of your coastline.
- Make a prediction of what will happen to the sand on the coastline that is supporting the three stilt houses, and the sand where there are no houses. Record your prediction in Table 4.



- Use the plastic trough and begin to generate waves in your model. Observe the erosion in areas where houses have been built in the coastline and areas where there are no houses. Record your observations in Table 4.

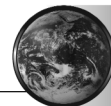
5. Sketch the new eroded shape of the coastline with houses in your stream table in Table 4.

Table 4: Coastal erosion observation with houses

Prediction of what will happen to coastline	Observation of what happens to coastline
Sketch of coastline with houses before waves	Sketch of coastline with houses after waves

7 Thinking about what you observed

- How does the rate of erosion of coastal areas change when the size and frequency of waves increases?
- What natural causes can create large and more frequent waves?
- How did the erosion of the coastline differ behind the jetty compared to the part of the coastline without the jetty in front of it? Explain the reasoning behind any differences.
- Explain the effects on the coastal areas between the seawall and the water. How would this process impact the sea life that lives in this area? How would it effect the way this land may be used by people?
- What do you think happens to the density of the sand and other sediments near the coast where houses are built? How would this effect the houses?
- Summarize how the building of hard structures such as seawalls, jetties, and houses can impact the natural erosion of coastal areas due to waves.



15A Natural Resources

What resources do we use and how can we conserve them?

Over 600 massive stone statues stand on a remote island in the South Pacific we now call Easter Island. Each mysterious stone statue is approximately 20 feet tall. Who made these statues and what happened to this advanced society? It is believed that when the population of the island reached its peak, resources started to be used at a faster rate than they could be replenished. As the lush forests were cleared for agriculture and to aid in the construction of the massive statues, wildlife began to disappear and the soil eroded away. Unable to sustain itself, the civilization as it had existed for hundreds of years tragically disappeared.



Photo by Captain Albert Theberge, NOAA Corps (ret.)

Materials

- Blender
- Rolling pin
- Measuring cup
- Large shallow pan
- Fine mesh wire screen
- Small cup and stirrer
- Cornstarch and water
- Wax paper
- Old newspaper
- Calculator
- Graph paper

In some ways, modern society is similar to the inhabitants of Easter Island. We are using resources such as clean water and trees faster than they can be renewed. How can we make sure we don't turn out like the inhabitants of Easter Island? Because we are so dependent on such resources, it is important that we learn how to reduce, reuse, and recycle them. In this investigation, we will discover which resources we are throwing away in landfills and experiment with recycling paper to learn about conserving resources.

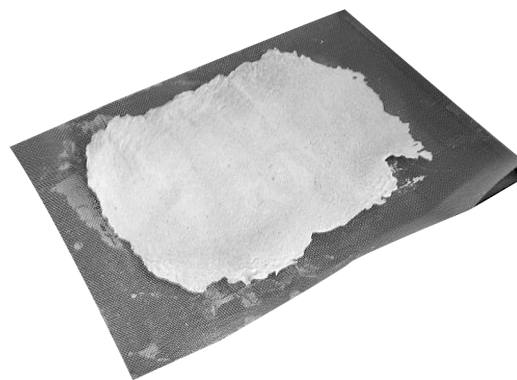
1 Stop and think

- The majority of our waste is disposed of in landfills. What proportion of the landfill do you think is taken up by paper? a. 4% b. 18% c. 34% d. 56%
- Predict how your paper will turn out after being recycled. Will it be similar or will it be different from the original sheet and if so, how?
- In this investigation, you will be making new paper by recycling old paper. Read through the lab and explain what is missing from the investigation to make it a scientific experiment.

2 Doing the activity: recycling paper

- Cover the work area with old newspaper.
- Tear up $\frac{1}{2}$ of a sheet of newspaper into small 2 cm by 2 cm pieces. Place the pieces in the shallow pan and cover them with water.
- In a small cup, mix 2 cups of water with $\frac{1}{8}$ cup of cornstarch and stir until cornstarch is dissolved. Pour mixture into the blender and blend for 15 seconds.
- In the pan, drain the water out and squeeze the newspaper pieces.

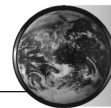
5. Put the newspaper pieces in the blender with the cornstarch mixture. Blend for approximately 30 seconds. If any chunks of newspaper remain, continue to blend until they disappear and you have a fuzzy liquid. You have just made pulp.
6. Place the screen in the pan. Pour the pulp mixture over the screen. Lift the screen gently from the pan so that only the pulp remains on the screen. Then place the screen on the newspapers in your work area and drain the pan in the sink.
7. Place the screen with the pulp back in the pan and use your fingers to spread the pulp out to the size of a sheet of paper. Cover the pulp with a sheet of wax paper.
8. Use the rolling pin to press the pulp flat and to press water out of the pulp mixture. Continue to periodically empty the water out of the pan.
9. Once you have pressed as much water as you think possible from the pulp, carefully remove the sheet of wax of paper.
10. Lay the screen with the pulp, screen down, over the newspapers and allow the pulp mixture to dry overnight.
11. Once dry, remove the paper from the screen by lightly rubbing the back of the screen.
12. Examine your recycled paper.



3 Doing the activity: examining a landfill

- a. Examine Table 1. Use a calculator to determine the percent of paper in a landfill. If necessary, ask your teacher for help.
- b. Besides recycling, list three ways we could reduce our paper use?
- c. If all yard trimmings and food scraps were composted, how much space would we save in landfills?
- d. On graph paper, create a bar graph or a pie graph to represent the data in Table 1.

Item	% Percent in landfill
Paper	?
Yard trimmings	13.1
Food scraps	11.9
Plastics	11.8
Metals	7.6
Rubber, leather, and textiles	7.3
Wood	5.7
Glass	5.2
Miscellaneous	3.4



4 Thinking about what you observed

- a. Examine your sheet of recycled paper. How is it different than the sheet of paper you started with?
- b. What is the difference between a renewable and a nonrenewable resource? Give examples of each.
- c. Besides the original paper, what other resources were necessary for the process of recycling?
- d. Why do you think conservationists argue that reducing is a better alternative than recycling?
- e. Think about the words reduce, reuse, and recycle. Explain the difference between each and give an example of each.

5 Exploring on your own

- a. How much waste does your family create in a day? In a week? In a month? Design an experiment to find out how much waste is produced. Check with your teacher before conducting the experiment.
- b. Can you influence your family to produce less trash? Design an experiment to find out. Check with your teacher before conducting the experiment.
- c. What are people's attitudes toward recycling? Design a survey to find out. Check with your teacher before conducting the survey.
- d. **Research** - Besides reducing the amount of material in our landfills, what other benefits are associated with composting? Is there some way composting may be of value to you or your family?

15B Water Quality and Ecosystems

How does surface water quality affect the surrounding ecosystem?

Water is one of our most important natural resources.

Consequently, many careers involve studying and taking care of our water supply. Some scientists test and monitor the water supply and some study weather patterns to better understand the water cycle.

People involved in government agencies, nonprofit organizations, and the media keep track of information about water and make this information available to the general public. In this investigation, you will meet a specialist in the field of water quality testing, and perform water quality tests. As you complete the investigation, think about what causes water pollution. What actions can you take to reduce your water usage and to improve water quality?

Materials

- Water quality test set
- Data sheet
- Clipboard and pencils
- Secchi disk (optional)
- Trash bags
- Moist towelettes for cleaning hands
- Safety goggles
- Disposable gloves

1 Meeting a water quality specialist

1. Before you meet the specialist, write down his or her name and occupation. Prepare three questions that you would like to ask the specialist.
2. During the meeting, take notes. Review your notes and write down at least three new things that you learned from the specialist.

WARNING — This lab contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

2 Preparing for your field trip

As you prepare for the field trip, be sure to record your work in your lab notebook.

On your own:

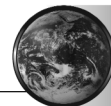
1. Read about the water cycle and water quality in Chapter 15 of your text.
2. Make sure you are familiar with the procedures for the water quality testing. Each test involves some special steps. Take notes as your teacher outlines the test procedures. The field trip will be more enjoyable if you understand the tests and how they are performed.

With your group:

1. Describe the place that your class will perform water quality testing. Where is it located? What kind of surface water will be tested?
2. Make a prediction about the quality of the surface water to be tested. Will the water in this location be clean or polluted? Justify your answer.

With the class:

1. Create data sheets for collecting quantitative and qualitative data. What information needs to go on the data sheets?
2. Look at a map of the surface water that will be tested. Discuss and decide where samples will be taken. Assign locations to each group.



3 Field trip: Testing surface water

Safety tip: Wear goggles and disposable gloves throughout the testing process. Be sure to wash your hands thoroughly when you have completed the tests.

1. Make general observations about the surface water and the day's weather.
2. Use your data sheets for recording information at each sampling sight.
3. You will be using supplies from a water quality testing kit to perform this investigation. Be sure to follow the directions and safety instructions for using these supplies while you perform the tests.

4 Thinking about what you observed

1. With your group, go over your data sheets carefully and make sure that you have recorded all the observations that you wanted to make.
2. Compile the data with the class. Make data tables for each test.
3. Using the compiled data, each group should create a water quality report for the surface water tested. Be sure to address whether or not the quality of the water at this site matched your prediction. In your report, include a section that addresses what your class can do to maintain the water quality at the test site or help improve the water quality at the test site.

5 Water quality and ecosystems

1. Describe the freshwater ecosystem you observed. Name both living and nonliving parts of the ecosystem. Identify at least three food chains.
2. Choose three of the tests you performed. Predict what would happen to the ecosystem if the result of each test changed. Consider each test separately. (You do not need to predict what would happen if all three changes occurred at once!) If the change is positive, suggest one way that local citizens could encourage this change. If the change is negative, suggest one way that citizens could work to prevent the change from occurring. Use the table below to organize your thoughts.

Table 1: Changes to the freshwater ecosystem

Water quality test	Proposed change	Positive or negative?	How can we encourage or prevent this change?
Sample: Water temp	Increased by 10°C	Negative. Less dissolved oxygen available to aquatic animals.	Let local industry know of harmful effects of discharging hot water into the lake.

16A Nonrenewable Resources

How fast are we using nonrenewable resources?

As the world population and demand for energy increases, having a variety of energy sources becomes more and more important. We consume energy quickly, so we need sources of energy that are long-lasting, efficient, and as clean as possible.

In this investigation, you will model the depletion of resources over time at a constant rate of use. Then you will model the depletion of resources when the rate of use increases. Next, you will make a physical model of an oil seep. This will help you understand how we find oil in the ocean.

Materials

- 1 open container per two students
- 2 types of dried beans or nuts—100 beans per pair (90% one color/type, 10% another color/type)
- Blindfold
- Large clear cup or glass
- Small mixing bowl
- 2 mL cooking oil
- 10 mL sand
- 30 mL soil
- 1 stick of modeling clay
- Water

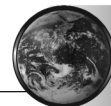
1 Stop and think

- a. What is the difference between renewable and nonrenewable resources?
- b. What are some examples of each of these resources?
- c. What type of resource do you expect will be depleted first?

2 Activity A

In this activity, you will learn how nonrenewable resources get depleted over time, especially as rate of use increases.

1. Fill your container with 100 beans (90 of one color type, 10 of another color/type). The 90 beans represent the fact that the United States currently uses nonrenewable fossil fuels for 90% of our energy needs. The other 10% of our energy needs are met with renewable resources.
2. One student in each pair will put on the blindfold. This student will choose beans from the container.
3. For the first trial, the situation is as follows: The population is NOT growing and the demand for resources stays exactly the same from one year to the next. The blindfolded student will randomly pick 10 beans out of the jar. Any “renewable beans” can be put back in the jar. After replacing these beans, count how many beans remain in the jar. Record this information in the “Year 1” column of Table 1. How many years do you think it will take to deplete the nonrenewable beans?
4. Repeat the process for year two. Continue until only renewable beans are left. Record all your data in Table 1. You may or may not use all of the columns available. You might even have to add more columns. Calculate the percentage left after each drawing. How many years did it take to run out of nonrenewable resources?

**Table 1: Renewable and nonrenewable energy use**

Consumption level	Year														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Remove 10 beans each year (constant use)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
# of beans remaining in container															
% renewable															
% nonrenewable															

- Now, remove the blindfold. Put it on the other student. Place all the beans back in the container. This time, you will be modeling a situation where the population is increasing and so is the demand for energy.
- Predict again how many years it will take to deplete the resources.
- Proceed in the same way, except follow the table to see how many beans to pull out each year.

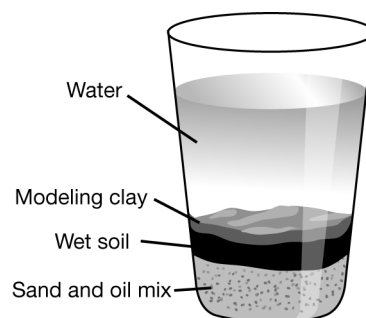
Consumption level	Year														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Remove 5 more beans each year (increasing demand)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
# of beans remaining in container															
% renewable															
% nonrenewable															

- Remove the blindfold. How many years did it actually take to run out of nonrenewable resources?
- Make two graphs—one for each table. On the x-axis put the year. On the y-axis, put the percent renewable and nonrenewable remaining.
- Answer the questions **a** through **d** in Part 4.

3 Activity B

In this activity, you will make a model of an oil seep, like those in the Santa Barbara Channel off the coast of California. There, cracks in rock layers of the ocean floor allow oil and gas to ooze or seep through the water to the surface. The gas dissipates in the air, but the oil floats on the ocean surface. Oil and gas are both fossil fuels.

- Pour the sand into the bottom of the glass or cup.
- Pour the oil into the sand. Add 1 mL of water.



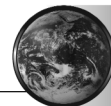
3. Now, get some soil and mix it with water so that it is very wet. Pack it tightly into the glass on top of the sand/oil mixture.
4. Take the clay and flatten it into a circle that can fit into the glass. Stick it into the glass, making a thin seal over the mud mixture.
5. Fill the rest of the glass with water.
6. Time how long it takes the oil to seep through the layers to the top of the water.
7. Now, answer questions **e** and **f** in Part 4.

4 Thinking about what you observed

- a. Which graph in Activity A is more realistic? Why?
- b. Which type of resource lasts for a longer time?
- c. Compare your predictions for the number of years it would take to deplete the resources to the actual number of years that you measured. How close were you? How did you come to your prediction?
- d. What did you learn about the rate of depletion of the two types of resources?
- e. How long did it take for the oil to seep to the top of the water? Do you think it would take longer if there was more water on top of the clay? Why?
- f. In the future, what should the United States try to do about its energy consumption? Why?

5 Exploring on your own

1. Try the oil seep experiment with a taller glass so that you can add more water. Also try it with salt water. Did it take more or less time for the oil to seep to the surface?
2. Research some ways that oil and natural gas are removed from the ocean floor.
3. How is coal created?



16B Renewable Resources

How do we produce electricity using fossil fuels and geothermal energy?

One way to make electricity is to burn fossil fuels like petroleum. When we do so, a chemical reaction occurs which creates soot, an air pollutant. Additionally, fossil fuels are non-renewable, which means we will eventually run out of them. Another way to make electricity is to use geothermal energy. This method uses steam created by magma-heated water underground. This steam turns a turbine that is connected to a generator, producing electricity.

In the Geysers area north of San Francisco, a lot of electricity is produced using geothermal energy—enough for a city of about one million people! In San Bernardino, California, hot water from below ground is used to heat some buildings during the winter.

In this investigation, you will light a candle and examine the products of burning the wax. Common candle wax is made from paraffin, a petroleum product, so the products are similar to those produced when fossil fuel is burned to make electricity. You will compare these products with those produced by geothermal energy use, represented by a beaker of boiling water. Next, you will learn how steam can be used to turn a turbine.

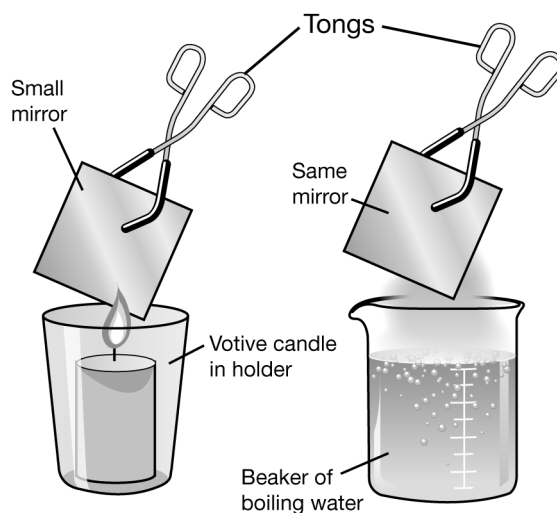
Materials

- Safety goggles, apron, and oven mitt or heat glove
- Pot holder (flame-proof mitten type)
- Paraffin candle
- Candle holder
- Matches or lighter
- Small mirror
- Kitchen tongs
- Water
- Heavy-duty aluminum foil
- Two 500- mL beakers
- Hot plate
- 10d nail
- Pinwheel
- Masking tape
- Stopwatch

1 Doing Activity A

Safety tip: Put on your goggles, apron, and flame-proof oven mitt. Review all safety procedures for working with open flames, hot plates, and hot water.

1. Place the candle into the candle holder. Make sure it is secure.
2. With your teacher's supervision, light the candle.
3. Use the tongs to hold the mirror in the candle flame for five seconds.
4. Take the mirror away from the flame and describe what you see.
5. Wash and dry the mirror well.
6. Put 300 milliliters of water in the beaker and place it on the hot plate. Heat the water to boiling. Then turn off the hot plate.
7. With oven mitt on, use the tongs to hold the mirror above the beaker for a few seconds.
8. Take the mirror away from the steam and describe what you see.
9. When the water has cooled, remove the beaker from the hot plate.

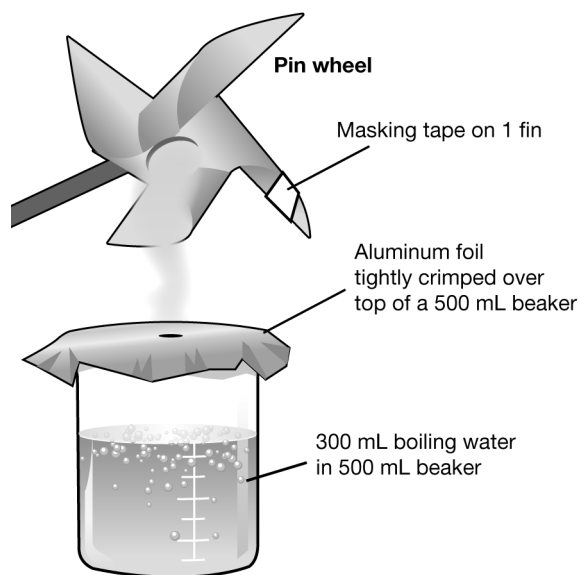


2 Setting up for Activity B

1. Put 300 milliliters of water into the second beaker.
2. Cover the top of the beaker with two layers of aluminum foil. Make a good seal around the edge by tightly crimping the foil.
3. Carefully punch a hole in the center of the foil (going through both layers) using the nail. Put the beaker to the side.
4. Use a small piece of masking tape to mark one fin of the pinwheel. This will make it easier to count the pinwheel's turns.

3 Doing Activity B

1. **Goggles, apron, and flame-proof oven mitt must be worn throughout Activity B.**
2. Using your hot plate, bring the beaker of water to a boil.
3. When steam starts to come out of the hole in the foil, hold the pinwheel (with your pot holders) over the hole. Slowly change the angle of the pinwheel until it begins to turn.
4. Count the number of turns the pinwheel makes in 10 seconds. Calculate the pinwheel's speed in turns per second.
5. Using the oven mitt, remove the beaker from the hot plate and carefully take off the foil. Add more water to the beaker up to the 300-milliliter mark.
6. Replace the foil. Punch ten more holes all over the foil with your nail.
7. Repeat the experiment by putting the pinwheel over only one center hole once the water is boiling. How fast did the pinwheel turn? Record your answer in turns per second.

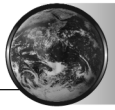


4 Thinking about what you observed

- a. Explain how the burning candle and steam in Activity A represent types of energy sources and air pollution.
- b. In the Geysers area of California, there has been a decrease in the amount of geothermal energy being created. It is thought that perhaps there are too many holes through which steam is escaping. Would your findings support that hypothesis? Why or why not?

5 Exploring on your own

What other places in California use geothermal energy to produce electricity? See if you can find four locations outside the Geysers area.



17A Planets in Motion

How do the planets move?

How fast can you go? Actually, every second you travel 18.5 miles through space! That's right, 18.5 miles per second, or 1,110 miles in one hour! And as a passenger on the planet Earth, each year you travel approximately 600 million miles along the Earth's orbit around the Sun, held in orbit by gravity. And while you are traveling at these vast speeds through space you are spinning in circles! And you are not alone. Alongside you is an orbiting moon. There are other planets traveling at different speeds too, following different orbits. Some closer to the Sun, and some further away. In this investigation, you will develop a greater understanding of the Earth's rotation on its axis and the Earth's revolutions around the Sun. Then you will compare the Earth's motions to other planets.

Materials

- 4 working flashlights
- Masking tape
- Black electrical tape
- Large open space for parts 1 and 2
- Classroom clock

Part I: The Earth's movements

1 Setting up

Earth has two particular motions: rotation and revolution. The rotation of Earth is its movement as it spins on its axis. One full rotation takes 24 hours. The revolution of Earth is its movement along its orbit around the Sun. Held in orbit by gravity, it takes Earth 1 year to make one full revolution.

1. Place 4 students back to back in the circle of masking tape in the center of the room. Turning the flashlight on, each student should face outward. These students represent the Sun.
2. All other students step on the black electrical tape and spread out around the circle. This tape represents the elliptical orbit Earth takes around the Sun and each student represents the Earth. Note: Earth tilts on its axis at a 23.5° angle.
3. Darken the room.
4. Follow the teacher's directions.

2 Doing the activity

1. Each student representing Earth should rotate on his/her axis.
2. Use the classroom clock and calculate how long it takes you to make one full rotation. How long does it take Earth to make one full rotation?
3. Rotate slowly. Stop when it is nighttime on your Earth.
4. Continue to rotate. Stop when it is daytime on Earth.
5. Continue to rotate. Stop when the Sun is just about to set on your Earth.
6. Each student stops rotating.
7. Begin revolving around the Sun in a counterclockwise direction. Do not bump into any other students.

8. Use the classroom clock and calculate how long it takes to make one full revolution. How long does the real Earth take to make one revolution?
9. Begin to revolve and rotate.
10. Make one full revolving rotation.
11. After one full revolving revolution, all students return to your seats.

Part 2: All the planetary movements

3 Setting Up

Our solar system primarily consists of the Sun and 8 known planets. Each planet rotates on its axis and revolves around the Sun. However, each planet rotates and revolves around the Sun at different speeds and along different orbits.

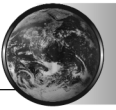
Examine Table 1 to learn about the movements of the planets. Circle any rotation or revolution times that are faster than the planet Earth.

Table 1: Rotation and revolution times of each planet

Planet	Length of time for one full rotation on its axis	Length of time for one full revolution around the Sun
Mercury	59 days	88 days
Venus	243 days	225 days
Earth	1 day	365.25 days
Mars	24.6 hours	687 days
Jupiter	10 hours	11.9 years
Saturn	10.7 hours	29.5 years
Uranus	17 hours	84 years
Neptune	16 hours	165 years

4 Doing the activity

1. The center circle of masking tape will represent the Sun.
2. One student will be selected to represent the Earth. That student should step on the black electrical tape and begin rotating and revolving.
3. The planets are listed in their order from the Sun. Choose a planet you would like to be. Remember the speed of your rotation, the speed of your revolution, and your location, in comparison to the Earth. Once you have decided, wait for further directions.



4. Using the Earth as a reference point, all other students should stand in the spot where they think their planet would belong and begin rotating and revolving at an accurate speed.

5 Thinking about what you observed

- a. Describe the difference between rotation and revolution. Include a diagram if it is helpful.
- b. Explain how rotation results in day and night.
- c. Which planet has the slowest rotation? Use a calculator to determine how many hours one day would take.
- d. Which planet do you think moves the most similarly to Earth? Provide evidence for your choice.
- e. What is incorrect about the comment, “The Sun is racing across the sky”?
- f. Predict: The Sun has a larger mass than Earth and a gravitational pull on Earth. Because Earth is moving forward at a rapid speed, it is not directly pulled into the Sun; it stays in an orbit around the Sun. Predict how Earth would travel differently if the Sun became small enough so that it no longer had the gravitational pull on Earth.

17B Solar System

How big is the solar system?

It is difficult to comprehend great distances. For example, how great a distance is 140,000 kilometers (the diameter of Jupiter) or 150,000,000 kilometers (the distance from the Sun to the Earth)? An easy way to compare these distances is to create a scale model. For instance, a globe is a scale model of Earth and road maps are scale models of geographic regions. These scale models help us visualize the true sizes of objects and the distances between them.

In this investigation, you will compare an astronomical distance—like the distance from the Sun to Neptune—to a measurable distance—like the length of a football or soccer field. Using proportions, you will make a scale model of the distances of the planets from the Sun.

Materials

- Access to a large space with a length of 100 meters (a soccer field is ideal)
- A metric tape measure or a trundle wheel
- A variety of objects to represent the relative sizes of the planets (examples: softball, soccer ball, bowling ball, small plastic balls, inflatable beach balls). To represent the Sun and some of the larger planets may require imagination.
- Blank paper for making signs
- A simple calculator

1 Using proportions to determine scale distances

Neptune is an average distance of 4.5 billion kilometers from the Sun. We can use a proportion to determine a scale distance for our model. Assume the largest distance you can measure is 100 meters. The length of a soccer field is usually between 90 and 120 meters long. For this investigation, we will use 100 meters as the scale distance between the Sun and Neptune.

$$100 \text{ m} = 4,500,000,000 \text{ km}$$

If the distance from the Sun to Neptune equals 100 meters, where would you find the other planets? You can answer this question by setting up the following proportion where x is the distance from the Sun to any planet, in meters:

$$\frac{x}{\text{Distance of the Sun to planet}} = \frac{100 \text{ m}}{4,500,000,000 \text{ km}}$$

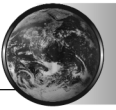
Mercury is 58,000,000 kilometers from the Sun. Using our proportion, we can find the scale distance:

$$\frac{x}{58,000,000 \text{ km}} = \frac{100 \text{ m}}{4,500,000,000 \text{ km}}$$

Cross-multiply and rearrange the variables to solve for x :

$$x = \frac{100 \text{ m}}{4,500,000,000 \text{ km}} \times 58,000,000 \text{ km} = 1.29 \text{ m}$$

Mercury is 1.29 meters from the Sun using this scale.



2 Determining scale distances for the other planets

Based on the example in Part 1, you would place Mercury 1.29 meters or 129 centimeters from the Sun in your 100-meter scale model. Use this example to help you calculate the placement of the other planets. Write the distance in meters for each planet in Table 1.

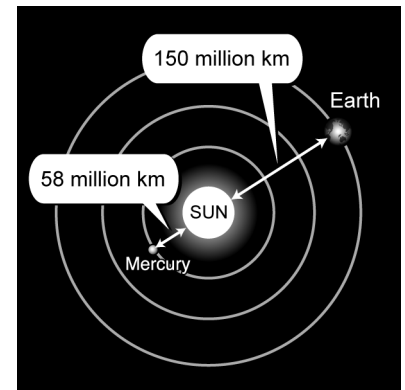
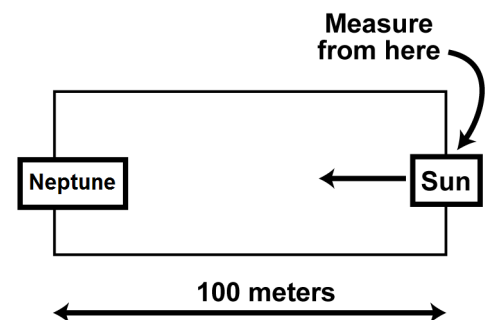


Table 1: Distance from the Sun

Planet	Actual distance to Sun (km)	Proportional distance from the Sun (m)
Mercury	58,000,000	1.29
Venus	108,000,000	
Earth	150,000,000	
Mars	228,000,000	
Jupiter	778,000,000	
Saturn	1,430,000,000	
Uranus	2,870,000,000	
Neptune	4,500,000,000	

3 Setting up the scale model

- To begin, make signs for each of the planets and one for the Sun. In your scale model, a student in your class will hold the sign at each position of the planet.
- In an area that is at least 100-meters long, identify the location of the Sun. A student will stand in this position with a sign that says “Sun.”
- Measure 100 meters from the position of the Sun. At the 100-meter mark, a student will stand with a sign that says “Neptune.” In this model, 100 meters is the scale distance from the Sun to Neptune.
- Now, use the scale distances from Table 1 to find the locations of each planet. At the location of each planet, a student will stand with the appropriate sign. Then, answer the questions.
 - After constructing a model of it, what is your impression of our solar system?



- b. Describe some disadvantages and advantages to this model of the solar system.
- c. Alpha Centauri is the closest star to Earth at 274,332 AU. One astronomical unit is equal to 150 million kilometers. Where would you place this star in the 100-meter scale model?
- d. The diameter of the Milky Way galaxy is known to be about 100,000 light years. One light year is 63,000 AU. How does the Milky Way compare using the 100-meter scale model?

4 Determining scale sizes of the planets

Mercury has a diameter of 4,880 kilometers. How big would Mercury be in your 100-meter scale model? You can use the same method to determine the scale diameter of Mercury that you used in Part 2:

$$\frac{x}{4,880 \text{ km}} = \frac{100 \text{ m}}{4,500,000,000 \text{ km}}$$

Cross-multiply and rearrange the variables to solve for x :

$$x = \frac{100 \text{ m}}{4,500,000,000 \text{ km}} \times 4,880 \text{ km} = 0.000108 \text{ m}$$

Based on the example above, the diameter of Mercury in a 100-meter scale solar system would be 0.000078 meters or 0.078 millimeters. For comparison purposes, a single human hair is about 0.1 millimeters in diameter or one-tenth of a millimeter.

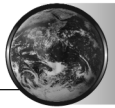
Use the above proportion to calculate the diameters of the other planets as well as the Sun and Earth's moon. Write these values in units of meters in the third column of Table 2.

Table 2: Diameters of the planets, our moon, and Sun

Planet	Actual diameter (km)	Scale diameter (m)	Scale diameter (mm)
Sun	1,391,980		
Mercury	4,880	0.000108	
Venus	12,100		
Earth	12,800		
Moon	3,475		
Mars	6,800		
Jupiter	142,000		
Saturn	120,000		
Uranus	51,800		
Neptune	49,500		

Now, answer these questions.

- a. How big is the Sun in this model in units of centimeters?
- b. How much larger is the Sun's diameter compared with Earth's? How much larger is Earth's diameter compared with the moon's?



- c. The smallest object that the human eye can see without magnification is 0.100 millimeters. Given this information, which planets would be visible to the human eye? Would you be able to see the Sun or the moon on this 100-meter scale model of the solar system?
- d. What is your impression of how the size of the planets and the Sun compare with the size of the solar system?

5 Extension: Making a larger scale model of the solar system

In this part of the investigation, you will use common objects to compare the diameters of planets, the Sun, and Earth's moon in our solar system. For example, an Earth globe can represent the scale size of Earth. The diameter of the globe we will use is 30 centimeters.

1. If an Earth globe is used to represent the size of Earth, what would the sizes of the Sun and the other planets be? How big would the moon be? Use what you have learned in this investigation to calculate the scale diameters of the other planets, the moon, and the Sun. Fill in the third column of Table 3 with these values.
2. What objects could be used to represent each of the planets, the moon, and the Sun? Fill in the fourth column of Table 3 with your answers to this question.

Table 3: A scale model of the solar system

Planet	Actual diameter of planet (km)	Scale diameter of Sun or planet (cm)	Representative object and its diameter or length (cm)
Sun	1,391,980		
Mercury	4,880		
Venus	12,100		
Earth	12,800	30 cm	Earth globe, 30 cm
Moon	3,475		
Mars	6,800		
Jupiter	142,000		
Saturn	120,000		
Uranus	51,800		
Neptune	49,500		

Now, answer these questions:

- a. How many times greater is 30 centimeters than 0.284 millimeters? These are the diameters of Earth for the two scale models you created.
- b. Using your answer to question 5a, what would be the distance between the Sun and Neptune on this larger scale? Come up with a way to explain or model this distance.
- c. Why is it challenging to make a scale model of the solar system that includes the distances between planets and the Sun and the sizes of the planets?

18A Days and Months

What are days and months?

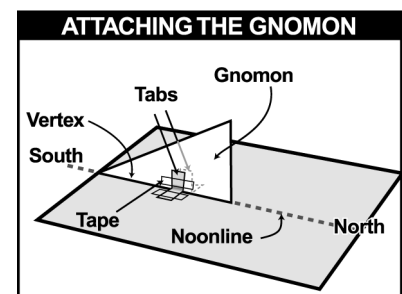
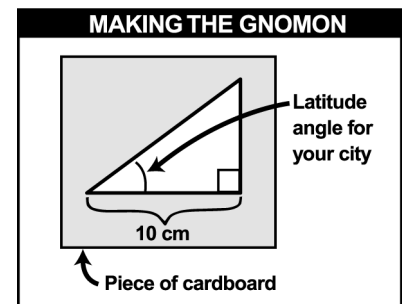
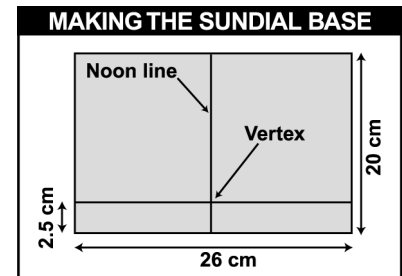
Measurement of days and months depends on the cycles between Earth and the Moon, and Earth and the Sun. Therefore, it is not surprising that some of the first clocks were sundials based on the movement of shadows as the Sun appeared to move across the sky. A sundial is a large timepiece on the ground. The “hand” of the clock to the right is a shadow created by an obelisk. In this investigation, you will build a sundial, and then calibrate it so that you use it to accurately tell the time. You will also model the lunar cycle and then observe it over the course of a month.

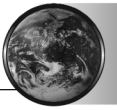
Materials

- A protractor
- Two pieces of 20-by-26-centimeter cardboard (or a file folder)
- Scissors
- Small metric ruler
- Tape
- Navigational compass
- A flashlight
- A 2-or-3 inch foam ball
- A pencil or popsicle stick

1 Building a sundial

1. Obtain a cardboard folder from your teacher. To build your sundial, measure and cut out a 20-by-26 centimeter size piece of the folder. First, draw one line dividing the piece in half. This will be the noon line. Then, draw a perpendicular line 2.5 centimeters from one edge. The place where the two lines intersect will be called the vertex.
2. Next you need to make the *gnomon*, the part of your sundial that casts a shadow. On another piece of the folder, mark off a baseline that is 10 centimeters long. Then, using your protractor, make an angle with this line that is equal to the angle of your particular location’s latitude on Earth. Your teacher will give you the correct latitude. Then, draw a second line, perpendicular to the baseline and making a right triangle. Write the angle for your latitude in the position shown on the diagram.
3. Cut out your gnomon. Then, attach the gnomon so that it is perpendicular to the base of the sundial. To keep the gnomon upright, cut out two rectangular tabs. Tape these to each side of the gnomon and fold them out in opposite directions. Then, tape them to the base of the sundial as shown.
4. Bring your sundial outside on a sunny day. Use a compass to help you point the noon line to the north.
5. Now, answer the questions on the next page.





- Do you see a shadow on the sundial? Where is it located?
- What will happen to the shadow as the day progresses? Explain your answer.
- Can you tell the time by looking at the location of the shadow on the sundial? What do you need to do in order to be able to tell the time?

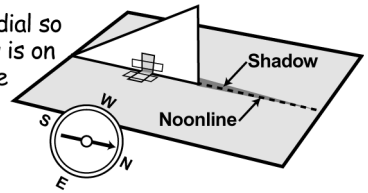
2 Calibrating the sundial

In order to tell the time accurately with your sundial, you need to calibrate it. You will need a few hours on a sunny afternoon to complete this part of the investigation.

- Take your sundial outside at noon on a sunny day. Use a navigational compass to point the noon line on the sundial toward the north.
- Move the sundial slightly to the right or left until the point of the gnomon's shadow is resting on the noon line.
- Use the compass to determine the exact direction that the noon line is pointing, and write it down.
- Leave your sundial for exactly one hour. Go back and mark where the point of the gnomon's shadow is located on the sundial. Write the time (1:00 pm) next to this mark.
- Repeat the fourth step five more times (until the actual time is 6:00 pm). You should have a mark for each hour after noon from 1:00 until 6:00.
- Take your sundial indoors. Use a ruler to connect each point to the vertex as shown. You have now calibrated your sundial to measure time from noon until 6:00 pm.
- Use a protractor to measure the angle between the noon line and the 1:00 line. Record this angle in Table 1.
- Measure the other angles from the noon line to each of the other marks and record the angles in Table 1.
- To calibrate the morning hours, you will use the same angles you measured for the afternoon hours. Table 1 will help you determine which angle to use for each morning hour.
- Test your sundial on another sunny day. To do this, make sure you use a compass to point the noon line in the direction you recorded earlier.

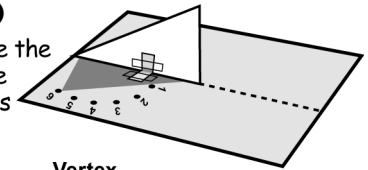
12:00 PM

Adjust sundial so the shadow is on the noonline

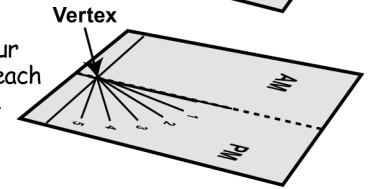


1:00 - 6:00 PM

Mark where the point of the shadow falls each hour



Connect your marks for each hour to the vertex



Add lines at the same angle for corresponding AM hours

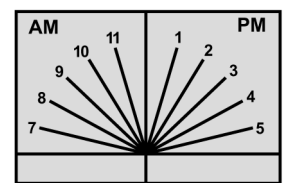
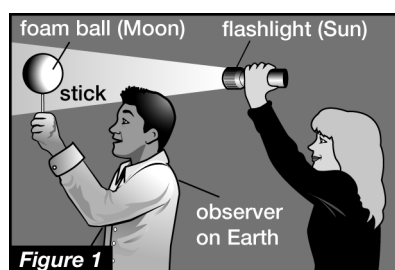


Table 1: Calibrating the sundial

Afternoon hour	Angle from noon line	Corresponding morning hour
1:00 pm		11:00 am
2:00 pm		10:00 am
3:00 pm		9:00 am
4:00 pm		8:00 am
5:00 pm		7:00 am
6:00 pm		6:00 am

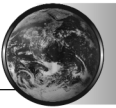
- Can you use your sundial to tell the time? How accurate is your sundial?
- How could you improve the accuracy of your sundial so you could tell the time within fifteen minutes?
- What variables affect the accuracy of your sundial? List as many variables as you can think of.
- What effect do you think that the time of year will have on the accuracy of your sundial? Explain your answer.
- How do you think Daylight Savings Time will affect the accuracy of your sundial? How could you adjust the sundial for this?

3 Modeling the lunar cycle



A sundial is an instrument that allows you to keep track of time during the day. Ancient civilizations used the Moon to keep track of the passage of each month. The Moon revolves around Earth in a counterclockwise direction. As it revolves, its appearance from Earth changes in a repeating pattern called the lunar cycle. In this part of the investigation, you will model the lunar cycle. You will work with another student, as shown in Figure 1.

Safety Note: Your teacher will turn out the classroom lights once you have gathered your materials. Be careful as you move about the classroom.



1. Place a foam ball on a pencil or stick. This ball represents the Moon.
2. Have another student hold a flashlight. The flashlight represents the Sun. Your head represents Earth.
3. Hold the ball above your head, at arm's length from your face. Stand about one meter from the flashlight, which is held at the same level as the ball.
4. Observe the Moon in each of the positions shown in Figure 2. Face the ball at each position.
5. For each position, indicate how much of the ball is dark and how much is illuminated, in the table below. Use a pencil to show the shaded regions.

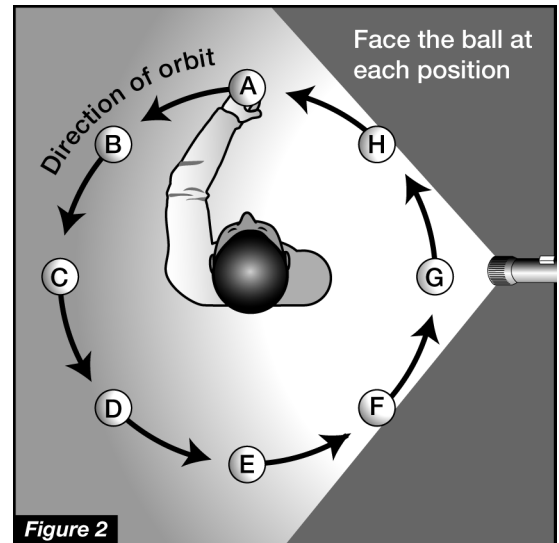


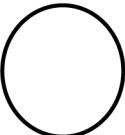
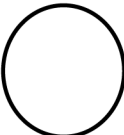
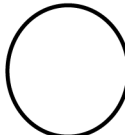
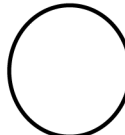
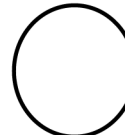
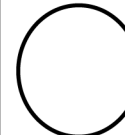
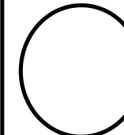
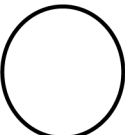
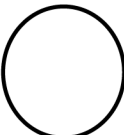
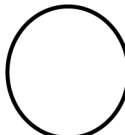
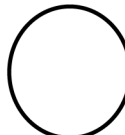
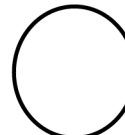
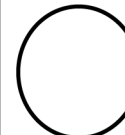
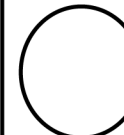
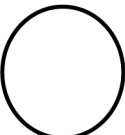
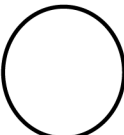
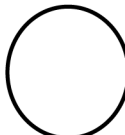
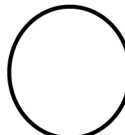
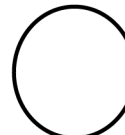
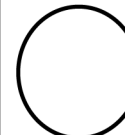
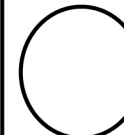
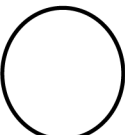
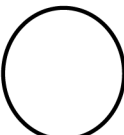
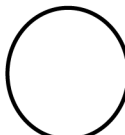
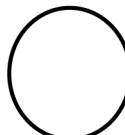
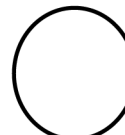
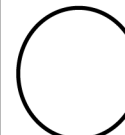
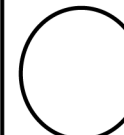
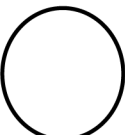
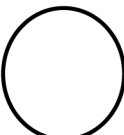
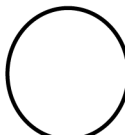
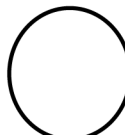
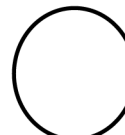
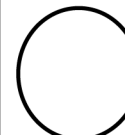
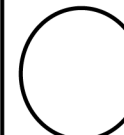
Table 2: Modeling the lunar cycle

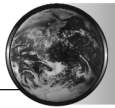
Position	Appearance	Position	Appearance
A		E	
B		F	
C		G	
D		H	

- Compare your observations to the diagram of the Moon phases in the student text. Based on your observations, what do the terms waning and waxing mean?
- During what position on Figure 2 would a solar eclipse occur? During what position on Figure 2 would a lunar eclipse occur?

4 Long-term project: Constructing a lunar calendar

Now, you will track time by following the phases of the Moon. In the chart below, draw the Moon as it appears in the sky each night for 28 nights. Record the date of your observation, the time, and illustrate the shape of the Moon for each night. Identify the phase of the Moon for each night. Refer to Cycles on Earth in your student text for a graphic that shows each phase. Use the following two-letter symbols to represent each phase: new Moon (NM), waxing crescent (XC), first quarter (FQ), waxing gibbous (XG), full Moon (FM), waning gibbous (NG), third quarter (TQ), waning crescent (NC).

SUN	MON	TUE	WED	THUR	FRI	SAT
 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____
 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____
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 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____	 Date ____ Time ____ Phase ____



18B Earth's Seasons

What causes the seasons?

In this investigation, you will use a solar cell and a digital meter to measure the intensity of light emitted by a light source that represents the Sun. You will first measure the intensity of light from the bulb at different distances from it—like Earth at different distances from the Sun. Then you will measure the intensity of light at various latitudes on the globe. By performing these two kinds of measurements, you will determine which factors cause the seasons.

Materials

- Globe
- Velcro® tabs
- 100-watt light source
- Solar (PV) cell
- Digital meter
- Tape measure or meter stick

1 Setting up

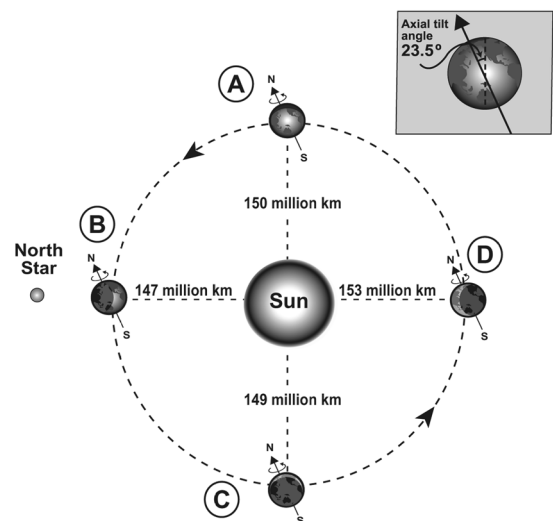
1. A light source representing the Sun will be placed in the center of your classroom. It is important that the light source emit light equally in all directions like the Sun does.
2. The globe will be used to represent Earth. Put the Velcro® dots on Earth so that the solar cell will adhere to the dots. Put the tabs at the equator, Tropic of Cancer (23.5 degrees north), and Tropic of Capricorn (23.5 degrees south).
3. With your class, choose a wall in your classroom that will represent the position of the North Star (Polaris) in the night sky. Tape a sign to this wall that says “North Star.”

Safety Note: If your light source is a light bulb, do not touch it. Light bulbs can get very hot!

2 Stop and think

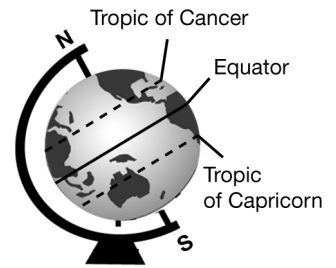
Earth's orbit around the Sun is slightly elliptical. At certain times during the year, Earth is a little closer to or farther from the Sun than at other times. Also, Earth is tilted as it moves around the Sun.

- a. Come up with a hypothesis stating why you think the seasons occur.
Do you think they are caused by changes in Earth's distance from the Sun?
Do you think Earth's tilt causes the seasons?
Do you think both of these factors play a role? Or do you think other factors cause the seasons?
- b. Which quarter of the diagram (A to B, B to C, C to D, or D to A) do you think represents summer in the northern hemisphere? Explain why you think this is so.



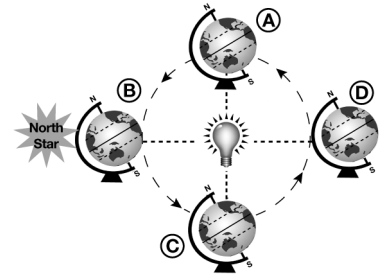
3 Doing the experiment, part A (complete with your class)

1. One student will move the globe, in a circle, to each position (A-D) in a counterclockwise direction around the light source (the “Sun”). This movement simulates one revolution around the Sun (or one year).
2. As the globe is moved from point to point, the axial tilt at the north pole of the globe should always point toward the “North Star.”
3. As Earth revolves around the Sun, it also spins on its axis. Note that the globe can also be spun on its axis.
4. Now, answer these questions. Use the globe and the diagram at right to help you.



Questions:

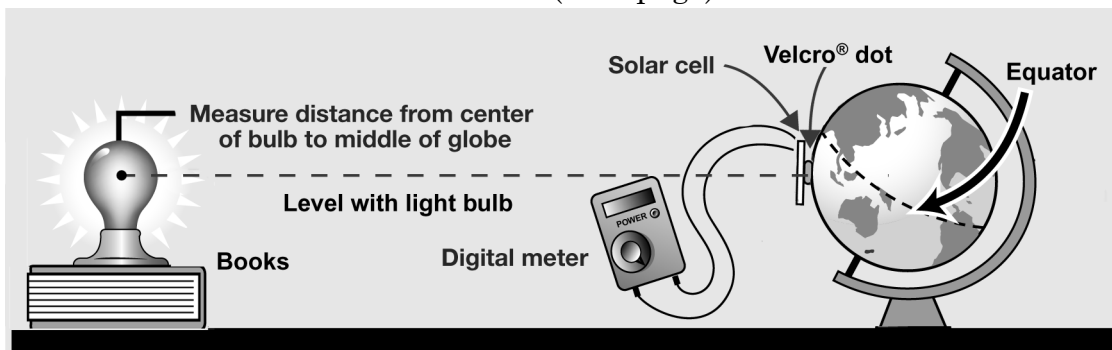
- a. Although the axis of Earth is always pointing in the same direction, what is happening to Earth itself as it revolves around the Sun?
- b. What does the side of the globe that faces the Sun represent? What does the side of the globe that faces away from the Sun represent?
- c. Diagram the following parts of the globe: equator, northern hemisphere, southern hemisphere, and latitude lines. At what latitude are you located right now?
- d. In which position in the diagram is the northern hemisphere pointing towards the Sun? In which position is the southern hemisphere pointing towards the Sun?

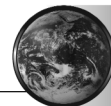


4 Doing the experiment, part B

Now, you will model the distance of Earth from the Sun using a scale distance. You will observe the amount of energy (light intensity) produced by a light source at each scale distance. Remember, Earth does not stay the same distance away from the Sun all year long.

It is impossible to measure millions of kilometers in your classroom, but you can use a scale distance of 1 centimeter to represent 1 million kilometers. Therefore, a distance of 150 million kilometers would be represented by 150 centimeters. Using the scale distance of 1 centimeter equals 1 million kilometers, determine the scale distance for positions B, C, and D. Write the scale distance in the third column of Table 1 (next page).





1. Attach the solar cell to the Velcro® dots found on the equator of the globe.
2. Place the globe so the face of the globe is exactly 150 centimeters from the center of the light source. The light source should be level with the center of the globe. One student can hold the end of the tape measure at the center of the globe closest to the light and another directly over the center of the light.
3. Measure the light intensity on the globe using the digital multimeter. Keep the solar cell at the center of the globe so you are only changing the distance of the globe to the light, not the angle of the solar cell. Your readings will be in milliamps (mA). Record your readings in Table 1.
4. Repeat this for the other scale distances, being careful to set the globe at the correct distance for each position A-D. NOTE: Do not move the globe to simulate Earth's orbit for each position. Vary only the distance from the light source.
5. Now answer these questions. Use Table 1 to help you.

Table 1: Light intensity at scale distances

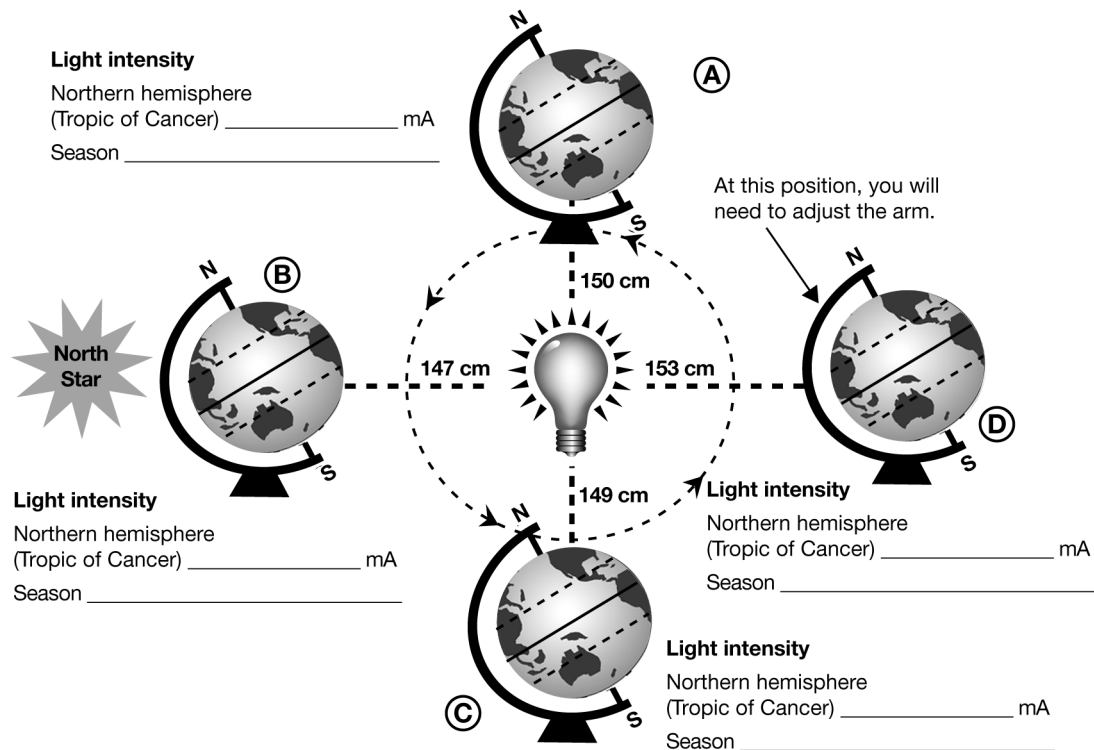
Position	Distance from the Sun (km)	Scale distance from the Sun (cm)	Light intensity (mA)
A	150,000,000	150	
B	147,000,000		
C	149,000,000		
D	153,000,000		

Questions:

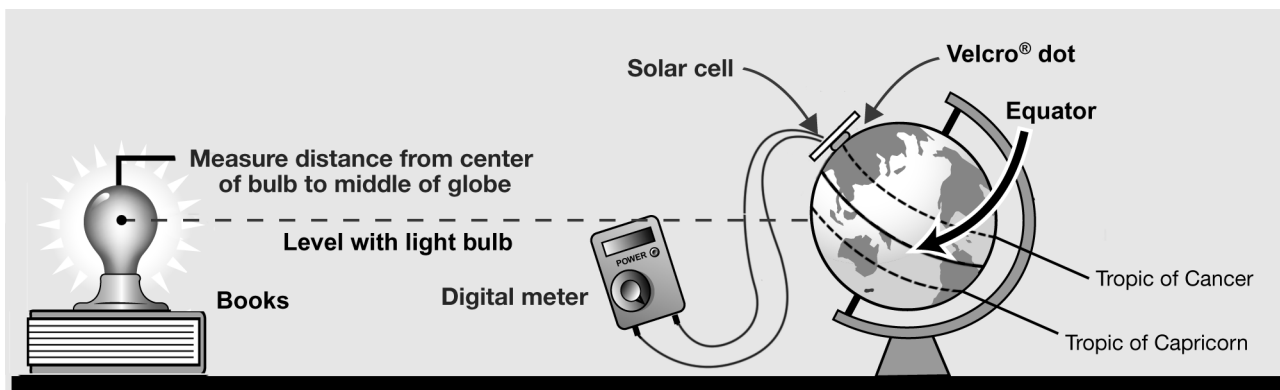
- a. Are there big or small differences in distances as Earth revolves around the Sun?
- b. Based on your data, how does the light intensity change as these distances change?
- c. Based on your results from this experiment, do you think Earth's changes in distance from the Sun over a year causes the seasons? Why or why not?

5 Doing the experiment, part C

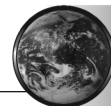
Now, you will simulate the effect that Earth's axial tilt has on the intensity of the Sun's light. You will model Earth's orbit around the Sun, in addition to its distance at the four positions shown below. Notice how the Sun's direct light never shines further south than the Tropic of Cancer or further north than the Tropic of Cancer.



1. Since you live in the northern hemisphere, you will place the solar cell on the Tropic of Cancer (23.5 degrees north).



2. At each position, make sure the north pole of the globe always points toward the North Star. Measure each distance from the center of the light bulb to the surface of the globe. You will not move the solar cell this time. The Sun's direct rays will strike the parts of Earth shown by the diagram and you will be able to measure the energy that the Tropic of Cancer receives each time.



- For Position A, the bulb should be level with the equator and the solar cell will be on the Tropic of Cancer. At this time of year, the Sun's direct rays don't hit the Tropic of Cancer—they hit the equator. The north pole should be pointed at the North Star. The distance should be 150 cm from the center of the bulb to the globe surface.
 - For Position B, the bulb should be level with the Tropic of Capricorn, since during this time of year, the Sun's direct rays hit here. Still leave the solar cell where it is.
 - For Position C, the bulb should be level again with the equator. This is where the direct rays of the Sun shine at this time of year.
 - See if you can figure out Position D on your own. If not, ask a partner or your teacher for help.
1. Write the light intensity values at each position on the graphic. At position D, you will need to move the arm of the globe slightly to the left or right in order to line up the bulb and solar cell.
 2. Answer the questions below and then complete the questions for part 6.

Questions:

- a. What role does axial tilt play in the intensity of light on Earth?
- b. At which position (A, B, C, or D) does the Tropic of Cancer receive the most light? What season do you think that represents?

6 Thinking about what you observed

- a. Of the two factors—distance from the light source and axial tilt – which plays the most significant role in causing the seasons? Was your hypothesis supported by your results?
- b. Based on your results, which position (A-D) represents the first day of summer in the northern hemisphere? Which position represents the first day of winter in the northern hemisphere?
- c. Which quarter of earth's orbit represents summer in the northern hemisphere (from A to B, B to C, C to D, or D to A)? Explain your answer based on your results from the investigation.
- d. Now go back to the diagram and write in all the northern hemisphere seasons at the appropriate positions. In the space below, write what would be happening at the same time in the southern hemisphere.

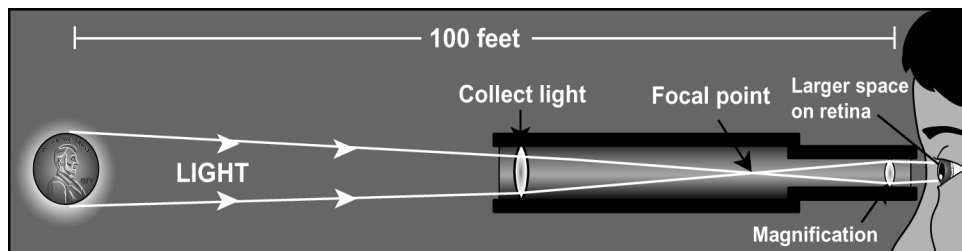
19A Tools of Astronomy

How does a telescope work?

A telescope is a device that makes objects that are far away appear to be closer. Telescopes work by collecting the light from a distant object with a lens or mirror and bringing that light into a concentrated point, called a focal point. The bright light from the focal point is then magnified by another lens (the eyepiece) so that it takes up more space on your retina (the light-sensing membrane of the eye). This makes the object appear to be larger and closer. In this investigation, you will identify the parts of a simple telescope and learn how it works. You will then use your telescope to observe features on the Moon including craters and maria (the Latin word for “seas”).

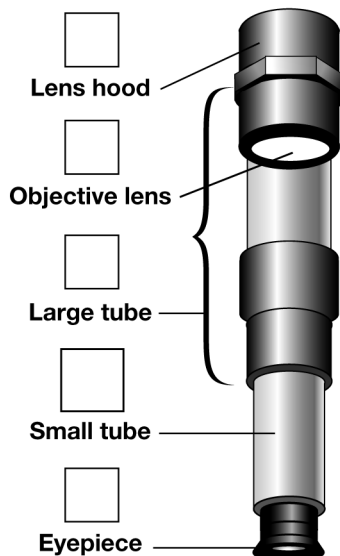
Materials

- Telescope
- 3 × 5 inch index card
- Metric tape measure (at least 10 meters)
- Ruler with millimeter divisions
- Graph paper
- Simple calculator

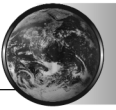


1 Learning the parts of a refracting telescope

For this investigation, you will use a small refracting telescope. This type of telescope uses a lens to gather light into a focal point, and another lens to magnify the image. Use the diagram below to identify the parts of your telescope. You may take your telescope apart and reassemble it to learn the parts. The function of each part is listed next to the diagram. Place the letter of each function next to the correct part.



- A. Moves in or out to focus image
- B. Magnifies image
- C. Reduces glare
- D. Holds the light-gathering lens
- E. Gathers light



2 Focusing a telescope

Safety Tip: Never look at the Sun or a bright object through your telescope! You will cause damage to your eye.

1. Pull the small tube all of the way out of your telescope and place a piece of masking tape lengthwise along the tube.
2. Write the letter “e” to measure 1 centimeter tall on a 3-by-5-inch card. Place the card at eye level on a wall in a large room (your classroom, the library, etc.).
3. Starting at the wall, lay a tape measure on the floor. Pull 10 meters of tape out from the wall. This will be your distance scale, 0-10, with zero at the wall.
4. Stand at the 10-meter mark and use your telescope to observe the letter on the card on the wall. Pull the small tube in or out until the letter comes sharply into focus. Record your observations in the table below. For your observations, describe the appearance of the image in terms of orientation and apparent size.
5. Draw a pencil line on the masking tape where the short tube enters the long tube. Write “10 m” (your distance from the card) next to the mark.
6. Repeat steps 4 and 5, moving closer to the wall by one meter for each trial. Continue to move 1 meter closer to the card, while repeating steps 4 and 5, until you cannot bring the letter into focus.
7. Use a ruler with millimeter markings to measure the length of the small tube, from your marks to the edge of the tube, as shown. Record your measurements in Table 1.

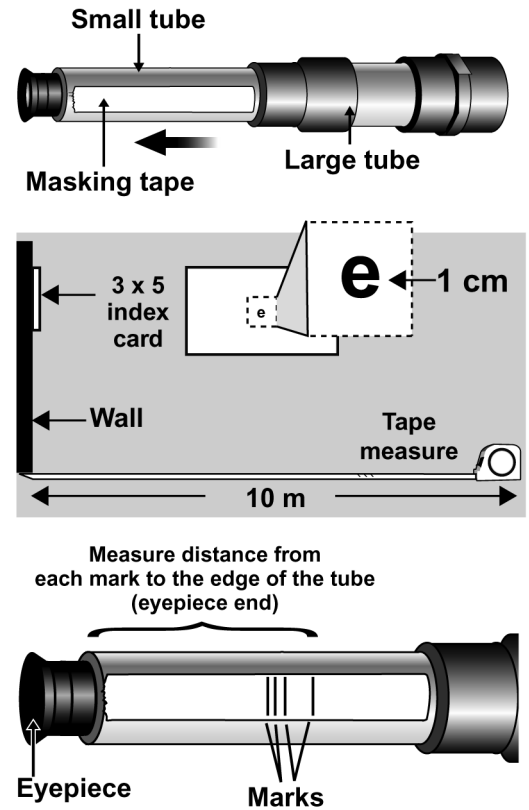


Table 1: Focusing a telescope

Distance from card (m)	Observations	Length of small tube (mm)
10		
9		
8		
7		
6		
5		
4		
3		
2		
1		

3 Stop and think

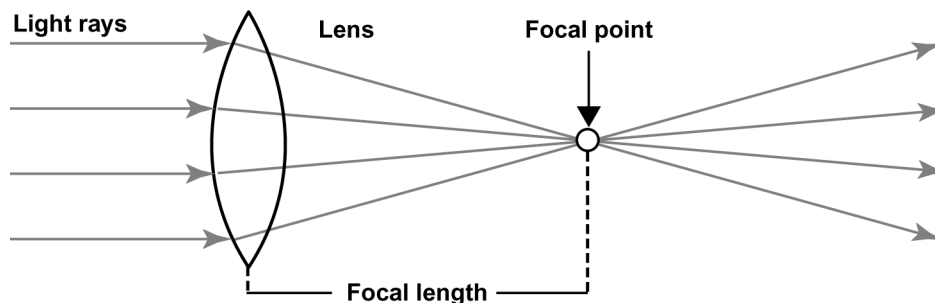
- In general, as you move closer to an object, how should you adjust the small tube?
- When you view the letter “e” through your telescope, why does the image appear upside down? (HINT: Trace the light rays coming from the penny in the picture on the first page of the investigation.)
- Make a graph of distance versus length of the small tube. Would you describe the relationship as direct or inverse? Explain your answer.

4 Determining the magnification of a telescope

A telescope’s magnification is a measure of the number of times the image being viewed is enlarged. A telescope magnification of 10x means the image of an object is magnified 10 times. The magnification of a telescope is the relationship between the objective lens and the eyepiece you are using. Since eyepieces in most telescopes can be interchanged, the magnification can vary. The magnification of a telescope is determined using the following equation:

$$\text{magnification} = \frac{\text{focal length of objective lens}}{\text{focal length of eyepiece}}$$

The **focal length** of a lens is the distance between the center of the lens and the focal point. The focal length of a lens is directly related to its diameter. The larger the diameter, the greater the focal length. Here is how the focal length of a lens is measured:

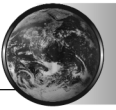


Popular focal lengths for eyepieces are 10 millimeters and 25 millimeters. Suppose your telescope has an objective lens with a focal length of 200 mm and an eyepiece with a focal length of 25 mm. What is the magnification of your telescope?

$$\text{magnification} = \frac{200 \text{ mm}}{25 \text{ mm}} = 8x$$

5 Thinking about what you observed

- If you wanted to increase the telescope’s magnification in the problem above, which eyepiece would you choose—10 mm or 40 mm? Explain your answer and show your solution to the problem.



- b. Calculate the magnification of the following telescopes:

Objective lens	Eyepiece	Magnification
1200 mm	10 mm	
1200 mm	25 mm	
800 mm	20 mm	

- c. A telescope with an 800 mm objective lens can gather more light than a telescope with a 200 mm objective lens. Does this mean that the 800 mm telescope has greater magnification than the 200 mm telescope? Explain your answer.
- d. The focal lengths of two telescopes are shown below. Which telescope would have the greater magnification? Through which telescope would you expect to see a brighter image? Explain your answers.

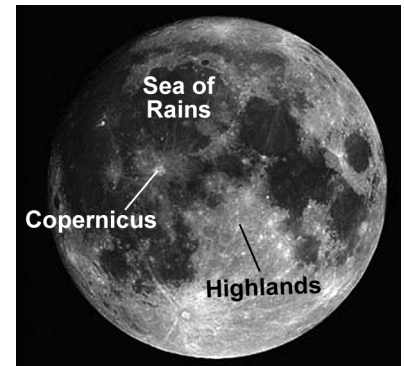
Telescope A: 800 mm objective lens; 20 mm eyepiece

Telescope B: 200 mm objective lens; 5 mm eyepiece

6 Observing the Moon

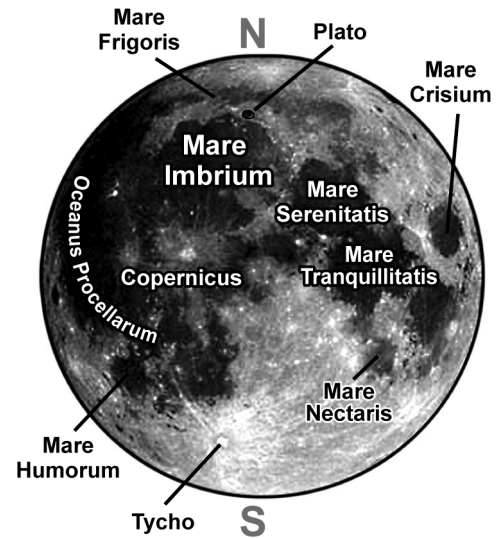
When you look at the Moon, you can see three main features of the lunar surface: craters, highlands, and maria. Craters are large, round pits that cover much of the Moon's surface. One of the Moon's largest craters, named for Copernicus, is hundreds of kilometers across.

Some areas of the Moon's surface appear bright, others dark. The brighter areas are called highlands because they are higher in elevation. The darker areas are called maria (a single area is called a mare) because early observers believed they were oceans. Maria are low, dry areas that were flooded with molten lava billions of years ago when the Moon was formed. Among the maria you can see through a telescope is a large one named Mare Imbrium, or Sea of Rains.



1. Find out on which evenings the Moon will be full, or at least 80 percent of its surface illuminated. This will be the best time for observing lunar features.
2. If you hold the telescope as steady as you can, what happens to the image of the Moon in your telescope over a few minutes, and why?

3. The diagram to the right shows the names of some of the craters, highlands, and maria you can observe. Study the diagram, then try to locate as many of the features as you can. Record all of the features you observe in a notebook.
4. As you observe the Moon, answer the questions below.

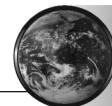


- a. How many craters can you see? Do they overlap? What do you believe this tells you about their age? Make sure you can locate Tycho, an 85-kilometer-wide crater on the lower part of the Moon that is the hub of a system of bright streaks.
- b. How many maria (Latin for seas, remember?) can you see?

7 CHALLENGE! Observing Jupiter and its moons

When it is visible, Jupiter is the third brightest object in the night sky—after the Moon and Venus. Though you will not be able to see any of Jupiter’s features through your telescope, you may be able to see four of its moons.

- a. Find out when Jupiter is visible in the night sky and the best time for viewing. Good resources include your local newspaper (the weather page) and the Internet.
- b. Use a telescope to view Jupiter. How many moons do you see?
- c. Why is Jupiter visible from Earth only during certain periods of time?



19B Stars

What are stars made of?

With the exception of the Sun, stars appear as small specks of light in the night sky. Astronomers use a technique called spectroscopy to analyze the light emitted by stars. Using spectroscopy, they can determine a star's temperature and the elements from which it is made. In this investigation, you will learn how to analyze light using spectroscopy. You will determine which elements are present in different light sources. You will then analyze the light emitted by the Sun.

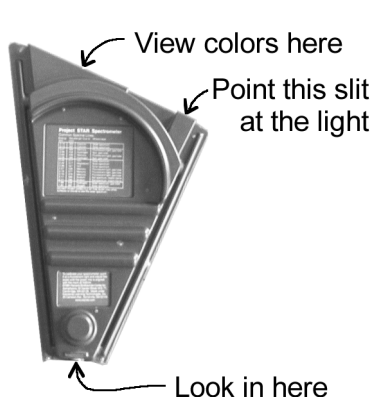
Materials

- Spectrometer
- Colored pencils

1 Using the spectrometer

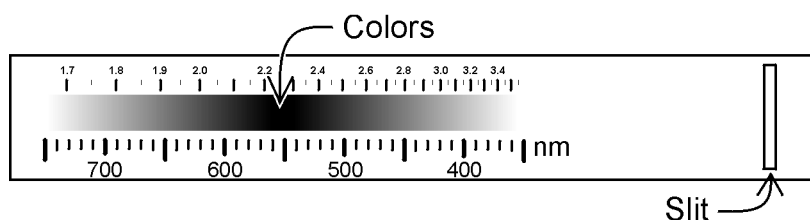
A spectrometer splits light into a spectrum of colors and displays the different colors of light along a scale. The scale measures the wavelengths of different colors of light in nanometers (nm).

Safety Tip: Never look directly into any light source—especially the Sun!

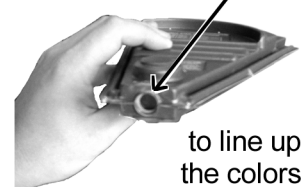


Hold the spectrometer so that the printed side is facing upward. In a well-lighted room, hold the spectrometer so that one eye is looking through the diffraction grating and the other eye is closed. You should see a scale, as illustrated below. The bottom scale measures wavelengths in nanometers. You should also notice colors at various places inside the spectrometer. This is caused by light entering the spectrometer from different sources.

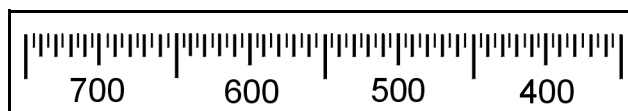
Notice that the plastic disk that is attached to the diffraction grating can be turned. Looking into the spectrometer, rotate the disk until you see colors in a horizontal stripe to your left. The colors should appear between the two lines of numbers on the scales.



Rotate the grating here ...



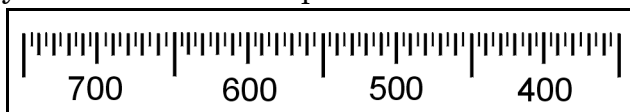
- While looking through the eyepiece, point the slit of the spectrometer directly at an incandescent bulb. Use colored pencils to show where the different colors of light appear on the spectrometer scale.



- Blue light has the highest energy and red light the lowest. Based on your observations with the spectrometer, what is the relationship between wavelength and amount of energy?

2 Using a spectrometer to identify elements in a fluorescent light

1. Use the spectrometer to examine a fluorescent light source (most likely the ones that illuminate your classroom). This time, you will see vertical lines (called spectral lines) of different colors instead of a smooth spectrum like you observed with the incandescent light.
2. You should see a green line at 546 nanometers on the scale. If the green line is not at 546 nanometers, ask your teacher to calibrate the spectrometer for you.
3. Use colored pencils to sketch the lines you observe. Be very precise in your sketch by placing the lines you see in the exact positions on the scale below.



4. Identify the wavelength of each spectral line, from left to right, then fill in Table 1.

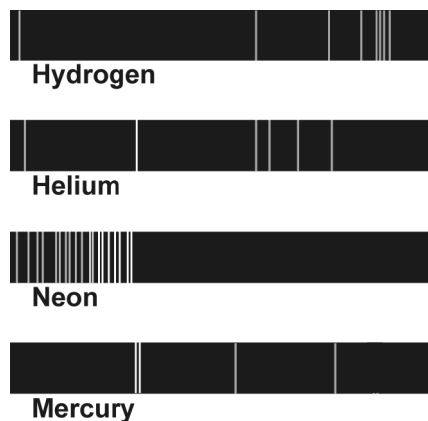
Table 1: Spectral lines produced by a fluorescent light

Line number	Spectral line color	Spectral line wavelength (nm)
1		
2		
3		
4		

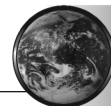
What do the lines mean?

When elements are heated until they are hot enough to emit light (like those elements that make up stars), they produce characteristic spectral lines. Each element produces a pattern of spectral lines that is like a fingerprint. Shown to the right are some examples of the spectral lines produced by four different elements. Each line has a specific wavelength (these values are not shown in the diagram).

The light produced by a fluorescent source is created when electric current is passed through a gas inside of the tube. This gas, which is made of only one element, absorbs energy, and emits light.



- a. The light produced by the fluorescent tube you observed contains only one element. Compare the spectral lines you observed with the ones shown in the diagram above. Which element does it contain?
- b. Fluorescent tubes have special instructions for disposal and must not end up in a landfill. Based on your spectral analysis of the gas inside the tube, why is this so?
- c. When astronomers use a spectrometer to analyze the light produced by stars, they observe the combined spectral lines of all of the elements present in the star. What specific information would an astronomer need to know in order to determine which elements are present in a star?



3 Analyzing light from different sources

Identify five different light sources to observe with the spectrometer. Examples include gym lights, street lights, security lights, monitor screens, plant growing lights, and glow sticks. Write the types of light sources in the first column of Table 2. Follow the steps below for each light source.

1. Use the spectrometer to analyze the light emitted by the light source.
2. Use colored pencils to draw the position of each spectral line in column 2 of Table 2.
3. Record the wavelength, in nanometers, of each spectral line in the third column of Table 2.
4. Table 4 on the next page lists the values, in nanometers, of the spectral lines produced by various elements. Use these values to identify the elements found in each light source you observed and write them in the last column of Table 2.

Table 2: Spectral lines produced by different light sources

Light source	Spectrometer scale (nm)	Position of each vertical line (nm)	Elements present

- a. If one light source displays more spectral lines than another, does that mean that it contains more elements? Explain your answer.
- b. Which light source contains the greatest variety of elements?
- c. Which light sources contain only one element?

4 Analyzing the light from a star

So far, the light sources you observed contain only a few elements. However, stars' atmospheres contain many elements and are much more complex.

1. Use the spectrometer to analyze the light of our closest star—the Sun. Do not point the spectrometer directly at the Sun. Instead, point it at reflected sunlight, off a cloud, for example, or a patch of blue sky.
2. Record in Table 3 the color and value, in nanometers, of each spectral line you observe.
3. Use Table 4, shown below, to identify the elements present in the Sun's atmosphere and record them in the third column of Table 3.

Safety Tip: Do not point the spectrometer directly at the Sun. Point it only at reflected sunlight. NEVER look directly at the Sun!

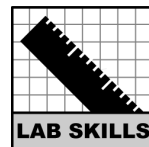
Table 3: Analyzing light from the Sun

Spectral line color	Spectral line wavelength (nm)	Element present

Table 4: Spectral lines and elements present

Spectral line (nm)	Element present	Spectral line (nm)	Element present
393	calcium	527	iron
397	calcium	546	mercury
405	mercury	577	mercury
434	hydrogen	579	mercury
436	mercury	589	sodium
486	hydrogen	590	sodium
517	magnesium	656	hydrogen
517	iron	687	oxygen

- a. Explain why the Sun's light produces more spectral lines than the light sources you observed in Parts 2 and 3.
- b. Where do elements in the Sun's atmosphere come from? Explain your answer in detail.
- c. The Sun is a middle-aged star. If you could analyze the light from a much older star, what would you expect to see? Justify your answer using your knowledge of the star life cycle.



Safety Skills

What can I do to protect myself and others in the lab?

Science equipment and supplies are fun to use. However, these materials must always be used with care. Here you will learn how to be safe in a science lab.

Materials

- Poster board
- Felt-tip markers

1 Follow these basic safety guidelines

Your teacher will divide the class into groups. Each group should create a poster-sized display of one of the following guidelines. Hang the posters in the lab. Review these safety guidelines before each Investigation.

1. **Prepare** for each Investigation.
 - a. Read the Investigation sheets carefully.
 - b. Take special note of safety instructions.
2. **Listen** to your teacher's instructions before, during, and after the Investigation. Take notes to help you remember what your teacher has said.
3. **Get ready to work:** Roll long sleeves above the wrist. Tie back long hair. Remove dangling jewelry and any loose, bulky outer layers of clothing. Wear shoes that cover the toes.
4. **Gather** protective clothing (goggles, apron, gloves) at the beginning of the Investigation.
5. **Emphasize teamwork.** Help each other. Watch out for one another's safety.
6. **Clean up** spills immediately. Clean up all materials and supplies after an Investigation.

2 Know what to do when...

1. **working with heat.**
 - a. Always handle hot items with a hot pad. Never use your bare hands.
 - b. Move carefully when you are near hot items. Sudden movements could cause burns if you touch or spill something hot.
 - c. Inform others if they are near hot items or liquids
2. **working with electricity.**
 - a. Always keep electric cords away from water.
 - b. Extension cords must not be placed where they may cause someone to trip or fall.

- c. If an electrical appliance isn't working, feels hot, or smells hot, tell a teacher right away.

3. disposing of materials and supplies.

- a. Generally, liquid household chemicals can be poured into a sink. Completely wash the chemical down the drain with plenty of water.
- b. Generally, solid household chemicals can be placed in a trash can.
- c. Any liquids or solids that **should not** be poured down the sink or placed in the trash have special disposal guidelines. Follow your teacher's instructions.
- d. If glass breaks, do not use your bare hands to pick up the pieces. Use a dustpan and a brush to clean up. "Sharps" trash (trash that has pieces of glass) should be well labeled. The best way to throw away broken glass is to seal it in a labeled cardboard box.

4. you are concerned about your safety or the safety of others.

- a. Talk to your teacher immediately. Here are some examples:
 - You smell chemical or gas fumes. This might indicate a chemical or gas leak.
 - You smell something burning.
 - You injure yourself or see someone else who is injured.
 - You are having trouble using your equipment.
 - You do not understand the instructions for the Investigation.
- b. Listen carefully to your teacher's instructions.
- c. Follow your teacher's instructions exactly.

3 Safety quiz

1. Draw a diagram of your science lab in the space below. Include in your diagram the following items. Include notes that explain how to use these important safety items.

- Exit/entrance ways
- Fire extinguisher(s)
- Fire blanket
- Eye wash and shower
- First aid kit
- Location of eye goggles and lab aprons
- Sink
- Trash cans
- Location of special safety instructions

2. How many fire extinguishers are in your science lab? Explain how to use them.

3. List the steps that your teacher and your class would take to safely exit the science lab and the building in case of a fire or other emergency.

4. Before beginning certain Investigations, why should you first put on protective goggles and clothing?

5. Why is teamwork important when you are working in a science lab?

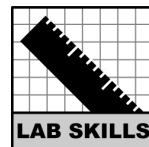
6. Why should you clean up after every Investigation?

7. List at least three things you should do if you sense danger or see an emergency in your classroom or lab.

8. Five lab situations are described below. What would you do in each situation?

- a. You accidentally knock over a glass container and it breaks on the floor.

- b. You accidentally spill a large amount of water on the floor.



- c. You suddenly you begin to smell a “chemical” odor that gives you a headache.

- d. You hear the fire alarm while you are working in the lab. You are wearing your goggles and lab apron.

- e. While your lab partner has her lab goggles off, she gets some liquid from the experiment in her eye.

- f. A fire starts in the lab.

Safety in the science lab is everyone’s responsibility!

4 Safety contract

Keep this contract in your notebook at all times.

By signing it, you agree to follow all the steps necessary to be safe in your science class and lab.

I, _____, (Your name)

- Have learned about the use and location of the following:
 - Aprons, gloves
 - Eye protection
 - Eyewash fountain
 - Fire extinguisher and fire blanket
 - First aid kit
 - Heat sources (burners, hot plate, etc) and how to use them safely
 - Waste-disposal containers for glass, chemicals, matches, paper, and wood
- Understand the safety information presented.
- Will ask questions when I do not understand safety instructions.
- Pledge to follow all of the safety guidelines that are presented on the Safety Skill Sheet at all times.
- Pledge to follow all of the safety guidelines that are presented on Investigation sheets.
- Will always follow the safety instructions that my teacher provides.

Additionally, I pledge to be careful about my own safety and to help others be safe. I understand that I am responsible for helping to create a safe environment in the classroom and lab.

Signed and dated,

Parent's or Guardian's statement:

I have read the Safety Skills sheet and give my consent for the student who has signed the preceding statement to engage in laboratory activities using a variety of equipment and materials, including those described. I pledge my cooperation in urging that she or he observe the safety regulations prescribed.

Signature of Parent or Guardian

Date

Writing a Lab Report

How do you share the results of an experiment?

A lab report is like a story about an experiment. The details in the story help others learn from what you did. A good lab report makes it possible for someone else to repeat your experiment. If their results and conclusions are similar to yours, you have support for your ideas. Through this process we come to understand more about how the world works.

1 The parts of a lab report

A lab report follows the steps of the scientific method. Use the checklist below to create your own lab reports:

- ☐ **Title:** The title makes it easy for readers to quickly identify the topic of your experiment.
- ☐ **Research question:** The research question tells the reader exactly what you want to find out through your experiment.
- ☐ **Introduction:** This paragraph describes what you already know about the topic, and shows how this information relates to your experiment.
- ☐ **Hypothesis:** The hypothesis states the prediction you plan to test in your experiment.
- ☐ **Materials:** List all the materials you need to do the experiment.
- ☐ **Procedure:** Describe the steps involved in your experiment. Make sure that you provide enough detail so readers can repeat what you did. You may want to provide sketches of the lab setup. Be sure to name the experimental variable and tell which variables you controlled.
- ☐ **Data/Observations:** This is where you record what happened, using descriptive words, data tables, and graphs.
- ☐ **Analysis:** In this section, describe your data in words. Here's a good way to start: *My data shows that...*
- ☐ **Conclusion:** This paragraph states whether your hypothesis was correct or incorrect. It may suggest a new research question or a new hypothesis.

2 A sample lab report

Use the sample lab report on the next two pages as a guide for writing your own lab reports. Remember that you are telling a story about something you did so that others can repeat your experiment.

Name: Miranda O.

Date: October 20, 2006

Title: Temperature change of air vs. water

Research question: Which heats up faster, air or water?

Introduction:

I have noticed that when I go swimming in an outdoor pool, the water feels cool on sunny days, even when the surrounding air is very warm. I know that the water and air are both heated by the same source, the sun.

Hypothesis: My hypothesis is that air heats up faster than water when the same amount of heat is applied.

Materials:

2 24-ounce clear plastic soda bottles

paper towels

tap water

stopwatch

1/2 cup sand

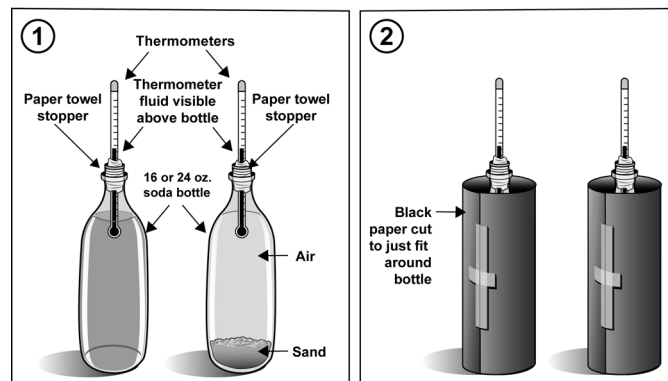
2 sheets black construction paper

2 standard Celsius thermometers

clear adhesive tape

Procedure:

1. I filled one 24-ounce clear plastic soda bottle with tap water to within 2.5 centimeters of the top.
2. I poured a handful of sand into another bottle of the same size and shape. This was just to steady the bottle by adding a little weight. This bottle was filled with air.
3. I wrapped strip of paper towel around a thermometer and stuck it in the neck of the first bottle. The thermometer's bulb was underwater. The top of the thermometer fluid could be seen above the paper towel (see diagram).



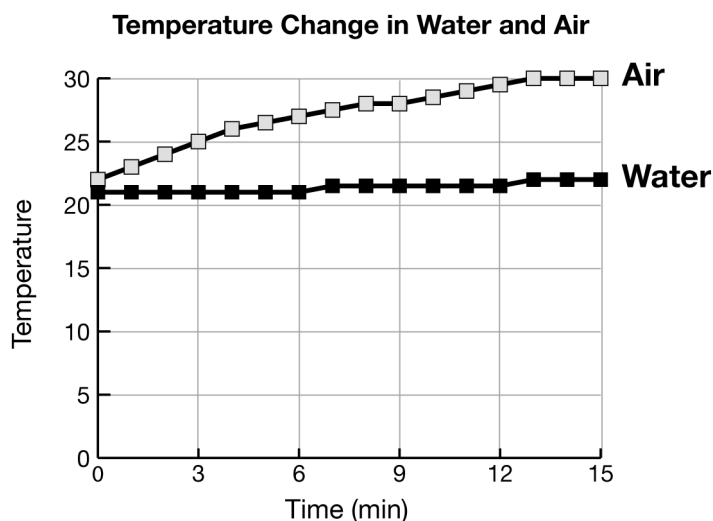
4. I put a thermometer in the second bottle using the same process.
5. I surrounded each bottle with black construction paper and taped it in place. The bottles were covered but the paper did not overlap. The black paper absorbed the sun's heat so that the bottles warmed up faster.

6. I put both bottles indoors on a table in front of a south-facing window when the afternoon sun was streaming in. I turned both bottles so the tape faced away from the window. Keeping the bottles inside prevented the wind from blowing them over.
7. I recorded the temperature every 60 seconds until it stopped rising in both bottles.

Data/Observations:

Table 1: Temperature change in water and air

Elapsed time (min)	Water temp (°C)	Air temp (°C)
0 (start)	21	22
1	21	23
2	21	24
3	21	25
4	21	26
5	21	26.5
6	21	27
7	21.5	27.5
8	21.5	28
9	21.5	28
10	21.5	28.5
11	21.5	29
12	21.5	29.5
13	22	30
14	22	30
15	22	30



Analysis: My data shows that the water temperature changed only one degree Celsius during the experiment. The air temperature rose eight degrees.

Conclusion: My hypothesis was correct—air does heat up faster than water. That’s why on a warm sunny day, the swimming pool water stays nice and cool even though the surrounding air is hot. I would like to do another experiment to find out if air also cools down faster than water. I could put my bottles in a refrigerator to test this research question.

Measuring Length

How do you find the length of an object?

Size matters! When you describe the length of an object, or the distance between two objects, you are describing something very important about the object. Is it as small as a bacteria (2 micrometers)? Is it a light year away (9.46×10^{15} meters)? By using the metric system you can quickly see the difference in size between objects.

Materials

- Metric ruler
- Pencil
- Paper
- Small objects
- Calculator

1 Reading the meter scale correctly

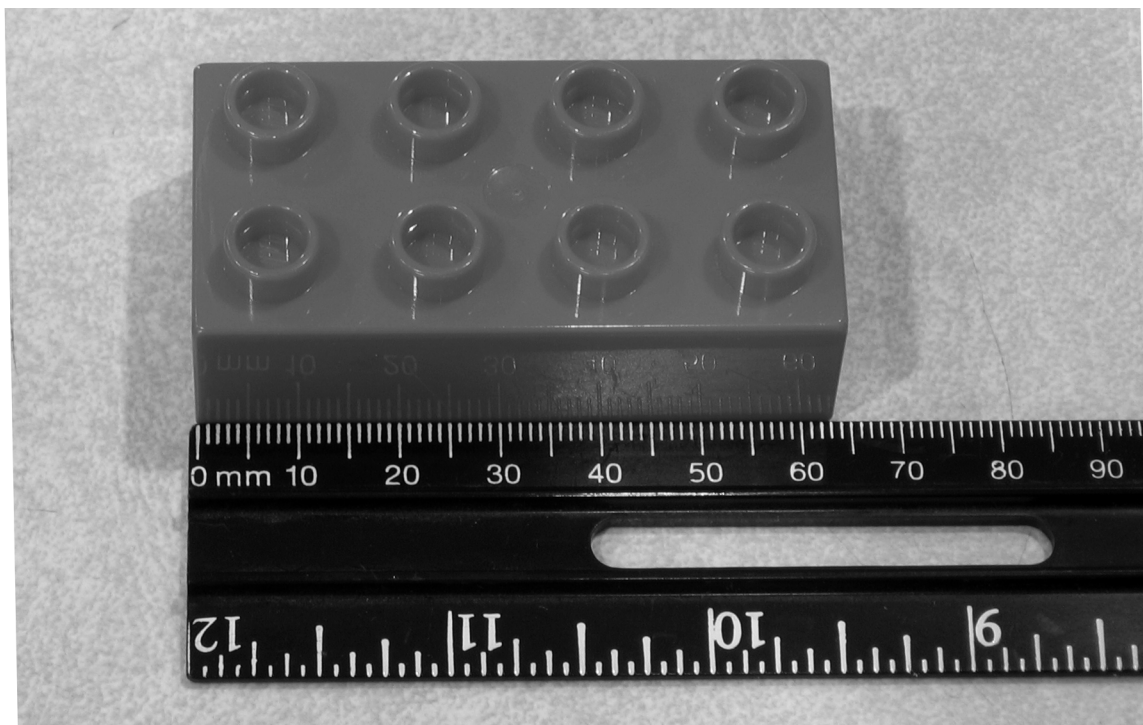


Look at the ruler in the picture above. Each small line on the top of the ruler represents one millimeter. Larger lines stand for 5 millimeter and 10 millimeter intervals. When the object you are measuring falls between the lines, read the number to the nearest 0.5 millimeter. Practice measuring several objects with your own metric ruler. Compare your results with a lab partner.

2 Stop and think

- a. You may have seen a ruler like this marked in centimeter units. How many millimeters are in one centimeter?
- b. Notice that the ruler also has markings for reading the English system. Give an example of when it would be better to measure with the English system than the metric system. Give a different example of when it would be better to use the metric system.

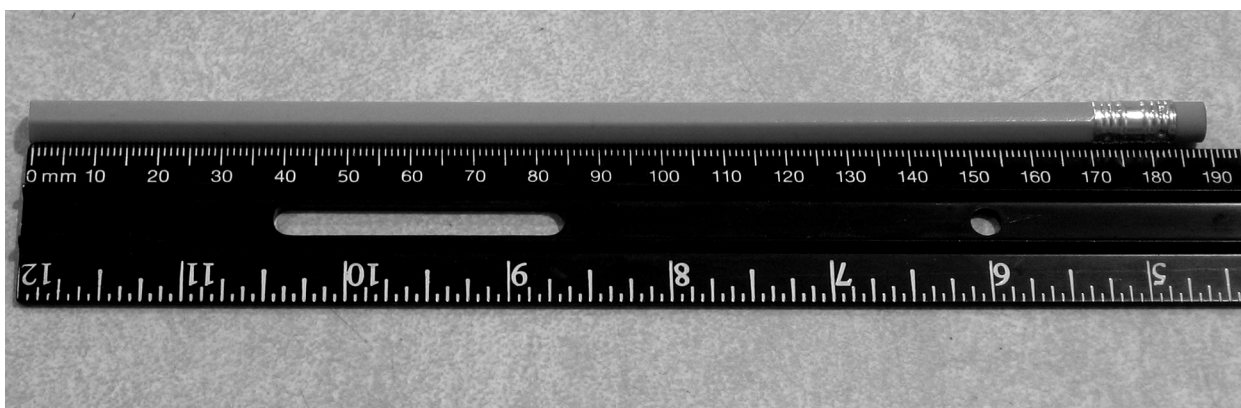
3 Example 1: Measuring objects correctly



Look at the picture above. How long is the building block?

1. Report the length of the building block to the nearest 0.5 millimeters.
2. Convert your answer to centimeters.
3. Convert your answer to meters.

4 Example 2: Measuring objects correctly

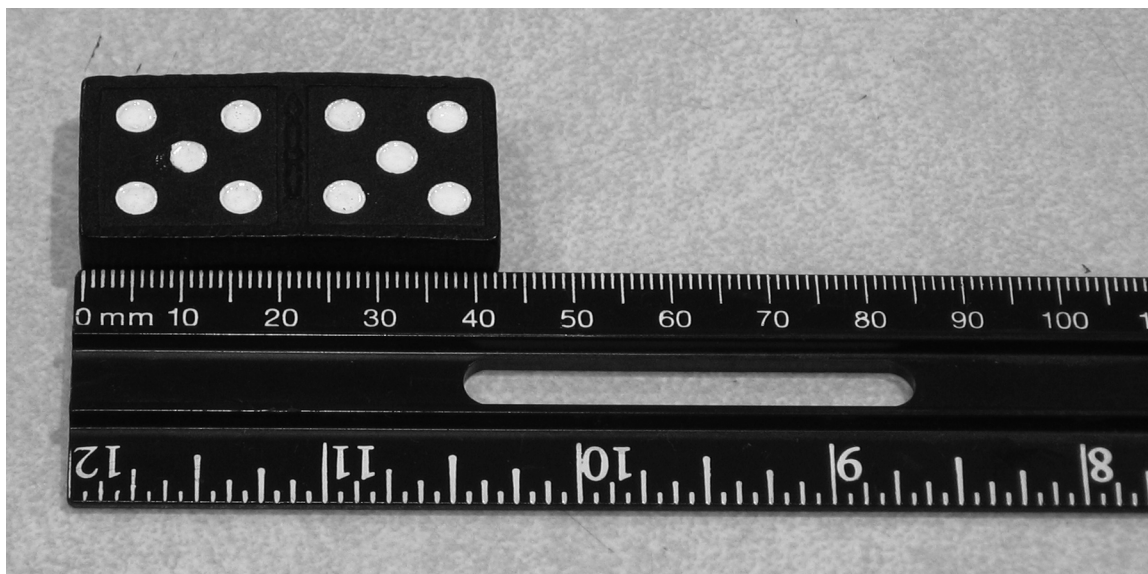


Look at the picture above. How long is the pencil?

1. Report the length of the pencil to the nearest 0.5 millimeters.
2. Challenge: How many building blocks in example 1 will it take to equal the length of the pencil?

3. Challenge: Convert the length of the pencil to inches by dividing your answer by 25.4 millimeters per inch.

5 Example 3: Measuring objects correctly



Look at the picture above. How long is the domino?

1. Report the length of the domino to the nearest 0.5 millimeters.
2. Challenge: How many dominoes will fit end to end on the 30 cm ruler?

6 Practice converting units for length

By completing the examples above you show that you are familiar with some of the prefixes used in the metric system like milli- and centi-. The table below gives other prefixes you may be less familiar with. Try converting the length of the domino from millimeters into all the other units given in the table.

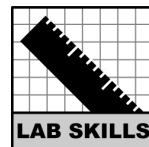
Refer to the multiplication factor this way:

- 1 kilometer equals 1000 meters.
 - 1000 millimeters equals 1 meter.
1. How many millimeters are in a kilometer?

$1000 \text{ millimeters per meter} \times 1000 \text{ meters per kilometer} = 1,000,000 \text{ millimeters per kilometer}$

2. Fill in the table with your multiplication factor by converting millimeters to the unit given. The first one is done for you.

$1000 \text{ millimeters per meter} \times 10^{-12} \text{ meters per picometer} = 10^{-9} \text{ millimeters per picometer}$



3. Divide the domino's length in millimeters by the number in your multiplication factor column. This is the answer you will put in the last column.

Prefix	Symbol	Multiplication factor	Scientific notation in meters	Your multiplication factor	Your domino length in:
<i>pico-</i>	p	0.000000000001	10^{-12}	10^{-9}	pm
<i>nano-</i>	n	0.000000001	10^{-9}		nm
<i>micro-</i>	μ	0.000001	10^{-6}		μm
<i>milli</i>	m	0.001	10^{-3}		mm
<i>centi-</i>	c	0.01	10^{-2}		cm
<i>deci-</i>	d	0.1	10^{-1}		dm
<i>deka-</i>	da	10	10^1		dam
<i>hecto-</i>	h	100	10^2		hm
<i>kilo-</i>	k	1000	10^3		km

Measuring Temperature

How do you find the temperature of a substance?

There are many different kinds of thermometers used to measure temperature. Can you think of some you find at home? In your classroom you will use a glass immersion thermometer to find the temperature of a liquid. The thermometer contains alcohol with a red dye in it so you can see the alcohol level inside the thermometer. The alcohol level changes depending on the surrounding temperature. You will practice reading the scale on the thermometer and report your readings in degrees Celsius.

Materials

- Alcohol immersion thermometer
- Beakers
- Water at different temperatures
- Ice

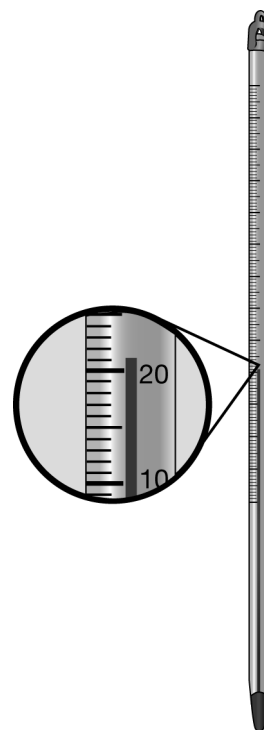
Safety: Glass thermometers are breakable. Handle them carefully. Overheating the thermometer can cause the alcohol to separate and give incorrect readings. Glass thermometers should be stored horizontally or vertically (never upside down) to prevent alcohol from separating.

1 Reading the temperature scale correctly

Look at the picture at right. See the close-up of the line inside the thermometer on the scale. The tens scale numbers are given. The ones scale appears as lines. Each small line equals 1 degree Celsius. Practice reading the scale from the bottom to the top. One small line above 20°C is read as 21°C. When the level of the alcohol is between two small lines on the scale, report the number to the nearest 0.5°C.

2 Stop and think

- What number does the large line between 20°C and 30°C equal? Figure out by counting the number of small lines between 20°C and 30°C.
- Give the temperature of the thermometer in the picture above.
- Practice rounding the following temperature values to the nearest 0.5°C: 23.1°C, 29.8°C, 30.0°C, 31.6°C, 31.4°C.
- Water at 0°C and 100°C has different properties. Describe what water looks like at these temperatures.
- What will happen to the level of the alcohol if you hold the thermometer by the bulb?



3 Reading the temperature of water in a beaker

An immersion thermometer must be placed in liquid up to the solid line on the thermometer (at least 2 and one half inches of liquid). Wait about 3 minutes for the temperature of the thermometer to equal the temperature of the liquid. Record the temperature to the nearest 0.5°C when the level stops moving.

1. Place the thermometer in the beaker. Check to make sure that the water level is above the solid line on the thermometer.
2. Wait until the alcohol level stops moving (about three minutes). Record the temperature to the nearest 0.5°C .

4 Reading the temperature of warm water in a beaker

A warm liquid will cool to room temperature. For a warm liquid, record the warmest temperature you observe before the temperature begins to decrease.

1. Repeat the procedure above with a beaker of warm (not boiling) water.
2. Take temperature readings every 30 seconds. Record the warmest temperature you observe.

5 Reading the temperature of ice water in a beaker

When a large amount of ice is added to water, the temperature of the water will drop until the ice and water are the same temperature. After the ice has melted, the cold water will warm to room temperature.

1. Repeat the procedure above with a beaker of ice and water.
2. Take temperature readings every 30 seconds. Record the coldest temperature you observe.



Calculating Volume

How do you find the volume of a three dimensional shape?

Volume is the amount of space an object takes up. If you know the dimensions of a solid object, you can find the object's volume. A two dimensional shape has length and width. A three dimensional object has length, width, and height. This investigation will give you practice finding volume for different solid objects.

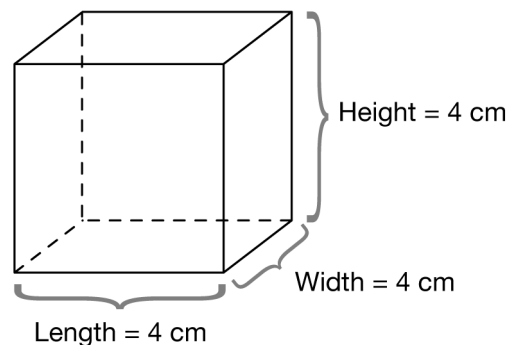
Materials

- Pencil
- Calculator

1 Calculating volume of a cube

A cube is a geometric solid that has length, width and height. If you measure the sides of a cube, you will find that all the edges have the same measurement. The volume of a cube is found by multiplying the length times width times height. In the picture each side is 4 centimeters so the problem looks like this:

$$V = l \times w \times h$$



Example:

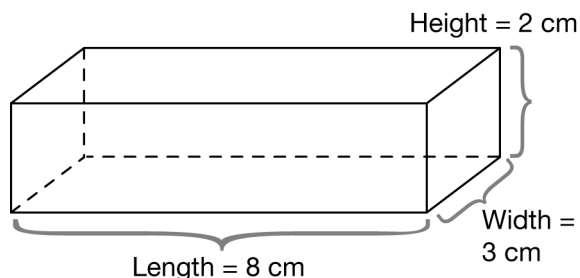
$$\text{Volume} = 4 \text{ centimeters} \times 4 \text{ centimeters} \times 4 \text{ centimeters} = 64 \text{ centimeters}^3$$

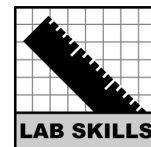
2 Stop and think

- What are the units for volume in the example above?
- In the example above, if the edge of the cube is 4 inches, what will the volume be? Give the units.
- How is finding volume different from finding area?
- If you had cubes with a length of 1 centimeter, how many would you need to build the cube in the picture above?

3 Calculating volume of a rectangular prism

Rectangular prisms are like cubes, except not all of the sides are equal. A shoebox is a rectangular prism. You can find the volume of a rectangular prism using the same formula given above $V = l \times w \times h$.



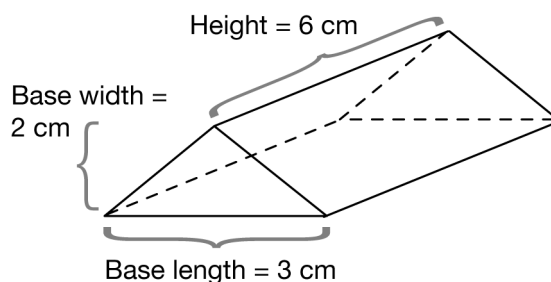


Another way to say it is to multiply the area of the base times the height.

1. Find the area of the base for the rectangular prism pictured above.
2. Multiply the area of the base times the height. Record the volume of the rectangular prism.
3. PRACTICE: Find the volume for a rectangular prism with a height 6 cm, length 5 cm, and width 3 cm. Be sure to include the units in all of your answers.

4 Calculating volume for a triangular prism

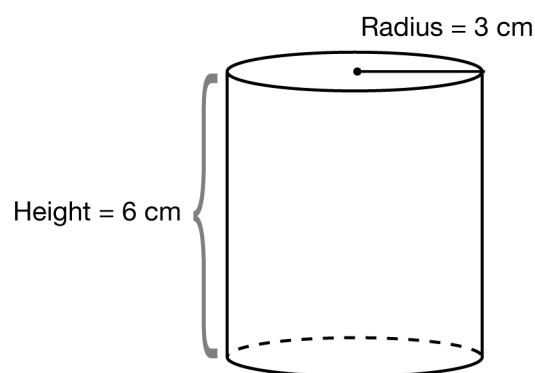
Triangular prisms have three sides and two triangular bases. The volume of the triangular prism is found by multiplying the area of the base times the height. The base is a triangle.



1. Find the area of the base by solving for the area of the triangle: $B = \frac{1}{2} \times l \times w$.
2. Find the volume by multiplying the area of the base times the height of the prism:
 $V = B \times h$. Record the volume of the triangular prism shown above.
3. PRACTICE: Find the volume of the triangular prism with a height 10 cm, triangular base width 4 cm, and triangular base length 5 cm.

5 Calculating volume for a cylinder

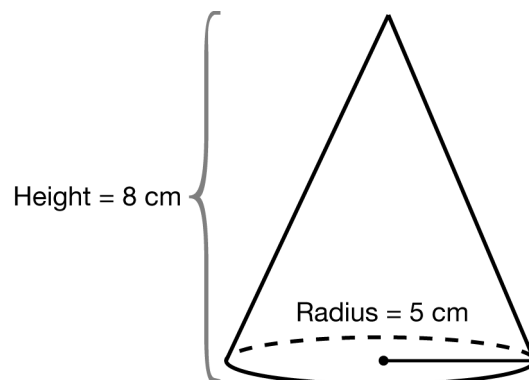
A soup can is a cylinder. A cylinder has two circular bases and a round surface. The volume of the cylinder is found by multiplying the area of the base times the height. The base is a circle.



1. Find the area of the base by solving for the area of a circle: $A = \pi \times r^2$.
2. Find the volume by multiplying the area of the base times the height of the cylinder:
 $V = A \times h$. Record the volume of the cylinder shown above.
3. PRACTICE: Find the volume of the cylinder with height 8 cm and radius 4 cm.

6 Calculating volume for a cone

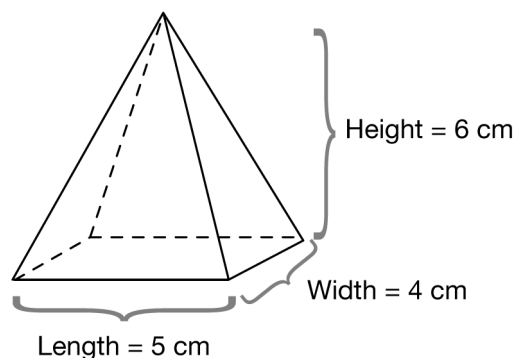
An ice cream cone really is a cone! A cone has height and a circular base. The volume of the cone is found by multiplying $\frac{1}{2}$ times the area of the base times the height.



1. Find the area of the base by solving for the area of a circle: $A = \pi \times r^2$.
2. Find the volume by multiplying $\frac{1}{2}$ times the area of the base times the height:
 $V = \frac{1}{2} \times A \times h$. Record the volume of the cone shown above.
3. PRACTICE: Find the volume of the cone with height 8 cm and radius 4 cm. Contrast your answer with the volume you found for the cylinder with the same dimensions. What is the difference in volume? Does this make sense?

7 Calculating the volume for a rectangular pyramid

A pyramid looks like a cone. It has height and a rectangular base. The volume of the rectangular pyramid is found by multiplying $\frac{1}{3}$ times the area of the base times the height.

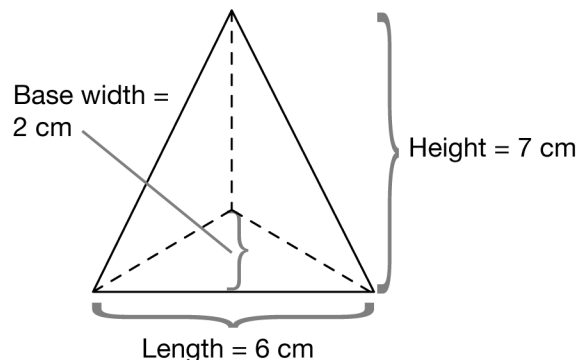


1. Find the area of the base by multiplying the length times the width: $A = l \times w$.
2. Find the volume by multiplying $\frac{1}{3}$ times the area of the base times the height:
 $V = \frac{1}{3} \times A \times h$. Record the volume of the rectangular pyramid shown above.
3. PRACTICE: Find the volume of a rectangular pyramid with height 10 cm and width 4 cm and length 5 cm.
4. EXTRA CHALLENGE: If a rectangular pyramid had a height of 8 cm and a width of 4 cm, what length would it need to have to give the same volume as the cone in practice question 4 above?

8 Calculating volume for a triangular pyramid

A triangular pyramid is like a rectangular pyramid, but its base is a triangle. Find the area of the base first. Then calculate the volume by multiplying $\frac{1}{3}$ times the area of the base times the height.

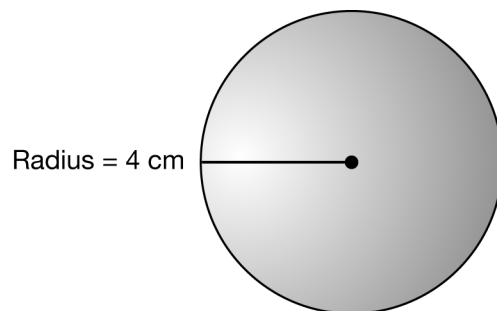
1. Find the area of the base by solving for the area of a triangle: $B = \frac{1}{2} \times l \times w$.
2. Find the volume by multiplying $\frac{1}{3}$ times the area of the base times the height: $V = \frac{1}{3} \times A \times h$. Find the volume of the triangular pyramid shown above.
3. **PRACTICE:** Find the volume of the triangular pyramid with height 10 cm and width 6 cm and length 5 cm.



9 Calculating volume for a sphere

To find the volume of a sphere, you only need to know one dimension about the sphere, its radius.

1. Find the volume of a sphere: $V = \frac{4}{3}\pi r^3$. Find the volume for the sphere shown above.
2. **PRACTICE:** Find the volume for a sphere with radius 2 cm.
3. **EXTRA CHALLENGE:** Find the volume for a sphere with diameter 10 cm.



Measuring Volume

How do you find the volume of an irregular object?

It's easy to find the volume of a shoebox or a basketball. You just take a few measurements, plug the numbers into a math formula, and you have figured it out. But what if you want to find the volume of a bumpy rock, or an acorn, or a house key? There aren't any simple math formulas to help you out. However, there's an easy way to find the volume of an irregular object, as long as the object is waterproof!

Materials

- Displacement tank
- Water source
- Disposable cup
- Beaker
- Graduated cylinder
- Sponges or paper towel
- Object to be measured

1 Setting up the displacement tank

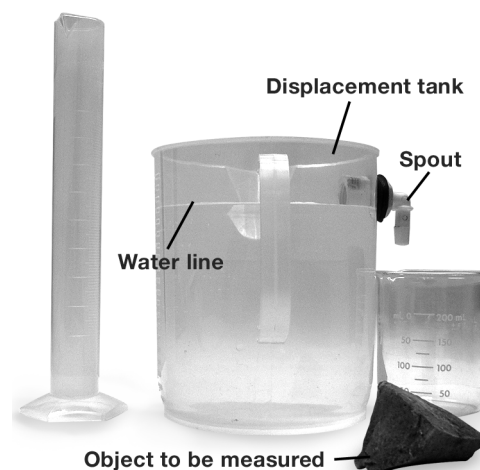
Set the displacement tank on a level surface. Place a disposable cup under the tank's spout. Carefully fill the tank until the water begins to drip out of the spout. When the water stops flowing, discard the water collected in the disposable cup. Set the cup aside and place a beaker under the spout.

2 Stop and think

- a. What do you think will happen when you place an object into the tank?
- b. Which object would cause more water to come out of the spout, an acorn or a fist-sized rock?
- c. Why are we interested in how much water comes out of the spout?
- d. Explain how the displacement tank measures volume.

3 Measuring volume with the displacement tank

1. Gently place a waterproof object into the displacement tank. It is important to avoid splashing the water or creating a wave that causes extra water to flow out of the spout. It may take a little practice to master this step.
2. When the water stops flowing out of the spout, it can be poured from the beaker into a graduated cylinder for precise measurement. The volume of the water displaced is equal to the object's volume.
Note: Occasionally, when a small object is placed in the tank, no water will flow out. This happens because an air bubble has formed in the spout. Simply tap the spout with a pencil to release the air bubble.
3. If you wish to measure the volume of another object, don't forget to refill the tank with water first!



Measuring Mass with a Triple Beam Balance

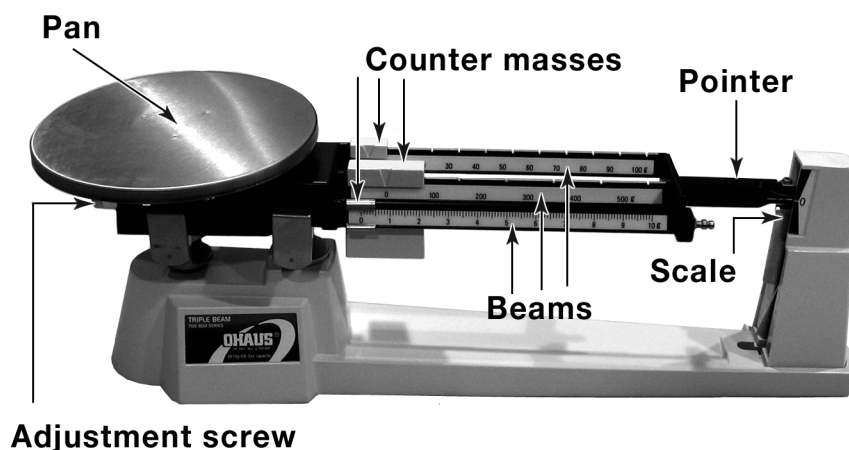
How do you find the mass of an object?

Why can't you use a bathroom scale to measure the mass of a paperclip? You could if you were finding the mass of a lot of them at one time! To find the mass of objects less than a kilogram you will need to use the triple beam balance.

Materials

- Triple beam balance
- Small objects
- Mass set (optional)
- Beaker

1 Parts of the triple beam balance



2 Setting up and zeroing the balance

The triple beam balance works like a see-saw. When the mass of your object is perfectly balanced by the counter masses on the beam, the pointer will rest at 0. Add up the readings on the three beams to find the mass of your object. The unit of measure for this triple beam balance is grams.

1. Place the balance on a level surface.
2. Clean any objects or dust off the pan.
3. Move all counter masses to 0. The pointer should rest at 0. Use the adjustment screw to adjust the pointer to 0, if necessary. When the pointer rests at 0 with no objects on the pan, the balance is said to be zeroed.

3 Finding a known mass

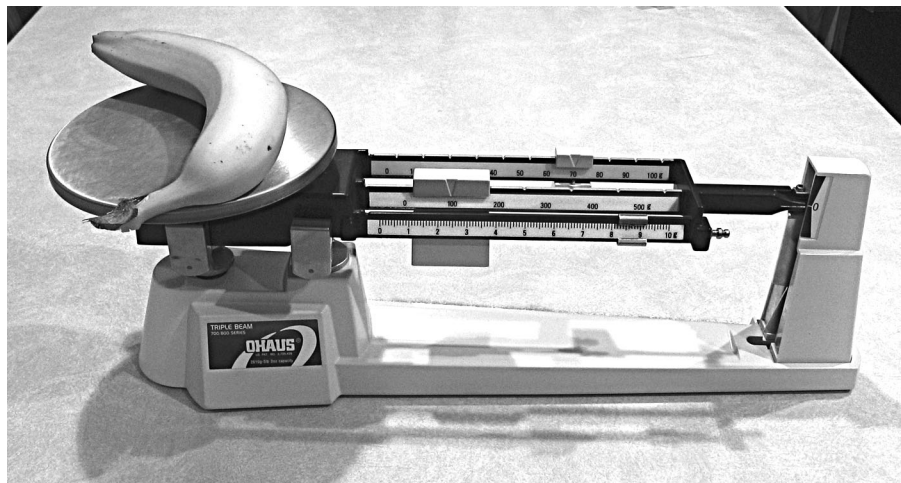
You can check that the triple beam balance is working correctly by using a mass set. Your teacher will provide the correct mass value for these objects.

1. After zeroing the balance, place an object with a known mass on the pan.
2. Move the counter masses to the right one at a time from largest to smallest. When the pointer is resting at 0 the numbers under the three counter masses should add up to the known mass.
3. If the pointer is above or below 0, recheck the balance set up. Recheck the position of the counter masses. Counter masses must be properly seated in a groove. Check with your teacher to make sure you are getting the correct mass before finding the mass an unknown object.

4 Finding the mass of an unknown object

1. After zeroing the balance, place an object with an unknown mass on the pan. Do not place hot objects or chemicals directly on the pan
2. Move the largest counter mass first. Place it in the first notch after zero. Wait until the pointer stops moving. If the pointer is above 0, move the counter mass to the next notch. Continue to move the counter mass to the right, one notch at a time until the pointer is slightly above 0. Go to step 3. If the pointer is below 0, move the counter mass back one notch. When the pointer rests at 0, you do not need to move any more counter masses.
3. Move the next largest counter mass from 0 to the first notch. Watch to see where the pointer rests. If it rests above 0, move the counter mass to the next notch. Repeat until the point rests at 0, or slightly above. If the pointer is slightly above 0, go to step 4.
4. Move the smallest counter mass from 0 to the position on the beam where the pointer rests at 0.
5. Add the masses from the three beams to get the mass of the unknown object. You should be able to record a number for the hundreds place, the tens place, the ones place, and the tenths place and the hundredths place. The hundredths place can be read to 0.00 or 0.05. You may have zeros in your answer.

5 Reading the balance correctly



Look at the picture above. To find the mass of the object, locate the counter mass on each beam. Read the numbers directly below each counter mass. You can read the smallest mass to 0.05 grams. Write down the three numbers. Add them together. Report your answer in grams. Does your answer agree with others? If not, check your mass values from each beam to find your mistake.

6 Finding the mass of an object in a container

To measure the mass of a liquid or powder you will need an empty container on the pan to hold the sample. You must find the mass of the empty container first. After you place the object in the container and find the total mass, you can subtract the container's mass from the total to find the object's mass.

1. After zeroing the balance, place a beaker on the pan.
2. Follow directions for finding the mass of an unknown object. Record the mass of the beaker.
3. Place a small object in the beaker.
4. Move the counter masses to the right, largest to smallest, to find the total mass.
5. Subtract the beaker's mass from the total mass. This is the mass of your object in grams.

Recording Observations in the Lab

How do you record valid observations for an experiment in the lab?

When you perform an experiment you will be making important observations. You and others will use these observations to test a hypothesis. In order for an experiment to be valid, the evidence you collect must be objective and repeatable. This investigation will give you practice making and recording good observations.

Materials

- Paper
- Pencil
- Calculator
- Ruler

1 Making valid observations

Valid scientific observations are objective and repeatable. Scientific observations are limited to one's senses and the equipment used to make these observations. An objective observation means that the observer describes only what happened. The observer uses data, words, and pictures to describe the observations as exactly as possible. An experiment is repeatable if other scientists can see or repeat the same result. The following exercise gives you practice identifying good scientific observations.

2 Exercise 1

- 1. Which observation is the most objective? Circle the correct letter.**
 - a. My frog died after 3 days in the aquarium. I miss him.
 - b. The frog died after 3 days in the aquarium. We will test the temperature and water conditions to find out why.
 - c. Frogs tend to die in captivity. Ours did after three days.
- 2. Which observation is the most descriptive? Circle the correct letter.**
 - a. After weighing 3.000 grams of sodium bicarbonate into an Erlenmeyer flask, we slowly added 50.0 milliliters of vinegar. The contents of the flask began to bubble.
 - b. We weighed the powder into a glass container. We added acid. It bubbled a lot.
 - c. We saw a fizzy reaction.
- 3. Which experiment has enough detail to repeat? Circle the correct letter.**
 - a. Each student took a swab culture from his or her teeth. The swab was streaked onto nutrient agar plates and incubated at 37 C.
 - b. Each student received a nutrient agar plate and a swab. Each student performed a swab culture of his or her teeth. The swab was streaked onto the agar plate. The plates were stored face down in the 37 C incubator and checked daily for growth. After 48 hours the plates were removed from the incubator and each student recorded his or her results.
 - c. Each student received a nutrient agar plate and a swab. Each student performed a swab culture of his or her teeth. The swab was streaked onto the agar plate. The plates were stored face down in the 37 C incubator and checked daily for growth. After 48 hours the plates were removed from the incubator and each student counted the number of colonies present on the surface of the agar.

3 Recording valid observations

As a part of your investigations you will be asked to record observations on a skill sheet or in the results section of a lab report. There are different ways to show your observations. Here are some examples:

1. **Short description:** Use descriptive words to explain what you did or saw. Write complete sentences. Give as much detail as possible about the experiment. Try to answer the following questions: What? Where? When? Why? and How?
2. **Tables:** Tables are a good way to display the data you have collected. Later, the data can be plotted on a graph. Be sure to include a title for the table, labels for the sets of data, and units for the values. Check values to make sure you have the correct number of significant figures.

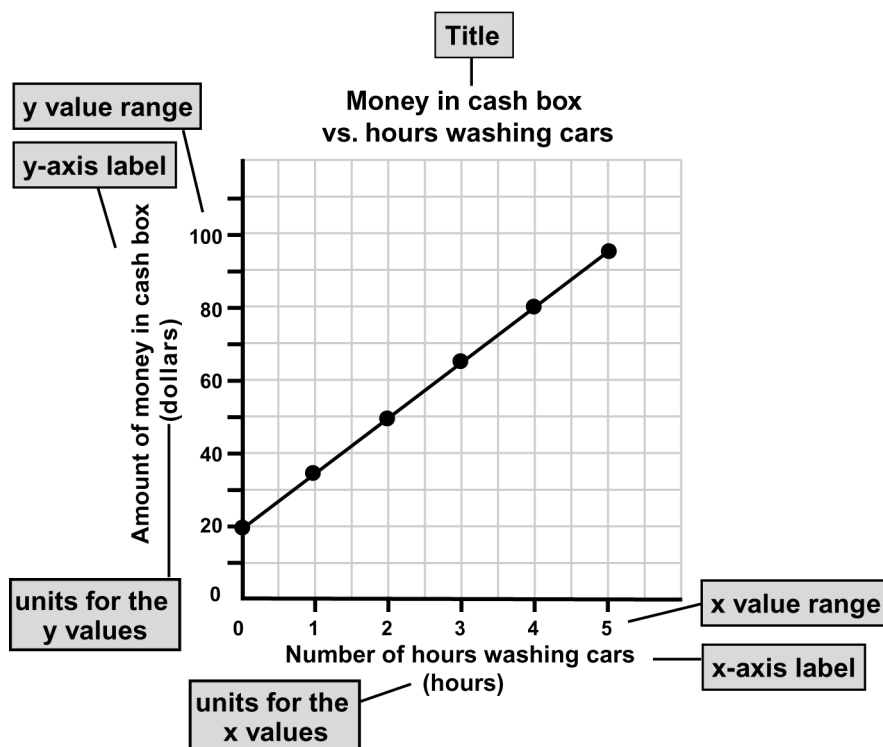
Table 1: U.S. penny mass by year

Year manufactured	1977	1978	1979	1980	1981	1982	1983	1984	1985
Mass (grams)	3.0845	3.0921	3.0689	2.9915	3.0023	2.5188	2.5042	2.4883	2.5230

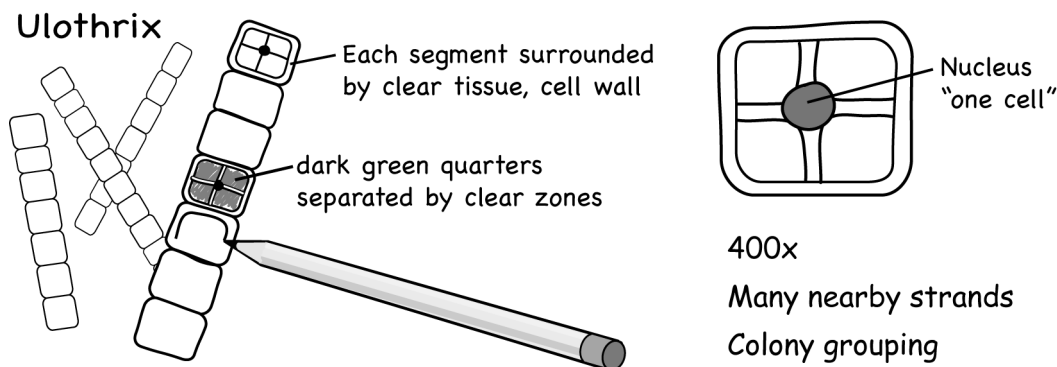
3. Graphs and charts:

A graph or chart is a picture of your data. There are different kinds of graphs and charts: line graphs, trend charts, bar graphs, and pie graphs, for example. A line graph is shown below. Label the important parts of your graph. Give your graph a title. The x-axis and y-axis should have labels for the data, the unit values, and the number range on the graph. The line graph in the example has a straight line

through the data. Sometimes data does not fit a straight line. Often scientists will plot data first in a trend chart to see how the data looks. Check with your instructor if you are unsure how to display your data.



4. **Drawings:** Sometimes you will record observations by drawing a sketch of what you see. The example below was observed under a microscope.



Give the name of the specimen. Draw enough detail to make the sketch look realistic. Use color, when possible. Identify parts of the object you were asked to observe. Provide the magnification or size of the image.

4 Exercise 2: Practice recording valid observations

A lab report form has been given to you by your instructor. This exercise gives you a chance to read through an experiment and fill in information in the appropriate sections of the lab report form. Use this opportunity to practice writing and graphing scientific observations. Then answer the following questions about the experiment.

A student notices that when he presses several pennies in a pressed penny machine, his brand new penny has some copper color missing and he can see silver-like material underneath. He wonders, “Are some pennies made differently than others?” The student has a theory that not all U.S. pennies are made the same. He thinks that if pennies are made differently now he might be able to find out when the change occurred. He decides to collect a U.S. penny for each year from 1977 to the present, record the date, and take its mass. The student records the data in a table and creates a graph plotting U.S. penny mass vs. year. Below is a table of some of his data:

Table 2: U.S. penny mass by year

Year manufactured	1977	1978	1979	1980	1981	1982	1983	1984	1985
Mass (grams)	3.0845	3.0921	3.0689	2.9915	3.0023	2.5188	2.5042	2.4883	2.5230

5 Stop and think

- What observation did the student make first before he began his experiment?
- How did the student display his observations?
- In what section of the lab report did you show observations?
- What method did you use to display the observations? Explain why you chose this one.