

Glencoe Science

Probeware Labs

Using probeware data collection and graphing calculator analysis

Student Edition



Credits

The photo of the CBL 2, graphing calculator, and pH probe on the front cover and at the top of the first page of each student lab appears courtesy of Texas Instruments, Inc. Each *Probeware Lab* activity was reviewed by Richard Sorensen of Vernier Software & Technology.

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To the Student

The activities in this book are designed to help you study science using probeware technology. A probeware lab is different from other labs because it uses a probe or sensor to collect data, a data collection unit to interpret and store the data, and a graphing calculator or computer to analyze the data. These components are connected with a software program called DataMate that makes them work together in an easy-to-use, handheld, system. These labs are designed specifically for the TI-73 or TI-83 Plus graphing calculators and a CBL 2™ (produced by Texas Instruments, Inc.) or LabPro® (produced by Vernier Software & Technology) data collection unit.

The activities in this book will help you improve your ability to recognize and use equipment properly and to analyze data. To help you get started, the next few pages will provide you with:

- information about **getting started with probeware**
- a list of **laboratory and safety guidelines**
- a reference page of **safety symbols**

Each lab activity in this manual includes the following sections:

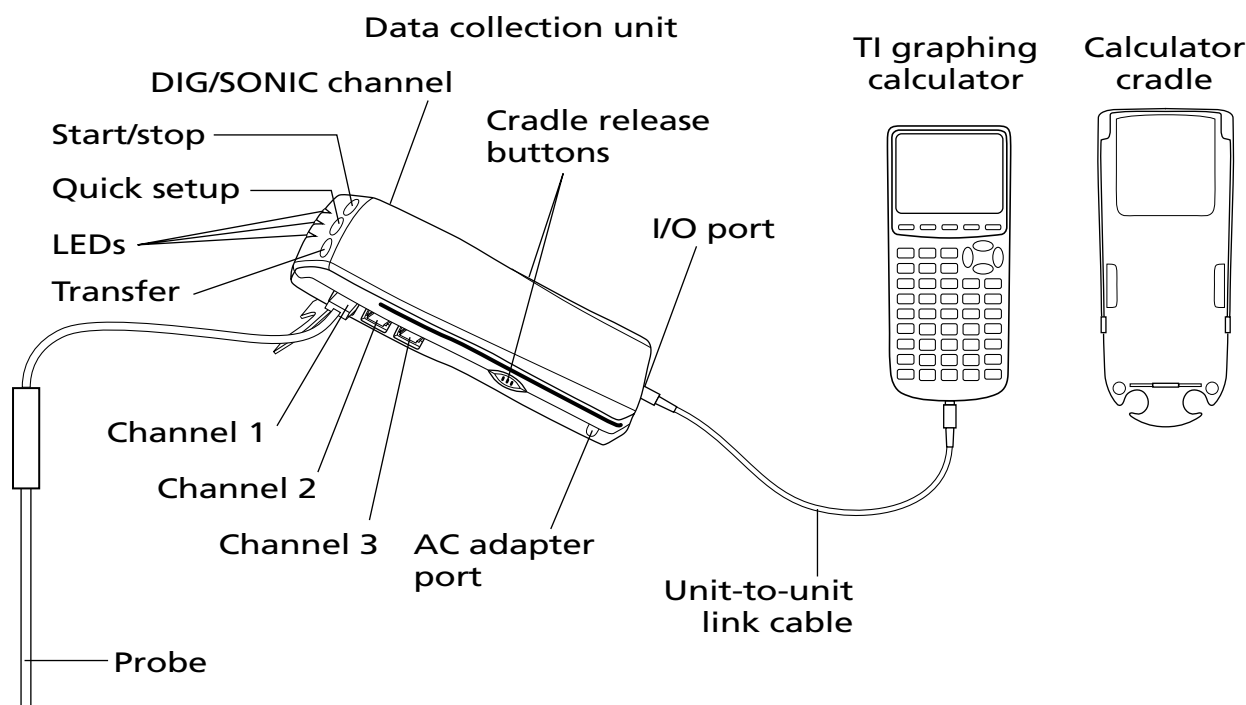
- **Introduction** provides a background discussion about the concepts you will study in the activity.
- **What You'll Investigate** contains questions that will be answered by completing the activity.
- **Goals** are statements of what you should accomplish during the activity.
- **Materials** lists the supplies and equipment you will need for the activity.
- **Safety Precautions** warn you of potential hazards in the laboratory. Before beginning any activity, refer to the list of safety symbols in page *viii* to see what each symbol means and take the necessary precautions.
- **Pre-Lab Questions** review your knowledge of important concepts needed to complete the activity successfully. Make sure that you discuss and understand the answers to these questions before you begin each investigation.
- **Procedure** includes numbered steps that tell you how to carry out the activity.
- **Cleanup and Disposal** provides instructions for cleaning equipment and your lab area. Instructions also are given for proper disposal of any wastes.
- **Conclude and Apply** includes a data table or other means for writing your laboratory data. Remember to always record data and observations in an organized way as you do the activity. This section also may show you how to perform the calculations necessary for you to analyze your data and reach conclusions. It provides questions to aid you in interpreting data and observations to help you reach an experimental result.

Getting Started with Probeware

The following instructions will guide you through the setup process for the data collection unit and the graphing calculator. The activities are compatible with either the CBL 2 or the LabPro unit. Each activity was written for use with TI-73 or TI-83 Plus graphing calculators. These activities can be adapted for use with other graphing calculators or other data collection units, if desired.

Connecting a Graphing Calculator to the CBL 2 or LabPro Unit

1. Insert batteries into the CBL 2 or LabPro unit and graphing calculator.
2. The cradle is an optional accessory that conveniently connects the two units. Slide the back of the cradle onto the front of the CBL 2 or LabPro unit until it clicks into place.
3. Insert the upper end of the calculator into the cradle and press down on the lower end until it locks into place.
4. Connect the CBL 2 or LabPro unit to the graphing calculator using the unit-to-unit link cable. Plug the cable into the I/O port at the end of the CBL 2 or LabPro unit and the other end into the I/O port at the end of the calculator. Make sure that the unit-to-unit link cable is securely in place.



Resetting the Calculator Memory

It is recommended that the memory of the calculator be cleared before the DataMate data collection program is transferred.

1. Press **2nd** [MEM].
2. Select **Reset**.
3. Select **ALL RAM...**
4. Select **Reset**. The calculator screen will display **RAM cleared**.

Transferring DataMate to the Calculator

The DataMate program is stored on the CBL 2 or LabPro unit and is transferred to the graphing calculator for use. Once DataMate is transferred to the graphing calculator, it will remain there until the calculator memory is reset using the instructions above.

1. For the TI-73, press **APPS**. Select **Link...**
For the TI-83 Plus, press **2nd** [LINK].
2. Use the right arrow to highlight **RECEIVE**. Press **ENTER**.
3. The screen will display **Waiting...** Press the large **TRANSFER** key found on the upper left-hand side of the CBL 2 or LabPro unit. When the transfer is complete, the screen will display the transferred programs followed by the word **Done**.
4. Press **2nd** [QUIT].

Starting DataMate

When you are ready to collect data, use the following instructions to start DataMate.

For the TI-73:

1. Press **PAGE**.
2. Select **DataMate**.
3. Press **ENTER**.

For the TI-83 Plus:

1. Press **APPS**.
2. Select **DataMate**.

Setting up Probes Manually

The CBL 2 and LabPro unit should recognize the probe attached automatically. If this does not happen, follow these instructions.

1. Select **SETUP** from the DataMate main screen.
2. Press **ENTER** to select channel 1, or select the channel where the probe is inserted.
3. Select the correct sensor number from the **SELECT SENSOR** menu.
4. If requested, select the type of probe used.
5. Select **OK** to return to the DataMate main screen.

Laboratory and Safety Guidelines

Emergencies

- Inform the teacher immediately of *any* mishap—fire, injury, glassware breakage, chemical spills, and so forth.
- Know the location of the fire extinguisher, safety shower, eyewash, fire blanket, and first-aid kit. Know how to use this equipment.
- If chemicals come into contact with your eyes or skin, flush with large quantities of water and notify your teacher immediately.

Preventing Accidents

- Do NOT wear clothing that is loose enough to catch on anything. Do NOT wear sandals or open-toed shoes. Remove loose jewelry—chains or blacelets—while doing lab work.
- Wear protective safety gloves, goggles, and aprons as instructed.
- Always wear safety goggles (not glasses) in the laboratory.
- Wear goggles throughout the entire activity, cleanup, and handwashing.
- Keep your hands away from your face while working in the laboratory.
- Remove synthetic fingernails before working in the lab (these are highly flammable).
- Do NOT use hair spray, mousse, or other flammable hair products just before or during laboratory work where an open flame is used (they can ignite easily).
- Tie back long hair and loose clothing to keep them away from flames and equipment.
- Eating, drinking, chewing gum, applying makeup, and smoking are prohibited in the laboratory.
- Do NOT inhale vapors or taste, touch, or smell any chemical or substance unless instructed to do so by your teacher.















Working in the Laboratory

- Study all instructions before you begin a laboratory or field activity. Ask questions if you do not understand any part of the activity.
- Work ONLY on activities assigned by your teacher. NEVER work alone in the laboratory.
- Do NOT substitute other chemicals/substances for those listed in your activity.
- Do NOT begin any activity until directed to do so by your teacher.
- Do NOT handle any equipment without specific permission.
- Remain in your own work area unless given permission by your teacher to leave it.
- Do NOT point heated containers—test tubes, flasks, and so forth—at yourself or anyone else.
- Do NOT take any materials or chemicals out of the classroom.
- Stay out of storage areas unless you are instructed to be there and are supervised by your teacher.

Laboratory Cleanup

- Keep work, lab, and balance areas clean, limiting the amount of easily ignitable materials.
- Turn off all burners, water faucets, probeware, and calculators before leaving the lab.
- Carefully dispose of waste materials as instructed by your teacher.
- With your goggles on, wash your hands thoroughly with soap and warm water after each activity.

Safety Symbols

SAFETY SYMBOLS		HAZARD	EXAMPLES	PRECAUTION	REMEDY		
DISPOSAL		Special disposal procedures need to be followed.	certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.		
BIOLOGICAL		Organisms or other biological materials that might be harmful to humans	bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.		
EXTREME TEMPERATURE		Objects that can burn skin by being too cold or too hot	boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.		
SHARP OBJECT		Use of tools or glassware that can easily puncture or slice skin	razor blades, pins, scalpels, pointed tools, dissecting probes, broken glass	Practice common-sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.		
FUME		Possible danger to respiratory tract from fumes	ammonia, acetone, nail polish remover, heated sulfur, moth balls	Make sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.		
ELECTRICAL		Possible danger from electrical shock or burn	improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus.	Do not attempt to fix electrical problems. Notify your teacher immediately.		
IRRITANT		Substances that can irritate the skin or mucous membranes of the respiratory tract	pollen, moth balls, steel wool, fiberglass, potassium permanganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.		
CHEMICAL		Chemicals that can react with and destroy tissue and other materials	bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammonia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.		
TOXIC		Substance may be poisonous if touched, inhaled, or swallowed	mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.		
OPEN FLAME		Open flame may ignite flammable chemicals, loose clothing, or hair	alcohol, kerosene, potassium permanganate, hair, clothing	Tie back hair. Avoid wearing loose clothing. Avoid open flames when using flammable chemicals. Be aware of locations of fire safety equipment.	Notify your teacher immediately. Use fire safety equipment if applicable.		
	Eye Safety Proper eye protection should be worn at all times by anyone performing or observing science activities.		Clothing Protection This symbol appears when substances could stain or burn clothing.		Animal Safety This symbol appears when safety of animals and students must be ensured.		Radioactivity This symbol appears when radioactive materials are used.

LAB
1 Probeware Activity



Size Limits of Cells

When you look at a leaf under a microscope, you notice that it is made of small, rectangular structures—cells. A plant cell constantly absorbs substances it needs to live and gives off waste products through its cell membrane and cell wall. The rate at which these processes can happen depends on the surface area of a cell or group of cells. If the surface area of a cell is too small for a given cell volume, the cell cannot take in substances fast enough to survive. Also, if wastes cannot be released fast enough, they can build up and damage the cell. In this lab, you will use bouillon cubes to model cells. When the cube is placed in water, the cube begins to dissolve into ions. The released ions increase the ability of the water to conduct electricity. By measuring the water's conductivity, you will observe how fast the ions are being released.

What You'll Investigate

- How does the surface area of cells affect the rate at which substances can be absorbed and released?
- How does the surface area of cells limit the size of an individual cell?

Goals

- Calculate** cell volumes and surface areas.
- Measure** the change in conductivity of solutions over time.
- Compare** the rate at which conductivity increases for various solutions.

Materials

- CBL 2 or LabPro unit
- TI graphing calculator
- link cable
- DataMate program
- conductivity probe
- 400-mL beaker
- distilled water
- 3 bouillon cubes (1 whole, 1 cut into two equal pieces, 1 cut into four equal pieces)
- metric ruler

Safety Precautions



- **CAUTION:** Never eat or drink any substances used in an experiment.
- The conductivity probe is fragile. Handle it carefully.

Pre-Lab

1. Define electrical conductivity.
2. Predict how the number of conducting particles in a solution affects the conductivity of the solution.
3. If a solid is broken into many smaller pieces, how will the rate at which the number of particles entering or leaving the solid be affected?

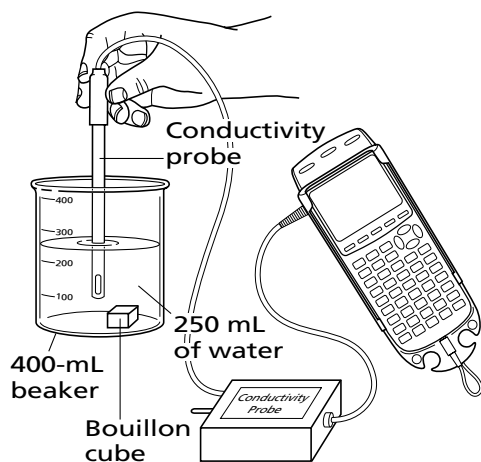
Probeware Activity 1 (continued)

Procedure

Part A: Preparing the CBL System

1. Set up the calculator and CBL 2 unit, as shown in **Figure 1**. Set the range on the conductivity probe to 0–20,000 μS . Plug the conductivity probe into channel 1 of the CBL 2 unit.
2. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program. The conductivity sensor should automatically be recognized. If not, turn to page *vi* for instructions on how to set up the probe manually.

Figure 1



Part B: Collecting Data

1. Using a metric ruler, measure the length, width, and height of a bouillon cube in centimeters. Write these dimensions in **Data Table 1** and in **Figure 2**.
2. Pour 250 mL of distilled water into a 400-mL beaker. Gently place the cube into the water.
3. Lower the conductivity probe into the water until it is about 1 cm above the cube. Select **START** to begin the three-minute measurement.
4. Gently swirl the conductivity probe in the water. The open end of the probe should be submerged but not hitting the bouillon cube.
5. After the measurement has ended, remove the probe and rinse it in distilled water. Set it aside carefully.
6. Press **ENTER** to go to the main screen. Select **TOOLS**. Then select **STORE LATEST RUN**.
7. Repeat steps 2–6 with two cube halves.
8. Repeat steps 2–6 with four cube quarters. The time measurements will be stored in List 1 (L1). The conductivity measurements will be stored in L4 (whole cube), L3 (two cube halves), and L2 (four cube quarters).

Part C: Graphing Data

1. From the main menu, select **GRAPH**. A graph will appear on the screen.
2. Press **ENTER**. Select **MORE**. A menu will appear that will allow you to select the desired graph.
3. Select **L2, L3, AND L4 vs L1**. A single graph with three curves will appear.
4. Sketch and label this graph in the space provided on the following page. Be sure to label the curves *whole cube*, *halved cube*, or *quartered cube*.
5. When you are finished with the graph, press **ENTER**. Select **QUIT**. Follow the directions on the calculator screen.

Cleanup and Disposal

1. Turn off the graphing calculator and disconnect the conductivity probe and CBL 2.
2. The conductivity probe is fragile. Carefully rinse and dry the probe.
3. Clean and return all equipment as directed by your teacher.

Probeware Activity 1 (continued)

Sketch of Conductivity Graph

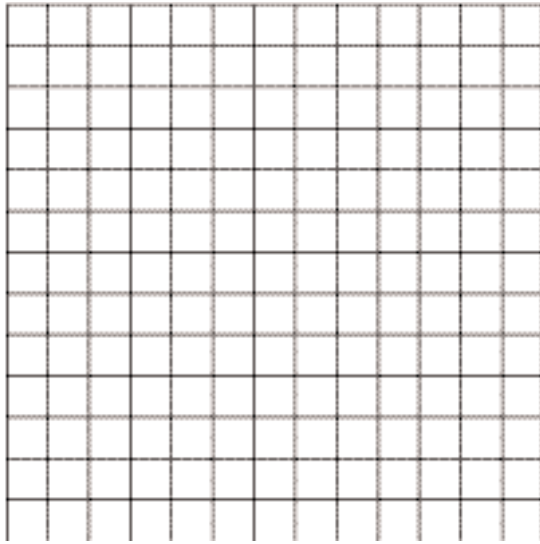
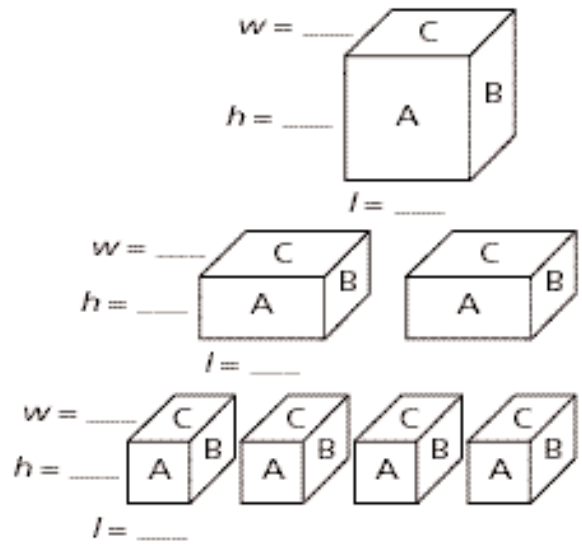


Figure 2



Data Table 1: Calculating Total Volume

	Length (cm)	Width (cm)	Height (cm)	Volume of One Piece	Number of Pieces	Total Volume of All Pieces
Whole cube						
Halved cube						
Quartered cube						

Data Table 2: Calculating Total Surface Area

	Area of Side A (cm ²)	Area of Side B (cm ²)	Area of Side C (cm ²)	Total Surface Area of One Piece	Number of Pieces	Total Area of All Pieces
Whole cube						
Halved cube						
Quartered cube						

Probeware Activity 1 (continued)**Part D: Analyzing Data**

1. Calculate the volume of the whole bouillon cube ($V = l \times w \times h$).
2. Using **Figure 2** as a guide, calculate the length, width, and height of a half cube and a quarter cube. Write these in the spaces provided in **Figure 2** and in **Data Table 1**. Check these with your teacher before proceeding.
3. Calculate the volume of each type of piece—a whole cube, a half cube, and a quarter cube. Enter these values in **Data Table 1**.
4. In **Data Table 1**, write the total number of pieces that are obtained when a whole cube is halved and when a whole cube is quartered.
5. Calculate the total volume of a whole cube, two cube halves, and four cube quarters and write these values in **Data Table 1**.
6. Using **Figure 2** as a guide, calculate the surface areas ($SA = l \times w$) of sides A, B, and C of a whole cube, a half cube, and a quarter cube. Write these in **Data Table 2**. Check these with your teacher before proceeding.
7. Calculate the total surface area of a whole cube, a half cube, and a quarter cube using the formula: $Total\ SA = 2A + 2B + 2C$. Why is the surface area of each side multiplied by two?
8. In **Data Table 1**, write the total number of pieces that are obtained when a whole cube is halved and when a whole cube is quartered.
9. Calculate the total surface area of a whole cube, two cube halves, and four cube quarters and write these values in **Data Table 1**.

Conclude and Apply

1. Compare the total volumes of the whole cube, the halved cube, and the quartered cube. Explain your observation. Compare the total surface areas of whole cube, the halved cube, and the quartered cube. What do you observe?

2. What do you observe about the conductivity of all three bouillon-cube solutions as time progressed? Explain your observations.

3. Explain the differences between the three conductivity curves. Which curve shows the fastest rate of dissolving? Explain your observations.

4. Which will allow a greater volume of substances to move into and out of a cell in a given amount of time—one large cell or an equal volume of several smaller cells? Explain.

LAB
2 Probeware Activity



Exercise and Heart Rate

Your heart is a pump in your chest that works all day, every day. It is part of your cardiovascular system, which also includes your blood vessels and blood. The cardiovascular system transports oxygen, food, and cellular products, such as insulin, to cells in your body. It also carries away cellular wastes. The systems of the human body strive for equilibrium. They work together to maintain normal conditions inside your body. During exercise, your muscles use more oxygen and generate more carbon dioxide than normal. Your brain senses this change and increases your breathing and heart rate to deliver oxygen-rich blood more quickly. When you finish exercising, your breathing and heart rate slow down. The heart rate of a physically fit person increases less during exercise and returns to normal more quickly than that of a less fit person.

One way you can investigate your heart's health is to count the number of times your heart beats in one minute. You may have done this before by lightly resting your fingers on your neck or wrist. It is called "taking your pulse." In this lab, you will use an electronic heart rate monitor. You will investigate the heart rates of you and your classmates while at rest and while exercising. You will use a graphing calculator to display and analyze your data.

What You'll Investigate

- What is your resting heart rate?
- What effect does exercise have on your heart rate?
- How long does it take your heart rate to return to normal after exercise?

Goals

- Collect** heart rate data.
- Observe and measure** the effect of exercise on heart rate.
- Compare and analyze** heart rate data using statistics.

Materials

- CBL 2 unit
- TI graphing calculator
- link cable
- DataMate program
- chest-belt heart rate monitor
- saline solution in a dropper or spray bottle
- stopwatch

Safety Precautions

- Inform your teacher if you have any health condition that might be aggravated by physical exercise.
- If during the exercise portion of this activity you feel dizzy, faint, or unwell, stop to rest and tell your teacher.

Pre-Lab

1. Predict your own heart rate in beats per minute.
2. Examine the heart rate monitor. How do you think it works?
3. How can you compare the data for the whole class?

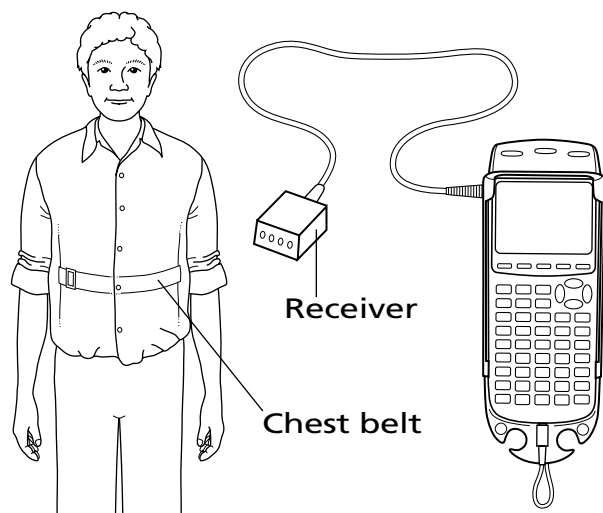
Probeware Activity 2 (continued)

Procedure

Part A: Preparing the CBL System

1. Set up the calculator and CBL 2 unit, as shown in **Figure 1**. Plug the heart rate receiver into channel 1 of the CBL 2 unit.

Figure 1



2. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program. The heart rate monitor should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.
3. Select **SETUP** on the DataMate main screen to set up the time interval between data points and the length of time the data will be collected.
4. Press the up arrow once until the cursor is beside the **MODE** line. Press **ENTER**.
5. Select **TIME GRAPH**. Select **CHANGE TIME SETTINGS**. The screen will display “Enter time between samples in seconds.”
6. Press **5** **ENTER**. The screen will display “Enter number of samples.”
7. Press **1** **0** **0**. Select **OK**. Select **OK** again. The calculator and CBL 2 unit are ready to obtain a heart rate reading every 5 seconds for 500 seconds.

Part B: Collecting Data

1. Put on a chest belt, selecting an elastic belt that fits snugly around your chest under your shirt. Secure one end of the elastic strap to the plastic transmitter.
2. Moisten the transmitter electrodes with saline solution.
3. Adjust and secure the belt in place over the base of your rib cage with the logo centered in the front.
4. Sit down. Have a partner hold the CBL 2 with the attached receiver module of the monitor. The receiver must remain within 80 cm of the transmitter belt.
5. Sit quietly for one minute to establish normal pulse and to ensure that the monitor is working.
6. Your partner should select **START** on the graphing calculator and start the stopwatch at the same time.
7. Sit quietly for 150 seconds.
8. When 150 seconds have elapsed, begin to exercise by stepping up onto the step and down again. Always place one foot and then the other completely on the surface of the step and floor. Exercise at a relaxed, even pace for 150 seconds.
9. When 150 seconds of exercise have elapsed, sit and rest quietly for 200 seconds. The graphing calculator will display a graph when the time is complete.
10. Sketch this graph in your **Science Journal**. Include a title, labels, and units for the x - and y -axis.

Probeware Activity 2 (continued)

Part C: Examining the Data

- Return to the main screen by pressing **ENTER**.
- Select **ANALYZE**.
- Select **STATISTICS**.
- Press **ENTER** to select the beginning of the initial resting phase. Use the right arrow key to select the end of the resting phase at about 150 seconds and press **ENTER**.
- Record the MEAN resting heart rate, rounding to the nearest whole beat per minute (BPM).
- Press **ENTER**. Select **STATISTICS**.
- Use the arrow keys to select the beginning and end of the exercise period. Press **ENTER**.
- Record the MEAN exercise heart rate, rounding to the nearest whole beat per minute.
- Press **ENTER**. Then select **RETURN TO THE MAIN SCREEN**. Select **GRAPH**.
- Use the right arrow to move to the highest point on the graph.
- Record the y -value (maximum heart rate) and x -value (time) that the maximum occurred.
- Use the right arrow key to find the time when your heart beat had returned to its normal resting rate (to within 3 BPM).
- Record this time. Then subtract the time of maximum rate to calculate your actual recovery time.
- Calculate your maximum exercise heart rate and your exercise intensity level using the formulas in **Data Table 1**.
- Repeat parts **B** and **C** for other members of your group.
- When you are finished, press **ENTER**. Select **MAIN SCREEN**. Select **QUIT**. Follow the instructions on the calculator screen.

Data Table 1: Heart Rate Monitor Experiment

Student:	A	B	C
Mean resting heart rate (mean BPM over the first 150 seconds)			
Mean exercise heart rate (mean BPM over the second 150 seconds)			
Maximum heart rate (BPM)			
Time at maximum heart rate (seconds)			
Time of return to mean resting heart rate (seconds)			
Recovery time (seconds)			
Maximum exercise heart rate (MEHR = $220 - \text{your age}$)			
Exercise intensity level (%) = $(\text{exercise heart rate}/\text{MEHR}) \times 100$			

Cleanup and Disposal

- Turn off the calculator. Unplug the receiver module from the CBL 2.
- Separate the elastic strap and the transmitter belt.
- Clean the transmitter belt as instructed by your teacher.
- Return the heart rate monitor and CBL 2 system as directed by your teacher.

Probeware Activity 2 (continued)

Conclude and Apply

1. Describe the effect that exercise had on your heart rate.

2. Share data with your classmates for resting heart rate, exercise heart rate, and recovery time. Design a data table to organize this information.

3. With your lab partners, divide the responsibility for constructing a histogram of the class data for each variable: resting heart rate, exercise heart rate, and recovery time. Your teacher may give you directions for using the graphing calculator to do this.

4. Determine the minimum, median, maximum, mean, and mode for each data set from the class. Record these in **Data Table 2**. Your teacher may give you directions for doing this with the graphing calculator.

Data Table 2: Class Statistics

	Resting Heart Rate (BPM)	Exercise Heart Rate (BPM)	Recovery Time (seconds)
Minimum			
Median			
Maximum			
Mean			
Mode			

5. You can visually display information such as you have in **Data Table 2** using a box plot. Your teacher may give you directions for making a box plot using your graphing calculator. Compare and contrast this method of displaying data with the “data table method” used in Question 4.

6. What can you conclude about heart rate among members of your class?

7. Research to find information about the assessment of physical fitness and improving physical fitness. Write one to two paragraphs reflecting on your own physical fitness. Include data from this activity. Set a specific goal for yourself related to maintaining or improving your cardiovascular health.



Probeware Activity



Cooking with Bacteria

Usually you think of bacteria as something that can make you sick. But some types of bacteria are useful in food preparation. When cabbage is salted and kept in a closed container, bacteria in the cabbage cause it to ferment and become sauerkraut. The salt kills some bacteria but the sauerkraut-producing bacteria on the cabbage survive. In this activity, you will conduct a 24-hour measurement to compare how fast lactic acid is produced during the fermentation of raw cabbage and cabbage that has been boiled.

What You'll Investigate

- How can bacteria help in food production?
- How does the amount of bacteria affect the rate of lactic acid production during the fermentation of cabbage?

Goals

Measure the change in pH during the fermentation of cabbage.

Hypothesize what is responsible for the production of lactic acid during the fermentation of cabbage.

Materials

CBL 2 or LabPro units (2)	wash bottle
TI graphing calculators (2)	glass stirring rod
link cable (2)	shredded raw cabbage
DataMate program	shredded boiled cabbage
AC power adapters (2)	distilled water
pH probes (2)	tongs (2)
ring stand (2)	non-iodized salt
test-tube clamps (2)	plastic food wrap
250-mL beakers, sterilized (2)	aluminum foil
400-mL beaker	

Safety Precautions



- Always wear safety goggles and a lab apron.
- CAUTION:** Never eat lab materials.

Pre-Lab

1. In the production of sauerkraut, the natural sugar in cabbage is broken down into lactic acid and carbon dioxide. What organism is responsible for this process?
2. As lactic acid is produced during the fermentation process, will the pH of the cabbage solution rise or fall?
3. How would boiling the cabbage affect the amount of lactic acid that is produced?
4. Hypothesize how the graphs of pH would differ if you measure the pH change in raw cabbage placed in salt water and boiled cabbage placed in salt water.

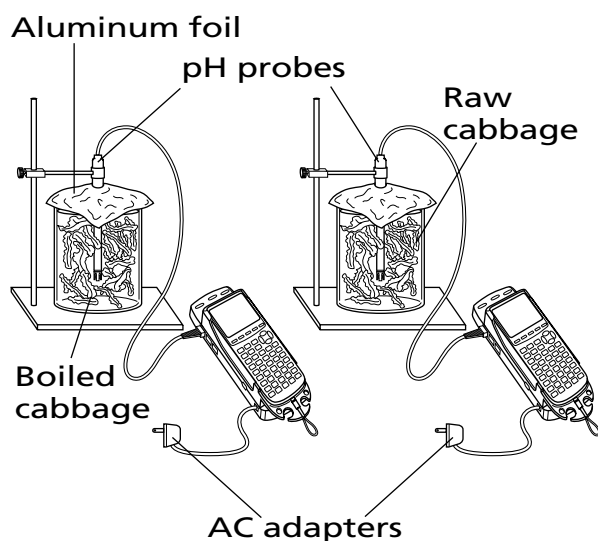
Probeware Activity 3 (continued)

Procedure

Part A: Preparing the CBL System

1. Set up the calculator and CBL 2 units, as shown in **Figure 1**. Connect each CBL 2 unit to an AC power adapter. Plug each adapter into an outlet. Plug the pH probes into channel 1 of each CBL 2 unit. Turn on the calculators and start DataMate. Press **CLEAR** to reset the program. The pH probes should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probes manually.

Figure 1



2. Select **SETUP**. Press the up arrow once until the cursor is beside the **MODE** line. Press **ENTER**.
3. Select **TIME GRAPH**. Then select **CHANGE TIME SETTINGS**. The calculator will ask you to input the time between samples in seconds. Press **1** **8** **0** **0**. Then press **ENTER**.
4. The calculator will ask you to enter the number of samples. Press **4** **8**. Then press **ENTER**.
5. Select **OK**. Then select **OK** again. The calculators and CBL 2 units are now ready to record pH readings every 1800 seconds (half hour) for 24 hours.

Part B: Collecting Data

1. Prepare a salt solution by mixing 10 g of salt in 400 mL of distilled water.
2. Using sterilized tongs, place boiled cabbage into one of the 250-mL beakers. Using another set of sterilized tongs, place raw cabbage into the other beaker. Fill both beakers to the 200-mL mark with cabbage. Then fill both beakers almost to the brim with salt solution.
3. Cover the beakers with plastic wrap, then with a square of aluminum foil. The plastic wrap and foil should have a small hole in the center to allow a pH probe to fit through it.
4. Remove the storage solution bottles from the pH probes. Slide the o-ring and cap up the sensor barrel, out of the way. Over a sink or empty beaker, use a wash bottle of distilled water to thoroughly rinse the probes. Attach the probes to the ring stand and place the ends of the probes in the solution in the beakers. Wrap extra foil around the end of the probe to keep the setup as clean as possible.
5. Wait a few minutes to allow the pH readings to stabilize. Select **START** on each calculator to begin the 24-hour measurements. A screen will appear that tells you to press "enter" to continue. Press **ENTER**. The calculators may be removed now. The CBL 2 units will continue collecting data.
6. After 24 hours, when the data collection is complete, reattach the calculators. Press **ON** to turn them on.
7. Start DataMate. A screen will appear reminding you that data has been collected. Press **ENTER** to go to the main screen. Select the **TOOLS** option. Select the **RETRIEVE DATA** option. A graph of the data should appear. Sketch and label the graphs in your **Science Journal**.

Probeware Activity 3 (continued)

Part C: Examining Data

1. For each graph, return to the main screen by pressing **ENTER**.
2. Select **ANALYZE**.
3. Select **STATISTICS**.
4. Press **ENTER** to select the beginning of the pH graph. Use the right arrow key to select the end of the pH graph. Press **ENTER**.
5. Your calculator will display the minimum and maximum pH values. Determine which of these is the initial pH and which is the final pH. Round these values to the hundredths place and record them in the **Data Table**.

6. When you are finished, press **ENTER**. Select **RETURN TO MAIN SCREEN**. Select **QUIT**. Follow directions on the screen.

Cleanup and Disposal

1. Remove the pH probes from the beakers of cabbage. Use distilled water in a wash bottle to rinse the probes thoroughly and place them in the storage-solution bottles.
2. Turn off the graphing calculators and disconnect the pH probes and CBL 2 units. Follow your teacher's instructions for disposing the contents of the beakers.
3. Clean and return all equipment as directed by your teacher.

Data Table: pH Changes of Raw and Cooked Cabbage

Type of Cabbage	Initial pH	Final pH	pH Change
Cooked			
Raw			

Conclude and Apply

1. Compare the pH graphs for the raw and boiled cabbage. Determine the pH change of each by subtracting the initial pH from the final pH. Why were the pH changes different?

2. Compare your results to your hypothesis in **Pre-Lab** question 4. Explain the source of any differences.

Notes

LAB
4 Probeware Activity



Sweat is Cool

The human body needs to maintain an internal body temperature of about 37°C to survive. When the body becomes too hot it begins to perspire, or sweat. Tiny sweat glands in the dermis layer of your skin secrete a fluid that contains water, salt, and wastes. This fluid absorbs heat from the body as it evaporates, cooling the body. In this lab you will observe how evaporation of a liquid is a cooling process.

What You'll Investigate

- Is heat removed from the environment during the evaporation of a liquid such as during perspiration?
- How can this loss of heat be observed?

Goals

Observe the temperature change as a liquid evaporates.
Interpret the data that is collected during the evaporation of a liquid.

Materials

CBL 2 or LabPro unit
 TI graphing calculator
 DataMate program
 link cable
 temperature probe
 1/2 coffee filter
 *filter paper
 *cotton ball
 *cotton gauze
 small rubber bands
 250-mL beaker
 electric fan
 isopropyl alcohol
 *Alternate materials

Safety Precautions



- Always wear safety goggles and a lab apron during a laboratory activity.
- Possible danger from electrical shock. Clean up spills immediately.
- Extinguish all flames during this activity. Isopropyl alcohol is flammable.

Pre-Lab

1. Where does the heat energy needed for a liquid to evaporate come from?
2. What measurement can be observed that shows this heat transfer?
3. Explain how perspiring cools your body.
4. What are some situations that can cause your rate of perspiration to change?

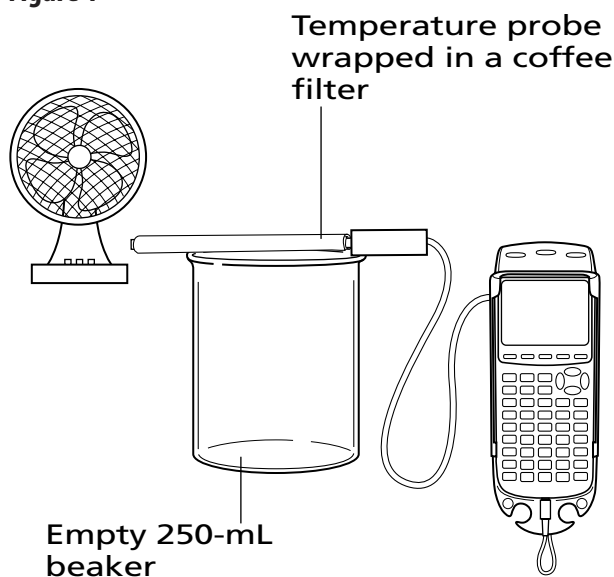
Probeware Activity 4 (continued)

Procedure

Part A: Preparing the CBL System

1. Set up the calculator and CBL 2 unit, as shown in **Figure 1**. Plug the temperature probe into channel 1 of the CBL 2 unit.

Figure 1



2. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program. The temperature probe should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.
3. Select **SETUP** on the DataMate main screen to setup the time interval between data points and the length of time the data will be collected.
4. Press the up arrow once until the cursor is beside the **MODE** line. Press **ENTER**.
5. Select **TIME GRAPH**.
6. Select **CHANGE TIME SETTINGS**. The screen will display “Enter the time interval between samples in seconds.” Press **1** **5** **ENTER**. The screen will display “Enter number of samples.” Press **4** **0** **ENTER**. The CBL 2 unit will collect data every 15 seconds for 10 minutes (600 seconds). Select **OK** twice to exit. The setup screen appears.

Part B: Collecting Data

1. Using the room-temperature water that your teacher provides, put 50 mL of water into the 250-mL beaker.
2. Fold the coffee filter into a strip approximately 2 cm wide. Wrap it around the temperature probe and secure it with a small rubber band.
3. Wet the coffee filter by dipping it into your cup of water. Use care when wetting the filter and do not get water on your lab table. Wipe up spills immediately.
4. Place the probe across the top of an empty beaker, as shown in **Figure 1**, to support it during the experiment.
5. Place an electric fan 40 cm from your probe. Turn the fan on low and position the airflow so that it flows across the wetted filter.
6. Select **START** to begin collecting data.

Part C: Examining the Data

1. After data collection is complete, sketch and label the graph shown on the calculator screen in your **Science Journal**. Return to the main screen by pressing **ENTER**.
2. Select **ANALYZE**.
3. Select **STATISTICS**.
4. Press **ENTER** to select the beginning of the temperature graph. Use the right arrow key to select the final temperature. Press **ENTER**.
5. The calculator will display the minimum and maximum temperatures. Determine which of these is the initial temperature and which of these is the temperature after the liquid has evaporated—the final temperature. Record these in the **Data Table**.
6. Press **ENTER**. Select **RETURN TO THE MAIN SCREEN**.
7. Repeat parts B and, steps 1–5 of part C using isopropyl alcohol.
8. When you are finished, press **ENTER**. Select **RETURN TO THE MAIN SCREEN**. Select **QUIT**. Follow the directions on the screen.

Probeware Activity 4 (continued)**Cleanup and Disposal**

1. Turn off the graphing calculator and disconnect the temperature probe and CBL 2 unit.
2. Put the solid waste into the container designated by your teacher.
3. Return all equipment to the proper location as directed by your teacher.

Data Table: Temperature Changes Due to Evaporation

	Initial Temperature	Final Temperature	Temperature Change
Water			
Alcohol			

Conclude and Apply

1. Find the temperature change for each substance by subtracting the initial temperature from the final temperature. Record your results in the **Data Table**.
2. What energy exchanges occurred during the evaporation process?

3. How is the evaporation process in this lab similar to perspiration in the human body? How is it different?

4. Perspiration occurs under heavy clothing in cold temperatures. Why is it beneficial to wear undergarments that wick the moisture away from the surface of the skin?

5. What differences do you observe in the time-temperature graphs for alcohol and water?

Notes

LAB
5 Probeware Activity



Biodiversity and Ecosystems

What lives in your home or on your school lawn? What lives in the wooded areas at the local park? You probably have noticed that some organisms' habitats include both a grassland and a wooded area while other organisms live only in one type of area. In this activity you will play the role of an ecologist in the field. You will observe plant and animal organisms at two different sample sites and collect data using a graphing calculator and a temperature probe.

What You'll Investigate

- What plants and animals live in two ecosystems?
- What is the effect of plant diversity on temperature?

Goals

Observe living organisms in a measured area.
Count the plant types observed using percentages.
Collect temperature data.
Compare the temperature data for two different sites.

Materials

CBL 2 or LabPro unit
 TI graphing calculator
 link cable
 DataMate program
 temperature probe
 meterstick
 string
 8 wooden dowels or craft sticks
 10 acetate grids (10 cm × 10 cm)
 colored transparency markers
 trowel
 drawing compass
 protractor

Safety Precautions

CAUTION: Do not touch or harass animals in the field. Do not eat any fruits, berries, or plant material from the site. Beware of poisonous and thorny plants.

Pre-Lab

1. Predict the type of living organisms you might find in a small plot of lawn.
2. Predict the types of animals you might find in a small plot with more diverse vegetation.
3. List any abiotic factors you could observe at a small site in the field.
4. Describe how you could measure one of the abiotic factors.

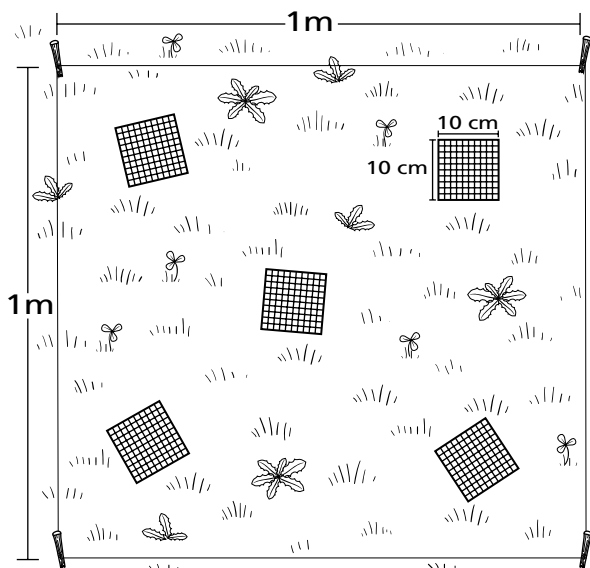
Probeware Activity 5 (continued)

Procedure

Part A: Collecting Plant and Animal Data

1. At your assigned site, measure a one-meter square area and mark it with string and sticks as demonstrated by your teacher.
2. Examine your area carefully. Count the different types of plants. Look for any animals or signs of animal life. Record your observations in **Data Table 1**. You do not need to know the exact name of the plants and animals, but include measurements. A description such as “short (4 cm), thin, yellowish-green grass” is acceptable.
3. Use a trowel to carefully lift out a section of soil. Describe how much effort was needed to remove the soil. Observe the humus layer and record its depth in **Data Table 1**. Replace the soil.
4. Randomly lay five of your 10-cm \times 10-cm acetate grids on the ground within your square meter, as shown in **Figure 1**.
5. Using transparency markers, code each small square with a color, number, or symbol to represent the type of plant visible within that square.
6. Repeat steps 1–5 for your second assigned site.

Figure 1



Part B: Collecting Temperature Data

1. Plug the temperature probe into channel 1 of the CBL 2.
2. Turn on the graphing calculator and start DataMate. Press **CLEAR** to reset the program. The temperature probe should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.
3. To investigate the effect of height above the ground on temperature, stand a meterstick in the middle of your sample site. Place the “zero” end on the ground.
4. Put the temperature probe on the ground next to the meterstick. The temperature reading is located in the upper right-hand corner of the calculator screen. Allow enough time for the temperature reading to stabilize. After 30 seconds have passed, record the temperature in **Data Table 3**.
5. Move the probe to the 10-cm mark and repeat the procedure. Measure and record the temperature at each 10-cm increment. Your last reading will be at 100 cm.
6. Repeat steps 1–5 for your second assigned site.
7. After all of your data is collected, select **QUIT**. Follow the directions on the calculator screen.

Cleanup and Disposal

1. Turn off the calculator and disconnect the temperature probe and CBL 2.
2. Return all lab materials to the appropriate location as directed by your teacher.
3. Collect personal belongings and pick up any trash at your site.

Probeware Activity 5 (continued)

Data Table 1: Soil Conditions and Organisms

	Site A	Site B
Plants found		
Animals/Animal signs found		
Depth of humus (cm)		
Ease of penetrating ground		

Data Table 2A: Plant Analysis at Site A

Plant Type	Number of Squares out of 100					Total (of 500)	Percent (%)
	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5		

Data Table 2B: Plant Analysis at Site B

Plant Type	Number of Squares out of 100					Total (of 500)	Percent (%)
	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5		

Probeware Activity 5 (continued)

Data Table 3: Temperature vs. Height

Height (cm)	Temperature (°C)	
	Site A	Site B
0		
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		

Part C: Analyzing Data

1. Count the number of small squares for each plant type and record it in **Data Table 2A** or **2B**. Convert the total count from the five grids to percentages.
2. Construct two circle graphs to compare the plant percentages for Site A and Site B. If you have a TI-73 your teacher may want you to make your circle graphs on the graphing calculator. See **Appendix E** for directions.
3. Construct a graph that shows the relationship between temperature and height for each site. Place the independent variable on the x -axis and the dependent variable on the y -axis. Include a key.

Conclude and Apply

1. Compare the diversity of organisms in your two ecosystems. List at least two similarities and three differences between Site A and Site B. Be specific.

2. In your temperature-height graph, what was your independent variable? What was your dependent (responding) variable? Why does the graph need a key?

3. Describe any differences in the temperature vs. height at Sites A and B. Explain how this factor might affect the plants and animals found there.



Probeware Activity



The Effect of Acid Rain on Limestone

Acid rain is harming some of the world's most beautiful structures. Ancient Mayan pyramids in Mexico are crumbling because the acidic rainwater slowly dissolves minerals in the rocks. The Taj Mahal in India has undergone extensive and costly reconstruction to repair damage from acid rain. Buildings and monuments in Washington, D.C. are slowly weathering because precipitation in the area is ten times more acidic than unpolluted rainwater. In this activity, you will observe the effect that acid rain has on limestone. Limestone is the type of rock that was used in the construction of many of the damaged structures. It is composed primarily of calcite (calcium carbonate), a mineral that is dissolved easily by weak acids.

What You'll Investigate

- What is the pH of rain in your area?
- How does the pH of acid rain change when limestone is added to it?
- What effect does acid rain have on limestone?

Goals

- Measure** the pH of rainwater.
Observe the effect that limestone has on the pH of acid rain.
Infer the effect that acid rain has on limestone buildings and monuments.

Materials

- CBL 2 or LabPro unit
- TI graphing calculator
- link cable
- DataMate program
- pH probe
- 150-mL beaker
- 400-mL beaker
- distilled water
- 1-L glass jar
- pea-sized limestone pebbles (5)

Safety Precautions



- Always wear safety goggles and a lab apron.

Pre-Lab

1. Explain the pH scale.
2. If the pH of an acidic solution rises, does this indicate that the solution is becoming more acidic or less acidic?
3. What effect would adding a basic substance have on the pH of an acidic solution?
4. The pH scale is logarithmic. How does a pH of 3 compare to a pH of 4?

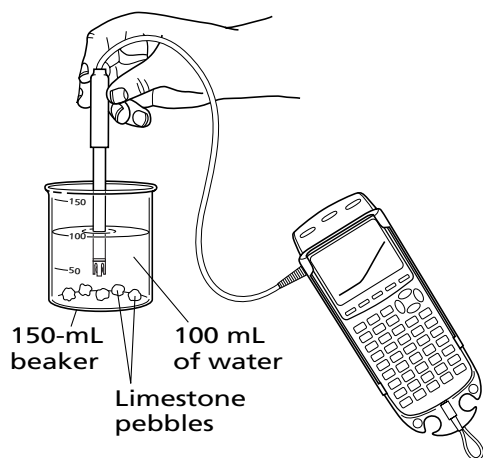
Probeware Activity 6 (continued)

Procedure

Part A: Preparing the CBL System

1. Place a glass jar outside, away from trees and buildings, during a rain shower. Collect at least 100 mL of rainwater. Cover the jar until you are ready to use it.
2. Connect the pH probe into channel 1 of the CBL 2 unit, as shown in **Figure 1**. Connect the CBL 2 unit to the graphing calculator.

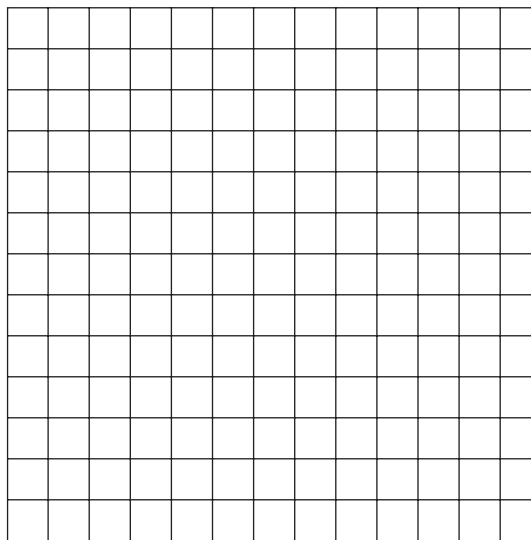
Figure 1



3. Turn on the graphing calculator and start the DataMate program. Press **CLEAR** to reset the program. The pH probe should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.
4. Select **SETUP**. Press the up arrow once to select **MODE: TIMEGRAPH**. Press **ENTER**.
5. Select **TIME GRAPH**. Select **CHANGE TIME SETTINGS**. The screen will display “Enter the time interval between samples in seconds.”
6. Press **1** **5** **ENTER**.
7. The screen will display “Enter number of samples.” Press **4** **0** **ENTER**. The CBL 2 unit will collect data every 15 seconds for 10 minutes. Select **OK** twice.

Part B: Collecting Data

1. Partially fill a 400-mL beaker with distilled water. This will be the soaking solution.
2. Carefully unscrew the pH sensor from the storage-solution bottle sliding the cap and o-ring up the barrel of the sensor. Set the storage bottle aside. Over a sink, rinse the sensor with distilled water and place it in the soaking solution.
3. Pour 100 mL of rainwater into a 150-mL beaker. Insert the pH probe and watch the pH reading at the top right of the calculator screen. When the reading has stabilized, select **START**.
4. Gently swirl the pH probe in the rainwater. After about 2 minutes, add the limestone pebbles to the rainwater.
5. Gently swirl the pH probe until the recording period ends. Remember that the probe is fragile. Be sure the recording tip remains submerged but do not allow it to hit the pebbles or the side of the beaker.
6. At the end of 10 minutes, the CBL 2 unit will make a tone. Remove the pH probe from the rainwater, rinse it over a sink, and place it in the soaking solution.
7. Sketch and label your graph in the space below.



Probeware Activity 6 (continued)

Part C: Examining the Data

- Observe the graph, noting what happened to the graph when the limestone was added.
- Determine the initial pH of the rainwater before the limestone was added.
 - Return to the main screen by pressing **ENTER**. Select **ANALYZE**. Select **STATISTICS**.
 - Press **ENTER** to select the beginning of the graph.
 - Use the right arrow key to select a point just before the limestone was added. Press **ENTER**.
 - Record the mean, which is the initial pH, in the **Data Table**. Press **ENTER**.
- Determine the pH after adding the limestone pebbles.
 - Select **RETURN TO THE MAIN SCREEN**. Select **GRAPH**.
 - Use the right arrow to select the last point on the graph. In the table below, record the y -value shown in the lower right corner of the screen. This is the final pH.
- When you are finished with the graph, press **ENTER**. Select **QUIT**.

Data Table: pH Change

Initial pH	
Final pH	
pH Change	

Cleanup and Disposal

- Remove the pH probe from the soaking beaker. Carefully place it in the storage-solution bottle.
- Turn off the calculator and disconnect the pH probe and CBL 2 unit.
- Follow your teacher's instructions for disposing of the contents of the beakers and returning all equipment to its proper location.

Conclude and Apply

- Look at the graph of your data. What was the approximate time (x) when you added the limestone? How can you tell?

- Why did the graph change after you added the limestone? Calculate the change in pH.

- What would you expect your graph to look like if you continued taking data for 10 additional minutes? How would this affect your final pH and the change in pH? How could you test this?

- Infer from your experiment how acid rain would affect a monument made of limestone.

Notes

LAB 7 Probeware Activity



The Formation of Caves

Many processes form caves. Powerful waves carve sea caves in rocks located next to the ocean. Lava flowing from volcanoes forms caves if the surface lava cools and hardens before the lava underneath stops flowing. The most common type of cave forms when underground layers of rock, such as limestone, are dissolved by acidic groundwater. In this process, rainwater absorbs carbon dioxide as it falls through the air. As the water seeps through the ground, it absorbs more carbon dioxide in soil pores. The rainwater becomes acidic because water and carbon dioxide form a weak acid known as carbonic acid. When this acidic water reaches bedrock, it seeps through cracks, dissolving the rock and creating open areas. Slowly, over many thousands of years, the water creates a cave in the rock. In this activity, you will demonstrate the effect of increasing the amount of carbon dioxide in water. The carbon dioxide in your breath will react with the water, similar to the way rainwater reacts with carbon dioxide as it falls to Earth and seeps through the soil.

What You'll Investigate

- How does an increase in carbon dioxide affect the acidity of water?
- How does the acidity of water lead to the formation of caves?

Goals

- Predict** how increasing the carbon dioxide in water will affect its acidity.
- Measure** the change in acidity of water as you exhale into it.
- Analyze** a graph to determine what chemical change has taken place.

Materials

- CBL 2 or LabPro unit
- TI graphing calculator
- link cable
- DataMate program
- pH probe
- timer
- distilled water
- 600-mL beaker
- wash bottle
- plastic drinking straw

Safety Precautions



- Always wear safety goggles and a lab apron.

Pre-Lab

1. Describe how rainwater can contribute to the formation of a cave.
2. Describe how the pH scale is used to determine whether a substance is basic or acidic.
3. Suppose you determine that a substance has a pH of 6. An hour later, it has a pH of 2. Has the acidity of the substance increased or decreased?
4. Predict how exhaling through a straw into water would affect the acidity of the water. Explain your answer.

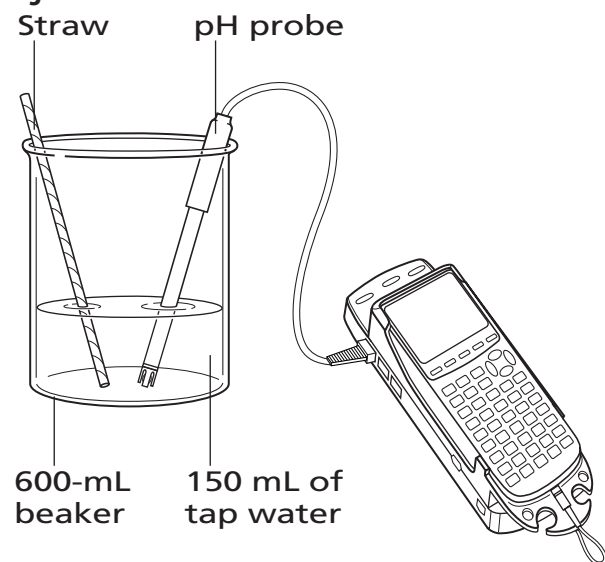
Probeware Activity 7 (continued)

Procedure

Part A: Preparing the CBL System

1. Set up the calculator and CBL 2 unit, as shown in **Figure 1**. Plug the pH probe into channel 1 of the CBL 2 unit. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program. The pH probe should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.

Figure 1



2. Select **Setup**. Press the up arrow once until the cursor is beside the **MODE** line. Press **ENTER**.
3. Select **TIME GRAPH**. Then select **CHANGE SETTINGS**. The calculator will ask you to input the time between seconds. Press **5** **ENTER**.
4. The calculator will ask you for the number of samples. Press **1** **2** **0** **ENTER**.
5. Select **OK**. Then select **OK** again. One pH reading will be collected every 5 seconds for 600 seconds (10 minutes).
2. Remove the pH probe from the storage-solution bottle. Slide the cap and o-ring up the barrel of the probe to move them out of the way. Over a sink or empty beaker, use distilled water in a wash bottle to thoroughly rinse the probe. Set the solution bottle aside in a location where it will not be disturbed. Place the pH probe in the 600-mL beaker.
3. Allow the pH probe to remain in the water for one minute until the readings stabilize. During this time you will be able to see the pH reading on the top right corner of the calculator screen.
4. Be sure the timer is set to count up. Select **START** on the calculator to begin the 10-minute measurement. When you hear the tone indicating the measurement is beginning, start the timer.
5. When 30 seconds have passed, use the straw to exhale into the water for 30 seconds. Cup your hands over the beaker as you exhale to ensure that water doesn't splash out onto the calculator. Do not try to exhale continuously. Inhale through your nose and exhale through the straw at a natural pace.
6. After exhaling for 30 seconds, allow the pH probe to remain in the water, undisturbed for the remainder of the 10-minute measurement.
7. A graph showing changes in the water's pH during the measurement period will appear on the calculator screen. Sketch and label this graph in your Science Journal.
8. Use the right and left arrow keys to move the cursor along the data points. The time (x) and the corresponding pH (y) values will appear at the bottom of the screen. Write the selected values in the **Data Table**.
9. When you are finished, press **ENTER**. Select **QUIT**. Follow the directions on the screen.

Part B: Collecting Data

1. Put 150 mL of tap water into the 600-mL beaker.

Probeware Activity 7 (continued)**Data Table: Selected pH Values**

Time (s)	pH
0	
100	
200	
300	
400	
500	
600	

Cleanup and Disposal

1. Turn off the graphing calculator and disconnect the pH probe and the CBL 2 unit. Rinse the end of the probe with distilled water and place the probe in the storage-solution bottle.
2. Follow your teacher's instructions for disposing of the contents of the beakers and returning all equipment to proper locations.

Conclude and Apply

1. Describe and explain what your graph looks like between 0 and 30 seconds.

2. Describe and explain the curve of your graph after 30 seconds.

3. Explain how the results you obtained in this activity are similar to what happens when caves form.

Notes



Probeware Activity



Measuring Earthquakes

A seismograph is an instrument that is used to measure the ground's movement during an earthquake. One type of seismograph has a pen attached to a pendulum. During an earthquake, a roll of paper moves beneath a pen creating lines that correspond to the motion of the ground. Many modern seismographs use a freely swinging magnet. The magnet is positioned inside a casing surrounded by coiled wire. When the ground moves, the casing moves relative to the magnet. Recall that a magnet is surrounded by a magnetic field. If a magnet moves in the coil, the magnetic field moves, and a current is generated in the wire. By measuring how this current changes, seismologists obtain a record of the ground's movement. In this activity, you will create a model seismograph with a magnet and coiled wire.

What You'll Investigate

- What is a seismograph?
- How does a seismograph register motion during an earthquake?
- What do the lines on a seismogram indicate about the strength of seismic waves?

Goals

- Build** a model seismograph.
- Observe** how a seismograph records motion.
- Measure** movement using a seismograph.
- Create** a seismogram.

Materials

- CBL 2 or LabPro unit
- TI graphing calculator
- DataMate program
- link cable
- current probe
- strong bar magnet
- enameled copper magnet wire
- cardboard or plastic tube
- sandpaper
- masking tape
- ruler
- string
- table
- chair

Safety Precautions

- Wear safety goggles and an apron during the lab.

Pre-Lab

1. What are some reasons why seismologists measure Earth's movement during an earthquake?
2. What is a seismograph?
3. How can you use a magnet to produce a current in a coiled wire?

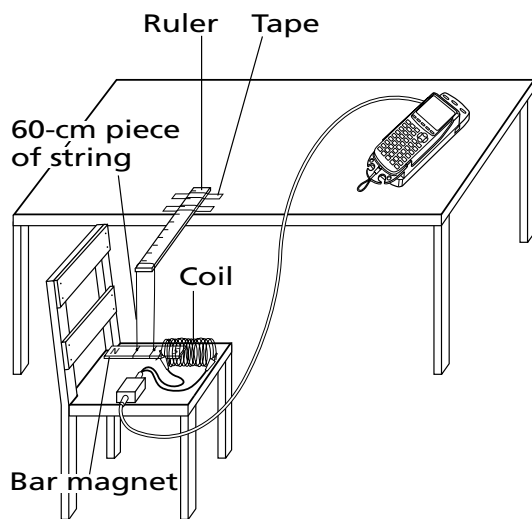
Probeware Activity 8 (continued)

Procedure

Part A: Preparing the CBL System

1. Connect the current probe to channel 1 of the CBL 2 unit, as shown in **Figure 1**.

Figure 1



2. Use a link cable to connect the CBL 2 unit to the graphing calculator. Turn on the graphing calculator. Start the DataMate program. Press **CLEAR** to reset the program. The current probe should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.
3. Select **SETUP**. Press the up arrow once until the cursor is beside the **MODE: TIME GRAPH** line. Press **ENTER**.
4. Select **TIME GRAPH**. Select **CHANGE TIME SETTINGS**. The calculator will display “Enter time between samples in seconds.” Press **0** **.** **2** **ENTER**.
5. The calculator will display “Enter number of samples.” Press **1** **2** **0** **ENTER**.
6. Select **OK**. Select **OK** again. The calculator and CBL 2 unit are now ready to record changes in the current every 0.2 seconds for 24 seconds.

Part B: Collecting Data

1. To create a model seismograph, first make a coil of wire. Starting at one end of a sturdy tube, begin winding the wire securely around it, leaving about 20 cm of wire free at the beginning. Do not cut the wire from the spool until you have completed making the coil. Tape the wire at the place where you begin so it won't unwind. The windings should be close together. Make at least 50 windings before you get to the other end of the tube. Tape the wire at the end, leaving about 20 cm of wire free.
2. Use sandpaper to completely strip the coating off the ends of the wire. The coating on the wire doesn't conduct electricity, so it must be removed to ensure a good connection to the current probe. Be careful when doing this so that the coil does not unwind.
3. Connect each of the stripped ends of the wire coming from your wire coil to the red and black connectors of the current probe.
4. Cut a 60-cm piece of string. Tie each end around the ends of the bar magnet and slide the knots near the center of the magnet until they are about 2 cm apart. Tape the ruler to a table so that one end hangs over the edge. Use the string to hang the magnet from the ruler, as shown in **Figure 1**.
5. Tape your wire coil to the seat of a chair placed near the table. Position it so that the magnet swings freely through the end of the coil. You may have to adjust the length of the magnet's string by wrapping the string around the magnet.

Probeware Activity 8 (continued)

- You are now ready to record movement with your seismograph. Select **START** to begin the 24-second measurement.
- During this time, gently bump the table that suspends the magnet so that the magnet moves in and out of the wire coil. Allow it to stop moving, then bump it again. Do this repeatedly until the measurement period ends.
- At the end of the measurement period, a graph of the movement will appear on the graphing calculator screen. Sketch and label the graph in your **Science Journal**. Use the graph to answer questions in the **Conclude and Apply** section. If you wish to repeat the measurement, press **ENTER**. Then select **START** again.
- When you are finished, press **ENTER**. Select **RETURN TO MAIN SCREEN**. Select **QUIT**. Follow the directions on the screen.

Cleanup and Disposal

- Turn off the graphing calculator and disconnect the CBL 2 unit and current probe. Disconnect the current probe wires from the wire coil. Remove the ruler from the table and the coil from the chair.
- Dispose of or recycle the lab materials as directed by your teacher.
- Return all equipment as directed by your teacher.

Conclude and Apply

- To what do the up-and-down lines and the flat parts on the graph correspond?

- How do you think your graph would differ if you had shaken the table harder? How does this relate to what a real seismogram shows about seismic waves?

- In this lab, your wire coil remained still and the magnet moved inside it. In a real seismograph, the magnet remains still and the wire coil moves around it, even though the magnet can swing freely and the coil is attached firmly to the ground. Explain how this can be true.

- Would you have obtained a similar or a different seismogram if you had moved the chair instead of the table? Explain.

Notes



Probeware Activity



Predicting the Weather

What will the weather be like tomorrow? You could watch the weather forecast on television, but you probably know more about predicting the weather than you realize. If you look outside early in the morning and see high, wispy clouds in a bright blue sky, you know it will be a beautiful day. But if you see low, dark clouds and a strong wind blowing, you know a storm is on the way. In this activity you will learn more about predicting the weather and use probes to monitor atmospheric pressure, relative humidity, and temperature. You will make daily observations of clouds and weather conditions.

What You'll Investigate

- What do changes in atmospheric pressure indicate about upcoming weather conditions?
- How can you use clouds to predict clear or stormy weather?
- How is relative humidity related to temperature changes?

Goals

- Create** a weather station.
- Measure** changes in atmospheric pressure, temperature, and relative humidity.
- Observe** changing weather conditions.
- Predict** the next day's weather based on data and observations.

Materials

- CBL 2 or LabPro units (2)
- TI graphing calculators (2)
- DataMate program
- AC adapter (2)
- link cables (2)
- barometer
- relative-humidity sensor
- temperature probe
- cloud chart
- Beaufort wind scale

Safety Precautions



- Always wear safety goggles in the laboratory.

Pre-Lab

1. What does a barometer measure?
2. What is humidity?
3. What is relative humidity?
4. Predict what increasing and decreasing atmospheric pressure indicate about upcoming weather.

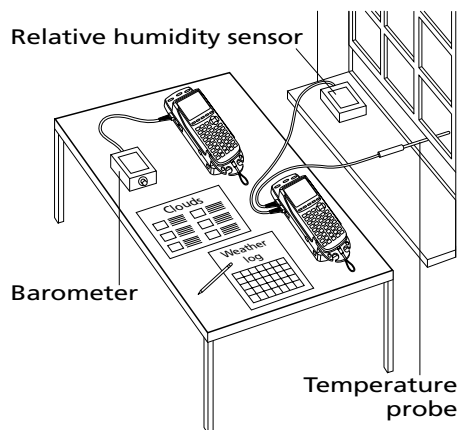
Probeware Activity 9 (continued)

Procedure

Part A: Preparing the First CBL System

1. Connect the barometer into channel 1 of the CBL 2 unit. Use a link cable to connect the CBL 2 unit to the graphing calculator as shown in **Figure 1**. Connect the AC adapter to the CBL 2 unit and plug the adapter into an outlet near the monitoring location.

Figure 1



2. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program. The barometer should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.
3. Select **SETUP** on the DataMate main screen to set up the time interval between data points and the length of time the data will be collected.
4. Press the up arrow once until the cursor is beside the **MODE** line. Press **ENTER**.
5. Select **TIME GRAPH**. Select **CHANGE TIME SETTINGS**. The screen will display “Enter time between samples in seconds.”
6. Press **7** **2** **0** **0** **ENTER**. The screen will display “Enter number of samples.” Press **6** **0**.

7. Select **OK**. Select **OK** again. The calculator and CBL 2 unit are ready to obtain atmospheric pressure readings every two hours for five days.

Part B: Preparing the Second CBL System

1. Connect the temperature probe into channel 1 and the relative humidity probe into channel 2 of the other CBL 2 unit. Use a link cable to connect the CBL 2 unit to the graphing calculator. Connect the AC adapter to the CBL 2 unit and plug the adapter into an outlet near the monitoring location.
2. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program. The temperature and relative humidity probes should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probes manually.
3. Select **SETUP**. Press the up arrow once to select **MODE: TIMEGRAPH**. Press **ENTER**.
4. Select **TIME GRAPH**. Select **CHANGE TIME SETTINGS**. The screen will display “Enter time between samples in seconds.”
5. Press **7** **2** **0** **0** **ENTER**. The screen will display “Enter number of samples.” Press **6** **0** **ENTER**.
6. Select **OK**. Select **OK** again. The calculator and CBL 2 are now ready to collect temperature and relative humidity readings every two hours for five days.
7. Select **START** on both calculators at the same time. A screen will appear that tells you to press “enter” to continue. Press **ENTER** on each calculator at the same time. The calculators now can be disconnected and the CBL 2 units will continue to collect data.

Probeware Activity 9 (continued)

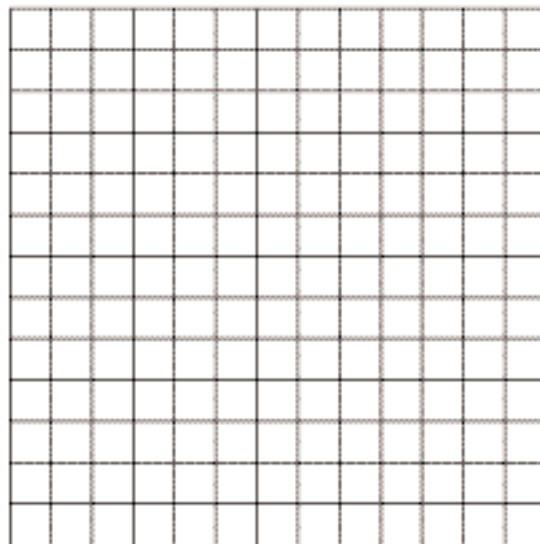
Part C: Collecting Data

1. During the five-day period, you will maintain a weather table. Prepare a chart similar to the one in the **Data Table**. Each day, record your weather observations. Use the cloud chart when recording cloud observations. Use the Beaufort wind scale when recording wind observations. Precipitation should be described by type (such as rain or snow) and amount (light, medium, or heavy).
2. After the data collection is complete, reattach the calculators. Press to turn them on.
3. On both calculators, start DataMate. A screen will appear indicating that data has been collected. Press . Select **TOOLS**, and select **RETRIEVE DATA**. The calculator connected to the CBL 2 and barometer will display a pressure-time graph. Sketch and label this graph in the space provided. When you are finished, press . Select **QUIT**. Follow the directions on the screen.
4. On the calculator connected to the temperature and relative-humidity probes, you are given the option to plot temperature or relative humidity. To plot both, select **MORE**. Then select **L2 and L3 vs L1**. A graph with both sets of data plotted on one axis will be displayed. Use the left/right arrow keys to trace the graph and the up/down arrow keys to select the graphs. Sketch and label this graph in the space provided.
5. When you are finished with the graph, press . Select **RETURN TO GRAPH SCREEN**. Then select **MAIN SCREEN**. Select **QUIT**. Follow the directions on the screen.

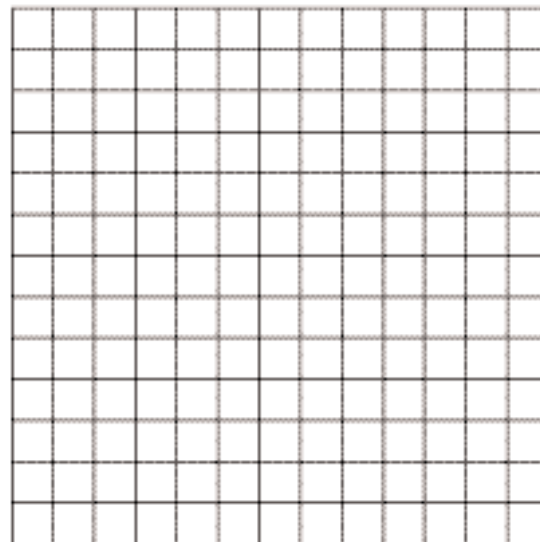
Cleanup and Disposal

1. Turn off the graphing calculators and disconnect the probes and CBL 2 units.
2. Return all equipment as directed by your teacher.

Experimental Graph: Atmospheric Pressure



Experimental Graph: Temperature and Relative Humidity



Probeware Activity 9 (continued)**Data Table: Weather Observations**

Day	Time	Clouds	Precipitation	Wind
1				
2				
3				
4				
5				

Conclude and Apply

1. What did changes in air pressure indicate about the next day's weather?

2. What cloud types did you find were useful weather indicators during the measurement period?

3. In general, what happens to the relative humidity as temperature decreases? Explain.

4. From the data you obtained, what relationship did you notice between barometric pressure and cloud cover?

5. What do you think would have made your model weather station more efficient for predicting weather?

6. Use the information you obtained from the graphs and observations to predict what the weather will be like tomorrow.

LAB 10 Probeware Activity



How are distance and light intensity related?

As you look up into the night sky, some stars seem to be brighter than others. Do these stars give off different amounts of light or is there another reason that these stars appear to vary in light intensity? In this activity you will explore the relationship between light intensity and distance. You also will investigate why scientists must classify stars according to absolute magnitude and apparent magnitude.

What You'll Investigate

- What is the relationship between light intensity and distance?

Goals

Collect light intensity and distance data.

Investigate the relationship between distance and light intensity.

Discover why stars must be classified according to apparent and absolute magnitude.

Materials

CBL 2 and LabPro unit
TI graphing calculator
Link cable
DataMate program
light-intensity sensor
lamp with 60-watt incandescent bulb
meterstick or measuring tape
masking tape
pen or marker
darkened room

Safety Precautions



- Always wear safety goggles and a lab apron during laboratory activities.

Pre-Lab

1. Does there appear to be a relationship between the intensity of a porch light or street lamp and distance?
2. Based on your experience of light sources and distance, infer the relationship between light intensity and the distance the observer is from the star.
3. Infer why the terms *apparent magnitude* and *absolute* (or actual) *magnitude* must be used when referring to the light intensity of stars.
4. What does the graph of the equation $y = 1 / x^2$ look like? If you are not sure, prepare a table using the numbers 1 through 5 for x and graph your results.

Probeware Activity 10 (continued)**Data Table**

Distance (m) (x)	Light Intensity (y)
1.0	
1.5	
2.0	
2.5	
3.0	
3.5	

Conclude and Apply

1. What is the relationship between light intensity and distance from the light source?

2. What are some of the sources for error in this experiment?

3. Explain why it can be deceptive to use light intensity of stars to estimate their distance from Earth.

4. Compare and contrast your experimental graph with the graph that you drew in pre-lab question number 4.

Notes

LAB 11 Probeware Activity



How fast do you walk?

Whether you walk fast or slow, your speed is almost always changing. When you walk from your classroom to the lunchroom, you may start out walking quickly. If the hall becomes crowded with other students, you probably will slow down. You can describe how fast you walked to the lunchroom by using your average speed for the entire trip or by your instantaneous speed at each point along the way. In this activity, you will use a motion sensor to record your speed as you walk. By analyzing your graph, you can compare your instantaneous speed and average speed.

What You'll Investigate

- How does your instantaneous speed change as you walk?
- How can you use a distance-time graph to determine when your speed is fastest and when it is slowest?

Goals

Measure your change in distance as you walk.

Analyze a distance-time graph.

Estimate instantaneous speed.

Calculate average speed.

Materials

CBL 2 or LabPro unit
TI graphing calculator
link cable
DataMate program
motion sensor
meterstick
masking tape

Safety Precautions

- Always wear safety goggles.

Pre-Lab

1. Suppose you walk in a straight line away from a table for a distance of 8 meters in 4.3 seconds. You then turn around and walk 8 meters toward the table in 6.8 seconds. What is your average speed as you walk away from the table? Toward the table?
2. Compare the steepness of a line on a distance-time graph when you walk quickly and when you walk slowly.
3. How can you determine where your speed is greatest by looking at a distance-time graph of motion?
4. If you walk away from a motion sensor, stop, turn around, and walk back toward the sensor, what will the distance-time graph of your motion look like for the time you stopped and turned around? Why?

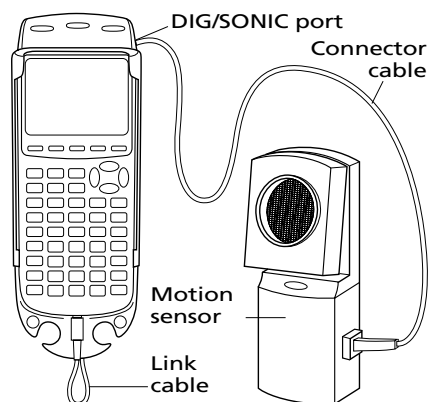
Probeware Activity 11 (continued)

Procedure

Part A: Preparing the CBL System

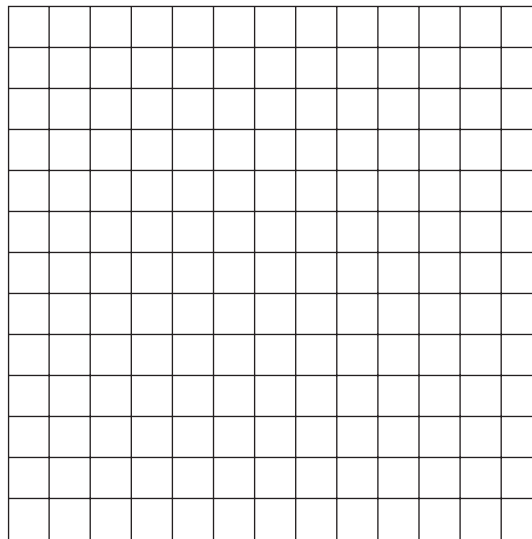
1. Place the motion sensor on the edge of a surface about 1 meter above the floor. Flip up the top of the sensor so that it points along a horizontal, clear space about 2-m long. The motion sensor must have the object that it is measuring in view at all times.
2. Use a meterstick to measure a straight, 2-m path away from the motion sensor. Use masking tape to mark the start and stop lines.
3. Plug the motion sensor connector cable into the DIG/SONIC port on the right side of the CBL 2 unit, as shown in **Figure 1**. Use a link cable to connect the CBL 2 unit to the graphing calculator.
4. Start the DataMate program. Press **CLEAR** to reset the program.

Figure 1



Part B: Collecting Data

1. Stand with your back at least 45 cm from the motion sensor. Have a partner select **START** on the calculator. When you hear the CBL 2 unit make a tone, begin walking along the path away from the motion sensor. Walk to the 2-m mark, turn around, and walk back. The entire trip should last 5 seconds.
2. When the measurement is complete, the calculator will display a screen giving you a choice of graphs. Press **ENTER** to choose **DIG-DISTANCE**, the distance-time graph.
3. A graph of your motion will appear on the screen. Use the left and right arrow keys to move the cursor along the curve. Data for time (x) and distance (y) will appear at the bottom of the screen. Find the selected time values listed in the **Data Table** on the x -axis of the curve and write the corresponding distance values in the **Data Table**. Round the distance values to the nearest tenth of a meter.
4. Sketch and label the graph on your calculator screen in the space below.



5. When you are finished with the graph, press **ENTER**. Select **QUIT**. Follow the directions on the calculator screen.

Cleanup and Disposal

1. Turn off the calculator. Disconnect the motion sensor and CBL 2 unit.
2. Return all equipment to the proper location as directed by your teacher. Answer the questions on the following page.

Probeware Activity 11 (continued)

Data Table: Selected Data Points

Distance from Detector (m)	Elapsed Time (s)	Distance Traveled	Change in Time	Instantaneous Speed (m/s)
	0.0	–	–	–
	0.5			
	1.0			
	1.5			
	2.0			
	2.5			
	3.0			
	3.5			
	4.0			
	4.5			
	5.0			

Conclude and Apply

1. Look at the distance-time graph of your data. Without looking at the data table, how can you tell where your speed was fastest and slowest?

2. Calculate the distance traveled during each time interval by subtracting the previous distance from the current distance. Calculate the change in time over each time interval by subtracting the previous time from the current time.
3. Calculate the total distance traveled by finding the sum of the values in the *Distance Traveled* column. Divide this value by the total time it took to travel that distance to obtain the average speed.
4. Calculate the approximate instantaneous speed over each time interval. Record the information in the **Data Table**. Round your answers to the nearest tenth. You can obtain an approximate value for your instantaneous speed at each time interval by using this formula:

$$\text{instantaneous speed} = \frac{\text{distance traveled}}{\text{change in time}}$$

5. Compare your average speed to your approximate instantaneous speed. Is it possible for average speed to be greater than instantaneous speed? Explain.

6. Notice that the instantaneous speed varied as you walked. What would your graph have looked like if you had traveled the entire time at the same instantaneous speed?

Notes

LAB
12 Probeware Activity



Transforming Energy

Everything you do involves a change of energy from one form to another. When you bounce a basketball, potential energy changes to kinetic energy to keep the ball bouncing. Electrical energy is transformed into radiant energy when you flip a light switch.

Friction is a force that converts kinetic energy to thermal energy when two objects rub against one another. Friction converts some of the kinetic energy of a moving match into thermal energy. This thermal energy causes the temperature of the match head to increase until chemicals in the match head catch fire. Friction also changes kinetic energy to thermal energy when the space shuttle returns to Earth. As the shuttle speeds back through the atmosphere, air molecules rush against it. Friction converts kinetic energy from the shuttle into thermal energy. The underside of the shuttle becomes so hot that it must be covered with special heat-resistant tiles to keep from burning up.

In this activity, you will use a temperature probe to look for evidence that friction causes an energy transformation when you shake sand in a jar.

What You'll Investigate

- How can friction cause an energy transformation to occur when you shake a jar of sand?
- What evidence suggests that an energy change has occurred?

Goals

Collect data on energy transformations.

Measure temperature of a solid.

Compare the temperature before and after shaking a solid.

Calculate any temperature changes that occur.

Materials

CBL 2 or LabPro unit
TI graphing calculator
link cable
DataMate program
temperature probe
hot mitt or gloves (2)
sand (250 mL)
clean, plastic jar (approx.
1,000 mL with screw lid)
timer

Safety Precautions

- Always wear safety goggles and a lab apron.
- Wash your hands before leaving the lab area.
- Extinguish all flames before beginning this activity.

Pre-Lab

1. What is kinetic energy?
2. Describe how friction produces an energy transformation that makes your hands feel warm when you rub them together rapidly.
3. Hypothesize what energy transformation will occur when you shake sand in a jar. How is friction between the sand particles related to this?
4. Why is it important to wear gloves while holding the jar during shaking and temperature readings?

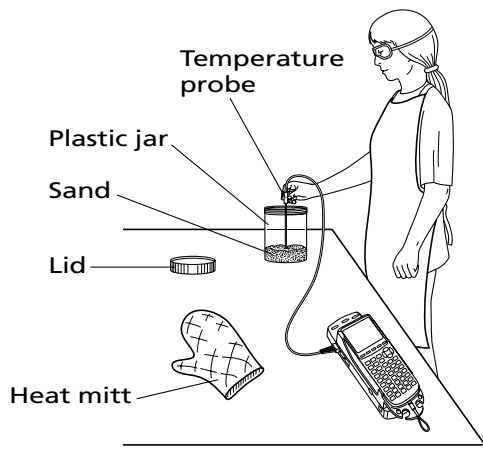
Probeware Activity 12 (continued)

Procedure

Part A: Preparing the CBL System

1. Set up the calculator and CBL 2 unit, as shown in **Figure 1**. Plug the temperature probe into channel 1 of the CBL 2 unit.
2. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program. The temperature probe should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.

Figure 1



Part B: Collecting Data

1. Fill the plastic jar about $\frac{1}{4}$ full of sand.
2. The calculator screen should display the room air temperature measured by the probe in the upper right corner of the screen. Record the room air temperature, to one decimal place, in the **Data Table**.
3. Place the temperature probe into the sand, as shown in **Figure 1** and allow it to sit undisturbed for about one minute. Record the temperature, to one decimal place, in the **Data Table**, as the start temperature.
4. For the next six minutes you will alternate shaking the closed jar of sand for one minute and then measuring the sand temperature during the next minute. Tighten the lid securely on the jar. Put on a pair of gloves and pick up the jar. Always hold the jar with two gloved hands. Shake the jar vigorously (hard) for one minute.
5. Remove the jar's lid and place the temperature probe into the sand. After about 30 to 45 seconds, record the sand's temperature in the **Data Table**. Tighten the lid back on the jar and repeat the procedure three times. Record the temperature for each trial in the **Data Table**.
6. Select **QUIT**. Follow the directions on the calculator screen.

Cleanup and Disposal

1. Turn off the graphing calculator and disconnect the temperature probe and the CBL 2 unit.
2. Clean off the temperature probe with a paper towel.
3. Return the CBL 2 and other laboratory equipment to its proper place as directed by your teacher.

Probeware Activity 12 (continued)

Data Table: Sand Temperature		
Time (minutes)	Task	Temperature °C
Start	Measure temperature	
0 – 1	Shake jar	
1 – 2	Measure temperature	
2 – 3	Shake jar	
3 – 4	Measure temperature	
4 – 5	Shake jar	
5 – 6 (End)	Measure temperature	

Conclude and Apply

1. Compare the sand temperature readings. Describe any change.

2. Suggest a possible explanation for your observations.

3. As you shook the jar of sand, chemical energy from the food you ate changed to kinetic energy in your muscles. This, in turn, provided kinetic energy to the sand. In the space below, create a concept map showing the series of energy transformations from the food you ate to the thermal energy released to the air.

4. How do you think your results would change if you shook the sand faster? How would the results change if you shook the sand longer? Explain.

5. A meteor is a meteoroid that falls through Earth's atmosphere. Based on the results you obtained in this experiment, explain why a meteor appears as a streak of light in the night sky.

Notes

LAB
13 Probeware Activity



Endothermic and Exothermic Processes

When a substance dissolves in water, a change in energy usually occurs. Although a change in energy can be a sign of a chemical change, the dissolving of a substance is a physical change. The water molecules break apart into positive and negative parts and surround the particles of the substance that is dissolving. In some cases, dissolving releases heat energy into the surroundings. Processes that release heat energy are called *exothermic*. In other cases, dissolving absorbs heat energy from the surroundings. Processes that absorb heat are called *endothermic*. How can you tell if heat energy is released or absorbed? In this activity you will collect data and search for clues to determine which type of heat energy transfer is taking place.

What You'll Investigate

- What happens when CaCl_2 and KCl are added to water?
- Will these processes produce temperature changes?

Goals

- Measure** the change in temperature when substances are added to water.
- Calculate** any change in water temperature that occurs during the process.
- Graph** temperature changes over time.

Materials

- CBL 2 or LabPro unit
- TI graphing calculator
- link cable
- DataMate program
- temperature probe
- 400-mL beaker
- 100-mL beaker
- plastic spoon
- glass stirring rod
- distilled water (room temperature)
- 5.0g calcium chloride (CaCl_2)
- 5.0g potassium chloride (KCl)

Safety Precautions



- Always wear safety goggles and a lab apron.
- Report any spills to your teacher.
- Do not taste, eat, or drink any materials used in the lab.
- Wash your hands before leaving the laboratory.

Pre-Lab

1. What is a physical change?
2. What are examples of physical change?
3. What is an exothermic process?
4. What is an endothermic process?

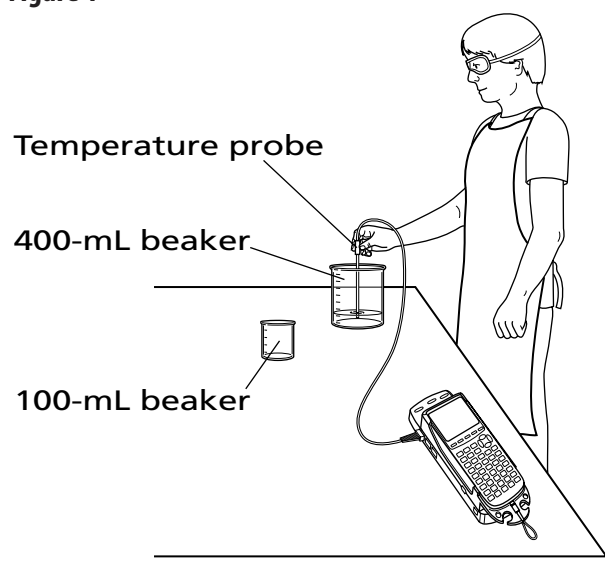
Probeware Activity 13 (continued)

Procedure

Part A: Preparing the CBL System

1. Set up the calculator and CBL 2 unit, as shown in **Figure 1**. Plug the temperature probe into channel 1 of the CBL 2 unit.
2. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program. The temperature probe should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.

Figure 1



Part B: Collecting Data

1. Add 100 mL of room-temperature water to the 400-mL beaker.
2. Place the temperature probe in the water.
3. Use a balance to measure 5.0 g of potassium chloride on a piece of weighing paper or in a weighing dish.
4. On the graphing calculator, select **START** to begin the data collection. About five seconds after data collection has begun, carefully add the potassium chloride to the water. Make sure all of the potassium chloride is emptied into the water. Data will be collected for 180 seconds.

5. Using a glass stirring rod, gently stir the water in the beaker for about 20 seconds to help the potassium chloride dissolve.
6. After 180 seconds have lapsed, the calculator will display a graph of temperature versus time with temperature on the y -axis and time on the x -axis. Sketch and label this graph in your **Science Journal**.

Part C: Examining the Data

1. Return to the main screen by pressing **ENTER**.
2. Select **ANALYZE**.
3. Select **STATISTICS**.
4. Press **ENTER** to select the beginning of the temperature graph. Use the right arrow key to select the last temperature data point reached. Press **ENTER** to select this point.
5. Your calculator will display the minimum and maximum temperatures reached. Determine which of these is the starting temperature and which is the ending temperature—the temperature after all of the solid dissolved. Record these temperatures in the **Data Table**. When you are finished, press **ENTER**. Select **RETURN TO MAIN SCREEN**.
6. Rinse your beaker thoroughly and repeat parts **B** and **C** using 5 g of calcium chloride.
7. When you are finished, press **ENTER**. Select **RETURN TO MAIN SCREEN**. Select **QUIT**. Follow the directions on the screen.

Cleanup and Disposal

1. Turn off the graphing calculator and disconnect the temperature probe and CBL 2 unit.
2. Clean and return all equipment as directed by your teacher and answer the questions on the following page.

Probeware Activity 13 (continued)**Data Table: Dissolving of KCl and CaCl₂**

Substance	Starting Temperature (°C)	Ending Temperature (°C)	Temperature Change (°C)	Type of Process
Potassium chloride (KCl)				
Calcium chloride (CaCl ₂)				

Conclude and Apply

1. Calculate the temperature change for each substance by subtracting the starting temperature from the ending temperature. Record your results in the **Data Table**. How are these temperature changes different?

2. Which process is endothermic and which is exothermic?

3. Look at your graphs. Suggest a possible explanation for why the temperature of the water changed rapidly at first and then leveled off.

4. From your results, infer what the result might be if twice as much potassium chloride was added to the same amount of water.

Notes

LAB
14 Probeware Activity



Thermal Conductivity

Heat is thermal energy that flows from a warmer material to a cooler material. One way that thermal energy is transferred is by a process called conduction. Conduction occurs because the particles in a warmer material are moving faster than the particles in a cooler material. When these materials are in contact, the particles collide with one another and some of the kinetic energy of the faster-moving particles is transferred to the slower-moving particles. When the warm material loses some kinetic energy, its temperature drops. When the cool material gains kinetic energy, its temperature rises. A material that is a thermal conductor transfers thermal energy more rapidly than a material that is a thermal insulator. In this lab you will observe and compare the thermal conduction of several different materials.

What You'll Investigate

- How do materials vary in thermal conductivity?
- Do similar materials have similar thermal conductivity?

Goals

Collect temperature data.
Compare the thermal conductivity of various materials.
Analyze temperature data and look for trends in various materials.

Materials

CBL 2 or LabPro unit
TI graphing calculator
temperature probe
link cable
DataMate program
hot mitt or thermal glove
test strips of various materials
400-mL beaker
masking tape
hot plate
tap water

Safety Precautions



- Always wear safety goggles and a lab apron.
- Observe laboratory rules.
- Use care near heat sources and when handling hot objects.

Pre-Lab

1. What is the difference between a thermal conductor and a thermal insulator?
2. Form a hypothesis about what types of materials are conductors. What types of materials do you think are insulators?
3. If the bottom half of a long strip of material is placed in hot water, how would you determine if it was a thermal conductor or insulator?
4. Describe the direction of heat flow between two objects.

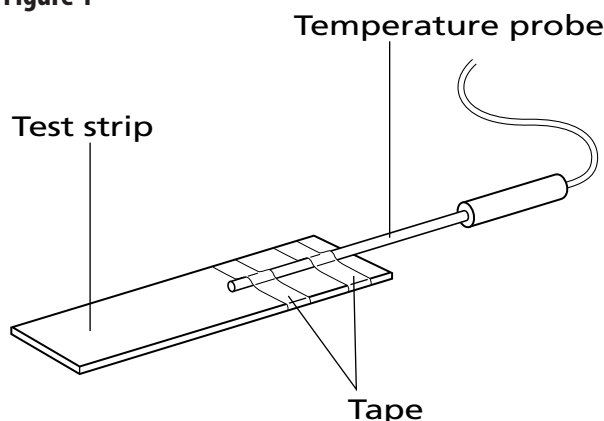
Probeware Activity 14 (continued)

Procedure

Part A: Preparing the CBL System

1. Set up the calculator and CBL 2 unit, as shown in **Figure 1**. Plug the temperature probe into channel 1 of the CBL 2 unit.
2. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program. The temperature probe should be recognized automatically. If not, turn to page *vi* for instructions on how to set up the probe manually.

Figure 1



Part B: Collecting Data

1. Put on your lab apron and safety goggles.
2. Lay the temperature probe over the metal strip so the bottom of the probe is 7 cm from the end, as shown in **Figure 1**. Tape the probe to the metal strip.
3. Fill the 400-mL beaker to the 150-mL mark with hot water obtained from your teacher.
4. Select **START** on your calculator to begin data collection. Using a gloved hand, place your test strip into the beaker of hot water being careful not to splash water onto the probes. The probe should not touch the hot water and should sit above the water line.

5. Data will be collected for 180 seconds. When the calculator stops, it will display a time-temperature graph with temperature on the *y*-axis and time on the *x*-axis. Sketch and label this graph in your **Science Journal**.

Part C: Examining Data

1. Return to the main screen by pressing **ENTER**.
2. Select **ANALYZE**.
3. Select **STATISTICS**.
4. Press **ENTER** to select the beginning of the temperature graph. Use the right arrow key to select the end of the temperature graph. Press **ENTER**.
5. Record the maximum and minimum temperatures in the **Data Table**.
6. Write your data in the group table provided by your teacher for data sharing. Fill in the remaining lines on the **Data Table** using the data from the group table.
7. When you are finished, press **ENTER**. Select **RETURN TO MAIN SCREEN**.
8. If time permits, test another sample. If not, select **QUIT**. Follow the directions on the screen.

Cleanup and Disposal

1. Turn off the graphing calculator and disconnect the temperature probes and CBL 2 unit.
2. Return all equipment as directed by your teacher.

Probeware Activity 14 (continued)**Data Table: Temperature Change of Different Materials**

Type of Test Material	Minimum Temperature (°C)	Maximum Temperature (°C)	Change in Temperature (°C)

Conclude and Apply

1. Find the change in temperature for each material tested by subtracting the minimum temperature from the maximum temperature. Record the difference in the **Data Table**.
2. What are some similarities of materials that are thermal insulators? What are some similarities of materials that are thermal conductors?

3. On a temperature-time graph, the steeper the slope of the line is, the faster the temperature change is in a given amount of time. The graph of which material had the steepest slope and, therefore, the fastest change of temperature?

4. Find a student group that tested the same material that you tested. How do your temperature changes compare? If the temperature changes were not the same, what are possible reasons that they were different?

Notes

LAB
15 Probeware Activity



Let the Races Begin!

Sledding down a hill in the snow, coasting down a hill on your bike, or speeding down a hill in a roller coaster would not be the same without a steep hill. You know that the higher the hill, the faster you'll be going when you reach the bottom. This is because objects at the top of a hill have potential energy. The amount of potential energy that an object has depends upon its height above Earth. This potential energy is converted into kinetic energy—energy of motion, when the object falls downward. Whether the hill is steep or has a gentle slope, your speed at the bottom depends on the height of the hill. In this experiment you will collect distance, velocity, and acceleration data by rolling a toy car down a board at two different heights.

What You'll Investigate

- How does the height of a ramp affect speed and acceleration?

Goals

Collect distance, velocity, and acceleration data.

Compare the graphs for each trial.

Identify sources of experimental error.

Materials

CBL 2 or LabPro unit
TI graphing calculator
link cable
DataMate program
motion sensor
board (at least 1.5 m long)
toy car or lab cart

Safety Precautions

- Always wear safety goggles and a lab apron during a laboratory activity.

Pre-Lab

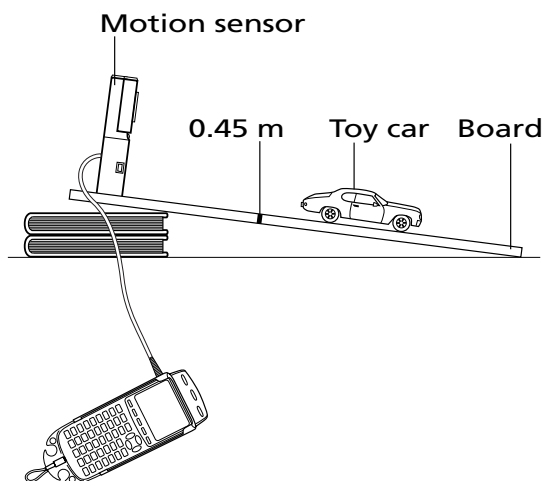
1. How are distance, speed, time, and acceleration related?
2. How does the kinetic and potential energy of an object change as the object falls?
3. The motion sensor works in a way that is similar to the way a radar-speed detector works. In looking at the motion sensor, the toy car, and the board, what things must be taken into consideration before starting your investigation?
4. Where are the sources of friction in this lab?

Probeware Activity 15 (continued)

Procedure

Part A: Preparing the CBL System

Figure 1



1. Set up the calculator and CBL 2 unit, as shown in **Figure 1**. The motion sensor should be plugged into the DIG/SONIC channel that is located on the right-hand side of the CBL 2 unit.
2. Turn on the calculator and start DataMate. Press **CLEAR** to reset the program.

Part B: Collecting Data

1. Use textbooks to elevate the board, as shown in **Figure 1**. Put just enough textbooks under the board so that the car rolls down the ramp.
2. Position the motion sensor at the top of the ramp so that it can “see” the car as it travels down the ramp. The car must be placed at least 45 cm from the motion sensor for the sensor to operate properly. When the car and motion sensor are in place, you will hear a series of soft clicks from the motion detector.
3. Select **START** on the calculator and release the car.

Part C: Examining the Data

1. After the run is complete, the screen will display a choice of three graphs: DIG-DISTANCE, DIG-VELOCITY, AND DIG-ACCELERATION. Select **DIG-VELOCITY** to display a velocity-time graph.
2. Sketch and label this graph in your **Science Journal**.
3. Use the arrow keys to obtain the maximum y -value (velocity) and the x -value (time) that maximum velocity occurred. Write these data in the **Data Table**. Press **ENTER**.
4. Select **DIG-ACCELERATION** to display an acceleration-time graph.
5. Sketch and label this graph in your **Science Journal**.
6. Use the arrow keys to obtain the maximum acceleration and the time that the maximum acceleration occurred. Write these data in the **Data Table**. Press **ENTER**.
7. Select **DIG-DISTANCE** to display a distance-time graph.
8. Sketch and label this graph in your **Science Journal**.
9. Press **ENTER**. Select **MAIN SCREEN**.
10. Repeat part B and part C, Steps 1–9, using additional textbooks to elevate the ramp at a steeper angle. Record the data for each trial in the **Data Table**. Sketch and label each graph.
11. From the main screen, select **QUIT**. Follow the directions on the screen.

Cleanup and Disposal

1. Turn off the graphing calculator and disconnect the motion sensor and CBL 2 unit.
2. Return all equipment to the proper location as directed by your teacher and answer the following questions.

Probeware Activity 15 (continued)**Data Table: Run Data**

	First Run	Second Run
Maximum velocity		
Time maximum velocity occurred		
Maximum acceleration		
Time maximum acceleration occurred		

Conclude and Apply

1. When did the velocity of the car reach a maximum? When did the acceleration of the car reach a maximum? Explain possible reasons why these occurred when they did.

2. Using your graphs, determine when the car appears to have completed the run or moved out of sight of the motion sensor.

3. If friction were not present, what would the graphs for velocity and acceleration look like?

4. Identify possible sources of experimental error in your experiment.

5. How did increasing the height of the car's starting position affect the potential energy of the car?

6. Explain why increasing the height of the car's starting position increased the car's speed at the bottom of the board.

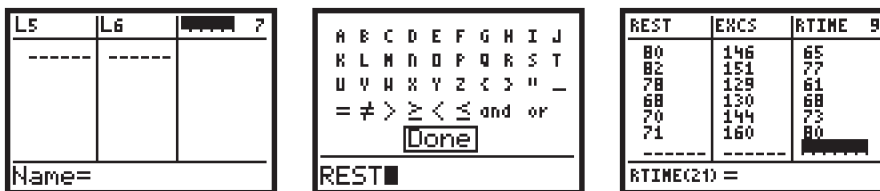
Notes

Appendix A

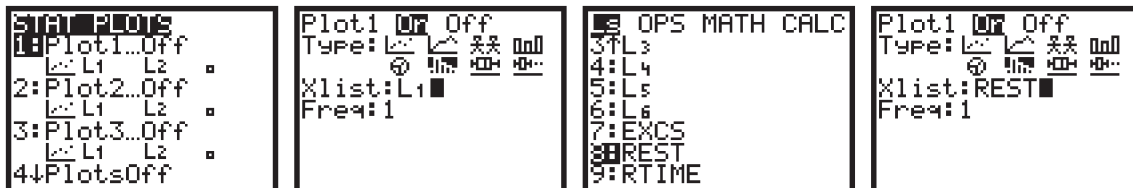
Using the TI-73 Graphing Calculator to Create a Histogram

A histogram is a graph that shows data divided into equal ranges and the number of data points that fall into each range. The following instructions explain how to make a histogram for the heart rate data in *Exercise and Heart Rate*.

- 1. Resetting Calculator Memory** Turn on your graphing calculator and press 2nd [MEM]. Select **Clr All Lists**. Press ENTER .
- 2. Creating and Entering Data Into Lists** Press LIST to access an empty data table. Name your lists before entering data. Scroll up to the title bar (the “top shelf”) and over to the first empty list beyond L6 (lists L1–L6 cannot be renamed). Press 2nd [TEXT]. Scroll to the desired letters, pressing ENTER after each. Choose a title of 5 or fewer letters. Then scroll down to **DONE**. Press ENTER twice to title your new list. Repeat for the other two variables. Enter your class data in all three lists.



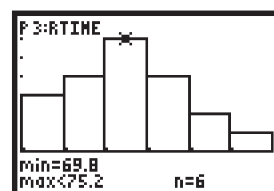
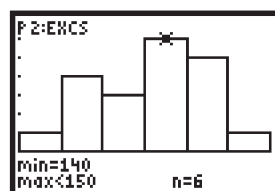
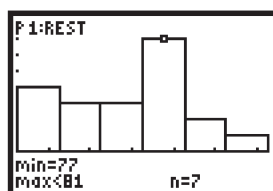
- 3. Setting up Graphs** Press 2nd [PLOT]. Select **Plot 1** by pressing ENTER . Use the arrow keys and ENTER to turn the plot on and to select the sixth graph icon, a histogram. For the Xlist, press 2nd [LIST] and scroll down to find the resting heart rate list. Press ENTER twice. Ignore Freq.



- Repeat **Step 3** to set up Plot 2 and Plot 3, but do not turn them ON yet. The Xlists will be your exercise heart rate and recovery time lists.



- 5. Plotting Data** Press ZOOM . Then select **ZoomStat** to see your first histogram for resting heart rate. Use the TRACE and arrow keys to find the heart rate range that occurred in the class most often and the number of students that were in this range.
- Press 2nd [PLOT] to turn off Plot 1, and turn on Plot 2. Repeat step 5 for Plot 3 to see the class histogram for exercise heart rate and recovery time.



Appendix B

Using the TI-83 Plus Graphing Calculator to Create a Histogram

- 1. Resetting Calculator Memory** Turn on your graphing calculator and press 2nd [MEM]. Select Clr All Lists. Press ENTER .
- 2. Creating and Entering Data into Lists** Name your lists before entering data. Press STAT and select **Edit**. Scroll up to the title bar (the “top shelf”) and over to the first empty list beyond L6 (lists L1–L6 cannot be renamed). The highlighted “A” in the upper corner indicates that you are already in locked-alpha mode. Find and press the desired letters on the keypad. Press ENTER to title your new list for the resting heart rate data. Repeat for exercise heart rate and recovery time. Choose abbreviations that make sense to you—the names are limited to five letters. Enter all data.

L5	L6	-----	?
-----	-----	-----	-----
Name=			

L5	L6	-----	?
-----	-----	-----	-----
Name=REST			

REST	EXCS	RTIME	9
80	146	65	
82	151	77	
78	129	61	
68	130	68	
70	144	73	
71	160	80	
-----	-----	-----	-----
RTIME(21) =			

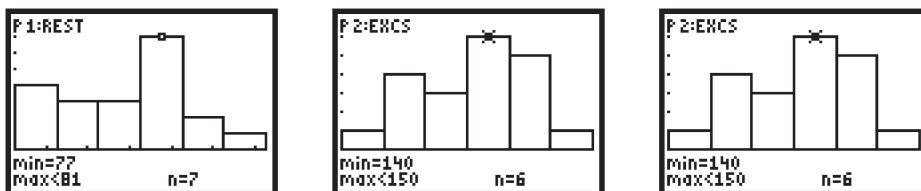
- 3. Setting up Graphs** Set up your calculator for graphing your data. Press 2nd [STAT PLOT]. Select **Plot 1** by pressing ENTER . Use the arrow keys and ENTER to turn the plot on and select the third graph icon, a histogram. For the Xlist, press 2nd [LIST] and scroll down to find your resting heart rate list. Press ENTER twice. Leave Freq. at 1.

STAT PLOTS	Plot1 Plot2 Plot3	NAME OPS MATH	Plot1 Plot2 Plot3
1:Plot1...Off	Off Off	3:L3	Off Off
2:Plot2...Off	Type: [] [] []	4:L4	Type: [] [] []
3:Plot3...Off	Xlist: []	5:L5	Xlist: REST
4:PlotsOff	Freq: 1	6:L6	Freq: 1
		7:EXCS	
		8:REST	
		9:RTIME	

- Repeat **Step 3** to set up Plot 2 and then Plot 3, but do not turn Plot 2 and Plot 3 ON yet. The Xlists will be your exercise heart rate and recovery time lists.

STAT PLOTS
1:Plot1...On
2:Plot2...Off
3:Plot3...Off
4:PlotsOff

- 5. Plotting Data** Press ZOOM . Then select **ZoomStat** to see the first histogram, for resting heart rate. Use the TRACE and arrow keys to find the heart rate range that occurred in the class most often and the number of students that were in this range.
- Press 2nd [STAT] [PLOT] to turn off Plot 1, and turn on Plot 2. Press ZOOM . Then select **ZoomStat** again to see the class histogram for exercise heart rate. Then turn off Plot 2 and turn on Plot 3 to see the class histogram for recovery time.



Appendix C

Using the TI-73 Graphing Calculator to Create a Box Plot and Display Statistics

Note: If you have already used the calculator to make histograms, skip to step #4.

- Resetting Calculator Memory** Turn on your graphing calculator and press 2nd [MEM]. Select **Clr All Lists**. Press ENTER .
- Press LIST to access an empty data table. Name your lists before entering data. Scroll up to the title bar (the “top shelf”) and over to the first empty list beyond L6 (lists L1–L6 cannot be renamed). Press 2nd [TEXT]. Use the arrow keys to select the desired letters, pressing ENTER after each. List names are limited to five letters. Go to **DONE** when you are finished entering the name. Press ENTER twice to title your new list for the resting heart rate data.



- Repeat for the other two variables, choosing abbreviations for exercise heart rate and recovery time with 5 or fewer letters. Enter your class data in all three lists.
- Order the data in your lists. Press 2nd [STAT]. Use the right arrow key to select **OPS**. Select the default, **Sort A**, by pressing ENTER . The blinking cursor is a signal to insert your list names. Press 2nd [LIST] and scroll down to select your first list. Then enter a comma. Repeat to select the second and third data lists. The commas will keep the lists separated so you can later investigate any relationship between variables. Press ENTER . With data sorted (in ascending order), you can easily determine the minimum, maximum, mode, and median.

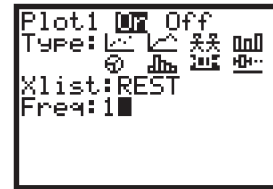
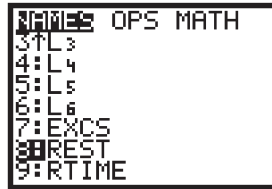
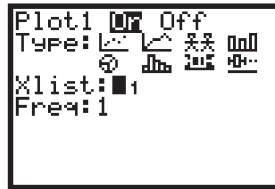


- For statistical analysis, access the one-variable statistics for each list. Press 2nd [STAT]. Use the right arrow key to select **CALC**. Select the default, **1-Var Stats**. Press ENTER . Press 2nd [LIST] to retrieve one of your lists. Press ENTER . The mean (\bar{x}) is the first entry. Scroll down to find the minimum (minX), median (Med), and maximum (maxX).



Appendix C (continued)

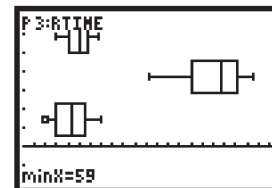
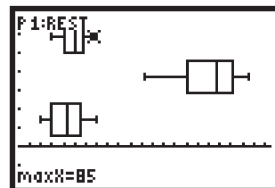
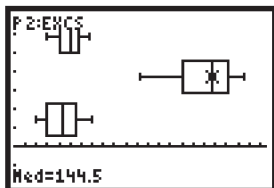
6. Set up your calculator for graphing your data. Press 2nd [PLOT]. Select the default, **Plot 1**, by pressing ENTER . Use the arrow keys and ENTER to turn the plot on and select the seventh graph icon, a standard box plot. For the Xlist, press 2nd [LIST] and scroll down to find your resting heart rate list. Press ENTER twice. Leave Freq. at 1.



7. Repeat **Step 5** to set up and turn on Plot 2 and then Plot 3. The Xlists will be your exercise heart rate and recovery time lists. Because the data for all three lists is in the same range (about 60–160), all three box plots can be viewed on the calculator screen simultaneously. Remember that the first two plots are heart rates measured in beats per minute while the last plot, recovery time, is measured in seconds.



8. Press ZOOM . Select **ZoomStat** to see all three box plots, for resting heart rate. Using the TRACE and arrow keys find the median exercise heart rate. The left and right arrows will give you the minimum, maximum, median, and quartiles. The up and down arrows allow you to trace the three plots—Plot 1 is at the top of the screen. You also can see that the maximum the minimum heart rates and recovery times.



Appendix D

Using the TI-83 Plus Graphing Calculator to Box Plot and Display Statistics

Note: If you have already used the calculator to make histograms, skip to step #3.

- Resetting Calculator Memory** Turn on your graphing calculator and press 2nd [MEM]. Select **Clr All Lists**. Press ENTER .
- Name your lists. Press STAT and select **Edit**. Scroll up to the title bar (the “top shelf”) and over to the first empty list beyond L6 (lists L1–L6 cannot be renamed). The highlighted “A” in the upper corner indicates that you are already in locked-alpha mode. Find and press the desired letters. Press ENTER to title your new list for the resting heart rate data. Repeat for the other two variables, exercise heart rate and recovery time. Choose abbreviations that make sense to you—list names are limited to five letters. Then enter all data.



- Order the data in your lists. Press 2nd [LIST] and use the right arrow key to select **OPS**. Select the default, **Sort A**, by pressing ENTER . The blinking cursor is a signal to insert your list names. Press 2nd [LIST] and scroll down to select your first list. Then enter a comma. Repeat to select the second and third data lists. Then put a right parentheses “)” after the lists. The commas will keep the lists separated so you can later investigate any relationship between variables if you like. Press ENTER . With data sorted (in ascending order here) you can easily determine the minimum, maximum, mode, and median.



- For statistical analysis, access the one-variable statistics for each list. Press STAT and arrow right to **CALC**. Select the default, **1-Var Stats**. Press ENTER . Press 2nd [LIST] and scroll down to retrieve one of your lists. Press ENTER twice. The mean (\bar{x}) is the first entry, then scroll down to find the minimum (minX), median (Med), and maximum (maxX).



Appendix D (continued)

5. Set up your calculator for graphing your data. Press 2nd [STAT PLOT]. Select the default, **Plot 1**, by pressing ENTER . Use the arrow and ENTER keys to turn the plot on and select the fifth graph icon, a standard box plot. For the Xlist, press 2nd [LIST] and scroll down to find your resting heart rate list. Press ENTER twice. Leave Freq at 1.

```

STAT PLOTS
1:Plot1...Off
  [ ] L1  L2  [ ]
2:Plot2...Off
  [ ] L1  L2  [ ]
3:Plot3...Off
  [ ] L1  L2  [ ]
4↓PlotsOff
  
```

```

Plot1 Plot2 Plot3
On Off
Type: [ ] [ ] [ ]
Xlist: [ ]
Freq: 1
  
```

```

NAME OPS MATH
3↑L3
4:L4
5:L5
6:L6
7:EXCS
8:REST
9:RTIME
  
```

```

Plot1 Plot2 Plot3
On Off
Type: [ ] [ ] [ ]
Xlist: REST
Freq: 1
  
```

6. Repeat **Step 5** to set up and turn on Plot 2 and Plot 3. The Xlists will be your exercise heart rate and recovery time lists. Because the data for all three lists is in the same range (about 60–160), all three box plots can be viewed on the calculator screen simultaneously. Remember that the first two plots are heart rates measured in beats per minute while the last plot, recovery time, is measured in seconds.

```

STAT PLOTS
1:Plot1...On
  [ ] REST 1
2:Plot2...On
  [ ] EXCS 1
3:Plot3...On
  [ ] RTIME 1
4↓PlotsOff
  
```

7. Press ZOOM and select **ZoomStat** to see all three box plots for resting heart rate. Using the TRACE and arrow keys, find the median exercise heart rate. The left and right arrows will give you the minimum, maximum, median, and quartiles. The up and down arrows allow you to trace the three plots—Plot 1 is at the top of the screen. You can find the maximum and minimum heart rates and recovery times.

