Getting Started with the CBL 2™ System

Safety Instructions

Observe all warnings, cautions, and other safety instructions indicated on the product and in the documentation. These instructions are intended to reduce the risk of injury, possible electrical shock, or damage to the unit.

AC Voltages

⚠ **WARNING!** Never attempt to measure AC voltages from a wall outlet. Connecting 115/230 Volts AC to any input probe may cause serious injury or electrical shock, and may damage the unit.

Low-Voltage Unit

⚠ **WARNING!** This product is designed for use with low voltages. Personal injury and damage to the unit may occur if voltages exceed 30 Volts DC on CH1, CH2, or CH3; or if voltages exceed 5.5 Volts DC on SONIC, DIG IN, or DIG OUT. To reduce risk of injury, do not connect probes to circuits that contain voltage sources more than 30 Volts DC. All voltage sources must be fully isolated from AC power lines.

Analog Inputs

⚠ **CAUTION!** It is very important that the ground connections of the analog inputs are never connected to different potentials. These ground connections are all in common. Connecting the grounds to different potentials may damage the CBL 2™ unit.

Batteries

⚠ **WARNING!** Do not heat, burn, or puncture batteries. Batteries contain hazardous chemicals and may explode or leak. Take the following precautions when replacing batteries.

- Do not leave batteries within the reach of children.
- Do not mix new and used batteries. Do not mix brands (or types within brands) of batteries.
- Do not mix rechargeable and non-rechargeable batteries.
- Install batteries according to polarity (+ and -) diagrams.
- Do not place non-rechargeable batteries in a battery recharger.
- Properly dispose of used batteries immediately.
- Do not incinerate or dismantle batteries.

FCC Information Concerning Radio Frequency Interference

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference with radio communications. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, you can try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/television technician for help.

CAUTION: Any changes or modifications to this equipment not expressly approved by Texas Instruments may void your authority to operate the equipment.

Contents

Collecting Data Out of the Box Using the CBL 2™ System

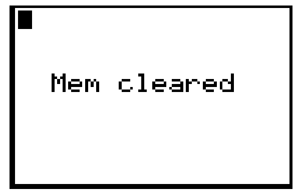
1. Insert batteries into the CBL 2.

2. Connect CBL 2 to a TI graphing calculator using the unit-to-unit link cable. (Use the cradle if desired; see diagram on the cradle or the instructions on page 4.)

If you are using the TI-83 Plus or TI-83 Plus Silver Edition, proceed to step 4.

If you are using the TI-89, TI-92 Plus, or Voyage™ 200 PLT (personal learning tool) proceed to step 5.

3. Reset the memory of your calculator. Reset is necessary only for the TI-73, TI-82, and TI-83. To reset RAM, press [2nd] [MEM], choose **7:Reset**, then choose **1:All RAM**, and then choose **2:Reset**.



This is a required step due to the size of the DataMate programs that are stored in RAM.

4. Put calculator in Receive Mode (waiting to receive information):

- For TI-73, press [APPS], choose [1] LINK, press [▸] to RECEIVE, and then press [ENTER].
- For the TI-82, TI-83, TI-83 Plus, and TI-83 Plus Silver Edition, press [2nd] [LINK], press [▸] to RECEIVE, then press [ENTER].

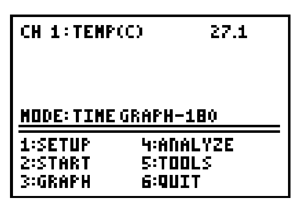
5. Press the **TRANSFER** button on the CBL 2. The CBL 2 detects the calculator to which it is connected and sends the appropriate version of the built-in DataMate software. (This software controls the CBL 2 and how it collects data.)

6. Plug your Stainless Steel Temperature sensor into Channel 1 (CH1) of the CBL 2.

7. Run DataMate:

- For TI-83 Plus and TI-83 Plus Silver Edition, press [APPS]. Press [▾] or [▴] to highlight DATAMATE and press [ENTER].
- For the TI-73, TI-82, and TI-83, press [PRGM]. Press [1] DATAMATE or press [ENTER]. DATAMATE is pasted to your home screen; press [ENTER] again to confirm your choice.
- For the TI-89, TI-92 Plus, and Voyage 200 PLT, if the Apps desktop is turned on, press [APPS], highlight DataMate, and press [ENTER].
  or
  If the Apps desktop is turned off, press [♦] [APPS], highlight DataMate, and press [ENTER].

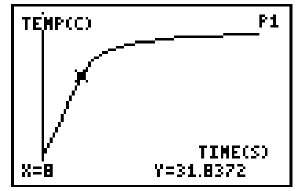
8. DataMate automatically identifies the Stainless Steel Temperature sensor, loads its calibration factors, and displays the name of the sensor, as well as the temperature in degrees C. It also loads a default temperature experiment.



9. Start collecting data with the default experiment. Hold the temperature sensor in your hand and press [2] START to begin data collection.

10. You will see a real-time graph of temperature. Wait about 30 seconds and then press [STO▸] to stop collecting data.

When finished, your graph will be similar to the one shown here.



11. You just successfully collected data. See the rest of the manual for other DataMate options (other sensors, analysis, saving data, etc.).

12. Explore the world around you.

Introduction

The Calculator-Based Laboratory 2 (CBL 2™) system, a second generation of the Calculator-Based Laboratory™ system, is a portable, handheld, battery-operated data collection device for collecting "real-world" data. Data collected with a CBL 2 can be retrieved and analyzed by TI graphing calculators. With the CBL 2 and appropriate sensors, you can measure motion, temperature, light, sound, pH, force and more.

CBL 2 has a port to connect and communicate with TI graphing calculators. A 6-inch unit-to-unit link cable is included with the CBL 2 for this purpose. For added portability, the CBL 2 unit comes with a cradle which attaches the calculator to the unit so the whole thing fits easily into one hand.

With a TI-GRAPH LINK™ cable (sold separately), you can also link the CBL 2 to a personal computer. As future software upgrades become available on the TI web site, you can download the software to your PC and then use a TI-GRAPH LINK cable to upgrade your CBL 2.

CBL 2 comes with the following equipment and sensors:

- CBL 2
- 6-inch unit-to-unit link cable
- calculator cradle
- Stainless steel temperature sensor
- TI light sensor
- TI voltage sensor
- 4 AA (LR6) alkaline batteries

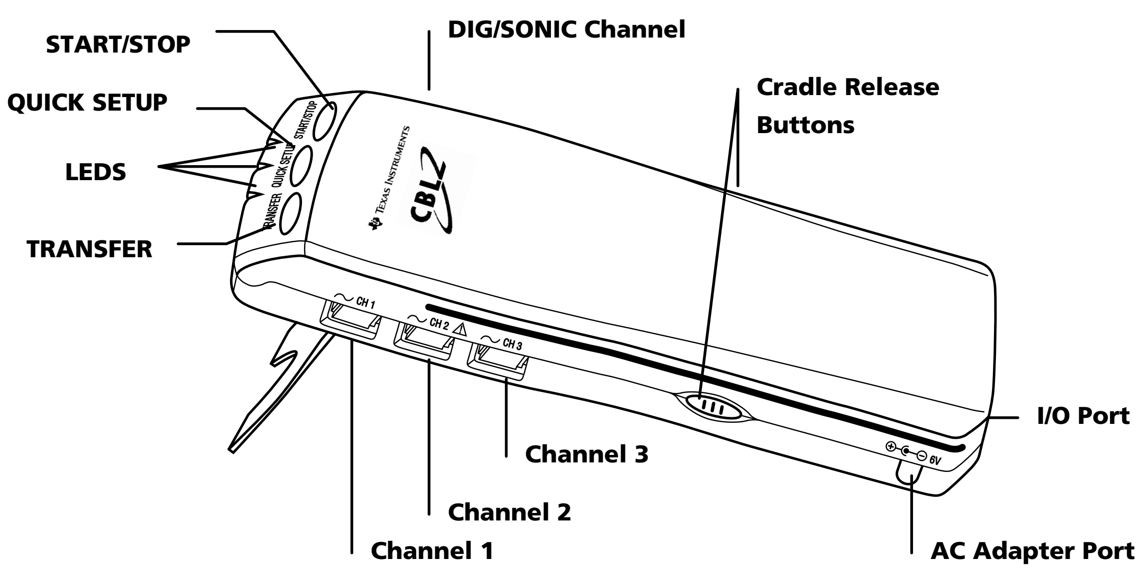


Figure 1. CBL 2 Features

Keys

CBL 2™ has three keys:

TRANSFER begins transfer of programs or Calculator Software Applications (apps) between the CBL 2 and an attached TI graphing calculator.

QUICK SET-UP clears any data stored in the CBL 2 system's MEMORY, then polls all channels for auto-ID sensors and sets them up to collect data. QUICK SET-UP is used when a calculator is not attached to CBL 2 and works only with auto-ID sensors.

START/STOP begins sampling for Quick Set-Up. Sampling continues until the default number of samples is collected or you press **START/STOP** again. This button also acts as a manual trigger, similar to the TRIGGER button on the original CBL.

LEDs

CBL 2 also has three LEDs:

Red indicates an error condition.

Yellow indicates that CBL 2 is ready to collect data samples.

Green indicates CBL 2 is collecting data.

Software

The CBL 2 comes with DataMate already loaded. DataMate is a multi-purpose user program containing the basic information needed to run experiments with a CBL 2, a TI graphing calculator, and various sensors.

DataMate is provided for the following TI graphing calculators: TI-73, TI-82, TI-83, TI-83 Plus, TI-83 Plus Silver Edition, TI-86, TI-89, TI-92, TI-92 Plus, and Voyage™ 200 PLT. For the TI-83 Plus, TI-83 Plus Silver Edition, TI-89, TI-92 Plus, and Voyage 200 PLT, DataMate is a calculator software application that is run from the APPS menu; for the other calculators, it is a program that is run from the calculator's program menu. The CBL 2 automatically detects which calculator is attached and sends the appropriate software.

Because of the differences in memory between the calculators, there are some differences in functionality between by the different versions of DataMate.

- The TI-83 Plus, TI-83 Plus Silver Edition, TI-86, TI-89, TI-92, TI-92 Plus, and Voyage 200 PLT versions support all of the DataMate functions.
- The TI-83 version of DataMate supports all of the functions except SAVE/LOAD.
- The TI-73 version of DataMate supports all of the functions except SAVE/LOAD and ADD MODEL.

- The TI-82 version of DataMate supports only auto-ID sensors: temperature, light, voltage, and the CBR™ device or the new Vernier Software and Technology (Vernier) motion detector. It supports all of the functions except SAVE/LOAD, SELECT REGION, ADD MODEL, and ANALYSIS.

See page 5 for instructions on using the DataMate software.

Sensors

Three sensors are provided with the CBL 2™ (stainless steel temperature, TI light, and TI voltage), and many other available sensors can be used with CBL 2, including the CBR and the following Vernier sensors:

CBL™ Motion Detector	Pressure Sensor
CBL Microphone	Thermocouple
Digital Control Unit	Colorimeter
Dual-Range Force Sensor	Conductivity Sensor
Student Force Sensor	Ion-Selective Electrodes (NO_3^-, Cl^-, Ca^{2+}, NH_4^+)
Flow Rate Sensor	Ion-Selective Electrode Amplifier
Magnetic Field Sensor	Instrumentation Amplifier
Turbidity	Student Radiation Monitor
Low-g Accelerometer	CO_2 Gas Sensor
25-g Accelerometer	O_2 Gas Sensor
3-Axis Accelerometer	Dissolved Oxygen Sensor
Extra Long Temperature Sensor	Biology Gas Pressure Sensor
Current/Voltage Sensor System	Gas Pressure Sensor
Vernier Photogate	Respiration Monitor Belt
Direct-Connect Temp Sensor	EKG Sensor
Stainless Steel Temp Sensor	Exercise Heart Rate Monitor
Relative Humidity Sensor	Heart Rate Monitor
pH Sensor	Barometer

Note: For updated lists of available sensors, see the web site for Vernier Software and Technology at www.vernier.com.

Sensors are attached to CBL 2 though input or output connections called *channels*. CBL 2 has three analog channels (CH1, CH2, CH3) and one other channel (DIG/SONIC) that can be used for ultrasonic motion detector or digital inputs and outputs.

When using DataMate, the auto-ID feature on the CBL 2 allows the unit to automatically identify specific sensors when you connect them to the unit. When you connect an auto-ID sensor to a channel, CBL 2 detects the sensor, loads calibration factors and a default experiment, and shows the channel number and sensor type in the calculator display. Auto-ID sensors include the stainless steel temperature, TI voltage, and TI light sensors included with the CBL 2, as well as the CBR and the Vernier motion detector. (Additional Vernier auto-ID sensors are planned.)

Sensors that are not auto-ID can also be used with CBL 2™ by selecting the sensor type from a list of sensors in DataMate.

Note: Technical specifications of TI sensors (including chemical tolerance) are provided in the CBL 2 Technical Reference document available on the TI web site and the Resource CD.

Getting Started

Before you begin working with the CBL 2 system and the DataMate software, you must connect the CBL 2 and your calculator and transfer the software from CBL 2 to your calculator.

Put the Pieces Together

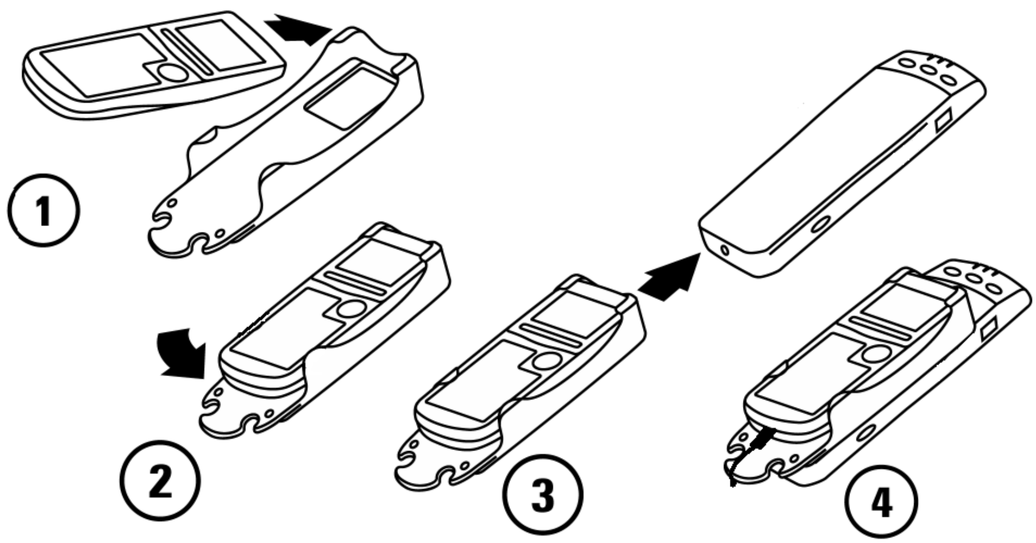


Figure 2. Connecting CBL 2 to a Calculator

1. Insert the upper end of the calculator into the cradle.
2. Press down on the lower end of the calculator until it snaps in place.
3. Slide the back of the cradle onto the front of the CBL 2 until it clicks in place.
4. Plug one end of the 6-inch unit-to-unit link cable into the I/O port in the end of the CBL 2, and plug the other end of the cable into the I/O port in the end of the calculator.

   The cradle cannot be used with the TI-92, TI-92 Plus, or Voyage™ 200 PLT. Attach these calculators using a unit-to-unit cable.

Transfer DataMate to the Calculator

DataMate comes already loaded on your CBL 2. When transferring DataMate from CBL 2 to the calculator, the CBL 2 automatically detects which calculator is attached and transfers the appropriate version of DataMate.

To transfer DataMate to a TI-83 Plus and TI-83 Plus Silver Edition calculator, follow these steps:

1. Connect the calculator to CBL 2™ with the unit-to-unit link cable.
2. Put the calculator in Receive mode. (For the TI-83 Plus and TI-83 Plus Silver Edition, press [2nd] [LINK] [▸] [ENTER].)
3. Push **TRANSFER** on CBL 2. The program/app is transferred and appears in the calculator's program list or application list.
4. When the transfer is complete, press [2nd] [QUIT] on the calculator.
   See steps 4 and 5 on page vi for the TI-73, TI-82, TI-83 Plus, and TI-83 Plus Silver Edition instructions.

Note: DataMate on the TI-89, TI-92 Plus, and Voyage™ 200 PLT is transferred in three segments/files, but only one will display in the App menu. All three segments are necessary for DataMate to run on these units.

Getting Started with DataMate

This section of the User Guide explains the procedures for using DataMate. The instructions were written with the DataMate app for TI-83 Plus and show TI-83 Plus screen examples. (See page 2 for information about the differences between DataMate programs/apps for the various TI graphing calculators.)

The basic steps for conducting an experiment with CBL 2, sensor(s), and a TI graphing calculator are:

1. Connect the sensor(s) to the CBL 2 system, connect CBL 2 and your calculator, and run the DataMate program or App. (See the next section, Start the DataMate App.)
2. Select the data collection mode, if necessary. (CBL 2 contains default experiment settings for most sensors.) (See page 9.)
3. Collect the data. (See page 12.)
4. Graph the data. (See page 13.)

In addition, DataMate allows you to calibrate some sensors, make changes to graphs, and analyze collected data with pre-programmed options. Procedures for all of these tasks are given on the following pages.

It is not necessary to have a calculator connected to the CBL 2 to collect data. The Quick Set-Up feature on the CBL 2 allows you to collect data without having a calculator connected to the CBL 2. You can then transfer the data to your calculator for graphing and analysis. The Quick Set-Up procedure is explained on page 16.

Special Use Calculator Keys

In addition to the keystrokes shown on the DataMate screens, two calculator keys have special uses in DataMate:

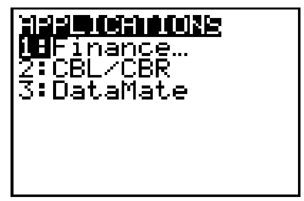
- Press [CLEAR] on the DataMate Main Screen or the Setup screen to restore DataMate's default settings. For example, if the sensor setup and/or data collection mode setting are not what you expect, press [CLEAR] to reset them.
- Press [STO▸] while collecting data to stop data collection.

Start the DataMate App

Note: If you are using the TI-73, TI-82 or TI-83, it is recommended that you remove any non-DataMate programs from the calculator before loading DataMate. See step 3 on page vi.

1. Connect the CBL 2™ to the calculator.

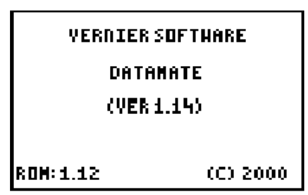
2. Press [APPS].



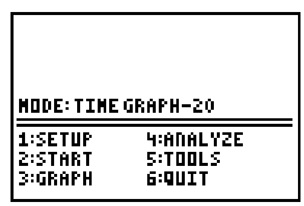
3. Press [▼] if needed to move the cursor to **DATAMATE** and press [ENTER].

The DataMate title screen displays.

This screen shows both the DataMate program version number (VER 1.14 in the example) and the operating system version number (ROM: 1.12 in the example).



Then the Main Screen appears.

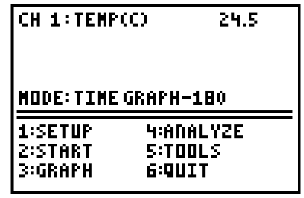


Connect a Sensor to the CBL 2 System

1. Connect the sensor to the appropriate channel.

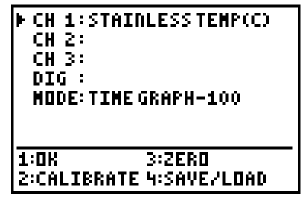
Note: When connecting sensors to analog channels, you should use the channels in numerical order. In other words, connect the first sensor to channel 1 (CH1), the second sensor to channel 2 (CH2), and the third sensor to channel 3 (CH3). If you are using only one sensor, it should be connected to channel 1.

2. If the sensor is auto-ID, the channel number and sensor type automatically display on the Main Screen. Go to

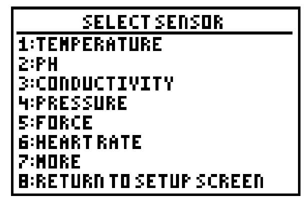


3. Select the Data Collection Mode on page 9.
   or
   If the sensor is *not* auto-ID, follow the steps below to tell the CBL 2™ that the sensor is connected.

4. On the DataMate Main Screen, press [1] SETUP.



5. Press [▼] as needed to move the cursor to the channel to which the sensor is connected. Press [ENTER]. A list of sensors appears.



5. If the sensor you want is not on the list, press [7] MORE to see more choices. (The list covers several screens.)

6. Press the number beside a sensor to choose that sensor.

Note: Some sensors, such as accelerometer or pressure, display another screen and require you to select a particular sensor, preferred unit of measure, or calibration.

7. When you finish choosing sensors, press [1] OK to return to the Main Screen.

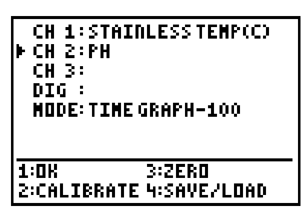
Calibrate a Sensor (optional)

When a sensor is selected, DataMate automatically loads the default calibration settings. Although it is not necessary, if you choose to calibrate a sensor, use the following procedure.

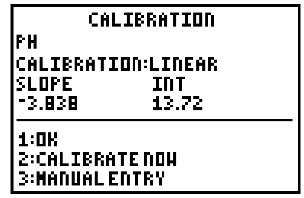
There are two ways to calibrate a sensor. The first way is to monitor the voltage until it is stable and enter that value; the second way is to manually enter the values. You will need to consult the sensor literature for proper calibration procedures. The examples below show calibration for the pH sensor.

To calibrate the pH sensor by monitoring the voltage, you will need two solutions with known pH values; for example, buffer solutions with values of 4 and 10. Follow these steps:

1. On the Main Screen, press [1].



2. Press [▼] as needed to move the cursor to the sensor you want to calibrate. Press [2] CALIBRATE.



Note: Not all sensors can be calibrated. If you select a sensor that cannot be calibrated, DataMate does not respond when you press [2] CALIBRATE.

3. Press [2] CALIBRATE NOW.

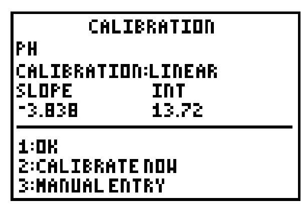
4. Put the pH sensor in the 4 buffer solution. Watch the screen until the voltage number stabilizes and then press [ENTER].

5. Key in the value of the buffer solution.
6. Repeat steps 3 and 4 for the 10 buffer solution.
7. Press [1] OK to return to the Setup screen.

Note: Refer to the documentation provided with your sensor for calibration procedures and default calibration values.

You can also calibrate the pH sensor by entering values. This procedures is used if a full calibration has been done previously and you want to manually input the new slope and intercept values. Follow these steps:

1. On the Setup screen, press [▼] as needed to move the cursor to the sensor you want to calibrate. Press [2] CALIBRATE NOW.



2. Press [3] MANUAL ENTRY.

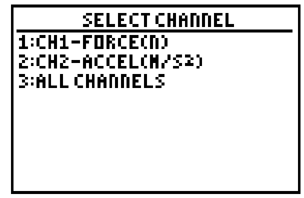
3. Key in the slope and press [ENTER].

4. Key in the intercept and press [ENTER]. The Calibration screen is displayed with the new values.

5. Press [1] OK to return to the Setup screen.

Zero a Sensor (optional)

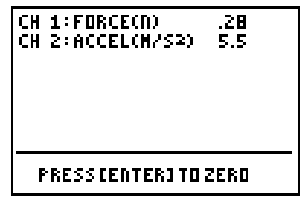
1. On the Setup screen, press [3] ZERO. The Select Channel screen appears.



Note: Not all sensors can be zeroed (for example, temperature probes and light probes). DataMate displays only the sensors that can be zeroed.

2. Press the number beside the sensor you want to zero. A screen appears showing the current reading(s) for the selected sensor(s).

   (In this example, [3] ALL CHANNELS was pressed, so both sensors are selected.)



3. Press [ENTER] to zero the sensor(s). The Main Screen appears.

Note: The new calibrations and zeros are not retained after quitting DataMate. They are only valid during the current session. Also, new calibrations and zeros can be reset to defaults during the current session by going to the Main Screen and pressing [CLEAR].

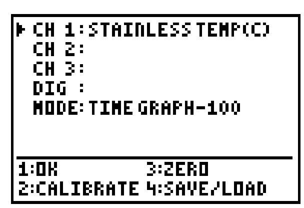
Select the Data Collection Mode

For each sensor from Vernier, DataMate loads a default experiment (data collection mode) appropriate for the sensor. The default data collection mode for all sensors is Time Graph (collecting data points at a predetermined rate). For a description of each of the data collection modes, see Select Mode screen on page 27.

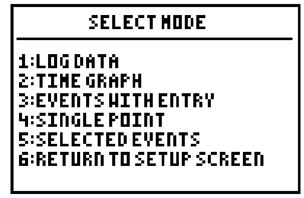
Note: If you close the DataMate program and then re-open it, the mode setting will be the same as when you closed it. However, if you exit DataMate in some other manner, the mode setting may be different when you re-open it. Or, you may open DataMate and find mode and sensor settings that are "left over" from a previous experiment. In any case, press [CLEAR] to return the mode and sensor settings to the default.

To change the data collection mode, follow the steps below.

1. On the DataMate Main Screen, press [1] SETUP.



2. Press [▲] or [▼] as needed to move the cursor to MODE and press [ENTER]. A list of data collection modes appears.



3. Press the number beside the mode you want.

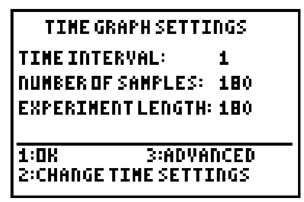
Note: If you choose Time Graph mode, another screen appears allowing you to choose the time interval between samples and the number of samples that you want. See Change Time Graph Settings below for instructions.

4. Press [1] OK twice to return to the Main Screen.

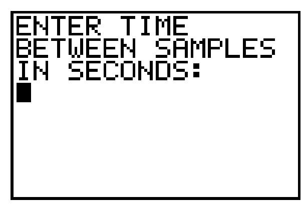
Change the Time Graph Settings (optional)

If you choose Time Graph on the Select Mode screen, the Time Graph Settings screen appears. Each sensor has a default time interval between samples (in seconds) and default number of samples (data points). To change the settings from the default, follow the steps below:

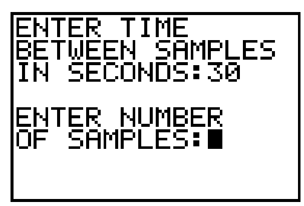
If you press [2] TIME GRAPH on the Select Mode screen, the Time Graph Settings screen appears.



1. Press [2] CHANGE TIME SETTINGS.



2. Key in the time interval between samples (in seconds) and press [ENTER].



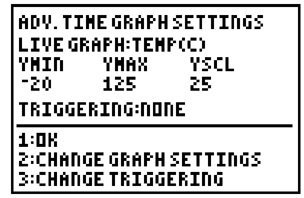
3. Key in the number of samples and press [ENTER]. The Time Graph Settings screen is displayed again. (EXPERIMENT LENGTH in seconds is calculated automatically.)

4. Press [1] OK to exit. The Setup screen appears.
   or
   Press [3] ADVANCED to change the advanced settings. (See Change the Advanced Time Graph Settings for instructions.)

Change the Advanced Time Graph Settings (optional)

DataMate contains default time graph settings for each sensor. You can change the "window" in which the collected data is graphed, and you can change the type of triggering used in the experiment.

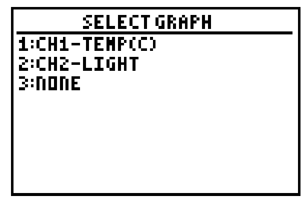
Follow the steps below to change advanced time graph settings:



If you press 3 ADVANCED on the Time Graph Settings screen, the Advanced Time Graph Settings screen appears.

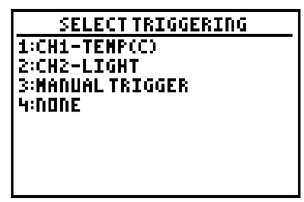
YMIN and YMAX refer to the "window" in which the collected data is graphed. YMIN refers to the lower bound of the graph, and YMAX refers to the upper bound of the graph. The YMIN and YMAX values shown on the screen are the default range of the sensor in channel 1. (This will vary depending on the sensor being used. For example, for the Temperature sensor, the range is -20 to 125.)

1. To change the window range to be graphed, press 2 CHANGE GRAPH SETTINGS.
   A list of the connected sensors appears.



2. Press the number beside the sensor you want.
3. To change the type of triggering, press 3 CHANGE TRIGGERING.

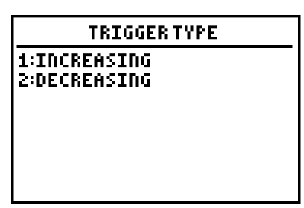
   In the example shown, there are two types of triggering:
   - For option 1 or 2, the CBL 2™ will trigger the start of data collection based on a change in the data being collected. (This is called threshold triggering.)
   - For option 3, MANUAL TRIGGER, the CBL 2 will start collecting data when the START/STOP button is pressed.
   - For option 4, NONE, no special triggering will be set.



4. Press the number beside the type of triggering you want.

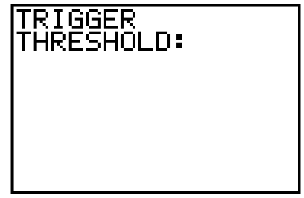
   If you select NONE, the Advanced Time Graph Settings screen appears.
   or
   If you select MANUAL TRIGGER, the triggering option is changed and the Advanced Time Graph Settings screen appears.
   or

   If you select threshold triggering, DataMate asks you to choose the trigger type.
   - INCREASING means that the values of the data being collected (such as light intensity or temperature) will be increasing.



- DECREASING means that the values of the data being collected will be decreasing.

5. Press the number beside the trigger type you want.



6. Key in the number (the threshold) at which you want data collection to begin and press [ENTER]. (Put in a threshold value in the units of the sensor you are using such as °C for temperature or Newtons for force.)

   When the values of the data being collected reach this number, CBL 2™ will begin storing data.

7. Key in the number (percent) of data you want the CBL 2 to prestore and press [ENTER]. The Advanced Time Graph Settings screen appears.

   "Prestore" is the amount of data collected before the threshold was reached that you want to keep (10 percent, 20 percent, and so on). From the time the experiment begins until the threshold is reached, CBL 2 collects data in its "buffer." When the threshold is reached, CBL 2 begins storing the data it is collecting and discards the data it collected before the threshold was reached unless a prestore value is entered.

8. Press [1] OK to exit the screen.

9. Press [1] OK again to return to the Setup screen.

Collect the Data

To start your experiment, press [2] START on the DataMate Main Screen. The CBL 2 begins collecting data according to the data collection mode you have set.

See page 27 for a description of the data collection modes.

When you finish collecting data, the Graph Menu screen is displayed. See Graph the Data below for more information.

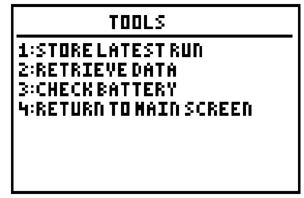
Note: In Time Graph mode, the data from CH1 is automatically graphed in REALTIME when you press [2]. Values are shown in the upper right corner of the screen as the data is plotting.

Store Latest Run

When you are collecting data with only one sensor, you can store two "active" data runs on the calculator. This allows you to view and compare data from three runs.

1. After you collect data, press [5] TOOLS on the DataMate Main Screen.

   DataMate places the data from your first run in List 2 (L2) of the calculator.



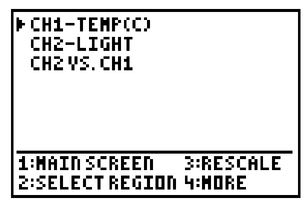
2. Press [1] STORE LATEST RUN. The Main Screen displays.

   The data that you just collected in List 2 is moved to List 3 of the calculator so that new data can be collected in List 2. You can store up to two runs. (If you store a second run, the data in List 3 is moved to List 4, the data is List 2 is moved to List 3, and new data is collected in List 2.)

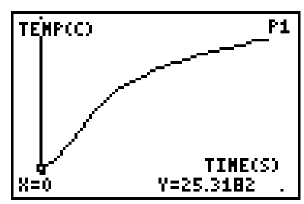
Graph the Data

1. If you have multiple sensors attached to the CBL 2™, the Graph Menu screen displays automatically when you finish collecting data.

Note: If you have only one sensor attached to the CBL 2, the graph itself displays.



2. Press [▲] or [▼] as needed to move the cursor to the channel/data you want to view as a graph and press [ENTER].



3. To view another graph, press [ENTER]. The Graph Menu screen appears again, and you can choose another channel.

4. If you want to change the region of the graph being displayed, go back to the Graph Menu screen and press [2] SELECT REGION.
   or
   If you want to change the graph scale, go back to the screen in which you see your graph and press [3] RESCALE. The Rescale Graph screen appears.
   or
   If you are finished viewing graphs, go back to the Graph Menu screen and press [1] MAIN SCREEN.

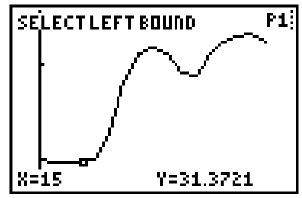
Select Region (optional)

In addition to viewing the whole graph, DataMate lets you select and view a portion of your graph.

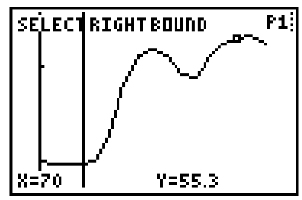
Note: If you select a region, only the data within the region is kept in the calculator. All of the data outside the region is deleted from the calculator memory. However, the entire data set is still stored in the CBL 2™ and can be retrieved at any time. (For instructions on how to retrieve data, see steps 5-9 on page 16.)

To view a portion or “region” of your graph, follow these steps:

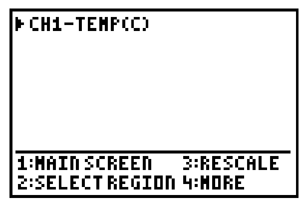
1. On the Graph Menu screen, press [2] SELECT REGION.



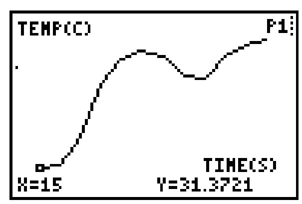
2. Change X and Y at the bottom of the screen by pressing [◄] or [►] to move the cursor to the point on the graph that you want for the left side of the graph. Press [ENTER].



3. Press [◄] or [►] to move the cursor to the point on the graph that you want for the right side of the graph and press [ENTER]. The Graph Menu appears.



4. Press [ENTER] to show the new graph.

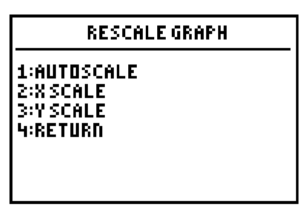


5. When you finish viewing the graph, press [ENTER]. The Graph Menu appears.

Rescale Graph (optional)

DataMate makes it easy to rescale the graph of your data. You can select AUTOSCALE, X SCALE, or Y SCALE. Follow the steps below to rescale a graph:

1. On the Graph Menu screen, press [3] RESCALE.



2. Press the number beside the scale you want to change.

Note: If you choose AUTOSCALE, DataMate scales the graph window to best fit the data you collected. If you choose X SCALE or Y SCALE, DataMate prompts you to key in the Xmin and Xmax or Ymin and Ymax, respectively (the upper and lower boundaries of your scale).

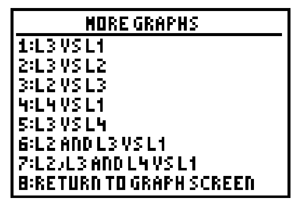
3. To see the graph with other scale options, press [ENTER] to return to the Rescale Graph screen and then select another scale.
4. When you finish viewing the graphs, press [ENTER] to return to the Rescale Graph screen, and then press [4] RETURN to go to the Main Screen.

More Graphs (optional)

DataMate gives you additional options for graphing and comparing the data you collected. For example, by choosing option 2 on the More Graphs screen, you can see a graph of the data stored in List 3 (L3) versus the data stored in List 2 (L2). To select more graphs to see, follow these steps:

1. On the Graph Menu screen, press [4] MORE.

   L1, L2, L3 and L4 refer to the lists in which your data is stored. For example, L3 VS L1 will graph the data is List 3 versus the data in List 1.



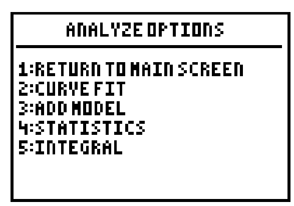
2. Press the number beside the graph you want to see.
3. To view additional graphs, repeat steps 1 and 2.

Analyze the Data

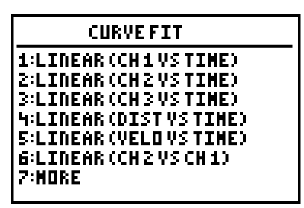
You can use the calculator's built-in regression models and statistics features to analyze the data. Follow the steps below to select these options:

1. On the DataMate Main Screen, press [4] ANALYZE.

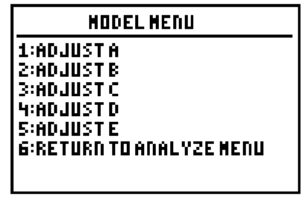
   The options for analyzing your data are explained in the following paragraphs.



   Option 2 CURVE FIT, displays a list of regression models from which to choose. When you choose a regression model, the calculator determines the line or curve of best fit and then gives you the option to scale the regression to your data.



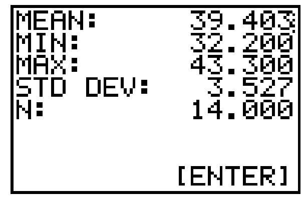
Option 3 ADD MODEL, allows you to create your own regression model.



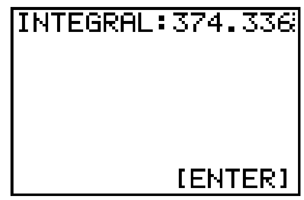
To use this option, you must first enter your equation in the **Y=** editor of your calculator *before* starting DataMate. For example, if you know the data you will collect is linear, you can enter *y=ax+b*. When you choose ADD MODEL, you can change the *a* and *b* coefficients until your own model fits the data to your satisfaction.

Note: This option is unavailable in DataMate for TI-73 and TI-82.

Option 4 STATISTICS, asks you to select the channel/data, then select left and right bounds. The one-variable statistics for the data display on the screen.



Option 5 INTEGRAL, asks you to select the graph, then select left and right bounds. The integral for the graph region display on the screen.



2. Press the number beside the option you want:
3. When you finish, press [ENTER]. The Analyze Options screen appears.

Collect Data with Quick Set-Up

Quick Set-Up is used to collect data without a calculator connected to the CBL 2™ system. In this mode only auto-ID sensors, CBR™, and the new Vernier auto-ID sensors can be used.

Up to four sensors can be used at the same time, and CBL 2 samples at default rates pre-set in DataMate. Data will be taken continuously and stored in memory.

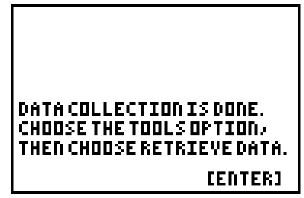
To collect data with the Quick Set-Up feature of the CBL 2:

1. Connect the auto-ID sensor(s) to CBL 2.
2. Press **QUICK SETUP**. The unit deletes any data in memory and checks for attached auto-ID sensors. It sets up the channel(s) to collect data automatically. When the yellow light flashes, it is ready to begin collecting data.
3. Press **START/STOP**. The green light flashes to show that CBL 2 is collecting data.
4. When the CBL 2 finishes collecting data, it stops.
   or
   If you want to stop collecting data before the CBL 2 finishes, press **START/STOP**. (The maximum number of data points that will be collected in this mode is 99.)

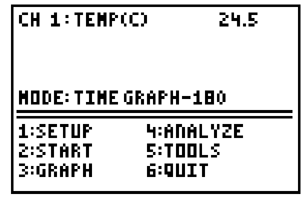
Next, transfer the data from CBL 2™ to your calculator:

5. Connect the calculator to CBL 2 with the cable.

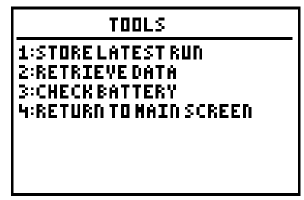
6. On the calculator, run the DataMate program or app.



7. Press [ENTER].



8. Press [5] TOOLS.



9. Press [2] RETRIEVE DATA. The program retrieves the data from the CBL 2 memory.

You can now graph this data from within the DataMate program or exit the program and use the plot feature of the calculator.

Save and Retrieve Experiments

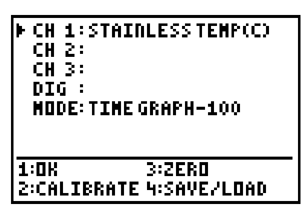
Some versions of DataMate allow you to save experiments in the CBL 2 system's *FLASH* memory, recall them later, and delete them when you no longer need them. You can save your experiment set-ups: sensor selections, data collection mode, calibrations, graph settings, and so forth, as well as any data you have collected.

Note: This option is available in DataMate for TI-83 Plus, TI-83 Plus Silver Edition, TI-86, TI-89, TI-92, TI-92 Plus, and Voyage™ 200 PLT. Screens shown in this section are from the TI-83 Plus.

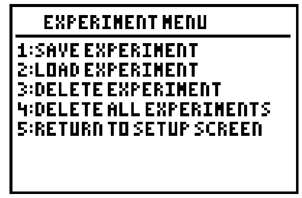
Save an Experiment

If you have entered the setting for an experiment but have not collected data, only the settings are saved. If you have entered the settings and collected data, both the settings and the last run of data are saved. Follow the steps below to save an experiment:

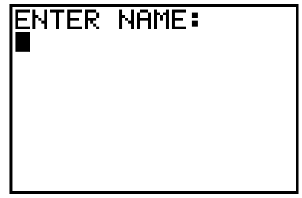
1. On the DataMate Main Screen, press [1] SETUP.



2. Press [4] SAVE/LOAD.



3. Press [1] SAVE EXPERIMENT.



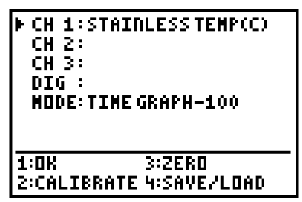
4. Key in a name (up to 20 alphabetic and/or numeric characters) and press [ENTER]. The experiment is saved, and the Experiment Menu is displayed again.

Note: Each experiment file must have a unique name (for example, temp1, temp2, and so forth). The CBL 2™ cannot distinguish between files with the same name. All files are displayed in the order in which they were saved.

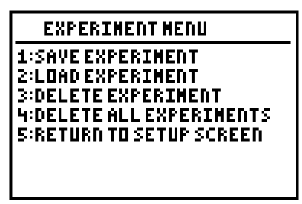
Load an Experiment

To re-load an experiment from the CBL 2™ system's *FLASH* memory, follow these steps:

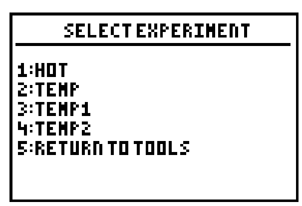
1. On the DataMate Main Screen, press [1] SETUP.



2. Press [4] SAVE/LOAD.



3. Press [2] LOAD EXPERIMENT.



4. Press the number beside the experiment you want. The experiment loads, and the Main Screen appears.

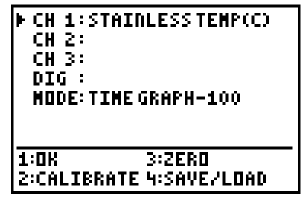
Note: Only one experiment file can be loaded at any one time.

Delete an Experiment

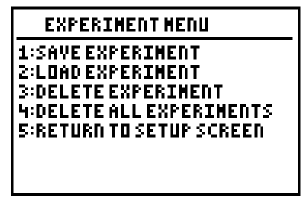
Experiment files stored in the CBL 2™ system's *FLASH* memory appear in the order in which they are stored. New experiments are added one after another. To make the best use of memory, you should delete files when they are no longer needed.

Follow these steps to delete an experiment:

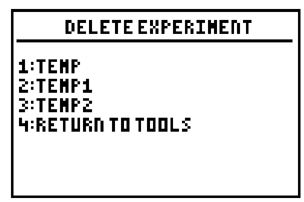
1. On the DataMate Main Screen, press [1] SETUP.



2. Press [4] SAVE/LOAD.



3. Press [3] DELETE EXPERIMENT.

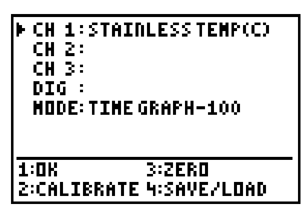


4. Press the number beside the experiment you want to delete. (*CAUTION: Deleted files cannot be retrieved!*) The experiment is deleted, and the Experiment Menu appears.

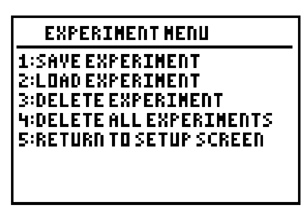
Delete All Experiments

In addition to deleting one experiment at a time, you can delete all the experiments that you have stored. To delete all experiments at the same time, follow these steps:

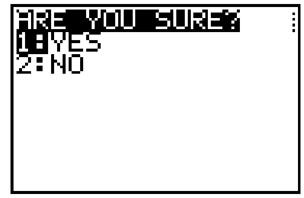
1. On the DataMate Main Screen, press [1] SETUP.



2. Press [4] SAVE/LOAD.



3. Press [4] DELETE ALL EXPERIMENTS.



4. Press [1] to delete all experiments. The experiments are deleted, and the Setup screen appears.

Using the CBL 2™ System with Other Programs

The CBL 2 system works with most of the existing CBL™ programs with no changes or only minor changes.

- The TI CBL programs in the Explorations™ activity books.
- TI programs from the TI web site **education.ti.com**.
- Programs that you create.

Follow the instructions in the activity books or on the web site to copy programs to your calculator. Then do the experiment as directed.

Appendix B contains a quick reference guide for the CBL 2 commands. If you want to create your own programs for CBL 2, we encourage you to consult the Technical Reference document on the Resource CD or the TI web site for detailed explanations and additional information on the commands.

Storing and Retrieving Programs with DATADIR

The DATADIR program allows you to store programs in the CBL 2 system's *FLASH* memory and then later retrieve them to your calculator. (This is like having an "external hard drive" for your calculator.) The CBL 2 has approximately 400K of *FLASH* memory available for storing experiment files and programs.

The DATADIR program is available on the TI Resource CD and on the TI web site at **education.ti.com**.

To store and retrieve programs, the CBL 2 must be connected to a TI graphing calculator.

Start the DATADIR Program

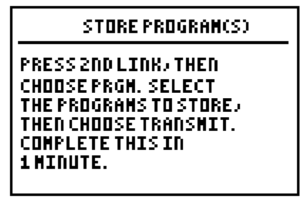
1. Press [PRGM].
2. Press [▼] to move the cursor to **DATADIR** and press [ENTER].

3. Press [ENTER] again to confirm your choice.
An introductory screen appears briefly, then the main menu displays.

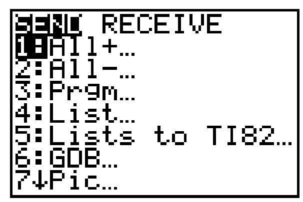
Store a Program

The program(s) you want to store must be on your calculator. You can store one program or several programs at the same time. Follow the instructions below:

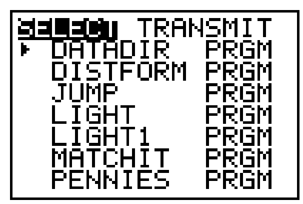
1. On the Directory Main Menu, press [2] STORE PROGRAM.



2. Press [2nd] [LINK].

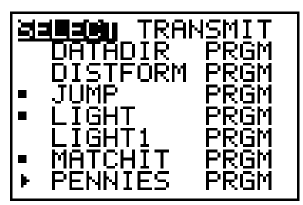


3. Press [3] Prgm.

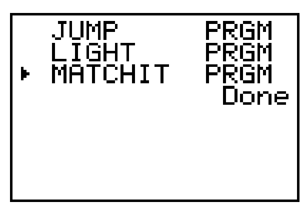


4. Press [▼] to move the cursor to the program you want to store and then press [ENTER]. A dot appears beside the program name.

   Repeat this instruction until you have selected all the programs you want to store.



5. Press [▶] to highlight **TRANSMIT** and press [ENTER]. When the program(s) have been stored, the calculator displays the message **Done**.



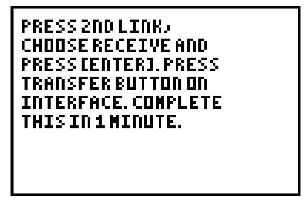
Note: The calculator exits the DATADIR program to make the transfer. Run the DATADIR program again to see the results of the transfer.

Retrieve a Program from Storage

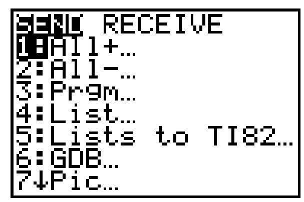
The DATADIR program also allows you to retrieve a program from storage in the CBL 2™ to your calculator. Although you can store several programs at once, you can retrieve only one at a time. The following instructions will guide you through this task:

1. On the Directory Main Menu, press [1] LOAD A PROGRAM.

2. Press the number beside the program you want to load and follow the instructions on the screen, as shown in steps 3-5 below.



3. Press [2nd] [LINK].



4. Press [▸] to highlight **RECEIVE** and press [ENTER].
5. When the calculator screen displays WAITING, press **TRANSFER** on the CBL 2. When the program has been loaded on the calculator, the calculator displays the message **Done**.

Note: The calculator exits the DATADIR program to make the transfer.

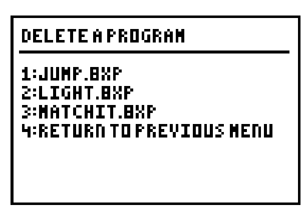
Delete a Program from Storage

The DATADIR program provides two options for deleting programs from storage. You can delete a single program (option 3) or you can delete all the programs that are stored on the CBL 2 (option 4).

Note: Deleting all programs will NOT delete the DataMate programs/Apps.

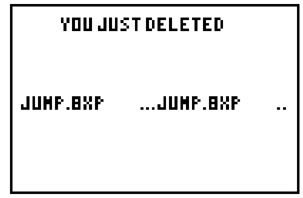
Follow these instructions to delete a single program that you have stored on the CBL 2:

1. On the Directory Main Menu, press [3] DELETE A PROGRAM.



2. Press the number beside the program you want to delete.

   The Directory Main Menu appears.



Follow these instructions to delete ALL the programs that you have stored on the CBL 2™:

1. On the Directory Main Menu, press [4] DELETE ALL PROGRAMS.
2. The programs are deleted and the Directory Main Menu appears.

Check Memory

The DATADIR program also allows you to check available memory space on the CBL 2. Follow the directions below to check memory:

1. On the Directory Main Menu, press [5] CHECK MEMORY.

2. When you finish viewing the screen, press [ENTER].

   The Directory Main Menu appears.

Collect Garbage

The DATADIR program allows you to optimize the available memory on the CBL 2.

1. On the directory main menu, press [6] COLLECT GARBAGE.
2. After completion, the program will return to the main menu.

Exit the DATADIR Program

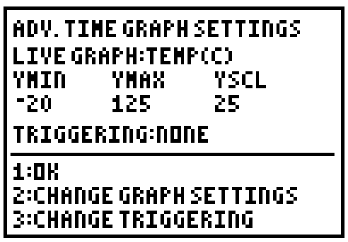
On the Directory Main Menu, press [7] QUIT.
The calculator displays the message **Done**.

DataMate Screen Reference

This section of the user guide shows the major screens in DataMate. Individual screens are shown, along with an explanation of each screen's options.

This section is meant to be used as a reference, so the screens are arranged in alphabetical order by screen name to make it easier to find a particular screen.

Advanced Time Graph Settings (option 3 on the Time Graph Settings screen)

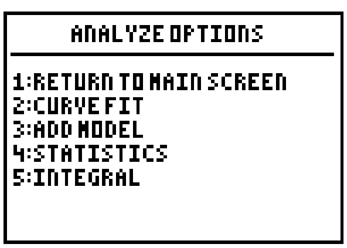


The top part of the screen shows two fields: Live Graph and Triggering. The bottom part lists the menu options.

The YMIN and YMAX values under Live Graph refer to the lower and upper boundaries, respectively, of the "window" in which the collected data is shown. The values shown on the screen are the default range of the sensor in channel 1. (In this example, it is the stainless steel temperature sensor.)

1:	OK	Returns to the Time Graph Mode screen.
2:	CHANGE GRAPH SETTINGS	Allows you to change the minimum and maximum of the y-axis and the y scale values for the graph displayed during live-graph data collection.
3:	CHANGE TRIGGERING	Allows you to change the trigger levels that start the data collection.

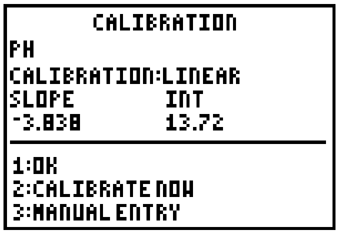
Analyze Options (option 4 on the Main Screen)*



1:	RETURN TO MAIN SCREEN	Exits the Analyze Options screen.
2:	CURVE FIT	Allows you to select regression models for the data.
3:	ADD MODEL	Allows you to create a new regression model for the data.
4:	STATISTICS	Allows you to determine one-variable statistics for a selected region of data.
5:	INTEGRAL	Allows you to determine the integral for a selected region.

*This option is not available on the TI-82 version of DataMate.

Calibration (option 2 on the Setup screen)

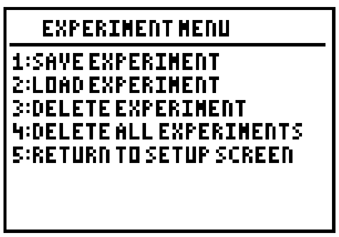


From this screen you calibrate a sensor in either of two ways. The first way is a two-point calibration; the second way is to manually enter slope and intercept values.

Note: Not all sensors can be calibrated. If you select a sensor that cannot be calibrated, DataMate does not display this screen.

1:	OK	Saves the changes and returns to the setup screen.
2:	CALIBRATE NOW	Allows you to select a two-point calibration method.
3:	MANUAL ENTRY	Allows you to key in known calibration values.

Experiment Menu (option 4 SAVE/LOAD on the Setup screen)

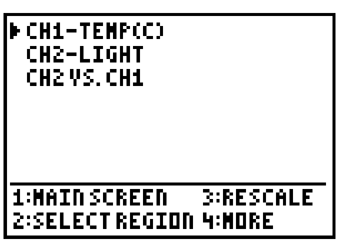


Note: If you have set up your experiment but have not collected data, this option saves the settings. If you have both settings and data, it saves both. However, only the current run of data is saved; previous runs of data that you may have stored will not be saved.

This screen is available in DataMate for TI-83 Plus, TI-83 Plus Silver Edition, TI-86, TI-89, TI-92, TI-92 Plus, and Voyage™ 200 PLT.

1:	SAVE EXPERIMENT	Saves the experiment to CBL 2™ *FLASH* memory.
2:	LOAD EXPERIMENT	Reloads an experiment from CBL 2 *FLASH* memory.
3:	DELETE EXPERIMENT	Deletes an experiment from CBL 2 *FLASH* memory.
4:	DELETE ALL EXPERIMENTS	Deletes all experiments from CBL 2 *FLASH* memory.
5:	RETURN TO SETUP SCREEN	Returns to the Setup screen.

Graph Menu (option 3 on the Main Screen)

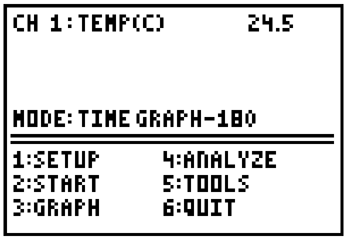


From this screen you can select the data you want to graph, select a region of the graph to view or analyze, and change the scale of the graph.

The top part of the screen shows the graphs that you can display on the screen. The bottom part lists the menu options.

1:	MAIN SCREEN	Returns to the Main Screen.
2:	SELECT REGION	Allows you to select a region of the graph. (Data outside the selected region is cleared from the graph and from the calculator lists in which the data is stored.)
3:	RESCALE	Allows you to change the graph by choosing autoscale or entering values for x-scale or y-scale.
4:	MORE	Displays additional graphing options.

Main Screen



The top part of the Main Screen shows the current sensor setup and data collection mode. The bottom part lists the menu options.

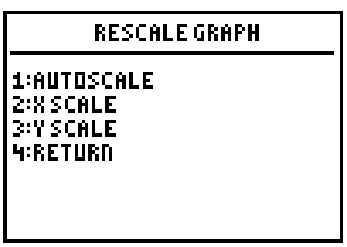
1:	SETUP	Select sensors, data collection mode, calibrate sensors, and manage experiment files.
2:	START	Begin collecting data.
3:	GRAPH	Select and view a graph of the data from the experiment.
4:	ANALYZE	Select the type of analysis you want to perform with the data.
5:	TOOLS	Select a tool such as RETRIEVE DATA or CHECK BATTERY.
6:	QUIT	Exit the DataMate program.

DataMate automatically recognizes an auto-ID sensor, identifies the channel to which it is connected, loads a default experiment appropriate to the sensor, and shows the current reading. All active channels are shown, and the Main Screen is updated as auto-ID sensors are added or removed.

Sensors that are not auto-ID, such as pressure sensors and pH sensors, must be set up manually. See instructions for Connect a Sensor to the CBL 2™ on page 6.

The Main Screen defaults to “meter mode” which updates readings for active sensors every few seconds. To turn meter mode off or on, press [+] on the calculator.

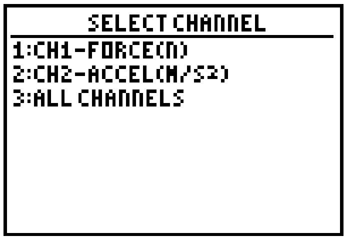
Rescale Graph (option 3 on the Graph Menu screen)



On this screen you can change the scale of the graph being rescaled.

1:	AUTOSCALE	Automatically rescales a graph to fit your data to the calculator screen (ZOOM STAT).
2:	X SCALE	Allows you to enter value(s) for the x-axis scale.
3:	Y SCALE	Allows you to enter value(s) for the y-axis scale.
4:	RETURN	Returns to the Graph Menu screen.

Select Channel [to Zero] (option 3 (ZERO) on the Setup screen)

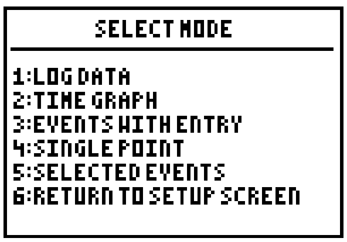


From this screen you can set one or more sensors to zero.

Note: Not all sensors can be zeroed. DataMate displays only the sensors that can be zeroed.

1:	CH1	Allows you to zero the sensor in this channel.
2:	CH. . .	Allows you to zero the sensor in this channel.
3:	ALL CHANNELS	Allows you to zero the sensors in *all* channels.

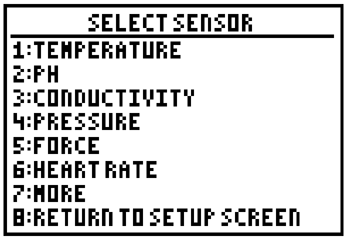
Select Mode (from the SetUp screen)



The default data collection mode for CBL 2™ is Time Graph. To change the mode, follow the steps in Select the Data Collection Mode on page 9.

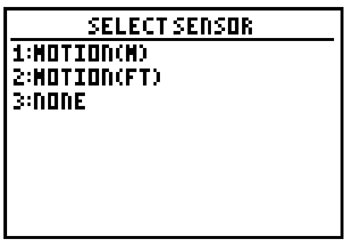
1:	LOG DATA	Asks you to start the Quick Set-Up Procedure.
2:	TIME GRAPH	Allows you to set the interval between samples and the number of data points collected. It is the default mode.
3:	EVENTS WITH ENTRY	Collects one data point each time you press [ENTER] and then asks you to correlate that data point to a numeric value. It is used for experiments such as titrations and Boyle's law.
4:	SINGLE POINT	Collects one data point per second for ten seconds and displays one averaged data point.
5:	SELECTED EVENTS	Collects one data point each time you press [ENTER] on the calculator.
6:	RETURN TO SETUP SCREEN	Returns to the setup screen.

Select Sensor (from the SetUp screen)



When you plug a non-auto-ID sensor into Channels 1-3 and select that channel on the Setup screen, DataMate displays a list of analog sensors from which you can choose.
This screen is the first of several screens.

1-6:	. . .	Tells the CBL 2™ that this sensor is attached to the selected channel.
7:	MORE	Displays the next screen of the sensor list.
8:	RETURN TO SETUP SCREEN	Returns to the Setup screen without selecting a sensor.

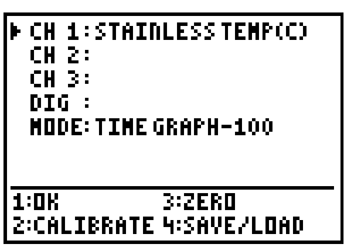


When you plug a non-auto-ID sensor into the digital channel and select that channel on the Setup screen, DataMate displays this list of motion sensors from which you can choose.

Note: Additional programs are required to run the Rotary Motion, Student Radiation, and Photogate sensors.

1:	MOTION(M)	Tells the CBL 2 that the sensor attached to this channel measures data in meters.
2:	MOTION(FT)	Tells the CBL 2 that the sensor attached to this channel measures data in feet.
3:	NONE	Returns to the Setup screen without selecting a sensor.

Setup (option 1 on the Main Screen)



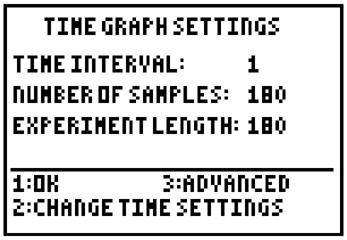
From this screen you can change the current experiment setup, including change the sensors, change the data collection mode, calibrate a sensor, set a sensor to zero, and save or load experiment files.

The top part of the screen shows the sensors that are connected to the CBL 2 channels and the current mode setting. The bottom part lists the menu options.

1:	OK	Returns to the Main Screen.
2:	CALIBRATE	Allows you to calibrate a sensor.
3:	ZERO	Sets a current sensor reading to zero.
4:	SAVE/LOAD*	Displays the Experiment Menu so you can save, reload, or delete experiment files in the CBL 2 system's *FLASH* memory.

* The SAVE/LOAD option is available only in DataMate for the TI-83 Plus, TI-83 Plus Silver Edition, TI-86, TI-89, TI-92, TI-92 Plus, and Voyage™ 200 PLT.

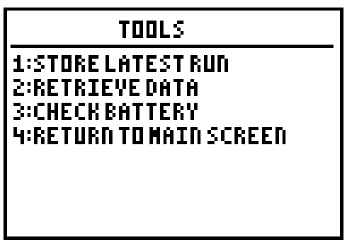
Time Graph Settings (option 2 on the Select Settings screen)



The top part of the screen shows three fields: Time Interval (the time in seconds between samples), Number of Samples, and Experiment Length (in seconds). The bottom part lists the menu options.

1:	OK	Returns to the select mode screen.
2:	CHANGE TIME SETTINGS	Allows you to change the Time Interval and Number of Samples.
3:	ADVANCED	Allows you to change graph settings and/or triggering levels.

Tools (option 5 on the Main Screen)



Options on the Tools menu allow you to perform various functions, including store data runs, retrieve data from the CBL 2™ to the calculator, and check battery status.

1:	STORE LATEST RUN	DataMate places the data from your first run in List 2 (L2) of the calculator. When you STORE LATEST RUN, this data in List 2 is moved to List 3 of the calculator so that new data can be collected in List 2. You can store up to two runs, which enables you to compare data from three runs. This option cannot be used with more than one sensor, nor can it be used with the motion sensor.
2:	RETRIEVE DATA	Retrieves to the calculator any data that is in the CBL 2 memory. This could be data collected using the CBL 2 QUICK START feature or data from your last DataMate experiment.
3:	CHECK BATTERY	Checks the CBL 2 battery level.
4:	RETURN TO MAIN SCREEN	Returns to the Main Screen.

Activity 1 – Add Them Up!!

Math Concepts

- Data collection
- Statistical plots
- Math modeling
- Multiplication as repeated addition
- Using a pattern to develop a formula

Science Concepts

- Data collection and analysis
- Measurement of electrical energy
- Batteries in series; series circuit

Materials

- CBL 2™
- TI Graphing Calculator
- 6-inch unit-to-unit link cable (or any length)
- TI voltage sensor
- 5 same size 1.5-volt batteries (for example, AA (LR6) or AAA batteries)
- Ruler with ridge down the center or any other device to hold the batteries in place

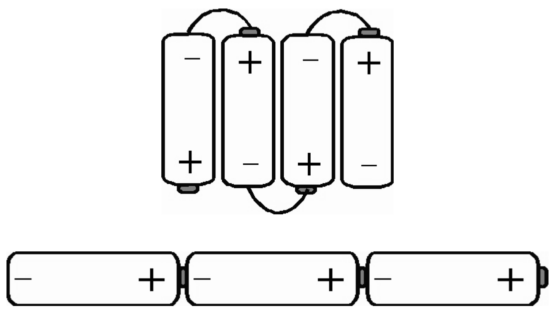
Introduction

Every day people use one or more batteries when they use a flashlight, their calculator and CBL 2, or any other battery-operated devices. Have you ever put batteries in a flashlight or your CBL 2? How much power do they get from the batteries inside?

Look on the outer jacket of your batteries. You should see a *positive terminal (+)* and a *negative terminal (–)* at the ends of the battery. You also will see the size, for example AAA, and the voltage, for example, 1.5 VOLTS.

If you look at the position of the batteries in many flashlights, you will notice that they are lined up in a column or a *series*. The batteries in the flashlight are lined up so that the positive terminal (+) touches the negative terminal (–). Observe the position of the batteries in the CBL 2. You will notice that even though the batteries are not in a row, the battery terminals alternate and there is a piece of metal connecting the positive terminals (+) with the negative terminals (–). These batteries are connected in *series* or serial arrangement (see the figure on the next page). Batteries supply electrical energy to electronic devices when a *circuit* is created. For now, think of a circuit as a path linking the positive terminal to the electronic device (the *load*) and then back to the negative terminal.

This investigation will help you explore how many total volts several batteries in series provide to battery-operated devices!



Batteries in Series

Set-up

First, you will use the CBL 2 and your calculator to measure the voltage of each of your five batteries. Next you will measure the voltage of one battery, then a series of two batteries, then three, and so on. It is recommended that you work in a group. There are three tasks that will need to be accomplished:

- Taking measurements with voltage leads.
- Operating the calculator and CBL 2.
- Positioning the batteries.

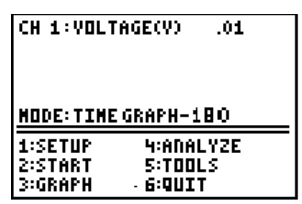
Use five batteries of the same size and voltage. It is best if you use new batteries or a set of batteries that have been used in the same device.

The batteries can be held in place using a battery holder, a ruler with a ridge down the center, or even the grout line between tiles on a table or floor.

The batteries should be lined up with a positive terminal (+) touching a negative terminal (–).

Data Collection

1. Connect the CBL 2 to your calculator using the unit-to-unit cable. Connect the voltage sensor to the CBL 2 in Channel 1 [CH 1].
2. On the calculator, run the DataMate program or app. DataMate automatically identifies the voltage sensor and loads a default experiment. The Main Screen of DataMate is shown on the right.

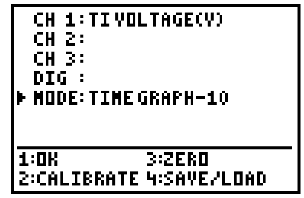
   

   (If the MODE setting is different than that shown, press CLEAR to reset the program.)
3. Place one battery in a battery holder or on a ruler. Touch and hold the appropriate voltage leads to the appropriate terminal, red to (+) and black to (–). You have now created a series circuit with the CBL 2.

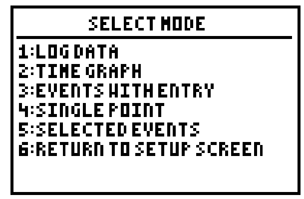
4. Read and record the voltage of each of the five batteries on the Student Data Reporting Sheet, question 1. (Notice that the voltage can be seen on the upper right hand corner of the DataMate Main Screen.)

5. Next, set up the CBL 2 to take a measurement in the mode EVENTS WITH ENTRY.

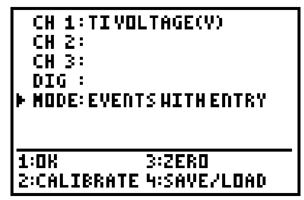
   On the Main Screen, press [1] to select SETUP.



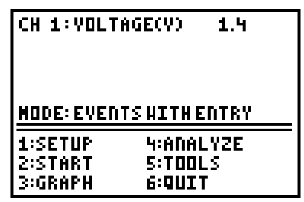
6. Press [▲] or [▼] to scroll to MODE and then press [ENTER].



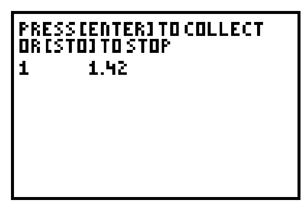
7. Press [3] for EVENTS WITH ENTRY. This means that you will record a voltage measure each time you press ENTER.



8. Now, press [1] OK.

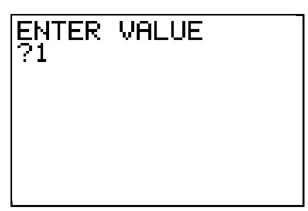


9. Press [2] START.



10. Press [ENTER] to take the first measurement of one battery. When you see ENTER VALUE?, press [1] then press [ENTER] for the first entry.

    (Each time you press [ENTER] to save a voltage, the calculator asks you to enter a value to keep track of the number of batteries.)



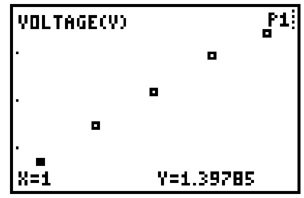
11. Now, line up two batteries in series. Again, touch the red voltage leads to the (+) terminal and the black voltage leads to the (–) terminals. Press [ENTER] to collect the voltage of the two batteries. Label this as the second entry.

12. Continue this process until all five measurements have been taken.

13. When you are through taking all of your data, press [STO▸]. You will see the graph of your data. Press [ENTER] to get to the DataMate Main Screen.

Analysis

1. From DataMate's Main Screen, press [3] GRAPH, and answer the questions 2-6 on the Student Data Reporting Sheet.



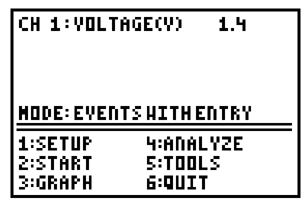
The slope of a line is the steepness of the line or the rate of change. The numerical value of the slope can be related to many physical models. In this model the slope is approximately voltage per battery. The unit of the slope in this model is voltage/battery. An equation that is often used for this linear model is called the slope-intercept form, which is:

$$Y = AX + B$$

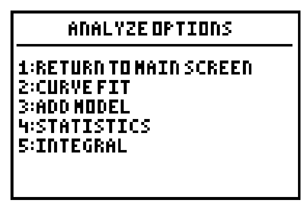
where A= the *slope* and B= the intersection of the line and the Y-axis (or the value of Y when X=0) which is also called the *Y-intercept*. You may have seen this equation written as y=mx+b, where m is the slope.

2. Answer question 7 on the Student Data Reporting Sheet.

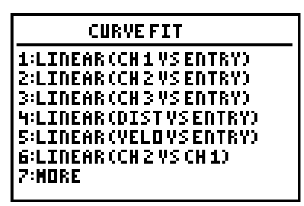
3. From the graph screen, press [ENTER], then press [1] for Main Screen.



4. Press [4] ANALYZE.



5. Press [2] CURVE FIT.



6. Press [1] LINEAR (CH1 VS ENTRY). Copy this regression information into question 8 on the Student Data Reporting Sheet.

7. Press [ENTER] to see the graph of your data and the curve fit.

8. Press [ENTER], then [1] RETURN TO MAIN SCREEN, then [6] QUIT to leave DataMate.

9. Complete questions 9 and 10 on the Student Data Reporting Sheet.

Going Further

Check to see if the slope of the Linear Regression Equation is the average of the voltage of the batteries used.

See how the voltage of the series of five batteries decreases over time by using the TIME GRAPH mode over several hours. You will need to ensure that the voltage leads are touching the battery terminals for the entire investigation.

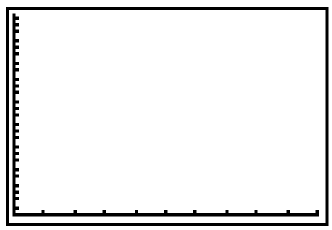
Investigate the configuration of a parallel circuit and explore the total voltage of batteries set up in parallel.

Student Data Reporting Sheet

1. Record the voltage for each of your five batteries in the table below.

Battery	1st	2nd	3rd	4th	5th
Voltage					

2. Draw the graph of the data collected from measuring the series of one battery, then two batteries, then three, and so on. Label the axes with the appropriate words.



3. If you connected the points on the graph, describe the general shape of the graph.

____

4. Press the arrow keys to trace along the data points and record your data, the voltage, in the table below:

# of Batteries X	Voltage Y
1	
2	
3	
4	
5	

5. What do you notice about the voltage measurements?

____

____

____

6. Predict the voltage of a series of six of your batteries. _______________

of 10? ____________ of 20? ______________ of X? ______________

7. If X= number of batteries and Y= the voltage, use your data to write an equation that describes the relationship of batteries to voltage.

____

Use your equation to fill in A= _____ B= _____ where Y=AX+B.

8. Record the values from the calculator when you used Curve Fit.

A= _____________ B= _____________ Y= _____________

9. For the equation of the line, Y=AX+B, A is called the __________and B is called the __________. Are the calculator values of A and B the same as your values for A and B? Write a comparison.

____

____

10. Summarize your investigation. Write a description of the total voltage a battery-operated device will receive if several batteries are lined up in a series. Include a sketch of the batteries in series.

____

____

____

____

Teacher Section

Theory

Science and Mathematics:

When batteries are lined up in series, the total voltage is the sum of the voltage of each battery. Notice that the total voltage is calculated by the repeated addition of, say, 1.4 volts. After gathering their data, students should use inductive reasoning to notice that the sequence of voltage can be generalized to 1.4X where X is the number of batteries. This gives a simple linear model of the relationship of voltage versus number of batteries.

If the batteries are approximately 1.4 volts, the linear equation should be approximately Y=1.4X + 0 where Y is the total voltage of the series and X is the number of batteries. The slope, or rate of change of the total voltage, is 1.4 volts per battery. The Y-intercept is at (0,0), no batteries, no volts. Have students write the equation using variable names that fit the problem.

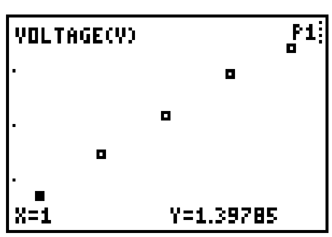
Students should compare their formula developed using their reasoning and number sense with the Linear Regression Line, Line of Best Fit (Curve Fit), calculated using the calculator. Point out that, for this simple problem, they were able to develop the model using their own reasoning skills.

Discuss with the students that they could have used (B,V) instead of variables (X,Y) to describe the model. The letters B and V may have more meaning in the physical problem. Notice that there would be confusion if they use B also for the Y-intercept in this case. Discuss this. Also, ask students how the linear equation used in the activity, Y=AX+B compares to the use of y=mx+b in their math classes. Point out that A=slope=m.

Note: If the batteries are brand new, the voltage measurement might be greater than 1.4 volts.

Answers

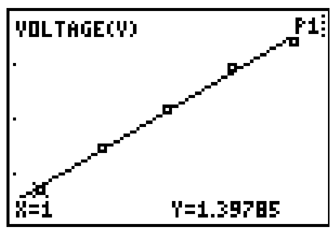
1. Answers will vary.
2. Sample graph:



3. The general shape of the graph should be a straight line if the batteries were all close to the same voltage.

4. Example: All batteries here are 1.4 volts.

# of Batteries X	Voltage Y
1	1.4
2	3.0
3	4.4
4	5.8
5	7.2

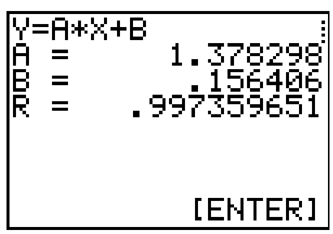


5. As you add a battery to the series, the total voltage increases by about 1.4 volts.

6. 8.6, 14, 28, 1.4X

7. Y= 1.4X, A=1.4, B=0

8. See the sample screens. Answers will vary depending on the voltage of each individual battery.



9. A = slope and B = Y-intercept. If the batteries have slightly different voltages, the value of the calculated slope will be the mean of the voltages. Responses will vary.

10. Look for the correct use of the vocabulary: *slope*, *intercept*, *terminal*, *volts*, and *series*.

Going Further

Check to see if the slope of the Linear Regression Equation is the average of the voltage of the batteries used.

See how the voltage of the series of five batteries decreases over time by using the TIME GRAPH mode over several hours. You will need to ensure that the voltage leads are touching the battery terminals for the entire investigation.

Investigate the configuration of a parallel circuit and explore the total voltage of batteries set up in parallel.

Reference

Data Collection Activities for the Middle Grades with the TI-73, CBL, and CBR: Johnston and Young; TI Explorations™ Book.

Activity 2 – Light from Afar

Math Concepts

- Graphical representation of data
- Comparing predictions to data
- Inverse square relationships
- Sources of error and their effects

Science Concepts

- Data collection and analysis
- Measurement of light and distance

Materials

- CBL 2™
- TI Graphing Calculator
- 6-inch unit-to-unit link cable (or any length)
- TI light sensor
- (Incandescent) 60 Watt light bulb and light socket
- Ruler or tape measure

Introduction

You've probably noticed that the intensity of light from a light bulb decreases as you move further away. Theoretically, the intensity of light *I* is related to the distance *d* from the light source by a function of the form:

$$I = \frac{A}{d^2}$$

where the value of the constant *A* depends on the light bulb. In this experiment you will compare theoretical predictions with actual measurements.

You will need a TI light sensor (included with the CBL 2) to measure light intensity. You can use either a tape measure or a measuring stick (a yardstick or a meter stick) to measure distance.

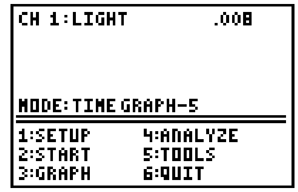
Set-up

You will need a relatively dark room. Place a bare light bulb at one end of the room with a dark background behind it. You will measure the intensity of the light from this bulb from various distances.

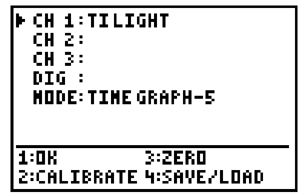
Data Collection

1. Connect the CBL 2 to your calculator using the unit-to-unit link cable. Connect the light sensor to the CH1 port on the CBL 2.

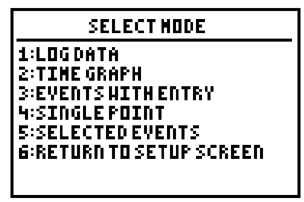
2. On the calculator, run the DataMate program or app. DataMate identifies the light sensor and loads a default experiment. The Main Screen is displayed.



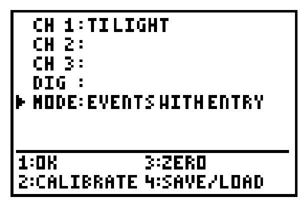
3. On the Main Screen, press [1] SETUP.



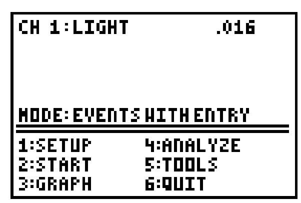
4. Use [▲] or [▼] to scroll to MODE and press [ENTER]. The Select Mode screen appears.



5. Press [3] to select EVENTS WITH ENTRY. The Setup screen is displayed again.



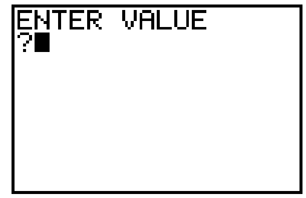
6. Press [1] to select OK to return to the Main Screen.



7. Press [2] START. You should see a screen similar to the one on the right. Notice that the reading changes as you move the light probe.

   You are now ready to make a series of light measurements with the light probe at various distances from the bulb and pointed toward the bulb. The distances .5, 1, 1.5, 2, 2.5, and 3 meters usually work well.

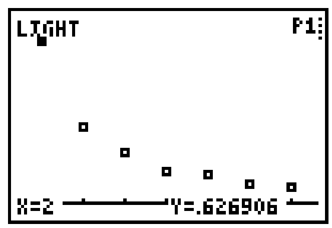
8. Position the probe for the first measurement and then press [ENTER] to record the first measurement. You should see a screen like the screen at the right.



9. Key in the distance from the tip of the light probe to the bulb.

10. Repeat the procedure above, making a series of light measurements from different distances. Six to eight measurements should be sufficient. After you have made all your measurements, press [STO▶] to end the data collection phase of this experiment.

    The screen below shows the results from a typical run.



Analysis

Work through the questions on the Student Data Reporting Sheet.

This experiment looks at a simple relationship but there are many potential sources of experimental error. You will attempt to identify as many potential sources of error as possible and either minimize or compensate for these problems.

Going Further

One way to determine the effects of measurement errors is by using theoretical predictions. Assume that a function of the form

$$I = \frac{A}{d^2}$$

correctly represents the relationship between light intensity and distance. What does this say about the relationship between a light intensity reading made at .5 meter and one made at 1 meter? What if the reading that was supposed to be made at .5 meter was actually made at 45 cm and the reading that was supposed to be made at 1 meter was actually made at 1.05 meters?

If you do everything you can to minimize all the sources of error, what sources are left? For example, you can never measure distances exactly. How precise are your distance measurements? How might the remaining errors affect your data?

Student Data Reporting Sheet

1. If you connected the points on the graph, describe the general shape of the graph.

____

2. Use ◀ and ▶ to determine the measurements from the graph, and record these measurements in the table below:

Distance	Light Intensity

3. Theoretically the relationship between light intensity and distance is given by a function of the form

$$I = \frac{A}{d^2}$$

where *I* is the intensity of the light and *d* is the distance from the tip of the light probe to the light bulb. If this is correct, what would you expect the ratio to be between the light intensity measurements made at .5 meter and 1 meter?

____

What would you expect the ratio to be between the light intensity measurements made at 1 meter and 2 meters?

____

What would you expect the ratio to be between the light intensity measurements made at 1.5 meters and 3 meters?

____

4. Compare the ratios from the actual data to your predictions above.

____

5. There is probably some difference between the predictions and the actual data. This frequently happens. There are two general reasons why this occurs. Either there are errors in the data or in the theory. In this activity we explore sources of experimental error. List several possible sources of experimental error.

____

____

6. One possible source of experimental error is in measuring the distance from the tip of the light probe to the light bulb. Make several different measurements trying to place the tip of the light probe exactly 1 meter from the light bulb. Describe the variation in the light intensity readings.

____

____

7. There are a number of things you can do to try to minimize this source of error. Describe some possibilities.

____

____

8. You can investigate the effects of errors in measuring the distance from the tip of the light probe to the light bulb by deliberately making errors. What is the effect of an error of 5 cm when the distance is supposed to be .5 meter?

____

9. What is the effect of an error of 5 cm when the distance is supposed to be 1 meter?

____

10. Another source of error is other light in the room. You can investigate the effects of this source of error by deliberately introducing an extra light and comparing measurements made with this extra light on and with this extra light off. What do you observe?

____

11. How can you correct for extra light in the room?

____

Repeat the original experiment doing everything you can to minimize measurement error.

Teacher Section

Theory

The relationship between light intensity and distance can be described by a function of the form

$$I = \frac{A}{d^2}$$

but there are so many potential sources of error that students are likely to see discrepancies between theoretical predictions and the data. It is also very important for students to realize that not all such discrepancies can be dismissed as "experimental error." This activity addresses this objective by attempting to identify and compensate for experimental error.

The main sources of error your students should identify are:

- Errors in measuring distance.
- Extraneous light in the room.
- Errors in aiming the light probe.
- The light probe may not be zeroed – that is, with no light the light probe may not read zero.

One way to convey the idea that not all discrepancies can be dismissed as "experimental error" is by having students make light intensity readings using a fluorescent bulb. Because fluorescent bulbs flicker, these measurements jump around.

Answers

Sample data with sample answers:

1. The left half of a "U." (Intensity falls off rapidly as distance increases.)

2.

Distance	Light Intensity
.5	.228
1	.070
1.5	.034
2	.026
2.5	.020
3	.014
3.5	.013

3. The measurement made at .5 meter should be 4 times the measurement made at 1 meter.

   The measurement made at 1 meter should be 4 times the measurement made at 2 meters.

   The measurement made at 1.5 meters should be 4 times the measurement made at 3 meters.

4. There is a large discrepancy. For example, the actual measurement made at 2 meters is only 3.06 times the actual measurement made at 4 meters.
5. extraneous light in the room, errors in measuring distance, the light probe is not zeroed, the light probe may not be aimed directly at the light bulb
6. depends on results
7. Cut pieces of string to very precise lengths and hold the light probe in place by holding one end of a piece of string against the tip of the light probe and the other end in a fixed position near the light bulb. Be careful not to burn yourself on the light bulb.
8. roughly a 4% error
9. roughly a 1% error
10. Extraneous light introduces an error. For example, a particular reading might go up by 0.15
11. Make two readings at each distance from the light bulb— one with the light bulb on and the other with the light bulb off. The difference between these two readings is the intensity from the light bulb.

Activity 3 – Dueling Sensors: Which Temperature is Which?

Math Concepts

- Real-life linear equation
- Collecting and analyzing temperature data
- Graphing and interpreting graphs

Science Concepts

- Measurement and conversions
- Data collection
- Physical science – temperature

Materials

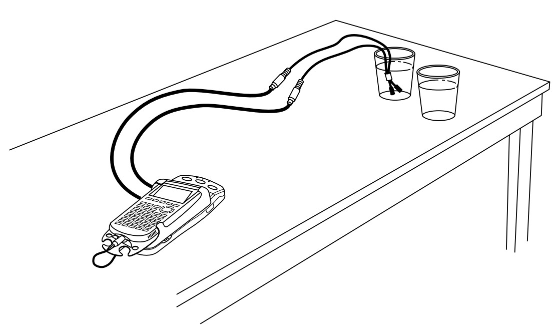
- CBL 2™
- TI Graphing Calculator
- 6-inch unit-to-unit link cable (or any length)
- 2 temperature sensors
- cup of lukewarm water
- cup of ice
- tape or one twist tie

Introduction

In this investigation, you will start with a glass of lukewarm water and add ice cubes to cool the water to a refreshingly cold temperature. Two temperature sensors will be used to take measurements in degrees Celsius and degrees Fahrenheit. From the data gathered, you will investigate the Celsius-to-Fahrenheit conversion formula which is a linear equation in the form Y=AX+B.

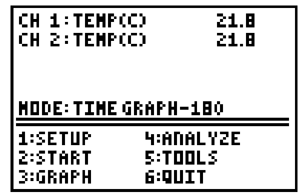
Set-up

Have one cup of lukewarm water and one cup with ice ready to use. Two temperature sensors should be attached, with tape or twist tie, about 5 cm from their tips. The sensors will be placed in the cup of lukewarm water. Since the ice will be added to the cup of lukewarm water, be sure to leave room for ice. You will need to keep the two sensors close together so they are measuring as close to the same part of the liquid as possible.

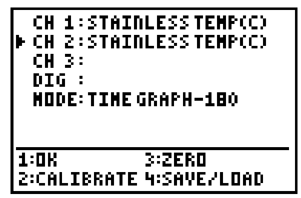


Data Collection

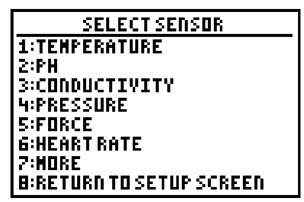
1. Connect the CBL 2 to the graphing calculator using the unit-to-unit cable.
2. Connect one temperature sensor in Channel 1 [CH 1], and one in Channel 2 [CH 2] of the CBL 2.
3. Place the two sensors in the lukewarm water.
4. On the calculator, run the DataMate program or app. CBL 2 automatically identifies the temperature sensors (either the flexible TI temperature sensor or then stainless steel temperature sensor) in Channels 1 and 2 and loads a default experiment.



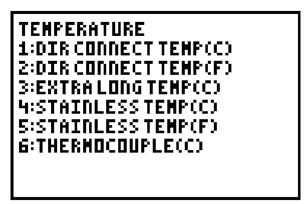
5. From the DataMate Main Screen, press [1] SETUP.



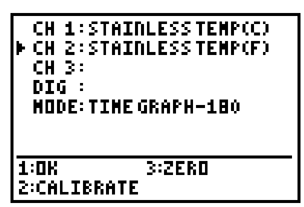
6. Change the sensor in Channel 2 to measure in degrees Fahrenheit. Press [▲] or [▼] to move the cursor to CH 2 and press [ENTER].



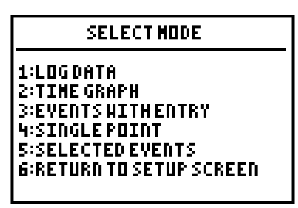
7. Press [1] TEMPERATURE.



8. Press [5] STAINLESS TEMP (F). This loads the calibration factors for the temperature probe to measure temperature in °F.



9. Press [▼] to move the cursor to MODE and then press [ENTER] to view the MODE list.

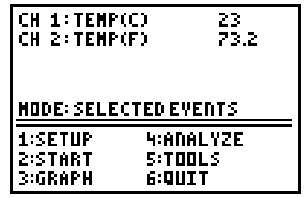


10. We now must choose the most appropriate data collection mode for this experiment. In this case, we want to use Selected Events. Press [5] SELECTED EVENTS .

Note: In this mode, each time you press [ENTER] while collecting data, the CBL 2 captures a data point for each probe connected to the unit.

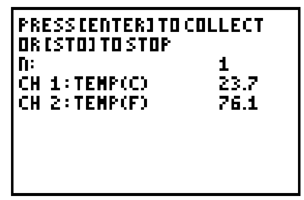
11. After making your choice, the setup screen appears. Press [1] OK to return to the DataMate Main Screen (shown on the right).

CBL 2 is set up to start collecting your data.



Collect the Data

1. Press [2] START. A screen similar to this will appear.



2. Follow the directions on the screen by pressing [ENTER] to collect your first two data points, one in °C and one in °F.

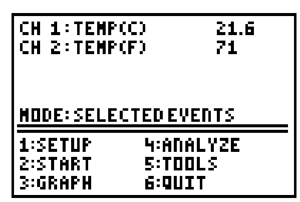
Note: Your goal is to collect about 10 data points of varying temperatures.

3. Add a few ice cubes to the water, stir with the temperature sensor, and wait about 5 seconds. Watch the calculator screen as the temperature falls, and when ready, press [ENTER] to collect another data point.

4. Continue this process as the Celsius temperature approaches freezing. You may need to allow more than 10 seconds between samples to allow the water to get close to 0 degrees Celsius.

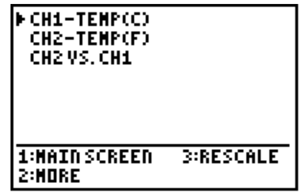
5. After you have collected 10 points, press [STO▶] to stop collecting data.

6. Press [1] MAIN SCREEN to continue with the next step in the investigation.



Analysis

1. On the Main Screen, press [3] GRAPH.



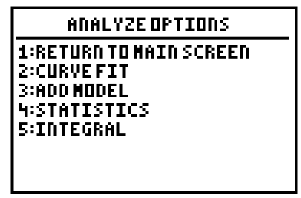
You can view three graphs (one at a time) by using [▲] or [▼] to move the cursor to the graph you want and then pressing [ENTER].

When you finish viewing the graphs, press [ENTER] to quit the graph.

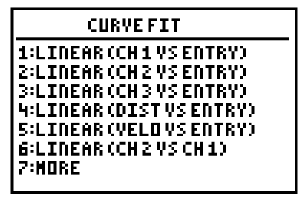
2. Use the graphs to answer question 1 on the Student Data Reporting Sheet.

3. Press [1] MAIN SCREEN to continue.

4. On the Main Screen, press [4] ANALYZE.



5. Press [2] CURVE FIT to find the line of best fit for the graph CH2 VS. CH1 (TEMP F VS. TEMP C).



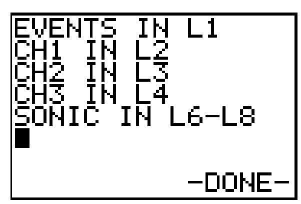
6. Press [6] LINEAR (CH2 VS CH1) to calculate a linear model of this physical relationship. A screen with the linear regression equations appears.

Answer question 2 on the Student Data Reporting Sheet.

7. Press [ENTER] to see the scatterplot and the graph of the linear regression. Use [◀] and [▶] to record data points from the linear regression graph.

Complete question 3 on the Student Data Reporting Sheet.

8. Press [ENTER] to return to the Analyze screen, then press [1] to go to the Main Screen. Press [6] QUIT.



The events (numbers associated with the order of your data points) you saved are in L1, Celsius temperatures are in L2, and Fahrenheit temperatures are in L3 as shown in the screen shot. You may want to use these for more investigations.

Complete questions 4-7 on the Student Data Reporting Sheet.

Going Further

Use List 4 and the Celsius-to-Fahrenheit conversion formula to create a new list of the conversions.

In List 5 find the absolute value of the difference of the measured and calculated Fahrenheit temperatures.

In List 6 find the percent of error for each measurement by dividing List 5 by List 4 and multiplying by 100.

On the Home screen, find the mean average of these percents.

Set up an inverse scatterplot where your *x* list is List 3 and *y* list is List 2. Derive the inverse formula for converting from F to C. Find the Celsius temperature when Fahrenheit is 0 degrees.

Graph both formulas on the graphing calculator and trace the Celsius line to find the Fahrenheit temperature at ⁻40 degrees Celsius.

Other 2-sensor combinations could be used to develop conversion equations dealing with pressure, light, or force.

Student Data Reporting Sheet

1. Compare the three graphs of CH1-TEMP (C), CH2-TEMP (F), and CH2 VS CH1 (TEMP (F) VS. TEMP (C)). Sketch the graphs on the axes below. Make sure you label the axes.

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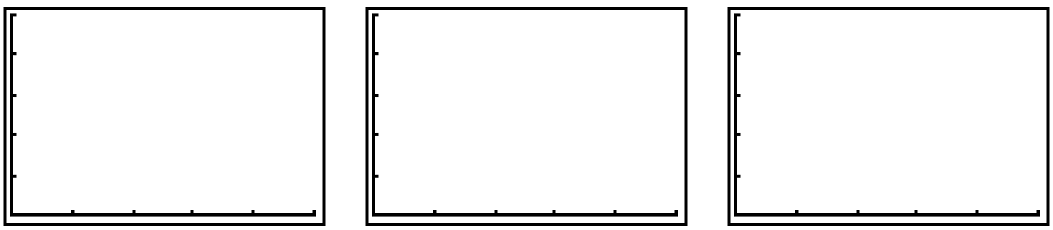
____

____



2. Write the linear regression equation found using the calculator. This is an approximate conversion formula to convert Celsius to Fahrenheit. Identify the slope and y-intercept. Round A and B to the nearest tenths.

   Approximate Conversion Formula: ____________________

   Slope (A) = ____________________

   Y-Intercept (B) = ____________________

3. Here is another method to find the conversion formula. Record two different data points that appear to be on the regression line and that are not very close together. Record the values in the table.

Celsius (X)	Fahrenheit (Y)
X1=	Y1=
X2=	Y2=

4. Use the points in the table in question 3 to calculate another estimate of the Slope (A) by using the formula A = (Y2 – Y1)/(X2 – X1).

   A = ____________________

5. Use the slope in question 4 and one data point from question 3 to derive another approximate conversion formula. Write this in the form Y= AX + B.

   Y = ____________________

6. It is generally known that 0°C equals 32°F and 100°C equals 212°F. Use this information to derive the exact conversion formula.

Celsius (X)	Fahrenheit (Y)
X1=	Y1=
X2=	Y2=

A = ______________________ B = ______________________

Y = AX + B Y = ______________________

7. Press [Y=]. Enter the following equations:

Y_1= Linear regression equation from question 2.

Y_2= Calculated approximate formula from question 5.

Y_3= The exact conversion formula from question 6.

Graph the functions one at a time and then simultaneously. Write about the similarities and differences in the graphs. Explain why you do or do not see differences in the graphs.

____

____

____

____

____

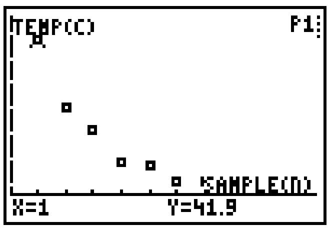
Teacher Section

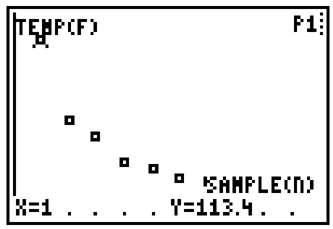
Theory

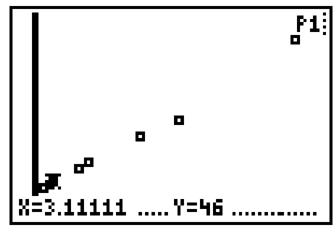
The conversion from Celsius to Fahrenheit is described by the linear function F = 1.8 C + 32 that is developed in this activity.

Answers

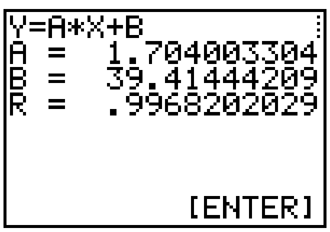
1. Answers will vary. The general shape of the first two plots will be similar. The third plot of F versus C will be linear. Sample data:

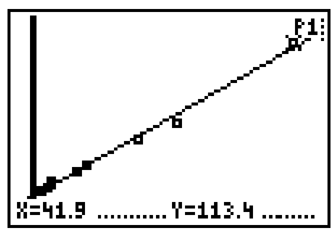






2. Answers will vary. Sample data: Y=1.7X + 39.4, A=1.7 and B=39.4.

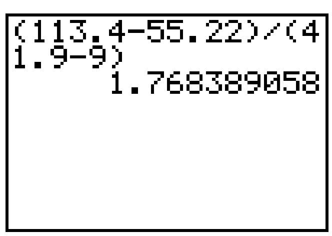




3. Answers will vary. Sample answers:

Celsius (X)	Fahrenheit (Y)
X1=9	Y1=55.2
X2=41.9	Y2=113.4

4. Answers will vary. A=1.8



5. Answers will vary. Sample data: B=39.3 so Y = 1.8X + 39.3

6.

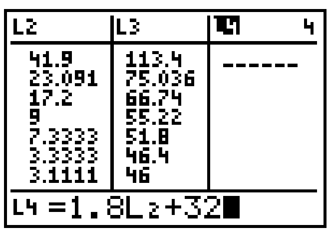
Celsius (X)	Fahrenheit (Y)
X1=0	Y1=32
X2=100	Y2=212

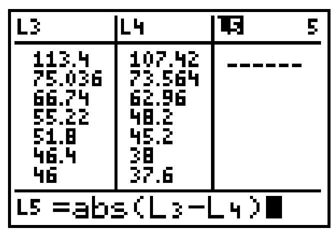
A= 1.8 or 9/5 B= 32 Y = AX + B Y= 1.8X + 32

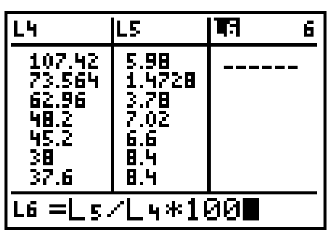
7. Answers will vary. All three graphs should be similar, but they will not match up exactly due to error in measurement. Y_1 and Y_2 will probably be the closest match.

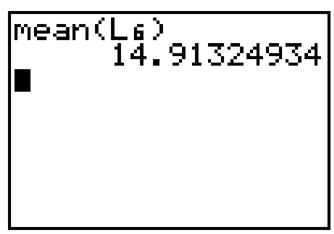
Going Further

Use List 4 and the C to F conversion formula to create a new list of the conversions. In List 5, find the absolute value of the difference of the measured and calculated Fahrenheit temperatures. In List 6, find the percent of error for each measurement by dividing List 5 by List 4 and multiplying by 100. On the Home Screen, find the mean average of these percents.









Set up an inverse scatterplot where your x-list is List 3 and y-list is List 2. Derive the inverse formula for converting from F to C. Find the Celsius temperature when Fahrenheit is 0 degrees.

Graph both formulas on the graphing calculator and trace the Celsius line to find the Fahrenheit temperature at -40 degrees Celsius.

Other 2-sensor combinations could be used to develop conversion equations dealing with pressure, light, or force.

Reference

Data Collection Activities for the Middle Grades with the TI-73, CBL and CBR: Johnston and Young; Activity 2: A Tale of Two Temperatures**;** TI Explorations™ Book.

Activity 4 – Fruit Battery

Math Concepts

- Measurement
- Data analysis
- Rate of change

Science Concepts

- Data collection
- Experimental design
- Physical science

Materials

- CBL 2™
- TI Graphing Calculator
- 6-inch unit-to-unit link cable (or any length)
- TI voltage sensor
- U. S. Penny (1959-1982) or a piece of copper
- Zinc washer
- 5 different types of fruit for batteries (orange, lemon, banana, potato, tomato, apple, and so forth)
- Plastic knife to make slots in the fruit
- Water and towel to wash and dry the penny and washer
- Ruler to measure centimeters

Introduction

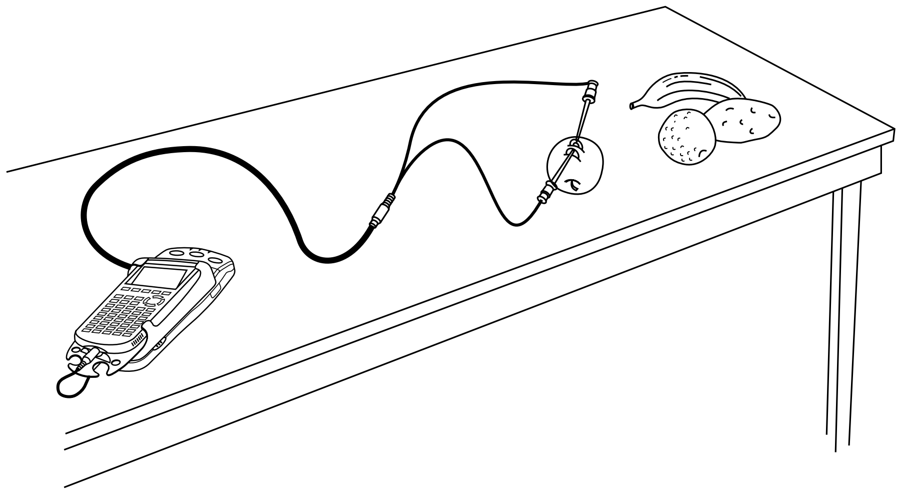
You may have heard of the potato battery that you can make with a penny and a zinc washer. Have you wondered if this really works? In this investigation, you will explore several items for their ability to become a battery. The material of the potato or other object serves as an electrolyte in the battery. These electrolytes allow ions to dissociate and this allows for the flow of electricity. The reaction is a result of many factors: the two metal terminals, the type of material they are connected through (electrolyte), the distance between the two metals, and the amount of contact with the fluid. In this experiment, you will try to control all the variables but one, the electrolyte, and discover the best battery!

In this activity you will:

- Collect data on voltage and graph in a scatter plot.
- Compare the values of different fruit batteries using the graph.
- Determine the rate of change of voltage over time for the "best" battery.

To start the experiment, control all the variables except the one that you want to measure, which is the voltage produced when the fruit is used as the electrolyte in the battery.

Part 1



Set up the Experiment

1. First, select a piece of copper (or U. S. penny that is dated between 1959 and 1982, inclusive) and a zinc washer. The washer can be any size, but the same washer must be used throughout the experiment. A washer the same diameter and thickness as the penny works well.

   Clean the penny and washer with soap and water and dry them. Answer question 1 on the Student Data Reporting Sheet.

2. Collect a container of water to clean the two metals as you switch from one item to the next. You also need paper towels, a plastic knife to cut notches in the fruit, and a ruler to measure the 2 cm distance between the notches. (This distance should be the same for all batteries.)

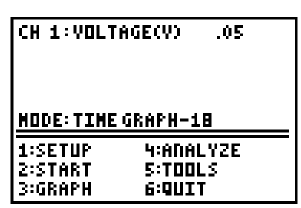
3. Collect the 5 fruits to test. The order in which you test them is not important, but you will need to give each fruit a number before you start the experiment.

   Fill in the first two columns in the table in question 2 on the Student Data Reporting Sheet.

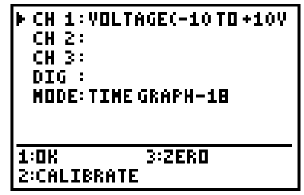
4. Connect the CBL 2 to your calculator. Connect the TI voltage sensor to Channel 1 (CH1) of the CBL 2.

5. On the calculator, run the DataMate program or app. DataMate automatically identifies the TI voltage sensor and loads a default experiment. (We will change these settings.)

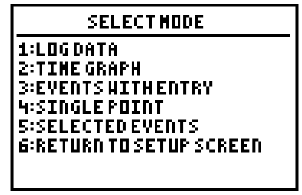
   The Main Screen of DataMate is shown.



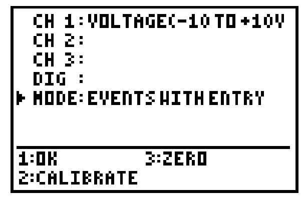
6. Press [1] SETUP to go to the setup screen.



7. Press [▲] or [▼] on the calculator to move the cursor to MODE and press [ENTER].



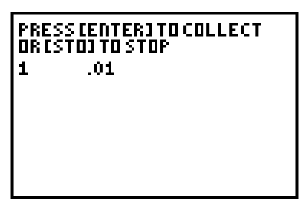
8. Press [3] EVENTS WITH ENTRY.



9. Press [1] OK to return to the Main Screen.
10. Connect the leads of the TI voltage sensor to the penny and washer before inserting them into the fruit to be tested. Securely connect the red lead (+) on the penny (copper) and the black lead (–) on the washer (zinc). You want to see if the metals will create a charge without the electrolyte. This is a control for the experiment to see what happens when you do nothing.

Collect the Data

1. Press [2] START to begin data collection.
2. Touch the penny and washer together to take the control reading. This number should be about 0 V. Press [ENTER] on the calculator to take the data point and press [0] when prompted by the calculator.



3. Now, insert the penny and washer into fruit number 1. The voltage reading should change on the calculator screen. Press [ENTER] on the calculator to take the data point and key in [1] when prompted.
4. Repeat this process until you have collected data for all of your fruit. When the last data point is collected, press the [STO▸] button on the calculator to end data collection.
5. The graph of your data is displayed on your calculator screen.

Analysis

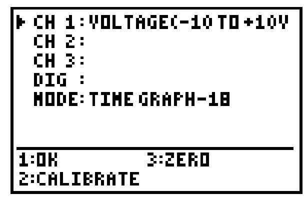
1. Use [◀] and [▶] to trace along the graph to the various data points and observe the collected voltage values. Record these values in the third column of the table on the Student Data Reporting Sheet.
2. Sketch the graph on question 3 of the Student Data Reporting Sheet.
3. Answer questions 4 – 8.

Part 2

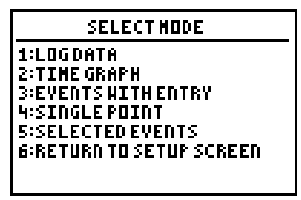
To see if the "best" battery has any staying power, you will need to collect data on the battery over a long period of time.

Set up the Experiment

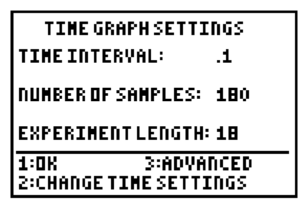
1. Return to Main Screen by pressing [ENTER] while on the graph screen.
2. Press [1] SETUP to go to the Setup Screen.



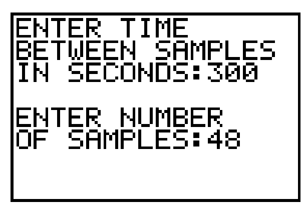
3. Press [▲] or [▼] to move the cursor to MODE, and then press [ENTER].



4. Press [2] TIME GRAPH to go to the Time Graph Settings menu.

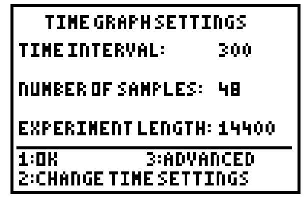


5. Press [2] CHANGE TIME SETTINGS.

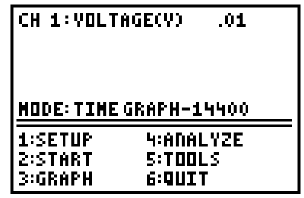


6. Enter 300 for TIME BETWEEN SAMPLES and 48 for NUMBER OF SAMPLES.

   DataMate updates the Time Graph Settings screen with the new information. As you can see, this experiment will take 14,400 seconds, or 4 hours. It will collect a voltage reading every 5 minutes during the 4-hour period.



7. Press [1] OK to return to the Setup Screen and [1] OK again to return the Main Screen.



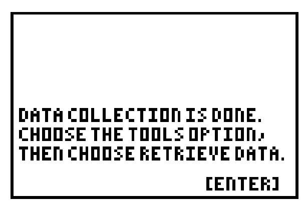
Collect the Data

1. Put the penny and washer into the "best" battery and attach the voltage leads to them.
2. You will want to place the experiment setup in a location where it will not be disturbed for 4 hours, but where it will be accessible if you want to check the status of the experiment periodically.
3. Press [2] START to begin the experiment.

   You can press [ENTER] on your calculator to quit the program and detach the calculator from the CBL 2. This will not affect your data collection. You may want to do this if you need to use your calculator during the 4-hour data collection period.

   You can reattach the calculator and restart DataMate to observe the latest data point collected.

4. After the 4-hour data collection period, reattach the calculator and restart DataMate. DataMate will tell you that data collection is done.

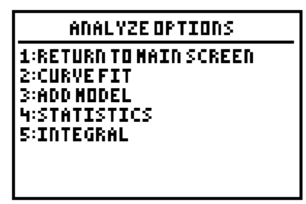


5. To retrieve the data, press [ENTER] to go to the Main Screen, then press [5] TOOLS and [2] RETRIEVE DATA. The calculator retrieves the data from the CBL 2 and plots it on the screen.

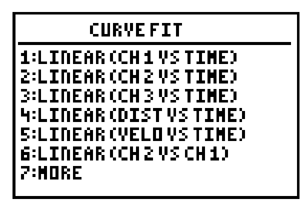
Analysis

1. Sketch the graph on question 9 on the Student Data Reporting Sheet and answer question 10.
2. To determine the rate at which the battery voltage dropped, we need to perform a regression on our data. Before we do that, we want to select data from the first part of the graph, usually about 2 hours (7200 seconds), where the voltage drop appears linear.

   From the graph screen, press [ENTER] to return to the Main Screen.
3. Press [3] GRAPH to go to the graph, and press [ENTER] to go to the Graph Options screen.
4. Press [2] SELECT REGION and follow the instructions on the screen to select the linear part of the graph.
5. Press [ENTER] to see the new graph.
6. From the Graph Menu screen, press [1] to return to the Main Screen, and press [4] ANALYZE to go to the Analyze Options menu.



7. Press [2] CURVE FIT.



8. Press [1] LINEAR (CH1 VS TIME) to perform a linear regression on our voltage data. The calculator displays the linear equation and the corresponding values.

   Enter this information on question 11 of your Student Data Reporting Sheet.
9. Answer questions 12-16.

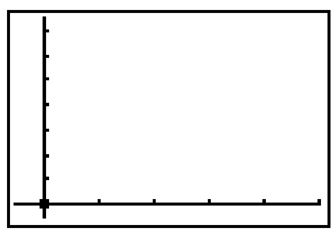
Student Data Reporting Sheet

1. Fill in the date of the penny ____________ and the full diameter of the washer ____________ and penny ____________.

2. Complete the table below using the name of each fruit and the number assigned to it.

Name of the fruit	Number	Voltage
control	0	

3. Sketch the graph of the collected data below.



4. Voltage without the electrolyte (the control, 0): ______________________

5. Which item produced the highest voltage? ______________________

6. Which item produced the lowest voltage? ______________________

7. As the experiment progressed, did you see any change in the condition of the washer or the penny? ______________________

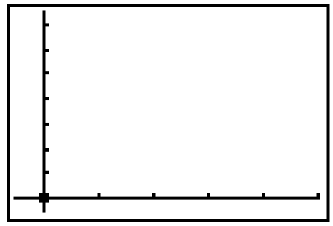
____

8. Which item made the "best" battery? Why do you believe this?

____

____

9. Sketch the graph of the long term data collection below.



10. What appears to be happening to the voltage as time goes on?

11. Enter the regression equation with the constants below.

12. What do the values A and B represent?

13. How much did the voltage drop over the time observed?

14. Based on the regression equation, how long would it take for the voltage to reach 0?

15. Compare this number to the original data. From the long-term trend of the original data, does the calculated time for the voltage to reach 0 match? What does happen to the data?

16. What factors do you think did or could affect the rate at which the voltage dropped?

Teacher Information

The reason for using pennies minted prior to 1983 is that the U.S. Treasury started making the zinc copper-clad pennies that year.

The washers can be any zinc washer from the hardware store.

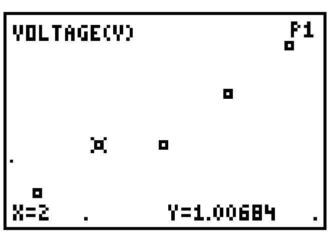
The 4-hour period used for the long-term example can be changed, although the time period selected must be long enough to record a change in the voltage of the battery. A couple of hours should be fine.

The distance between the penny and washer for all of the batteries needs to remain constant. A change in distance will affect the voltage.

Sample Answers

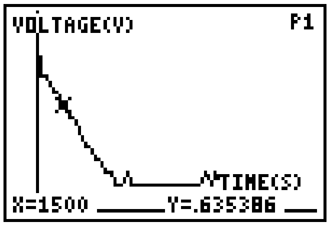
1. The open voltage or control will usually read close to zero. The reason it may not is due to the nature of the internal workings of the CBL 2.
2. Table of batteries used for this sample data:

Name of the fruit	Number	Voltage
control	0	0.03
potato	1	0.99
banana	2	1.01
tomato	3	1.01
orange	4	1.04
lemon	5	1.05

3. 

4. 0.03
5. lemon (1.05 volts)
6. potato (0.99 volts)
7. Yes, they tended to change color. The penny gets shinier and the washer tarnishes.

8. The lemon produced the highest voltage. Other factors to consider: least messy (ease of use), lowest cost, and so forth. You may also want to discuss which battery is the “best”: the battery with the highest voltage or the battery that maintains its voltage the longest (a slower rate of change).

9. 

10. the voltage drops

11. y = ax + b, a = ⁻4.2E-5, b = 0.7

12. *A* represents the rate at which the voltage is dropping. The value of *B* is the y-intercept. This should be close to the voltage at the beginning of the long-term experiment.

13. .73 - .52 = .21 volts

14. 16,667 seconds (4 hours, 38 minutes)

15. No, it does not. The original data taken shown that the voltage had leveled off at about .5 volts at 1.5 hours and stayed there.

16. The fruit chosen, the electrolyte (juice) of the fruit drying up, the penny and washer getting “dirty” or tarnished over time

Reference

Data Collection Activities for the Middle Grades with the TI-73, CBL and CBR: Young and Johnston; Activity 12: You’ll Get a Charge Out of This!; TI Explorations™ Book.

Activity 5 – Lights Out!

Math Concepts

- Periodic functions
- Graphing and interpreting graphs

Science Concepts

- Data collection and analysis
- Period and frequency

Materials

- CBL 2™
- TI Graphing Calculator
- 6-inch unit-to-unit link cable (or any length)
- TI light sensor
- 1 non-fluorescent light source (regular light bulb)
- 1 fluorescent light source

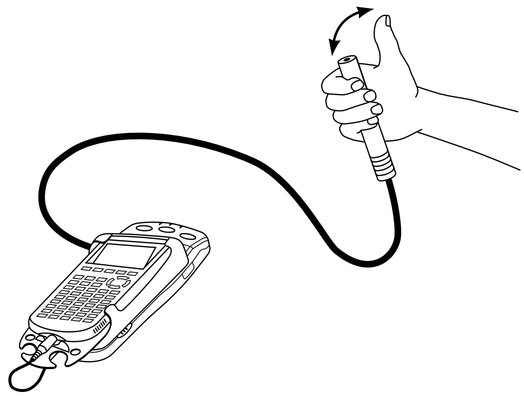
Introduction

A rocking chair moving back and forth, a ringing telephone, and water dripping from a leaky faucet are all examples of *periodic* phenomena. They are called periodic because they can be characterized by rhythmic cycles occurring in regular time intervals. The time required to observe one complete cycle of the behavior is called the *period*. The number of times the cycle occurs per unit of time is known as the *frequency*.

In the following activities, you will use the CBL 2 and a light sensor to collect data for two different types of periodic phenomena. You will then analyze this data with your calculator to find the period and the frequency of the observed behavior.

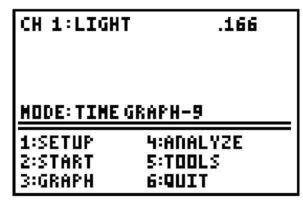
Part 1

In this activity, you will point a light sensor towards a light source such as a light bulb, window or an overhead lamp. To start, the end of the sensor will be covered by your thumb. When the CBL 2 is activated, you will begin alternately lifting your thumb from the sensor and re-covering it. Light intensity readings will be collected by the CBL 2 and then displayed as a graph on the screen of your calculator.



Set up the Experiment

1. Connect the CBL 2 to your calculator using the unit-to-unit cable. Then connect the light sensor into Channel 1 (CH1) of the CBL 2.
2. On the calculator, run the DataMate program or app. DataMate automatically identifies the light sensor and loads a default experiment. The Main Screen of DataMate is shown.



3. Hold the light sensor inside your fist with the end of the sensor protruding about ½ inch, as shown in the picture above. The end of the sensor must be pointed toward a light source while the CBL 2 is sampling.
4. The top right corner of the DataMate Main Screen shows the light intensity readings from the light sensor as it is covered and uncovered.

Collect the Data

1. Press [2] START to begin data collection using the default experiment.
2. Cover and uncover the sensor in regular time intervals, about once per second.
3. If your data is not satisfactory, press [2] START to perform another trial.

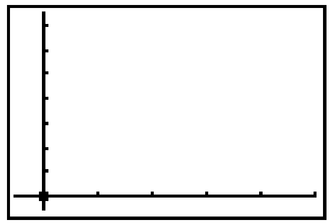
   Your data should show intensity levels which start at a large value then alternate between this value and a value close to zero in a regular pattern. The time interval between cycles should appear to be relatively constant.

Analysis

If your data is satisfactory, sketch a plot of your data on the axes on the Student Data Reporting Sheet 1.

Student Data Reporting Sheet 1

1. Make a sketch of your data. Label the axes.



For the data plot above, what do the plateaus represent? What do the minimum values represent?

____

____

2. Press ◄ or ► to move the cursor along the plot. The *x*-values shown at the bottom of your calculator screen are times and the *y*-values are intensities. Trace to the first time value corresponding to zero intensity (or very near zero) following the initial plateau. Record this time value below, rounding to the nearest hundredth of a second:

A = ____________________ seconds

3. Use the arrow keys to move to the first time value corresponding to zero intensity (or very near zero) following the last complete plateau shown on the screen. Record this time value below, rounding to the nearest hundredth of a second:

B = ____________________ seconds

4. How many cycles were completed between time *A* and time *B*? That is, how many times did you uncover then re-cover the sensor during this time interval? Record this number below:

C = ____________________

(At this point, you can press [ENTER] and then press [6] to quit the program.)

5. The *period* is the time required to complete one cycle. Subtract A from B and then divide by C, $\frac{(B-A)}{C}$ to find the average time period. Record this value below, rounding to the nearest hundredth of a second:

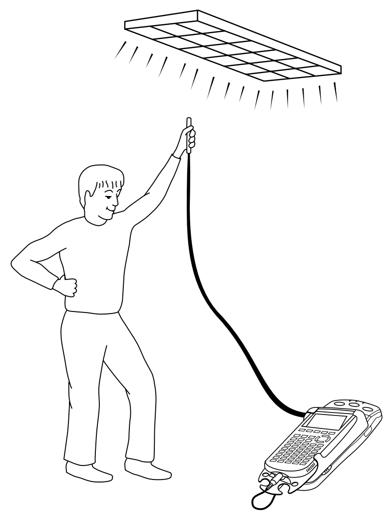
Period: ____________________ seconds

6. While the period represents the number of seconds per cycle, the *frequency* is the number of cycles per second. Find the frequency of the cover-uncover motion by taking the reciprocal of the period value you just found. Record this value below.

Frequency: ____________________ cycles per second

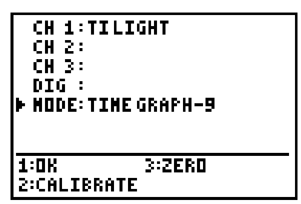
Part 2

For the second part of this experiment, you will point the light sensor at a single fluorescent light bulb and record its intensity for a very short period of time. The resulting plot of intensity vs. time is interesting because it shows that fluorescent lights do not stay on continuously but rather flicker off and on very rapidly in a periodic way. Since the human eye cannot distinguish between flashes that occur more than about 50 times a second, the light appears to be on all the time. The data you collect will be used to determine the period and frequency at which the bulb flickers.

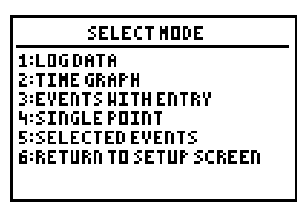


Set up the experiment

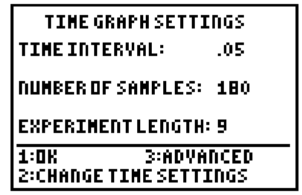
1. Make sure the TI light sensor is connected to CH1 of the CBL 2.
2. Run the DataMate program or app.
3. Press [1] SETUP to go to the Setup screen.



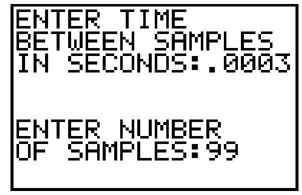
4. Press [▲] or [▼] to move the cursor to MODE and then press [ENTER].



5. Press [2] TIME GRAPH.

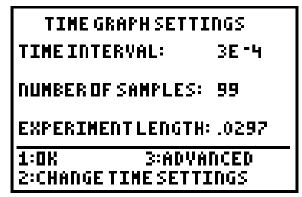


6. Press [2] CHANGE TIME SETTINGS to enter new time graph settings.

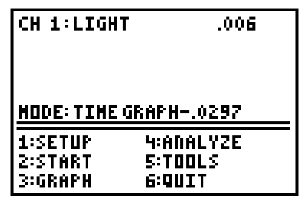


7. Enter **.0003** for the time between samples and enter **99** for number of samples.

Your Time Graph Settings screen should now be updated with the new values. As you can see, the experiment length is very short.



8. Press [1] OK to return to the Setup screen, and press [1] OK again to return to the Main Screen.



Collect the Data

1. Hold the light sensor close to the fluorescent light bulb, and press [2] START to begin collecting data. The CBL 2 beeps when it begins collecting data. The data collection will be finished almost immediately.

2. If your data is not satisfactory, press [2] START to perform another trial.

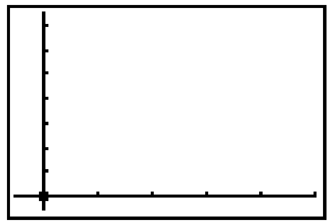
Your data should resemble a series of uniformly spaced peaks of approximately the same size.

Analysis

If your data is satisfactory, sketch a plot of your data on the axes on the Student Data Reporting Sheet 2.

Student Data Reporting Sheet 2

1. Make a sketch of your data. Label the axes.



From the intensity versus time graph on your calculator, it appears that light intensity values are rising and falling in a regular pattern. What do the peaks or maximum values on your data set represent in terms of the flashing bulb? What do the minimum values represent?

____

____

2. To calculate the average period of the bulb's flicker, find the average time interval between the first and last peaks. (The calculator should now be in Trace Mode.) Use the arrow keys to move the cursor to the apparent maximum of the first peak. The *x*-value at the bottom of the screen represents the time when this maximum occurred. Record this value below.

A = ____________________ seconds

3. Next, move the cursor to the maximum of the last peak on the graph. Record this value below.

B = ____________________ seconds

4. From the first peak, count the number of peaks to the last one. Record that value below.

C = ____________________ peaks

(At this point, you can press [ENTER] and then press [6] to quit the program.)

5. Subtract A from B and then divide by C, $\frac{(B\text{-}A)}{C}$ to find the average time period. Record this value below.

Period: ____________________ seconds

6. The period value found in question 5 represents the time required for one complete on-off cycle; that is, the seconds per cycle. Find the frequency (cycles per second) by taking the reciprocal of the period.

Frequency: ____________________ cycles per second

7. In the United States, electric utilities use a current whose frequency is 60 cycles per second. Is this consistent with your findings from this activity?

____

Hint: *The so-called alternating current used in households actually switches polarity two times per cycle.*

8. If the light source really is turning off every half-cycle, why isn't the minimum y-value on your intensity vs. time plot equal to zero?

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Teacher Section

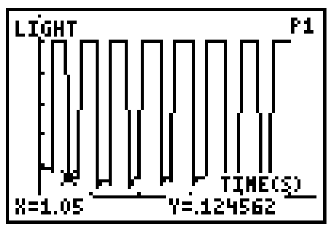
For best results, use a bright light source for Part 1 of the activity. The actual acts of covering and uncovering the light sensor should be done by moving the thumb very quickly. The time between these events is not so important, provided that it remains relatively constant from cycle to cycle.

For Part 2 of the activity, use a single fluorescent bulb, if possible. If more than one bulb is used, undesirable interference patterns may show up on the plot of intensity versus time.

Answers

Part 1: Answers based on our sample data.

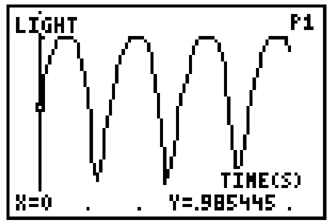
1. The plateaus represent instances when the sensor is uncovered; minimums represent instances when it is covered.



2. A= 1.05 seconds
3. B= 7.9 seconds
4. There were 6 cycles completed.
5. The period is 1.14 seconds.
6. The frequency is .88 cycles per second.

Part 2: Answers based on our sample data.

1. Peaks correspond to times when the bulb is fully illuminated; minimums correspond to times when the bulb is momentarily off.



2. A= .003 seconds
3. B= .045 seconds
4. C= 5 peaks
5. Period is .0084 seconds
6. Frequency is 119.05 cycles per second
7. Since the polarity switches twice per cycle, we would expect to observe a frequency of 120 cycles per second. This is very close to the calculated value, 119.05 cycles per second.
8. The minimum *y*-value is non-zero due to the presence of background light.

Reference

Real-World Math with the CBL System: Activities for the TI-83 and TI-83 Plus: Brueningsen, Bower, Antinone and Brueningsen-Kerner; Activity 15: Lights Out; TI Explorations Book.

Activity 6 – Night and Day

Math Concepts

- Data to graph to model visualization
- Number sense to determine length of experiment

Science Concepts

- Measurement
- Experience with sensors of different types, and the units that relate to the measured values (such as temperature in Celsius and Fahrenheit)
- Experimental design and technique
- Scientific method
- Thermodynamics
- Environmental science and the analysis of ecosystems

Materials

- CBL 2™
- TI Graphing Calculator
- 6-inch unit-to-unit link cable (or any length)
- Stainless steel temperature sensor and TI light sensor
- Power supply such as the TI-9920 AC adapter, or Vernier's CBL-EPA External Power adapter with a power source such as a 6-volt battery (Optional)
- TI-GRAPH LINK™ with cable (Optional)

Note: The voltage sensor might be used with a solar cell or in a circuit that measures conductivity as it relates to changes in climate (the conductivity of a banana battery as the room heats or cools). Other sensors are designed for weather data such as Barometric Pressure and Relative Humidity. Check out the TI web page for a listing of all sensors available for the CBL 2 at education.ti.com/cblprobes. Use the TI-9920 AC adapter to supply power for the CBL 2 for long term data collection, or to power a particular sensor use, Vernier's External Power Adapter CBL-EPA.

Introduction

In this investigation, we will set up a simple weather station to collect data over the period of a day from two sensors to help us better understand patterns in the weather.

Before We Start

1. With your lab partner or in a small group, discuss why we want to collect weather data over the period of a day. On a separate piece of paper, write down the group's thoughts.
2. In your group, make a hypothesis as to what will happen to the temperature and the intensity of light during the experiment. Write down your hypothesis.

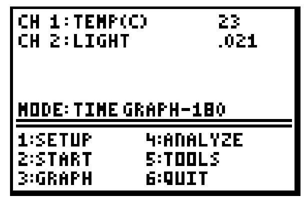
Set-up

We need to carefully control the variables in the experiment. Watch for light from a street light or heat from a vent that would change the data. If the equipment is placed in an external remote location, protecting the unit from moisture by placing it in a bag might be important, and securing it from theft needs to be considered.

Set up the Sensors

1. Connect the stainless steel temperature sensor and the TI light sensor to Channel 1 and Channel 2 of the CBL 2, respectively. Connect the CBL 2 to the calculator.

2. On the calculator, run the DataMate program or app. The CBL 2 automatically identifies the temperature and light sensors. The DataMate program also loads a default experiment, but we will change these settings.



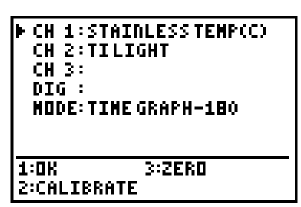
Change the Mode

Now we need to select an appropriate data collection MODE for the experiment. This is an essential part of the experiment design. What makes sense for our experiment? Do we want to collect a data point every second for 24 hours? Should we collect 1,000 data points? What are we trying to accomplish with our experiment?

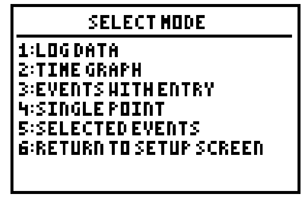
- The calculator has limited memory, so we do not want to collect more data points than the calculator can handle. On some TI calculators, a selection of more than 180 points may cause some problems with the analysis. Some good "rules of thumb":
  - When using 1 sensor, collect 180 points of data or less.
  - When using 2 sensors, collect 90 points per channel or less.
  - When using 3 sensors, collect 60 points per channel or less.
- Additionally, the type of sensor needs to be considered. Collecting data at the rate of 50,000 data points a second (one reading each 0.00002 seconds) would be inappropriate for many sensors, as well as being too fast for an examination of the temperature change as a cold front moves through the area.

For this investigation, we want to collect data every 16 minutes for 90 samples.

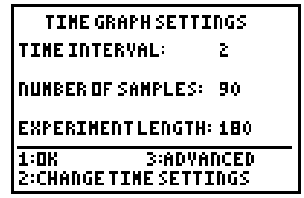
1. After DataMate auto-ID's the sensors, press [1] SETUP to enter the Setup screen.



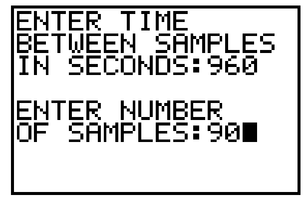
2. Press [▲] or [▼] to move the cursor to MODE and press [ENTER].



3. Choose [2] TIME GRAPH.

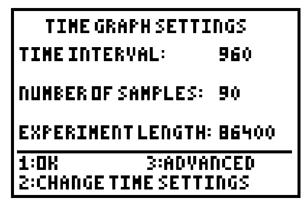


4. We want to change the experiment's time settings, so press [2] CHANGE TIME SETTINGS.



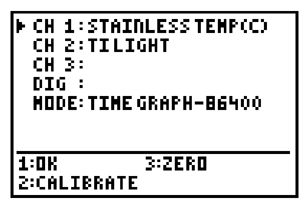
5. We need to give the appropriate information for the timing of the experiment. We will be collecting data every 16 minutes (960 seconds) for 90 samples.

   Key in **960** for TIME BETWEEN SAMPLES IN SECONDS and key in **90** for NUMBER OF SAMPLES.



Note: we can change the time settings again if we miscued on the last attempt. It is important that careful consideration be given to the experiment time settings.

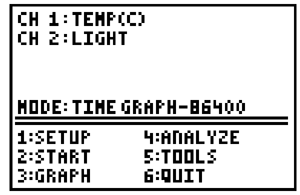
6. We are now ready to start our experiment. Press [1] OK to return to the Setup screen.



7. Press [1] OK to return to the DataMate Main Screen.

Collect the Data

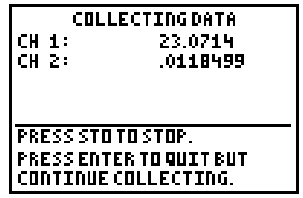
1. Move the CBL 2 and calculator to the location where the experiment will occur.



2. On the Main screen, press [2] START.

The green light on the CBL 2 blinks and a tone sounds indicating that the CBL 2 is collecting data.

We want to disconnect the calculator, but still continue to collect data.



3. Press [ENTER] to QUIT BUT CONTINUE COLLECTING.

4. Disconnect the calculator from the CBL 2. We are now collecting data.

Note: When the experiment is active, the green LED on the CBL 2 flashes as data is being collected. After 24 hours the data collection will be completed.

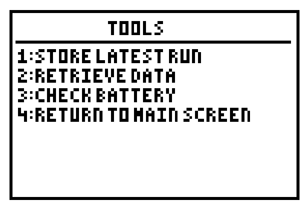
Retrieve the Data

Once the experiment is complete, follow these instructions to get the data from the CBL 2 into the calculator.

1. Connect the calculator to the CBL 2.

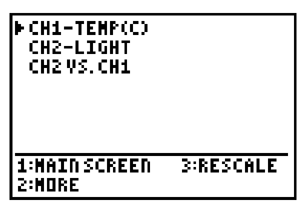
2. Run the DataMate program or app.

3. On the DataMate Main Screen, press [5] TOOLS.



4. Press [2] RETRIEVE DATA.

When the data is in your calculator, options for viewing graphs of the data are shown.



5. To view the graph with Temperature as the y-axis, and Time as the x-axis, press [▲] or [▼] to move the cursor to CH1-TEMP(C), and press [ENTER].

6. View the graph for Light Intensity vs. Time (CH2).

Analysis

From the data, both graphical and numerical, we need to explore the patterns.

1. For the event, did our hypothesis hold?
2. What does the data show about changes in the weather over the time of the experiment?
3. What would or could we do to help better explain the phenomena?
4. Did we determine another relationship to be explored?

Going Further

Repeat the experiment during different weather patterns. Collect data as a cold front or warm front passes your location.

Use different sensors, such as relative humidity and barometric pressure, to explore other more complex aspects of the weather.

Surf the Internet to find temperature data for your location. Does your data match the data on the Web?

Student Data Reporting Sheet

1. Make a sketch of the setup of the apparatus, including the specific location and orientation of each sensor in relationship to the "weather" factors. Make sure you label these factors (sun, wind, heating or cooling vents, etc.)

2. State the type and units used for each sensor in the table below:

Channel	Sensor	Units
1		
2		
3		
DIG/SONIC		

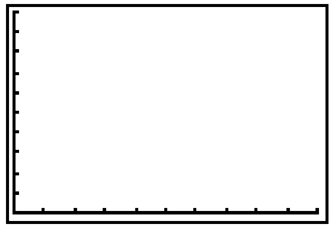
3. Calculate the length of the experiment in the most appropriate units.

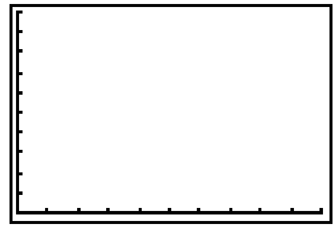
Rate of data collection (seconds per point): ______________________________

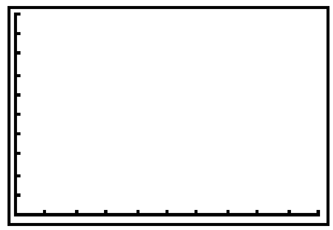
Number of data points: ____

Length of experiment: ____

4. Make a sketch of your Time v. Temperature and your Time v. Light Intensity graphs. Make sure you label each graph. Are there any other graphs that might be informative?







5. Now that you have seen one set of data, how would you modify the experiment to better understand the relationship(s) that you are exploring? Address the need for additional, or different sensors, changes in the times used for data collections and location and/or environment of the experimental setup.

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6. Using your answers from questions 1-5, write a lab report about your experiment. Tell a story about the data you collected. What happened in the experiment to produce the data you collected? Explain any anomalies in your data.

Teacher Section

Theory

Experimental design is the critical part of this investigation of climatic-type data. Controlling the variables and selecting a time and rate of collection that is appropriate for the event and the tolerances of the sensor is critical. Events such as a front moving through the area, differences between day and night (radiation cooling, and so forth), monitoring seasons by collecting data throughout the year, and various storms (including hurricanes and tornadoes) are some ideas for data collection.

Sample data from the experiment might look like this:

Time (s)	Temp (°C)	Light Intensity
960	23.8333	0.7882
2880	23.6429	0.718241
7680	23.7381	0.523911
14400	22.6136	0.196464
18240	21.5	0.01185
24960	20.093	0.00602
38400	18.5714	0.00602
44160	18.1905	0.00602
60480	17.8095	0.00602
62400	18	0.008935
68160	18.7619	0.078894
72960	20.186	0.452008

Answers

1. The sketch should show the location and orientation of each sensor and all the "sources" of possible changes in the measure of the items detected by the sensor. A photograph might be useful that then could be placed on your web page.
2. The table would look like this for the set up used above:

Channel	Sensor	Units
1	Temperature	degrees C
2	Light Intensity	No units (relative)
3	Not used	
DIG/SONIC	Not used	

3. In this set up we have:
   Rate of data collection (seconds per point): 960 seconds/point
   Number of data points: 90 points
   Length of experiment: 24 hrs
4. The sketches could have Time as the x-axis, but greater insight might come from the relationship between the data from the two sensors (like temperature versus light intensity). In addition, using two y-variables as a function of time might be an informative graph (temperature versus light intensity). Make sure units are included in the labeling.
5. Answers will vary depending on the experiment. Two things to watch for are the need to modify the time settings based on the fact that they may get more information with the new settings, and the second would be the exclusion or inclusion of sensors trying to focus the hypothesis to one or two variables.
6. Answers will vary.

Going Further

You may, of course, use any sensors you like for this weather station experiment (for example, barometer, relative humidity, and so forth). Some sensors may call for calibration. Select the options for this from the Setup screen as your cursor points to the channel where you connected the sensor.

If you are using TI InterActive!™ or TI-GRAPH LINK™ computer software, your students can include graphs and data from their experiment in their lab reports. Also, if you are using TI InterActive! your students can include local temperature data downloaded from the Internet. For more information about TI InterActive!, visit

education.ti.com/interactive

References

Data Collection Activities for the Middle Grades with the TI-73, CBL and CBR: Johnston and Young; Activity 5: Light and Day; TI Explorations™ Book.

Real-World Math with the CBL System: Activities Using the TI-83 and TI-83 Plus: Brueningsen, Bower, Antinone, and Brueningsen-Kerner; Activity 21: And Now, the Weather...; TI Explorations Book.

Appendix A: General Information

Battery and Adapter Information

Operating Power Requirements

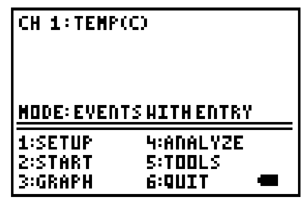
The CBL 2™ is designed to operate with four AA (LR6) alkaline batteries.

Factors that affect battery life are the actual time that the CBL 2 is collecting data and the amount of current used by connected probes during your experiments. To extend battery life in the classroom we recommend that you use an approved power adapter.

For long-term experiments out of the classroom, you can connect an external 6-Volt lantern battery to the CBL 2. (See Connecting an External 6-Volt Battery on page A-3.)

When to Replace Batteries

The batteries should be replaced when the low-battery icon is displayed in the lower right corner of the calculator while running the DataMate program.



In addition, you can check the batteries at any time by choosing option [3] CHECK BATTERY on the DataMate Tools screen.

Note: Save any collected data before removing batteries. All collected data is lost if the batteries are removed. (CBL 2 FLASH memory is not affected.)

Recommended Batteries

- Four 1.5-Volt size AA (LR6) alkaline batteries.
- One 6-Volt lantern type. Recommended for long-term experiments performed outside the classroom that draw large amounts of current (for example, when using a motion detector). See Connecting an External 6-Volt Battery on page A-3 for instructions.

Battery Precautions

Take these precautions when replacing batteries:

- Do not leave batteries within the reach of children.
- Do not mix new and used batteries. Do not mix brands (or types within brands) of batteries.
- Do not mix rechargeable and non-rechargeable batteries.
- Install batteries according to polarity (+ and −) diagrams.

- Do not place non-rechargeable batteries in a battery recharger.
- Properly dispose of used batteries immediately.
- Do not incinerate or dismantle batteries.

Installing the AA (LR6) Batteries

Follow these steps to replace the batteries:

1. Holding the CBL 2™ upright, push the latch on the battery cover down with your finger and pull the cover out.
2. Replace all four AA (LR6) alkaline batteries. Be sure to position them according to the polarity (+ and −) diagram inside the battery compartment.
3. Replace the cover.

Connecting an Optional AC Adapter

1. Connect one end of an approved adapter to the external power input connection located on the bottom left side of the CBL 2.
2. Plug the other end of the adapter into an electrical wall outlet.

Approved AC Power Adapters

The CBL 2 is designed to accept voltage input from an external AC-to-DC power adapter that provides a regulated 6 Volts DC output when plugged into an electrical wall outlet.

The Texas Instruments model AC-9920 power supply is an AC-to-DC power adapter approved for use with the CBL 2. The model AC-9201 power supply can also be used with the CBL 2. Use of other power adapters may result in RF interference and/or unacceptable performance.

To order an adapter, call Customer Support at:

1-800-TI-CARES (1-800-842-2737).

Building an External Battery Adapter Cable

To build an external battery adapter cable, you will need a connector, 16-gauge wire (about 6 feet), and two alligator clips.

Note: At the time of this printing, the Radio Shack™ Coaxial DC Power Plug #274-1569 (5.5mm O.D., 2.1mm I.D.) or equivalent is an acceptable connector.

1. Identify one 3-foot length of the wire as black (ground) and solder it to the insulated pin of the connector.
2. Identify the other 3-foot length of wire as red and solder it to the outside of the connector.
3. Connect an alligator clip to the open end of each wire.

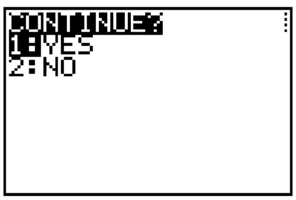
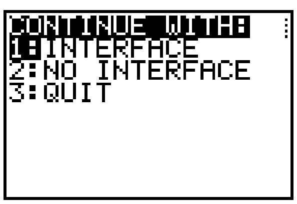
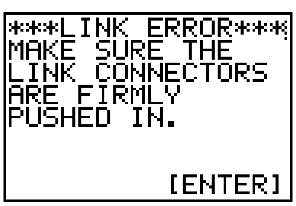
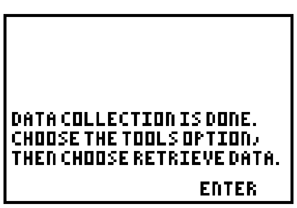
Connecting an External 6-Volt Battery

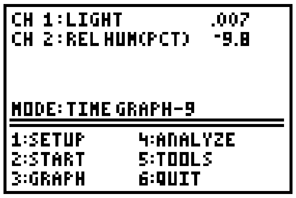
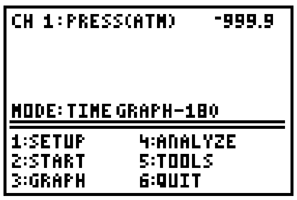
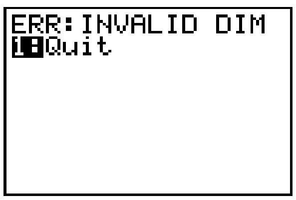
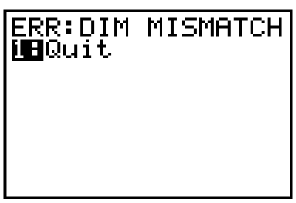
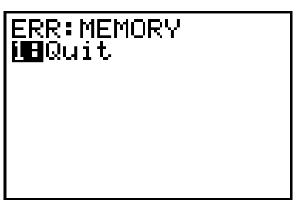
1. Connect one end of the external battery adapter to the external power input connection located on the bottom left side of the CBL 2™.
2. Connect the red lead to the positive (+) terminal of the battery. Connect the black lead to the negative (–) terminal of the battery.

Error Messages

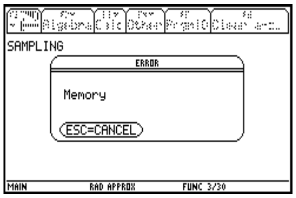
DataMate Troubleshooting

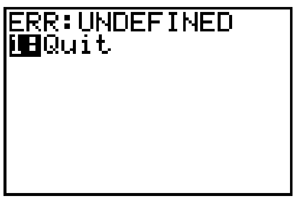
The screens shown below may occur when using the DataMate program.

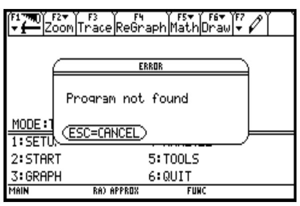
Screen	Explanation
	This screen appears when too much time has passed on a screen without activity. This timeout feature takes advantage of the Automatic Power Down™ (APD™) feature of the calculator and CBL 2 to conserve battery power. ♦ Press [1] YES to continue the program. ♦ Press [2] NO to quit.
 	This screen appears when CBL 2 is not connected to the calculator or when CBL 2 needs new batteries. ♦ Check the connection between CBL 2 and your TI calculator. Firmly push in the link cable, and then choose 1: INTERFACE. ♦ Check batteries in the CBL 2. Disconnect the calculator from the CBL 2; then press TRANSFER on the CBL 2. If the CBL 2 does not make a sound or light the red LED, change the batteries in the CBL 2. If you choose 1: INTERFACE without correcting the problem, the link error screen appears. Check the connection and batteries as explained above and then press ENTER.
	This screen appears when: ♦ The CBL 2 has collected data and that data has not been retrieved to the calculator. or ♦ The user exits DataMate in the middle of data collection (possibly by pressing ON) and then restarts DataMate. Press ENTER. Then choose one of the following: ♦ To retrieve the data, press [5] TOOLS and then [2] RETRIEVE DATA. ♦ To delete the data, press CLEAR to reset the CBL 2.

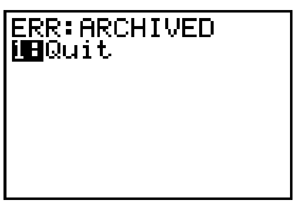
Screen	Explanation
	The DataMate main screen shows a non-autoID sensor from a previous experiment even though the sensor is no longer connected. (For example, the screen on the left shows a Relative Humidity sensor even though the sensor was removed and DataMate was restarted.) Press [CLEAR] to reset the CBL 2™ to initial conditions. (In general, whenever you see something on the screen that does not look correct, press [CLEAR] to reset.)
	This screen appears when the CBL 2 is disconnected from the calculator and used for a different task or when the CBL 2 loses power. When the CBL 2 and calculator are reconnected, the calculator may not recheck the sensor setup, and this error results. Press [CLEAR] to reset, and then set up the channel again.
  	These three screens usually appear when there is not enough memory available in the calculator to collect any or all of the data and then graph it. Reduce the number of data points you are trying to collect. Following are *estimates* of the number of data points that can be collected if the calculator RAM memory has been reset prior to sending DataMate to the calculator:

Calculator	1 sensor	2 sensors	Sonic
TI-73	~120	~90	~70
TI-82	98*	98*	98*
TI-83	~200	~150	~120
TI-83 Plus / TI-83 Plus Silver Edition	998*	~600	~400
TI-86	~3000	~2000	~1500
TI-89**	998	998	998
TI-92	~300	~200	~150
TI-92 Plus**	998	998	998
Voyage 200™ PLT**	998	998	998

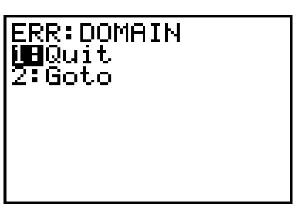
<table>
<tr><th>Screen</th><th>Explanation</th></tr>
<tr><td>
</td><td>continued from previous page
* This is the limit of the TI-82, TI-83 Plus, and TI-83 Plus Silver Edition calculator list.
** This is the data variable limit for these calculators. You must have Operating System (OS) version 2.05 or higher. The latest OS is available at education.ti.com/softwareupdates.

If using a TI-89, TI-92, TI-92 Plus, or Voyage 200 PLT and a memory error occurs because too many data points were attempted, you must go into the memory management of the calculator and delete the "cbldata" data var. Then restart DataMate and begin data collection. Remember to reduce the number of points collected.</td></tr>
<tr><td>

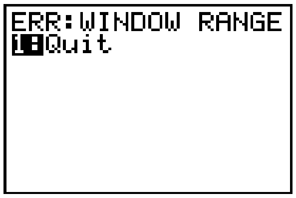
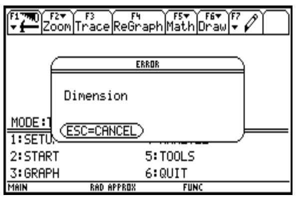
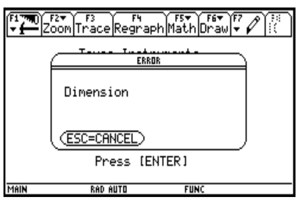
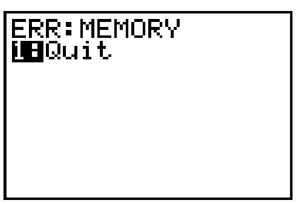

</td><td>This screen usually appears when the user is running DataMate and one of the DataMate subprograms has been deleted from the calculator memory. All of the subprograms must be present in order for DataMate to function properly. (All related programs begin with "DATxxxx.")

Reset the RAM on the calculator, then transfer the DataMate program from CBL 2™ to the calculator and begin again.</td></tr>
<tr><td>
</td><td>This screen appears on a TI-83 Plus calculator when one of the variables accessed by the DataMate app has been archived in the calculator memory. These variables are:

lists: L1 - L11, list C, list M
real: A - Z
matrix: [A]
string: Str0 - Str6

Go into Memory Management and unarchive any of the above variables.
Note: For the TI-89, TI-92 Plus, and Voyage™ 200 PLT, to unarchive any variable press [2nd] [VAR-LINK].</td></tr>
<tr><td>
</td><td>You have attempted a calculation outside the valid range. The most common cause of this error is trying to perform a power curve fit on Time Graph data. In Time Graph, DataMate collects a data point at time x=0. When the curve fit equation tries to divide by the 0, this error occurs.

The easiest way to correct this is to use the SELECT REGION option to eliminate the x=0 point from the graph. Then try the power curve fit option again.</td></tr>
</table>

Screen	Explanation
	The calculator tried to draw a graph but was not able to use the window settings. This problem can occur if you collect data and the data does not change (for example, the temperature does not change). If DataMate tries to autoscale the graph of this data (which it usually does), the calculator may not be able to set the y-axis scale. Press [ENTER] to quit. Press [WINDOW] and set the x-axis or y-axis scales, making sure that the *maximum* value exceeds the *minimum*. Then press [GRAPH] to draw the graph again.
	This screen can appear when running DataMate on a TI-89, TI-92, TI-92 Plus, or Voyage™ 200 PLT. It is caused by a loss of communications between the calculator and the CBL 2™ and usually means there is a problem with the link port on the calculator. Check that the cable is securely connected to the calculator and the CBL 2. Then restart the program.
	This screen appears when the user tries to run the Ranger program using the TI-89, TI-92, TI-92 Plus, or Voyage 200 PLT after using the DataMate program. This is caused by a conflict in some information left over in List 5. The information in the list cannot be used properly, so the calculator gives a Dimension error. To correct this, go into the calculator's memory management and delete List 5 (L5).
	This screen can appear on the TI-83 Plus. It can be caused by running the DataMate app while the Interactive Graphing app is loaded and turned on. Turn off the Interactive Graphing app before running DataMate. Also, go into memory management and check the programs listing. There will be a program listed that has a "strange" character as its name. Reset the RAM on the calculator before doing anything else with the calculator.
	When using the TI-82 with a motion detector and two other analog sensors, the data from the sensor in Channel 2 is not collected. The TI-82 has the capacity for only six lists, so there are not enough lists available to collect data on all channels. When using a motion detector, you can only use one analog sensor in Channel 1.

Screen	Explanation
	The sensors and Time Graph Mode were set up in DataMate. Then Triggering was set up. When data collection started, the live graph did not display. When triggering is selected, the CBL 2 does not allow a live graph. On the CBL 2, you can have either a live graph or triggering, but not both. The CBL 2 will use the one that was set up last and will turn off the other one.

CBL 2™ Error Messages

Error messages that may occur when using the CBL 2 system without the DataMate program are listed in the table below. To retrieve an error message, use Command 7 listed in Appendix B.

In almost all cases, an error result will cause the unit to sound the “low tone” two or more times and illuminate the red LED two or more times. When this happens, send the request for status message and then observe the “error” parameter of the list returned. The “error” parameter is one of the values in the following table.

Error Number	Error Cause
0	This is normal. No corrective action is needed.
1	Invalid FASTMODE. An attempt to select fast sampling mode was made. When in FASTMODE, only a single analog channel can be active. This error number also displays if the FASTMODE selection is a value other than 0 or 1.
2	FASTMODE ABORT. During FASTMODE, an attempt to communicate with the CBL 2 was made while it was waiting for a trigger. As a result, sampling was aborted.
5	The list being sent contains a number that is too large to be represented internally. This can only happen when the list being sent contains an error.
6	The list being sent contains a non-integer number where only integers are allowed. For example, command numbers must be integers and a command of 3.5 will produce this error.
8	The list being sent contained too many numbers for proper conversion. In general, no more than 32 numbers can be sent for some commands and no more than 44 numbers for other commands.
9	The command number sent (first number of the list) did not specify a valid command.
12	The channel selected for setup did not exist. Channel numbers must be 1-3, 11, 21, 31.
13	The operation selected for the channel being set up is invalid. For example, sonic channels cannot be setup for a voltage probe.
14	An invalid value was selected for the post processing parameter. This must be a number from 0 to 2.
16	An invalid equation on/off parameter was found. The equation on/off parameter must be a 0 or a 1.
17	An invalid Frequency/Period selection parameter was found. This error usually occurs when a second channel is selected for a measurement during Frequency/Period measurements.

Error Number	Error Cause
18	Multiple channels are not allowed to be selected at the same time for the Digital/Sonic inputs. This error usually means that the sonic port and a corresponding digital port have been selected.
22	Command 2 contains invalid data.
30	The filter type must be between 0 and 6 for NON-REALTIME data collection mode and 0, 7, 8, or 9 for REALTIME data collection mode. This error results from a filter selection outside of this range.
31	Command 3 was sent prior to performing any channel setups.
32	Sample time must be greater than 0 and less than 16000 seconds. The value is normally rounded to the nearest 100 µsec, but can be rounded to the nearest 50 µsec in FASTMODE. If the selected channels cannot support the rate selected, a slower sample rate will be used.
33	The number of samples must be -1 for REALTIME sampling and between 1 and 12,000 for NON-REALTIME sampling. 0 is not allowed except for a special case of REALTIME sampling with manual entry.
34	Trigger type must be an integer between 0 and 6. Any other value will produce this error.
35	The trigger channel must be a valid channel number (e.g., 1-3 or 11) and must be have been enabled using the channel select command.
36	The trigger threshold must be a value between the maximum and minimum legal values for the sensor selected. For example, for the +/-10V probe, legal values are from –10V to +10V.
37	The prestore value must be an integer between 0 and 100%. Any other values will produce this error message.
38	The external clock parameter is limited to values of 0 or 1. Any other value will produce this error.
39	The record time parameter is limited to values between 0 and 2. Any other values will produce this error message.
40	This error will occur when too few parameters are sent in the list. For example, when setting up an equation with 5 constants, if only 4 are sent, this error will result.
42	The equation channel number must be a 0 to reset equation, or a 1-3 for the analog channels or 11 for the sonic channel. Equation numbers outside of this range will produce this error.
43	The equation number must be in the range of -1 to 12 for analog channels and either 0 or 13 for the sonic channel. Equation numbers outside of this range will produce this error.

Error Number	Error Cause
44	The order of the equation must be appropriate for the equation type selected. For example, an equation order of 5 is not valid for the mixed polynomial equation.
45	This error occurred because (1) equations were enabled when sending Command 1, but the equation was never sent using Command 4, or (2) GET statement was issued before sending Command 4.
49	Invalid units were selected for temperature when sending the temperature for the sonic to use. Valid values are from 0 to 4.
52	A channel was selected that is not a valid channel. The channel numbers are 1-3, 11, 21, and 31.
53	A data group was selected that is not valid. Valid values are from 0 to 5.
54	The beginning-of-data selector must be 0 (for start of data) or 1 through the number of points collected. A number outside of this range will produce this error message.
55	The end-of-data selector must be 0 (for end of data) or 1 through the number of points collected. A number outside of this range will produce this error message. In addition, the end of the data must not be before the beginning of the data.
59	Digital probe has failed to read or write as commanded by the host.
61	An attempt has been made to collect more data than can be stored in one data collection. This unit has 24K of memory dedicated to data storage, allowing up to 12K samples to be stored. (for example, 3072 samples per channel for 4 channels.) If more than this is attempted, an error will result.
62	This error results when an attempt to return data is made and the data has not been collected.
63	This error results when sending Command 6 and an invalid second parameter.
76	This error results when sending Command 10 for a channel that does not have data stored.
77	This error results when sending a Command 10 and selecting an algorithm that has not been defined.
78	This error results when advanced algorithm is selected and the input parameters for it are not correct.
80	This error indicates that the battery voltage is too low to safely write to *FLASH* memory and an attempt has been made to write to *FLASH* memory. The batteries should be replaced immediately for the unit to continue to perform properly.

Error Number	Error Cause
81	This error indicates that an attempt to write to the *FLASH* memory failed and that the *FLASH* memory did not retain the value written. This problem can occur under several circumstances including the batteries becoming low after a *FLASH* write has been started (or removing the AC9920 adapter during *FLASH* writes). If the problem occurs often, this could indicate a hardware failure.
82	This error indicates an attempt was made to change the contents of *FLASH* memory without properly enabling *FLASH* writes.
83	This error indicates that the *FLASH* memory directory is full and an attempt to write to the *FLASH* memory occurred. If this occurs, delete some items from *FLASH* memory and repeat.
84	This error indicates an attempt was made to access an item in the *FLASH* memory that does not exist.
85	This error indicates that an attempt was made to access an item that is in the *FLASH* memory, but hasn't been properly opened for access.
86	This error indicates that the archive data type is not one of the data formats supported. This error can result from trying to archive a dataset that has not been properly stored.
87	The data to be archived must be NON-REALTIME data. REALTIME data cannot be archived. This error results when trying to archive REALTIME data.
88	This error results when an attempt is made to archive data during sampling. Archive operations must occur only when the unit is idle.
97	This error indicates an attempt to use a channel that does not exist on CBL 2™ (for example, channel 42).
98	This error indicates an undefined error has occurred.
99	This error indicates that the current load on the analog or digital ports is more than can be supplied by the unit and the power has been turned off to prevent damage. Do not attempt to restart sampling until the problem has been corrected.

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Phone:	1-800-TI-CARES (1-800-842-2737) For U.S., Canada, Mexico, Puerto Rico, and Virgin Islands only
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Appendix B: Command Tables

The tables in this section provide a quick reference to CBL 2™ commands. Please consult the Technical Reference document on the Resource CD or the TI web site for detailed explanations and additional information on the commands. Default values are shown in **boldface** type.

Command 0 Clears and resets system {0}

Clears data memory back to power-up state. Clears error information; does not clear *FLASH* memory.

Command 1 Channel Setup

{1,0} — **Clears all channels**

{1,*channel*,0} — **Clears the selected channel**

channel

1	Analog Channel 1
2	Analog Channel 2
3	Analog Channel 3
11	Sonic Channel
21	Digital Input Channel
31	Digital Output Channel

{1,1-3,*operation,post-processing,(delta),equ*} — **Analog channel setup**

operation

0		Turns channel off
1		Runs auto-ID sequence for this channel
2	TI Voltage sensor	Reads data from the ±10V input
3	Current sensor	Reads data from the ±10V input but scales data in Amps when using a current sensor
4	Resistance sensor	Reads resistance on selected analog channel when using a resistance sensor
5	Period measurement	Measures period of input data, CH 1 only
6	Frequency measurement	Measures frequency of input data, CH 1 only
7	Radiation count mode	Measures counts from radiation monitor, CH 1 only
10	Stainless steel temperature sensor and TI temperature sensor	Measures temperature, values in Centigrade
11	Stainless steel temperature sensor and TI temperature sensor	Measures temperature, values in Fahrenheit

12	TI light sensor	Measures relative light intensity
14	Voltage measurement	Measures voltage on 0-5V input of selected channel

post-processing		*Results*
0	None	Performs no post processing (RT* and NON-RT**)
1	d/dt	Calculates and returns 1st derivative of data (NON-RT)
2	d/dt and d^2/dt^2	Calculates and returns 1st and 2nd derivatives (NON-RT)

*RT = REALTIME
**NON-RT = NON-REALTIME

(delta)		This parameter is ignored.

equ		*Results*
0	Off	Returns data without converting
1	On	Applies conversion equation to data (must also send Command 4)

{1,11,*operation,post-processing,(delta),equ*} Sonic channel setup

operation		*Results*
0		Resets channel
1	Scales distance in meters	Returns distance and ∆time (RT* and NON-RT**)
2	Scales distance in meters	Returns distance and ∆time (RT and NON-RT)
3	Scales distance in feet	Returns distance and ∆time (RT and NON-RT)
4	Scales distance in meters	Returns distance, velocity, and ∆time (RT) or distance and ∆time(NON-RT)
5	Scales distance in feet	Returns distance, velocity, and ∆time (RT) or distance and ∆time(NON-RT)
6	Scales distance in meters	Returns distance, velocity, and ∆time (RT) or distance and ∆time(NON-RT)
7	Scales distance in feet	Returns distance, velocity, acceleration and ∆time (RT) or distance and ∆time (NON-RT)

*RT = REALTIME
**NON-RT = NON-REALTIME

post-processing		*Results*
0	None	Performs no post processing (RT and NON-RT)
1	d/dt	Calculates and returns 1st derivative of data (NON-RT)
2	d/dt and d^2/dt^2	Calculates and returns 1st and 2nd derivatives (NON-RT)

(delta)		This parameter is ignored.
equ		*Results*
0	Off	Returns data without converting
1	On	Commands use of temperature input from user when making speed of sound calculations (must also send Command 4 for temperature compensation)

When programming channel 21 (Digital In), use the syntax shown below:

{1,21,*operation*}

operation

0	Off
1	On

When programming channel 31 (Digital Out), use the syntax shown below:

{1,31,*operation,list of values*}

operation

0	Clears the channel until reprogrammed
1-32	Count: number of data elements in list
list of values	Lists values output to digital output port

Note: The list of values *must have one element for each* count*.*

Command 2 Data Type

This command is not used and should not be sent. However, it is included for compatibility with older CBL™ programs.

Command 3 Trigger Setup

{3,-1}	Repeats last Command 3 (used to quickly collect new data)

{3,*samptime, numpoints, trigtype, trigchan, trigthresh, prestore, (extclock), rectime, filter, fastmode*}

samptime		*Results*
>0 to ≤16000		Specifies number of seconds between samples
0.5	**default**	
numpoints		*Results*
-1		Specifies REALTIME mode
0	Invalid	Returns error message
1 to 12,000		Specifies NON-REALTIME mode and the number of points to collect

trigtype		*Results*
0	Immediate trigger	Takes data immediately after GET command
1	Manual trigger	Takes data when START/STOP is pressed
2	Rising edge/rising edge	Takes data after input crosses threshold voltage
3	Falling edge/falling edge	Takes data after input crosses threshold voltage
4	Rising edge/falling edge	Takes data after input crosses threshold voltage
5	Falling edge/rising edge	Takes data after input crosses threshold voltage
6	Single sample	Takes one data point each time START/STOP is pressed

trigchan		*Results*
0		Disables the trigger
1	Hardware or software (hardware trigger only for Command 1 operation 5, 6, 7; software trigger for all others)	Triggers on channel 1; channel must be active
2	Software only	Triggers on channel 2; channel must be active
3	Software only	Triggers on channel 3; channel must be active
11	Software only	Triggers on channel 11; channel must be active

trigthresh		*Results*
– channel limit to + channel limit		Begins taking data when signal crosses threshold in trigtype direction

[channel limit is determined by the sensor that is attached to the channel]

1V	default	

prestore		*Results*
0% to 100%		Retains this much data from before triggering
(extclock)		This parameter is ignored

rectime		*Results*
0	None	Does not record time during sampling
1	Absolute	Records absolute time
2	Relative	Records relative time

Note: This default is different from the original CBL™. Default on original CBL was 0.

filter		*Results*
0	No filtering	Disables the filtering process (RT* and NON-RT**)
1		Uses Savitzsky-Golay 5 point filter (NON-RT)
2		Uses Savitzsky-Golay 9 point filter (NON-RT)
3		Uses Savitzsky-Golay 17 point filter (NON-RT)

4		Uses Savitzsky-Golay 29 point filter (NON-RT)
5		Uses Median Pruning 3 point filter (NON-RT)
6		Uses Median Pruning 5 point filter (NON-RT)
7		Uses Light Realtime tracking filter (RT)
8		Uses Medium Realtime tracking filter (RT)
9		Uses Heavy Realtime tracking filter (RT)

*RT = REALTIME
**NON-RT = NON-REALTIME

fastmode		*Results*
0	OFF	Operates in normal mode
1	ON	Operates in FAST sampling mode

Note: In FASTMODE, only one channel can be active, and it must be an analog channel. Sampling can be as fast as 20µs/sample in this mode. FASTMODE is operational only for sample rates from 50,000 sample/second to 5,000 samples/second.

Command 4 **Conversion Equation Setup (Analog Channels Only)** ***{4, channel, equtype, equord, const(s)}***

channel		*Results*
0		Clears the equations for all channels
1		Sets the equation for input channel 1
2		Sets the equation for input channel 2
3		Sets the equation for input channel 3

equtype		*Results*	
-1		Unary equation – returns raw data for the channel	
0		Clears the equation for the selected channel	
1	Polynomial	$K_0 + K_1X + K_2X^2 + \ldots + K_nX^n$ (order: n=1-9) No restrictions other than overflow	
2	Mixed Polynomial	$K_{-m}X^{-m} + \ldots + K_{-1}X^{-1} + K_0 + K_1X + \ldots + K_nX^n$ order: m=0–4, n=0–4, m+n>0)	$X\neq0$
3	Power	$K_0X^{(K_1)}$	$X>0$
4	Modified Power	$K_0K_1^{(X)}$	$(K_1>0)$
5	Logarithmic	$K_0 + K_1\ln(X)$	$(X>0)$
6	Modified Logarithmic	$K_0 + K_1\ln(1/X)$	$(X>0)$
7	Exponential	$K_0\, e^{(K_1X)}$	No restrictions other than overflow
8	Modified Exponential	$K_0\, e^{(K_1/X)}$	$(X\neq0)$
9	Geometric	$K_0X^{(K_1X)}$	$(X\geq0)$
10	Modified Geometric	$K_0X^{(K_1/X)}$	$(X>0)$
11	Reciprocal Logarithmic	$[K_0 + K_1\ln(K_2X)]^{-1}$	$(K_2X>0)$

12	Steinhart-Hart Model	$[K_0 + K_1 (\ln 1000X) + K_2(\ln 1000X)^3]^{-1}$ (X>0)

equord and *constant(s)* — *Results*

Used with *equtype* = 1 or 2. Sets the equation order and constants used to fully define the equation data.

Command 4 Conversion Equation Setup (Sonic Channel Only) {*4, channel, equtype, units*}

channel		*Results*
4		Sets the equation for sonic 1 if *equtype*=13
11		Sets the equation for sonic 1
equtype		*Results*
0		Clears the equation for the selected channel
13		Sets temperature compensation for sonic
units		*Results*
0	° Celsius	Temperature in degrees Celsius
1	° Fahrenheit	Temperature in degrees Fahrenheit
2	° Celsius	Temperature in degrees Celsius
3	Kelvin	Temperature in Kelvin
4	Rankin	Temperature in Rankin

Command 5 Data Control {5,*channel,dataselect,databegin,dataend*}

channel		*Results*
-1		Sends the recorded time
0		Sends the lowest active channel
1		Sends data from channel 1
2		Sends data from channel 2
3		Sends data from channel 3
11		Sends data from sonic CH 1
21		Sends data from digital input CH 1
dataselect		*Results*
0		Sends raw data filtered
1	d/dt	Sends 1st derivative data filtered
2	d^2/dt^2	Sends 2nd derivative data filtered
3		Sends raw collected data unfiltered
4	d/dt	Sends 1st derivative data unfiltered
5	d^2/dt^2	Sends 2nd derivative data unfiltered

databegin	*Results*
0	Starts sending data at first point collected
1 to n	Starts sending data at the point selected
dataend	*Results*
0	Stops sending data at the last point collected
1 to n	Stops sending data at the point selected

Note: dataselect=0, 1, 2; filtered if Filter=1-6 in Command 3. dataselect=3, 4, 5; ignore filter setting in Command 3. Data End must be greater than or equal to Data Begin (unless Data End=0) and both must be less than or equal to the number of samples sent to the CBL 2™ in the last Command 3.

Command 6 System Setup

{6,*command*}

command	*Results*
0	Abort sampling
2	Abort sampling
3	**Turns sampling sound off (default on power-up)**
4	Turns sampling sound on

{6,*command,parm*}

command	*Results*
5	
parm	
number you specify	Sets an ID number for the CBL 2 (used to identify a specific CBL 2 when you have multiple units linked together)

{6,*command,filter*}

command	*Results*
6	Applies new filter to existing data
filter	
0 to 6	the number of the new filter to be applied

Command 7 Request System Status {7}

Generates and prepares to return the following status information.

softwareID	Current software version
error	If non-zero, CBL 2™ should be reset
battery	*Results*
0	Battery is OK for use
1	Battery is low during sampling
2	Battery is low all the time
8888	Constant value; ensures the status message was received correctly
sample time	Sample time commanded by host during last sample run
trigger condition	Triggering condition commanded by host during last sample run
channel function	Triggering channel commanded by host during last sample run
channel post	Post-processing setting commanded by host during last sample run
channel filter	Filter commanded by host during last sample run
num samples	Number of samples commanded by host during last sample run (or, if sampling was aborted, the actual number of samples taken)
record time	*Results*
0	No time was recorded in the last run
1	Absolute time was recorded in the last run
2	Relative time was recorded in the last run
temperature	Temperature used for temperature correction of sonic data during last run (if a sonic sensor was selected)
piezo flag	*Results*
0	No sound commanded
1	Sound is enabled

system state

1	Idle
2	Armed
3	Busy
4	Done
5	Self-test
99	Initializing code

data start	First point of data available for transmission to host unless host has sent Command 5 to override
data end	Last point of data available for transmission to host unless host has sent Command 5 to override
systemID	System ID that was set using Command 6

Command 8 Request Channel Status {8,*channel, request type*}

channel=1, 2, 3, or 11 — Returns a list with three elements: E_1, E_2, E_3

E_1 = sensor type (one of the *operation* options shown under Command 1)

E_2 = last valid data read from sensor, if any [only valid when sampling is active] (not applicable to CH1 ops 5, 6, 7 or CH21 or CH31)

E_3 = last valid data position (data buffer location number where that data is deposited) [only valid when sampling is active]

request type=0 or 1

0 = returns current data (such as, read and return channel ID information)

1 = returns data stored when channel was last set up

Command 9 Request Channel Data {9,*channel, mode*}

channel=1, 2, 3, or 11 — Immediately reads and returns one data point. Used to verify that setup is correct.

Mode

0	Re-test input auto-ID value
1	Return stored auto-ID value

Command 10 Advanced Data Reduction {10,*channel,alg,P1,P2,P3. . .Pn*}

channel=1, 2, 3, or 11		Re-reduces data in selected channel
alg		*Results*
1		Selects the HeartBeat Algorithm. This algorithm will return one value. The value is the number of cycles per sample.
2. . .n		TBD

P1 to Pn (Parameters for algorithms)

For algorithm 1:

P1		*Results*
0 to 100	LowerThld	Determines when data transitions from "high" to "low"
P2		*Results*
0 to 100	UpperThld	Determines when data transitions from "low" to "high"
P3		*Results*
	RejectThld	Determines the minimum difference in data between UpperThld and LowerThld

Command 12 {*12,channel,mode,. . .*}

channel

41 (Works only with digital channels)

{12,41,1} Samples digital input

Send the following commands to return the data from the CBL 2™ to the host:

Command:	Results:
{12,41,0}	{number of points available}
{12,41,-1,*Start,Stop*}	{state,state,state,state. . .}
{12,41,-2,*Start,Stop*}	{time,time,time,time. . .}

{12,41,2,*direction*} Measures pulse width of a single pulse

direction

0	low active pulse
1	high active pulse

Send the following commands to return the data from the CBL 2 to the host:

Command:	*Results*:
{12,41,0}	{number of points available} (0 or 1)
{12,41,-1,*Start,Stop*}	{Δtime}
{12,41,-2,*Start,Stop*}	{time}

{12,41,3,*direction*}	**Measures the widths of pulses in a continuous stream of pulses**

direction

0	low active pulse
1	high active pulse

Send the following commands to return the data from the CBL 2™ to the host:

Command:	*Results*:
{12,41,0}	{number of points available}
{12,41,−1,*Start,Stop*}	{Δtime, Δtime, Δtime, Δtime. . .}
{12,41,−2,*Start,Stop*}	{time,time,time,time. . .}

{12,41,4,*direction*}	**Measures the periods of pulses in a continuous stream of pulses**

direction

0	low active pulse
1	high active pulse

Send the following commands to return the data from the CBL 2 to the host:

Command:	*Results*:
{12,41,0}	{number of points available}
{12,41,−1,*Start,Stop*}	{Δtime, Δtime, Δtime, Δtime. . .}
{12,41,−2,*Start,Stop*}	{time,time,time,time. . .}

{12,41,5}	**Counts the transitions on the digital input line**

Send the following commands to return the data from the CBL 2 to the host:

Command:	*Results*:
{12,41,0}	{number of points available}
{12,41,−1,*Start,Stop*}	{count,count,count. . .}

{12,41,6,*StartPos,ScaleFactor*}	**Measures the position of a rotary motion sensor**
StartPos	The initial position (in user units)
ScaleFactor	The number of user units to increment/ decrement for each count change

Send the following commands to return the data from the CBL 2 to the host:

Command:	*Results*:
{12,41,0}	{number of points available}
{12,41,−1,*Start,Stop*}	{pos,pos,pos. . .}

Command 102 Power Control Command {102,*pwrctl*}

pwrctl		*Results*
0		Power level controls in Normal Mode
-1		Power port ON all the time
xxx	1 through 1000	Channel powers up xxx seconds before data taken

Note: Please see the Technical Information provided on the TI web site or the Resource CD for additional important information regarding this command.

Command 115 {115,*channel*}

channel=1, 2, 3, or 11

Returns the following information:

CBL 2™ sig	CBL 2 significant figures
LabPro™ sig	LabPro significant figures
Y-min	Suggested Y-min for graphing
Y-max	Suggested Y-max for graphing
Y-scale	Suggested Y-scale for graphing
sample rate	Typical sample rate
number of samples	Typical number of samples to collect
operation command	Typical operation command
calculation equation	Suggested calculation equation for Command 4
sensor warm-up time	Sensor warm-up time (in seconds)
first coefficient	Suggested first coefficient for Command 4
second coefficient	Suggested second coefficient for Command 4
third coefficient	Suggested third coefficient for Command 4
number of pages	Sensor’s number of calculation pages (usually 0)
active page	Sensor’s active calculation page (usually 0)

Command 116 **{116,*channel*}**

channel=1, 2, 3, or 11

Returns the following information:

long sensor name	Returns long sensor name in a format that the calculator can handle

Command 117 **{117,*channel*}**

channel=1, 2, 3, or 11

Returns the following information:

short sensor name	Returns short sensor name in a format that the calculator can handle

Command 1998 Set LED Command **{*1998, P_1, P_2*}**

P_1		Selects the LED
1	Red	
2	Yellow	
3	Green	
P_2		Turns the LED off or on
0	Off	
1	On	

Note: Leaving a LED turned on will run down the batteries in the CBL 2™.

Command 1999 Sound Command **{*1999, [length,Pd_1], . . .*}**

length	Sound stays on this long (in 100µs steps)
Pd_1	Tone half period in 100µs steps

[You can enter up to 32 pairs of values.]

Command 2001 Direct Output to Dig-Out **{2001,data1,data2,data3, . . .dataN}**

data1...dataN	data to output
0-15	Behavior is undefined for values outside this range.

Command 201 Archive Operations Command {201,operation,operand1,operand2,related_info_list}

This command allows the calculator to determine the contents of FLASH memory. Please see the CBL 2™ Technical Reference provided on the TI web site for detailed instructions on using this command.