



Getting Started with The CBR™ 2 Motion Sensor

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Introduction

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What is the CBR™ 2 Motion Sensor?

CBR™ 2 (Calculator-Based Ranger™) motion sensor use with TI-84 Plus, TI-Nspire™ CX II family, TI-Nspire™ CX software, TI-84 Plus CE, TI-84 Plus CE Python and TI-84 Plus Silver Edition bring real-world data collection and analysis into the classroom.

What does the CBR™ 2 motion sensor do?

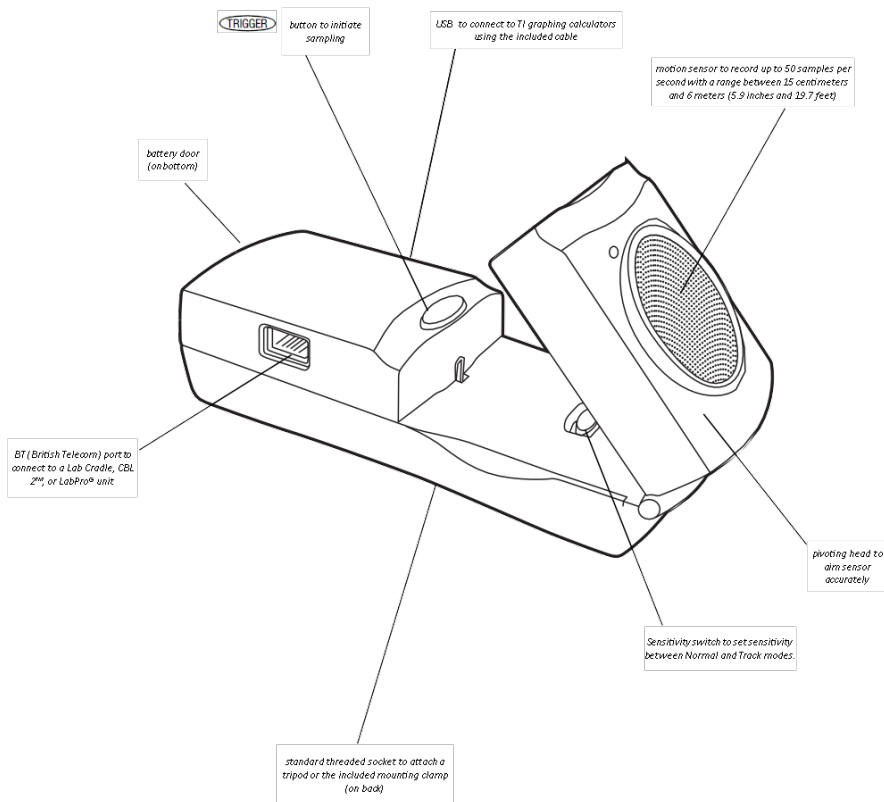
With the CBR™ 2 motion sensor and a TI graphing calculator, students can collect, view, and analyze motion data without tedious measurements and manual plotting.

The CBR™ 2 motion sensor lets students explore the mathematical and scientific relationships between distance, velocity, acceleration, and time using data collected from activities they perform. Students can explore math and science concepts such as:

- motion: distance, velocity, acceleration
- graphing: coordinate axes, slope, intercepts
- functions: linear, quadratic, exponential, sinusoidal
- calculus: derivatives, integrals
- statistics and data analysis: data collection methods, statistical analysis
- physics: motion, use with dynamics tracks, pendulum analysis, position, velocity, acceleration
- physical science: motion experiments

What's in this guide?

Getting Started with the CBR™ 2 Motion Sensor is designed to be a guide for teachers who do not have extensive calculator experience. It includes quick-start instructions for using the CBR™ 2 motion sensor, hints on effective data collection.



The CBR™ 2 motion sensor includes everything you need to begin classroom activities easily and quickly — just add a TI graphing calculator (and readily available props for some activities).

Getting started with the CBR™ 2 Motion Sensor

With the CBR™ 2 motion sensor, you're just a few steps from the first data sample!

Download

Your graphing calculator may have been preloaded with a number of Apps (software applications), including the Vernier EasyData® App on the TI-84 Plus-family, or on the TI-Nspire™ CX II family use the Vernier DataQuest™ App. For any TI-84 family calculator, press **[APPS]** to see the Apps installed on your calculator. If Vernier EasyData® App is not installed, you may find the latest version of this App at education.ti.com. If necessary, download the Vernier EasyData® App now.

Connect

Connect the CBR™ 2 motion sensor to your TI graphing calculator using the Standard-B to Mini-A USB cable (unit-to-CBR™ 2), and push in firmly at both ends to make a secure connection.

Sensitivity switch

The sensitivity switch has two modes—Track and Normal. The Track mode is intended for activities using dynamics tracks and carts; the Normal mode is intended for all other activities, such as, walking, ball toss, bouncing ball, pendulum, etc.



Set the Sensitivity switch to Normal mode for walking, ball toss, pendulum, etc., or to Track mode for use with dynamics tracks and carts.

If you are getting lots of extra noise in your data, the sensitivity switch may be in the Normal mode. Moving the sensitivity switch to the Track position, will reduce the sensitivity of the sensor and may produce better data.

About the unit-to-CBR™ 2 cable:

- Can be used with the Vernier EasyData® App on the TI-84 Plus-family, or can also be used with the Vernier DataQuest™ App on the TI-Nspire™ CX II family.
 - Provides for an auto-launch capability of the Vernier EasyData® App when connecting a CBR™ 2 motion sensor to a TI-84 Plus-family, or the Vernier DataQuest™ App when connecting to the TI-Nspire™ CX II family.
-

Run

Run either Vernier EasyData® App (TI-84 Plus-family) or Vernier DataQuest™ App (TI-Nspire™ CX II family) on the graphing calculator connected to the CBR™ 2 motion sensor.

In most cases, if the calculator is turned on, plugging in a TI CBR™ 2 will automatically launch the data collection applications. If not, then find either Vernier EasyData® or Vernier DataQuest™ applications and launch them manually. They will recognize the sensor that is plugged in.

Once you see that the app is displaying your CBR™ 2 motion data, press start (or the play button if using TI-Nspire™ CX II family).

For the TI-84 Plus connected with a unit-to-CBR™ 2 cable, perform steps 1 and 4.

1. Turn on the calculator and have it on the home screen.
2. Press **[APPS]** to display the list of Apps on your graphing calculator.
3. Choose EasyData and press **[ENTER]**.

The opening screen is displayed for about 2–3 seconds, and then the main screen is displayed.

4. Select Start (press **[ZOOM]**) in the main screen to start collecting data.

Important Information for CBR™ 2 motion sensor

Safety Tip

- When setting up activities, ensure that the CBR™ 2 motion sensor is securely anchored and that the cord cannot be tripped over.

Hints for effective data collection

Getting better samples

How does the CBR™ 2 motion sensor work?

Understanding how a motion sensor works can help you get better data plots. The motion sensor sends out an ultrasonic pulse and then measures how long it takes for that pulse to return after bouncing off the closest object.

The CBR™ 2 motion sensor, like any motion sensor, measures the time interval between transmitting the ultrasonic pulse and the first returned echo, but the CBR™ 2 motion sensor has a built-in microprocessor that does much more. When the data is collected, the CBR™ 2 motion sensor calculates the distance of the object from the CBR™ 2 motion sensor using a speed-of-sound calculation. Then it computes the first and second derivatives of the distance data with respect to time to obtain velocity and acceleration data. It stores these measurements in lists.

Object size

Using a small object at a far distance from the CBR™ 2 motion sensor decreases the chances of an accurate reading. For example, at 5 meters, you are much more likely to detect a soccer ball than a ping-pong ball.

Minimum range

When the CBR™ 2 motion sensor sends out a pulse, the pulse hits the object, bounces back, and is received by the CBR™ 2 motion sensor. If an object is closer than 15 centimeters (about six inches), consecutive pulses may overlap and be misidentified by the CBR™ 2 motion sensor. The plot would be inaccurate, so position the CBR™ 2 motion sensor at least 15 centimeters away from the object.

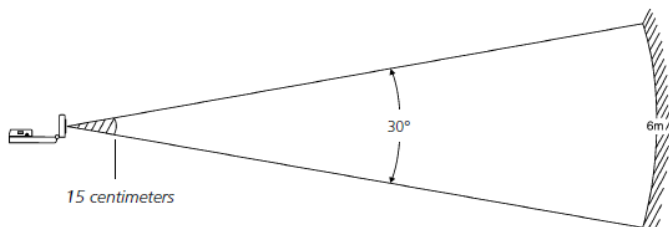
Maximum range

As the pulse travels through the air, it loses its strength. After about 12 meters (6 meters on the trip to the object and 6 meters on the trip back to the CBR™ 2 motion sensor), the return echo may be too weak to be reliably detected by the CBR™ 2 motion sensor. This limits the typical reliably effective distance from the CBR™ 2 motion sensor to the object to less than 6 meters (about 20 feet).

The clear zone

The path of the CBR™ 2 motion sensor beam is not a narrow, pencil-like beam, but fans out in all directions up to 15° from center in a 30° cone-shaped beam.

To avoid interference from other objects in the vicinity, try to establish a clear zone in the path of the CBR™ 2 motion sensor beam. This helps ensure that objects other than the target do not get recorded by the CBR™ 2 motion sensor. The CBR™ 2 motion sensor records the closest object in the clear zone.



Reflective surfaces

Some surfaces reflect pulses better than others. For example, you might see better results with a relatively hard, smooth surfaced ball than with a tennis ball. Conversely, samples taken in a room filled with hard, reflective surfaces are more likely to show stray data points. Measurements of irregular surfaces (such as a toy car or a student holding a calculator while walking) may appear uneven.

A Distance-Time plot of a non-moving object may have small differences in the calculated distance values. If any of these values map to a different pixel, the expected flat line may show occasional blips. The Velocity-Time plot may appear even more jagged, because the change in distance between any two points over time is, by definition, velocity.

Vernier EasyData® App settings

Setup data collection for Time Graph

Experiment length is the total time in seconds to complete all sampling. It's determined by the number of samples multiplied by the sample interval.

Enter a number between 0.05 (for very fast moving objects) and 0.5 seconds (for very slow moving objects).

Menu name	Description	Default setting
Sample Interval	Measures time between samples in seconds.	0.05
Number of Samples	Total number of samples to collect.	100
Experiment Length	Length of the experiment in seconds.	5

Starting and stopping

To start sampling, select Start (press **ZOOM**). Sampling will automatically stop when the number of samples set in the Time Graph Settings menu is reached. The CBR™ 2 motion sensor will then display a graph of the sampled data on the graphing calculator.

To stop sampling before it automatically stops, select Stop (press and hold **ZOOM**) at any time during the sampling process. When sampling stops, a graph of the sampled data is displayed.

Noise—what is it and how do you get rid of it?

When the CBR™ 2 motion sensor receives signals reflected from objects other than the primary target, the plot shows erratic data points (noise spikes) that do not conform to the general pattern of the plot. To minimize noise:

- Make sure the CBR™ 2 motion sensor is pointed directly at the target. Try adjusting the sensor head while viewing live data on the home-screen meter. Make sure the reading you receive is appropriate before starting an activity or experiment.
- Try to sample in a clutter-free space (see the clear zone drawing).
- Choose a larger, more reflective object or move the object closer to the CBR™ 2 (but farther than 15 centimeters).
- When using more than one CBR™ 2 motion sensor in a room, one group should complete a sample before the next group begins their sample.
- Try moving the sensitivity switch to the Track position to reduce the sensitivity of the sensor.

Speed of sound

The approximate distance to the object is calculated by assuming a nominal speed of sound. However, actual speed of sound varies with several factors, most notably the air temperature.

The CBR™ 2 motion sensor has a built-in temperature sensor to automatically compensate for changes in the speed of sound due to the temperature of the surrounding air. The temperature conversion from 0° to 40° Celsius, at standard pressure, is fairly linear at about +0.6 meters/second per degree Celsius. The speed of sound increases from about 331 meters/second at 0° Celsius to about 355 meters/second at 40° Celsius. These speeds assume a relative humidity of 35% (dry air).

When using the EasyData® App or Vernier DataQuest™ App with the CBR™ 2 motion sensor, this temperature compensation will take place when collecting motion data. The sensor is located underneath the holes on the back of the CBR™ 2 motion sensor; therefore, when collecting data, do not cover these holes with something that is of a different temperature from the surrounding ambient temperature.

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Access Activities

To access math and science activities that use the CBR™ 2 motion sensor, go to <https://education.ti.com/en/activity/search/advanced>. Click on “CBR™/CBR™2” and then your preferred calculator to filter activities. For any version of the TI-84 Plus-family, select all of the various types for maximum results (ex. If you have TI-84 Plus CE, select that and the other types of TI-84 Plus devices also).

There are many activities available for your CBR™ 2 motion sensor.

- For other math & science activities for your TI-84 Plus-family - go to TI's 84 Activity Central at education.ti.com/en/84activitycentral/us/home
- For other math & science activities for your TI-Nspire™ family check out:
 - Math Nspired - www.mathnspired.com
 - Science Nspired - www.sciencenspired.com

Teacher Information

How might your classes change with a CBR™ 2 motion sensor?

The CBR™ 2 motion sensor is an easy-to-use system with features that help you integrate it into your lesson plans quickly and easily.

The CBR™ 2 motion sensor offers significant improvements over other data-collection methods you may have used in the past. This, in turn, may lead to a restructuring of how you use class time, as your students become more enthusiastic about using real-world data.

- You'll find that your students feel a greater sense of ownership of the data because they actually participate in the data-collection process rather than using data from textbooks, periodicals, or statistical abstracts. This impresses upon them that the concepts you explore in class are connected to the real world and aren't just abstract ideas. But it also means that each student will want to take his or her turn at collecting the data.
- Data collection with CBR™ 2 motion sensor is considerably more effective than creating scenarios and manually taking measurements with a ruler and stopwatch. Since more sampling points give greater resolution and since a motion sensor is highly accurate, the shape of curves is more readily apparent. You will need less time for data collection and have more time for analysis and exploration.
- With CBR™ 2 motion sensor students can explore the repeatability of observations and variations in what-if scenarios. Such questions as "Is it the same parabola if we drop the ball from a greater height?" and "Is the parabola the same for the first bounce as the last bounce?" become natural and valuable extensions.
- The power of visualization lets students quickly associate the plotted list data with the physical properties and mathematical functions the data describes.

Other changes occur once the data from real-world events is collected. CBR™ 2 motion sensor lets your students explore underlying relationships both numerically and graphically.

Explore data graphically

Use automatically generated plots of distance, velocity, and acceleration with respect to time for explorations such as:

- What is the physical significance of the y-intercept? the x-intercept? the slope? the maximum? the minimum? the derivatives? the integrals?
- How do we recognize the function (linear, parabolic, etc.) represented by the plot?
- How would we model the data with a representative function? What is the significance of the various coefficients in the function (e.g., $AX^2 + BX + C$)?

Explore data numerically

Your students can employ statistical methods (mean, median, mode, standard deviation, etc.) appropriate for their level to explore the numeric data. When you exit the Vernier EasyData® App, a prompt reminds you of the lists in which time (L1), distance (L2), velocity (L3), and acceleration (L4) are stored.

CBR™ 2 motion sensor plots—connecting the physical world and mathematics

The plots created from the data collected by Vernier EasyData® App are a visual representation of the relationships between the physical and mathematical descriptions of motion. Students should be encouraged to recognize, analyze, and discuss the shape of the plot in both physical and mathematical terms. Additional dialog and discoveries are possible when functions are entered in the Y= editor and displayed with the data plots.

Performing the same calculations as CBR™ 2 motion sensor is an interesting classroom activity.

1. Collect sample data. Exit the Vernier EasyData® App.
2. Use the sample times in L1 in conjunction with the distance data in L2 to calculate the velocity of the object at each sample time. Then compare the results to the velocity data in L3.

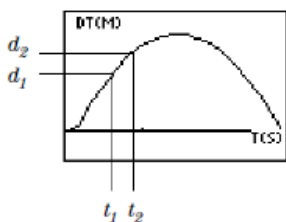
$$L3_n = \frac{(L2_{n+1} + L2_n)/2 - (L2_n + L2_{n-1})/2}{L1_{n+1} - L1_n}$$

3. Use the velocity data in L3 (or the student-calculated values) in conjunction with the sample times in L1 to calculate the acceleration of the object at each sample time. Then compare the results to the acceleration data in L4.
 - A Distance-Time plot represents the approximate position of an object (distance from the CBR™ 2 motion sensor) at each instant in time when a sample is collected. y-axis units are meters or feet; x-axis units are seconds.
 - A Velocity-Time plot represents the approximate speed of an object (relative to, and in the direction of, the CBR™ 2 motion sensor) at each sample time. y-axis units are meters/second or feet/second; x-axis units are seconds.
 - An Acceleration-Time plot represents the approximate rate of change in speed of an object (relative to, and in the direction of, the CBR™ 2 motion sensor) at each sample time. y-axis units are meters/second² or feet/second²; x-axis units are seconds.
 - The first derivative (instantaneous slope) at any point on the Distance-Time plot is the speed at that instant.
 - The first derivative (instantaneous slope) at any point on the Velocity-Time plot is the acceleration at that instant. This is also the second derivative at any point on the Distance-Time plot.
 - A definite integral (area between the plot and the x-axis between any two points) on the Velocity-Time plot equals the displacement (net distance traveled) by the object during that time interval.
 - Speed and velocity are often used interchangeably. They are different, though related, properties. Speed is a scalar quantity; it has magnitude but no specified direction, as in “6 feet per second.” Velocity is a vector quantity; it has a specified direction as well as magnitude, as in “6 feet per second due North.”

A typical CBR™ 2 motion sensor Velocity-Time plot actually represents speed, not velocity. Only the magnitude (which can be positive, negative, or zero) is given. Direction is only implied. A positive velocity value indicates movement away from the CBR™ 2 motion sensor; a negative value indicates movement toward the CBR™ 2 motion sensor.

The CBR™ 2 motion sensor measures distance only along a line from the sensor. Thus, if an object is moving at an angle to the line, it only computes the component of velocity parallel to this line. For example, an object moving perpendicular to the line from the CBR™ 2 motion sensor shows zero velocity.

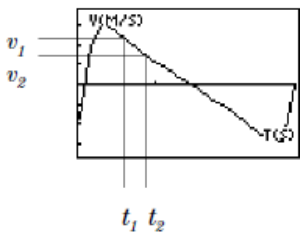
The mathematics of distance, velocity, and acceleration



Distance-Time plot

$$V_{\text{average}} = \frac{\Delta d}{\Delta t} = \frac{d_2 - d_1}{t_2 - t_1} = \text{slope of Distance-Time plot}$$

$$V_{\text{instantaneous}} = \lim_{\Delta t \rightarrow 0} \left(\frac{\Delta d}{\Delta t} \right) = \frac{d(s)}{dt} \quad \text{where } s = \text{distance}$$



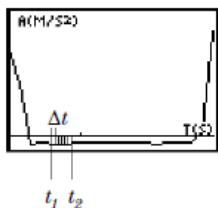
Velocity-Time plot

$$A_{\text{average}} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} = \text{slope of Velocity-Time plot}$$

$$A_{\text{instantaneous}} = \lim_{\Delta t \rightarrow 0} \left(\frac{\Delta v}{\Delta t} \right) = \frac{dv}{dt}$$

The area under the Velocity-Time plot from t_1 to $t_2 = \Delta d = (d_2 - d_1) = \text{displacement from } t_1 \text{ to } t_2 \text{ (net distance traveled)}$.

$$\text{So, } \Delta d = \left(\sum_{t=1}^{t=2} v(\Delta t) \right) \text{ or } \Delta d = \int_{t=1}^{t=2} v(dt)$$



Acceleration-Time plot

Web-site resources

At TI's Web Site, education.ti.com, you will find:

- a listing of supplemental material for use with the CBR™ 2 motion sensor and TI graphing calculators
- an activities page with applications developed and shared by teachers like you - <https://education.ti.com/en/activity/search/advanced>

Technical Information

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Motion Sensor Data is Stored in Lists

Collected data is stored lists L1, L2, L3, and L4

When the CBR™ 2 motion sensor collects data, it automatically transfers it to the calculator and stores the data in lists. Each time you exit the Vernier EasyData® App, you are reminded of where the data is stored.

- L1 contains time data.
- L2 contains distance data.
- L3 contains velocity data.
- L4 contains acceleration data.

For example, the 5th element in list L1 represents the time when the 5th data point was collected, and the 5th element in list L2 represents the distance of the 5th data point.

Using the TI-Nspire™ CX and CX II application, “Vernier DataQuest™ App”

If you are using a TI-Nspire™ CX or CX II family, the Vernier DataQuest™ application can be used with your CBR™ 2. It will collect your data in real-time and display it in a list and graph visible within the app. The data is also available to other TI-Nspire™ applications such as “Graphs”, “Data and Statistics”, “Calculator”, and “Lists & Spreadsheet”.

Note: You can access popular programs such as “Motion Match” from selecting the Graph view and then selecting “Analyze/Motion Match” from the menu.

Using the data lists

The lists are not deleted when you exit the Vernier EasyData® App. Thus, they are available for additional graphical, statistical, and numerical explorations and analyses.

You can plot the lists against each other, display them in the list editor, use regression analysis, and perform other analytical activities. For example, you could collect data from a student walking away from the CBR™ 2 motion sensor. Then using the TI-84 Plus calculator manual-fit linear regression, you could have students find a line of best fit.

Vernier EasyData® App Settings

Changing the Vernier EasyData® App settings

Vernier EasyData® App displays the most commonly used settings before data collection begins.

1. From the main screen in the Vernier EasyData® App, choose Setup > 1: Dist or 2: Time Graph. The current settings are displayed on the calculator.

Note: Settings for 3: Distance Match and 4: Ball Bounce in the Setup menu are preset and cannot be changed.

2. Select Next (press **ZOOM**) to move to the setting you want to change. Press **CLEAR** to clear a setting.
3. Repeat to cycle through the available options. When the option is correct, select Next to move to the next option.
4. To change a setting, enter 1 or 2 digits, and then select Next.
5. When all the settings are correct, select OK (press **GRAPH**) to return to the main screen.

The new settings remain in effect unless you choose to set Vernier EasyData® App to its default settings, run an application, or run another activity that changes the settings. If you manipulate L5 outside the Vernier EasyData® App or delete L5, the default settings may be restored the next time you run the Vernier EasyData® App.

Restoring the Vernier EasyData® App settings to the defaults

The default settings are appropriate for a wide variety of sampling situations. If you are unsure of the best settings, begin with the default settings, and then adjust the settings for your specific activity.

- To restore the default settings in Vernier EasyData® App while the CBR™ 2 motion sensor is connected to the calculator, choose File > 1:New.
- To change settings, follow the steps previously described above.
- Select Start (press **ZOOM**) to begin collecting data.

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Batteries

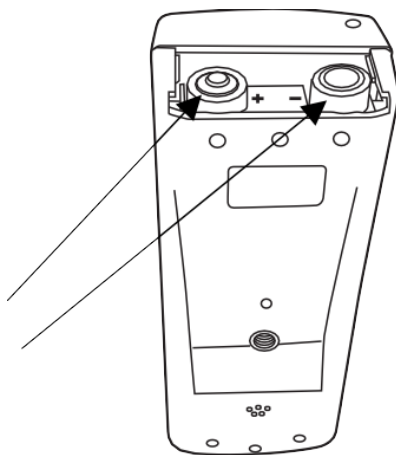
Battery type

CBR™ 2 motion sensor is designed to operate with 4 AA alkaline batteries. CBR™ 2 motion sensor can run without batteries only if attached to a CBL 2™.

Battery installation

Exit the Vernier EasyData® App before changing batteries.

1. Holding the CBR™ 2 motion sensor upside down, use your thumb to slide the battery compartment cover toward the back of the CBR™ 2 motion sensor.
2. Position batteries according to the diagram on the inside of the CBR™ 2 motion sensor battery compartment.
3. Two batteries fit positive side up in the side marked +. Two batteries fit negative side up in the side marked -
4. Slide the cover back on. CBR™ 2 motion sensor is ready to begin sampling.



CBR™ 2 motion sensor low battery warnings

The CBR™ 2 motion sensor has two mechanisms to alert you that the batteries are low:

- The Vernier EasyData® App displays a warning message on calculator screen while trying to collect data.
- The red light flashes intermittently while the CBR™ 2 motion sensor is collecting sample data.

Battery precautions

- DO NOT use rechargeable batteries.
- Replace all four batteries at the same time. Do not mix brands of batteries. Do not mix types within a battery brand.
- Install batteries according to the diagrams inside the battery compartment.

- Properly dispose of used batteries immediately. Do not leave them within the reach of children.
- Do not heat, burn, or puncture batteries. Batteries contain hazardous chemicals and may explode or leak.
- Do not mix rechargeable and non-rechargeable batteries.
- Do not place non-rechargeable batteries in a battery recharger.


In Case of Difficulty


If you have this problem:	Try this:
Difficulty collecting data	Check for a poor calculator-to-CBR™ 2 motion sensor connection. Always push in firmly on both ends of the cable. Check for low batteries.
The CBR™ 2 motion sensor begins collecting data by itself	If you set down the CBR™ 2 motion sensor with the TRIGGER button face down, the TRIGGER button may depress and activate sampling. Press TRIGGER again to stop sampling. Before storing the CBR™ 2 motion sensor, properly exit the EasyData App (using Quit) or any other CBR™ 2 motion sensor or CBL 2™ system App.
The CBR™ 2 motion sensor doesn't quit collecting data	Press TRIGGER to stop sampling. Repeat sample. If problem continues, remove one battery and put it back in. Note: Any data stored in the CBR™ 2 motion sensor will be lost.
Communication Error	Attach the CBR™ 2 motion sensor to the calculator with the Standard-B to Mini- A USB cable (unit-to-CBR™ 2). Check for a poor calculator-to-CBR™ 2 motion sensor connection. Always push in firmly on both ends of the cable. If you do not want to (or cannot) attach the CBR™ 2 motion sensor to the calculator, quit the Vernier EasyData® App.
Insufficient memory	You must have sufficient memory for the Vernier EasyData® App and the data lists. Vernier EasyData® App needs 5000 bytes to run effectively. You need to delete items from the calculator memory. On the TI calculator, press [2nd] [MEM] 2:Mem Mgmt./Del . Choose items to delete and press DEL to delete the selected items.
Calculator doesn't match activity instructions	This guide applies to all the TI calculators that can load the Vernier EasyData® App. You may find that some of the menu names, screens, or keys in this guide do not match exactly those on your calculator. If using Ranger, or other programs, choose the closest match. For example, if the instructions say "Choose DISTANCE MATCH," on the TI-83 you would choose DIST MATCH .

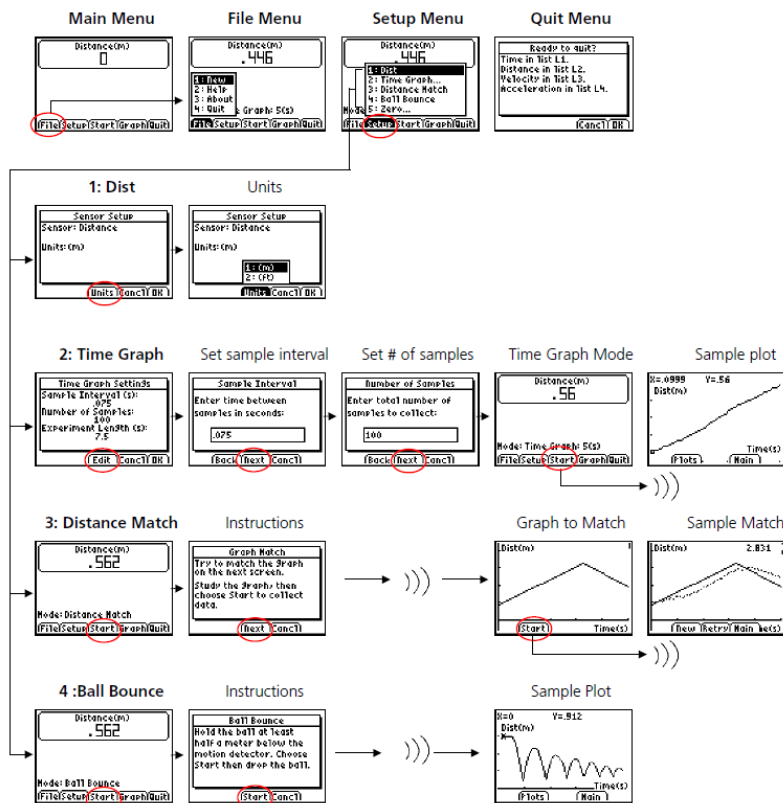
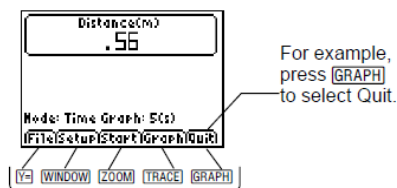
<p>Data doesn't look right:</p> <ul style="list-style-type: none"> • points not on the curve • jagged plots • flat plots • broken plot 	<p>Repeat the sample, ensuring that the CBR™ 2 motion sensor is aimed directly at the object.</p> <p>Read pages 6–9 on getting good data samples.</p> <p>Check that the clear zone does not contain students, tables, or other objects. Check the position of the Sensitivity switch.</p> <p>When using two CBR™ 2 units at the same time in the same room, one group should complete a sample before the next group begins their sample.</p> <p>Check for a poor calculator-to-CBR™ 2 motion sensor connection. Always push in firmly on both ends of the cable.</p> <p>Check for low batteries.</p>
<p>Frequently low batteries</p>	<p>Before storing the CBR™ 2 motion sensor, properly exit the Vernier EasyData® App (using Quit) or any other CBR™ 2 motion sensor or CBL 2™ program, and disconnect the CBR™ 2 motion sensor from the calculator.</p>

Vernier EasyData® App menu map

Each screen displays one or more options along the bottom of the screen. To select an option, press the graphing key directly below the option.

To navigate the menus as indicated below, select the menu options indicated by .

 indicates data is being collected.



General Information

Online Help

education.ti.com/eguide

Select your country for more product information.

Contact TI Support

education.ti.com/ti-cares

Select your country for technical and other support resources.

Service and Warranty Information

education.ti.com/warranty

Select your country for information about the length and terms of the warranty or about product service.

Limited Warranty. This warranty does not affect your statutory rights.